100754

ORIGINAL (Red)

ATTACHMENT C

STANDARD OPERATING PROCEDURES

- Consolidated Rail Corporation (Conrail)
- American Society for Testing Materials (ASTM)

SPECIFIC REQUIREMENTS

OF

CONSOLIDATED RAIL CORPORATION

FOR

WORK ON ITS RIGHT OF WAY

APPROVED:

J D Cossel 2/1/95

J. D. COSSEL
CHIEF ENGINEER - CONSTRUCTION

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SCOPE

It must be clearly understood that Conrail owns and uses its right of way for the primary purpose of operating a railroad. All work shall therefore be done in a manner such that the rail operations and facilities are not interfered with, interrupted or endangered. In addition, any facilities that are a result of the proposed work shall be located to minimize encumbrance to the right of way so that the railroad will have unrestricted use of its property for current and future operations. The sponsor of the project is ultimately responsible for assuring that its agents, consultants, contractors and sub-contractors fully comply with the specifications contained herein. The term 'sponsor' used throughout these specifications shall mean the sponsor, its employees, its agents, consultants, contractors, sub-contractors, etc.
The following terms and conditions shall apply to any project which requires performance of work on the right of way or property of Consolidated Rail Corporation (Conrail).

RIGHT OF ENTRY ON CONRAIL PROPERTY

No entry upon Conrail property will be permitted without the proper authorization by Conrail to the sponsor in the form of an agreement or a proper permit-to-enter prepared by the Chief Engineer - Construction. The applicant must pay the associated fees and execute the permit-to-enter prior to entering Conrail property.
It is to be clearly understood that the issuance of a permit-to-enter does not constitute authority to proceed with any construction work. Construction cannot begin until a formal agreement is executed by Conrail and the sponsor, and the sponsor receives permission from the designated inspection agency of Conrail to proceed with the work.

INSURANCE

In addition to any other forms of insurance or bonds required under the terms of the contract and specifications, Contractor will be required to carry insurance of the following kinds and amounts:

1. Public Liability Insurance
Contractor shall furnish evidence that, with respect to the operations it performs, it carries Public Liability Insurance, including contractual liability insurance with a limit of not less than $5,000,000 single limit, bodily injury and/or property damage combined, for damages arising out of bodily injuries to or death of all persons in any one occurrence and for damage to or destruction of property, including the loss of use thereof, in any one occurrence.
2. Automobile Public Liability Insurance
When any motor vehicles are used in connection with the work to be performed, Contractor shall furnish evidence that it carries Automobile Public Liability Insurance and Property Damage Liability Insurance with a limit of not less than $5,000,000 covering bodily injury and/or property damage for each occurrence.
3. Workers' Compensation in Statutory Amounts
Contractor shall furnish evidence that it carries Employers' Liability and Occupational Disease Insurance with limits of $1,000,000 each accident, $1,000,000 policy limit and $1,000,000 each employee.

4. Railroad's Protective Public Liability Insurance
In addition to Items 1 and 2 shown above, Contractor shall furnish evidence that, with respect to the operations it or any of its subcontractors perform, it has provided Railroad Protective Public Liability Insurance (ISO-RIMA form) in the name of Consolidated Rail Corporation providing for a limit of not less than $2,000,000 single limit, bodily injury and/or property damage combined, for damages arising out of bodily injuries to or death of all persons in any one occurrence and for damage to or destruction of property, including the loss of use thereof, in any one occurrence. Such insurance shall be furnished with an aggregate of not less than $6,000,000 for all damages as a result of more than one occurrence.

The insurance hereinbefore specified shall be carried until all work required to be performed under the terms of the contract is satisfactorily completed and formally accepted. Failure to carry or keep such insurance in force until all work is satisfactorily completed shall constitute a breach of contract. The aforesaid insurance protection shall be enforceable by any legitimate claimant after the termination or cancellation of the project whether by expiration of time, by operation of law or otherwise, so long as the basis of the claim against the insurance company occurred during the periods of time for which such insurance was obtained. Contractor shall furnish to Conrail at the address listed below, certificates evidencing the insurance outlined in sections 1, 2 & 3 above, and shall furnish the original ISO-RIMA policy for the Railroad Protective Public Liability Insurance referred to in section 4. Conrail must be named as additional insured under insurances outlined in sections 1 & 2 above. Each insurance policy shall be endorsed to provide that the insurance company shall notify the following via registered or certified mail at least thirty (30) days in advance of termination of or any change in the policy:
Insurance Department
Consolidated Rail Corporation
2001 Market Street - 25A
PO Box 41425
Philadelphia, Pennsylvania 19101-1425

CHANGES IN RAILROAD FACILITIES

Temporary and permanent changes of signal, communication, power transmission lines, trailers, drainage and other railroad facilities required in connection with the project to clear temporary and/or permanent work of the sponsor as shown on the approved construction plans will be made or caused to be made by Conrail at the sole cost and expense of the sponsor in accordance with Conrail's force account estimate. Any other changes made or services furnished by Conrail at the request of the sponsor shall be the sole cost and expense of the sponsor.

PROTECTION OF RAILROAD OPERATIONS

The sponsor shall conduct the work in such a manner as to safeguard the operations, facilities, right of way and property of Conrail. All work affecting the above items shall be subject to the approval of the Chief Engineer - Construction or his designated representative. The sponsor's operations adjacent to, over or under Conrail's tracks, facilities, right of way, and property shall be governed by Conrail's standards and by such other requirements as specified by Conrail's representative so as to insure the safe operation of trains, prevent delay to trains and insure the safety of all concerned including the sponsor's forces.

An operating track shall be considered obstructed or fouled when any object is brought closer than fifteen (15) feet (4.6 m) horizontally from the centerline of track and projects above the top of tie or as determined by the Conrail representative. A power line shall be considered fouled when any object is brought to a point less than eight (8) feet (2.5 m) therefrom. A signal line shall be considered fouled when any object is brought nearer than six (6) feet (1.8 m) to any wire or cable. Cranes, trucks and other equipment shall be considered as fouling the track, power line or signal line when failure of equipment, whether working or idle, with or without load, will obstruct the track or other Conrail facilities.

Equipment used by the sponsor shall be in first-class condition to preclude any failure that would cause interfering with the operation of trains or damage to Conrail facilities. The sponsor's equipment shall not be placed or put in operation adjacent to the tracks or facilities of Conrail without obtaining clearance from the Conrail representative. All such equipment shall be operated by the sponsor in a manner satisfactory to Conrail. No equipment or material is to be stored on Conrail property.

In general, a hazard occurs and a flagman is necessary during (1) the driving of sheeting or piles within twenty five (25) feet (7.6 m) of the tracks, (2) the removal or demolition of all or part of an overhead or adjacent structure, (3) the erection of any structural material, or (4) the performance of any other operation that could obstruct or foul (as described above) the tracks or other facilities of Conrail as determined by Conrail's representative.

Minimum overhead and lateral clearances as specified by Conrail are to be maintained during the performance of the work. Existing overhead and lateral clearances are to be maintained during construction unless a temporary reduction in clearance for construction purposes is approved, in writing, by Conrail. The sponsor shall erect a highly visible construction fence no closer than fifteen (15) feet (4.6 m) from the centerline of the track through the work area to insure that the lateral clearance requirement is being met.

All wire and attachments shall be treated as live unless notified by the Conrail representative that same have been grounded and de-energized. Particular attention shall be given to the use of hand lines containing metal strands which cannot be used when working near or above exposed live wires. When working over wires, tools and materials not in use shall be stored in a manner to prevent them from falling. Tools or materials shall not be thrown to or from men working over the wires to men on the ground. The sponsor shall be responsible for locating and protecting all underground facilities.

Painting and paint removal procedures must be approved by the Chief Engineer - Construction, and installed and inspected by his representative prior to beginning the work over railroad right of way. The sponsor will be required to protect the track structure and railroad property from any material used in conjunction with performing the work. A flagman will be required whenever the above described work fouls the track as previously defined.

The sponsor shall give notice to Conrail's Chief Engineer - Construction or his designated representative fourteen (14) days in advance of the time work is to be commenced. Conrail will assign at the sole cost and expense of the sponsor, conductors and/or flagmen, or other similar qualified employees to protect its trains and facilities when in the opinion of its representative, the construction work will cause or may cause a hazard to Conrail facilities and the safe operation of trains. No operations of the sponsor shall be carried out without all the necessary protection to properly safeguard the work.

The minimum hours per day for railroad employees engaged in flagging service shall be eight (8) hours. The overtime rate will be charged for all time in excess of eight (8) hours. Flagmen are paid from the time they leave headquarters until they arrive back at headquarters. The travel time to and from project site is known as "deadheading" and is paid at full rate of pay, plus travel expenses. No conductor or flagman may remain on duty longer than twelve (12) hours in any twenty-four (24) hour period.

The providing of flagmen, inspectors or other precautionary measures, shall not, however, relieve the sponsor from liability for payment of damages caused by their operations. The sponsor must obtain permission from the flagman before fouling or obstructing any track.

The sponsor shall be responsible for damage to Conrail facilities or property arising out of the execution of its work. Conrail shall undertake any necessary repair work at the sole cost and expense of the sponsor. Billing for the work shall be in accordance with Conrail's standard billing procedures.

Labor will be charged to sponsor at actual rate plus amount paid for insurance, railroad retirement, excise tax, vacation allowance, holidays, health and welfare benefits, small tools and overhead in accordance with Conrail's standard billing procedures. Materials will be charged to the sponsor at actual cost to Conrail plus transportation costs, handling expense and applicable taxes.

RAILROAD ENGINEERING AND INSPECTION

Conrail, at its sole discretion, may assign an engineer or inspector for the general protection of railroad property and operations during the construction of the project. This inspection service will be supplied at the sole cost and expense of the sponsor.

PAYMENT OF RAILROAD SERVICES

It is a requirement that the sponsor shall reimburse Conrail in full for work undertaken by Conrail in accordance with any provision of these special requirements. Final contract payment will not be made by the sponsor to its contractor, sub-contractor, consultant or agent, until Conrail certifies that all railroad bills against them have been paid in full.

TEMPORARY GRADE CROSSING

Under most circumstances, a grade crossing of our track will not be permitted; however, the creation of such a crossing will be at the sole discretion of the Chief Engineer - Construction. Should the sponsor demonstrate a necessity for a temporary grade crossing of Conrail's tracks, the sponsor will be required to apply for and execute the standard private grade crossing agreement for each crossing required. Application for the crossing shall be made to Conrail at least twelve (12) weeks before the crossing is required and addressed to:

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Mr. J. D. Cossel, Chief Engineer - Construction
Consolidated Rail Corporation
2001 Market Street -12B
PO Box 41412
Philadelphia, Pennsylvania 19101-1412

A letter size plan showing the location, size, construction details, and access to the requested crossing should accompany the letter of application. The plan should be fully detailed and dimensioned with all Conrail facilities shown and referenced. The letter should state the purpose for which the crossing is needed and the expected life of the crossing. All application fees, construction, maintenance, protection and removal costs will be at the sole cost and expense of the sponsor. The roadbed and all other Conrail facilities will be restored to the original condition subject to the approval of Conrail's Chief Engineer - Construction or his designated representative.

SHEETING AND SHORING REQUIREMENTS

The following items are to be included in the design and construction procedures for all permanent and temporary facilities adjacent to Conrail tracks.

1) Footings for all piers, columns, walls or other facilities shall be located and designed so that any temporary sheeting and shoring for support of adjacent track or tracks during construction will **not** be closer than toe of ballast slope [7'-5" (2.3 m) is the dimension from gauge of rail to toe of ballast for tangent track; see Conrail Standard Plan 48747 (attached) for dimensions on curved track].
2) When excavation for construction of the above mentioned facilities is within the theoretical railroad embankment line (see drawing SK-1), interlocking steel sheet piling, driven prior to excavation, must be used to protect track stability. The use of trench boxes or similar devices is not acceptable. Soldier piling and lagging will be considered for supporting adjacent track(s) only when its use is approved by the Chief Engineer - Construction. Consideration for the use of soldier piling and lagging will be made if the required penetration of steel sheet piling cannot be obtained and when dry, non-running, stable material will be encountered.
3) The sheeting shall be designed to support all lateral forces caused by the earth, railroad and other surcharge loads. The railroad loading to be applied is an E-80 loading. This loading consists of 80 Kip (356 KN) axles spaced five (5) feet (1.5 m) on centers. The lateral forces acting on the sheeting shall be computed as follows:
   a. The active earth pressure due to the weight of the soil is to be computed by the Rankine theory.
   b. The Boussinesq analysis shall be used to determine the lateral pressure caused by the railroad loading. The load on the track shall be taken as a strip load with a width equal to the length of the ties (8'-6" or 2.6 m). The vertical surcharge, q (psf), caused by each axle, shall be uniform and equal to the axle weight divided by the tie length and the axle spacing (5'-0" or 1.5 m). For an E-80 loading, this results in: $q = 80{,}000 / (8.5 \times 5) = 1882$ psf (90.1 KPa). The horizontal pressure due to the live load surcharge at any point on the sheet piling wall is Ph and can be calculated by the following: $Ph = (2q/\pi)(\beta - \sin\beta \cos 2\alpha)$ (see drawing SK-2).
4) The allowable stresses for the sheet piling and other steel members (wales, struts, etc.) shall be in accordance with AREA Chapter 15, Parts 1 and 2. These allowable stresses may be increased ten percent (10%) due to the temporary nature of the installations.

5) Where soil or rock anchors are used, all anchors must be tested. Testing shall be in accordance with industry standards with ten percent (10%) of the anchors "Performance Tested" and all others "Proof Tested".
6) Exploratory trenches, three (3) feet (0.9 m) deep and fifteen (15) inches (0.4 m) wide in the form of an "H" with outside dimensions matching the outside of sheeting dimensions are to be hand dug, prior to placing and driving steel sheeting, in areas where railroad underground installations are known to exist. These trenches are for exploratory purposes only and are to be backfilled with the backfill compacted immediately. This work must be done in the presence of a Conrail representative.
7) Absolute use of track is required while driving sheeting within fifteen (15) feet (4.6 m) from centerline of a live track. The procedure for arranging the use of track shall be as outlined on Pages Three and Four.
8) Cavities adjacent to the sheet piling, created by the driving of sheet piling, shall be filled with sand and any disturbed ballast must be restored and tamped immediately.
9) Sheet piling shall be cut off at the top of tie during construction. After construction and backfilling has been completed, piling within ten (10) feet (3.0 m) from centerline of track, or when bottom of excavation is below a line extending a 1:1 slope from end of tie to point of intersection with sheeting, shall be cut off eighteen (18) inches (0.5 m) below existing ground line and left in place.
10) Any excavation adjacent to track shall be covered and ramped and provided with barricades as required by Conrail. A lighted walkway with a handrail must be provided adjacent to the track for any excavation within ten (10) feet (3.0 m) of the centerline.
11) Final backfilling of excavation shall be as required by project specifications.
12) The sponsor is to advise Conrail of the time schedule of each operation and obtain approval of Conrail for all work to be performed adjacent to Conrail tracks so that it may be properly supervised by railroad personnel.
13) All drawings for temporary sheeting and shoring shall be prepared and stamped by a Registered Professional Engineer and shall be accompanied by complete design computations when submitted for approval.
14) Where physical conditions of design impose insurmountable restrictions requiring the placing of sheeting closer than specified above, the matter must be submitted to the Chief Engineer - Construction for approval of any modifications.
15) Five (5) copies of the submission are to be sent to Conrail's Area Engineer. The sponsor is advised to expect a minimum thirty (30) day review period from the day the submission is received by the Area Engineer.
16) Conrail's representative must be present at the site during the entire sheeting and shoring procedure period. The sponsor must notify the railroad representative at least seventy-two (72) hours in advance of the work. No changes will be accepted after that time.

ERECTION, HOISTING AND DEMOLITION REQUIREMENTS

1) A plan showing the locations of cranes, horizontally and vertically, operating radii, with delivery or disposal locations shown. The location of all tracks and other railroad facilities should also be shown.
2) Crane rating sheets showing cranes to be adequate for 150% of the actual weight of the pick. A complete set of crane charts, including crane, counterweight, and boom nomenclature is to be submitted.

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3) Plans and computations showing weight of picks must be submitted. Where beams are being removed over Conrail facilities, the weight shall include the weight of concrete or other material that will be included in each pick. Calculations shall be made from plans of the existing and/or proposed structure showing complete and sufficient details with supporting data for the demolition or erection of the structure.
4) If the sponsor can prove to Conrail that plans do not exist and weights must be calculated from field measurements, the field measurements are to be made under the supervision of the Registered Professional Engineer submitting the procedure and he shall include sketches and estimated weight calculations with his procedure. If possible, field measurements shall be taken with a Conrail representative present. Weights shall include the weight of concrete, or other material, that will be included in the lifts.
5) If the procedure involves either the cutting of steel or the bolting of joints which would affect Conrail operations, a detailed staging plan with estimated durations will be required.
6) A location plan showing all obstructions such as wires, poles, adjacent structures, etc., must be provided to show that the proposed lifts are clear of these obstructions.
7) A data sheet shall be prepared listing the type, size and arrangements of slings, shackles, or other connecting equipment. Include copies of a catalog or information sheets for specialized equipment.
8) A complete procedure is to be included, indicating the order of lifts and any repositioning or rehitching of the crane or cranes.
9) Demolition shield submittals must include a plan showing the details of the shield, a written installation and removal procedure and design calculations verifying the capacity of the shield. The shield should be designed for a minimum load of fifty (50) pounds/sq.ft (245 kgs./sq.m) plus the weight of the equipment, debris and any other load to be carried.
10) Temporary support of any components (overhead or undergrade) or intermediate stages is to be shown and detailed. A guardrail (railroad) will be required to be installed in a track where a temporary bent is located within twelve (12) feet (3.7 m) from the centerline of that track.
11) A time schedule of the various stages must be shown as well as a schedule for the entire lifting procedure.
12) All bridge erection or demolition procedures submitted will be prepared, signed and sealed by a Registered Professional Engineer.
13) Five (5) copies of the lifting procedures are to be sent to Conrail's Area Engineer. The sponsor is to expect a minimum thirty (30) day review period from the day the submission is received by The Area Engineer.
14) Conrail's field representative must be present at the site during the entire demolition and erection procedure period. The sponsor must notify the railroad representative at least seventy-two (72) hours in advance of the work. No changes will be accepted after that time.
15) The name and experience of the employee supervising the operation must be supplied to Conrail.

OVERGRADE BRIDGE REQUIREMENTS

CLEARANCES

1) The minimum vertical clearance above the top of the higher rail shall be twenty three (23) feet (7 m) at all times. In areas where the railroad has been electrified with a catenary wire, and areas which are likely to be electrified, the minimum vertical

clearance must be twenty four (24) feet, six (6) inches (7.5 m) above the top of the higher rail.

2) The minimum horizontal clearance measured from the centerline of track to the near face of the obstruction must be twenty (20) feet (6.1 m) for tangent track and twenty one (21) feet (6.4 m) for curves. See Conrail Standard Plan 48754-B attached.
3) Whenever practicable, bridge structures must have the piers and abutments located outside of the railroad right of way. All piers located less than twenty five (25) feet (7.6 m) from the centerline of track require a crashwall designed in accordance with specifications outlined in the current AREA manual.
4) All piers should be located so that they do not interfere with ditches. Where special conditions make this impossible, an explanation of these conditions must be submitted with the drainage plans for review by Conrail.
5) The permanent clearances should be correlated with the methods of construction so that temporary construction clearances will not be less than the minimum allowed.
6) Bridge structures shall provide sufficient lateral and vertical clearance for anticipated future tracks, changes in track centers and raising of tracks for maintenance purposes. The locations of these tracks shall be determined by inquiry to Conrail's Chief Engineer - Construction.
7) The profile of the top of rail should be examined to determine if the track is in a sag at the location of the bridge. If the track is in a sag, the vertical clearance from the track to the bridge should be increased sufficiently to allow raising the track to remove the sag.
8) Plans for bridges must show dimensioned locations of all utilities which might be located on the railroad right of way.
9) Vertical and horizontal clearances must be adjusted so that the sight distance to railroad signals is not reduced from what is existing.
10) All proposed temporary clearances which are less than those listed above must be submitted to Conrail for review and must be approved by Conrail prior to construction.
11) Clearances are subject to the requirements of the state in which the construction takes place and must be approved by the State and Conrail if less than those prescribed by law.

<u>DRAINAGE</u>

1) Maintaining the existing drainage and providing for future drainage improvements is of the utmost importance. Conrail will give special attention to reviewing the drainage details.
2) Drainage plans must be included with the general plans submitted to Conrail for approval. These plans must include hydrologic and hydraulic studies and computations showing the frequency and duration of the design storm used, as well as the method of analysis such as Soil Conservation Service or the Rational method. Conrail uses storms with a 100-year recurrence interval as the minimum design storm.
3) Lateral clearances must provide sufficient space for construction of the required track ditch parallel to the standard roadbed section. If the ditch cannot be provided, or the pier will interfere with the ditch, then a culvert of sufficient size must be provided. See Conrail Standard Plan 48754-B, which is attached.
4) Ditches and culverts must be sized to accommodate all increased run-off due to the construction and the increased size must continue to the natural outlet of the ditch. Ditches must be designed in accordance with good drainage engineering practices and must meet all local codes and ordinances.

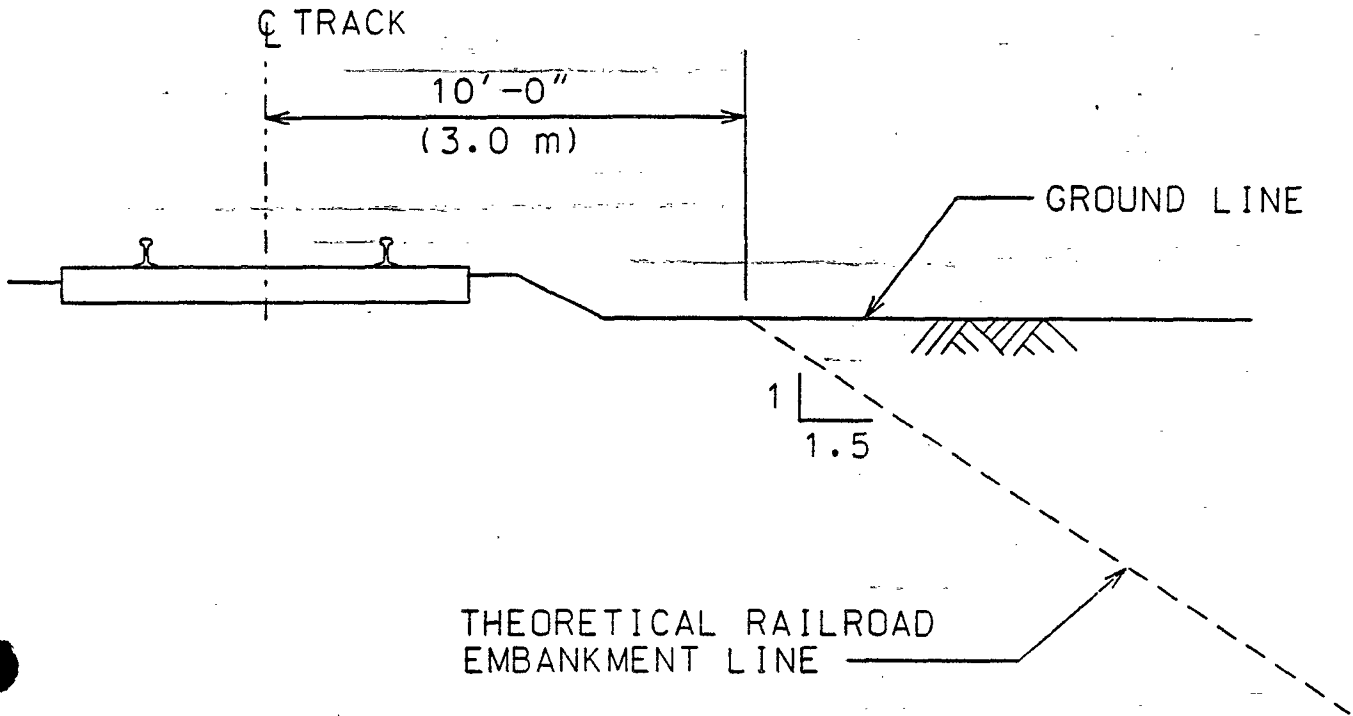
5) No scuppers or other deck drains, roadway drainage, catch basins, inlets or outlets are permitted to drain onto Conrail property. Any variation of this policy must have the prior approval of the Chief Engineer - Construction. If an exception is ultimately granted, maintenance of such should not be Conrail's. Drainage from scuppers and deck drains must be conveyed through pipes, preferably to a point which is off Conrail property. If the drainage must be conveyed into a railroad ditch, calculations must be provided to Conrail which indicate the ability of the ditch to carry the additional run-off.
6) Additional drainage may require the installation of a pipe, new ditch or reprofiling of the existing ditch.

EROSION CONTROL

1) Embankment slopes adjacent to the track must be paved for a minimum of two (2) feet (0.6 m) beyond the outside edge of the bridge foundation structure. The purpose of the pavement is to minimize erosion of the embankment material and to reduce deterioration of the sub-grade material by drainage water. The pavement shall consist of a prepared sub-base and/or filter fabric with grouted rip-rap on the surface.
2) The general plans for the bridge should indicate the proposed methods of erosion control during construction and must specifically address means to prevent silt accumulation in ditches and culverts and to prevent fouling the track ballast and sub-ballast. If the plans do not show erosion control, the contractor must submit a proposed method of erosion control and must have this method approved by Conrail prior to beginning any grading on the site.
3) Existing track ditches must be maintained at all times throughout the construction period. After the construction has been completed, all erosion and siltation must be removed and the ditches must be restored.
4) Conrail's approval of drainage and erosion control plans will not relieve the sponsor submitting these plans from ultimate responsibility for a satisfactory plan.

REFERENCES

1) In areas where underground utilities may be affected, Conrail's C.E. 8, "Specifications for Pipeline Occupancy" will govern.
2) In areas where power or communication lines will be affected, Conrail's C.E. 4, "Specifications for Wire, Conduit and Cable Occupations" will govern.



REQUIREMENTS FOR TEMPORARY SHEET PILING ADJACENT TO TRACK

1. STEEL SHEET PILING FOR TRACK SUPPORT IS NOT REQUIRED FOR EXCAVATION OUTSIDE THE THEORETICAL RAILROAD EMBANKMENT LINE. SHORING IN ACCORDANCE WITH OSHA REQUIREMENTS SHALL BE USED IN THIS AREA.

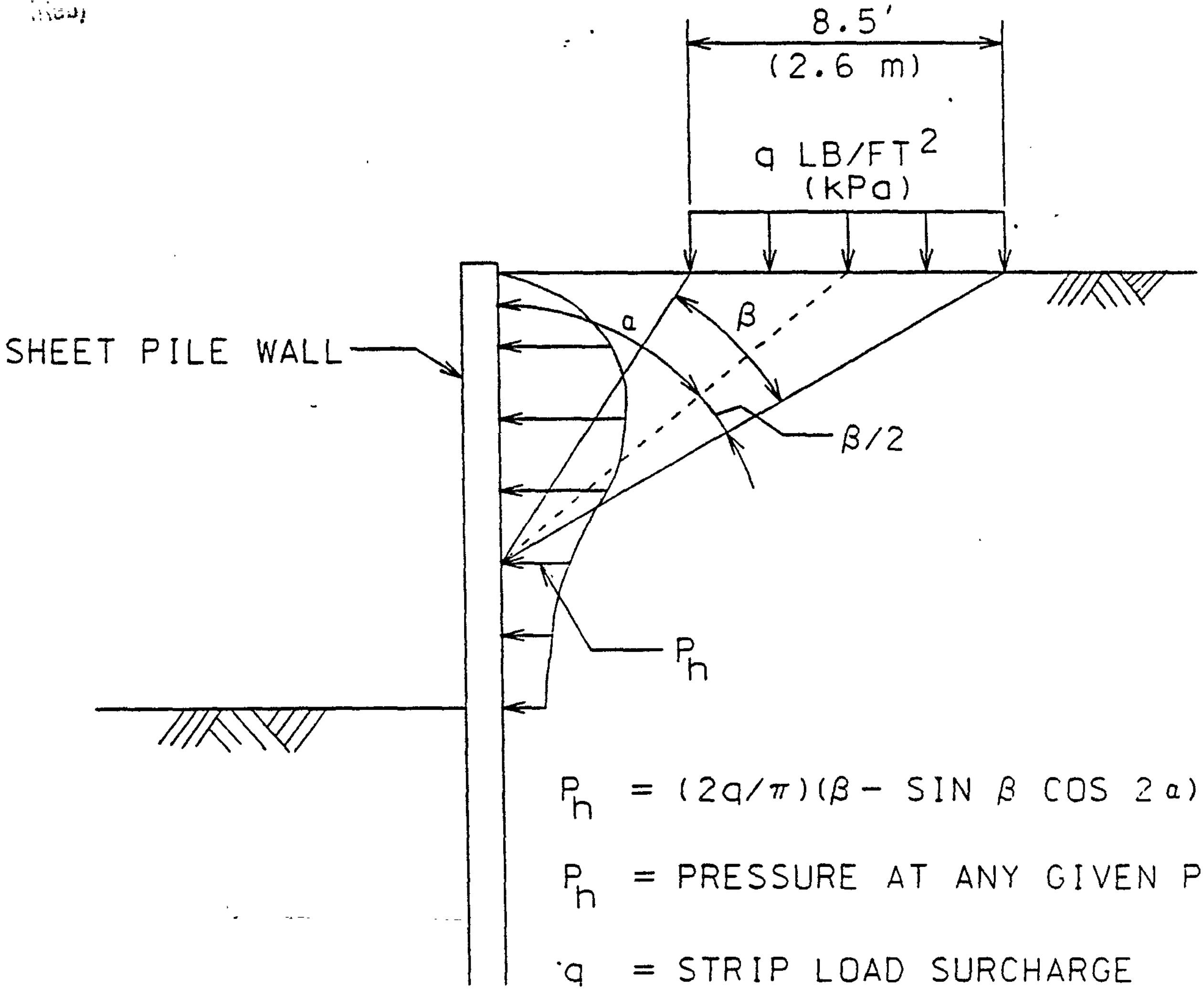
2. STEEL SHEET PILING, DRIVEN PRIOR TO EXCAVATION, IS REQUIRED WHEN EXCAVATION IS WITHIN THE THEORETICAL RAILROAD EMBANKMENT LINE.

3. ALL SHEET PILING IS TO BE DESIGNED FOR AN E-80 LOADING. THE BOUSSINESQ ANALYSIS IS TO BE USED TO DETERMINE THE LATERAL PRESSURE CAUSED BY THE RAILROAD LOADING.

OFFICE OF CHIEF ENGINEER - D & C

FEB 1, 1995 DWG. NO.: SK-1

LATERAL PRESSURE DIAGRAM



$P_h = (2q/\pi)(\beta - \sin\beta \cos 2\alpha)$

P_h = PRESSURE AT ANY GIVEN POINT

q = STRIP LOAD SURCHARGE

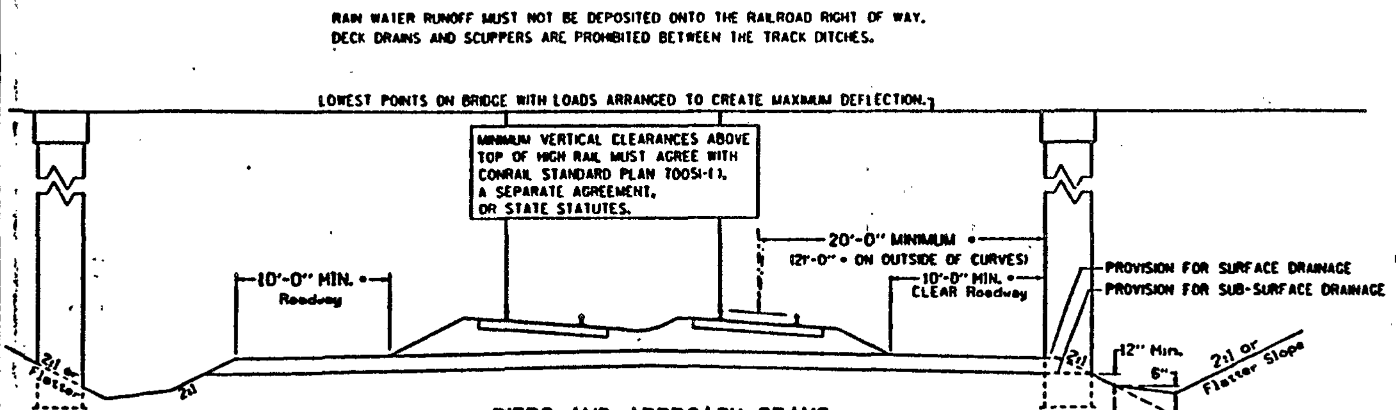
α = ANGLE IN DEGREES

β = ANGLE IN RADIANS

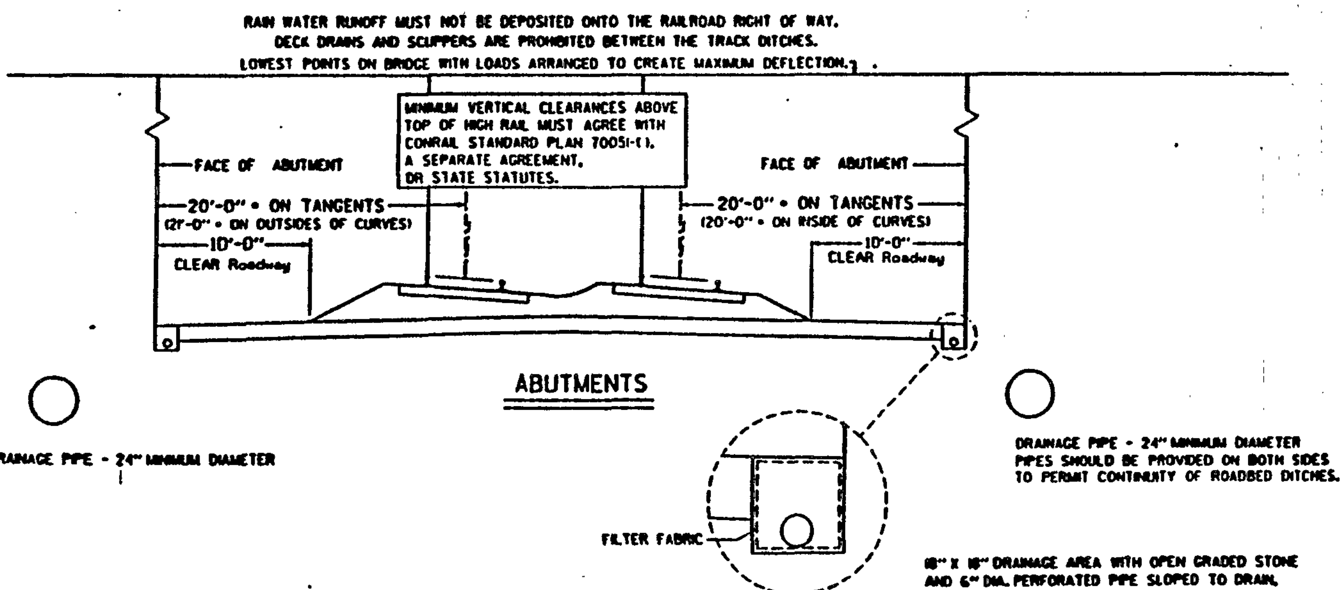
LATERAL PRESSURE DUE TO STRIP LOAD

OFFICE OF CHIEF ENGINEER – D & C

FEB 1, 1995 DWG. NO.: SK-2



PIERS AND APPROACH SPANS



ABUTMENTS

DRAINAGE PIPE - 24" MINIMUM DIAMETER

DRAINAGE PIPE - 24" MINIMUM DIAMETER
PIPES SHOULD BE PROVIDED ON BOTH SIDES TO PERMIT CONTINUITY OF ROADBED DITCHES.

18" X 18" DRAINAGE AREA WITH OPEN GRADED STONE AND 6" DIA. PERFORATED PIPE SLOPED TO DRAIN. (WITH FILTER FABRIC WHEN REQUIRED).

ALL SIDE SLOPES THROUGH THE BRIDGE AREA MUST BE COVERED WITH RIP-RAP.

DITCHES AND SLOPES THROUGH THE BRIDGE AREA MUST MEET THE EXISTING DRAINAGE FACILITIES AND MATCH OR EXCEED THEM IN HYDRAULIC CAPACITY.

PIERS LOCATED LESS THAN 25 FEET FROM THE CENTERLINE OF ANY TRACK MUST BE PROTECTED BY CRASH WALLS IN ACCORDANCE WITH THE SPECIFICATIONS IN CHAPTER 8, PART 2.1.5 OF THE A.R.E.A. MANUAL FOR RAILWAY ENGINEERING.

• - LATERAL CLEARANCES MARKED "•" MAY BE REDUCED BY 2 FEET IF A ROADWAY IS NOT REQUIRED.

ADDITIONAL CLEARANCE MAY BE REQUIRED TO ACCOMODATE COMMUNICATION AND SIGNAL POLE LINES, OR AS OTHER FIELD CONDITIONS REQUIRE.

FLAT BOTTOM DITCHES, AS SHOWN, ARE TO BE USED. "V" BOTTOM DITCHES ARE PERMITTED ONLY IN CONJUNCTION WITH A DRAINAGE PIPE. THE PIPE MUST HAVE AT LEAST 4 FEET OF COVER, OR BE AT AN ELEVATION MEETING THE EXISTING DITCHES, AND MUST BE AT LEAST 24" DIAMETER.

THE DITCH SECTION SHOWN IS THE MINIMUM ACCEPTABLE SECTION. DITCH SIZES MUST BE INCREASED WHEN NECESSARY AS DETERMINED BY HYDROLOGIC AND HYDRAULIC STUDIES, OR IF THE DRAINAGE PATTERN IS ALTERED BY CONSTRUCTION.

CONRAIL 48754-B

OVERHEAD BRIDGE MINIMUM CLEARANCE DIAGRAM

CHIEF ENGINEER B&C

FEBRUARY, 1990

AR305346

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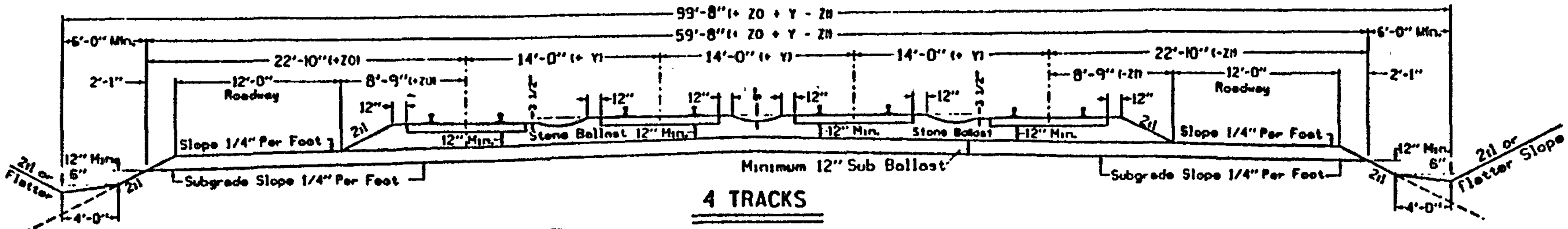
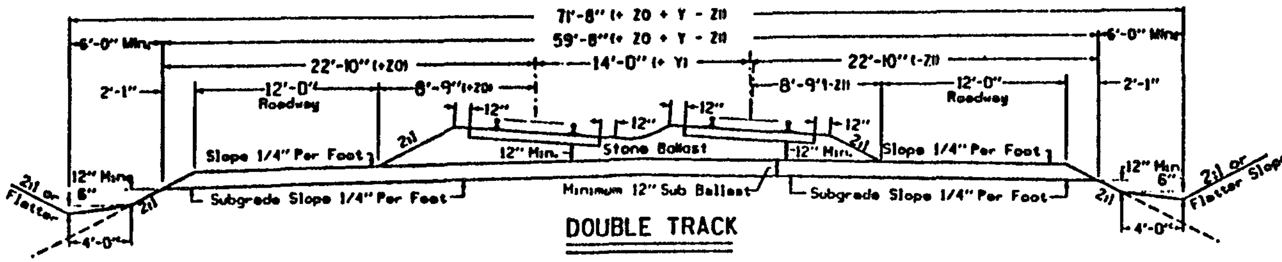
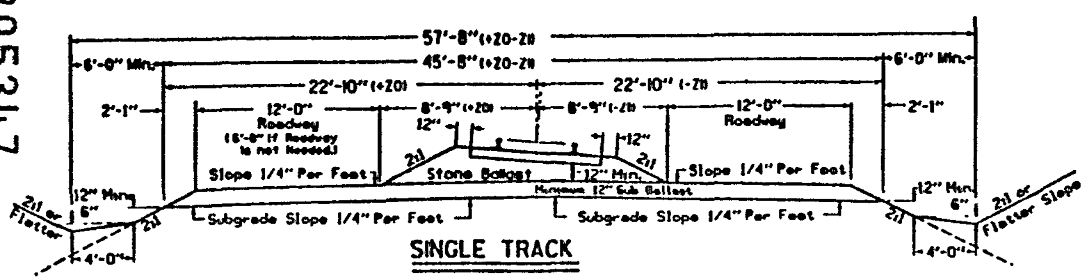


4 TRACKS

Note: Z0 and Z1 are indicated for tracks which curve to the right.



DOUBLE TRACK



SINGLE TRACK

AR305347

Y DIMENSION

On adjacent tracks where the super-elevation is the same or the outer track has less, Y=2" per degree of curve.

Where super-elevation is greater on the outer track, Y = 2" per degree of curve added to 3 1/2 times the amount of difference in super-elevation.

Z Dimensions 2 or More Tracks

Super-Elevation	Z0 - Outside of Curve	Z1 - Inside of Curve
0"	0"	0"
1"	4"	1"
2"	7"	5"
3"	10"	6"
4"	1'-1"	7"
5"	1'-4"	8"
6"	1'-7"	10"

Z Dimensions Single Track

Super-Elevation	Z0 - Outside of Curve	Z1 - Inside of Curve
0"	0"	0"
1"	2"	2"
2"	5"	4"
3"	8"	5"
4"	11"	6"
5"	1'-3"	7"
6"	1'-6"	9"

CONRAIL 48747

TYPICAL
ROADBED AND BALLAST SECTIONS

AUGUST, 1988

CHIEF ENGINEER M&C

Langan
Engineering and Environmental Services, Inc.

MEMORANDUM

TO: Bill Mercurio

FROM: Carole Sforza CS

INFO: Bob Koto

DATE: 13 September 1995

RE: Conrail Procedures for Subsurface Investigation

In accordance with a conversation with Mr. Mark Sawyer, Conrail Engineer, on 12 September 1995, the following Conrail procedures are necessary for subsurface investigations in or near the railroad embankment:

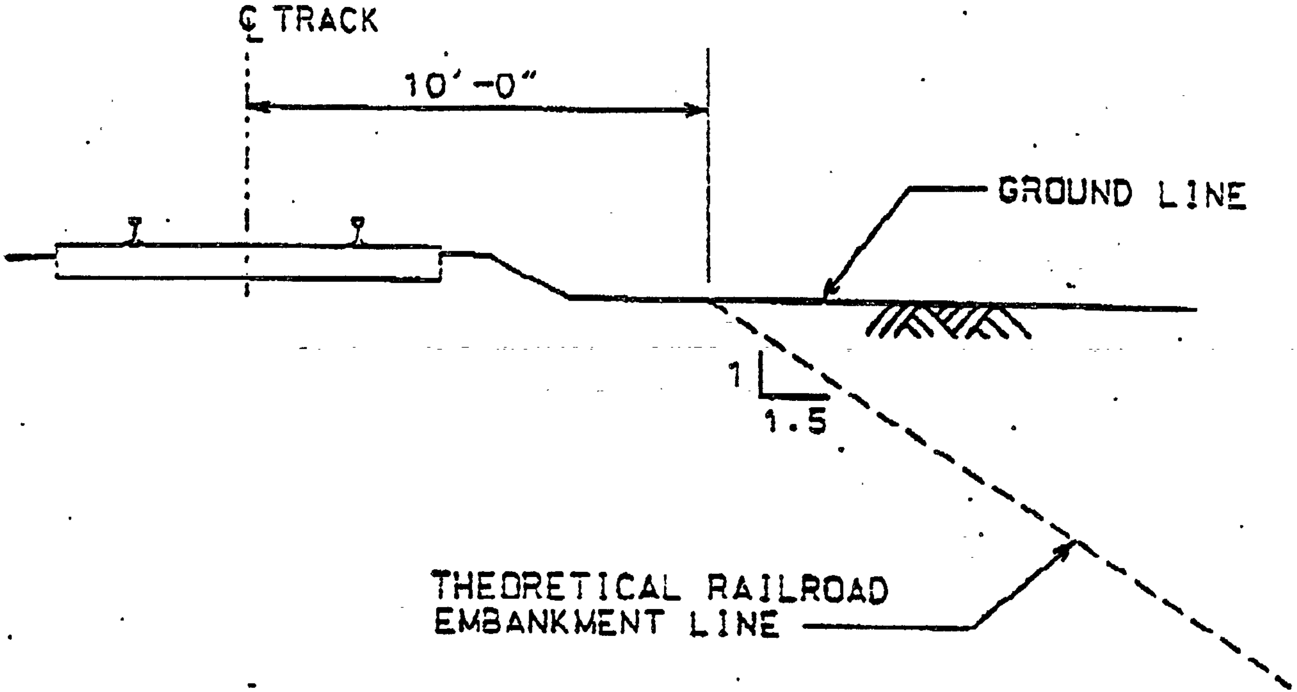
- excavate within the embankment using interlocking steel sheeting to support the weight of a train (250 tons);
- move sampling locations outside the embankment line (as shown on the attached diagram);
- collect samples using a drill rig; however, if the drill rig is within 12 feet of the rail, a Conrail engineer must be present to determine the available "windows" during the day to drill as trains will not be stopped;
- collect samples using a skid rig or jackhammer borings so that the rig is not close to the track in order to eliminate the need to drill only during the available "windows"; and
- collect samples using a backhoe; however, a Conrail engineer must be present to determine the available "windows" during the day to excavate and backfill in between

train traffic. (Test pits should be limited to a length of 3 feet parallel to the railroad and a compactor must be used.)

Mr. Sawyer assigned an engineer to the Halby site starting Monday (18 September 1995). A copy of the Republic insurance certificate should be given to the Conrail representative on Monday. Mr. Sawyer wants to discuss the details of the subsurface investigation prior to Monday so that he can determine whether the presence of a Conrail engineer is necessary, whether shoring is necessary, whether sampling during the available "windows" is necessary, etc. He also wants a confirmation phone call on Friday, 15 September 1995.

sforza\conrail.mem

CAROLE SFORZA –
201-794-7501 x
0366



REQUIREMENTS FOR TEMPORARY SHEET PILING ADJACENT TO TRACK

1. STEEL SHEET PILING FOR TRACK SUPPORT IS NOT REQUIRED FOR EXCAVATION OUTSIDE THE THEORETICAL RAILROAD EMBANKMENT LINE. SHORING IN ACCORDANCE WITH OSHA REQUIREMENTS SHALL BE USED IN THIS AREA.

2. STEEL SHEET PILING, DRIVEN PRIOR TO EXCAVATION, IS REQUIRED WHEN EXCAVATION IS WITHIN THE THEORETICAL RAILROAD EMBANKMENT LINE.

3. ALL SHEET PILING IS TO BE DESIGNED FOR AN E-80 LOADING. THE BOUSSINESQ ANALYSIS IS TO BE USED TO DETERMINE THE LATERAL PRESSURE CAUSED BY THE RAILROAD LOADING.

OFFICE OF CHIEF ENGINEER – D & C

JAN 11, 1993 DWG. NO.: SK-1

TOTAL P.01

ORIGINAL (Red)

CE-8
5/1/95

SPECIFICATIONS

FOR

PIPELINE OCCUPANCY

OF

CONSOLIDATED RAIL CORPORATION

PROPERTY

RECOMMENDED:

System Engineer Design - Structures

APPROVED:

Chief Engineer - Construction

AR305351

ORIGINAL (Red)

INDEX

APPENDIX

Specifications For Pipeline Occupancy Of Consolidated Rail Corporation Property

1.0 GENERAL

1.1 Scope

a. This specification shall apply to the design and construction of pipelines carrying flammable or non-flammable substances and casings containing wires and cables across and along Conrail property and facilities. This specification shall also apply to tracks owned by others (sidings, industry tracks, etc.) over which Conrail operates its equipment.

b. It is to be clearly understood that Conrail owns its right-of-way for the primary purpose of operating a railroad. All occupancies shall therefore be designed and constructed so that rail operations and facilities are not interfered with, interrupted or endangered. In addition, the proposed facility shall be located to minimize encumbrance to the right-of-way so that the railroad will have unrestricted use of its property for current and future operations.

1.2 Definitions

a. Conrail - Consolidated Rail Corporation

b. Chief Engineer - Conrail's Chief Engineer - Construction or his designated representative

c. Owner (Applicant) - Individual, corporation or municipality desiring occupancy of Conrail property.

d. Professional Engineer - Engineer licensed in the state where the facilities are to be constructed.

e. Carrier Pipe - Pipe used to transport the product.

f. Casing Pipe - Pipe through which the carrier pipe is installed.

g. Sidings or industry tracks - Tracks located off of Conrail's right-of-way, serving an industry.

1.3 Application For Occupancy

a. Individuals, corporations or municipalities desiring occupancy of Conrail property by pipeline occupations must agree, upon approval of the engineering and construction details by the Chief Engineer, to execute an appropriate Conrail occupational agreement and pay any required fees and/or rentals specified therein.

b. The application for an occupancy shall be by letter addressed to the Chief Engineer - Construction, Consolidated Rail Corporation, 2001 Market Street - 11C, P.O. Box 41411, Philadelphia, PA., 19101-1411, giving the following:

(1) Full name of Owner.

(2) Complete mailing address of the applicant.

(3) Name and title of person who will sign the agreement.

(4) The State in which the applicant is incorporated.

ORIGINAL (Red)

c. All applications shall be accompanied with six (6) copies of all design and construction plans and three (3) copies of all specifications and engineering computations for the proposed occupancy. On extensive projects, only those plans involving work on, or affecting Conrail property and operations, shall be submitted. Included shall be a plan showing the extent of the total project upon which that portion of the work affecting Conrail is clearly defined

d. All of the above plans, specifications and computations must be prepared by and bear the seal of a Professional Engineer.

1.4 Right Of Entry

a. No entry upon Conrail property for the purpose of conducting surveys, field inspections, obtaining soils information or any other purposes associated with the design and construction for the proposed occupancy, will be permitted without a proper entry permit prepared by the Chief Engineer, or his designated representative. The applicant must pay the associated fees and execute the entry permit.

b. It is to be clearly understood that the issuance of an entry permit does not constitute authority to proceed with any construction. Construction can not begin until a formal agreement is executed by Conrail and the Owner receives permission, from the designated inspection agency of Conrail, to proceed with the work.

1.5 Site Inspection

a. For longitudinal occupancy of Conrail property a site inspection along the proposed pipeline route may be required before final design plans are prepared. When a site inspection is required, the applicant and/or his engineer must meet with representatives of the Chief Engineer's Office to view the entire length of the proposed occupancy.

b. Prior to the site inspection the applicant must submit the following information:

(1) A plan view of the proposed route showing all tracks, both Conrail right-of-way lines and all other facilities located on the right-of-way. The distance from the proposed pipeline to the adjacent track and to the right-of-way lines must be shown.

(2) A complete "Pipe Data Sheet" (See Plate I)

(3) Typical cross sections along the proposed route. (See Plate V)

c. Site inspections for pipe crossings are not required unless, in the opinion of the Chief Engineer, the size and location of the facility warrant an inspection.

1.6 Information Required for Submission

1.6.1 Plans and Computations

a. Plans for proposed pipeline occupancies shall be submitted to and approved by the Chief Engineer prior to Conrail's issuance of an agreement and start of construction.

b. Plans are to be prepared in sizes as small as practical and shall be folded, individually, by the applicant to an 8 1/2 inch by 11 inch (216 x 279 mm) size, as shown on Plate X, prior to submission. Where more than one plan is involved, the folded plans shall be assembled into complete sets by the applicant before submission. **Failure of the applicant to comply with these requirements may be sufficient cause for rejection of the application.**

c. Plans shall be drawn to scale and shall include the following (See Plates I to VII):

(1) Plan view of proposed pipeline in relation to all Conrail facilities and facilities immediately adjacent to Conrail including, but not limited to, tracks, buildings, signals, pole lines, other utilities and all other facilities that may affect or influence the pipeline design and construction. (See Plate II)

(2) The location, in feet (meters), of the pipe crossing from the nearest Conrail Milepost and/or from the centerline of a Conrail bridge, giving the Conrail bridge number. If the above is not available, provide distance to the nearest highway grade crossing of the railroad.

(3) In all cases, the name of the State and County in which the proposed facilities are located must be shown. In States where Townships, Ranges and Sections are used, show the distance in feet to the nearest Section line and identify the Section number, Township and Range.

(4) The profile of the ground above the centerline of the pipe, from field survey, showing relationship of the pipeline and/or casing pipe to the ground levels, the tracks and other facilities, (See Plate III). For longitudinal occupations, the top of rail profile of the adjacent track shall be shown on the pipeline profile, (See Plate IV).

(5) All Conrail property lines indicated by dimensions, in feet (meters), to the centerline of adjacent track, as well as the overall width of the Conrail right-of-way. If the pipeline is in a public highway, the limits of the dedicated highway right-of-way, as well as the limits of any paving, sidewalks etc., shall be defined, by dimensions in feet (meters), from the centerline of the dedicated right-of-way.

(6) The angle of the crossing in relation to the centerline of the track(s). (See Plate II)

(7) On pipelines having valves, the distance in feet (meters) along the pipeline from the crossing to the nearest valves and/or control stations.

(8) A separate "Pipe Data Sheet" (See Plate I) shall be submitted on an 8 1/2 inch by 11 inch (216 x 279 mm) sheet, for each crossing.

d. The plan shall be specific, on Conrail property and under tracks that are not on Conrail property, as to the:

(1) Method of installation. (See Section 5.1)

(2) Size and material of the casing pipe. (See Section 4.3)

(3) Size and material of the carrier pipe. (See Section 4.4)

These items **can not** have an alternative and any application that is received that indicates options in any of the above items **will not be processed**.

e. Once the application has been approved by the Chief Engineer, no variance from the plans, specifications, method of installation, construction, etc., as approved in the occupancy document, will be considered or permitted without the payment to Conrail of additional fees for the re-processing of the application.

f. All plans and computations associated with the work under the agreement shall be prepared by, and bear the seal of, a Professional Engineer. If not so imprinted, the application will be given no further consideration. This requirement also applies to all data submitted by the

Owner's contractor. Contractor's plans and computations that are not stamped will be returned and construction will not be permitted to proceed.

1.6.2 Specifications

a. Project specifications, for all work on and affecting the railroad right-of-way, shall be included with the submission. All pertinent requirements of this document shall be included.

1.7 Notification to Proceed with Construction

a. After approval of the engineering plans and specifications and execution of the occupational agreement, the Owner will be notified of the appropriate Conrail Area Engineer's Office that must be contacted prior to start of construction. The Area Engineer's Office will provide Conrail's inspection of the project and coordinate all other construction aspects of the project that relate to Conrail (flagging, track work, protection of signal cables, etc.).

b. The Area Engineer's Office must be notified a minimum of fourteen (14) working days prior to desired start of construction.

2.0 GENERAL REQUIREMENTS

2.1 Use of a Casing Pipe

a. A casing pipe will be required for all pipeline crossings carrying liquid flammable or non-flammable substances under pressure.

b. For flammable and nonflammable gas pipelines the casing pipe may be omitted provided the carrier pipe meets the requirements provided in the AREA manual Chapter 1, Part 5, Section 5.2.3. The Chief Engineer may require use of a casing pipe at locations where increased risks from specific site conditions (track speed, traffic density, etc.) are present.

c. For non-pressure sewer or drainage crossings, where the installation can be made by open cut (see Section 5.1.2) or reinforced concrete pipe can be jacked under the railroad (see Section 5.1.4), the casing pipe may be omitted.

d. Pressure pipelines that do not cross under the track but are located within 25 feet (7.6 m) of the centerline of any track or closer than 45 feet (13.7 m) to nearest point of any bridge, building or other important structure, shall be encased.

e. The casing pipe shall be laid across the entire width of the right-of-way, except where a greater length is required to comply with Section 4.3.1.f. of this specification, even though such extension is beyond the right-of-way. For non-pressure sewer or drainage crossings, where a casing is used for carrier pipe installation purposes only, the casing need only to extend from the boring pit to the receiving pit.

2.2 Location of Pipeline on the Right-of-Way

a. Pipelines laid longitudinally on Conrail's right-of-way shall be located as far as practicable from any tracks or other important structures and as close to the railroad property line as possible. Longitudinal pipelines must not be located in earth embankments or within ditches located on the right-of-way.

b. Pipelines shall be located, where practicable, to cross tracks at approximate right angles to the track, but preferably at not less than 45 degrees.

c. Pipelines shall not be placed within a culvert, under railroad bridges, nor closer than 45 feet (13.7 m) to any portion of any railroad bridge, building, or other important structure, except in special cases, and then by special design, as approved by the Chief Engineer.

d. Pipelines shall not be located within the limits of a turnout (switch) when crossing the track. The limits of the turnout extend from the point of the switch to the last long timber.

e. Pipeline installations shall not be designed as an open cut installation where the pipeline is to be located within the limits of a grade crossing. If it is shown that no other method of installation is possible, the owner will be responsible for reimbursing Conrail for all costs associated with the removal and reconstruction of the grade crossing.

f. Pipelines carrying liquefied petroleum gas shall, where practicable, cross the railroad where tracks are carried on embankment.

g. Uncased gas pipelines must not be located within 25 feet (7.6 m) of any track.

2.3 Depth of Installation

2.3.1 Pipelines conveying non-flammable substances

a. Casing/carrier pipes placed under Conrail track(s) shall be not less than 5½ feet (1.7 m) from base of rail to top of pipe at its closest point, except that under sidings or industry tracks this distance may be 4½ feet (1.4 m) as approved by the Chief Engineer. On other portions of the right-of-way, where the pipe is not directly beneath any track, the depth from ground surface or from bottom of ditch to top of pipe shall not be less than 3 feet (0.9 m). Where 3 feet (0.9 m) of cover can not be provided from bottom of ditch, a 6 inch (152 mm) thick concrete slab shall be provided over the pipeline for protection.

b. Pipelines laid longitudinally on Conrail's right-of-way, 50 feet (15.2 m) or less from centerline track, shall be buried not less than 4 feet (1.2 m) from ground surface to top of pipe. Where the pipeline is laid more than 50 feet (15.2 m) from centerline of track, the minimum cover shall be at least 3 feet (0.9 m).

2.3.2 Pipelines conveying flammable substances

a. Casing pipes under Conrail track(s) shall be not less than 5½ feet (1.7 m) from base of rail to top of pipe at its closest point, except that under sidings or industry tracks this distance may be 4½ feet (1.4 m) as approved by the Chief Engineer. On other portions of the right-of-way, where the pipe is not directly beneath any track, the depth from ground surface or from bottom of ditch to top of pipe shall not be less than 3 feet (0.9 m). Where 3 feet (0.9 m) of cover can not be provided from bottom of ditch, a 6 inch (152 mm) thick concrete slab shall be provided over the pipeline for protection.

b. Uncased gas pipelines, under Conrail track(s), shall not be less than 10 feet (3.0 m) from the base of rail to the top of the pipe at its closest point. At all other locations where crossing the right-of-way, the minimum ground cover must be 6 feet (1.8 m). Where it is not possible to obtain the above depths, use of a casing pipe will be required.

c. Pipelines laid longitudinally on Conrail's right-of-way, 50 feet (15.2 m) or less from centerline track, shall be buried not less than 6 feet (1.8 m) from ground surface to top of pipe. Where the pipeline is laid more than 50 feet (15.2 m) from centerline of track, the minimum cover shall be at least 5 feet (1.5 m).

2.4 Pipelines within Limits of a Dedicated Highway

a. Pipelines within the limits of a dedicated highway are subject to all the requirements of this specification and must be designed and installed in accordance with them.

b. The limits of the dedicated highway (right-of-way) must be clearly shown on the plans.

c. Construction can not begin until an agreement has been executed between Conrail and the Owner and proper notification has been given to Conrail's Area Engineer. (See Section 1.7)

2.5 Modification of Existing Facilities

a. Any replacement or modification of an existing carrier pipe and/or casing shall be considered as a new installation, subject to the requirements of this specification.

2.6 Abandoned Facilities

a. The owner of all abandoned pipe crossings and other occupancies shall notify the Chief Engineer, in writing, of the intention to abandon.

b. Abandoned pipelines shall be removed or completely filled with cement grout, compacted sand or other methods as approved by the Chief Engineer.

c. Abandoned manholes and other structures shall be removed to a minimum distance of 2 feet (0.6 m) below finished grade and completely filled with cement grout or compacted sand.

2.7 Conflict of Specifications

a. Where laws or orders of public authority prescribe a higher degree of protection than specified herein, then the higher degree so prescribed shall be deemed a part of this specification.

2.8 Insulation

a. Pipelines and casings shall be suitably insulated from underground conduits carrying electric wires on Conrail property.

2.9 Corrosion Protection and Petroleum Leak Prevention

a. Pipelines on Conrail property that carry petroleum products or hazardous liquids shall be designed in accordance with current federal, state and/or local regulations that mandate leak detection automatic shutoff, leak monitoring, and sacrificial anodes and/or exterior coatings to minimize corrosion and prevent petroleum releases.

3.0 SOIL INVESTIGATION

3.1 General

a. Test borings or other soil investigations, approved by the Chief Engineer, shall be made to determine the nature of the underlying material for all pipe crossings 60 inches (1524 mm) in diameter and larger under track(s). (See Section 1.4 relative to procedures)

b. Test borings or other soil investigations, approved by the Chief Engineer, may be required when, in the judgment of the Chief Engineer, they are necessary to determine the adequacy of the design and construction of pipe crossings less than 60 inches (1524 mm) in diameter and for other facilities located on the right-of-way.

3.2 Location

a. Borings shall be made on each side of the track(s), on the centerline of the pipe crossing, and as close to the track(s) as practicable. (See Section 1.4 relative to procedures)

b. Test boring logs shall be accompanied with a plan, drawn to scale, showing the location of the borings in relation to the track(s) and the proposed pipe.

3.3 Sampling

a. Test borings shall be made in accordance with current ASTM Designation D 1586 except that sampling must be continuous from the ground surface to 5 feet (1.5 m) below the proposed invert unless rock is encountered before this depth. Where rock is encountered, it is to be cored using a Series "M" Double Tube Core Barrel, with a diamond bit, capable of retrieving a rock core at least 1 5/8" (41.3 mm) in diameter. Individual core runs are not to exceed 5 feet (1.5 m) in length.

3.4 Boring Logs

a. Test boring logs shall comply with Plate VIII and clearly indicate all of the following:

(1) Boring number as shown on the required boring location plan.

(2) Ground elevation at each boring using same datum as the pipeline construction plans.

(3) Engineering description of soils or rock encountered.

(4) Depth and percent recovery of all soil samples.

(5) Depth from surface for each change in strata.

(6) Blows for each 6 inches (152 mm) of penetration for the standard penetration test described in ASTM D 1586. Blows for lesser penetrations should be recorded.

(7) Percent recovery and Rock Quality Designation (RQD) for all rock cores.

(8) Depth to ground water while sampling and when it has stabilized in the bore hole.

b. The location of the carrier pipe and/or casing pipe shall be superimposed on the boring logs before submission to the Chief Engineer.

c. All borings shall be sealed, for their full depth, with a 4-3-1 bentonite-cement-sand grout after accurate ground water readings have been taken and recorded.

d. Soil samples taken from auger vanes or return washwater are not acceptable.

3.5 Additional Information

a. When directed by the Chief Engineer, additional borings may be required for the purpose of taking undisturbed thin-wall piston samples or Dennison type samples for laboratory testing to determine the index and engineering properties of certain soil strata.

4.0 DESIGN REQUIREMENTS

4.1 Design Loads

4.1.1 General Requirements

a. All pipes, manholes and other facilities shall be designed for the external and internal loads to which they will be subjected.

b. To allow for placement of additional track(s) or shifting of the existing track(s), all proposed pipelines or structures shall be designed as if a railroad loading is directly above the facility.

4.1.2 Earth Load

a. The dead load of the earth shall be considered as 120 pounds per cubic foot (18.9 kN/m^3) unless soil conditions warrant the use of a higher value.

4.1.3 Railroad Load (live load and impact)

a. The railroad live load used shall be a Cooper E-80 loading. This loading consists of 80 kip (356 kN) axle loads spaced 5 feet (1.5 m) on centers.

b. An impact factor of 1.75 (multiply live load by the impact factor) shall be used for depth of cover up to 5 feet (1.5 m). Between 5 and 30 feet (1.5 and 9.1 m), the impact factor is reduced by 0.03 per foot (0.1 per m) of depth. Below a depth of 30 feet (9.1 m), the impact factor is one.

c. The values shown in Table 1 shall be used for the vertical pressure on a buried structure for the various heights of cover.

Table 1
Live loads, including impact, for various heights of cover for a Cooper E-80 loading.

Height of Cover		Load	
feet	(meter)	lb/sq ft	(kPa)
2	(0.6)	3800	(162.8)
3	(0.9)	3150	(150.8)
4	(1.2)	2850	(136.5)
5	(1.5)	2550	(122.1)
6	(1.8)	2250	(107.7)
7	(2.1)	1950	(93.4)
8	(2.4)	1700	(81.4)
9	(2.7)	1500	(71.8)
10	(3.0)	1300	(62.2)
12	(3.7)	1000	(47.9)
14	(4.3)	800	(38.3)
16	(4.9)	625	(29.9)
18	(5.5)	500	(23.9)
20	(6.1)	400	(19.2)
25	(7.6)	250	(12.0)
30	(9.1)	150	(7.2)

d. To determine the horizontal pressure caused by the railroad loading on a sheet pile wall or other structure adjacent to the track, the Boussinesq analysis shall be used. The load on the track shall be taken as a strip load with a width equal to the length of the ties, 8½ feet (2.6 m). The vertical surcharge, q (psf), caused by each axle, shall be uniform and equal to the axle load divided by the tie length and the axle spacing, 5 feet (1.5 m). For the E-80 loading this results in;

$$q = 80{,}000 / (8.5 \times 5) = 1882 \text{ psf.} \qquad (q = 356 / (2.591 \times 1.524) = 90.1 \text{ kPa})$$

The horizontal pressure due to the live load surcharge at any point on the wall or other structure is p_h and can be calculated by the following:

$$p_h = (2q/\pi)(\beta - \sin\beta(\cos 2\alpha))$$ (See PLATE IX)

e. The vertical and horizontal pressures given above shall be used unless an alternate design method is approved by the Chief Engineer. Proposals to use an alternate design method must include acceptable references and a statement explaining the justification for choosing the alternate method.

4.2 Design Assumptions

a. To design a casing pipe or an uncased carrier pipe for the external loads on Conrail's right-of-way, the following design assumptions shall be used, unless site conditions indicate more conservative values are required:

b. Flexible Pipe (Steel, DIP, CMP, Tunnel Liner Plate)

(1) Steel Pipe (Bored and jacked in place)
- Spangler's Iowa formula shall be used for design with:

(a) Deflection lag factor - $D_l = 1.5$
(b) Modulus of soil reaction - $E' = 1080$ psi (7.45 MPa)
(c) Bedding constant - Kb = 0.096
(d) Soil loading constant - $K_u' = 0.13$
(e) Allowable deflection of pipe - 3% of pipe diameter

(2) Ductile Iron Pipe (Open Cut)
- ANSI Specification A 21.50 shall be used for design with:

(a) Pipe laying condition = Type 3 (see Sec. 5.1.2 for backfill requirements on RR R/W)
(b) Earth load - ANSI A 51.50 prism method

(3) Corrugated Steel Pipe & Corrugated Structural Steel Plate Pipe (Open Cut)
- AREA Chapter 1, Part 4, Sections 4.9 & 4.10 shall be used for design with:

(a) Soil stiffness factor - K = 0.33
(b) Railroad impact as per Section 4.1.3.b. of this specification.

(4) Tunnel Liner Plate (Tunneled)
- AREA Chapter 1, Part 4, Section 4.16 shall be used for design with:

(a) Soil stiffness factor - K = 0.33
(b) Railroad impact as per Section 4.1.3.b. of this specification.

c. Rigid Pipe (RCP, Vitrified Clay Pipe and PCCP)

(1) Reinforced Concrete Pipe, Vitrified Clay Pipe & Prestressed Concrete Cylinder Pipe (Open Cut)
- American Concrete Pipe Association design manual shall be used for design with:

(a) Marston load theory used for earth load
(b) Bedding (Load Factor) - $L_f = 1.9$
(c) Factor of safety - FS = 1.25 for RCP FS = 1.50 for VCP

(d) Railroad impact as per Section 4.1.3.b. of this specification.

(2) Reinforced Concrete Pipe (Jacked)

- American Concrete Pipe Association design manual shall be used for design with:

(a) Marston load theory used for earth load
(b) Bedding (Load Factor) - $L_f = 3.0$
(c) Factor of safety = 1.25
(d) Railroad impact as per Section 4.1.3.b. of this specification.

4.3 Casing Pipe

4.3.1 General Requirements

a. Casing pipe shall be so constructed as to prevent leakage of any substance from the casing throughout its length, except at ends of casing where ends are left open, or through vent pipes when ends of casing are sealed. Casing shall be installed so as to prevent the formation of a waterway under the railroad, and with an even bearing throughout its length, and shall slope to one end (except for longitudinal occupancy).

b. The casing pipe and joints shall be of steel and of leakproof construction when the pipeline is carrying liquid flammable products or highly volatile substances under pressure.

c. The inside diameter of the casing pipe shall be such as to allow the carrier pipe to be removed subsequently without disturbing the casing or the roadbed. For steel pipe casings, the inside diameter of the casing pipe shall be at least 2 inches (51 mm) greater than the largest outside diameter of the carrier pipe joints or couplings, for carrier pipe less than 6 inches (152 mm) in diameter; and at least 4 inches (102 mm) greater for carrier pipe 6 inches (152 mm) and over in diameter.

d. For flexible casing pipe, a maximum vertical deflection of the casing pipe of 3 percent of its diameter, plus ½ inch (13 mm) clearance shall be provided so that no loads from the roadbed, track, traffic or casing pipe itself are transmitted to the carrier pipe. When insulators are used on the carrier pipe, the inside diameter of the flexible casing pipe shall be at least 2 inches (51 mm) greater than the outside diameter of the carrier pipe for pipe less than 8 inches (203 mm) in diameter; at least 3¼ inches (83 mm) greater for pipe 8 inches to 16 inches (203 mm to 406 mm), inclusive, in diameter and at least 4½ inches (114 mm) greater for pipe 18 inches (457 mm) and over in diameter.

e. In no event shall the casing pipe diameter be larger than is necessary to permit the insertion of the carrier pipe.

f. Casing pipe under railroad tracks and across Conrail's right-of-way shall extend the **greater** of the following distances, measured at right angle to centerline of track:

(1) Across the entire width of the Conrail right-of-way.

(2) 3 feet (0.9 m) beyond ditch line.

(3) 2 feet (0.6 m) beyond toe of slope.

(4) A minimum distance of 25 feet (7.6 m) from each side of centerline of outside track when casing is sealed at both ends.

(5) A minimum distance of 45 feet (13.7 m) from centerline of outside track when casing is open at both ends.

(6) Beyond the theoretical railroad embankment line. This line begins at a point, on existing grade, 10 feet (3 m) horizontally from centerline track and extends downward on a 1½ (H) to 1 (V) slope. (See Plate III).

g. If additional tracks are constructed in the future, the casing shall be extended correspondingly at the Owner's expense.

4.3.2 Steel Pipe

a. Steel pipe may be installed by open cut, boring or jacking.

b. Steel pipe shall have a specified minimum yield strength, SMYS, of at least 35,000 psi (241 MPa). The ASTM or API specification and grade for the pipe are to be shown on the Pipe Data Sheet (Plate I).

c. Joints between the sections of pipe shall be fully welded around the complete circumference of the pipe.

d. Steel casing pipe, with a minimum cover of 5½ ft. (1.7 m), shall have a **minimum** wall thickness as shown in Table 2, unless computations indicate that a thicker wall is required.

Table 2

Pipe Diameter Nominal Pipe Size		Coated or Cathodically Protected Nominal Wall Thickness		Uncoated and Unprotected Nominal Wall Thickness	
inches	(mm)	inches	(mm)	inches	(mm)
10 and under	(254 & under)	0.188	(4.78)	0.188	(4.78)
12 & 14	(305 & 356)	0.188	(4.78)	0.250	(6.35)
16	(406)	0.219	(5.54)	0.281	(7.14)
18	(457)	0.250	(6.35)	0.312	(7.92)
20 & 22	(508 & 559)	0.281	(7.14)	0.344	(8.74)
24	(610)	0.312	(7.92)	0.375	(9.53)
26	(660)	0.344	(8.74)	0.406	(10.31)
28	(711)	0.375	(9.53)	0.438	(11.07)
30	(762)	0.406	(10.31)	0.469	(11.91)
32	(813)	0.438	(11.07)	0.500	(12.70)
34 & 36	(864 & 914)	0.469	(11.91)	0.532	(13.49)
38	(965)	0.500	(12.70)	0.562	(14.27)
40	(1016)	0.531	(13.49)	0.594	(15.09)
42	(1067)	0.562	(14.27)	0.625	(15.88)
44 & 46	(1118 & 1168)	0.594	(15.09)	0.657	(16.66)
48	(1219)	0.625	(15.88)	0.688	(17.48)
50	(1270)	0.656	(16.66)	0.719	(18.26)
52	(1321)	0.688	(17.48)	0.750	(19.05)
54	(1372)	0.719	(18.26)	0.781	(19.84)
56 & 58	(1422 &1473)	0.750	(19.05)	0.812	(20.62)
60	(1524)	0.781	(19.84)	0.844	(21.44)
62	(1575)	0.812	(20.62)	0.875	(22.23)
64	(1626)	0.844	(21.44)	0.906	(23.01)
66 & 68	(1676 & 1727)	0.875	(22.23)	0.938	(23.83)
70	(1778)	0.906	(23.01)	0.969	(24.61)
72	(1829)	0.938	(23.83)	1.000	(25.40)

e. Coated steel pipe that is bored or jacked into place shall conform to the wall thickness requirements for uncoated steel pipe since the coating may be damaged during installation.

f. Smooth wall steel pipes with a nominal diameter over 72 inches (1829 mm) will not be permitted.

4.3.3 Ductile Iron Pipe

a. Ductile iron pipe may be used only when placed by the open cut method. Jacking or boring through the railroad embankment is not permitted due to the bell and spigot joints.

b. Ductile iron pipe shall conform to the requirements of ANSI A21.51/AWWA C-151. Class 56 pipe shall be used unless computations, in accordance with Sections 4.1 and 4.2, are provided.

c. Table 3 is based on the design assumptions given in Section 4.2. b. (2) with a minimum cover of 5½ ft. (1.7 m). This table is provided for information only.

Table 3

Pipe diameter		Thickness Class			Pressure Class		
		Wall thickness		Class	Wall thickness		Class
in.	(mm)	in.	(mm)		in.	(mm)	
3	(89)	0.25	(6.35)	51	0.25	(6.35)	350
4	(114)	0.26	(6.60)	51	0.25	(6.35)	350
6	(168)	0.25	(6.35)	50	0.25	(6.35)	350
8	(219)	0.27	(6.86)	50	----	----	----
10	(273)	0.32	(8.13)	51	----	----	----
12	(324)	0.34	(8.64)	51	----	----	----
14	(356)	0.39	(9.91)	52	----	----	----
16	(406)	0.40	(10.2)	52	----	----	----
18	(457)	0.44	(11.2)	53	----	----	----
20	(508)	0.45	(11.4)	53	----	----	----
24	(610)	0.53	(13.5)	55	----	----	----
30	(762)	0.63	(16.0)	56	----	----	----
36	(914)	0.73	(18.5)	56	----	----	----
42	(1067)	0.83	(21.1)	56	----	----	----
48	(1219)	0.93	(23.6)	56	----	----	----
54	(1372)	1.05	(26.7)	56	----	----	----

d. The pipe shall have mechanical or push on type joints.

4.3.4 Corrugated Steel Pipe and Corrugated Structural Steel Plate Pipe

a. Corrugated steel pipe and corrugated structural steel plate pipe may be used for a casing only when placed by the open cut method. Jacking or boring through the railroad embankment is not permitted.

b. Corrugated steel pipe and corrugated structural steel plate pipe may be used for a casing provided the pressure in the carrier pipe is less than 100 psi (689 kPa).

c. Pipe shall be bituminous coated and shall conform to the current American Railway Engineering Association Specifications Chapter 1, Part 4.

d. Corrugated steel pipe shall have a minimum sheet thickness as shown in Table 4. Corrugated structural steel plate pipe shall have a minimum plate thickness of 8 gage, 0.168 in. (4.27 mm). If computations indicate that a greater thickness is required, the thicker sheet or plate shall be used.

TABLE 4

Pipe Diameter		Sheet Thickness		
inches	(mm)	Gage	inches	(mm)
12 to 30	(305 to 762)	14	0.079	(2.01)
36	(914)	12	0.109	(2.77)
42 to 54	(1067 to 1372)	10	0.138	(3.51)
60 to 120	(1524 to 3048)	8	0.168	(4.27)

4.3.5 Steel Tunnel Liner Plates

a. Liner plates shall be installed by the tunneling method as detailed in Section 5.1.5 of this specification.

b. Tunnel liner plates shall be galvanized and bituminous coated and shall conform to current AREA Specification Chapter 1, Part 4, Section 4.16. If the tunnel liner plates are used only to maintain a tunneled opening until the carrier pipe is installed, and the annular space between the carrier pipe and the tunnel liner is completely filled with cement grout within a reasonably short time after completion of the tunnel, then the tunnel liner plates need not be galvanized and coated.

c. Tunnel liner plates are to be a minimum of 12 gage and shall be fabricated from structural quality, hot-rolled, carbon-steel sheets or plates conforming to ASTM Specification A 569.

d. The following liner plate information must be shown on the Pipe Data Sheet (Plate I):

(1) Number of flanges (2 or 4)

(2) Width of plate

(3) Type of plate (smooth or corrugated)

4.3.6 Reinforced Concrete Pipe

a. Reinforced concrete pipe shall be installed by the open cut or jacking method.

b. Reinforced concrete pipe shall conform to ASTM Specification C 76. Class V pipe, Wall B or C shall be used unless computations, in accordance with Section 4.2, are provided.

c. Reinforced concrete pipe may be used for a casing provided the pressure in the carrier pipe is less than 100 psi (689 kPa).

d. Pipe placed by open cut shall be installed in accordance with AREA Chapter 8, Part 10, Section 10.4 except that backfill and compaction shall be in accordance with Section 5.1.2 of this specification.

e. Pipe jacked into place shall have tongue and groove joints and shall be installed in accordance with Section 5.1.4 of this specification.

f. Joints between sections of the RCP shall be sealed with a gasket conforming with ASTM C 443 or approved equal.

4.3.7 Concrete Encasement

a. At locations where the installation is by open cut and a casing pipe is required, but can not be installed due to elbows or other obstructions, concrete encasement may be used when approved by the Chief Engineer.

b. The concrete encasement must provide a minimum cover of 6 inches of concrete (152 mm) around the pipe. A 6 x 6 - W 2.9 x W 2.9 (152 x 152 MW 18.7 x MW 18.7) welded wire fabric shall be placed in the concrete on all sides.

4.4 Carrier Pipe

4.4.1 General Requirements

a. The pipe shall be laid with sufficient slack so that it is not in tension.

b. Steel pipe shall not be used to convey sewage, storm water or other liquids which could cause corrosion.

c. Carrier pipes located on Conrail's right-of-way or under tracks which Conrail operates, shall be manufactured in accordance with the following specifications:

(1) Steel Pipe - The ASTM or API specification and grade for the pipe is to be shown on the Pipe Data Sheet. The specified minimum yield strength is to be at least 35,000 psi (241 MPa). For flammable substances see Sections 4.4.2 and 4.4.3 for additional requirements.

(2) Ductile Iron Pipe - ANSI A21.51/AWWA C151

(3) Corrugated Metal Pipe - AREA Chapter 1, Part 4

(4) Reinforced Concrete Pipe - ASTM C 76

(5) Vitrified Clay Pipe - ASTM C 700

(6) Prestressed Concrete Cylinder Pipe - AWWA C301
Reinforced Concrete Cylinder Pipe - AWWA C300

(7) Others - As approved by the Chief Engineer.

d. Carrier pipes installed within a casing pipe shall be designed for the internal pressure to which it will be subjected.

e. Gravity flow carrier pipes, installed without a casing pipe, shall meet the requirements, of the particular pipe material, as given in Section 4.3 of this specification.

f. Design computations, stamped by a P.E., must be submitted for all uncased pressure pipelines installed on Conrail's right-of-way. The pipe must be designed for the internal and external loads (see Section 4.1) to which it may be subjected. The design assumptions given in Section 4.2 shall apply.

4.4.2 Pipelines Carrying Flammable Substances

a. Pipelines carrying oil, liquefied petroleum gas and other flammable products shall be of steel and conform to the requirements of the current ANSI B 31.4 Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols, and other applicable ANSI codes, except that the maximum allowable stresses for design of steel pipe shall not exceed the following percentages of the specified minimum yield strength (multiplied by the longitudinal joint factor) of the pipe as defined in the above codes:

(1) The following percentages apply to hoop stress in steel pipe within a casing under railroad tracks, across railroad right-of-way and longitudinally on railroad right-of-way:

(a) Seventy-two percent on oil pipelines.

(b) Fifty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other liquid petroleum products.

(c) Sixty percent for installations on gas pipelines.

(2) The following percentages apply to hoop stress in steel pipe laid longitudinally on railroad right-of-way without a casing:

(a) Sixty percent for oil pipelines.

(b) Forty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other liquid petroleum products.

(c) For gas pipelines see Section 4.4.3.b.

b. Computations, based on the above requirements and stamped by a P.E., shall be submitted with the application for occupancy.

4.4.3 Uncased Pipelines Carrying Gas

a. Pipelines carrying flammable and nonflammable gas products shall be steel and shall conform to the requirements of the current ANSI B 31.8 Gas Transmission and Distribution Piping Systems, and other applicable ANSI codes.

b. The minimum wall thickness for uncased carrier pipe shall be in accordance with the values provided in AREA, Chapter 1, Part 5, Section 5.2, Tables 5.2.3 (a through j).

c. A durable coating, which will resist abrasion (fusion bonded epoxy or other suitable material), shall be used to protect the uncased pipeline when the boring method of installation is used.

d. If the Chief Engineer determines there is the potential for damage to the uncased pipeline (foreign material in the subgrade, third party damage, etc.), special protection of the pipeline will be required. Special protection may include the use of concrete jacketed carrier pipe, a protection slab over the pipeline, increased depth of bury or other means.

4.5 Casing Pipe End Seals

a. Casings for carrier pipes of flammable and hazardous substances shall be suitably sealed to the outside of the carrier pipe. Details of the end seals shall be shown on the plans.

b. Casings for carrier pipes of non-flammable substances shall have both ends of the casing blocked up in such a way as to prevent the entrance of foreign material, but allowing leakage to pass in the event of a carrier break.

c. The ends of a casing pipe may be left open when the ends are at or above ground surface and above high water level, provided drainage is afforded in such a manner that leakage will be conducted away from railroad tracks and structures.

4.6 Vents

a. Sealed casings for flammable substances shall be properly vented. Vent pipes shall be of sufficient diameter, but in no case less than two inches (51 mm) in diameter, and shall be attached near each end of the casing and project through the ground surface at right-of-way lines or not less than 45 feet (13.7 m), measured at right angles from centerline of nearest track.

b. Vent pipes shall extend not less than 4 feet (1.2 m) above the ground surface. Top of vent pipe shall have a down-turned elbow, properly screened, or a relief valve. Vents in locations subject to high water shall be extended above the maximum elevation of high water and shall be supported and protected in a manner approved by the Chief Engineer.

c. Vent pipes shall be at least 4 feet (1.2 m), vertically, from aerial electric wires or greater if required by National Electrical Safety Code (ANSI C2).

d. When the pipeline is in a public highway, street-type vents shall be installed.

4.7 Signs

a. All pipelines (except those in streets where it would not be practical to do so) shall be prominently marked at right-of-way lines (on both sides of track for crossings) by durable, weatherproof signs located over the centerline of the pipe. Signs shall show the following:

(1) Name and address of owner

(2) Contents of pipe

(3) Pressure in pipe

(4) Pipe depth below grade at point of a sign

(5) Emergency telephone number in event of pipe rupture

b. For pipelines running longitudinally on Conrail property, signs shall be placed over the pipe (or offset and appropriately marked) at all changes in direction of the pipeline. Such signs should also be located so that when standing at one sign the next adjacent marker in either direction is visible. In no event shall they be placed more than 500 feet (152.4 m) apart unless otherwise specified by the Chief Engineer.

c. The Owner must maintain all signs on Conrail's right-of-way as long as the occupational agreement is in effect.

4.8 Warning Tape

a. All pressure pipelines installed by the trench method, without a casing, shall have a warning tape placed directly above the pipeline, 2 feet (0.6 m) below the ground surface.

4.9 Shut-off Valves

a. Accessible emergency shut-off valves shall be installed within effective distances each side of the railroad at locations selected by the Chief Engineer where hazard to life and property must be guarded against. No additional valves will be required where pipelines are provided with automatic control stations and within distances approved by the Chief Engineer.

4.10 Cathodic Protection

a. Cathodic protection shall be applied to all pipelines carrying flammable substances on Conrail's right-of-way.

b. For crossings and at other locations where the pipeline must be placed within a casing, the casing is to have cathodic protection or the wall thickness is to be increased to the requirements of Section 4.3.2 Table 2.

c. Uncased gas carrier pipes must be coated and cathodically protected to industry standards and test sites, for monitoring the pipeline, provided within 50 feet (15.2 m) of the crossing.

d. Where casing and/or carrier pipes are cathodically protected by other than anodes, the Chief Engineer shall be notified and a suitable test made to ensure that other railroad structures and facilities are adequately protected from the cathodic current in accordance with the recommendation of current Reports of Correlating Committee on Cathodic Protection, published by the National Association of Corrosion Engineers.

e. Where sacrificial anodes are used the locations shall be marked with durable signs.

4.11 Manholes

a. Manholes shall not be located on Conrail property where possible. At locations where this is not practical, including longitudinal occupancies, manholes shall be precast concrete sections conforming to ASTM Designation C 478, "Specification for Precast Concrete Manhole Sections".

b. The top of manholes located on Conrail property shall be flush with top of ground.

c. The distance from centerline of adjacent track to centerline of proposed manhole shall be shown on the plans.

4.12 Box Culverts

a. Reinforced concrete box culverts shall conform to the requirements of AREA Chapter 8, Parts 13 and 16.

4.13 Drainage

a. Occupancies shall be designed, and their construction shall be accomplished, so that adequate and uninterrupted drainage of Conrail's right-of-way is maintained.

b. All pipes, ditches and other structures carrying surface drainage on Conrail property and/or under Conrail track(s) shall be designed to carry the run-off from a one hundred (100) year storm. Computations indicating this design, prepared by a Professional Engineer, and suitable topographic plans, outlining the total drainage area, shall be submitted for Conrail's approval.

c. If the drainage is to discharge into an existing drainage channel on Conrail's right-of-way and/or through a drainage structure under Conrail's track(s), the computations must include the hydraulic analysis of any existing ditch and/or structure.

d. When calculating the capacity of existing or proposed drainage structures, under Conrail's track(s), the headwater at the structure shall not be greater than one (1).

e. Pipe(s) used to carry surface drainage on Conrail's right-of-way shall have a minimum diameter of 18 inches (457 mm).

f. Detention ponds must not be placed on any part of Conrail's right-of-way. Also, the railroad embankment must not be used as any part of a detention pond structure.

g. Formal approval of the proposed design, by the appropriate governmental agency having jurisdiction, shall be submitted with the drainage computations.

4.14 Pipelines on Bridges

a. Pipelines of any type shall not be installed on any bridge carrying Conrail tracks.

b. New overhead pipe bridges shall not be constructed over Conrail's right-of-way where underground installation of the pipeline is possible. Where the Applicant can show that no practicable alternative is available, this type of structure will be permitted provided the following conditions are met:

(1) The vertical clearance, distance from top of rail to bottom of structure, is shown and is a minimum of 23 feet (7.01 m), measured at a point 6 feet (1.83 m) horizontally from centerline track.

(2) The support bents for the overhead structure are located off of Conrail's right-of-way or a minimum clear distance of 18 feet (5.5 m) from centerline track, whichever distance is greater.

(3) Support bents within 25 feet (7.6 m) of centerline track have pier protection in accordance with AREA, Chapter 8, Part 2, Section 2.1.5.

(4) Complete structural plans and design computations for the structure and foundations, stamped by a Professional Engineer, are submitted with the application.

(5) A fence (with barbed wire) or other measures are provided which will prevent access to the bridge by unauthorized personnel or vandals.

c. Pipelines carrying flammable substances or non-flammable substances, which by their nature might cause damage if escaping on or near railroad facilities or personnel, shall not be installed on bridges over Conrail tracks. In special cases when it can be demonstrated to the Chief Engineer's satisfaction that such an installation is necessary and that no practicable alternative is available, the Chief Engineer may permit the installation and only by special design approved by him.

d. When permitted, pipelines on bridges over Conrail tracks shall be so located as to minimize the possibility of damage from vehicles, railroad equipment, vandalism and other external causes. They shall be encased in a casing pipe as directed by the Chief Engineer (See Plate VII).

5.0 CONSTRUCTION REQUIREMENTS

5.1 Method of Installation

5.1.1 General Requirements

a. Bored, jacked or tunneled installations shall have a bore hole essentially the same as the outside diameter of the pipe plus the thickness of the protective coating.

b. The use of water or other liquids to facilitate casing emplacement and spoil removal is prohibited.

c. If during installation an obstruction is encountered which prevents installation of the pipe in accordance with this specification, the pipe shall be abandoned in place and immediately filled with grout. A new installation procedure and revised plans must be submitted to, and approved by, the Chief Engineer before work can resume.

5.1.2 Open Cut

a. The Owner must request open cut approval when making application for occupancy.

b. Installations beneath the track by open trench methods will be permitted only with the approval of the **General Manager Transportation & Customer Service** of the Division involved.

c. Installations by open cut will not be permitted under mainline tracks, tracks carrying heavy tonnage or tracks carrying passenger trains. Also, open cut shall not be used within the limits of a highway/railroad grade crossing or its approaches, 25 feet (7.6 m) either side of traveled way, where possible.

d. Rigid pipe (RCP, VCP and PCCP) must be placed in a Class B bedding or better.

e. At locations where open cut is permitted, the trench is to be backfilled with crushed stone with a top size of the aggregate to be a maximum of 2 inches (51 mm) and to have no more than 5% passing the number 200 sieve. The gradation of the material is to be such that a dense stable mass is produced.

f. The backfill material shall be placed in loose 6 inch (152 mm) lifts and compacted to at least 95% of its maximum density with a moisture content that is no more than 1% greater than or 2% less than the optimum moisture as determined in accordance with current ASTM Designation D - 1557 (Modified Proctor). When the backfill material is within 3 feet (9.1 m) of the subgrade elevation (the interface of the ballast and the subsoil) a compaction of at least 98% will be required. Compaction test results confirming compliance must be provided to Conrail's Area Engineer by the Owner.

g. All backfilled pipes laid either perpendicular or parallel to the tracks must be designed so that the backfill material will be positively drained. This may require the placement of lateral drains on pipes laid longitudinally to the track and the installation of stub perforated pipes at the edge of the slopes.

h. Unless otherwise agreed upon, all work involving rail, ties and other track material will be performed by railroad employees at the sole expense of the Owner.

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b. The use of water or other liquids to facilitate casing emplacement and spoil removal is prohibited.

c. If during installation an obstruction is encountered which prevents installation of the pipe in accordance with this specification, the pipe shall be abandoned in place and immediately filled with grout. A new installation procedure and revised plans must be submitted to, and approved by, the Chief Engineer before work can resume.

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d. Rigid pipe (RCP, VCP and PCCP) must be placed in a Class B bedding or better.

e. At locations where open cut is permitted, the trench is to be backfilled with crushed stone with a top size of the aggregate to be a maximum of 2 inches (51 mm) and to have no more than 5% passing the number 200 sieve. The gradation of the material is to be such that a dense stable mass is produced.

f. The backfill material shall be placed in loose 6 inch (152 mm) lifts and compacted to at least 95% of its maximum density with a moisture content that is no more than 1% greater than or 2% less than the optimum moisture as determined in accordance with current ASTM Designation D - 1557 (Modified Proctor). When the backfill material is within 3 feet (9.1 m) of the subgrade elevation (the interface of the ballast and the subsoil) a compaction of at least 98% will be required. Compaction test results confirming compliance must be provided to Conrail's Area Engineer by the Owner.

g. All backfilled pipes laid either perpendicular or parallel to the tracks must be designed so that the backfill material will be positively drained. This may require the placement of lateral drains on pipes laid longitudinally to the track and the installation of stub perforated pipes at the edge of the slopes.

h. Unless otherwise agreed upon, all work involving rail, ties and other track material will be performed by railroad employees at the sole expense of the Owner.

5.1.3 Bore and Jack (Steel Pipe)

a. This method consists of pushing the pipe into the earth with a boring auger rotating within the pipe to remove the spoil.

b. The boring operation shall be progressed on a 24-hour basis without stoppage (except for adding lengths of pipe) until the leading edge of the pipe has reached the receiving pit.

c. The front of the pipe shall be provided with mechanical arrangements or devices that will positively prevent the auger from leading the pipe so that no unsupported excavation is ahead of the pipe.

d. The auger and cutting head arrangement shall be removable from within the pipe in the event an obstruction is encountered. If the obstruction cannot be removed without excavation in advance of the pipe, procedures as outlined in Section 5.1.1 c. must be implemented immediately.

e. The over-cut by the cutting head shall not exceed the outside diameter of the pipe by more than ½ inch (13 mm). If voids should develop or if the bored hole diameter is greater than the outside diameter of the pipe (plus coating) by more than approximately 1 inch (25 mm), grouting (see Section 5.2) or other methods approved by the Chief Engineer, shall be employed to fill such voids.

f. The face of the cutting head shall be arranged to provide a reasonable obstruction to the free flow of soft or poor material.

g. Plans and description of the arrangement to be used shall be submitted to the Chief Engineer for approval and no work shall proceed until such approval is obtained.

h. Any method that employs simultaneous boring and jacking for pipes over 8 inches (203 mm) in diameter that does not have the above approved arrangement will not be permitted. For pipe 8 inches (203 mm) and less in diameter, augering or boring without this arrangement may be considered for use only as approved by the Chief Engineer.

5.1.4 Jacking (RCP and Steel Pipe)

a. This method consists of pushing sections of pipe into position with jacks placed against a backstop and excavation performed by hand from within the jacking shield at the head of the pipe. Ordinarily 36 inch (914 mm) pipe is the least size that should be used, since it is not practical to work within smaller diameter pipes.

b. Jacking shall be in accordance with the current American Railway Engineering Association Specifications, Chapter 1, Part 4, "Jacking Culvert Pipe Through Fills." This operation shall be conducted without hand-mining ahead of the pipe and without the use of any type of boring, auguring, or drilling equipment.

c. Bracing and backstops shall be so designed and jacks of sufficient rating used so that the jacking can be progressed on a 24-hour basis without stoppage (except for adding lengths of pipe) until the leading edge of the pipe has reached the receiving pit.

d. When jacking reinforced concrete pipe, a jacking shield shall be fabricated as a special section of reinforced concrete pipe with a steel cutting edge, hood, breasting attachments, etc., cast into the pipe. The wall thickness and reinforcing shall be designed for the jacking stresses.

e. When jacking reinforced concrete pipe, grout holes, tapped for no smaller than 1½ inch (38 mm) pipe, shall be cast into the pipe at manufacture. Three grout holes, equally spaced around the circumference and 4 feet (12.2 m) longitudinally shall be provided for RCP 54 inches (1372 mm) and smaller. Four grout holes, equally spaced around the circumference and 4 feet (12.2 m) longitudinally shall be provided for RCP 60 inches (1524 mm) and larger.

f. Immediately upon completion of jacking operations, the installation shall be pressure grouted as per Section 5.2 of this specification.

5.1.5 Tunneling (Tunnel liner plate)

a. This method consists of placing rings of liner plate within the tail section of a tunneling shield or tunneling machine. A tunneling shield shall be used for all liner plate installations unless otherwise approved by the Chief Engineer.

b. The shield shall be of steel construction, designed to support a railroad track loading as specified in Section 4.1.3 of this specification, in addition to the other loadings imposed. The advancing face shall be provided with a hood, extending no less than 20 inches (508 mm) beyond the face and extending around no less than the upper 240 degrees of the total circumference. It shall be of sufficient length to permit the installation of at least one complete ring of liner plates within the shield before it is advanced for the installation of the next ring of liner plates. The shield shall conform to and not exceed the outside dimensions of the liner plate tunnel being placed by more than 1 inch (25.4 mm) at any point on the periphery unless otherwise approved by the Chief Engineer.

c. The shield shall be adequately braced and provided with necessary appurtenances for completely bulkheading the face with horizontal breastboards, and arranged so that the excavation can be benched as may be necessary. Excavation shall not be advanced beyond the edge of the hood, except in rock.

d. Manufacturer's shop detail plans and manufacturer's computations showing the ability of the tunnel liner plates to resist the jacking stresses shall be submitted to the Chief Engineer for approval.

e. Unless otherwise approved by the Chief Engineer, the tunneling shall be conducted continuously, on a 24-hour basis, until the tunnel liner extends at least beyond the theoretical railroad embankment line (See Plate III).

f. At any interruption of the tunneling operation, the heading shall be completely bulkheaded.

g. The liner plates shall have tapped grout holes for no smaller than 1½ inch (38 mm) pipe, spaced at approximately 3 feet (0.9 m) around the circumference of the tunnel liner and 4 feet (1.2 m) longitudinally.

h. Grouting behind the liner plates shall be in accordance with Section 5.2 of this specification.

5.1.6 Directional Boring / Horizontal Directional Drilling (Steel Pipe)

<u>**Method "A"**</u>

a. This method consists of setting up specialized drilling equipment on existing grade (launching and receiving pits are not required) and boring a small diameter pilot hole on the desired vertical and horizontal alignment, using a mechanical cutting head with a high pressure fluid (bentonite slurry) to remove the cuttings. The drill string is advanced with the bentonite slurry pumped through the drill string to the cutting head and then forced back along the outside of the drill string, carrying the cuttings back to the surface for removal. When the cutting head reaches the far side of the crossing, it is removed and a reamer (with a diameter greater than the cutting head) is attached to the lead end of the drill string. The pipeline is attached to the reamer and the pilot hole is then back reamed while the pipeline is pulled into place.

b. This method is used to place pipelines under rivers, wetlands and other obstructions which would be difficult to cross by conventional methods. The length of the bore is generally several hundred feet in length, with installations over a thousand feet possible.

c. Installations by this method are generally not acceptable, however, consideration will be given where the depth of cover is substantial, greater than 40 feet (12.2 m), or the bore is in rock. Factors considered will be track usage, pipe size, contents of pipeline, soil conditions, etc.

d. The following preliminary information must be submitted with the request for consideration of this type of installation:

(1) A site plan of the area.

(2) A plan view and profile of the crossing.

(3) A Pipe Data Sheet.

(4) Several soil borings along the proposed pipeline route.

(5) A construction procedure, including a general description of equipment to be used.

If the Chief Engineer determines this method of installation is acceptable, final design plans and specifications are to be prepared and submitted for approval.

e. The project specifications must require the contractor to submit, to the Chief Engineer for approval, a complete construction procedure of the proposed boring operation. Included with the submission shall be the manufacture's catalog information describing the type of equipment to be used.

Method "B"

a. This method is used to place small diameter conduit for electric lines and other utilities. This method consists of using hydraulic jacking equipment to push a solid steel rod under the railroad from a launching pit to a receiving pit. At the receiving pit, a cone shaped "expander" is attached to the end of the rod and the conduit (casing pipe) is attached to the expander. The rod, expander and conduit are then pulled back from the launching pit until the full length of the conduit is in place.

b. This method may be used to place steel conduit (casing pipe), up to and including 6 inches (152 mm) in diameter, under the railroad.

c. The project specifications must require the contractor to submit, to the Chief Engineer for approval, a complete construction procedure of the proposed boring operation. Included with the submission shall be the manufacture's catalog information describing the type of equipment to be used.

5.2 Grouting

a. For jacked and tunneled installations a uniform mixture of 1:6 (cement:sand) cement grout shall be placed under pressure through the grout holes to fill any voids which exist between the pipe or liner plate and the undisturbed earth.

b. Grouting shall start at the lowest hole in each grout panel and proceed upwards simultaneously on both sides of the pipe.

c. A threaded plug shall be installed in each grout hole as the grouting is completed at that hole.

d. When grouting tunnel liner plates, grouting shall be kept as close to the heading as possible, using grout stops behind the liner plates if necessary. Grouting shall proceed as directed by the Chief Engineer, but in no event shall more than 6 lineal feet (1.8 m) of tunnel be progressed beyond the grouting.

5.3 Soil Stabilization

a. Pressure grouting of the soils or freezing of the soils before jacking, boring, or tunneling may be required at the direction of the Chief Engineer to stabilize the soils, control water, prevent loss of material and prevent settlement or displacement of embankment. Grout shall be cement, chemical or other special injection material selected to accomplish the necessary stabilization.

b. The materials to be used and the method of injection shall be prepared by a Registered Professional Soils Engineer, or by an experienced and qualified company specializing in this work and submitted for approval to the Chief Engineer before the start of work. Proof of experience and competency shall accompany the submission.

5.4 Dewatering

a. When water is known or expected to be encountered, pumps of sufficient capacity to handle the flow shall be maintained at the site, provided the contractor has received approval from the Chief Engineer to operate them. Pumps in operation shall be constantly attended on a 24-hour basis until, in the sole judgment of the Chief Engineer, the operation can be safely halted. When dewatering, close observation shall be maintained to detect any settlement or displacement of railroad embankment, tracks, and facilities.

5.5 Safety Requirements

a. All operations shall be conducted so as not to interfere with, interrupt, or endanger the operation of trains nor damage, destroy, or endanger the integrity of railroad facilities. All work on or near Conrail property shall be conducted in accordance with Conrail safety rules and regulations. The contractor shall secure and comply with the Conrail safety rules and shall give written acknowledgment to Conrail that they have been received, read, and understood by the contractor and its employees. Operations will be subject to Conrail inspection at any and all times.

b. All cranes, lifts, or other equipment that will be operated in the vicinity of the railroad's electrification and power transmission facilities shall be electrically grounded as directed by the Chief Engineer.

c. At all times when the work is being progressed, a field supervisor for the work with no less than twelve (12) months experience in the operation of the equipment being used shall be present. If boring equipment or similar machines are being used, the machine operator also shall have no less than twelve (12) months experience in the operation of the equipment being used.

d. Whenever equipment or personnel are working closer than 15 feet (4.6 m) from the centerline of an adjacent track, that track shall be considered as being obstructed. Insofar as possible, all operations shall be conducted no less than this distance. Operations closer than 15 feet (4.6 m) from the centerline of a track shall be conducted only with the permission of, and as directed by, a duly qualified railroad employee present at the site of the work.

e. Crossing of tracks at grade by equipment and personnel is prohibited except by prior arrangement with, and as directed by, the Chief Engineer.

5.6 Blasting

a. Blasting will not be permitted under or on Conrail's right-of-way.

5.7 Temporary Track Supports

a. When the jacking, boring or tunneling method of installation is used, and depending upon the size and location of the crossing, temporary track supports shall be installed at the direction of the Chief Engineer.

b. Details of the temporary track supports shall conform to Conrail Standard Plan No. 43380-R1 (Rev. 4-10-90)

c. The Owner's contractor shall supply the track supports with installation and removal performed by Conrail employees.

d. The Owner shall reimburse Conrail for all costs associated with the installation and removal of the track supports.

5.8 Protection of Drainage Facilities

a. If, in the course of construction, it may be necessary to block a ditch, pipe or other drainage facility, temporary pipes, ditches or other drainage facilities shall be installed to maintain adequate drainage, as approved by the Chief Engineer. Upon completion of the work, the temporary facilities shall be removed and the permanent facilities restored.

b. Soil erosion methods shall be used to protect railroad ditches and other drainage facilities during construction on and adjacent to Conrail's right-of-way.

5.9 Support of Excavation Adjacent to Track

5.9.1 Launching and Receiving Pits

a. The location and dimensions of all pits or excavations shall be shown on the plans. The distance from centerline of adjacent track to face of pit or excavation shall be clearly labeled. Also, the elevation of the bottom of the pit or excavation must be shown on the profile.

b. The face of all pits shall be located a minimum of 25 feet (7.6 m) from centerline of adjacent track, measured at right angles to track, unless otherwise approved by the Chief Engineer.

c. If the bottom of the pit excavation intersects the theoretical railroad embankment line (See Plate III) interlocking steel sheet piling, driven prior to excavation, must be used to protect the track stability. The use of trench boxes or similar devices are not acceptable in this area.

d. Design plans and computations for the pits, stamped by a Professional Engineer, must be submitted by the Owner at time of application or by the contractor prior to start of construction. If the pit design is to be submitted by the contractor, the project specifications must require the contractor to obtain Conrail's approval prior to beginning any work on or which may affect Conrail property.

e. The sheeting shall be designed to support all lateral forces caused by the earth, railroad and other surcharge loads. See Section 4.1.3 for railroad loading.

f. After construction and backfilling, all sheet piling within 10 feet (3.0 m) of centerline track must be cut off 18 inches (457 mm) below final grade and left in place.

g. All excavated areas are to be illuminated (flashing warning lights not permitted), fenced and otherwise protected as directed by the Chief Engineer or his designated representative.

5.9.2 Parallel Trenching and Other Excavation

a. When excavation for a pipeline or other structure will be within the theoretical railroad embankment line (See Plate V) of an adjacent track, interlocking steel sheet piling will be required to protect the track.

b. The design and construction requirements for this construction shall be in accordance with the requirements of Section 5.9.1.

5.10 Inspection and Testing

a. For pipelines carrying flammable or hazardous materials, ANSI Codes, current at time of constructing the pipeline, shall govern the inspection and testing of the facility on Conrail property, except as follows:

(1) One-hundred percent of all field welds shall be inspected by radiographic examinations, and such field welds shall be inspected for 100 percent of the circumference.

(2) The proof testing of the strength of carrier pipe shall be in accordance with ANSI requirements.

5.11 Reimbursement of Conrail Costs

a. All Conrail costs associated with the pipe installation (inspection, flagging, track work, protection of signal cables, etc.) shall be reimbursed to Conrail by the Owner of the facility. Reimbursement by the contractor is not acceptable.

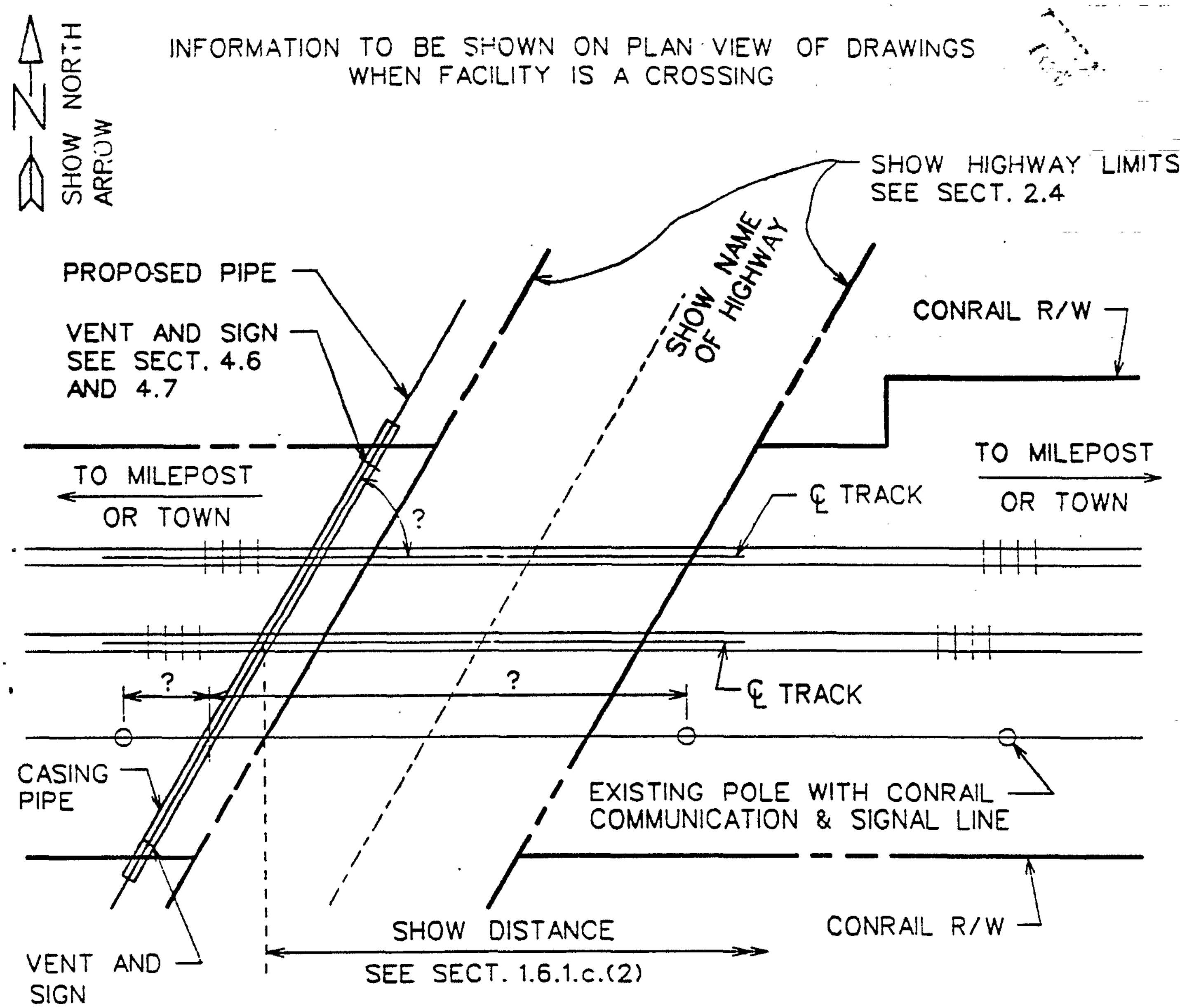
PIPE DATA SHEET

(For crossings and longitudinal occupancy)

	PIPE DATA	
	CARRIER PIPE	CASING PIPE
CONTENTS TO BE HANDLED		
NORMAL OPERATING PRESSURE		
NOMINAL SIZE OF PIPE		
OUTSIDE DIAMETER		
INSIDE DIAMETER		
WALL THICKNESS		
WEIGHT PER FOOT		
MATERIAL		
PROCESS OF MANUFACTURE		
SPECIFICATION		
GRADE OR CLASS		
TEST PRESSURE		
TYPE OF JOINT		
TYPE OF COATING		
DETAILS OF CATHODIC PROTECTION		
DETAILS OF SEALS OR PROTECTION AT ENDS OF CASING		
METHOD OF INSTALLATION		
CHARACTER OF SUBSURFACE MATERIAL AT THE CROSSING LOCATION		
APPROXIMATE GROUND WATER LEVEL		
SOURCE OF INFORMATION ON SUBSURFACE CONDITIONS (BORINGS, TEST PITS OR OTHER)		

NOTE: Any soil investigation made on railroad property or adjacent to tracks shall be carried on under the supervision of Conrail's Chief Engineer. (See Section 1.4)

PLATE II



PLAN

SCALE OF DRAWING TO BE SHOWN

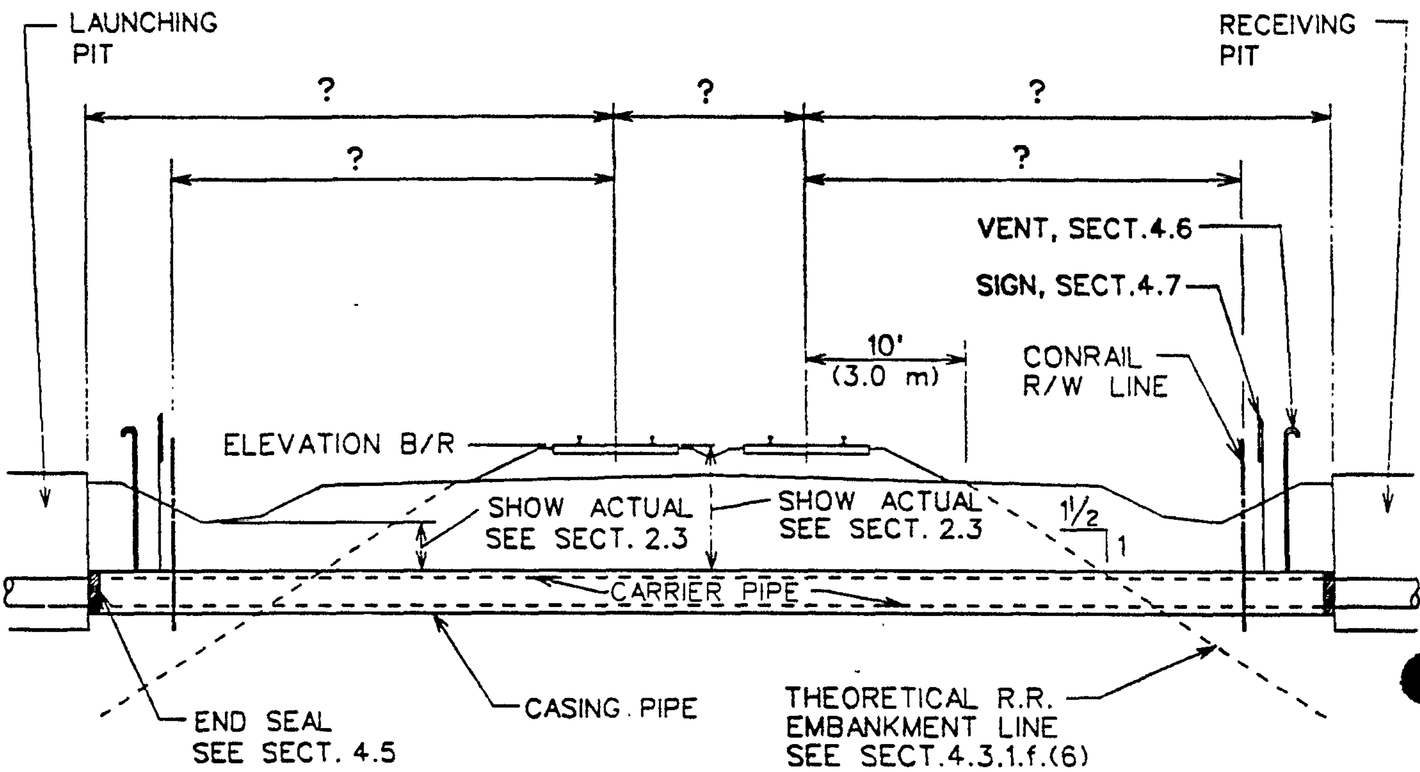
NOTES:

IF THE PROPOSED PIPELINE IS WITHIN HIGHWAY LIMITS, THE SAME INFORMATION IS REQUIRED AS SHOWN ON THIS PLATE.

IF THE PROPOSED PIPE IS TO SERVE A NEW DEVELOPMENT, A MAP SHOWING THE AREA IN RELATION TO ESTABLISHED AREAS AND ROADS IS TO BE SENT WITH THE REQUEST.

PLATE III

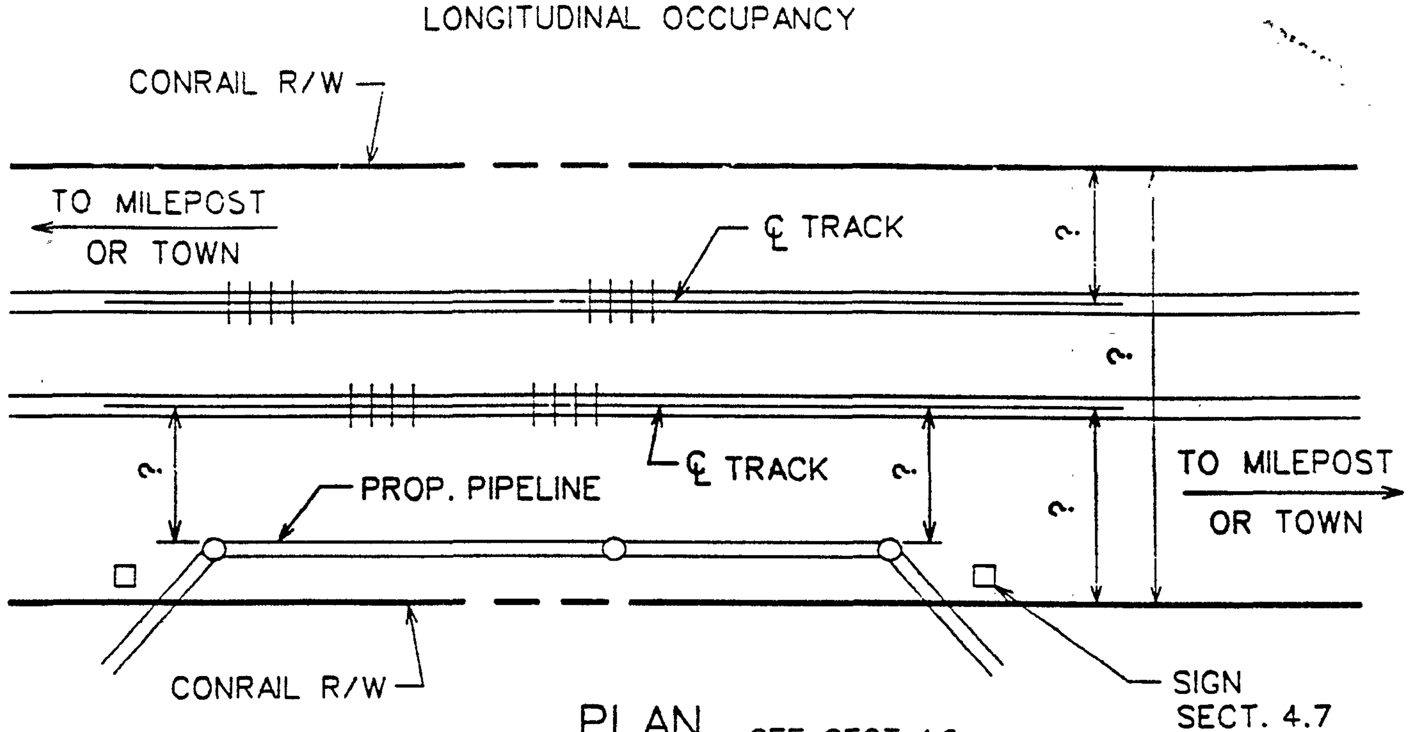
PIPELINE CROSSING



PROFILE

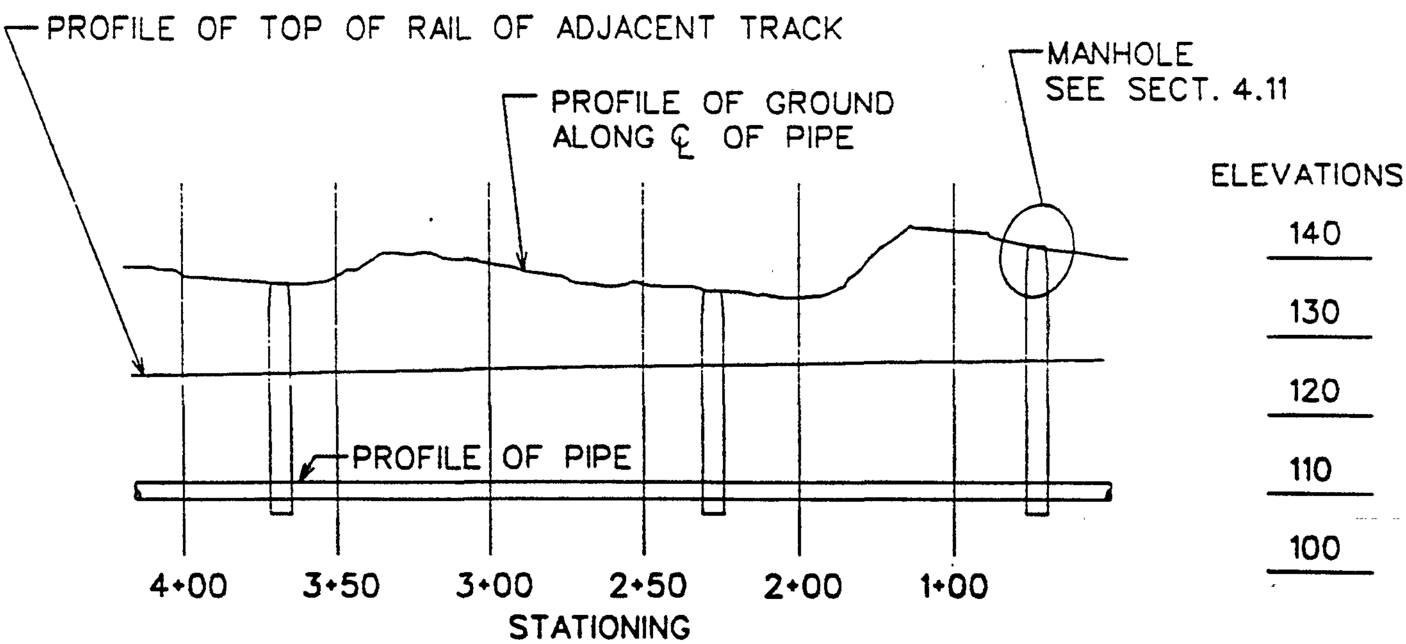
SCALE OF DRAWING TO BE SHOWN

PLATE IV



PLAN -SEE SECT. 1.6

SCALE OF DRAWING TO BE SHOWN



PROFILE -SEE SECT. 1.6

SCALE: HORIZ. : ____________

VERT. : ____________

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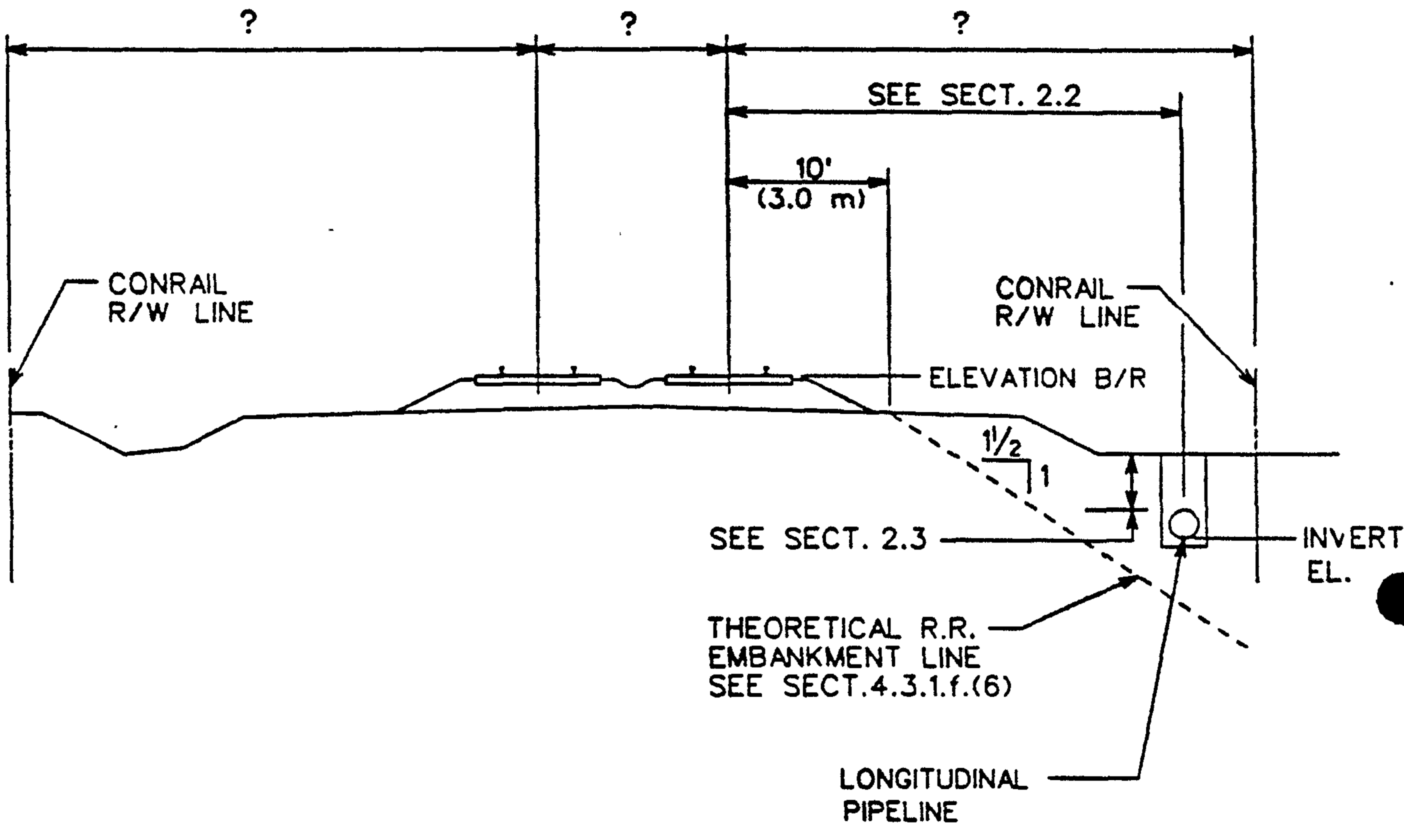
LONGITUDINAL OCCUPANCY

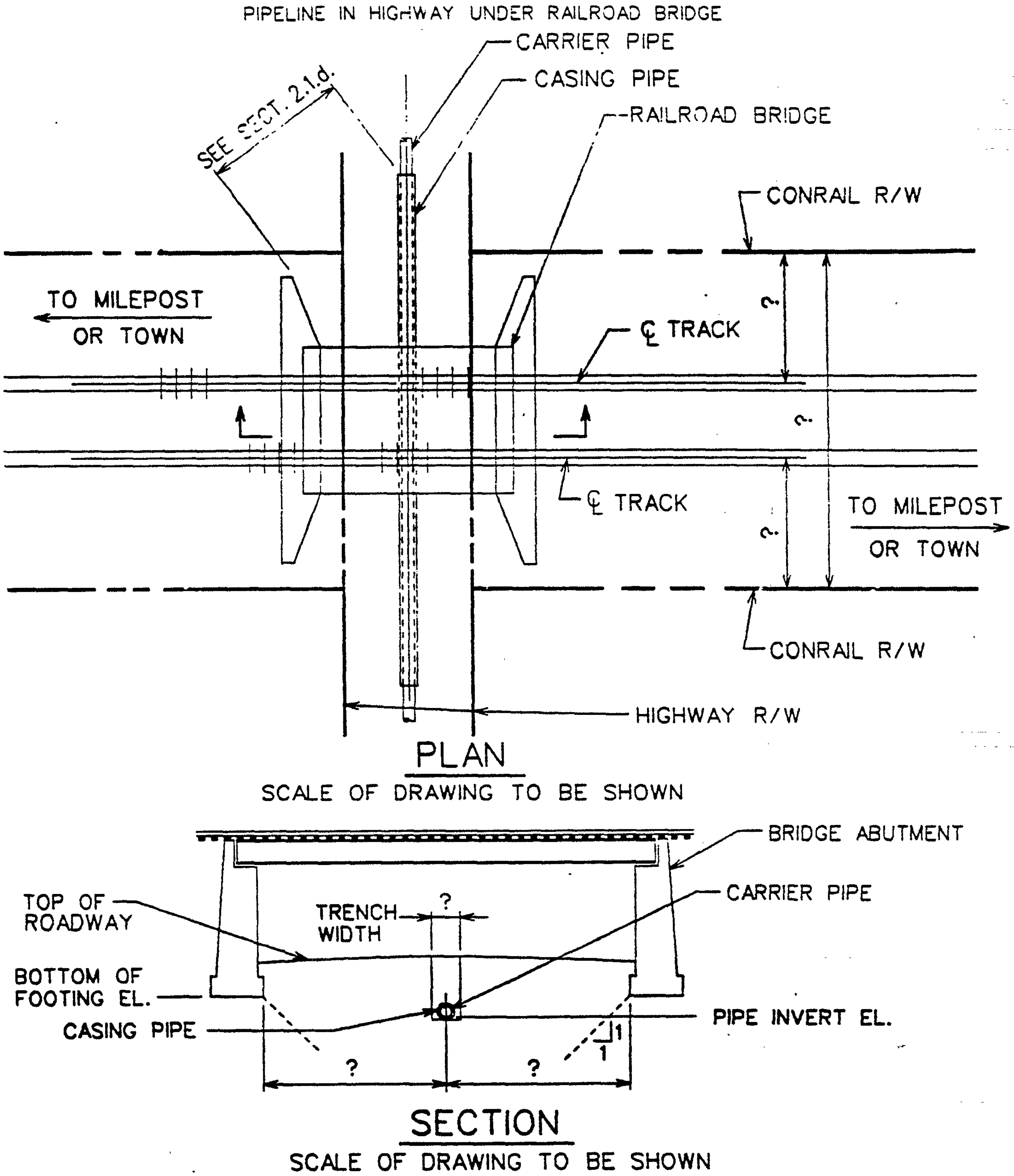


SECTION

SCALE OF DRAWING TO BE SHOWN

NOTE: SECTIONS TO BE TAKEN EVERY 500 FEET (152 m), MAXIMUM.

PLATE VI



NOTE: PIPE OR EXCAVATION MUST NOT BE WITHIN THE 1 TO 1 SLOPE LINE THAT EXTENDS FROM BOTTOM OF FOOTING.

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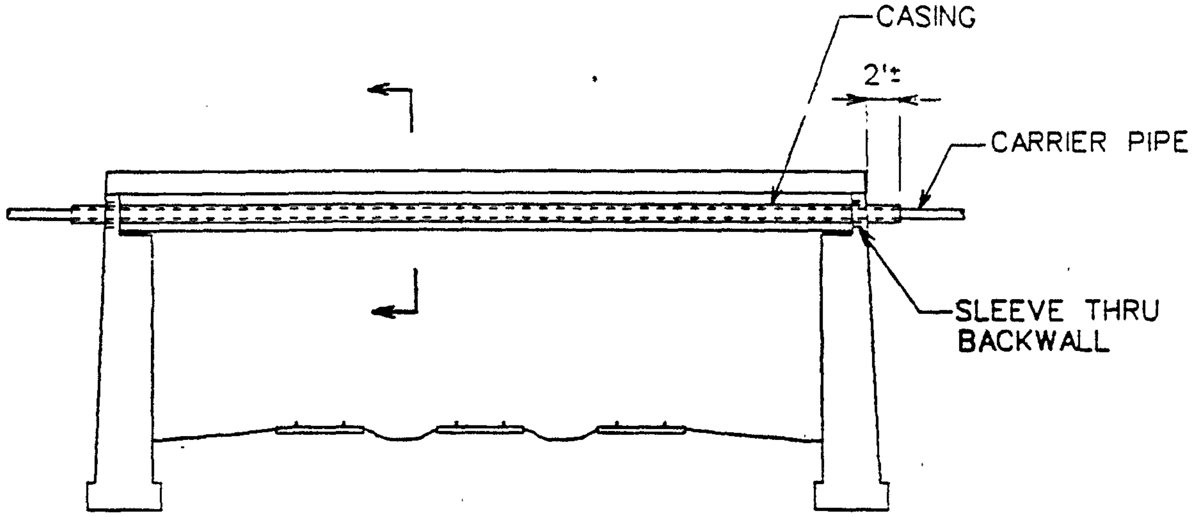
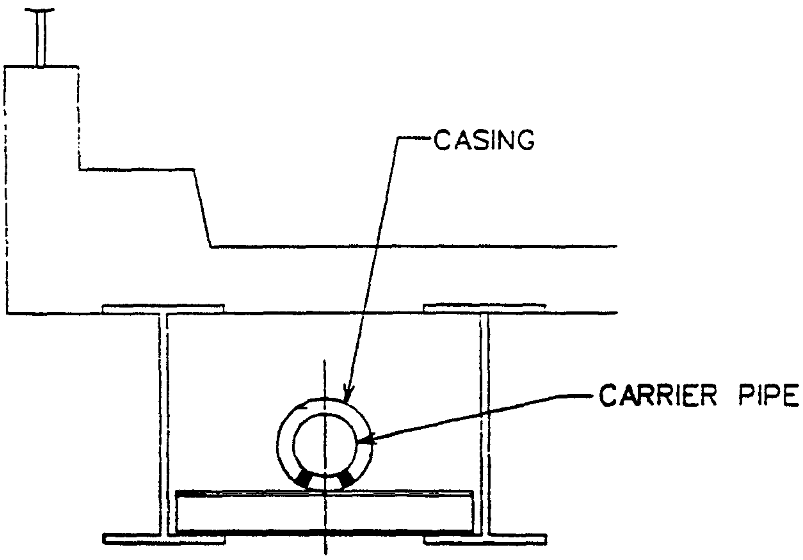
PLATE VII

PIPELINE ON HIGHWAY BRIDGE OVER RAILROAD



ELEVATION

SCALE OF DRAWING TO BE SHOWN



SECTION

SCALE OF DRAWING TO BE SHOWN

TEST BORING LOG

PROJECT

LOCATION

DATE STARTED

DATE COMPLETED

HOLE NO.

SURF. EL.

JOB NO.

GROUND WATER DEPTH WHILE DRILLING

BEFORE CASING REMOVED

AFTER CASING REMOVED

N — NO. OF BLOWS TO DRIVE SAMPLER 12" W/140# HAMMER FALLING 30" — ASTM D-1586, STANDARD PENETRATION TEST

C — NO. OF BLOWS TO DRIVE CASING 12" W/ # HAMMER FALLING "/OR — % CORE RECOVERY

CASING TYPE - HOLLOW STEM AUGER

SHEET 1 OF 1

Pipe Invert Elev.

DEPTH	SAMPLE DEPTH	SAMPLE NUMBER	C	SAMPLE DRIVE RECORD PER 6"	N	DESCRIPTION OF MATERIAL	STRATA CHANGE DEPTH
	0.0'-	1		6/14		Brown moist medium dense fine to coarse SAND and fine to medium GRAVEL, little silt	
	2.0'			14/19	28		
	2.0'-	2		9/15			
	4.0'			15/23	30		
5.0	4.0'-	3		17/18			
	6.0'			11/21	29		6.0'
	6.0'-	4		9/6		Brown moist stiff SILT	
	8.0'			5/7	11		8.5'
	8.0'-	5		10/12		Brown moist very stiff SILT, little fine to coarse sand, little fine gravel	
10.0	10.0'			11/11	23		
	10.0'-	6		12/11			
	11.3'			50-.3'			12.5'
						Gray dry hard silty weathered SHALE	
15.0						Top of Rock	15.0'
	15.0'-	R-1	Rec	BX Core		Gray weathered steeply bedded SHALE	
	20.0'		46"	77%			
20.0						Bottom of Boring	20.0'

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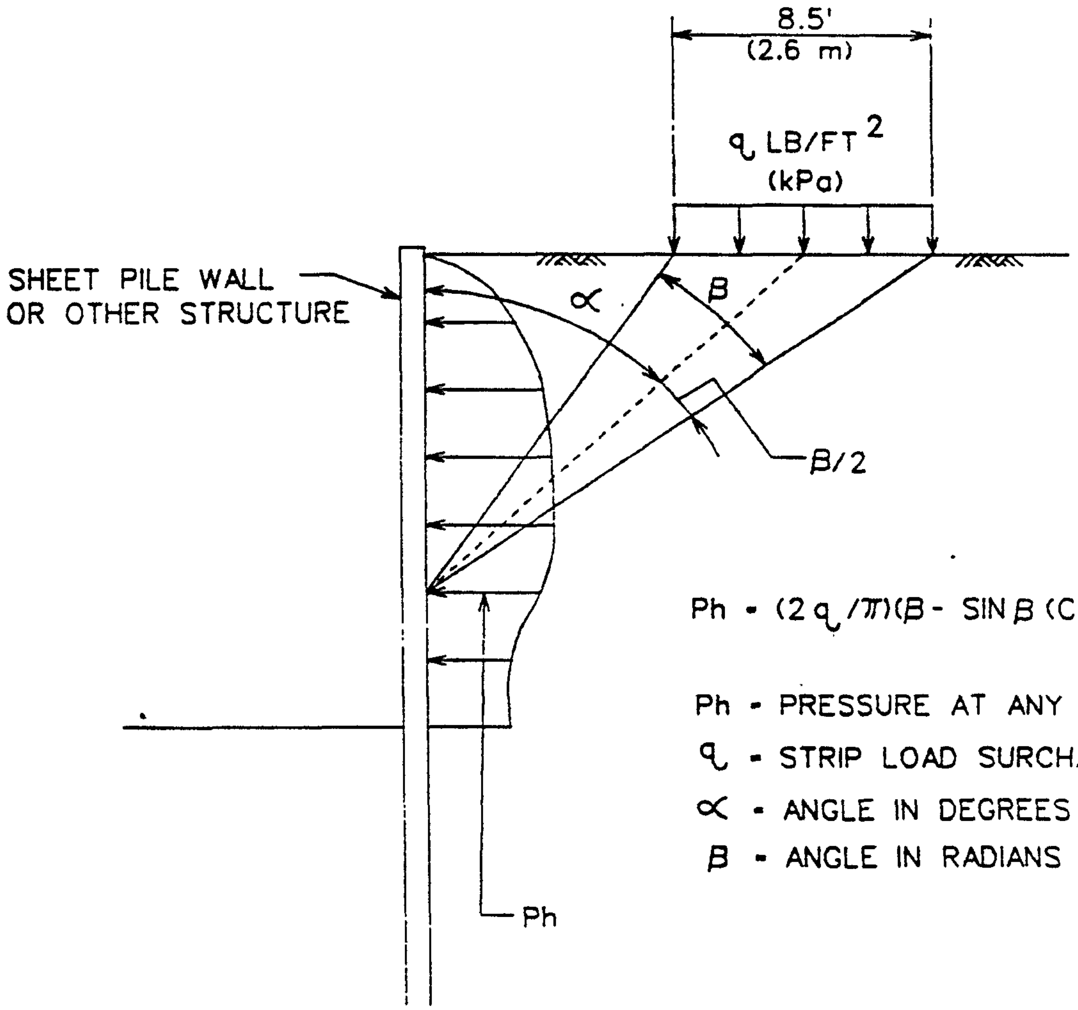
LATERAL PRESSURE DIAGRAM



$Ph = (2q/\pi)(\beta - \sin\beta(\cos 2\alpha))$

Ph - PRESSURE AT ANY GIVEN POINT

q - STRIP LOAD SURCHARGE

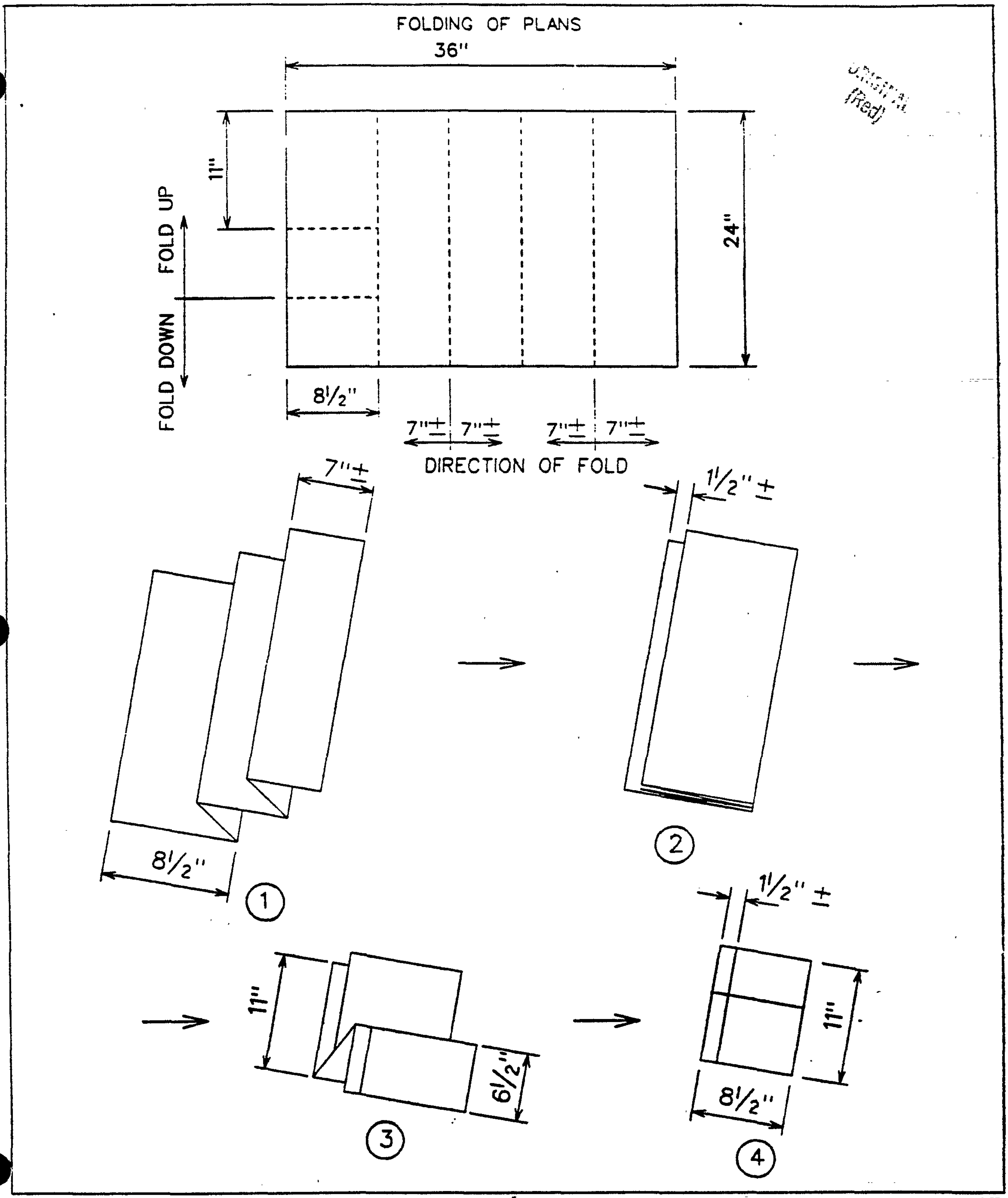
∝ - ANGLE IN DEGREES

β - ANGLE IN RADIANS

ELEVATION

LATERAL PRESSURE DUE TO STRIP LOAD

PLATE X



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ORIGINAL (Red)

PUBLICATION STANDARDS SOURCES

ANSI	American National Standards Institute, Inc. 1430 Broadway New York, NY 10018 (212) 642-4900
AREA	American Railway Engineering Association 50 F Street, N.W. Washington, DC 20001 (202) 639-2190
ASTM	American Society for Testing and Materials 1916 Race Street Philadelphia, PA 19103-1187 (215) 299-5585
AWWA	American Water Works Association, Inc. 6666 West Quincy Avenue Denver, CO 80235
	The National Association of Corrosion Engineers Houston, TX 77026

NOTE: If other than AREA, ASTM or AWWA specifications are referred to for design, materials or workmanship on the plans and specifications for the work, then copies of the applicable sections of such other specifications referred to shall accompany the plans and specifications for the work.

Designation: D 420 – 87

Standard Guide for Investigating and Sampling Soil and Rock[1]

This standard is issued under the fixed designation D 420; 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.

INTRODUCTION

Investigation, sampling, and identification of subsurface materials involve complex techniques accomplished by many different procedures and interpretations. These are frequently site specific and are influenced by geological and geographical conditions; purpose of the investigation; design requirements; and the background, training, and experience of the investigator.

This guide for soil, rock, and ground water investigation and sampling, based on standard procedures, will lessen inconsistency and will encourage rational methods of site evaluation. An acceptable and consistent investigation and sampling program will help to determine the influence of geologic and geographic environment on subsurface conditions.

1. Scope

1.1 This guide identifies recognized methods by which soil, rock, and ground water conditions may be determined. The objective of the investigation should be to identify and locate, both horizontally and vertically, significant soil and rock types and ground water conditions present within a given site area and to establish the characteristics of the subsurface materials by sampling and in situ testing. Laboratory testing of soil and rock samples is governed by other ASTM standards.

1.2 *Key Words:*

1.2.1 *Site Investigations (see Practice D 3584):*

UF Reconnaissance Surveys
 Subsurface Investigations
 Geological Investigations
 Field Investigations
BT Explorations
 Feasibility Studies
NT *Hydrologic Investigations*
 Foundation Investigations
 Geophysical Investigation
RT Soil Surveys
 Maps
 Preliminary Investigations
 Sampling

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 119 Definitions of Terms Relating to Dimension Stone[2]
C 294 Descriptive Nomenclature of Constituents of Natural Mineral Aggregates[2]
C 851 Practice for Estimating Scratch Hardness of Coarse Aggregate Particles[3]
D 75 Practice for Sampling Aggregates[2]
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
D 1194 Test Method for Bearing Capacity of Soil for Static Load on Spread Footings[2]
D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]
D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]
D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]
D 2113 Practice for Diamond Core Drilling for Site Investigation[2]
D 2487 Test Method for Classification of Soils for Engineering Purposes[2]
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]
D 2573 Test Method for Field Vane Shear Test in Cohesive Soil[2]
D 2607 Classification of Peats, Mosses, Humus, and Related Products[2]
D 2937 Test Method for Density of Soil In Place by the Drive-Cylinder Method[2]
D 3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes[2]
D 3385 Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometers[2]
D 3397 Methods for Triaxial Classification of Base Materials, Soils, and Soil Mixtures[4]
D 3441 Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil[2]
D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

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[1] This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Reconnaissance.

Current edition approved Aug. 19, 1987. Published October 1987. Originally published as D 420 – 65 T. Last previous edition D 420 – 69 (1979)ε1.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.03.

D 3584 Practice for Indexing Papers and Reports on Soil and Rock for Engineering Purposes[2]

D 3740 Practice for the Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[2]

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4427 Classification of Peat Samples by Laboratory Testing[2]

G 51 Test Method for pH of Soil for Use in Corrosion Testing[2]

G 57 Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method[2]

3. Significance and Use

3.1 An adequate soil, rock, and ground water investigation provides pertinent information for decision making on one or more of the following subjects:

3.1.1 Location of the proposed construction both vertically and horizontally.

3.1.2 Location and preliminary evaluation of suitable borrow and other local sources of construction material.

3.1.3 Need for special excavating and dewatering techniques.

3.1.4 Investigations of slope stability in natural slopes, cuts, and embankments.

3.1.5 Conceptual selection of embankment types, foundations for structures, and hydraulic barrier requirements.

3.1.6 Ground water resource planning and development detailed investigations.

3.1.7 Identification of ground water contamination and development of detailed monitoring studies.

3.1.8 Development of additional detailed subsurface investigations for specific structures or facilities.

3.2 A subsurface soil, rock, and ground water investigation should provide sufficiently large soil and rock samples of such quality as to allow adequate testing to determine the soil or rock classification or mineralogic type, or both, and the engineering properties pertinent to the proposed design.

3.3 This guide is not meant to be an inflexible description of investigation requirements; other techniques may be applied as appropriate.

4. Apparatus

4.1 The type of equipment required for a subsurface investigation depends upon various factors including the type of subsurface material, the depth of exploration, the nature of the terrain, and the intended use of the data.

4.2 *Hand Augers, Hole Diggers, Shovels, and Push Tube Samplers*, suitable for exploration of surficial soils to depths of 3 to 9 ft (1 to 3 m).

4.3 *Earth Excavation Equipment*, such as backhoes, draglines, and drilled pier augers (screw or bucket) to allow in situ examination of soil deposits and sampling of materials containing very large particles.

Techniques

5.1 Geophysical or remote sensing techniques may be used for mapping of the areal extent of geological formations and for evaluating variations in soil and rock properties.

5.1.1 Satellite and aircraft spectral mapping tools, such as LANDSAT, may be used to find and map the areal extent of subsurface materials and geologic structure. Interpretation of aircraft photographs and satellite imagery may locate and identify significant geologic features that may be indicative of faults and fractures. Some ground control is generally required to verify information derived from remote sensing data. Table 13.8 of Ref. (1)[5] is a useful summary of remote sensing capabilities.

5.1.2 Seismic refraction/reflection and ground penetrating radar techniques may be used to map soil horizons and depth profiles, water tables, and depth to bedrock in many situations, with depth penetration and resolution varying with local conditions. Electromagnetic induction, electrical resistivity, and induced polarization (or complex resistivity) techniques may be used to map variations in water content and quality, clay horizons, stratification, and depth to aquifer/bedrock. Other geophysical techniques such as gravity and magnetic methods may be useful under certain specific conditions. Crosshole shear wave velocity measurements may provide soil and rock parameters for dynamic analyses.

5.4 Currently available ASTM standards on boring and sampling are:

5.4.1 Practice D 1452 on auger boring.

5.4.2 Method D 1586 on standard penetration test.

5.4.3 Practice D 1587 on thin walled tube sampling.

5.4.4 Practice D 2113 on diamond core drilling.

5.4.5 Test Method D 2573 on field vane shear test.

5.4.6 Test Method D 3385 on double ring infiltrometer.

5.4.7 Method D 3441 on cone penetration tests.

5.4.8 Practice D 3550 on ring-lined barrel sampling.

6. Exploration Plan

6.1 The project design and performance requirements must be established prior to final development of the exploration plan. A complete soil, rock, and ground water investigation should encompass the following activities:

6.1.1 Review of available information on the geologic history, rock, soil, and ground water conditions occurring at the proposed location and in the immediate vicinity of the site.

6.1.2 Interpretation of air-photo and other remote sensing data.

6.1.3 Field reconnaissance for identification of surficial geologic conditions, mapping of stratigraphic exposures and outcrops, and examination of the performance of existing structures.

6.1.4 On site investigation of the surface and subsurface materials by geophysical surveys, borings, or test pits.

6.1.5 Recovery of representative disturbed samples for laboratory classification tests of soil, rock, and local construction material. These should be supplemented by undisturbed specimens suitable for the determination of those engineering properties pertinent to the investigation.

6.1.6 Determination of the position of the ground water table, or water tables if there is perched or artesian ground

[5] The boldface numbers in parentheses refer to the list of references at the end of this standard.

water, and of the variability of that position in both short and long time frames.

6.1.7 Determination of the location of suitable foundation material, either bedrock or satisfactory load-bearing soils.

6.1.8 Field identification of soil and rock types with the depth of their occurrence and the locations of their structural discontinuities.

6.1.9 Evaluation of the performance of existing installations, relative to their foundation material and environment in the immediate vicinity of the proposed site.

7. Reconnaissance of Project Area

7.1 Technical data should be reviewed before any field program is started. This includes, but is not limited to, topographic maps, airphotos, satellite imagery, geologic maps, statewide or county soil surveys and mineral resource surveys, and engineering soil maps covering the proposed project area. Reports of subsurface investigations of nearby or adjacent projects should be studied.

NOTE 1—While certain of the older maps and reports may be obsolete and of limited value in the light of current knowledge, a comparison of the old with the new will often reveal valuable unexpected information.

7.1.1 The United States Geological Survey and the geological surveys of the various states are the principal sources of geologic maps and reports on mineral resources and ground water.

7.1.2 United States Department of Agriculture Soil Conservation Service soil survey reports, where available and of up to date, should enable the engineer to estimate the range of soil profile characteristics to depths of 5 or 6 ft (1.5 or 2 m) for each soil mapped.

NOTE 2—Each soil type has a distinctive soil profile due to age, parent material, relief, climatic condition, and vegetative cover. These properties can assist in identifying the various soil types, each requiring special engineering considerations and treatment. Similar engineering soil properties are often found where similar soil profile characteristics exist. Changes in soil properties in adjacent areas often indicate changes in parent material or relief.

7.2 In areas where descriptive data are limited by inadequate geologic or soils maps, the soil and rock in open cuts in the vicinity of the proposed project should be studied and various soil and rock profiles noted. Field notes of such studies should include data outlined in 8.4.

7.3 Where a preliminary map covering the area of the project is desired, it can be prepared on maps compiled from airphotos showing the ground conditions. The distribution of the predominant soil and rock deposits likely to be encountered during the investigation may be shown using data obtained from geologic maps and limited ground reconnaissance. Experienced airphoto interpreters can deduce much subsurface data from a study of black and white, color, and infrared photographs because similar soil or rock conditions, or both, usually have similar airphoto patterns in regions of similar climate or vegetation.

7.4 In areas where documentary information is insufficient, some knowledge of subsurface conditions can be obtained from land owners and local well drillers and construction people.

NOTE 3—This preliminary map may be expanded into a detailed engineering map by locating all test holes, pits, and sampling stations and by revising boundaries as determined from the detailed subsurface survey.

8. Determination of Subsurface Conditions

8.1 Subsurface conditions are positively defined only at the individual test pit, hole, boring, or open cut examined. A stratigraphic profile can be developed by detailed investigations only where determinations of a continuous relationship of the depths and locations of various types of soil and rock can be made. This phase of the investigation may be implemented by plotting logs of soil and rock exposures in walls of excavations or cut areas or by plotting logs of the test borings, or both, and then interpolating between these logs. The spacing of these investigations will depend on the geologic complexity of the project area and on the importance of soil and rock continuity to the project design. Exploration should be deep enough to identify all strata that might be significantly affected by the proposed use of the site and to develop the engineering data required to allow analysis of the items listed in Section 3 for each project.

8.2 Geophysical survey methods may be used to supplement borehole and outcrop data and to interpolate between holes. Seismic, ground penetrating radar, and electrical resistivity methods can be particularly valuable when distinct differences in the properties of contiguous subsurface materials are indicated.

8.2.1 The seismic refraction method is especially useful in determining depth to, or rippability of, rock in locations where successively denser strata are encountered.

8.2.2 The seismic reflection method is useful in delineating geological units at depths below 10 ft (3 m). It is not constrained by layers of low seismic velocity and is especially useful in areas of rapid stratigraphic change.

8.2.3 The electrical resistivity method is similarly useful in determining depth to rock and anomalies in the stratigraphic profile, in evaluating stratified formations where a denser stratum overlies a less dense stratum, and in investigation of prospective sand-gravel or other sources of borrow material. Resistivity parameters also are required for the design of grounding systems and cathodic protection for buried structures.

8.2.4 The ground penetrating radar method is useful in defining soil and rock layers and manmade structures in the depth range of 1 to 30 ft (⅓ to 10 m).

NOTE 4—Geophysical investigations can be a useful guide in determining boring or test hole locations. The interpretation of geophysical studies should be verified by borings or test excavations.

8.3 The depth of exploratory borings or test pits for roadbeds, airport paving, or vehicle parking areas should be to at least 5 ft (1.5 m) below the proposed subgrade elevation. Special circumstances may increase this depth. Borings for structures or embankments should extend below the level of significant influence of the proposed load as determined by a subsurface stress analysis.

8.3.1 When drainage may be influenced by either pervious water-bearing materials or impervious materials that can block internal drainage, borings should extend down into these materials sufficiently to determine those engineering and geologic properties relevant to the project design.

8.3.2 In all borrow areas the borings or test pits should be sufficient in number and depth to outline the required quantities of material meeting the specified quality requirements.

8.3.3 Where frost penetration must be considered in the behavior of soil and rock, borings should extend significantly below the depth of maximum frost penetration.

8.4 Exploration records shall be kept in a systematic manner for each project. Such records shall include:

8.4.1 Description of each site or area investigated. Each test hole, boring, test pit, or geophysical test site shall be clearly located (horizontally and vertically) with reference to some established coordinate system, datum, or permanent monument.

8.4.2 Logs of each test hole, boring, test pit, or cut surface exposure in which the field description and location of each material encountered is clearly shown either by symbol or word description.

NOTE 5—Color photographs of rock cores, soil samples, and exposed strata may be of considerable value. Each photograph should include an identifying number or symbol, a date, and a scale.

8.4.3 Identification of all soils based on Practice D 2488, Classification D 2607, or Practice D 4083. Identification of rock materials based on Definitions of Terms C 119, Descriptive Nomenclature C 294, or Practice C 851. Classification of soil materials is discussed in Section 10.

8.4.4 Seepage and water-bearing zones and piezometric elevations found in each test hole, boring, or test pit.

8.4.5 In situ test results, where required, such as the penetration resistance or vane shear tests discussed in 9.3, plate load tests, or other in situ tests for engineering properties of soils or rock.

8.4.6 Percentage of core recovery and rock quality designation in core drilling as outlined in 9.3.5.

8.4.7 Graphical presentation of field and laboratory data and its interpretation facilitates comprehensive understanding of subsurface conditions.

9. Sampling and In Situ Testing

9.1 Obtain representative samples of each subsurface material that is significant to the project design and construction. The size and type of sample required is dependent upon the tests to be performed and the percentage of coarse particles in the sample.

NOTE 6—The size of disturbed or bulk samples for routine tests may vary at the discretion of the geotechnical investigator, but the following quantities are suggested as suitable for most materials: (a) Visual classification—50 to 500 g (2 oz to 1 lb); (b) Soil constants and particle size analysis of non-gravelly soil—500 g to 2.5 kg (1 to 5 lb); (c) Soil compaction tests and sieve analysis of gravelly soils—20 to 40 kg (40 to 80 lb); (d) Aggregate manufacture or aggregate properties tests—50 to 200 kg (100 to 400 lb).

9.2 Accurately identify each sample with the boring, test hole, or testpit number and depth below reference ground surface from which it was taken. Place a waterproof identification tag inside the container, securely close the container, protect it to withstand rough handling, and mark it with proper identification on the outside. Keep samples for natural moisture determination in sealed containers to prevent moisture loss. When drying of samples may affect classification or engineering properties test results, protect them to minimize moisture loss. Practices D 4220 address the transportation of samples from field to laboratory.

9.3 Recommended ASTM procedures for in situ sampling and testing are as follows:

9.3.1 Practice D 75 describes the sampling of coarse and fine aggregates for the preliminary investigation of a potential source of supply.

9.3.2 Test Method D 1194 describes the estimation of the bearing capacity of soil in place by means of field loading tests. The results can be useful for design of spread footings based on static loading conditions. The load test should be performed in conjunction with other field tests, generally in accordance with Method D 1586 or Method D 3441, to allow a determination of the applicability of the results.

9.3.3 Practice D 1452 describes the use of augers in soil investigations and sampling where disturbed soil samples can be used. This procedure is also valuable in connection with ground water exploration. Depths of auger investigations are limited by ground water conditions, soil characteristics, and equipment used.

9.3.4 Method D 1586 describes a procedure to obtain representative soil samples for identification and classification laboratory tests and to measure the resistance of the soil to penetration by a standardized sampler.

9.3.5 Practice D 1587 describes a procedure to recover relatively undisturbed soil samples suitable for laboratory testing.

9.3.6 Practice D 2113 describes a procedure to recover intact samples of rock and certain soils too hard to sample by Method D 1586 or Practice D 1587.

9.3.7 Practice D 3550 describes a procedure to recover moderately disturbed, representative samples of soil for classification testing and in some cases shear or consolidation testing.

9.3.8 Test Method D 2573 describes a procedure to measure the in situ unit shear resistance of cohesive soils by rotation of a four-bladed vane in a horizontal plane.

9.3.9 Test Method D 2937 describes a procedure for pushing a thin-wall tube 4 to 6 in. (100 to 150 mm) into a soil mass to recover a relatively undisturbed sample of known volume allowing the measurement of wet or total density and natural moisture content.

9.3.10 Test Method D 3385 describes a procedure for field measurement of the infiltration rate of soils. Water under a constant head is allowed to seep into the top surface of a fixed soil area and the volume rate of inflow into a known volume of soil is measured.

9.3.11 Method D 3441 describes the determination of the end bearing and side friction components of the resistance to penetration of a conical penetrometer into a soil mass.

9.3.12 Method G 57 describes the measurement of the electrical resistivity of a soil mass. A Wenner four-electrode configuration is used.

NOTE 7—Other in situ test procedures are being prepared by ASTM Committee D-18.

10. Classification of Earth Materials

10.1 Identify samples of soil and rock after submission to the laboratory for identification and classification tests in accordance with one or more of the following standards or applicable references (2 through 11), or both.

10.1.1 Descriptive Nomenclature 294.
10.1.2 Test Method D 2487.
10.1.3 Practice D 3282.
10.1.4 Method D 3397.
10.1.5 Practice D 2488.
10.1.6 Practice D 4083.
10.1.7 Classification D 4427.

11. Subsurface Profile

11.1 Delineate subsurface profiles only from actual geophysical, test-hole, test-pit, or cut-surface data. Interpolation between locations should be made on the basis of available geologic knowledge of the area and should be clearly identified. The use of geophysical techniques as discussed in 8.2 is a valuable aid in such interpolation. Geophysical survey data should be identified separately from sample data or in situ test data.

12. Interpretation of Results

12.1 Interpret the results of an investigation in terms of actual findings and make every effort to collect and include all field and laboratory data from previous investigations in the same area. Extrapolation of data into local areas not surveyed and tested should be made only for conceptual studies. Such extrapolation can be done only where geologically uniform subsurface disposition of soil and rock is known to exist on the basis of other data. Engineering properties of the soil and rock encountered on important projects should not be predicted solely on field identification or classification but should be verified by laboratory tests made on samples collected in accordance with Section 9 or by in situ testing, or both.

12.2 The recommendations for design parameters can be made only by professional engineers or geologists specializing in the field of geotechnical engineering and familiar with the purpose, conditions, and requirements of the study. Soil mechanics, rock mechanics, and geomorphological concepts must be combined with a knowledge of geotechnical engineering or hydrogeology to make a complete application of the results of the soil, rock, and ground water investigation. Complete design recommendations may require a more detailed study than that envisioned by this guide.

13. Report

13.1 The report of a subsurface investigation shall include:

13.1.1 Location of the area investigated in terms pertinent to the project. This may include sketch maps or aerial photos on which the test pits, bore holes, and sample areas are located, as well as geomorphological data relevant to the determination of the various soil and rock types. Such data includes elevation contours, streambeds, sink holes, cliffs, and the like. Where feasible, include in the report a geologic map or an agronomic soils map, or both, of the area investigated.

13.1.2 Describe the investigation procedures and include copies of all borings and testhole logs, all laboratory test results, and graphical interpretations of the geophysical measurements.

13.1.3 Include cross sections delineating the extent of the stratigraphic units and note anomalies or otherwise significant conditions.

13.1.4 Describe and relate the findings obtained under Sections 7, 8, and 12, using the subhead titles for the respective sections.

14. Precision and Bias

14.1 This guide provides qualitative data only; therefore, a precision and bias statement is not applicable.

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(5) Howell, J. V., and Weller, J. M., eds., "Glossary of Geology," American Geological Institute, Washington, DC, 1972.

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(8) Dowding, C. H., ed., "Site Characterization and Exploration," *Proc. Specialty Workshop*, ASCE, Northwestern Univ., Evanston, IL, 1978.

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Designation: D 421 – 85

Standard Practice for
Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[1]

This standard is issued under the fixed designation D 421; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the dry preparation of soil samples as received from the field for particle-size analysis and the determination of the soil constants.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Significance and Use

3.1 This practice can be used to prepare samples for particle-size and plasticity tests where it is desired to determine test values on air-dried samples, or where it is known that air drying does not have an effect on test results relative to samples prepared in accordance with Practice D 2217.

4. Apparatus

4.1 *Balance*, sensitive to 0.1 g.

4.2 *Mortar and Rubber-Covered Pestle*, suitable for breaking up the aggregations of soil particles.

4.3 *Sieves*—A series of sieves, of square mesh woven wire cloth, conforming to Specification E 11. The sieves required are as follows:

No. 4 (4.75-mm)
No. 10 (2.00-mm)
No. 40 (425-μm)

4.4 *Sampler*—A riffle sampler or sample splitter, for quartering the samples.

5. Sampling

5.1 Expose the soil sample as received from the field to the air at room temperature until dried thoroughly. Break up the aggregations thoroughly in the mortar with a rubber-covered pestle. Select a representative sample of the amount required to perform the desired tests by the method of quartering or by the use of a sampler. The amounts of material required to perform the individual tests are as follows:

5.1.1 *Particle-Size Analysis*—For the particle-size analysis, material passing a No. 10 (2.00-mm) sieve is required in amounts equal to 115 g of sandy soils and 65 g of either silt or clay soils.

5.1.2 *Tests for Soil Constants*—For the tests for soil constants, material passing the No. 40 (425-μm) sieve is required in total amount of 220 g, allocated as follows:

Test	Grams
Liquid limit	100
Plastic limit	15
Centrifuge moisture equivalent	10
Volumetric shrinkage	30
Check tests	65

6. Preparation of Test Sample

6.1 Select that portion of the air-dried sample selected for purpose of tests and record the mass as the mass of the total test sample uncorrected for hygroscopic moisture. Separate the test sample by sieving with a No. 10 (2.00-mm) sieve. Grind that fraction retained on the No. 10 sieve in a mortar with a rubber-covered pestle until the aggregations of soil particles are broken up into the separate grains. Then separate the ground soil into two fractions by sieving with a No. 10 sieve.

6.2 Wash that fraction retained after the second sieving free of all fine material, dry, and weigh. Record this mass as the mass of coarse material. Sieve the coarse material, after being washed and dried, on the No. 4 (4.75-mm) sieve and record the mass retained on the No. 4 sieve.

7. Test Sample for Particle-Size Analysis

7.1 Thoroughly mix together the fractions passing the No. 10 (2.00-mm) sieve in both sieving operations, and by the method of quartering or the use of a sampler, select a portion weighing approximately 115 g for sandy soils and approximately 65 g for silt and clay soil for particle-size analysis.

8. Test Sample for Soil Constants

8.1 Separate the remaining portion of the material passing the No. 10 (2.00-mm) sieve into two parts by means of a No. 40 (425-μm) sieve. Discard the fraction retained on the No. 40 sieve. Use the fraction passing the No. 40 sieve for the determination of the soil constants.

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved July 26, 1985. Published September 1985. Originally published as D 421 – 35 T. Last previous edition D 421 – 58 (1978)ε1

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

AR305395

Designation: D 422 – 63 (Reapproved 1990)[ε1]

Standard Test Method for Particle-Size Analysis of Soils[1]

This standard is issued under the fixed designation D 422; 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.

[ε1] NOTE—Section 19 was added editorially in September 1990.

1. Scope

1.1 This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 µm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 µm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Notes 1 and 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-µm), or No. 200 (75-µm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-µm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 µm.

2. Referenced Documents

2.1 *ASTM Standards:*

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

E 100 Specification for ASTM Hydrometers[4]

3. Apparatus

3.1 *Balances*—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 *Stirring Apparatus*—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup[5] (Note 3) conforming to the general details shown in Fig. 3 (Notes 4 and 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft³/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 *Hydrometer*—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 *Sedimentation Cylinder*—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 *Thermometer*—A thermometer accurate to 1°F (0.5°C).

3.6 *Sieves*—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved Nov. 21, 1963. Originally published 1935. Replaces D 422 – 62.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. Order Adjunct No. 12-404220-00.

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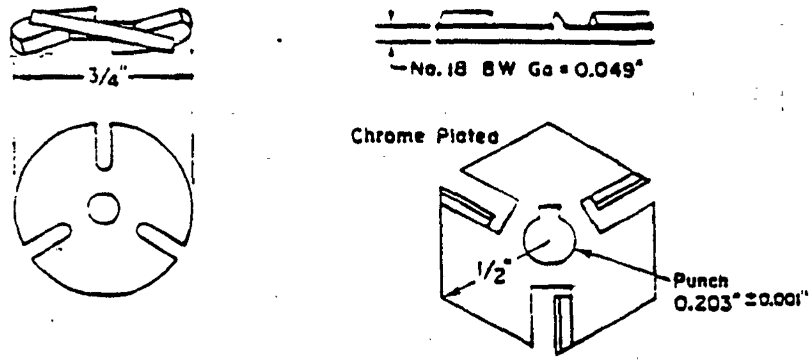


(a) (b)

Metric Equivalents

in	0.001	0.049	0.203	½	¾
mm	0.03	1.24	5.16	12.7	19.0

FIG. 1 Detail of Stirring Paddles

3-in. (75-mm)
2-in. (50-mm)
1½-in. (37.5-mm)
1-in. (25.0-mm)
¾-in. (19.0-mm)
⅜-in. (9.5-mm)
No. 4 (4.75-mm)
No. 10 (2.00-mm)
No. 20 (850-µm)
No. 40 (425-µm)
No. 60 (250-µm)
No. 140 (106-µm)
No. 200 (75-µm)

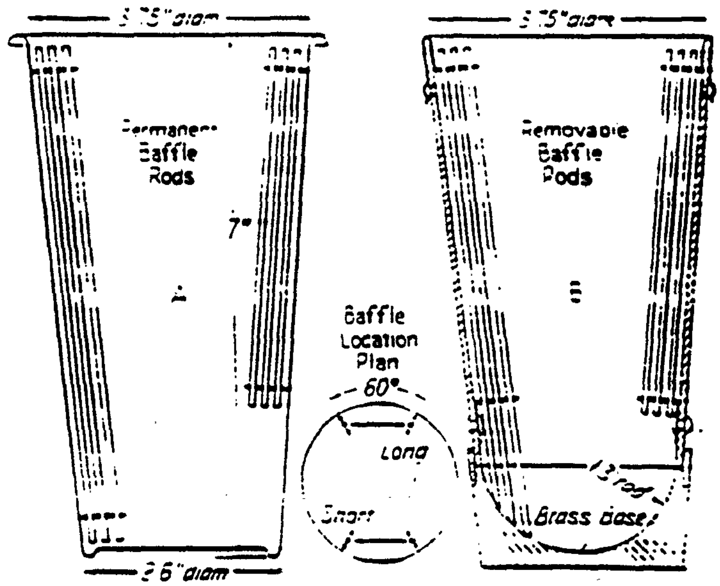
NOTE 6—A set of sieves giving uniform spacing of points for the graph, as required in Section 17, may be used if desired. This set consists of the following sieves:

3-in. (75-mm)
1½-in. (37.5-mm)
¾-in. (19.0-mm)
⅜-in. (9.5-mm)
No. 4 (4.75-mm)
No. 8 (2.36-mm)
No. 16 (1.18-mm)
No. 30 (600-µm)
No. 50 (300-µm)
No. 100 (150-µm)
No. 200 (75-µm)

3.7 *Water Bath or Constant-Temperature Room*—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

3.8 *Beaker*—A beaker of 250-mL capacity.

3.9 *Timing Device*—A watch or clock with a second hand.



Metric Equivalents

in	1.3	2.6	3.75
mm	33	66	95.2

FIG. 2 Dispersion Cups of Apparatus

4. Dispersing Agent

4.1 A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

NOTE 7—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

4.2 All water used shall be either distilled or demineralized water. The water for a hydrometer test shall be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

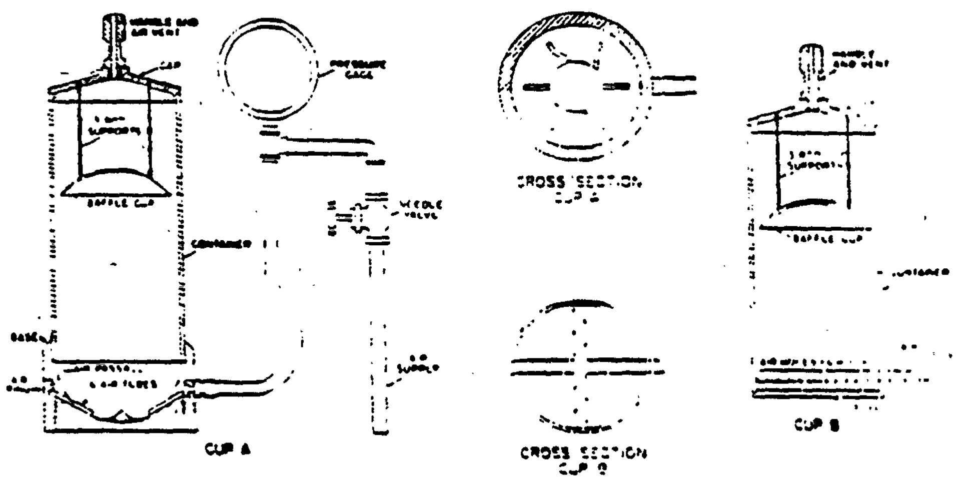


FIG. 3 Air-Jet Dispersion Cups of Apparatus B

5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
⅜ (9.5)	500
¾ (19.0)	1000
1 (25.4)	2000
1½ (38.1)	3000
2 (50.8)	4000
3 (76.2)	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in Section 5 of Practice D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

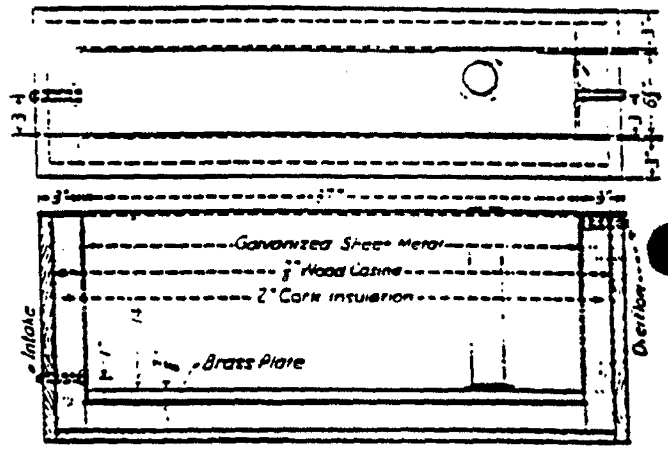
SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm), 2-in. (50-mm), 1½-in. (37.5-mm), 1-in. (25.0-mm), ¾-in. (19.0-mm), ⅜-in. (9.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.



Metric Equivalents

in.	⅞	1	3	6¼	14	37
mm	22.2	25.4	76.2	158.2	356	940

FIG. 4 Insulated Water Bath

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HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1° temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cylinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hydrometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at 230 ± 9°F (110 ± 5°C), and weigh again. Record the masses.

9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/L). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. If stirring apparatus A is used, transfer the soil - water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

NOTE 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil - water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, if necessary, so that the total volume in the cup is 250 mL, but no more.

NOTE 10—The initial air pressure of 1 psi is required to prevent the soil - water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil - water slurry to the sedimentation cylinder.

10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil - water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns.

Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75-μm) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at 230 ± 9°F (110 ± 5°C) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

CALCULATIONS AND REPORT

12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the ⅜-in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the ⅜-in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

13. Hygroscopic Moisture Correction Factor

13.1 The hydroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight W in the equation for percentage remaining in suspension.

TABLE 1 Values of Correction Factor, a, for Different Specific Gravities of Soil Particles[A]

Specific Gravity	Correction Factor[A]
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

[A] For use in equation for percentage of soil remaining in suspension when using Hydrometer 152H.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\,000/W) \times G/(G - G_1)](R - G_1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) \times 100$$

where:

a = correction faction to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

P = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

R = hydrometer reading with composite correction applied (Section 7),

W = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,

G = specific gravity of the soil particles, and

G_1 = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for R is based on a value of one for G_1.

15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. According to Stokes' law:

$$D = \sqrt{[30n/980(G - G_1)] \times L/T}$$

where:

D = diameter of particle, mm.

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n = coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),
L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (Table 2)).
T = interval of time from beginning of sedimentation to the taking of the reading, min.
G = specific gravity of soil particles, and
G_1 = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE 14—Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows:

$$D = K\sqrt{L/T}$$

where:
K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 3. The value of K does not change for a series of readings constituting a test, while values of L and T do vary.

15.3 Values of D may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of L is divided by T using the A- and B-scales, the square root being indicated on the D-scale. Without ascertaining the value of the square root it may be multiplied by K, using either the C- or CI-scale.

16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

17. Graph

17.1 When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an

TABLE 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes[A]

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.9	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

[A] Values of effective depth are calculated from the equation:

$$L = L_1 + \frac{1}{2}(L_2 - (V_B/A))$$

where:
L = effective depth, cm,
L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm,
L_2 = overall length of the hydrometer bulb, cm,
V_B = volume of hydrometer bulb, cm³, and
A = cross-sectional area of sedimentation cylinder, cm²

Values used in calculating the values in Table 2 are as follows:
For both hydrometers, 151H and 152H:
L_2 = 14.0 cm
V_B = 67.0 cm³
A = 27.8 cm²
For hydrometer 151H:
L_1 = 10.5 cm for a reading of 1.000
= 2.3 cm for a reading of 1.031
For hydrometer 152H:
L_1 = 10.5 cm for a reading of 0 g/litre
= 2.3 cm for a reading of 50 g/litre

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TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature, °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

18. Report.

18.1 The report shall include the following:

18.1.1 Maximum size of particles.

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

(1) Gravel, passing 3-in. and retained on No. 4 sieve
(2) Sand, passing No. 4 sieve and retained on No. 200 sieve
(a) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve
(b) Medium sand, passing No. 10 sieve and retained on No. 40 sieve
(c) Fine sand, passing No. 40 sieve and retained on No. 200 sieve
(3) Silt size, 0.074 to 0.005 mm
(4) Clay size, smaller than 0.005 mm
Colloids, smaller than 0.001 mm

18.4 For materials for which compliance with defi specifications is not indicated and when the soil cont material retained on the No. 4 sieve sufficient to r sieve analysis on that portion, the results may be reporte follows (Note 17):

SIEVE ANALYSIS

Sieve Size	Percentage Passing
3-in	
2-in.	
1½-in	
1-in	
¾-in	
⅜-in.	
No. 4 (4.75-mm)	
No. 10 (2.00-mm)	
No. 40 (425-um)	
No. 200 (75-um)	

HYDROMETER ANALYSIS

0.074 mm
0.005 mm
0.001 mm

NOTE 17—No. 8 (2.36-mm) and No. 50 (300-um) sieves m substituted for No. 10 and No. 40 sieves.

19. Keywords

19.1 grain-size; hydrometer analysis; hygroscopic ; ture; particle-size; sieve analysis

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Designation: D 698 – 78 (Reapproved 1990)[ε1]

An American National Standard

Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[1]

This standard is issued under the fixed designation D 698; 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.

These methods have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

ε1 Note—Section [illegible] was added editorially in September 1990.

1. Scope

1.1 These laboratory compaction methods cover the determination of the relationship between the moisture content and density of soils and soil-aggregate mixtures (Note 1) when compacted in a mold of a given size with a 5.5-lb (2.49-kg) rammer dropped from a height of 12 in. (305 mm) (Note 2). Four alternative procedures are provided as follows:

1.1.1 *Method A*—A 4-in. (101.6-mm) mold: material passing a No. 4 (4.75-mm) sieve;

1.1.2 *Method B*—A 6-in. (152.4-mm) mold: material passing a No. 4 (4.75-mm) sieve;

1.1.3 *Method C*—A 6-in. (152.4-mm) mold: material passing a ¾-in. (19.0-mm) sieve; and

1.1.4 *Method D*—A 6-in. (152.4-mm) mold: material passing a ¾-in. (19.0-mm) sieve, corrected by replacement for material retained on a ¾-in. sieve.

Note 1—Soils and soil-aggregate mixtures should be regarded as natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

Note 2—These laboratory compaction test methods when used on soils and soil-aggregates which are not free-draining will, in most cases, establish a well-defined optimum moisture content and maximum density (see Section 7). However, for free-draining soils and soil-aggregate mixtures, these methods will not, in many cases, produce a well-defined moisture-density relationship and the maximum density obtained will generally be less than that obtained by vibratory methods.

1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Section 5 shall govern.

2. Referenced Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]

D 854 Test Method for Specific Gravity of Soils[3]

D 2168 Test Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[3]

D 2487 Test Method for Classification of Soils for Engineering Purposes[3]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[3]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Apparatus

3.1 *Molds*—The molds shall be cylindrical in shape, made of rigid metal and be within the capacity and dimensions indicated in 3.1.1 or 3.1.2. The molds may be the "split" type, consisting either of two half-round sections, or a section of pipe split along one element, which can be securely locked together to form a cylinder meeting the requirements of this section. The molds may also be the "taper" type, providing the internal diameter taper is uniform and is not more than 0.200 in./linear ft (16.7 mm/linear m) of mold height. Each mold shall have a base plate assembly and an extension collar assembly, both made of rigid metal and constructed so they can be securely attached to or detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2 in. (50.8 mm), which may include an upper section that flares out to form a funnel provided there is at least a ¾-in. (19-mm) straight cylindrical section beneath it.

3.1.1 *Mold*, 4.0 in. (101.6 mm) in diameter, having a capacity of 1/30 = 0.0004 ft³ (944 ± 11 cm³) and conforming to Fig. 1.

3.1.2 *Mold*, 6.0 in. (152.4 mm) in diameter, having a capacity of [illegible] = 0.0009 ft³ (2124 ± 25 cm³) and conforming to Fig. 2.

3.1.3 The average internal diameter, height, and volume of each mold shall be determined before initial use and at intervals not exceeding 1000 times the mold is filled.

[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vols 04.02 and 04.03.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vols 04.01, 04.06, and 14.02.

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mold volume shall be calculated from the average of at least six internal diameter and three height measurements made to the nearest 0.001 in. (0.02 mm), or from the amount of water required to completely fill the mold, corrected for temperature variance in accordance with Table 1. If the average internal diameter and volume are not within the tolerances shown in Figs. 1 or 2, the mold shall not be used. The determined volume shall be used in computing the required densities.

3.2 *Rammer*—The rammer may be either manually operated (see 3.2.1) or mechanically operated (see 3.2.2). The rammer shall fall freely through a distance of 12.0 ± 1/16 in. (304.8 ± 1.6 mm) from the surface of the specimen. The manufactured weight of the rammer shall be 5.5 ± 0.02 lb (2.49 ± 0.01 kg). The specimen contact face shall be flat.

3.2.1 *Manual Rammer*—The specimen contact face shall be circular with a diameter of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). The rammer shall be equipped with a guidesleeve which shall provide sufficient clearance so that the free fall of the rammer shaft and head will not be restricted. The guidesleeve shall have four vent holes at each end (eight holes total) located with centers ¾ ± 1/16 in. (19.0 ± 1.6 mm) from each end and spaced 90 deg apart. The minimum diameter of the vent holes shall be ⅜ in. (9.5 mm).

3.2.2 *Mechanical Rammer*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03 in. (2.5 ± 0.8 mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. When used with the 4.0-in. (101.6-mm) mold, the specimen contact face shall be circular with a diameter of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). When used with the 6.0-in. (152.4-mm) mold, the specimen contact face shall have the shape of a section of a circle of a radius equal to 2.90 ± 0.02 in. (73.7 ± 0.5 mm). The sector face rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen. The mechanical rammer shall be calibrated and adjusted, as necessary, in accordance with 3.2.3.

3.2.3 *Calibration and Adjustment*—The mechanical rammer shall be calibrated, and adjusted as necessary, before initial use; near the end of each period during which the mold was filled 1000 times; before reuse after anything, including repairs, which may affect the test results significantly; and whenever the test results are questionable. Each calibration and adjustment shall be in accordance with Methods D 2168.

3.3 *Sample Extruder* (optional)—A jack, frame or other device adapted for the purpose of extruding compacted specimens from the mold.

3.4 *Balances*—A balance or scale of at least 20-kg capacity sensitive to ± 1 g and a balance of at least 1000-g capacity sensitive to ±0.01 g.

3.5 *Drying Oven*, thermostatically controlled, preferably of the forced-draft type, capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C) for determining the moisture content of the compacted specimen.

3.6 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10 in. (254 mm). The scraping edge shall have a straightness tolerance of ±0.005

TABLE 1 Volume of Water per Gram Based on Temperature[A]

Temperature, °C (°F)	Volume of Water, ml/g
12 (53.6)	1.00048
14 (57.2)	1.00073
16 (60.8)	1.00103
18 (64.4)	1.00138
20 (68.0)	1.00177
22 (71.6)	1.00221
24 (75.2)	1.00268
26 (78.8)	1.00320
28 (82.4)	1.00375
30 (86.0)	1.00435
32 (89.6)	1.00497

[A] Values other than shown may be obtained by referring to the Handbook of Chemistry and Physics.[5]

TABLE 2 Dry Preparation Method—Standing Times

Classification D 2487	Minimum Standing Time, h
GW, GP, SW, SP	no requirement
GM, SM	3
ML, CL, OL, GC, SC	18
MH, CH, OH, PT	36

TABLE 3 Precision

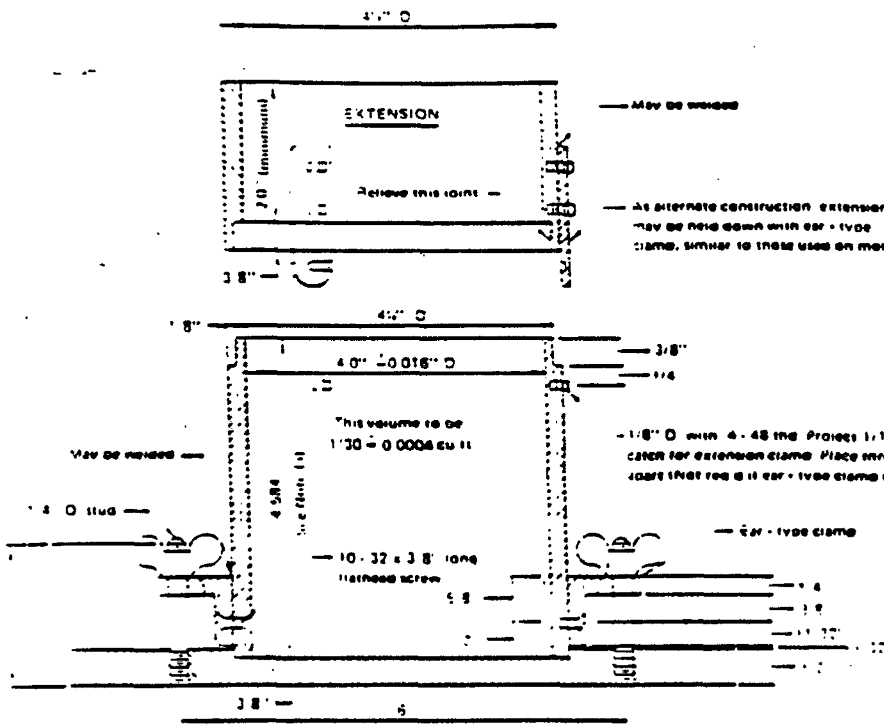
	Standard Deviation, s	Acceptable Range of Two Results, Expressed as Percent of Mean Value[A]
Single-operator precision:		
Maximum density		1.9
Optimum moisture content		9.5
Multilaboratory precision:		
Maximum density	±1.66	4.0
Optimum moisture content	±0.86	15.0

[A] This column indicates a limiting range of values which should not be exceeded by the difference between any two results, expressed as a percentage of the average value. In cooperative test programs it has been determined that 95 % of the tests do not exceed the limiting acceptable ranges shown below. All values shown in this table are based on average test results from a variety of different soils and are subject to future revision.

TABLE 4 Metric Equivalents for Figs. 1 and 2

in.	mm
0.016	0.41
0.026	0.66
1/32	0.80
1/16	1.6
⅛	3.2
¼	6.4
11/32	8.7
⅜	9.5
½	12.7
⅝	15.9
2	50.8
2½	63.5
4	101.6
4¼	108.0
4½	114.3
4.584	116.43
6	152.4
6½	165.1
8	203.2
ft³	**cm³**
1/30	944
0.004	11
1/13.333	2124
0.0009	25

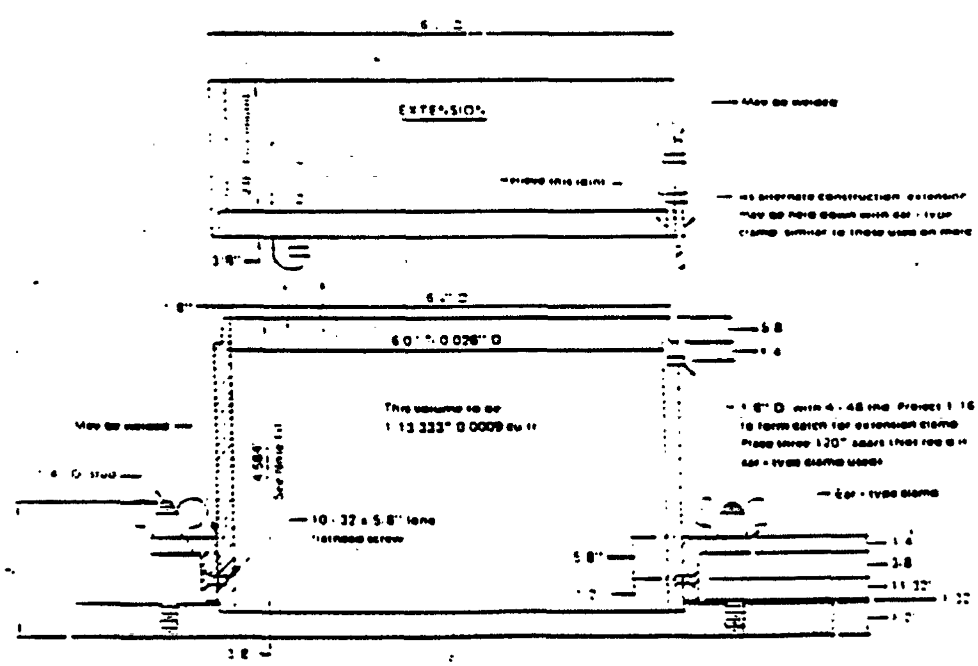
[5] Available from Chemical Rubber Publishing Co.



NOTE 1—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE 2—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 1 Cylindrical Mold, 4.0-in. for Soil Tests (see Table 4 for metric equivalents)



NOTE 1—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE 2—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 2 Cylindrical Mold, 6.0-in. for Soil Tests (see Table 4 for metric equivalents)

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in. (±0.13 mm) and shall be beveled if it is thicker than 1/8 in. (3 mm).

3.7 *Sieves*, 3-in. (75-mm), 3/4-in. (19.0-mm) and No. 4 (4.75-mm), conforming to the requirements of Specification E 11.

3.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

4. Procedure

4.1 *Specimen Preparation*—Select a representative portion of quantity adequate to provide, after sieving, an amount of material weighing as follows: Method A—25 lb (11 kg); Methods B, C, and D—50 lb (23 kg). Prepare specimens in accordance with either 4.1.1 through 4.1.3 or 4.1.4.

4.1.1 *Dry Preparation Procedure*—If the sample is too damp to be friable, reduce the moisture content by drying until the material is friable: see 4.1.2. Drying may be in air or by the use of a drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). After drying (if required), thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the particles. Pass the material through the specified sieve as follows: Methods A and B—No. 4 (4.75-mm); Methods C and D—3/4-in. (19.0-mm). Correct for oversize material in accordance with Section 5, if Method D is specified.

4.1.2 Whenever practicable, soils classified as ML, CL, OL, GC, SC, MH, CH, OH and PT by Test Method D 2487 shall be prepared in accordance with 4.1.4.

4.1.3 Prepare a series of at least four specimens by adding increasing amounts of water to each sample so that the moisture contents vary by approximately 1½ %. The moisture contents selected shall bracket the optimum moisture content, thus providing specimens which, when compacted, will increase in mass to the maximum density and then decrease in density (see 7.2 and 7.3). Thoroughly mix each specimen to ensure even distribution of moisture throughout and then place in a separate covered container and allow to stand prior to compaction in accordance with Table 2. For the purpose of selecting a standing time, it is not required to perform the actual classification procedures described in Test Method D 2487 (except in the case of referee testing), if previous data exist which provide a basis for classifying the sample.

4.1.4 *Moist Preparation Method*—The following alternate procedure is recommended for soils classified as ML, CL, OL, GC, SC, MH, CH, OH, and PT by Test Method D 2487. Without previously drying the sample, pass it through the 3/4-in. (19.0-mm) and No. 4 (4.75-mm) sieves. Correct for oversize material in accordance with Section 5, if Method D is specified. Prepare a series of at least four specimens having moisture contents that vary by approximately 1½ %. The moisture contents selected shall bracket the optimum moisture content, thus providing specimens which, when compacted, will increase in mass to the maximum density and then decrease in density (see 7.2 and 7.3). To obtain the appropriate moisture content of each specimen, the addition of a predetermined amount of water (see 4.1.3) or the removal of a predetermined amount of moisture by drying may be necessary. Drying may be in air or by the use of a drying apparatus such that the temperature of the specimen does not exceed 140°F (60°C). The prepared specimens shall then be thoroughly mixed and stand, as specified in 4.1.3 and Table 2, prior to compaction.

NOTE 3—With practice, it is usually possible to visually judge the point of optimum moisture closely enough so that the prepared specimens will bracket the point of optimum moisture content.

4.2 *Specimen Compaction*—Select the proper compaction mold, in accordance with the method being used, and attach the mold extension collar. Compact each specimen in three layers of approximately equal height. Each layer shall receive 25 blows in the case of the 4-in. (101.6-mm) mold; each layer shall receive 56 blows in the case of the 6-in. (152.4-mm) mold. The total amount of material used shall be such that the third compacted layer is slightly above the top of the mold, but not exceeding 1/4 in. (6 mm). During compaction the mold shall rest on a uniform rigid foundation, such as provided by a cylinder or cube of concrete weighing not less than 200 lb (91 kg).

4.2.1 In operating the manual rammer, care shall be taken to avoid rebound of the rammer from the top end of the guidesleeve. The guidesleeve shall be held steady and within 5 deg of the vertical. Apply the blows at a uniform rate not exceeding approximately 1.4 s per blow and in such a manner as to provide complete coverage of the specimen surface.

4.2.2 Following compaction, remove the extension collar; carefully trim the compacted specimen even with the top of the mold by means of the straightedge and determine the mass of the specimen. Divide the mass of the compacted specimen and mold, minus the mass of the mold, by the volume of the mold (see 3.1.3). Record the result as the wet density, γ_m, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen.

4.2.3 Remove the material from the mold. Determine moisture content in accordance with Method D 2216, using either the whole specimen or alternatively a representative specimen of the whole specimen. The whole specimen must be used when the permeability of the compacted specimen is high enough so that the moisture content is not distributed uniformly throughout. If the whole specimen is used, break it up to facilitate drying. Obtain the representative specimen by slicing the compacted specimen axially through the center and removing 100 to 500 g of material from one of the cut faces.

4.2.4 Repeat 4.2 through 4.2.3 for each specimen prepared.

5. Oversize Corrections

5.1 If 30 % or more of the sample is retained on a 3/4-in. (19.0-mm) sieve, then none of the methods described under these methods shall be used for the determination of either maximum density or optimum moisture content.

5.2 *Methods A and B*—The material retained on the No. 4 (4.75-mm) sieve is discarded and no oversize correction is made. However, it is recommended that if the amount of material retained is 7 % or greater, Method C be used instead.

5.3 *Method C*—The material retained on the 3/4-in. (19.0-mm) sieve is discarded and no oversize correction is made.

However, if the amount of material retained is 10 % or greater, it is recommended that Method D be used instead.

5.4 *Method D:*

5.4.1 This method shall not be used unless the amount of material retained on the 3/4-in. (19.0-mm) sieve is 10 % or greater. When the amount of material retained on the 3/4-in. sieve is less than 10 %, use Method C.

5.4.2 Pass the material retained on the 3/4-in. (19.0-mm) sieve through a 3-in. or 75-mm sieve. Discard the material retained on the 3-in. sieve. The material passing the 3-in. sieve and retained on the 3/4-in. sieve shall be replaced with an equal amount of material passing a 3/4-in. sieve and retained on a No. 4 (4.75-mm) sieve. The material for replacement shall be taken from an unused portion of the sample.

6. Calculations

6.1 Calculate the moisture content and the dry density of each compacted specimen as follows:

$$w = [(A - B)/(B - C)] \times 100$$

and

$$\gamma_d = [\gamma_m/(w + 100)] \times 100$$

where:

w = moisture content in percent of the compacted specimens,

A = mass of container and moist specimen,

B = mass of container and oven-dried specimen,

C = mass of container,

γ_d = dry density, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen, and

γ_m = wet density, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen.

7. Moisture-Density Relationship

7.1 From the data obtained in 6.1, plot the dry density values as ordinates with corresponding moisture contents as abscissas. Draw a smooth curve connecting the plotted points. Also draw a curve termed the "curve of complete saturation" or "zero air voids curve" on this plot. This curve represents the relationship between dry density and corresponding moisture contents when the voids are completely filled with water. Values of dry density and corresponding moisture contents for plotting the curve of complete saturation can be computed using the following equation:

$$w_{sat} = [(62.4/\gamma_d) - (1/G_s)] \times 100$$

where:

w_{sat} = moisture content in percent for complete saturation,

γ_d = dry density in pounds per cubic foot (or kilograms per cubic metre),

G_s = specific gravity of the material being tested (see Note 4), and

62.4 = density of water in pounds per cubic foot (or kilograms per cubic metre).

NOTE 4—The specific gravity of the material can either be assumed or based on the weighted average values of: (a) the specific gravity of the material passing the No. 4 (4.75-mm) sieve in accordance with Test Method D 854; and (b) the apparent specific gravity of the material retained on the No. 4 sieve in accordance with Test Method C 127.

7.2 *Optimum Moisture Content, w*—The moisture content corresponding to the peak of the curve drawn as directed in 7.1 shall be termed the "optimum moisture content."

7.3 *Maximum Density, γ_{max}*—The dry density in pounds per cubic foot (or kilograms per cubic metre) of the sample at "optimum moisture content" shall be termed "maximum density."

8. Report

8.1 The report shall include the following:

8.1.1 Method used (Method A, B, C, or D).

8.1.2 Optimum moisture content.

8.1.3 Maximum density.

8.1.4 Description of rammer (whether manual or mechanical).

8.1.5 Description of appearance of material used in test, based on Practice D 2488 (Test Method D 2487 may be used as an alternative).

8.1.6 Origin of material used in test.

8.1.7 Preparation procedure used (moist or dry).

9. Precision and Bias

9.1 Criteria for judging the acceptability of the maximum density and optimum moisture content test results are given in Table 3. The standard deviation, *s*, is calculated from the equation:

$$s^2 = \frac{1}{n-1} \sum_{1}^{n} (x - \bar{x})^2$$

where:

n = number of determinations,

x = individual value of each determination, and

$\bar{x}$ = numerical average of the determinations.

9.2 Criteria for assigning standard deviation values for single-operator precision are not available at the present time.

9.3 *Bias*—There is no accepted reference value for this test method therefore, bias cannot be determined.

10. Keywords

10.1 maximum dry density; moisture-density; optimum moisture content; optimum water content; proctor test; standard proctor test

Designation: D 854 – 83 (Reapproved 1990)[ε1]

American Association State Highway and Transportation Officials Standard AASHTO No.: T 100

Standard Test Method for Specific Gravity of Soils[1]

This standard is issued under the fixed designation D 854; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

[ε1] NOTE—Section 11 was added editorially in September 1990.

1. Scope

1.1 This test method covers determination of the specific gravity of soils by means of a pycnometer. When the soil is composed of particles larger than the No. 4 (4.75-mm) sieve, the method outlined in Test Method C 127 shall be followed. When the soil is composed of particles both larger and smaller than the No. 4 sieve, the sample shall be separated on the No. 4 sieve and the appropriate test method used on each portion. The specific gravity value for the soil shall be the weighted average of the two values (Note 1). When the specific gravity value is to be used in calculations in connection with the hydrometer portion of Method D 422, it is intended that the specific gravity test be made on that portion of the soil which passes the No. 10 (2.00-mm) sieve.

NOTE 1—The weighted average specific gravity should be calculated using the following equation

$$G_{avg} = \frac{1}{\frac{R_1}{100G_1} + \frac{P_1}{100G_2}}$$

where:

G_{avg} = weighted average specific gravity of soils composed of particles larger and smaller than the No. 4 (4.75-mm) sieve,
R_1 = percent of soil particles retained on the No. 4 sieve,
P_1 = percent of soil particles passing the No. 4 sieve,
G_1 = apparent specific gravity of soil particles retained on the No. 4 sieve as determined by Test Method C 127, and
G_2 = specific gravity of soil particles passing the No. 4 sieve as determined by this test method.

1.2 The values stated in acceptable metric units are to be regarded as the standard.

1.3 *This standard does not purport to address the safety problems 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]
D 422 Method for Particle-Size Analysis of Soils[3]
E 12 Definitions of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases[4]

3. Definition

3.1 *specific gravity*—the ratio of the mass of a unit volume of a material at a stated temperature to the mass in air of the same volume of gas-free distilled water at a stated temperature (per Definitions E 12).

4. Significance and Use

4.1 The specific gravity of a soil is used in almost every equation expressing the phase relationship of air, water, and solids in a given volume of material.

4.2 The term "solid particles," as used in geotechnical engineering, is typically assumed to mean naturally occurring mineral particles that are not very soluble in water. Therefore, the specific gravity of materials containing extraneous matter (such as cement, lime, etc.), water-soluble matter (such as sodium chloride), and soils containing matter with a specific gravity of less than one, typically require special treatment or a qualified definition of specific gravity.

5. Apparatus

5.1 *Pycnometer*—Either a volumetric flask having a capacity of at least 100 mL or a stoppered bottle having a capacity of at least 50 mL (Note 2). The stopper shall be of the same material as the bottle, and of such size and shape that it can be easily inserted to a fixed depth in the neck of the bottle, and shall have a small hole through its center to permit the emission of air and surplus water.

NOTE 2—The use of either the volumetric flask or the stoppered bottle is a matter of individual preference, but in general, the flask should be used when a larger sample than can be used in the stoppered bottle is needed due to maximum grain size of the sample.

5.2 *Balance*—Either a balance sensitive to 0.01 g for use with the volumetric flask, or a balance sensitive to 0.001 g for use with the stoppered bottle.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved Nov. 28, 1983. Published January 1984. Originally issued as D 854 – 45. Last previous edition D 854 – 58 (1979).

[2] *Annual Book of ASTM Standards*, Vol 04.02.
[3] *Annual Book of ASTM Standards*, Vol 04.08.
[4] *Annual Book of ASTM Standards*, Vol 15.05.

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6. Calibration of Pycnometer

6.1 The pycnometer shall be cleaned, dried, weighed, and weight recorded. The pycnometer shall be filled with distilled water (Note 3) essentially at room temperature. The weight of the pycnometer and water, W'_a, shall be determined and recorded. A thermometer shall be inserted in the water and its temperature T_i determined to the nearest whole degree.

NOTE 3—Kerosine is a better wetting agent than water for most soils and may be used in place of distilled water for oven-dried samples.

6.2 From the weight W'_a determined at the observed temperature T_i, a table of values of weights W'_a shall be prepared for a series of temperatures that are likely to prevail when weights W_b are determined later (Note 4). These values of W'_a shall be calculated as follows:

$$W'_a \text{ (at } T_x) = (\text{density of water at } T_x / \text{density of water at } T_i) \times (W'_a \text{ (at } T_i) - W'_f) + W'_f$$

where:

W'_a = weight of pycnometer and water, g,
W'_f = weight of pycnometer, g,
T_i = observed temperature of water, °C, and
T_x = any other desired temperature, °C.

NOTE 4—This method provides a procedure that is most convenient for laboratories making many determinations with the same pycnometer. It is equally applicable to a single determination. Bringing the pycnometer and contents to some designated temperature when weights W'_a and W'_b are taken, requires considerable time. It is much more convenient to prepare a table of weights W'_a for various temperatures likely to prevail when weights W_b are taken. It is important that weights W'_a and W'_b be based on water at the same temperature. Values for the relative density of water at temperatures from 18 to 30°C are given in Table 1.

7. Sampling

7.1 The soil to be used in specific gravity test may contain its natural moisture or be oven-dried. The weight of the test sample on an oven-dry basis shall be at least 25 g when the volumetric flask is to be used, and at least 10 g when the stoppered bottle is to be used.

7.2 *Samples Containing Natural Moisture*—When the sample contains its natural moisture, the weight of the soil, W_o, on an oven-dry basis shall be determined at the end of the test by evaporating the water in an oven maintained at 230 ±9°F (110 ±5°C) (Note 5). Samples of clay soils containing their natural moisture content shall be dispersed in distilled water before placing in the flask, using the dispersing equipment specified in Method D 422 (Note 6).

7.3 *Oven-Dried Samples*—When an oven-dried sample is to be used, the sample shall be dried for at least 12 h, or to constant weight, in an oven maintained at 230 ±9°F (110 ±5°C) (Note 5), cooled in a desiccator, and weighed upon removal from the desiccator. The sample shall then be soaked in distilled water for at least 12 h.

NOTE 5—Drying of certain soils at 110°C may bring about loss of moisture of composition or hydration, and in such cases drying shall be done, if desired, in reduced air pressure and at a lower temperature.

NOTE 6—The minimum volume of slurry that can be prepared by the dispersing equipment specified in Method D 422 is such that a 500-mL flask is needed as the pycnometer.

TABLE 1 Relative Density of Water and Conversion Factor K For Various Temperatures

Temperature, °C	Relative Density of Water	Correction Factor K
18	0.9986244	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977
30	0.9956780	0.9974

8. Procedure

8.1 Place the sample in the pycnometer, taking care not to lose any of the soil in case the weight of the sample has been determined. Add distilled water to fill the volumetric flask about three-fourths full or the stoppered bottle about half full.

8.2 Remove entrapped air by either of the following methods: (1) subject the contents to a partial vacuum (air pressure not exceeding 100 mm Hg) or (2) boil gently for at least 10 min while occasionally rolling the pycnometer to assist in the removal of the air. Subject the contents to reduced air pressure either by connecting the pycnometer directly to an aspirator or vacuum pump, or by use of a bell jar. Some soils boil violently when subjected to reduced air pressure. It will be necessary in those cases to reduce the air pressure at a slower rate or to use a larger flask. Cool samples that are heated to room temperature.

8.3 Fill the pycnometer with distilled water, clean the outside and dry with a clean, dry cloth. Determine the weight of the pycnometer and contents, W_b, and the temperature in degrees Celsius, T_x, of the contents as described in Section 6.

9. Calculation and Report

9.1 Calculate the specific gravity of the soil, based on water at a temperature T_x, as follows:

$$\text{Specific gravity, } G \text{ at } T_x = W_o / [W_o + (W_a - W_b)]$$

where:

W_o = weight of sample of oven-dry soil, g,
W_a = weight of pycnometer filled with water at temperature T_x (Note 7), g,
W_b = weight of pycnometer filled with water and soil at temperature T_x, g, and
T_x = temperature of the contents of the pycnometer when weight W_b was determined, °C.

NOTE 7—This value shall be taken from the table of values of W_a, prepared in accordance with 6.2, for the temperature prevailing when weight W_b was taken.

9.2 Unless otherwise required, specific gravity values reported shall be based on water at 20°C. The value based on water at 20°C shall be calculated from the value based on water at the observed temperature T_x, as follows:

$$\text{Specific gravity, } G \text{ at } 20°C = (K) \times (\text{specific gravity, } G \text{ at } T_x)$$

where:

K = a number found by dividing the relative density of water at temperature T_x by the relative density of water at 20°C. Values for a range of temperatures are given in Table 1.

9.3 When it is desired to report the specific gravity value based on water at 4°C, such a specific gravity value may be calculated by multiplying the specific gravity value at temperature T_x by the relative density of water at temperature T_x.

9.4 When any portion of the original sample of soil is eliminated in the preparation of the test sample, the portion on which the test has been made shall be reported.

10. Precision and Bias

10.1 Criteria for judging the acceptability of specific gravity test results obtained by this test method on material passing the No. 4 (4.75-mm) sieve are given as follows (Note 8):

Material and Type Index	Standard Deviation[A]	Acceptable Range of Two Results (percent of mean)[A]
Single-operator precision		
Cohesive soils	0.021	0.06
Noncohesive soils	[B]	[B]
Multilaboratory precision		
Cohesive soils	0.056	0.16
Noncohesive soils	[B]	[B]

[A] These numbers represent, respectively, the (1S) and (D2S) limits as described in Practice C 670.

[B] Criteria for assigning standard deviation values for non-cohesive soils are not available at the present time.

10.2 *Bias*—There is no accepted reference value for this test method, therefore bias cannot be determined.

NOTE 8—The figures given in Column 2 are the standard deviations that have been found to be appropriate for the materials described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

11. Keywords

11.1 specific gravity

Standard Test Method for Amount of Material in Soils Finer Than the No. 200 (75-μm) Sieve[1]

This standard is issued under the fixed designation D 1140; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

[ε1] Note—Editorial changes were made throughout in September 1990.

1. Scope

1.1 This test method covers determination of the total amount of material in soils finer than the No. 200 (75-μm) sieve.

2. Referenced Documents

2.1 *ASTM Standards:*

D 422 Method for Particle-Size Analysis of Soils[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Apparatus

3.1 *Sieves*—A nest of two sieves, the lower being a No. 200 (75-μm) sieve and the upper a No. 40 (425-μm) sieve, both conforming to ASTM Specification E 11.

3.2 *Containers*—A pan or vessel of sufficient size to contain the test sample covered with water and to permit vigorous agitation without advertent loss of any part of the sample, and a second pan or container for use in drying the test sample after washing.

4. Test Sample

4.1 The test sample shall be selected from material that has been thoroughly mixed. A representative sample, sufficient to yield not less than the approximate weight of dried material shown in the following table, shall be selected using a sample splitter or by the method of quartering:

Nominal Diameter of Largest Particle, in.	Approximate Minimum Weight of Sample, g
0.0787 (No. 10 sieve) (2.0 mm)	200
0.187 (No. 4 sieve) (4.75 mm)	500
¾ (19.0 mm)	1500
1 (25.0 mm)	2000
1½ or over (37.5 mm)	2500

5. Procedure

5.1 Dry the test sample to a constant weight at a temperature not exceeding 230 ± 9 F (110 ± 5 C) and weigh to the nearest 0.05 percent, or alternatively, weigh the test sample moist and use an auxiliary moisture content sample to determine the moisture content of the sample. The weight of the moisture content sample shall be between 20 and 30 percent of the weight of the test sample. Calculate the oven-dry weight of the test sample from the moist weight and the moisture content.

5.2 Place the test sample in the container, add sufficient clean water to cover it, and allow to soak a minimum of 2 h (preferably overnight).

5.3 Agitate the contents of the container vigorously and pour the wash water immediately over the nested sieves, arranged with the coarser sieve on top. Repeat the process of adding clear water to the container to cover the sample, agitating the contents of the container, and pouring the wash water over the nested sieves until the wash water is clear. When the total sample is small, the entire contents of the soaking container may be transferred to the nested sieves after the first washing and the washing operation completed in accordance with 5.4. The wash water need not be saved.

Note 1—The percentage value secured at the end of the test may not be correct (being too low) for soils containing relatively high percentages of the minus 200 fraction. This appears to be due chiefly to inadequate agitation. When it is desired to secure the exact percentage for the minus 200 fraction for such a soil, the portion of the sample passing the No. 40 sieve and retained on the No. 200 sieve secured in the washing operation, shall be transferred to the dispersion cup of the stirring apparatus used in Method D 422. The cup filled half full with water and the contents agitated for 1 min. After this agitation the contents of the cup shall be transferred to the nested sieves and washing continued.

If the stirring apparatus has not been used prior to the drying of the portion of the sample larger than the No. 200 (75-μm) sieve, and it is desired to do so after drying, the dried material shall be separated on the No. 40 (425-μm) sieve; the portion retained shall be saved; and the portion passing shall be placed in the dispersion cup with water and agitated for 1 min with the stirring apparatus as previously described. The contents of the cup shall be transferred to the No. 200 sieve, washed, and dried. The revised total weight retained on the No. 200 sieve shall be secured by combining and weighing the two fractions.

5.4 Transfer the sample to the nested sieves and wash with running water (Note 2). When the sample is larger than can be handled at one time on the nested sieves, wash a portion of the sample and transfer to the container in which it is to be dried.

Note 2—Tapping of sieves has been found to expedite the washing operations.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved Sept. 15, 1954. Originally issued 1950. Replaces D 1140 – 50 T.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vols 04.01, 04.02, 04.06, 05.05, and 14.02.

5.5 Dry the washed material retained on the nested sieves in a container to a constant weight at a temperature not exceeding 230 ± 9 F (110 ± 5 C) and dry-sieve it on the nested sieves (Note 3). Weigh the dry material retained on the nested sieves to the nearest 0.05 percent.

NOTE 3—Some material passes the No. 200 (75-µm) sieve on dry sieving that did not pass during the washing operation. When desired, a sieve analysis may be made on the portion of the sample retained on the No. 200 sieve, in accordance with Method D 422.

6. Calculation

6.1 Calculate the results as follows:

$$P = [(W'_o - W'_t)/W'_o] \times 100$$

where:

P = percentage of material finer than No. 200 (75-µm) sieve.

W'_o = weight of original sample on an oven-dry basis, g and

W'_t = oven-dry weight of sample after washing and dry-sieving, g.

7. Keywords

7.1 grain-size; No. 200 sieve; particle-size; sieve analysis

Designation: D 1452 – 80 (Reapproved 1990)[ε1]

Standard Practice for Soil Investigation and Sampling by Auger Borings[1]

This standard is issued under the fixed designation D 1452; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

[ε1] NOTE—Section 6 was added editorially in July 1990.

1. Scope

1.1 This practice covers equipment and procedures for the use of earth augers in shallow geotechnical exploration. This practice does not apply to sectional continuous flight augers.

1.2 *This standard does not purport to address the safety problems 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.*

2. Significance and Use

2.1 Auger borings often provide the simplest method of soil investigation and sampling. They may be used for any purpose where disturbed samples can be used and are valuable in connection with ground water level determination and indication of changes in strata and advancement of hole for spoon and tube sampling. Equipment required is simple and readily available. Depths of auger investigations are, however, limited by ground water conditions, soil characteristics, and the equipment used.

3. Apparatus

3.1 *Hand-Operated Augers*

3.1.1 *Helical Augers*—Small lightweight augers generally available in sizes from 1 through 3 in. (25.4 through 76.2 mm).

3.1.1.1 *Spiral-Type Auger*, consisting of a flat thin metal strip, machine twisted to a spiral configuration of uniform pitch; having at one end, a sharpened or hardened point, with a means of attaching a shaft or extension at the opposite end.

3.1.1.2 *Ship-Type Auger*—Similar to a carpenter's wood bit. It is generally forged from steel and machined to the desired size and configuration. It is normally provided with sharpened and hardened nibs at the point end and with an integral shaft extending through its length for attachment of a handle or extension at the opposite end.

3.1.2 *Open Tubular Augers*, ranging in size from 1.5 through 8 in. (38.1 through 203.2 mm) and having the common characteristic of appearing essentially tubular when viewed from the digging end.

3.1.2.1 *Orchard-Barrel Type*, consisting essentially of a tube having cutting lips or nibs hardened and sharpened to penetrate the formation on one end and an adaptor fitting for an extension or handle on the opposite end.

3.1.2.2 *Open-Spiral Type*, consisting of a flat thin metal strip that has been helically wound around a circular mandrel to form a spiral in which the flat faces of the strip are parallel to the axis of the augered hole. The lower helix edges are hard-faced to improve wear characteristics. The opposite end is fitted with an adaptor for extension.

3.1.2.3 *Closed-Spiral Type*—Nearly identical to the open-spiral type except, the pitch of the helically wound spiral is much less than that of the open-spiral type.

3.1.3 *Post-Hole Augers*, generally 2 through 8 in. (50.8 through 203.2 mm), and having in common a means of blocking the escape of soil from the auger.

3.1.3.1 *Clam-Shell Type*, consisting of two halves, hinged to allow opening and closing for alternately digging and retrieving. It is not usable deeper than about 3.5 ft (1.07 m).

3.1.3.2 *Iwan Type*, consisting of two tubular steel segments, connected at the top to a common member to form a nearly complete tube, but with diametrically opposed openings. It is connected at the bottom by two radial blades pitched to serve as cutters which also block the escape of contained soil. Attachment of handle or extension is at the top connector.

3.2 *Machine-Operated Augers*:

3.2.1 *Helical Augers*, generally 8 through 48 in. (203.2 through 1219 mm), consisting essentially of a center shaft fitted with a shank or socket for application of power, and having one to three complete 360° (6.28-rad) spirals for conveyance and storage of cut soil. Cutter bits and pilot bits are available in moderate and hard formation types and normally replaceable in the field. They are normally operated by heavy-duty, high-torque machines, designed for heavy construction work.

3.2.2 *Stinger Augers*, generally 6 through 30 in. (152.4 through 762 mm), are similar to the helical auger in 3.2.1, but lighter and generally smaller. They are commonly operated by light-duty machines for post and power pole holes.

3.2.3 *Disk Augers*, generally 10 through 30 in. (254 through 762 mm), consisting essentially of a flat, steel disk with diametrically opposed segments removed and having a

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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shank or socket located centrally for application of power. Replaceable cutter bits, located downward from the leading e[illegible] of the remaining disk, dig and load soil that is held on the disk by valves or shutters hinged at the disk in order to close the removed segments. The disk auger is specifically designed to be operated by machines having limited vertical clearance between spindle and ground surface.

3.2.4 *Bucket Auger*, generally 12 through 48 in. (304.8 through 1219 mm), consisting essentially of a disk auger, without shank or socket, but hinge-mounted to the bottom of a steel tube or bucket of approximately the same diameter as the disk auger. A socket or shank for power application is located in the top center of the bucket diametral cross piece provided for the purpose.

3.3 *Casing* (when needed), consisting of pipe of slightly larger diameter than the auger used.

3.4 *Accessory Equipment*—Labels, field log sheets, sample jars, sealing wax, sample bags, and other necessary tools and supplies.

4. Procedure

4.1 Make the auger boring by rotating and advancing the desired distance into the soil. Withdraw the auger from the hole and remove the soil for examination and test. Return the empty auger to the hole and repeat the procedure. Continue the sequence until the required depth is reached.

4.2 Casing is required in unstable soil in which the bore hole fails to stay open and especially when the boring is extended below the ground-water level. The inside diameter of the casing must be slightly larger than the diameter of the [illegible] used. The casing shall be driven to a depth not greater than the top of the next sample and shall be cleaned out by means of the auger. The auger can then be inserted into the bore hole and turned below the bottom of the casing to obtain a sample.

4.3 The soil auger can be used both for boring the hole and for bringing up disturbed samples of the soil encountered. The structure of a cohesive soil is completely destroyed and the moisture may be changed by the auger. Seal all samples in a jar or other airtight container and label appropriately. If more than one type of soil is picked up in the sample, prepare a separate container for each type of soil.

4.4 *Field Observations*—Record complete ground water information in the field logs. Where casing is used, measure ground water levels, both before and after the casing is pulled. In sands, determine the water level at least 30 min after the boring is completed; in silts, at least 24 h. In clays, no accurate water level determination is possible unless pervious seams are present. As a precaution, however, water levels in clays shall be taken after at least 24 h.

5. Report

5.1 The data obtained in boring shall be recorded in the field logs and shall include the following:

5.1.1 Date of start and completion of boring,

5.1.2 Identifying number of boring,

5.1.3 Reference datum including direction and distance of boring relative to reference line of project or other suitable reference points,

5.1.4 Type and size of auger used in boring,

5.1.5 Depth of changes in strata,

5.1.6 Description of soil in each major stratum,

5.1.7 Ground water elevation and location of seepage zones, when found, and

5.1.8 Condition of augered hole upon removal of auger, that is, whether the hole remains open or the sides cave, when such can be observed.

6. Keywords

Auger borings; sampling; soil investigations

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Designation: D 1557 – 78 (Reapproved 1990)[ε1]

An American National Standard

Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop[1]

This standard is issued under the fixed designation D 1557; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

[ε1] Note—Section 10 was added editorially in September 1990.

1. Scope

1.1 These laboratory compaction methods cover the determination of the relationship between the moisture content and density of soils and soil-aggregate mixtures (Note 1) when compacted in a mold of a given size with a 10-lb (4.54-kg) rammer dropped from a height of 18 in. (457 mm) (Note 2). Four alternative procedures are provided as follows:

1.1.1 *Method A*—A 4-in. (101.6-mm) mold: material passing a No. 4 (4.75-mm) sieve;

1.1.2 *Method B*—A 6-in. (152.4-mm) mold: material passing a No. 4 (4.75-mm) sieve;

1.1.3 *Method C*—A 6-in. (152.4-mm) mold: material passing a ¾-in. (19.0-mm) sieve; and

1.1.4 *Method D*—A 6-in. (152.4-mm) mold: material passing a ¾-in. (19.0-mm) sieve, corrected by replacement for material retained on a ¾-in. sieve.

Note 1—Soils and soil-aggregate mixtures should be regarded as natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

Note 2—These laboratory compaction test methods when used on soils and soil-aggregates which are not free-draining will, in most cases, establish a well-defined optimum moisture content and maximum density (see Section 7). However, for free-draining soils and soil-aggregate mixtures, these methods will not, in many cases, produce a well-defined moisture-density relationship and the maximum density obtained will generally be less than that obtained by vibratory methods.

1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Section 5 shall govern.

1.3 *This standard does not purport to address the safety problems 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]

D 854 Test Method for Specific Gravity of Soils

D 2168 Test Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[3]

D 2487 Test Method for Classification of Soils for Engineering Purposes[3]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Apparatus

3.1 *Molds*—The molds shall be cylindrical in shape, made of rigid metal and be within the capacity and dimensions indicated in 3.1.1 or 3.1.2. The molds may be the "split" type, consisting either of two half-round sections, or a section of pipe split along one element, which can be securely locked together to form a cylinder meeting the requirements of this section. The molds may also be the "taper" type, providing the internal diameter taper is uniform and is not more than 0.200 in./linear ft (16.7 mm/linear m) of mold height. Each mold shall have a base plate assembly and an extension collar assembly, both made of rigid metal and constructed so they can be securely attached to or detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2 in. (50 mm) which may include an upper section that flares out to form a funnel providing there is at least a ¾-in. (19-mm) straight cylindrical section beneath it.

3.1.1 *Mold*, 4.0 in. (101.6 mm) in diameter, having a capacity of 1/30 ± 0.0004 ft³ (944 ± 11 cm³) and conforming to Fig. 1.

[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved April 27, 1978. Published July 1978. Originally published as D 1557 – 58 T. Last previous edition D 1557 – 70.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vols 04.01, 04.06, and 14.02.

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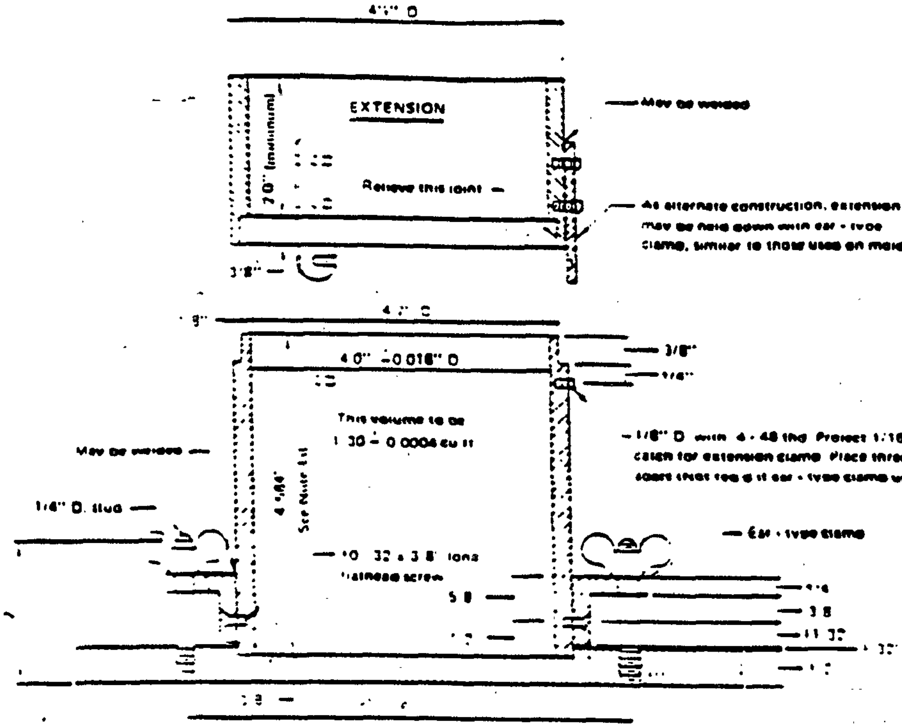
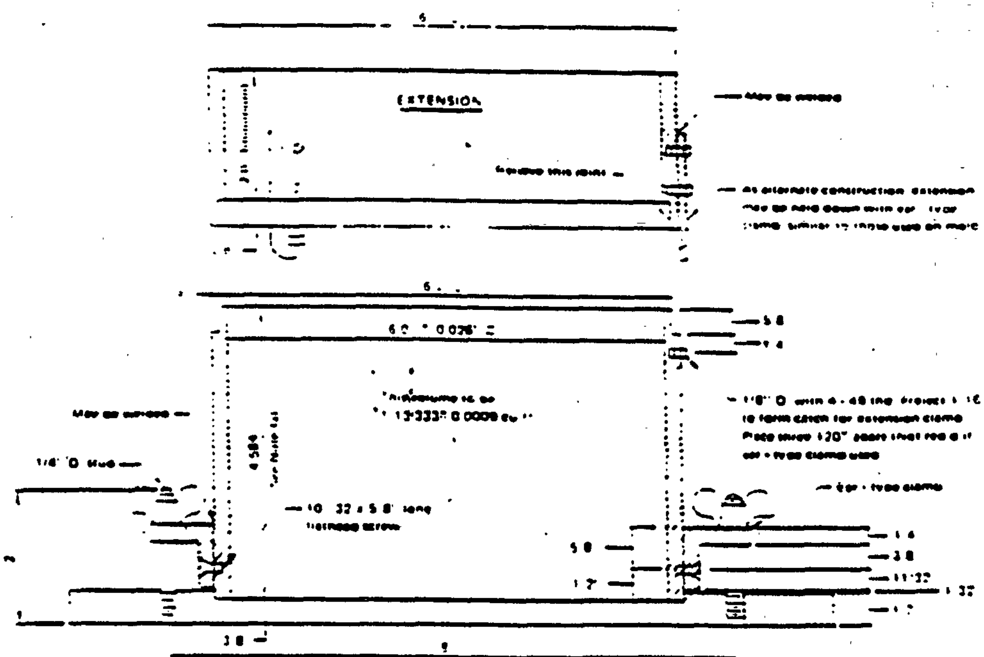


NOTE 1—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE 2—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable providing the attachments are equally as rigid as those shown.

FIG. 1 Cylindrical Mold, 4.0-in. for Soil Tests (see Table 4 for metric equivalents)



NOTE 1—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE 2—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable providing the attachments are equally as rigid as those shown.

FIG. 2 Cylindrical Mold, 6.0-in. for Soil Tests (see Table 4 for metric equivalents)

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3.1.2 *Mold*, 6.0 in. (152.4 mm) in diameter, having a capacity of 1/13.333 = 0.0009 ft³ (2124 ± 25 cm³) and conforming to Fig. 2.

3.1.3 The average internal diameter, height, and volume of each mold shall be determined before initial use and at intervals not exceeding 1000 times the mold is filled. The mold volume shall be calculated from the average of at least six internal diameter and three height measurements made to the nearest 0.001 in. (0.02 mm), or from the amount of water required to completely fill the mold, corrected for temperature variance in accordance with Table 1. If the average internal diameter and volume are not within the tolerances shown in Figs. 1 or 2, the mold shall not be used. The determined volume shall be used in computing the required densities.

3.2 *Rammer*—The rammer may be either manually operated (see 3.2.1) or mechanically operated (see 3.2.2). The rammer shall fall freely through a distance of 18.0 ± 1/16 in. (457.2 ± 1.6 mm) from the surface of the specimen. The manufactured weight of the rammer shall be 10.00 ± 0.02 lb (4.54 ± 0.01 kg). The specimen contact face shall be flat.

3.2.1 *Manual Rammer*—The specimen contact face shall be circular with a diameter of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). The rammer shall be equipped with a guidesleeve which shall provide sufficient clearance so that the free fall of the rammer shaft and head will not be restricted. The guidesleeve shall have four vent holes at each end (eight holes total) located with centers 3/4 ± 1/16 in. (19.0 ± 1.6 mm) from each end and spaced 90° apart. The minimum diameter of the vent holes shall be 3/8 in. (9.5 mm).

3.2.2 *Mechanical Rammer*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03 in. (2.5 ± 0.8 mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. When used with the 4.0-in. (101.6-mm) mold, the specimen contact face shall be circular with a diameter of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). When used with the 6.0-in. (152.4-mm) mold, the specimen contact face shall have the shape of a section of a circle of a radius equal to 2.90 ± 0.02 in. (73.7 ± 0.5 mm). The sector face rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen. The mechanical rammer shall be calibrated and adjusted, as necessary, in accordance with 3.2.3.

3.2.3 *Calibration and Adjustment*—The mechanical rammer shall be calibrated, and adjusted as necessary, before initial use; near the end of each period during which the mold was filled 1000 times; before reuse after anything, including repairs, which may affect the test results significantly; and whenever the test results are questionable. Each calibration and adjustment shall be in accordance with Test Methods D 2168.

3.3 *Sample Extruder* (optional)—A jack, frame, or other device adapted for the purpose of extruding compacted specimens from the mold.

3.4 *Balances*—A balance or scale of at least 20-kg capacity sensitive to ±1 g and a balance of at least 1000-g capacity sensitive to ±0.01 g.

3.5 *Drying Oven*, thermostatically-controlled, preferably of the forced-draft type, capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C) for determining the moisture content of the compacted specimen.

3.6 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10 in. (254 mm). The scraping edge shall have a straightness tolerance of ±0.005 in. (±0.13 mm) and shall be beveled if it is thicker than 1/8 in. (3 mm).

3.7 *Sieves*, 3-in. (75-mm), 3/4-in. (19.0-mm), and No. 4 (4.75-mm), conforming to the requirements of Specification E 11.

3.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

TABLE 1 Volume of Water per Gram based on Temperature[A]

Temperature, °C (°F)	Volume of Water, mL/g
12 (53.6)	1.00048
14 (57.2)	1.00073
16 (60.8)	1.00103
18 (64.4)	1.00138
20 (68.0)	1.00177
22 (71.6)	1.00221
24 (75.2)	1.00268
26 (78.8)	1.00320
28 (82.4)	1.00375
30 (86.0)	1.00435
32 (89.6)	1.00497

[A] Values other than shown may be obtained by referring to the *Handbook of Chemistry and Physics*.

4. Procedure

4.1 *Specimen Preparation*—Select a representative portion of quantity adequate to provide, after sieving, an amount of material weighing as follows: Methods A—25 lb (11 kg); Methods B, C, and D—50 lb (23 kg). Prepare specimens in accordance with either 4.1.1 through 4.1.3 or 4.1.4.

4.1.1 *Dry Preparation Procedure*—If the sample is too damp to be friable, reduce the moisture content by drying until the material is friable; see 4.1.2. Drying may be in air or by the use of a drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). After drying (if required), thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the particles. Pass the material through the specified sieve as follows: Methods A and B—No. 4 (4.75-mm); Methods C and D—3/4-in. (19.0-mm). Correct for oversize material in accordance with Section 5, if Method D is specified.

4.1.2 Whenever practicable, soils classified as ML, CL, OL, GC, SC, MH, CH, OH and PT by Test Method D 2487 shall be prepared in accordance with 4.1.4.

4.1.3 Prepare a series of at least four specimens by adding increasing amounts of water to each sample so that the moisture contents vary by approximately 1 1/2 %. The moisture contents selected shall bracket the optimum moisture content, thus providing specimens which, when compacted, will increase in mass to the maximum density and then decrease in density (see 7.2 and 7.3). Thoroughly mix each

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TABLE 2 Dry Preparation Method—Standing Times

Classification D 2487	Minimum Standing Time, h
GW, GP, SW, SP	no requirement
GM, SM	3
ML, CL, OL, GC, SC	18
MH, CH, OH, PT	36

TABLE 3 Precision

	Standard Deviation, s	Acceptable Range of Two Results, Expressed as Percent of Mean Value[A]
Single-operator precision:		
Maximum density		1.9
Optimum moisture content		9.5
Multilaboratory precision:		
Maximum density	±1.66	4.0
Optimum moisture content	±0.86	15.0

[A] This column indicates a limiting range of values which should not be exceeded by the difference between any two results, expressed as a percentage of the average value. In cooperative test programs it has been determined that 95 % of the tests do not exceed the limiting acceptable ranges shown below. All values shown in this table are based on average test results from a variety of different soils and are subject to future revision.

TABLE 4 Metric Equivalents for Figs. 1 and 2

in.	mm
0.016	0.41
0.026	0.66
1/32	0.8
1/16	1.6
1/8	3.2
1/4	6.4
11/32	8.7
3/8	9.5
1/2	12.7
5/8	15.9
2	50.8
2 1/2	63.5
4	101.6
4 1/4	108.0
4 1/2	114.3
4.584	116.43
6	152.4
6 1/2	165.1
8	203.2
ft³	**cm³**
1/30	944
0.0004†	11
1/13.333	2124
0.0009	25

† Editorially corrected.

specimen to ensure even distribution of moisture throughout and then place in a separate covered container and allow to stand prior to compaction in accordance with Table 2. For the purpose of selecting a standing time, it is not required to perform the actual classification procedures described in Test Method D 2487 (except in the case of referee testing), if previous data exist which provide a basis for classifying the sample.

4.1.4 *Moist Preparation Method*—The following alternate procedure is recommended for soils classified as ML, CL, OL, GC, SC, MH, CH, OH and PT by Test Method D 2487. Without previously drying the sample, pass it through the ¾-in. (19.0-mm) and No. 4 (4.75-mm) sieves. Correct for oversize material in accordance with Section 5, if Method D is specified. Prepare a series of at least four specimens having moisture contents that vary by approximately 1½ %. The moisture contents selected shall bracket the optimum moisture content, thus providing specimens which, when compacted, will increase in mass to the maximum density and then decrease in density (see 7.2 and 7.3). To obtain the appropriate moisture content of each specimen, the addition of a predetermined amount of water (see 4.1.3) or the removal of a predetermined amount of moisture by drying may be necessary. Drying may be in air or by the use of a drying apparatus such that the temperature of the specimen does not exceed 140°F (60°C). The prepared specimens shall then be thoroughly mixed and stand, as specified in 4.1.3 and Table 2, prior to compaction.

NOTE 3—With practice, it is usually possible to visually judge the point of optimum moisture closely enough so that the prepared specimens will bracket the point of optimum moisture content.

4.2 *Specimen Compaction*—Select the proper compaction mold, in accordance with the method being used, and attach the mold extension collar. Compact each specimen in five layers of approximately equal height. Each layer shall receive 25 blows in the case of the 4-in. (101.6-mm) mold; each layer shall receive 56 blows in the case of the 6-in. (152.4-mm) mold. The total amount of material used shall be such that the fifth compacted layer is slightly above the top of the mold, but not exceeding ¼ in. (6 mm). During compaction the mold shall rest on a uniform rigid foundation, such as provided by a cylinder or cube of concrete weighing not less than 200 lb (91 kg).

4.2.1 In operating the manual rammer, care shall be taken to avoid rebound of the rammer from the top end of the guidesleeve. The guidesleeve shall be held steady and within 5 deg of the vertical. The blows shall be applied at a uniform rate not exceeding approximately 1.4 s per blow and in such a manner as to provide complete and uniform coverage of the specimen surface.

4.2.2 *Mold Sizes*—The mold size used shall be as follows: Method A, 4-in. (101.6-mm); Methods B, C, and D, 6-in. (152.4-mm).

4.2.3 Following compaction, remove the extension collar; carefully trim the compacted specimen even with the top of the mold by means of the straightedge and determine the mass of the specimen. Divide the mass of the compacted specimen and mold, minus the mass of the mold, by the volume of the mold (see 3.1.3). Record the result as the wet density, γ_m, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen.

4.2.4 Remove the material from the mold. Determine moisture content in accordance with Method D 2216, using either the whole compacted specimen or alternatively a representative specimen of the whole specimen. The whole specimen must be used when the permeability of the compacted specimen is high enough so that the moisture content is not distributed uniformly throughout. If the whole specimen is used, break it up to facilitate drying. Obtain the representative specimen by slicing the compacted specimen axially through the center and removing 100 to 500 g of material from one of the cut faces.

4.2.5 Repeat 4.2 through 4.2.4 for each specimen prepared.

5. Oversize Corrections

5.1 If 30 % or more of the sample is retained on a ¾-in. (19.0-mm) sieve, then none of the methods described under these methods shall be used for the determination of either maximum density or optimum moisture content.

5.2 *Methods A and B*—The material retained on the No. 4 (4.75-mm) sieve is discarded and no oversize correction is made. However, it is recommended that if the amount of material retained is 7 % or greater, Method C be used instead.

5.3 *Method C*—The material retained on the ¾-in. (19.0-mm) sieve is discarded and no oversize correction is made. However, if the amount of material retained is 10 % or greater, it is recommended that Method D be used instead.

5.4 *Method D:*

5.4.1 This method shall not be used unless the amount of material retained on the ¾-in. (19.0-mm) sieve is 10 % or greater. When the amount of material retained on the ¾-in. sieve is less than 10 %, use Method C.

5.4.2 Pass the material retained on the ¾-in. (19.0-mm) sieve through a 3-in. or 75-mm sieve. Discard the material retained on the 3-in. sieve. The material passing the 3-in. sieve and retained on the ¾-in. sieve shall be replaced with an equal amount of material passing a ¾-in. sieve and retained on a No. 4 (4.75-mm) sieve. The material for replacement shall be taken from an unused portion of the sample.

6. Calculations

6.1 Calculate the moisture content and the dry density of each compacted specimen as follows:

$$w = [(A - B)/(B - C)] \times 100$$

and

$$\gamma_d = [\gamma_m/(w + 100)] \times 100$$

where:

w = moisture content in percent of the compacted specimens,

A = mass of container and moist specimen,

B = mass of container and oven-dried specimen,

C = mass of container,

γ_d = dry density, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen, and

γ_m = wet density, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen.

7. Moisture-Density Relationship

7.1 From the data obtained in 6.1, plot the dry density values as ordinates with corresponding moisture contents as abscissas. Draw a smooth curve connecting the plotted points. Also draw a curve termed the "curve of complete saturation" or "zero air voids curve" on this plot. This curve represents the relationship between dry density and corresponding moisture contents when the voids are completely filled with water. Values of dry density and corresponding moisture contents for plotting the curve of complete saturation can be computed using the following equation:

$$w_{sat} = [(62.4/\gamma_d) - (1/G_s)] \times 100$$

where:

w_{sat} = moisture content in percent for complete saturation,

γ_d = dry density in pounds per cubic foot (or kilograms per cubic metre),

G_s = specific gravity of the material being tested (see Note 4), and

62.4 = density of water in pounds per cubic foot (or kilograms per cubic metre).

NOTE 4—The specific gravity of the material can either be assumed or based on the weighted average values of: (a) the specific gravity of the material passing the No. 4 (4.75-mm) sieve in accordance with Test Method D 854; and (b) the apparent specific gravity of the material retained on the No. 4 (4.75-mm) sieve in accordance with Test Method C 127.

7.2 *Optimum Moisture Content*, w—The moisture content corresponding to the peak of the curve drawn as directed in 7.1 shall be termed the "optimum moisture content."

7.3 *Maximum Density*, γ_{max}—The dry density in pounds per cubic foot (or kilograms per cubic metre) of the sample at "optimum moisture content" shall be termed "maximum density."

8. Report

8.1 The report shall include the following:

8.1.1 Method used (Method A, B, C, or D),

8.1.2 Optimum moisture content,

8.1.3 Maximum density,

8.1.4 Description of rammer (whether manual or mechanical),

8.1.5 Description of appearance of material used in test, based on Practice D 2488 (Test Method D 2487 may be used as an alternative),

8.1.6 Origin of material used in test,

8.1.7 Preparation procedure used (moist or dry).

9. Precision

9.1 Criteria for judging the acceptability of the maximum density and optimum moisture content test results are given in Table 3. The standard deviation s is calculated from the equation:

$$s^2 = \frac{1}{n - 1}\sum (x - \bar{x})^2$$

where:

n = number of determinations,

x = individual value of each determination, and

$\bar{x}$ = numerical average of the determinations.

9.2 Criteria for assigning standard deviation values for single-operator precision are not available at the present time.

10. Keywords

10.1 maximum dry density; modified proctor test; moisture-density; optimum moisture content; optimum water content; proctor test

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Designation: D 1586 – 84

Standard Method for Penetration Test and Split-Barrel Sampling of Soils[1]

This standard is issued under the fixed designation D 1586; 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.

This method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.9 *ΔN*—the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earthworks and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in

[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

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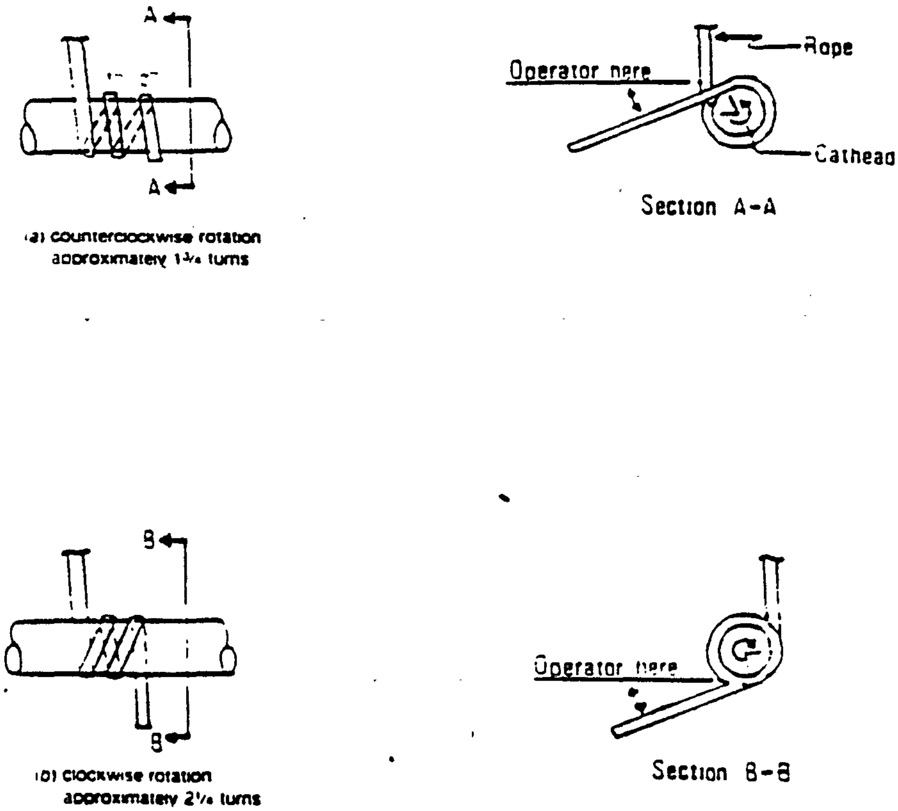


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the N-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 2—Both theory and available test data suggest that N-values may increase between 10 to 30 % when liners are used.

5.4 *Drive-Weight Assembly*:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

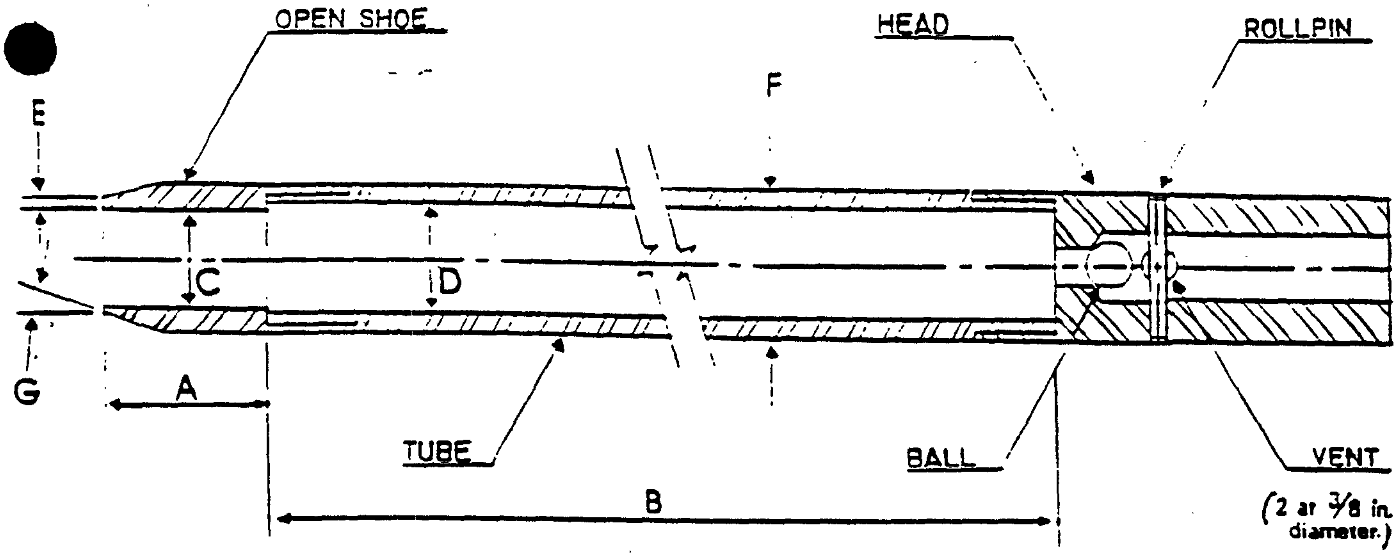
NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

mittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring [for] subsequent insertion of the sampler solely by means of [previ]ous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

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7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "N-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job.

8.1.2 Names of crew.

8.1.3 Type and make of drilling machine.

8.1.4 Weather conditions.

8.1.5 Date and time of start and finish of boring.

8.1.6 Boring number and location (station and coordinates, if available and applicable).

8.1.7 Surface elevation, if available.

8.1.8 Method of advancing and cleaning the boring.

8.1.9 Method of keeping boring open.

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made.

8.1.11 Location of strata changes.

8.1.12 Size of casing, depth of cased portion of boring.

8.1.13 Equipment and method of driving sampler.

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners).

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number.

8.2.2 Description of soil.

8.2.3 Strata changes within sample.

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 Variations in N-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, N-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.2 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in N-values obtained between operator-drill rig systems.

9.3 The variability in N-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting N on the basis of comparative energies. A method for energy measurement and N-value adjustment is currently under development.

AR305425

Designation: D 2166 – 85[ε1]

Standard Test Method for Unconfined Compressive Strength of Cohesive Soil[1]

This standard is issued under the fixed designation D 2166; 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.

ε1 NOTE—Section 11 was added editorially in January 1991.

1. Scope

1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition, using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel bleed water (water expelled from the soil due to deformation or compaction) during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved materials, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compression strength values.

NOTE 1—The determination of the unconsolidated, undrained strength of cohesive soils with lateral confinement is covered by Test Method D 2850.

1.4 This test method is not a substitute for Test Method D 2850.

1.5 The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 422 Method for Particle-Size Analysis of Soils[2]
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
D 854 Test Method for Specific Gravity of Soils[2]
D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]
D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]
D 2487 Test Method for Classification of Soils for Engineering Purposes[2]
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]
D 2850 Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression[2]
D 4220 Practices for Preserving and Transporting Soil Samples[2]
D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 *Descriptions of Terms Specific to this Standard:*

3.2.1 *unconfined compressive strength* (q_u)—the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test method unconfined compressive strength is taken as the maximum load attained per unit area or the load per unit area at 15 % axial strain, whichever is secured first during the performance of a test.

3.2.2 *shear strength* (s_u)—for unconfined compressive strength test specimens, the shear strength is calculated to be ½ of the compressive stress at failure, as defined in 3.2.1.

4. Significance and Use

4.1 The primary purpose of the unconfined compression test is to quickly obtain the approximate compressive strength of soils that possess sufficient cohesion to permit testing in the unconfined state.

4.2 Samples of soils having slickensided or fissured structure, samples of some types of loess, very soft clays, dry and crumbly soils and varved materials, or samples containing significant portions of silt or sand, or both (all of which usually exhibit cohesive properties), frequently display higher shear strengths when tested in accordance with Test Method D 2850. Also, unsaturated soils will usually exhibit different shear strengths when tested in accordance with Test Method D 2850.

4.3 If both an undisturbed and a remolded test are performed on the same sample, the sensitivity of the material can be determined. This method of determining sensitivity is suitable only for soils that can retain a stable specimen shape in the remolded state.

NOTE 2—For soils that will not retain a stable shape, a vane shear test or Test Method D 2850 can be used to determine sensitivity.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Structural Properties of Soils.

Current edition approved July 26, 1985. Published September 1985. Originally published as D 2166 – 63T. Last previous edition D 2166 – 66 (1979)[ε1].

[2] *Annual Book of ASTM Standards*, Vol 04.08.

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5. Apparatus

5.1 *Compression Device*—The compression device may be a platform weighing scale equipped with a screw-jack-activated load yoke, a hydraulic loading device, or any other compression device with sufficient capacity and control to provide the rate of loading prescribed in 7.1. For soil with an unconfined compressive strength of less than 100 kPa (1.0 ton/ft²) the compression device shall be capable of measuring the compressive stress to within 1 kPa (0.01 ton/ft²). For soil with an unconfined compressive strength of 100 kPa (1.0 ton/ft²) or greater, the compression device shall be capable of measuring the compressive stress to the nearest 5 kPa (0.05 ton/ft²).

5.2 *Sample Extruder*, capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube, at a uniform rate, and with negligible disturbance of the sample. Conditions at the time of sample removal may dictate the direction of removal, but the principal concern is to keep the degree of disturbance negligible.

5.3 *Deformation Indicator*—The deformation indicator shall be a dial indicator graduated to 0.03 mm (0.001 in.) or better and having a travel range of at least 20 % of the length of the test specimen, or some other measuring device, such as an electronic deformation measuring device, meeting these requirements.

5.4 *Dial Comparator*, or other suitable device, for measuring the physical dimensions of the specimen to within 0.1 % of the measured dimension.

NOTE 3—Vernier calipers are not recommended for soft specimens, which will deform as the calipers are set on the specimen.

5.5 *Timer*—A timing device indicating the elapsed testing time to the nearest second shall be used for establishing the rate of strain application prescribed in 7.1.

5.6 *Balance*—The balance used to weigh specimens shall determine the mass of the specimen to within 0.1 % of its total mass.

5.7 *Equipment*, as specified in Method D 2216.

5.8 *Miscellaneous Apparatus*, including specimen trimming and carving tools, remolding apparatus, water content cans, and data sheets, as required.

6. Preparation of Test Specimens

6.1 *Specimen Size*—Specimens shall have a minimum diameter of 30 mm (1.3 in.) and the largest particle contained within the test specimen shall be smaller than one-tenth of the specimen diameter. For specimens having a diameter of 72 mm (2.8 in.) or larger, the largest particle size shall be smaller than one sixth of the specimen diameter. If, after completion of a test on an undisturbed specimen, it is found, based on visual observation, that larger particles than permitted are present, indicate this information in the remarks section of the report of test data (Note 4). The height-to-diameter ratio shall be between 2 and 2.5. Determine the average height and diameter of the test specimen using the apparatus specified in 5.4. Take a minimum of three height measurements (120° apart), and at least three diameter measurements at the quarter points of the height.

NOTE 4—If large soil particles are found in the sample after testing, a particle-size analysis performed in accordance with Method D 422 may be performed to confirm the visual observation and the results provided with the test report.

6.2 *Undisturbed Specimens*—Prepare undisturbed specimens from large undisturbed samples or from samples secured in accordance with Practice D 1587 and preserved and transported in accordance with the practices for Group C samples in Practices D 4220. Tube specimens may be tested without trimming except for the squaring of ends, if conditions of the sample justify this procedure. Handle specimens carefully to prevent disturbance, changes in cross section, or loss of water content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut it off in small sections to facilitate removal of the specimen without disturbance. Prepare carved specimens without disturbance, and whenever possible, in a humidity-controlled room. Make every effort to prevent any change in water content of the soil. Specimens shall be of uniform circular cross section with ends perpendicular to the longitudinal axis of the specimen. When carving or trimming, remove any small pebbles or shells encountered. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. When pebbles or crumbling result in excessive irregularity at the ends, cap the specimen with a minimum thickness of plaster of paris, hydrostone, or similar material. When sample condition permits, a vertical lathe that will accommodate the total sample may be used as an aid in carving the specimen to the required diameter. Where prevention of the development of appreciable capillary forces is deemed important, seal the specimen with a rubber membrane, thin plastic coatings, or with a coating of grease or sprayed plastic immediately after preparation and during the entire testing cycle. Determine the mass and dimensions of the test specimen. If the specimen is to be capped, its mass and dimensions should be determined before capping. If the entire test specimen is not to be used for determination of water content, secure a representative sample of cuttings for this purpose, placing them immediately in a covered container. The water content determination shall be performed in accordance with Method D 2216.

6.3 *Remolded Specimens*—Specimens may be prepared either from a failed undisturbed specimen or from a disturbed sample, providing it is representative of the failed undisturbed specimen. In the case of failed undisturbed specimens, wrap the material in a thin rubber membrane and work the material thoroughly with the fingers to assure complete remolding. Avoid entrapping air in the specimen. Exercise care to obtain a uniform density, to remold to the same void ratio as the undisturbed specimen, and to preserve the natural water content of the soil. Form the disturbed material into a mold of circular cross section having dimensions meeting the requirements of 6.1. After removal from the mold, determine the mass and dimensions of the test specimens.

6.4 *Compacted Specimens*—Specimens shall be prepared to the predetermined water content and density prescribed by the individual assigning the test (Note 5). After a specimen is formed, trim the ends perpendicular to the longitudinal axis, remove from the mold, and determine the mass and dimensions of the test specimen.

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NOTE 5—Experience indicates that it is difficult to compact, handle, and obtain valid results with specimens that have a degree of saturation that is greater than 90 %.

7. Procedure

7.1 Place the specimen in the loading device so that it is centered on the bottom platen. Adjust the loading device carefully so that the upper platen just makes contact with the specimen. Zero the deformation indicator. Apply the load so as to produce an axial strain at a rate of ½ to 2 %/min. Record load, deformation, and time values at sufficient intervals to define the shape of the stress-strain curve (usually 10 to 15 points are sufficient). The rate of strain should be chosen so that the time to failure does not exceed about 15 min (Note 6). Continue loading until the load values decrease with increasing strain, or until 15 % strain is reached. The rate of strain used for testing sealed specimens may be decreased if deemed desirable for better test results. Indicate the rate of strain in the report of the test data, as required in 9.1.7. Determine the water content of the test specimen using the entire specimen, unless representative cuttings are obtained for this purpose, as in the case of undisturbed specimens. Indicate on the test report whether the water content sample was obtained before or after the shear test, as required in 9.1.2.

NOTE 6—Softer materials that will exhibit larger deformation at failure should be tested at a higher rate of strain. Conversely, stiff or brittle materials that will exhibit small deformations at failure should be tested at a lower rate of strain.

7.2 Make a sketch, or take a photo, of the test specimen at failure showing the slope angle of the failure surface if the angle is measurable.

7.3 A copy of a sample data sheet is included in Appendix X1. Any data sheet can be used, provided the form contains all the required data.

8. Calculations

8.1 Calculate the axial strain, ϵ_1, to the nearest 0.1 %, for a given applied load, as follows:

$$\epsilon_1 = \Delta L / L_o$$

where:

ΔL = length change of specimen as read from deformation indicator, mm (in.), and

L_0 = initial length of test specimen, mm (in.).

8.2 Calculate the average cross-sectional area, A, for a given applied load, as follows:

$$A = A_0/(1 - \epsilon_1)$$

where:

A_0 = initial average cross-sectional area of the specimen, mm² (in.²), and

ϵ_1 = axial strain for the given load, %.

8.3 Calculate the compressive stress, σ_c, to three significant figures, or nearest 1 kPa (0.01 ton/ft²), for a given applied load, as follows:

$$\sigma_c = (P/A)$$

where:

P = given applied load, kPa (ton/ft²),

A = corresponding average cross-sectional area mm² (in.²).

8.4 *Graph*—If desired, a graph showing the relationship between compressive stress (ordinate) and axial strain (abscissa) may be plotted. Select the maximum value of compressive stress, or the compressive stress at 15 % axial strain, whichever is secured first, and report as the unconfined compressive strength, q_u. Whenever it is considered necessary for proper interpretation, include the graph of the stress-strain data as part of the data reported.

8.5 If the unconfined compressive strength is determined the sensitivity, S_T, is calculated as follows:

$$S_T = \frac{q_u \text{ (undisturbed specimen)}}{q_u \text{ (remolded specimen)}}$$

9. Report

9.1 The report should include the following:

9.1.1 Identification and visual description of the specimen, including soil classification, symbol, and whether the specimen is undisturbed, remolded, compacted, etc. Also include specimen identifying information, such as project location, boring number, sample number, depth, etc. Visual descriptions shall be made in accordance with Practice D 2488.

9.1.2 Initial dry density and water content (specify if water content specimen was obtained before or after shear and whether from cuttings or the entire specimen).

9.1.3 Degree of saturation (Note 7), if computed.

NOTE 7—The specific gravity determined in accordance with Method D 854 is required for calculation of the degree of saturation.

9.1.4 Unconfined compressive strength and shear strength.

9.1.5 Average height and diameter of specimen.

9.1.6 Height-to-diameter ratio.

9.1.7 Average rate of strain to failure, %.

9.1.8 Strain at failure, %.

9.1.9 Liquid and plastic limits, if determined, in accordance with Test Method D 4318.

9.1.10 Failure sketch or photo.

9.1.11 Stress-strain graph, if prepared.

9.1.12 Sensitivity, if determined.

9.1.13 Particle size analysis, if determined, in accordance with Method D 422, and

9.1.14 *Remarks*—Note any unusual conditions or data that would be considered necessary to properly interpret the results obtained, for example, slickensides, stratification, shells, pebbles, roots, or brittleness, the type of failure (that is, bulge, diagonal shear, etc.).

10. Precision and Bias

10.1 No method presently exists to evaluate the precision of a group of unconfined compression tests on undisturbed specimens due to specimen variability. Undisturbed specimens from apparently homogeneous soil deposits at the same location often exhibit significantly different strength and stress-strain properties.

10.2 A suitable test material and method of specimen preparation have not been developed for the determination of laboratory variances due to the difficulty in producing identical cohesive soil specimens. No estimates of precision for this test method are available.

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Keywords

Cohesive soils; sensitivity; shear strength; stress-strain curves; unconfined compression test; unconfined compressive strength.

APPENDIX

(Nonmandatory Information)

X1. Example Data Sheet

UNCONFINED COMPRESSION TEST—UI

Name ____________ Date ____________ Job No. ____________

Location ____________

Boring No ____________ Sample No. ____________ Depth/Elev ____________

Description of Sample ____________

Proving Ring No ____________ Apparatus No ____________

Water Content Determination

Tare No ____________ ____________

Wt Specimen Wet + Tare

Wt Specimen Dry + Tare

Wt Water ____________

Wt Tare ____________

Wt Specimen Wet ____________

Wt Specimen Dry ____________

Water Content in % Dry Wt at 105°C ____________ %

Wet Density ____________

Dry Density ____________

Unconfined Compressive Strength

Initial Diameter D_o ____________

Initial Area A_o ____________

Initial Height L_o ____________

Initial Volume V_o ____________

Specific Gravity ____________

Stress = $\frac{\text{Load}}{\text{Corr. Area}}$

Test Data

Unit Strain = $\frac{}{}$

$\bar{\delta}$ = ____________

Corr. Area = $\frac{A_o}{1 - \text{Unit Strain}}$

Elapsed Time-min	Load Dial	Axial Load	Strain Dial	Total Strain	Unit Strain	Corrected Area	Stress

Type of Sample ____________

Attach a photo or sketch of the specimen after failure to this form

Strain Rate ____________ %/Min

Remarks ____________

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Designation: D 2216 – 90

Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[1]

This standard is issued under the fixed designation D 2216; 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 covers the laboratory determination of the water (moisture) content of soil, rock, and similar materials by mass. For simplicity, the word "material" hereinafter also refers to either soil or rock, whichever is most applicable.

1.2 The water content of a material is defined by this standard as the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material.

1.3 The term "solid particles" as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, and the like) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method (110°C). Materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water) may present a special problem as this material slowly dehydrates at the standard drying temperature (110°C) and at very low relative humidities, forming a compound (calcium sulfate hemihydrate) which is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum, or to reduce decomposition in highly organic soils, it may be desirable to dry these materials at 60°C or in a desiccator at room temperature. Thus, when a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from standard water content determined at the standard drying temperature.

NOTE 1—Test Method D 2974 provides an alternate procedure for determining water content of peat materials.

1.4 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments) when tested by this method will give a mass of solids which includes the previously soluble solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must be used.

1.5 This test method requires several hours for proper drying of the water content specimen. Test Method D 4643 provides for drying of the test specimen in a microwave oven which is a shorter process.

1.6 This standard requires the drying of material in an oven at high temperatures. If the material being dried is contaminated with certain chemicals, health and safety hazards can exist. Therefore, this standard should not be used in determining the water content of contaminated soils unless adequate health and safety precautions are taken.

1.7 *This standard does not purport to address all of the safety problems 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock and Contained Fluids[2]

D 2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils[2]

D 4220 Practice for Preserving and Transporting Soil Samples[2]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

D 4643 Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method[2]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing[2]

E 145 Specification for Gravity—Convection and Forced—Ventilation Ovens[3]

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *water content* (of a material)—the ratio of the mass of water contained in the pore spaces of soil or rock material, to the solid mass of particles in that material, expressed as a percentage.

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

4. Summary of Method

4.1 A test specimen is dried in an oven to a constant mass. Loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen.

5. Significance and Use

5.1 For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its properties.

5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.

5.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D 4318, is used to express its relative consistency or liquidity index.

6. Apparatus

6.1 *Drying Oven*, thermostatically-controlled, preferably of the forced-draft type, meeting the requirements of Specification E 145 and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

6.2 *Balances*—All balances must meet the requirements of Specification D 4753 and this Section. A Class GP1 balance of 0.01g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1g readability is required for specimens having a mass over 200 g.

6.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g; while for specimens having a mass greater than about 200 g, containers without lids may be used. One container is needed for each water content determination.

NOTE 2—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.

6.4 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium phosphate. It is preferable to use a desiccant which changes color to indicate it needs reconstitution. See Section 10.5.

NOTE 3—Anhydrous calcium sulfate is sold under the trade name Drierite.

6.5 *Container Handling Apparatus*, gloves, tongs, or suitable holder for moving and handling hot containers after drying.

6.6 *Miscellaneous*, knives, spatulas, scoops, quartering cloth, sample splitters, etc. as required.

7. Samples

7.1 Samples shall be preserved and transported in accordance with Practice 4220 Groups B, C, or D soils. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct contact with sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to prevent or minimize moisture condensation on the insides of the containers.

7.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corrodible containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values given before shall apply.

8.2 The minimum mass of moist material selected to be representative of the total sample, if the total sample is not tested by this method, shall be in accordance with the following:

Maximum particle size (100 % passing)	Standard Sieve Size	Recommended minimum mass of moist test specimen for water content reported to ±0.1 %	Recommended minimum mass of moist test specimen for water content reported to ±1 %
2 mm or less	No. 10	20 g	20 g*
4.75 mm	No. 4	100 g	20 g*
9.5 mm	3/8-in	500 g	50 g
19.0 mm	3/4-in	2.5 kg	250 g
37.5 mm	1-1/2 in	10 kg	1 kg
75.0 mm	3-in.	50 kg	5 kg

NOTE—*To be representative not less than 20 g shall be used.

8.2.1 If the total sample is used it does not have to meet the minimum mass requirements provided in the table above. The report shall indicate that the entire sample was used.

8.3 Using a test specimen smaller than the minimum indicated in 8.2 requires discretion, though it may be adequate for the purposes of the test. Any specimen used not meeting these requirements shall be noted in the report of results.

8.4 When working with a small (less than 200g) specimen containing a relatively large gravel particle, it is appropriate not to include this particle in the test specimen. However, any discarded material shall be described and noted in the report of the results.

9. Test Specimen Selection

9.1 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, and the likes.)

9.2 For disturbed samples such as trimmings, bag samples, and the like, obtain the test specimen by one of the following methods (listed in order of preference):

9.2.1 If the material is such that it can be manipulated and handled without significant moisture loss, the material should be mixed and then reduced to the required size by quartering or splitting.

9.2.2 If the material is such that it cannot be thoroughly

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mixed and/or split, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.

9.2.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as possible at random locations that will best represent the moisture condition. Combine all the portions for the test specimen.

9.3 Intact samples such as block, tube, split barrel, and the like, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample.

9.3.1 Carefully trim at least 3 mm of material from the outer surface of the sample to see if material is layered and to remove material that is drier or wetter than the main portion of the sample. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the entire exposed surface or from the interval being tested.

9.3.2 Slice the sample in half. If material is layered see Section 9.3.3. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the exposed surface of one half, or from the interval being tested. Avoid any material on the edges that may be wetter or drier than the main portion of the sample.

NOTE 4—Migration of moisture in some cohesionless soils may require that the full section be sampled.

9.3.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on data sheets.

10. Procedure

10.1 Determine and record the mass of the clean and dry specimen container (and its lid, if used).

10.2 Select representative test specimens in accordance with Section 9.

10.3 Place the moist test specimen in the container and, if used, set the lid securely in position. Determine the mass of the container and moist material using a balance (See 6.2) selected on the basis of the specimen mass. Record this value.

NOTE 5—To prevent mixing of specimens and yielding of incorrect results, all containers, and lids if used, should be numbered and the container numbers shall be recorded on the laboratory data sheets. The lid numbers should match the container numbers to eliminate confusion.

NOTE 6—To assist in the oven-drying of large test specimens, they should be placed in containers having a large surface area (such as pans) and the material broken up into smaller aggregations.

10.4 Remove the lid (if used) and place the container with moist material in the drying oven. Dry the material to a constant mass. Maintain the drying oven at 110 ± 5°C unless otherwise specified (see 1.3). The time required to obtain constant mass will vary depending on the type of material, size of specimen, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment, and experience with the materials being tested and the apparatus being used.

NOTE 7—In most cases, drying a test specimen overnight (about 12 to 16 h) is sufficient. In cases where there is doubt concerning the adequacy of drying, drying should be continued until the change in mass after two successive periods (greater than 1 h) of drying is an insignificant amount (less than about 0.1 %). Specimens of sand may often be dried to constant mass in a period of about 4 h, when a forced-draft oven is used.

NOTE 8—Since some dry materials may absorb moisture from moist specimens, dried specimens should be removed before placing moist specimens in the same oven. However, this would not be applicable if the previously dried specimens will remain in the drying oven for an additional time period of about 16 h.

10.5 After the material has dried to constant mass remove the container from the oven (and replace the lid if used). Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands and the operation of the balance will not be affected by convection currents and/or its being heated. Determine the mass of the container and oven-dried material using the same balance as used in 10.3. Record this value. Tight fitting lids shall be used if it appears that the specimen is absorbing moisture from the air prior to determination of its dry mass.

NOTE 9—Cooling in a desiccator is acceptable in place of tight fitting lids since it greatly reduces absorption of moisture from the atmosphere during cooling especially for containers without tight fitting lids.

11. Calculation

11.1 Calculate the water content of the material as follows:

$$w = [(M_{cws} - M_{cs})/(M_{cs} - M_c)] \times 100 = \frac{M_w}{M_s} \times 100$$

where:

w = water content, %,
M_{cws} = mass of container and wet specimen, g,
M_{cs} = mass of container and oven dry specimen, g,
M_c = mass of container, g,
M_w = mass of water ($M_w = M_{cws} - M_{cs}$), g, and
M_s = mass of solid particles ($M_s = M_{cs} - M_c$), g.

12. Report

12.1 The report (data sheet) shall include the following:

12.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, container number etc.

12.1.2 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum sample used. If this method is used in concert with another method, the water content of the specimen should be reported to the value required by the test method for which the water content is being determined.

12.1.3 Indicate if test specimen had a mass less than the minimum indicated in 8.2.

12.1.4 Indicate if test specimen contained more than one material type (layered, etc.).

12.1.5 Indicate the method of drying if different from oven-drying at 110 ± 5°C.

12.1.6 Indicate if any material (size and amount) was excluded from the test specimen.

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13. Precision and Bias

13.1 *Statement on Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

13.2 *Statements on Precision:*

13.2.1 *Single-Operator Precision*—The single-operator coefficient of variation has been found to be 2.7 percent. Therefore, results of two properly conducted tests by the same operator with the same equipment should not be considered suspect unless they differ by more than 7.8 percent of their mean.

13.2.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 5.0 percent. Therefore, results of two properly conducted tests by different operators using different equipment should not be considered suspect unless they differ by more than 14.0 percent of their mean.

14. Keywords

14.1 Consistency; index property; laboratory; moisture analysis; moisture content; soil aggregate; water content

Designation: D 2217 – 85

Standard Practice for
Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[1]

This standard is issued under the fixed designation D 2217; 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.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This practice covers the wet preparation of soil samples as received from the field for particle-size analysis and determination of soil constants.

1.2 Procedure A provides for drying the field sample at a temperature not exceeding 140°F (60°C), making a wet separation on the No. 10 (2.00-mm) sieve, or No. 40 (425-μm) sieve, or both, as needed, and finally drying at a temperature not exceeding 140°F. Procedure B provides that the sample shall be kept at a moisture content equal to or greater than the natural water content. The procedure to be used should be indicated in the specification for the material being tested. If no procedure is specified, the provisions of Procedure B shall govern.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

D 422 Method for Particle-Size Analysis of Soils[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Significance and Use

3.1 Procedure A is used to prepare soil samples for plasticity tests and particle-size analysis when the coarse-grained particles of a sample are soft and pulverize readily, as in Practice D 421, or when the fine particles are very cohesive and tend to resist removal from the coarse particles.

3.2 Some soils never dry out in nature and may change their characteristics greatly when dried. If the true natural gradation and plasticity characteristics of such soils are desired, these soils should be shipped to the laboratory in sealed containers and processed in accordance with Procedure B of this practice.

3.3 Liquid limit and plasticity index values derived from samples containing their natural moisture are usually, but not always, equal to or higher than values derived from similar samples of the dried soil. In the case of fine-grained organic soil, there is a radical drop in plasticity due to oven drying.

4. Apparatus

4.1 *Balance*, sensitive to 0.1 g.

4.2 *Mortar and Rubber-Covered Pestle*, suitable for breaking up the aggregations of soil particles.

4.3 *Sieves*, No. 10 (2.00-mm) and No. 40 (425-μm), of square mesh woven-wire cloth, conforming to Specification E 11.

4.4 *Sampler*—A riffle sampler or sample splitter for quartering the samples.

4.5 *Drying Apparatus*—Thermostatically controlled drying oven for use at 140°F (60°C) or below and at 230°F (110°C), infrared lamps; air drier; or other suitable device for drying samples.

4.6 *Filter Funnels or Candles*—Büchner funnels 10 in. (254 mm) in diameter and filter paper or filter candles.

4.7 *Miscellaneous Equipment*—Pans 12 in. (304.8 mm) in diameter and 3 in. (76.2 mm) in depth; a suitable container that will prevent loss of moisture during storage of the moist test sample prepared in Procedure B.

PROCEDURE A

5. Sampling

5.1 Dry the soil sample as received from the field, using one of the following methods: (*1*) in air at room temperature, (*2*) in a drying oven at a temperature not exceeding 140°F (60°C), or (*3*) using any warming device that will not raise the temperature of the sample above 140°F. Break up thoroughly any aggregations of particles using the mortar and rubber-covered pestle or other suitable device (Note 1). Select a representative portion by the method of quartering or by use of the sampler. This portion must be sufficient to provide samples for particle-size analyses of material retained on and passing the No. 10 (2.00-mm) sieve, and to provide an adequate amount of material passing the No. 40 (425-μm) sieve for the tests to determine soil constants. The amounts of material required to perform the individual tests are as follows:

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

Particle-Size Analysis of Material Retained on No. 10 (2.00-mm) Sieve:	
Gravelly soils, g	4 000 to 10 000
Sandy soils, g	1 500
Silty or clayey soils, g	400
Particle-Size Analysis of Material Passing No. 10 (2.00-mm) Sieve:	
Sandy soils, g	115
Silty or clayey soils, g	65
Tests for Determination of Soil Constants	
Liquid limit, g	100
Plastic limit, g	15
Centrifuge moisture equivalent, g	10
Shrinkage factors, g	30
Check tests, g	65

NOTE 1—When the sample contains particles of soft shale or sandstone or similar weak material, proper care must be exercised to avoid excessive reduction in the size of the particles.

6. Preparation of Test Samples

6.1 *For Particle-Size Analysis*

6.1.1 Weigh the portion of the test sample selected for particle-size analysis and record as the weight of test sample uncorrected for hygroscopic moisture. Separate this material into two portions using the No. 10 (2.00-mm) sieve. Set aside the portion passing for later recombination with additional material washed from the portion retained on the No. 10 (2.00-mm) sieve.

6.1.2 Place the material retained on the No. 10 (2.00-mm) sieve in a pan, cover with water, and allow to soak until the particle aggregations become soft. After soaking, wash the material on a No. 10 (2.00-mm) sieve in the following manner: Place an empty No. 10 (2.00-mm) sieve on the bottom of a clean pan and pour the water from the soaked sample into the sieve. Add sufficient water to bring the level approximately ½ in. (12.7 mm) above the mesh of the sieve. Transfer the soaked material to the sieve in increments not exceeding 1 lb (0.45 kg), stirring each increment with the fingers while agitating the sieve up and down. Crumble or mash any lumps that have not slaked, using the thumb and fingers. Raise the sieve above the water in the pan and complete the washing operation using a small amount of clean water. Transfer the washed material on the sieve to a clean pan before placing another increment of soaked material on the sieve.

6.1.3 Dry the material retained on the No. 10 (2.00-mm) sieve at a temperature of 230 ± 9°F (110 ± 5°C)..sieve on the No. 10 (2.00-mm) sieve, and add the material passing the sieve to similar material obtained in 6.1.1. Set aside the material retained on the sieve for use in the particle-size analysis.

6.1.4 Set aside the pan containing the washings for a period of several hours or until the water above the particles is clear. Decant, pipet, or siphon off as much of the clear water as possible (Note 2). Dry the soil remaining in the pan at a temperature not exceeding 140°F (60°C). Grind the dried soil in the mortar with the rubber-covered pestle or other suitable device, and combine with similar material obtained in 6.1.1.

6.1.5 Alternatively, after all the soaked material has been washed, remove most of the water by filtering the wash water on one or more Büchner funnels fitted with filter paper or by using filter candles. Remove the moist soil from the filter paper or filter candles, combine with any sediment remaining in the pan, and dry at a temperature not exceeding 140°F (60°C). Grind the dried soil in the mortar with a rubber-covered pestle or other suitable device and combine with similar material obtained in 6.1.1.

NOTE 2—In some instances, the wash water will not become clear in a reasonable length of time; in this case the entire volume must be evaporated.

6.2 *For Determination of Soil Constants*—Proceed in accordance with 6.1, substituting a No. 40 (425-µm) sieve for the No. 10 (2.00-mm) sieve.

NOTE 3—In some areas it is possible that the cations of salts present in the tap water may exchange with the natural cations in the soil and alter significantly the values of the soil constants should tap water be used in the soaking and washing operations. Unless it is known that such cations are not present in the tap water, distilled or demineralized water should be used. The soaking and washing operation will remove soluble salts contained in the soil. When soluble salts are present in the soil, the wash water should be saved and evaporated, and the salts returned to the soil sample.

7. Test Samples

7.1 Keeping each portion separate from the other portion, mix thoroughly the portions of the soil sample passing the No. 10 (2.00-mm) sieve and the No. 40 (425-µm) sieve. By the method of quartering or by the use of the sampler, select and weigh out test samples of the weights indicated in Section 5, as may be needed to make the required tests.

PROCEDURE B

8. Samples

8.1 Samples prepared in accordance with this procedure must be shipped from the field to the laboratory in sealed containers and must contain all their natural moisture. Samples obviously containing only particles passing the No. 10 (2.00-mm) sieve may be tested in the particle-size analysis without first washing on the No. 10 (2.00-mm) sieve. Samples obviously containing only particles passing the No. 40 (425-µm) sieve may be used in the tests to determine soil constants without first washing on the No. 40 (425-µm) sieve.

9. Preparation of Test Samples

9.1 *For Particle-Size Analysis:*

9.1.1 Select and weigh a representative portion of the moist sample estimated to contain 50 g of particles passing the No. 10 (2.00-mm) sieve for silty and clayey soil, or 100 g for sandy soil. For samples containing particles not passing the No. 10 (2.00-mm) sieve for which a particle-size analysis is required, select and weigh a representative sample estimated to contain the required amounts of particles both passing and not passing the No. 10 (2.00-mm) sieve. Determine the moisture content at 230 ± 9°F (110 ± 5°C) using an auxiliary sample, for use in Method D 422.

9.1.2 Soak the moist sample and wash on a No. 10 (2.00-mm) sieve as described in 6.1.2. After washing, dry the material retained on the No. 10 (2.00-mm) sieve in an oven at a temperature of 230 ± 9°F (110 ± 5°C), weigh, and retain for the particle-size analysis. If the volume of the wash water and soil is too large for use in the sedimentation procedure of the test for particle-size analysis, evaporate excess water by exposure to air at room temperature, by heating in an oven

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at a temperature not exceeding 230°F (110°C), or by boiling. Regardless of the method of evaporation used, the following precautions must be taken: (*1*) stir the slurry from time to time to prevent a dry soil ring from forming on the walls of the evaporation vessel, and (*2*) return the temperature of the sample to room temperature before testing.

9.2 *For Determination of Soil Constants*—Select a representative portion of the moist sample estimated to contain sufficient particles passing the No. 40 (425-μm) sieve to make the required tests for determination of soil constants. Soak this selected portion of the moist sample and wash on the No. 40 (425-μm) sieve as described in 6.2 (Note 2). Reduce the moisture content of the material passing the No. 40 (425-μm) sieve until the mass reaches a putty-like consistency (such as 30 to 35 drops of the cup in the liquid limit test) but never below the natural moisture content. Reduction of moisture content may be accomplished as follows: by exposure to air at ordinary room temperature, by heating in an oven at a temperature not exceeding 230°F (110°C), by boiling, by filtering on a Büchner funnel, or by use of filter candles. During evaporation and cooling, stir the sample often enough to prevent overdrying of the fringes and soil pinnacles on the surface. Cool the heated samples to normal room temperature before testing. For soil samples containing soluble salts, use a method of water reduction that will not eliminate the soluble salts from the test sample. Protect the prepared sample in a suitable container from further drying until all required tests have been performed.

Designation: D 2434 – 68 (Reapproved 1974)^ε1^

Standard Test Method for Permeability of Granular Soils (Constant Head)[1]

This standard is issued under the fixed designation D 2434; 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.

ε1 NOTE—Section 2 was added editorially and subsequent sections renumbered in July 1984.

1. Scope

1.1 This test method covers the determination of the coefficient of permeability by a constant-head method for the laminar flow of water through granular soils. The procedure is to establish representative values of the coefficient of permeability of granular soils that may occur in natural deposits as placed in embankments, or when used as base courses under pavements. In order to limit consolidation influences during testing, this procedure is limited to disturbed granular soils containing not more than 10 % soil passing the 75-μm (No. 200) sieve.

2. Referenced Documents

2.1 *ASTM Standards*:

D 422 Method for Particle-Size Analysis of Soils[2]

D 2049 Test Method for Relative Density of Cohesionless Soils[3]

3. Fundamental Test Conditions

3.1 The following ideal test conditions are prerequisites for the laminar flow of water through granular soils under constant-head conditions:

3.1.1 Continuity of flow with no soil volume change during a test.

3.1.2 Flow with the soil voids saturated with water and no air bubbles in the soil voids.

3.1.3 Flow in the steady state with no changes in hydraulic gradient, and

3.1.4 Direct proportionality of velocity of flow with hydraulic gradients below certain values, at which turbulent flow starts.

3.2. All other types of flow involving partial saturation of soil voids, turbulent flow, and unsteady state of flow are transient in character and yield variable and time-dependent coefficients of permeability; therefore, they require special test conditions and procedures.

4. Apparatus

4.1 *Permeameters*, as shown in Fig. 1, shall have specimen cylinders with minimum diameters approximately 8 or 12 times the maximum particle size in accordance with Table 1. The permeameter should be fitted with: (*1*) a porous disk or suitable reinforced screen at the bottom with a permeability greater than that of the soil specimen, but with openings sufficiently small (not larger than 10 % finer size) to prevent movement of particles; (*2*) manometer outlets for measuring the loss of head, *h*, over a length, *l*, equivalent to at least the diameter of the cylinder; (*3*) a porous disk or suitable reinforced screen with a spring attached to the top, or any other device, for applying a light spring pressure of 22 to 45-N (5 to 10-lbf) total load, when the top plate is attached in place. This will hold the placement density and volume of soil without significant change during the saturation of the specimen and the permeability testing to satisfy the requirement prescribed in 3.1.1.

4.2 *Constant-Head Filter Tank*, as shown in Fig. 1, to supply water and to remove most of the air from tap water, fitted with suitable control valves to maintain conditions described in 3.1.2.

NOTE 1—De-aired water may be used if preferred.

4.3 *Large Funnels*, fitted with special cylindrical spouts 25 mm (1 in.) in diameter for 9.5-mm (⅜-in.) maximum size particles and 13 mm (½ in.) in diameter for 2.00-mm (No. 10) maximum size particles. The length of the spout should be greater than the full length of the permeability chamber—at least 150 mm (6 in.).

4.4 *Specimen Compaction Equipment*[2]—Compaction equipment as deemed desirable may be used. The following are suggested: a vibrating tamper fitted with a tamping foot 51 mm (2 in.) in diameter; a sliding tamper with a tamping foot 51 mm (2 in.) in diameter, and a rod for sliding weights of 100 g (0.25 lb) (for sands) to 1 kg (2.25 lb) (for soils with a large gravel content), having an adjustable height of drop to 102 mm (4 in.) for sands and 203 mm (8 in.) for soils with large gravel contents.

4.5 *Vacuum Pump or Water-Faucet Aspirator*, for evacuating and for saturating soil specimens under full vacuum (see Fig. 2).

4.6 *Manometer Tubes*, with metric scales for measuring head of water.

4.7 *Balance*, of 2-kg (4.4-lb) capacity, sensitive to 1 g (0.002 lb).

4.8 *Scoop*, with a capacity of about 100 g (0.25 lb) of soil.

4.9 *Miscellaneous Apparatus*—Thermometers, clock with sweep second hand, 250-mL graduate, quart jar, mixing pan, etc.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties of Soil and Rocks.

Current edition approved Sept. 1968. Originally issued 1965. Replaces D 2434 – 65 T.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] Discontinued—See *1983 Annual Book of ASTM Standards*, Vol 04.08.

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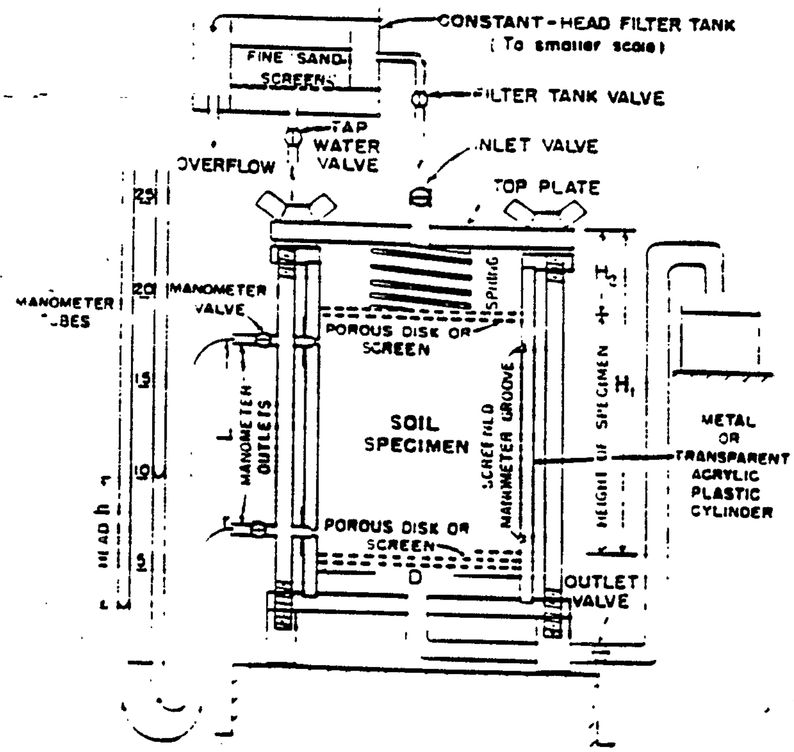

FIG. 1 Constant-Head Permeameter

5. Sample

5.1 A representative sample of air-dried granular soil, containing less than 10 % of the material passing the 75-μm (No. 200) sieve and equal to an amount sufficient to satisfy the requirements prescribed in 5.2 and 5.3, shall be selected by the method of quartering.

5.2 A sieve analysis (see Method D 422) shall be made on a representative sample of the complete soil prior to the permeability test. Any particles larger than 19 mm (3/4 in.) shall be separated out by sieving (Method D 422). This oversize material shall not be used for the permeability test, but the percentage of the oversize material shall be recorded.

NOTE 2—In order to establish representative values of coefficients of permeabilities for the range that may exist in the situation being investigated, samples of the finer, average, and coarser soils should be obtained for testing.

5.3 From the material from which the oversize has been removed (see 5.2), select by the method of quartering, a sample for testing equal to an amount approximately twice that required for filling the permeameter chamber.

6. Preparation of Specimens

6.1 The size of permeameter to be used shall be as prescribed in Table 1.

6.2 Make the following initial measurements in centimetres or square centimetres and record on the data sheet (Fig. 3): the inside diameter, D, of the permeameter; the length, L, between manometer outlets; the depth, H_1, measured at four symmetrically spaced points from the upper surface of the top plate of the permeability cylinder to the top of the upper porous stone or screen temporarily placed on the lower porous plate or screen. This automatically deducts the thickness of the upper porous plate or screen from the height measurements used to determine the volume of soil placed in the permeability cylinder. Use a duplicate top plate containing four large symmetrically spaced openings through which the necessary measurements can be made to determine the average value for H_1. Calculate the cross-sectional area, A, of the specimen.

6.3 Take a small portion of the sample selected as prescribed in 5.3 for water content determinations. Record the weight of the remaining air-dried sample (see 5.3), W_1,

TABLE 1 Cylinder Diameter

Maximum Particle Size Lies Between Sieve Openings	Minimum Cylinder Diameter			
	Less than 35 % of Total Soil Retained on Sieve Opening		More than 35 % of Total Soil Retained on Sieve Opening	
	2.00-mm (No. 10)	9.5-mm (3/8-in.)	2.00-mm (No. 10)	9.5-mm (3/8-in.)
2.00-mm (No. 10) and 9.5-mm (3/8 in.)	76 mm (3 in.)		114 mm (4.5 in.)	
9.5-mm (3/8-in.) and 19.0-mm (3/4 in.)		152 mm (6 in.)		229 mm (9 in.)

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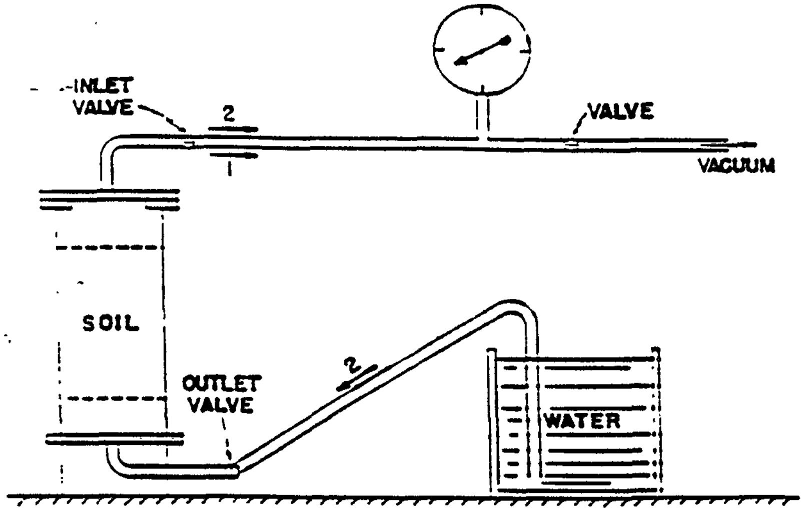

FIG. 2 Device for Evacuating and Saturating Specimen

for unit weight determinations.

6.4 Place the prepared soil by one of the following procedures in uniform thin layers approximately equal in thickness after compaction to the maximum size of particle, but not less than approximately 15 mm (0.60 in.).

6.4.1 For soils having a maximum size of 9.5 mm (⅜ in.) or less, place the appropriate size of funnel, as prescribed in 4.3, in the permeability device with the spout in contact with the lower porous plate or screen, or previously formed layer, and fill the funnel with sufficient soil to form a layer, taking soil from different areas of the sample in the pan. Lift the funnel by 15 mm (0.60 in.), or approximately the unconsolidated layer thickness to be formed, and spread the soil with a slow spiral motion, working from the perimeter of the device toward the center, so that a uniform layer is formed. Remix the soil in the pan for each successive layer to reduce segregation caused by taking soil from the pan.

6.4.2 For soils with a maximum size greater than 9.5 mm (⅜ in.), spread the soil from a scoop. Uniform spreading can be obtained by sliding a scoopful of soil in a nearly horizontal position down along the inside surface of the device to the bottom or to the formed layer, then tilting the scoop and drawing it toward the center with a single slow motion; this allows the soil to run smoothly from the scoop in a windrow without segregation. Turn the permeability cylinder sufficiently for the next scoopful, thus progressing around the inside perimeter to form a uniform compacted layer of a thickness equal to the maximum particle size.

6.5 Compact successive layers of soil to the desired relative density by appropriate procedures, as follows, to a height of about 2 cm (0.8 in.) above the upper manometer outlet.

6.5.1 *Minimum Density (0 % Relative Density)*—Continue placing layers of soil in succession by one of the procedures described in 6.4.1 or 6.4.2 until the device is filled to the proper level.

6.5.2 *Maximum Density (100 % Relative Density)*:

6.5.2.1 *Compaction by Vibrating Tamper*—Compact each layer of soil thoroughly with the vibrating tamper, distributing the light tamping action uniformly over the surface of the layer in a regular pattern. The pressure of contact and the length of time of the vibrating action at each spot should not cause soil to escape from beneath the edges of the tamping foot, thus tending to loosen the layer. Make a sufficient number of coverages to produce maximum density, as evidenced by practically no visible motion of surface particles adjacent to the edges of the tamping foot.

6.5.2.2 *Compaction by Sliding Weight Tamper*—Compact each layer of soil thoroughly by tamping blows uniformly distributed over the surface of the layer. Adjust the height of drop and give sufficient coverages to produce maximum density, depending on the coarseness and gravel content of the soil.

6.5.2.3 *Compaction by Other Methods*—Compaction may be accomplished by other approved methods, such as by vibratory packer equipment, where care is taken to obtain a uniform specimen without segregation of particle sizes (see Test Method D 2049).

6.5.3 *Relative Density Intermediate Between 0 and 100 %*—By trial in a separate container of the same diameter as the permeability cylinder, adjust the compaction to obtain reproducible values of relative density. Compact the soil in the permeability cylinder by these procedures in thin layers to a height about 2.0 cm (0.80 in.) above the upper manometer outlet.

NOTE 3—In order to bracket, systematically and representatively, the relative density conditions that may govern in natural deposits or in compacted embankments, a series of permeability tests should be made to bracket the range of field relative densities.

6.6 *Preparation of Specimen for Permeability Test:*

6.6.1 Level the upper surface of the soil by placing the upper porous plate or screen in position and by rotating it gently back and forth.

6.6.2 Measure and record: the final height of specimen, $H_1 - H_2$, by measuring the depth, H_2, from the upper surface of the perforated top plate employed to measure H_1 to the top of the upper porous plate or screen at four symmetrically spaced points after compressing the spring lightly to seat the porous plate or screen during the measurements; the final weight of air-dried soil used in the test ($W_1 - W_2$) by

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PERMEABILITY TEST ON GRANULAR SOIL

Test No. Date of Test

Location of Sample Date Sampled Report

Boring— Sample— Depth—

(a) DESCRIPTION OF SOIL

MATERIALS USED:

(b) UNIT WEIGHT DETERMINATION:

Diameter, D, cm	Height Before, H_1	Weight Before, W_1
Area, A, cm²	Height After, H_2	Weight After, W_2
Length, L, cm	Height Net, cm	Weight Net, g
	Moisture Content (air-dried)	
W (max)	Dry Unit Weight, lb/ft³ W	
W (min)	Void Ratio, e	
	Relative Density, RD	

(c) PERMEABILITY TEST (DEGREE OF COMPACTNESS)

Test No.	Manometers H_1	Manometers H_2	Head, h cm	Q cm³	t s	Q/At	h/L	Temperature, °C	k cm/s
1									
2									
3									
4									
5									
6									

FIG. 3 Permeability Test Data Sheet

weighing the remainder of soil, W_2, left in the pan. Compute and record the unit weights, void ratio, and relative density of the test specimen.

6.6.3 With its gasket in place, press down the top plate against the spring and attach it securely to the top of the permeameter cylinder, making an air-tight seal. This satisfies the condition described in 3.1.1 of holding the initial density without significant volume change during the test.

6.6.4 Using a vacuum pump or suitable aspirator, evacuate the specimen under 50 cm (20 in.) Hg minimum for 15 min to remove air adhering to soil particles and from the voids. Follow the evacuation by a slow saturation of the specimen from the bottom upward (Fig. 2) under full vacuum in order to free any remaining air in the specimen. Continued saturation of the specimen can be maintained more adequately by the use of (*1*) de-aired water, or (*2*) water maintained in an in-flow temperature sufficiently high to cause a decreasing temperature gradient in the specimen during the test. Native water or water of low mineral content (Note 4) should be used for the test, but in any case the fluid should be described on the report form (Fig. 3). This satisfies the condition described in 3.1.2 for saturation of soil voids.

NOTE 4—Native water is the water occurring in the rock or soil *in situ*. It should be used if possible, but it (as well as de-aired water) may be a refinement not ordinarily feasible for large-scale production testing.

6.6.5 After the specimen has been saturated and the permeameter is full of water, close the bottom valve on the outlet tube (Fig. 2) and disconnect the vacuum. Care should be taken to ensure that the permeability flow system and the manometer system are free of air and are working satisfactorily. Fill the inlet tube with water from the constant-head tank by slightly opening the filter tank valve. Then connect the inlet tube to the top of the permeameter, open the inlet valve slightly and open the manometer outlet cocks slightly, to allow water to flow, thus freeing them of air. Connect the water manometer tubes to the manometer outlets and fill with water to remove the air. Close the inlet valve and open

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the outlet valve to allow the water in the manometer tubes to reach their stable water level under zero head.

7. Procedure

7.1 Open the inlet valve from the filter tank slightly for the first run to conditions described in 3.1.3, delay measurements of quantity of flow and head until a stable head condition without appreciable drift in water manometer levels is attained. Measure and record the time, t, head, h (the difference in level in the manometers), quantity of flow, Q, and water temperature, T.

7.2 Repeat test runs at heads increasing by 0.5 cm in order to establish accurately the region of laminar flow with velocity, v (where $v = Q/At$), directly proportional to hydraulic gradient, i (where $i = h/L$). When departures from the linear relation become apparent, indicating the initiation of turbulent flow conditions, 1-cm intervals of head may be used to carry the test run sufficiently along in the region of turbulent flow to define this region if it is significant for field conditions.

NOTE 5—Much lower values of hydraulic gradient, h/L, are required than generally recognized, in order to ensure laminar flow conditions. The following values are suggested: loose compactness ratings, h/L from 2 to 0.3, and dense compactness ratings, h/L from 0.3 to 0.5, the lower values of h/L applying to coarser soils and the higher values to finer soils.

7.3 At the completion of the permeability test, drain the specimen and inspect it to establish whether it was essentially homogeneous and isotropic in character. Any light and dark alternating horizontal streaks or layers are evidence of segregation of fines.

8. Calculations

8.1 Calculate the coefficient of permeability, k, as follows:

$$k = QL/Ath$$

where:

k = coefficient of permeability,
Q = quantity of water discharged,
L = distance between manometers,
A = cross-sectional area of specimen,
t = total time of discharge,
h = difference in head on manometers.

8.2 Correct the permeability to that for 20°C (68°F) by multiplying k (see 8.1) by the ratio of the viscosity of water at test temperature to the viscosity of water at 20°C (68°F).

9. Report

9.1 The report of permeability test shall include the following information:

9.1.1 Project, dates, sample number, location, depth, and any other pertinent information.

9.1.2 Grain size analysis, classification, maximum particle size, and percentage of any oversize material not used.

9.1.3 Dry unit weight, void ratio, relative density as placed, and maximum and minimum densities.

9.1.4 A statement of any departures from these test conditions, so the results can be evaluated and used.

9.1.5 Complete test data, as indicated in the laboratory form for test data (see Fig. 3), and

9.1.6 Test curves plotting velocity, Q/At, versus hydraulic gradient, h/L, covering the ranges of soil identifications and of relative densities.

Designation: D 2487 – 90

Standard Test Method for Classification of Soils for Engineering Purposes[1]

This standard is issued under the fixed designation D 2487; 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.

This test method has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This test method describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this sytem is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this test method is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This test method is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 The system is based on the widely recognized Unified Soil Classification System which was adopted by several U.S. Government agencies in 1952 as an outgrowth of the Airfield Classification System developed by A. Casagrande.[2]

1.6 *This standard does not purport to address the safety problems 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 117 Test Method for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing[3]

C 136 Method for Sieve Analysis of Fine and Coarse Aggregates[3]

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size[3]

D 420 Guide for Investigating and Sampling Soil and Rock[4]

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[4]

D 422 Method for Particle-Size Analysis of Soils[4]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75-µm) Sieve[4]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[4]

D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[4]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[4]

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[4]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[4]

D 4427 Classification of Peat Samples by Laboratory Testing[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terms and Symbols D 653.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and

Boulders—particles of rock that will not pass a 12in. (300-mm) square opening.

3.1.1 *gravel*—particles of rock that will pass a 3-in.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved June 29, 1990. Published August 1990. Originally published as D 2487 – 66 T. Last previous edition D 2487 – 85ε1

[2] Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

(75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

Coarse—passes 3-in. (75-mm) sieve and retained on 3/4-in. (19-mm) sieve, and

Fine—passes 3/4-in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.2 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-μm) U.S. standard sieve with the following subdivisions:

Coarse—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve.

Medium—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425-μm) sieve, and

Fine—passes No. 40 (425-μm) sieve and retained on No. 200 (75-μm) sieve.

3.1.3 *clay*—soil passing a No. 200 (75-μm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line.

3.1.4 *silt*—soil passing a No. 200 (75-μm) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the "A" line.

3.1.5 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.6 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.7 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *coefficient of curvature*, Cc—the ratio $(D_{30})^2/(D_{10} \times D_{60})$, where D_{60}, D_{30}, and D_{10} are the particle diameters corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity*, Cu—the ratio D_{60}/D_{10}, where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

4. Summary of Test Method

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions are further subdivided into a total of 15 basic soil groups.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 2 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

5. Significance and Use

5.1 This test method classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

5.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This test method provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

5.4 This test method may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This test method may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 3, and a cumulative particle-size distribution curve, similar to Fig. 4, are required.

NOTE 5—The "U" line shown on Fig. 3 has been empirically determined to be the approximate "upper limit" for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Recommended Guide D 420 or by other accepted procedures.

7.2 For accurate identification, the minimum amount of test sample required for this test method will depend on which of the laboratory tests need to be performed. Where only the particle-size analysis of the sample is required, specimens having the following minimum dry weights are required:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1 1/2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

Whenever possible, the field samples should have weights two to four times larger than shown.

7.3 When the liquid and plastic limit tests must also be performed, additional material will be required sufficient to provide 150 g to 200 g of soil finer than the No. 40 (425-μm) sieve.

7.4 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

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TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well-graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12 % fines[C]	Fines classify as ML or MH	GM	Silty gravel[F,G,H]
			Fines classify as CL or CH	GC	Clayey gravel[F,G,H]
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines[D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			$Cu < 6$ and/or $1 > Cc > 3$[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12 % fines[D]	Fines classify as ML or MH	SM	Silty sand[G,H,I]
			Fines classify as CL or CH	SC	Clayey sand[G,H,I]
Fine-Grained Soils 50 % or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic clay[K,L,M,N] Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic clay[K,L,M,P] Organic silt[K,L,M,Q]
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12 % fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D] Sands with 5 to 12 % fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15 % sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15 % gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.

[M] If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

AR305446

Designation: D 2488 – 90

Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)[1]

This standard is issued under the fixed designation D 2488; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems 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 Section 8.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[2]

3. Terminology

3.1 *Definitions*

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 *clay*—soil passing a No. 200 (75-μm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 *sand*—particles of rock that will pass a No. 4

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved June 29, 1990. Published August 1990. Originally published as D 2488 – 66 T. Last previous edition D 2488 – 84ε1.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

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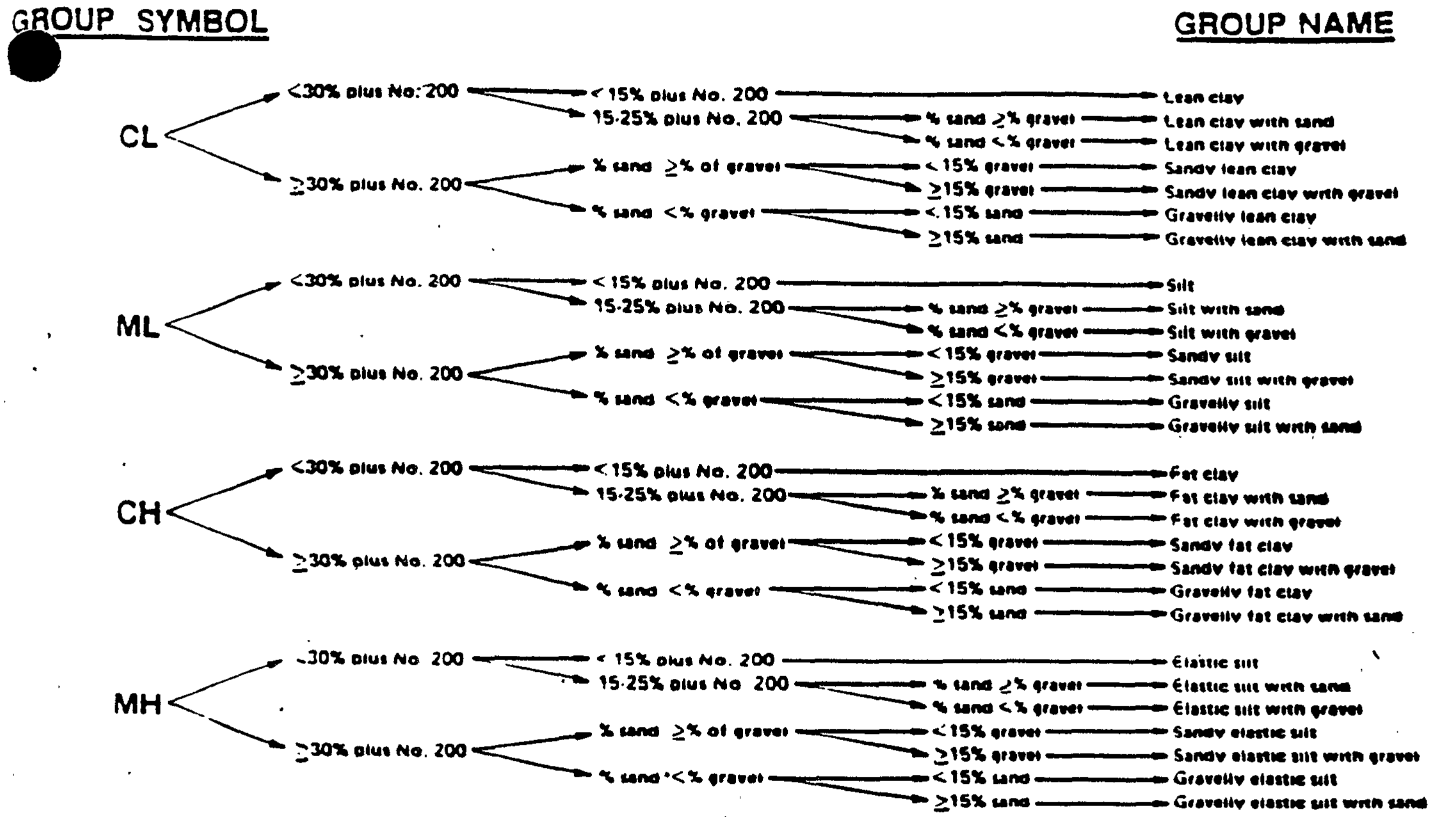


NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

fine—passes a No. 40 (425-µm) sieve and is retained on a No. 200 (75-µm) sieve.

3.1.8 *silt*—soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D 2487).

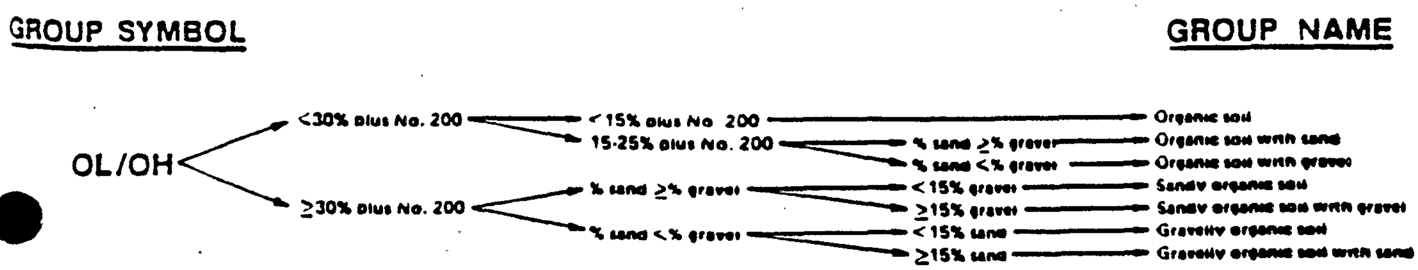
4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

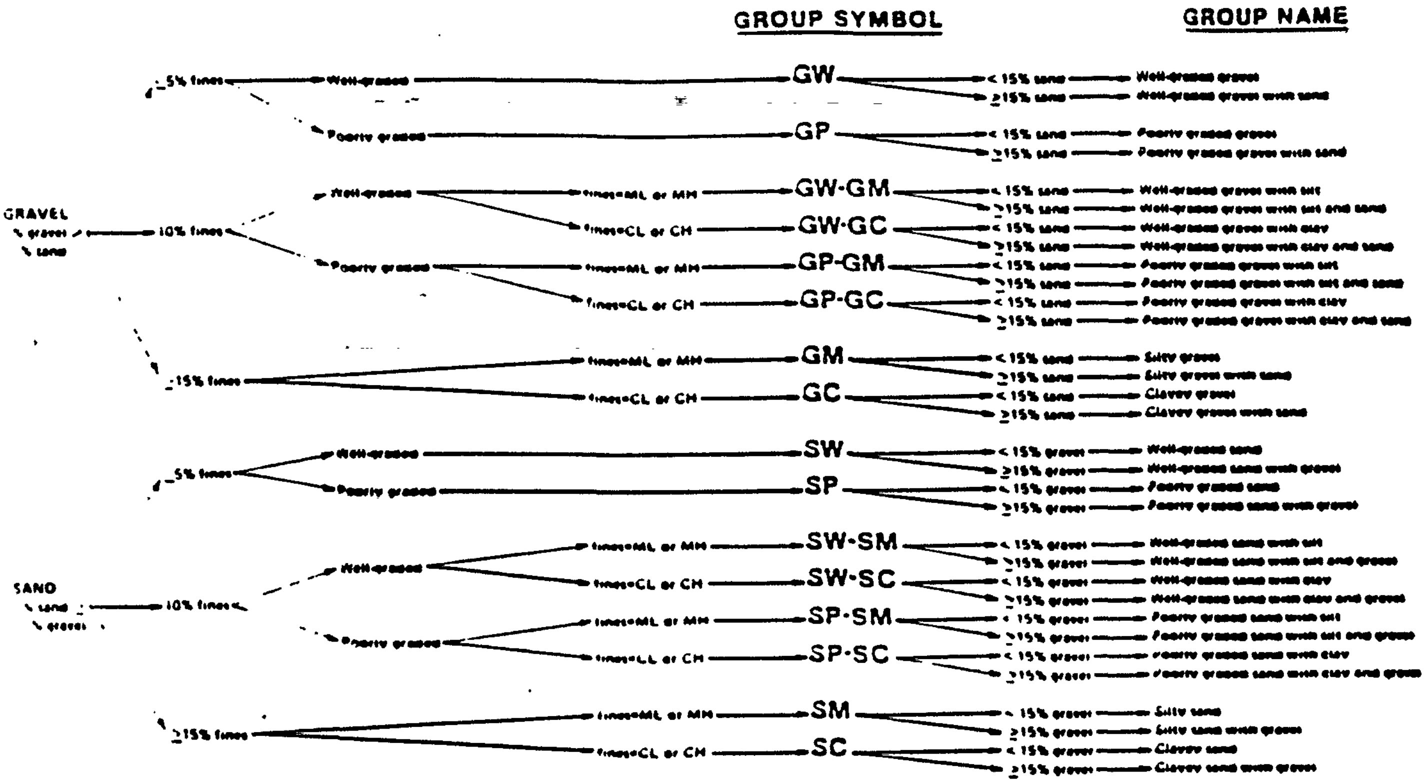
NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

en the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens.*

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 *N*) to three parts water (This reagent is optional for use with this practice). See Section 8.

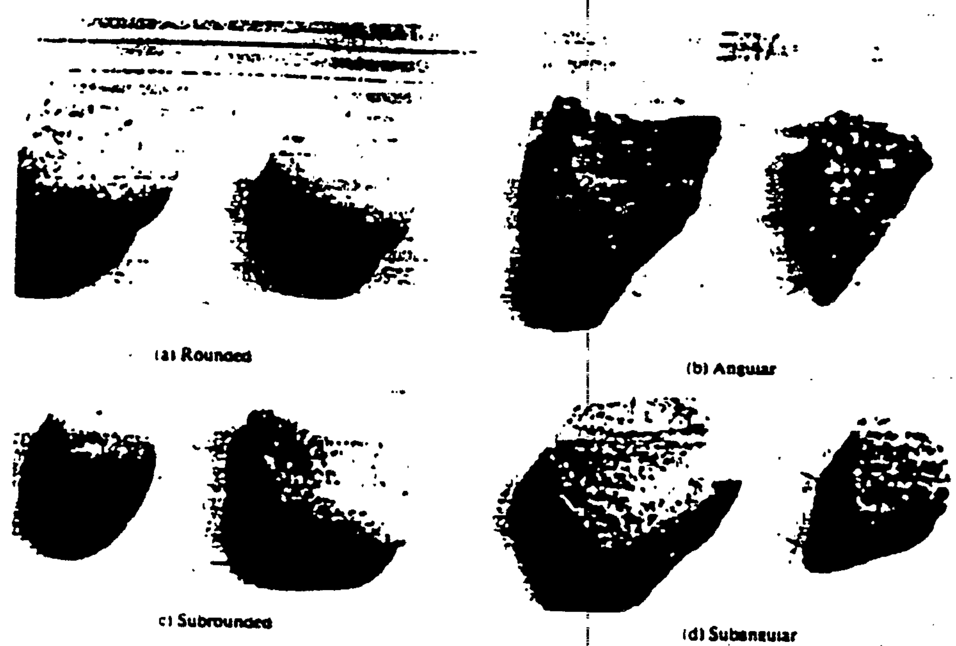


FIG. 3 Typical Angularity of Bulky Grains

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1 1/2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceeding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

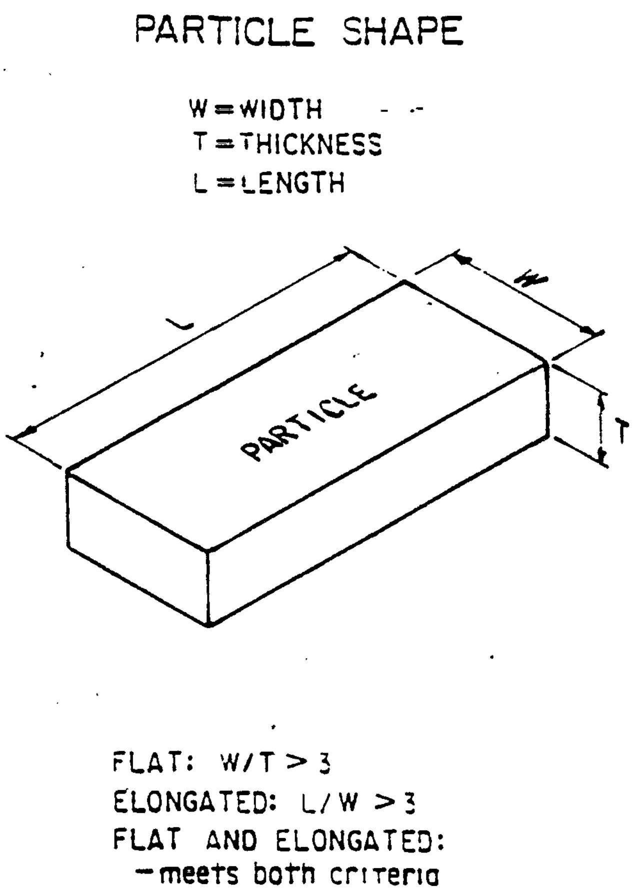


FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

)cality it may also be useful in identifying materials of
milar geologic origin. If the sample contains layers or
atches of varying colors, this shall be noted and all
epresentative colors shall be described. The color shall be
escribed for moist samples. If the color represents a dry
ondition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils ontaining a significant amount of organic material usually iave a distinctive odor of decaying vegetation. This is specially apparent in fresh samples, but if the samples are ried, the odor may often be revived by heating a moistened ample. If the odor is unusual (petroleum product, chemical, nd the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condiion as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as e, weak, or strong, in accordance with the critera in ble 4. Since calcium carbonate is a common cementing igent, a report of its presence on the basis of the reaction vith dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpre-

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

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TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 *Dry Strength*:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy*:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness:*

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about ⅛ in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about ⅛ in. The thread will crumble at a diameter of ⅛ in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils:*

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A ⅛-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 *Identification of Organic Fine-Grained Soils:*

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %
Few—5 to 10 %
Little—15 to 25 %
Some—30 to 45 %
Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
   Gravel—fine, coarse
   Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

For intact samples:

18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

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APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show h... ...tion required in 16.1 can be reported. The ... that is included in descriptions should be ... vidual circumstances and need.

X1.1.1 *Well-Graded Gravel with* ... —About 75 % fine to coarse, hard, subangular ... % fine to coarse, hard, subangular sand: ... aximum size, 75 mm, brown, dry: no reacti...

X1.1.2 *Silty Sand with Gravel* ... 0 % predominantly fine sand: about 25 ... with low plasticity, low dry strength, rapid ... ow toughness: about 15 % fine, hard, ... el, a few gravel-size particles fractured wi... maximum size, 25 mm: no reaction with H... ample size smaller than recommended).

In-Place Conditions—Firm, ... ar ... ntains lenses of silt 1 to 2 in. (25 to 50 mm ... own to gray: in-place density 106 lb/ft^3: in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness: wet, dark brown, organic odor: weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand: about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy: wet: maximum size, coarse sand: weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel: about 15 % fine, hard, subrounded to subangular sand: about 10 % silty nonplastic fines: moist, brown: no reaction with HCl: original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFI... ON ... OCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, ... L ... SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification p... e be used as a descriptive system applied to materials ... at exist in-situ as shale, claystone, sandstone, ... ne, mudstone, etc., but convert to soils after field or ... tory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as ... However, the procedures used in this practice for d... ing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)": about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness: about 35 % fine to medium, hard sand: about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation: "Poorly Graded Sand with Silt (SP-SM)": about 90 % fine to medium sand: about 10 % nonplastic fines: dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells: about 30 % sand and sand-size shell pieces: about 10 % fines: "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7, "Poorly Graded Gravel (GP)": about 90 % fine, hard, angular gravel-size particles: about 10 % coarse, hard, angular sand-size particles: dry, tan: no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle ...ze distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time: the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. RATIONALE

X5.1 This practice was significantly revised in the D 2488 – 84 version from the previous version D 2488 – 69 (1975). The revisions are documented in the literature.[5]

X5.2 Changes in this version from the previous version include rewording of 1.2.3 to say (disturbed and undisturbed), the addition of 5.7 to refer to the practice for describing frozen soils, and the addition of Appendix X5 on Rationale.

[5] Howard, A. K., "The Revised ASTM Standard on the Description and Identification of Soils (Visual-Manual Procedure)," *Geotechnical Testing Journal*, GTJODJ Vol 10, No. 4, December 1987.