Change 1

Headquarters
Department of the Army
Washington, DC, 29 December 2000

Materials Testing

1. Change FM 5-472, 27 October 1999, as follows:

Remove Old Pages	Insert New Pages
2-65 and 2-66	2-65 and 2-66
2-77 and 2-78	2-77 and 2-78
2-81 and 2-82	2-81 and 2-82
2-87 and 2-88	2-87 and 2-88

2. A bar (|) marks new or changed material.

3. File this transmittal sheet in front of the publication.

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SPECIFIC-GRAVITY TESTS

1. PROJECT ENGINEER CENTER EXPANSION		2. DATE 1 DEC 99
3. BORING NUMBER 5-C-1	4. JOB NUMBER 16-P-T	5. EXCAVATION NUMBER 5-C

6. SPECIFIC GRAVITY OF SOLIDS (G_s)

FLASK CALIBRATION DATA	a. FLASK NUMBER	b. CLEAN, DRY WEIGHT, W_b	c. FLASK + WATER WEIGHT, W_{bw}	d. OBSERVED TEMPERATURE, T_i
	#2A	171.05 Grams	667.88 Grams	25 °C

e. SAMPLE OR DETERMINATION NUMBER		5-C-1			
DETERMINATION DATA	f. DISH NUMBER		2A		
	g. WEIGHT OF DISH + DRY SOIL	Grams	308.48		
	h. WEIGHT OF DISH	Grams	269.83		
	i. WEIGHT OF DRY SOIL, W_s	Grams	38.65		
	j. WEIGHT OF FLASK + WATER + IMMERSED SOIL, W_{bws}	Grams	692.05		
	k. TEMPERATURE OF WATER, T_x	°C	23°		
	l. CALCULATED WEIGHT OF FLASK + WATER AT T_x, W_{bw}	Grams	668.12		
	m. CORRECTION FACTOR FOR T_x, K		0.9993		
n. SPECIFIC GRAVITY OF SOLIDS	$G_s = \frac{W_s K}{W_s + W_{bw} - W_{bws}}$		2.62		

7. APPARENT (G_a) AND BULK (G_m) SPECIFIC GRAVITY

a. SAMPLE OR SPECIMEN NUMBER				
b. TEMPERATURE OF WATER AND SOIL (°C) (must be within 23 ±1.7°C)				
c. TARE + SATURATED SURFACE - DRY SOIL				
DETERMINATION DATA	d. TARE			
	e. SATURATED SURFACE - DRY SOIL, *(B)*			
	f. (WIRE BASKET + SOIL) IN WATER			
	g. WIRE BASKET IN WATER			
	h. SATURATED SOIL IN WATER, *(C)*			
	i. TARE AND DRY SOIL			
	j. TARE			
	k. DRY SOIL, *(A)*			
l. APPARENT SPECIFIC GRAVITY	$G_a = (A) / (A - C)$			
m. BULK SPECIFIC GRAVITY	$G_m = (A) / (B - C)$			
n. BULK SPECIFIC GRAVITY, SATURATED SURFACE DRY (SSD)	$G_m = (B) / (B - C)$			

SAMPLE

8. REMARKS

9. TECHNICIAN *(Signature)*	10. COMPUTED BY *(Signature)*	11. CHECKED BY *(Signature)*
EACN Pineda, AP	EACN Pineda, AP	SSG Dobbs WD

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Figure 2-36. Sample DD Form 1208

$$W_{bw}\ (\textit{for specified temperature}, T_x) = \left[\frac{\rho_w(T_x)}{\rho_w(T_i)} \times \left[(W_{bw}\ \textit{at}\ T_i) - W_b\right]\right] + W_b$$

where—

ρ_w (T_x) = density of water identified by temperature (T_x) (see Table 2-7)

ρ_w (T_i) = density of water identified by temperature (T_i) (see Table 2-7)

W_{bw} = weight of pycnometer and water, in grams

W_b = weight of pycnometer, in grams

T_i = observed/recorded temperature of water, in °C

T_x = any other desired temperature, in °C

Table 2-7. Relative density of water and correction factor (K) at various temperatures

Temp °C	Relative Density	Correction Factor (K)
18.0	0.99862	1.0004
19.0	0.99843	1.0002
20.0	0.99823	1.0000
21.0	0.99802	0.9998
22.0	0.99780	0.9996
23.0	0.99757	0.9993
24.0	0.99733	0.9991
25.0	0.99708	0.9988
26.0	0.99682	0.9986
27.0	0.99655	0.9983
28.0	0.99627	0.9980
29.0	0.99598	0.9977
30.0	0.99568	0.9974
31.0	0.99537	0.9971
32.0	0.99505	0.9968

NOTE: Data obtained from ASTM. Correction factor, K, is found by dividing the relative density of water at the test temperature by the relative density of water at 20°C.

A completed graph using the above formula for the following data can be seen in *Figure 2-37*.

Calibration data:

W_{bw} = 656.43

W_b = 158.68

T_i = 24°C

$$column\ 18 = \frac{block\ 23 - column\ 16}{block\ 23} \times 100$$

Step 23. Determine the percentages for gravel, sand, and fines. Record the information on the form.

- Gravel is the material retained on the No. 4 sieve.
- Sand is the material passing the No. 4 sieve and retained on the No. 200 sieve.
- Fines are the material passing the No. 200 sieve.

Step 24. Prepare DD Form 1207 (see *Figure 2-42, page 2-78*).

a. Record the identifying information for the sample in the remarks block.

b. Use the sieve-analysis data to plot (on DD Form 1207) the sieve size and the percentage passing the sieve.

c. Using a french curve, connect the plotted points to form a smooth, free-flowing curve (the grain-size distribution curve, *Figure 2-42*).

d. Determine the coefficient of uniformity (C_u).

NOTE: The grain size, in millimeters, which corresponds to 10 percent passing on the grain-size-distribution curve, is called Hazen's effective size. It is designated by the symbol D_{10}. If the grain-size-distribution curve extends to or below 10 percent passing, then the C_u can be determined. The uniformity coefficient is the ratio between the grain diameter, in millimeters, corresponding to 60 percent passing (D_{60}) and 10 percent passing on the curve. Use the following formula and record on the form:

$$C_u = \frac{D_{60}}{D_{10}}$$

If D_{10} cannot be determined using the data from the sieve analysis, a hydrometer analysis may be required to obtain information about the smaller size grains and to extend the distribution curve to make it more complete.

e. Determine the coefficient of curvature (C_c) by using D_{60} and D_{10} as previously discussed and D_{30}, the grain diameter, in millimeters, corresponding to 30 percent passing on the grain-size-distribution curve. These numbers are used in the following formula and recorded on the form:

$$C_c = \frac{(D_{30})^2}{(D_{60} \times D_{10})}$$

NOTE: The values for D_{60}, D_{10}, and D_{30} are obtained by going to the percent passing by weight on the left vertical scale, then moving horizontally across to the right until the grain-size-distribution curve is intercepted, and then vertically down to the horizontal axis where the diameter of the material is read in millimeters. See *Figure 2-42*, for the completed gradation chart.

Step 25. Determine the gradation by using the abbreviated information listed below. Record the information on the form.

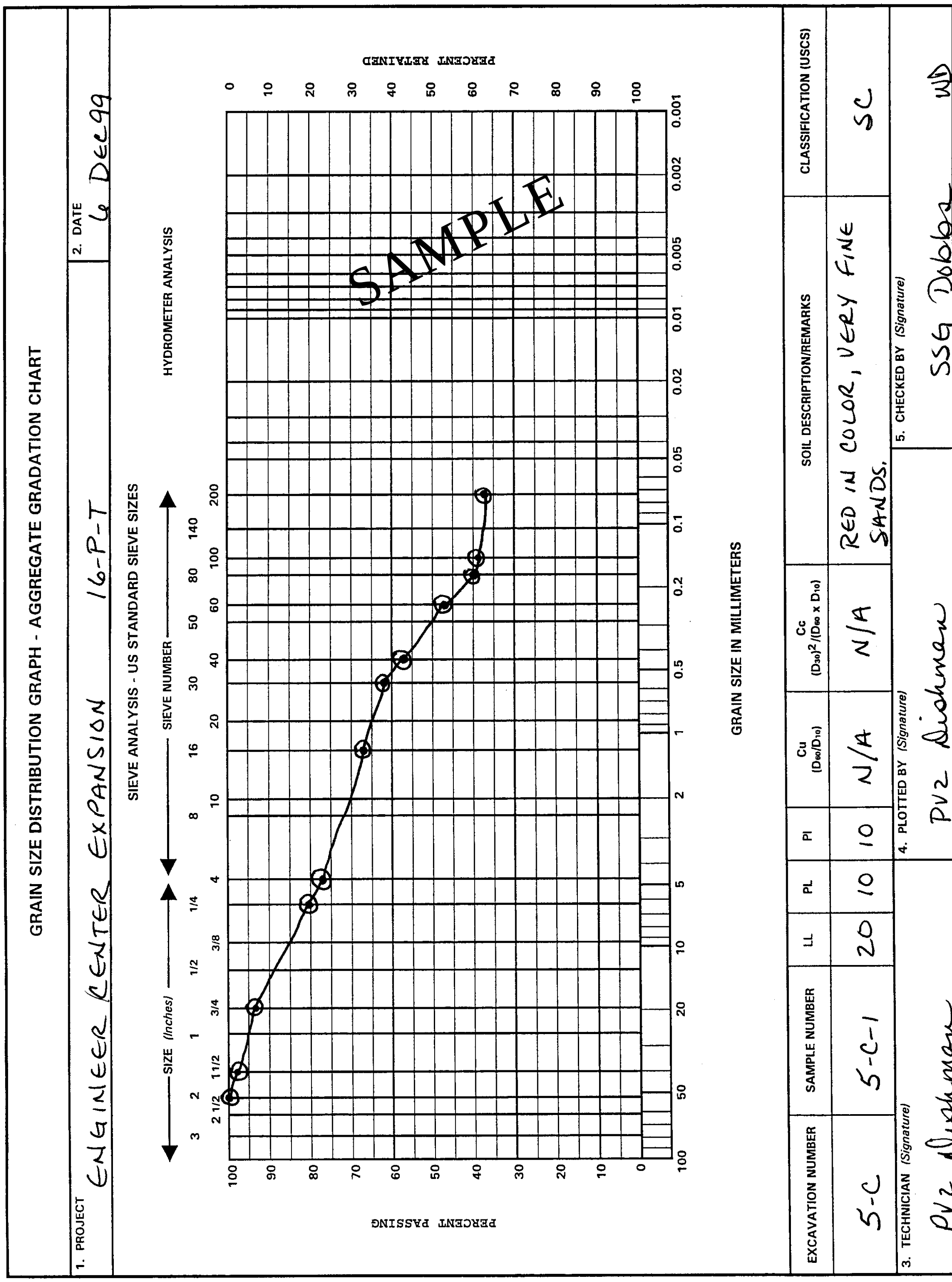

Figure 2-42. Sample DD Form 1207

GRAIN-SIZE ANALYSIS (HYDROMETER METHOD)

1. PROJECT ENGINEER CENTER EXPANSION		2. DATE 6 DEC 99
3. BORING NUMBER 5-C	4. SAMPLE OR SPECIMEN NUMBER 5-C-1	5. CLASSIFICATION SC
6. DISH NUMBER 4-A	7. GRADUATE NUMBER #3	8. HYDROMETER NUMBER/TYPE *(151H/152H)* 359557
9. DISPERSING AGENT USED SODIUM HEXAMETAPHOSPHATE		10. QUANTITY 15 ML
11. COMPOSITE CORRECTION 0.5	12. DECIMAL FINES *(Block 29, DD Form 1206)* 0.366	13. SPECIFIC GRAVITY OF SOLIDS *(Block 6n, DD Form 1208)* G_s = 2.62

14. TIME	15. ELAPSED TIME, *(T)* *minutes*	16. ACTUAL HYDROMETER READING *(R^1)*	17. CORRECTED READING *(R)*	18. TEMP *(°C)*	19. TEMPERATURE AND SPECIFIC GRAVITY CONSTANT *(K)*	20. EFFECTIVE DEPTH *(L)*	21. PARTICLE DIAMETER *(D), mm*	22. PERCENT FINER a. PARTIAL	22. PERCENT FINER b. TOTAL
0930	0								
0931	1	45.0	45.5	26	0.01272	8.8	0.0377	93.3	34.1
0932	2	43.0	43.5	26	0.01272	9.1	0.0271	89.2	32.6
0935	5	38.5	39.0	26	0.01272	9.9	0.0178	79.9	29.2
0945	15	23.5	24.0	26	0.01272	12.4	0.0115	49.2	18.0
1000	30	18.5	19.0	25	0.01286	13.2	0.0084	38.9	14.2
1030	60	15.0	15.5	25	0.01286	13.7	0.0060	31.8	11.6
1130	120	13.0	13.5	25	0.01286	14.0	0.0043	27.7	10.1
1330	240	11.0	11.5	25	0.01286	14.3	0.0031	23.6	8.6
0930	1440	8.5	9.0	24	0.01301	14.8	0.0012	18.4	6.7

WEIGHT *(Grams)*		
	23. DISH + DRY SOIL	324.90
	24. DISH	275.62
	25. DRY SOIL *(W_s)*	49.28

The particle diameter (D) is calculated from Stokes' equation using the corrected hydrometer reading. Use the following formula to solve for particle diameter (D): $D = K\sqrt{L/T}$

Corrected hydrometer reading (R) = actual hydrometer reading (R^1) + composite correction

W_s = Oven-dry weight (in grams) of soil used for hydrometer analysis

Hydrometer graduated in specific gravity (151H)

$$\text{Partial Percent Finer} = \left[\frac{G_s}{G_s - 1} \times \frac{100{,}000}{W_s}\right](R - 1)$$

Total Percent Finer = Partial Percent Finer x Decimal fines (Block 12)

0.366

Hydrometer graduated in grams per liter (152H)

$$\frac{(R)(a)}{W_s} \times 100$$

(a = specific gravity of solids correction factor)

a = 1.01

SAMPLE

26. REMARKS

RED IN COLOR, VERY FINE SANDS

FROST GROUP: F 4

27. TECHNICIAN *(Signature)*	28. COMPUTED BY *(Signature)*	29. CHECKED BY *(Signature)*
PVT Butler	PVT Butler	SFC McKimmey

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Figure 2-43. Sample DD Form 1794

Table 2-9. Dispersing agents

Dispersing Agent	Stock Solution		Manufacturer
	Concentration	Grams Per Liter	
Sodium tripolyphosphate	0.4N	29	Blockson Chemical Co, Joliet, IL
Sodium polyphosphate	0.4N	36	Blockson Chemical Co, Joliet, IL
Sodium tetraphosphate (Quadrofos)	0.4N	31	Rumford Chemical Works, Rumford, NJ
Sodium hexametaphosphate (Calgon)	0.4N	41	Calgon Co, Pittsburgh, PA

Step 2. Determine the type of hydrometer. If the hydrometer scale ranges from 1.000 to 1.038, it is a Type 151H and measures specific gravity of the suspension. If the scale ranges from 0 to 60, it is a Type 152H and measures grams per liter of the suspension. The dimensions for both hydrometers are the same.

Step 3. Determine the composite correction.

NOTE: Before performing the hydrometer test, a composite correction for hydrometer readings must be determined to correct for items that tend to produce errors in the test.

The first of these items needing correction is the meniscus reading. 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.

The second of these items needing correction is a result of using a dispersing agent in the water to control flocculation. This leads to errors in the analysis. While the dispersing agent assists in keeping the soil grains from adhering to each other, it also increases the specific gravity of the fluid used.

The net amount of the correction for the two corrections required is designated as the composite correction.

a. Place about 500 milliliters of distilled water in a graduated cylinder.

b. Place the amount of dispersing agent that was used in step 1 in the cylinder and mix well.

c. Add additional distilled water to the cylinder to reach the 1,000-milliliter mark.

d. Place the hydrometer in the cylinder and allow it to settle for 20 to 25 seconds. Read the hydrometer at the top of the meniscus formed on the

Table 2-12. Specific-gravity correction factors applied to hydrometer 152H for computing partial percent finer

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

f. Compute the total percent finer for each hydrometer reading and record it on the form using the formula—

Total percent finer = partial percent finer x decimal fines (block 12)

PRESENTATION OF RESULTS

Plot the grain-size distribution on DD Form 1207 using the particle diameters (D, grain-size, in millimeters) and the total percent finer (percent passing) and connect the plotted points with a smooth curve (see *Figure 2-44, page 2-88*).

Read the curve on the form and determine if 3 percent or more of the particles are smaller than 0.02 millimeter in diameter; if so, the soil is frost susceptible.

Frost-susceptible soils are listed in four groups in the order of increasing susceptibility (see *Table 2-13, page 2-89*).

Soils in group F-4 have high frost susceptibility. Record the frost-susceptibility group for the soil type in block 27 of DD Form 1794 (see *Figure 2-43, page 2-81*).

This curve can be used to determine the coefficient of uniformity (C_u) and the coefficient of curvature (C_c).

The data in the example shown on DD Form 1794 (*Figure 2-43, page 2-81*) is plotted on DD Form 1207 to give an example of such a curve for a mixed soil (see *Figure 2-44*). For this soil, the diameter corresponding to 60 percent passing (D_{60}) is 0.5 millimeter. The diameter corresponding to 10 percent passing (D_{10}) is 0.0045 millimeter. Hence, the coefficient of uniformity is as follows:

$$C_U = \frac{D_{60}}{D_{10}} = \frac{0.5}{0.0045} = 111.11$$

The diameter for 30 percent passing (D30) is 0.024 millimeters. Thus, the coefficient of curvature is as follows:

$$C_C = \frac{(D_{30})^2}{D_{60} \times D_{10}} = \frac{(0.024)^2}{0.5 \times 0.0045} = \frac{0.000576}{0.00225} = 0.256$$

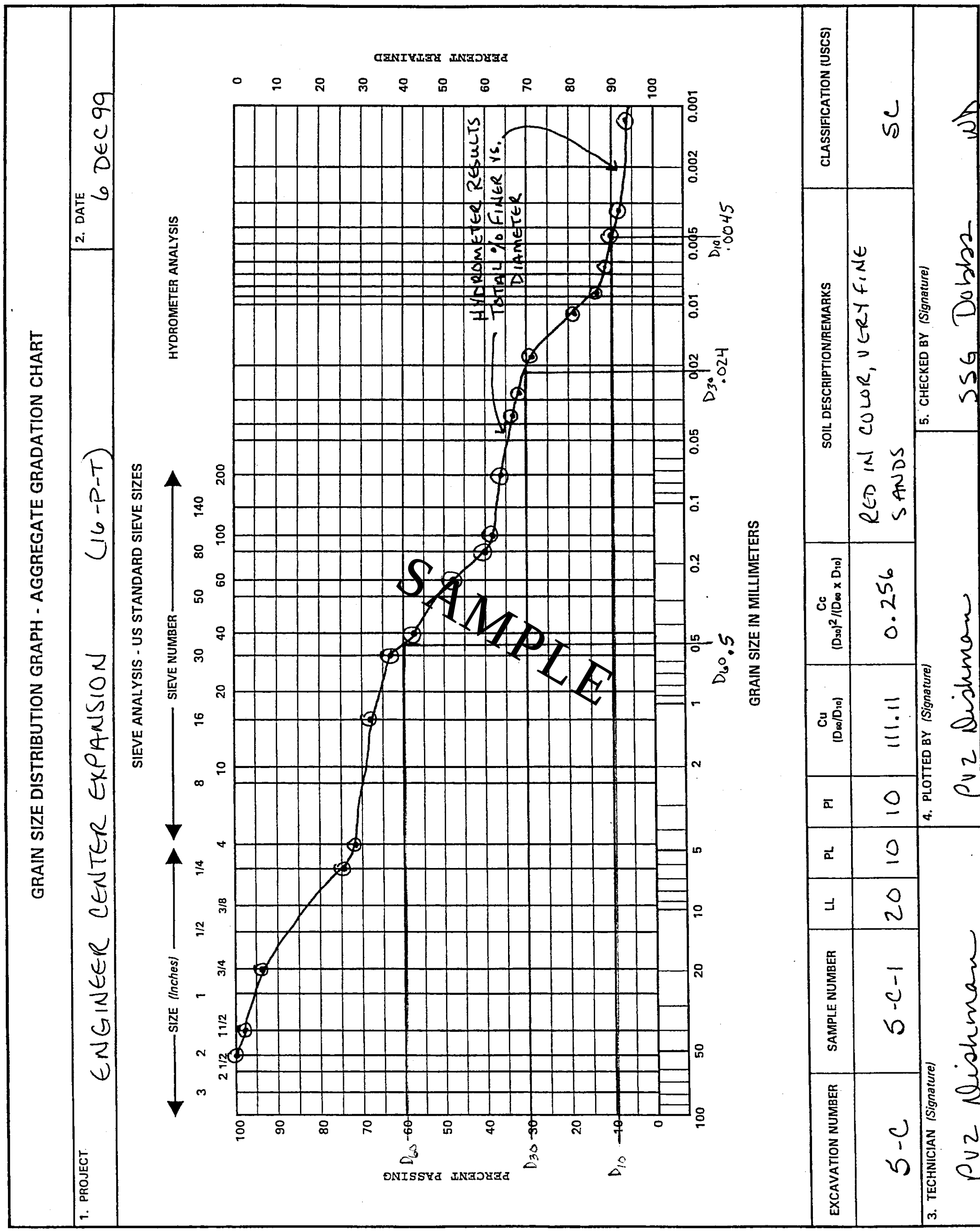

Figure 2-44. Sample DD Form 1207