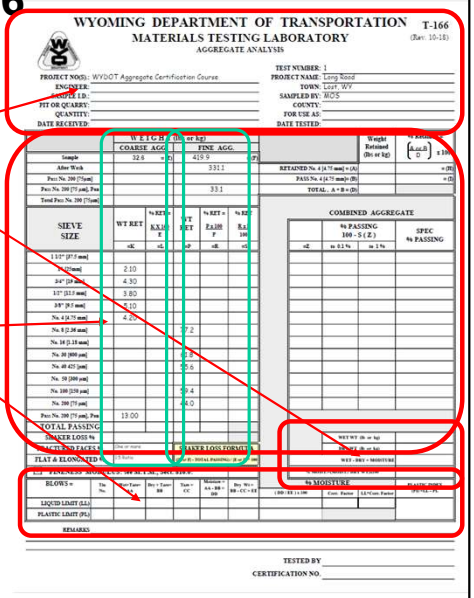
AGGREGATES

Section 8 – Aggregate Gradation Calculations

Aggregate Analysis
T-166

- The T-166 form has several important parts.
  - Project Identification
  - Initial Moisture Content
  - Atterberg Limits
  - Gradation Analysis
- The sheet shows the results of the lab testing.
  - Coarse Aggregate (Gilson) Test
  - Fine Aggregate and Wash Sieve Tests


WYOMING DEPARTMENT OF TRANSPORTATION T-166
MATERIALS TESTING LABORATORY
AGGREGATE ANALYSIS

T-166 Example 1

	WEIGHT (lbs or kg)				
	COARSE AGG.		FINE AGG.		
Sample	32.6 = (E)		419.9 = (F)		
After Wash			331.1		
Pass No. 200 [75µm]			88.8		
Pass No. 200 [75 µm], Pan			33.1		
Total Pass No. 200 [75µm]					

SIEVE SIZE	WT RET	% RET = K X 100 / E	WT RET	% RET = P x 100 / F	% RET R x I / 100
	=K	=L	=P	=R	=S
1 1/2" [37.5 mm]					
1" [25mm]	2.10	6.4			
3/4" [19 mm]	4.30				
1/2" [12.5 mm]	3.80				
3/8" [9.5 mm]	5.10	15.6			
No. 4 [4.75 mm]	4.20	12.9			
No. 8 [2.36 mm]			77.2		7.4
No. 16 [1.18 mm]					
No. 30 [600 µm]			61.8	14.7	
No. 40 425 [µm]			55.6		
No. 50 [300 µm]					
No. 100 [150 µm]			59.4	14.1	5.6
No. 200 [75 µm]			44.0	10.5	4.2
Pass No. 200 [75 µm], Pan	13.00	39.9	121.9	29.0	11.6
TOTAL PASSING			419.9	99.9	
SHAKER LOSS %	0.3 %		0.0 %		
FRACTURED FACES %	One or more		SHAKER LOSS FORMULA		
FLAT & ELONGATED %	1:5 Ratio		([E or F] - TOTAL PASSING) / [E or F] * 100		

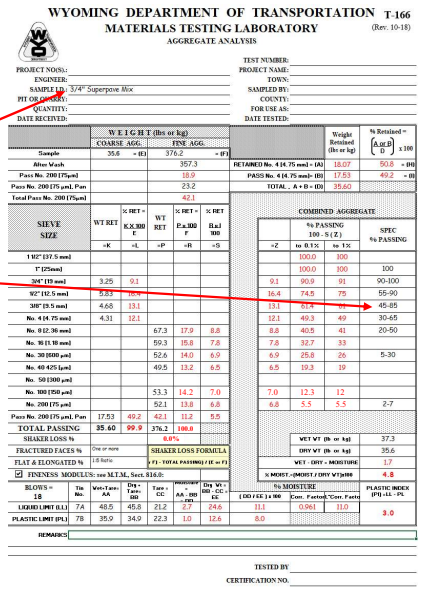
	Weight Retained (lbs or kg)	% Retained = (A or B / D) x 100
RETAINED No. 4 [4.75 mm] = (A)	19.50	= (H)
PASS No. 4 [4.75 mm]= (B)		40.0 = (I)
TOTAL , A + B = (D)	32.50	

COMBINED AGGREGATE				
	% PASSING 100 - S (Z)		SPEC % PASSING
=Z	to 0.1 %	to 1 %	
	100.0		
	93.6		
13.2	80.4		
11.7			
15.6			
		40	
7.4	32.8	33	
5.9	26.9	27	
5.3	21.6	22	
5.6	16.0	16	
4.2	11.8	12	

WET WT (lb or kg)	
DRY WT (lb or kg)	
WET - DRY = MOISTURE	

Aggregate Analysis
T-166

- **This example tests the gradation against the specification for a 3/4" Superpave Mix.**
  - **The sieve specification range is written in the right-hand column.**
  - **After the sieve analysis is completed, the results are compared against the range.**
- **Note: This is a complete sheet with water content, Atterburg Limits and Gradations all calculated.**



WYOMING DEPARTMENT OF TRANSPORTATION T-166
MATERIALS TESTING LABORATORY (Rev. 10-18)
AGGREGATE ANALYSIS

PROJECT NO(S): | TEST NUMBER:
ENGINEER: | PROJECT NAME:
SAMPLE ID: 3/4" Superpave Mix | TOWN:
PIT OR SOURCE: | SAMPLED BY:
QUANTITY: | COUNTY:
DATE RECEIVED: | FOR USE AS:
| DATE TESTED:

	WEIGHT (lbs or kg) COARSE AGG.		FINE AGG.		
Sample	35.6	= (E)	376.2		= (F)
After Wash			357.3		
Pass No. 200 [75 µm]			18.9		
Pass No. 200 [75 µm], Pan			23.2		
Total Pass No. 200 [75µm]			42.1		

	Weight Retained (lbs or kg)	% Retained = (A or B / D) x 100
RETAINED No. 4 [4.75 mm] = (A)	18.07	50.8 = (H)
PASS No. 4 [4.75 mm]= (B)	17.53	49.2 = (I)
TOTAL , A + B = (D)	35.60	

SIEVE SIZE	WT RET =K	% RET = K X 100 / E =L	WT RET =P	% RET = P x 100 / F =R	% RET 100 - R =S	COMBINED AGGREGATE % PASSING 100 - S (Z) =Z	to 0.1%	to 1%	SPEC % PASSING
1 1/2" [37.5 mm]							100.0	100	
1" [25mm]							100.0	100	100
3/4" [19 mm]	3.25	9.1				9.1	90.9	91	90-100
1/2" [12.5 mm]	5.83	16.4				16.4	74.5	75	55-90
3/8" [9.5 mm]	4.68	13.1				13.1	87.4	87	45-85
No. 4 [4.75 mm]	4.31	12.1				12.1	49.3	49	30-65
No. 8 [2.36 mm]			67.3	17.9	8.8	8.8	40.5	41	20-50
No. 16 [1.18 mm]			59.3	15.8	7.8	7.8	32.7	33	
No. 30 [600 µm]			52.6	14.0	6.9	6.9	25.8	26	5-30
No. 40 425 [µm]			49.5	13.2	6.5	6.5	19.3	19	
No. 50 [300 µm]									
No. 100 [150 µm]			53.3	14.2	7.0	7.0	12.3	12	
No. 200 [75 µm]			52.1	13.8	6.8	6.8	5.5	5.5	2-7
Pass No. 200 [75 µm], Pan	17.53	49.2	42.1	11.2	5.5				
TOTAL PASSING	35.60	99.9	376.2	100.0					
SHAKER LOSS %			0.0%						

FRACTURED FACES %	One or more	SHAKER LOSS FORMULA	WET WT (lb or kg)	37.3
FLAT & ELONGATED %	1:5 Ratio	(F) - TOTAL PASSING) / (E or F)	DRY WT (lb or kg)	35.6
☑ FINENESS MODULUS: see M.T.M., Sect. 816.b:			WET - DRY = MOISTURE	1.7
			% MOIST = [MOIST / DRY WT]x100	4.8

BLOWS = 18	Tin No.	Wet+Tare AA	Dry+Tare BB	Tare = CC	MOISTURE = AA - BB = DD	Dry Wt = BB - CC = EE	% MOISTURE (DD / EE) x 100	Corr. Factor	Corr. Factor	PLASTIC INDEX (PI) =LL - PL
LIQUID LIMIT (LL)	7A	48.5	45.8	21.2	2.7	24.6	11.1	0.961	11.0	3.0
PLASTIC LIMIT (PL)	7B	35.9	34.9	22.3	1.0	12.6	8.0			

REMARKS:

TESTED BY
CERTIFICATION NO.

T-166
Example 2

	WEIGHT (lbs or kg)						Weight Retained (lbs or kg)	% Retained = (A or B / D) x 100
	COARSE AGG.		FINE AGG.					
Sample	35.6 = (E)		376.2 = (F)					
After Wash			357.3		RETAINED No. 4 [4.75 mm] = (A)		18.07	50.8 = (H)
Pass No. 200 [75µm]			18.9		PASS No. 4 [4.75 mm]= (B)		17.53	49.2 = (I)
Pass No. 200 [75 µm], Pan			23.2		TOTAL , A + B = (D)		35.60	
Total Pass No. 200 [75µm]								

SIEVE SIZE	WT RET	% RET = K X 100 / E	WT RET	% RET = P x 100 / F	% RET R x I / 100	COMBINED AGGREGATE			
							% PASSING 100 - S (Z)		SPEC % PASSING
	=K	=L	=P	=R	=S	=Z	to 0.1 %	to 1 %	
1 1/2" [37.5 mm]							100.0	100	
1" [25mm]									100
3/4" [19 mm]	3.25	9.1				9.1	90.9	91	90-100
1/2" [12.5 mm]	5.83	16.4				16.4	74.5	75	55-90
3/8" [9.5 mm]	4.68								45-85
No. 4 [4.75 mm]	4.31								30-65
No. 8 [2.36 mm]			67.3	17.9	8.8	8.8			20-50
No. 16 [1.18 mm]			59.3	15.8	7.8	7.8	32.7		
No. 30 [600 µm]			52.6				25.8	26	5-30
No. 40 425 [µm]			49.5						
No. 50 [300 µm]									
No. 100 [150 µm]			53.3		7.0			12	
No. 200 [75 µm]			52.1			6.8	5.5	5.5	2-7
Pass No. 200 [75 µm], Pan	17.53		42.1		5.5				
TOTAL PASSING		99.9	376.2	100.0					
SHAKER LOSS %	0.0 %		0.0 %				WET WT (lb or kg)		37.3
FRACTURED FACES %	One or more		SHAKER LOSS FORMULA				DRY WT (lb or kg)		35.6
FLAT & ELONGATED %	1:5 Ratio		([E or F] - TOTAL PASSING) / [E or F] * 100				WET - DRY = MOISTURE		1.7

Section 8 – 5

WYOMING DEPARTMENT OF TRANSPORTATION T-166

MATERIALS TESTING LABORATORY (Rev. 10-18)

AGGREGATE ANALYSIS

PROJECT NO(S).: TEST NUMBER:
ENGINEER: PROJECT NAME:
SAMPLE I.D.: 3/4" Superpave Mix TOWN:
PIT OR QUAREY: SAMPLED BY:
QUANTITY: COUNTY:
DATE RECEIVED: FOR USE AS:
DATE TESTED:

	WEIGHT (lbs or kg)							Weight Retained (lbs or kg)	% Retained = (A or B / D) x 100	
	COARSE AGG.		FINE AGG.							
Sample	35.60	=(E)	376.2	=(F)						
After Wash			357.3		RETAINED No. 4 [4.75 mm] = (A)			18.07	50.8	=(H)
Pass No. 200 [75µm]			18.9		PASS No. 4 [4.75 mm]= (B)			17.53	49.2	=(I)
Pass No. 200 [75µm], Pan			23.2		TOTAL , A + B = (D)			35.60		
Total Pass No. 200 [75µm]			42.1							

SIEVE SIZE	WT RET	% RET = K x 100 / E	WT RET	% RET = P x 100 / F	% RET R x I 100	COMBINED AGGREGATE Z	% PASSING 100 - S (Z) to 3.1 %	to 1%	SPEC % PASSING
	=K	=L	=P	=R	=S				
1 1/2" [37.5 mm]							100.0	100	
1" [25mm]							100.0	100	100
3/4" [19 mm]	3.25	9.1				9.1	90.9	91	90-100
1/2" [12.5 mm]	5.83	16.4				16.4	74.5	75	55-90
3/8" [9.5 mm]	4.68	13.1				13.1	61.4	61	45-85
No. 4 [4.75 mm]	4.31	12.1				12.1	49.3	49	30-55
No. 8 [2.36 mm]			67.3	17.9	8.8	8.8	40.5	41	20-50
No. 16 [1.18 mm]			59.3	15.8	7.8	7.8	32.7	33	
No. 30 [600 µm]			52.6	14.0	6.9	6.9	25.8	26	5-30
No. 40 425 µm]			49.5	13.2	6.5	6.5	19.3	19	
No. 50 [300 µm]									
No. 100 [150 µm]			53.3	14.2	7.0	7.0	12.3	12	
No. 200 [75 µm]			52.1	13.8	6.8	6.8	5.5	5.5	2-7
Pass No. 200 [75µm], Pan	17.53	49.2	42.1	11.2	5.5				
TOTAL PASSING	35.60	99.9	376.2	100.1					
SHAKER LOSS %							WET WT (lb or kg)		37.3
FRACTURED FACES %	One or more		SHAKER LOSS FORMULA				DRY WT (lb or kg)		35.6
FLAT & ELONGATED %	1:5 Ratio		(F1 - TOTAL PASSING) / E or F1				WET - DRY = MOISTURE		1.7
☑ FINENESS MODULUS: see M.T.M., Sect. 816.0:							% MOIST.=(MOIST./ DRY WT)x100		4.8

BLOWS = 13	Tin No.	Wet+Tare= AA	Dry+Tare= BB	Tare = CC	Moisture = AA - BB = DD	Dry Wt.= BB - CC = EE	% MOISTURE (DD / EE) x 100	Corr. Factor	"Corr. Factor	PLASTIC INDEX (PI) =LL - PL
LIQUID LIMIT (LL)	7A	48.5	45.8	21.2	2.7	24.6	11.0	0.961	11	3
PLASTIC LIMIT (PL)	73	35.9	34.9	22.3	1.0	12.6	8			

REMARKS

TESTED BY

CERTIFICATION NO.

- **Note: This is a complete sheet with water content, Atterburg Limits and Gradations all calculated.**

Correlation of Testing Technicians for Gradation

The actual calculations of the correlation will not be on the exam but you would need to have an appreciation to the process. In addition, you would need to be able to answer general questions about the process.

Correlation of Testing Technicians for Gradation

(WYDOT MTM 126.0)

- **General**
  - **Compares aggregate gradations obtained by WYDOT field laboratory and Contractor's laboratory.**
  - **The paired t-test is used.**
  - **If difference is significant, then the dispute resolution procedure will start.**
  - **Re-correlate if either tester is changed.**
  - **Can be done during aggregate production.**

Correlation of Testing Technicians for Gradation

- **Procedure**
  - **Obtain 15 aggregate samples**
    - **Groups of 3**
    - **Sample according to WYDOT MTM 804**
    - **5 samples for WYDOT, 5 for contractor, and 5 for referee**
    - **When sampling from a belt, the middle sample should be the referee sample**
  - **Test samples**
    - ***WYDOT MTM 814.0***

Procedural Steps on Form

- Determine percent passing each sieve size
- Perform t-test separately for each sieve size
- Calculate the difference between % passing
- Determine the mean and the Standard Deviation (s) of the differences

Procedure (continued)

- **Compare s to the minimum and maximum values in Table 1.**
- **Calculate** $t = \dfrac{|\bar{x}|}{\sqrt{\dfrac{s^2}{n}}}$
- **If t < 4.604; No significant difference**
- **If t > 4.604; Significant difference**
- **Check for Sign Error – Do the Differences all have the same sign? May Indicate Bias.**

Table 1. Allowable Range of Standard Deviation

Percent Retained	Grading			
	Coarse		Fine	
	Maximum	Minimum	Maximum	Minimum
< 3%	3.00	0.39	0.60	0.21
3% - 10%	3.00	1.06	1.60	0.57
10% - 20%	4.70	1.66	2.70	0.95
20% - 30%	5.70	2.01	3.50	1.24
30% - 40%	6.90	2.44	4.00	1.41
>40%	9.00	3.18	5.20	1.41

- **Use the coarse values unless the nominal maximum aggregate size is #4 or less, in which case use the fine values**

Directional Bias

- **Evaluate for directional bias. "Directional bias" exists when all of the paired test differences are positive or negative and the average difference on at least one sieve exceeds the Allowable Gradation Difference in Table 3.**
- **If directional bias exists, consult Subsection 114.3.3, Correlation.**
- **Continue evaluation to find the cause of the directional bias.**

Table 3 Allowable Gradation Differences

Table 3. Allowable Gradation Difference

	Grading (Nominal Maximum Size)					
	1 inch	¾ inch	½ inch	⅜ inch	PMWC	Concrete
Sieve	Allowable Difference (% Passing)					
1 ¼ inch	1.5					1.5
1 inch	2.0	1.5				2.0
¾ inch	3.0	2.0	1.5			3.0
½ inch	3.4	3.0	2.0	1.5	1.5	3.4
⅜ inch	3.4	3.4	3.4	2.0	2.0	3.4
No. 4	3.4	3.4	3.4	3.4	3.4	3.4
No. 8	3.3	3.3	3.3	3.3	3.3	3.3
No. 16						3.3
No. 30	2.9	2.9	2.9	2.9		
No. 50						2.9
No. 100						2.9
No. 200	1.2	1.2	1.2	1.2	1.2	1.2

Resolving Directional Bias

Perform additional correlation tests if the correlation procedure shows that directional bias is present. Continue performing correlation testing until the directional bias no longer exists in accordance with Subsection 114.3.4, Resolving Field Test Discrepancies. The department's test results will be used for pay factor analysis while correlation testing is being done. Perform new correlation tests if new equipment or personnel (department or contractor) are introduced during testing.

114.3.4 Resolving Field Testing Discrepancies

1. Meet with department personnel and review testing procedures, equipment condition, and equipment calibrations in attempt to solve the problem.
2. When cause of the discrepancy has been identified and corrected, repeat the correlation procedure.
3. If the second correlation determines that the contractor's and department's test results represent different sample populations, conduct referee testing.

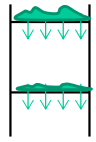
114.3.4 Resolving Field Testing Discrepancies

4. The Materials Program will conduct the referee tests using the retained referee samples for aggregate gradations and the department's cores for density testing.
5. The Materials Program will make its results available within five working days of receiving the samples.
6. If the samples represent a quality acceptance lot, the engineer will use test results correlating with the Materials Program test results for the quality acceptance calculations.

Correlation of Testing Technicians for Gradation

Example- #1:

Sampler: _____ Contractor: _____
Project: _____ Location: _____
Test Sieve Size: #4 Date: _____
Average % Passing 1/2" is 57.2%
Grading W - Coarse Gradation



% Retained =

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A	49.2	49.8	
B	50.6	46.3	
C	49.6	51.2	
D	51.2	48.3	
E	50.9	48.2	
		Mean -x̄:	
Average Passing =	49.53	Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If t > t_{crit}, then the data sets are Significantly Different
If t ≤ t_{crit}, then the data sets are Not Significantly Different
Is there directional bias?_____

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$

$s = 2.513$

$s \times s = 2.513 \times 2.513$

$s^2 = 6.315$

$\frac{s^2}{n} = \frac{6.315}{5}$

$\frac{s^2}{n} = 1.263$

$\sqrt{\frac{s^2}{n}} = \sqrt{1.263}$

$\sqrt{\frac{s^2}{n}} = 1.124$

$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}} = \frac{1.54}{1.124}$

$t = 1.371$

Section 8 - 18

Correlation of Testing Technicians for Gradation

Example - #2:

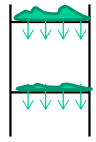
Sampler: _____ Contractor: _____

Project: _____ Location: _____

Test Sieve Size: #4 Date: _____

Average % Passing 1/2" is 57.2%

Grading W - Coarse Gradation



% Retained =

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A	49.2	46.7	
B	50.6	47.3	
C	49.6	47.3	
D	51.2	48.3	
E	50.9	48.2	
		Mean - $\bar{x}$:	
Average Passing =	48.93	Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If $t > t_{crit}$, then the data sets are Significantly Different

If $t \leq t_{crit}$, then the data sets are Not Significantly Different

Is there directional bias?_____

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$

s = _____

s x s = ____ x ____

s^2 = _____

$\frac{s^2}{n}$ = _____ / 5 =

$\frac{s^2}{n}$ = _____

$\sqrt{\frac{s^2}{n}}$ = $\sqrt{\_\_\_\_}$ =

$\sqrt{\frac{s^2}{n}}$ = _____

$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$ = _____ =

t = _____

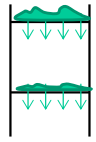
Section 8 - 19

Correlation of Testing Technicians for Gradation

Example - #3:

Sampler: _____ Contractor: _____
Project: _____ Location: _____
Test Sieve Size: #200 Date: _____
Average % Passing #30 is 14.5%
Grading W - Coarse Gradation

$$t = \frac{|\bar{x}|}{\sqrt{\frac{s^2}{n}}}$$



% Retained =

Sample	Percent Passing Test Sieve WYDOT (A)	Contractor (B)	Difference (A) - (B)
A	2.75	2.64	
B	2.60	2.81	
C	3.12	3.53	
D	3.05	3.69	
E	2.88	3.01	
		Mean -x̄:	
Average Passing =	3.01	Std Dev - s:	
		Min SD:	
		Max SD:	
		SD Used:	
		t :	
		t > (t_{crit}=4.604):	

If t > t_{crit}, then the data sets are Significantly Different
If t ≤ t_{crit}, then the data sets are Not Significantly Different
Is there directional bias? _____

Section 8 - 20

Correlation of Aggregate Gradations

WYOMING DEPARTMENT OF TRANSPORTATION

T 165 AG
REV (4-2004)

CORRELATION OF AGGREGATE GRADATIONS

Contractor: ______ Consultant: ______ Project No(s): ______
WYDOT: ______ Resident Engineer: ______ Test is to Correlate (Check One)
Testing Date: ______ Testers A______
QC Supervisor: ______ Mechanical Sampler: ______ B______

Control Sieve Sizes & Average %	Tester	Percents Passing					Avg	Std Dev	Max SD	Min SD	t crit=	
		Pair A	Pair B	Pair C	Pair D	Pair E					t=	Pass / Fail
	Contractor											
	WYDOT											
	Difference											
	Contractor											
	WYDOT											
	Difference											
	Contractor											
	WYDOT											
	Difference											
	Contractor											
	WYDOT											
	Difference											
	Contractor											
	WYDOT											
	Difference											
	Contractor											
	WYDOT											
	Difference											

Directional Bias on Any Sieve? ______ Which One(s)? ______

Comments: ______

Signature of Tester A: ______ Signature of Tester B: ______ Date: ______

Correlation of Aggregate Gradations

WYOMING DEPARTMENT OF TRANSPORTATION

T 165 AG
REV (4-2004)

CORRELATION OF AGGREGATE GRADATIONS

Contractor: Curly Queue Consultant: Besttesters Project No(s): 12-34-(56)
WYDOT: Moe Thyme Resident Engineer: Larry Stuge Test is to Correlate (Check One)
Testing Date: 2/29/99 Testers A X
QC Supervisor: M. Magoo Mechanical Sampler: B

Control Sieve Sizes & Average %	Tester	Percents Passing					Avg	Std Dev	Max SD	Min SD	t crit=	
		Pair A	Pair B	Pair C	Pair D	Pair E					t=	Pass / Fail
1"	Contractor	89.9	88.5	92.5	91.1	86.5	89.8					
	WYDOT	91.0	89.6	88.4	92.0	88.9						
10.2	*Difference*	-1.1	-1.1	4.1	-0.9	-2.4	-0.28	2.52	4.7	1.66	0.248	Pass
3/4"	Contractor	78.6	79.0	77.2	81.2	81.0	79.2					
	WYDOT	79.2	78.9	76.5	79.9	80.5						
10.6	*Difference*	-0.6	0.1	0.7	1.3	0.5	0.4	0.71	4.7	1.66	0.539	Pass
1/2"	Contractor	56.3	55.4	55.0	60.4	59.8	58.6					
	WYDOT	58.9	58.0	59.5	60.2	62.3						
20.6	*Difference*	-2.6	-2.6	-4.5	0.2	-2.5	-2.4	1.68	5.7	2.01	2.67	Pass
#4	Contractor	24.8	24.2	27.2	22.3	24.7	28.2					
	WYDOT	31.3	35.6	31.1	31.6	29.5						
30.4	*Difference*	-6.5	-11.4	-3.9	-9.3	-4.8	-7.18	3.13	6.9	2.44	5.129	Fail
#30	Contractor	11.5	12.6	10.5	14.0	14.6	13.3					
	WYDOT	14.0	12.9	11.6	15.4	15.9						
14.9	*Difference*	-2.5	-0.3	-1.1	-1.4	-1.3	-1.32	0.88	4.7	1.66	1.778	Pass
#200	Contractor	6.5	8.2	6.8	7.3	8.9	7.6					
	WYDOT	7.1	8.4	7.3	7.1	7.9						
5.8	*Difference*	-0.6	-0.2	-0.5	0.2	1.0	-0.02	0.65	3	1.06	0.042	Pass

Directional Bias on Any Sieve? Yes Which One(s)? #4

Comments: There appears to be a significant problem on the #4.

Signature of
Tester A: Curly Queue

Signature of
Tester B: Moe Thyme Date: 2/29/99