ASPHALT CONTENT OF HOT BITUMINOUS MIXES USING NUCLEAR ASPHALT CONTENT GAUGES

Final Report

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16. Abstract

The Oregon State Highway Division (OSHD) currently uses the Vacuum Extraction procedure for acceptance testing for asphalt content of asphaltic concrete. Because of the concern with Chlorinated solvent, i.e. safety, disposal, and expense, OSHD has investigated the potential of Nuclear Asphalt Content Gauges.

In June 1988, OSHD published a report titled "Precision and Accuracy of Nuclear Asphalt Content Gauges in Determining Asphalt Content in Asphaltic Concrete Pavement." This report concluded a proper calibration is essential, moisture correction is necessary, and the Nuclear Gauges are cost effective. This study is to validate previous findings, evaluate field performance, and develop necessary calibration and operation procedures.

A total of thirteen OSHD projects were included in this study. Asphalt content comparisons were evaluated between Extraction, Nuclear Gauge, Tank Stick, and Plant Meter. The latest model Nuclear Gauges, Troxler 3241-C and CPN AC-2, were used. Gradation comparisons were evaluated between extracted and cold feed grading.

This study concluded the asphalt gauge to be a precise and accurate instrument, but the reading must be corrected for moisture content. The Microwave moisture correction is not acceptable, therefore, a detailed procedure was written for moisture correction using a conventional oven. Also, a new nuclear gauge procedure entailed the use of calibration transfers for field operation.

Oregon is proceeding with outfitting each OSHD Region with asphalt nuclear gauges and is immediately reducing solvent usage by replacing vacuum extraction testing of open graded and plant mix bituminous base mixtures with a Tank Stick/Meter asphalt content determination method.

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We would also like to thank Troxler and CPN Corporations for their generous loan of the nuclear asphalt content gauges used in this study.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents of this report do not necessarily reflect the views or policies of the Oregon Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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1.0 INTRODUCTION

1.1 Problem Statement

The Oregon State Highway Division (OSHD) currently uses the vacuum extraction procedure to determine the asphalt content of asphaltic concrete pavements. This procedure uses a chlorinated solvent (111-trichlorethane) during the extraction process, which creates concerns about safety of the operator and disposal of the hazardous waste. OSHD has explored several alternatives to the use of chlorinated solvent, and this study details the research undertaken with the nuclear asphalt content gauge (asphalt gauge) alternative.

1.2 Background

The National Asphalt Pavement Association 1988 report[1] surveyed all state highway agencies to determine the acceptance methods used for asphalt determination. Figure 1 shows 10 states using asphalt gauges as of June 1988.

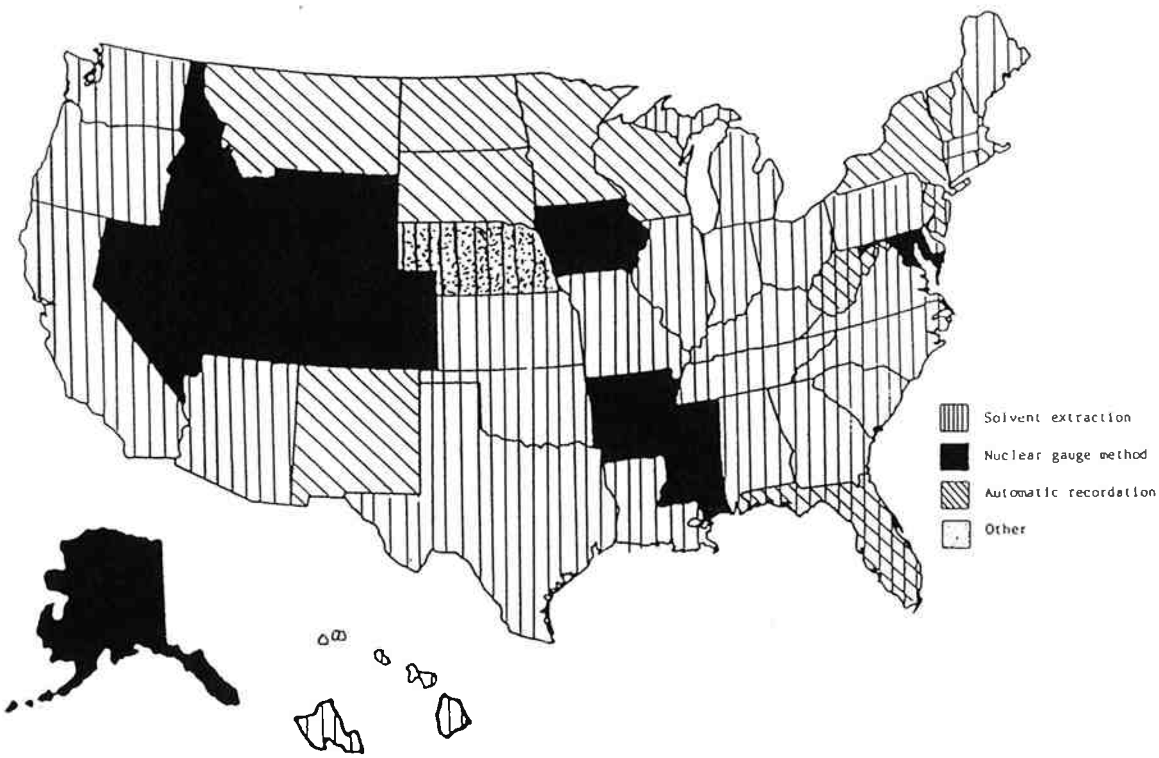

FIGURE 1 NAPA SURVEY

Currently nineteen states are using the asphalt gauge as a viable alternative. Some states have written research studies evaluating the gauges[2,3,4,5,6,7,8,9,10], while other states are continuing to evaluate the possibilities. Oregon first evaluated the asphalt gauge in 1980. In 1987 OSHD began a new evaluation process, because of the concern about worker safety, testing time, expense incurred with solvent, and the associated problems with solvent disposal. In June, 1988, OSHD published an asphalt gauge report.[7] This report, in part, concluded the following:

- The asphalt gauge is a precise and accurate instrument when properly used. Proper calibration is essential and test results must be corrected for moisture content. It can be a useful tool to determine the asphalt content of virgin asphaltic concrete mixtures.

- Within the range of 0.0% - 1.5% moisture, the asphalt gauge measures moisture linearly, as it would asphalt. Therefore, an accurate, but rapid test is needed to determine moisture content of AC samples.

- The asphalt gauge appears to be a reasonable alternative to chemical solvents based on relative safety.

- When using the asphalt gauge, the aggregate gradation needs to be determined by some other method. This is the greatest obstacle to immediately substituting the asphalt gauge method for the vacuum extraction method.

- It appears that the asphalt gauge is cost effective and could pay for itself in savings over several smaller projects or a few larger projects.

Recommendations from this research report include the following:

- Further evaluate the asphalt gauge on selected projects as an asphalt content job control test device. At the same time, use the vacuum extraction method for determining asphalt content pay factors. This will provide comparison of the two methods under field conditions.

- Conduct additional studies...and to develop a testing procedure which could be used both in the laboratory and in the field.

- Develop an alternate method to determine the aggregate gradation of the mixture at the point of final placement.

This study was undertaken to address these issues. Field trials are necessary to verify previous findings, test operating procedures, and evaluate field performance of the asphalt gauges. The manufactures have updated their gauges since the 1988 report, and this study is to utilize the latest gauges available to verify the technical gains in equipment.

1.3 Objectives

The objectives of this study are to:

- Compare the field test results obtained with asphalt gauge, vacuum extraction, tank stick, and asphalt meter. The intent is to further verify the findings of the June 1988 Report.[7]

- Compare aggregate gradation obtained at the cold feed with gradation obtained from extraction results.

- Develop the necessary calibration and testing procedures. The development of test procedures, which can be easily implemented by field personnel, which are accurate, and which can be consistent between operators, is a primary goal.

- Document the testing procedures for future use.

- Document any savings in manpower, testing cost, and contractor waiting time.

- Perform an analysis comparing the different brands of asphalt gauges.

2.0 DESCRIPTION OF TEST PROGRAM

2.1 Program Overview

The study was designed to test two manufactures asphalt gauges under a variety of field conditions and to test the feasibility of using cold feed aggregate gradations. The two different asphalt gauges used were:

- CPN AC-2
- Troxler 3241-C

Projects were selected with differing aggregate sources, asphalt brands, asphalt grades, inspectors, bituminous mix designs, and contract specifications. The study was completed in two phases:

Phase I was the first attempt at the field application process and was limited to the testing completed in 1988. This phase used the CPN AC-2 gauge exclusively, and it included three projects.

- Detroit - Idanha
- Noti - Veneta
- Wapato - NCL Yamhill

Phase II began with OSHD purchasing a Troxler 3241-C asphalt gauge in January 1989, and included follow-up field testing in the summer of 1989. Six projects evaluated asphalt contents, and seven projects evaluated cold feed gradations. Four projects used Troxler gauges and two used CPN gauges.

A total of thirteen OSHD projects were included in this study, and the extent of testing completed is listed by project in Table 1.

TABLE 1 PROJECT SUMMARY

PROJECT	EXTRACTION	NUCLEAR GAUGE	TANK STICK	METER	COLD FEED
DETROIT-IDANHA	YES	CPN	YES	NO	NO
NOTI-VENETA	YES	CPN	YES	NO	NO
WAPATO-NCL YAMHILL	YES	CPN	YES	NO	NO
DISTRICT 5 LIME TREAT	YES	TROXLER	YES	YES	NO
DISTRICT 5 NO LIME	YES	TROXLER	YES	YES	NO
CAMAS MT	YES	CPN	NO	NO	NO
FISH CREEK	YES	CPN	NO	NO	YES
E. MCMINNVILLE	YES	TROXLER	YES	NO	YES
DISTRICT 7	YES	TROXLER	YES	NO	YES
COLUMBIA RIVER	NO	NO	NO	NO	YES
CAZADERO	NO	NO	NO	NO	YES
QUEEN AVE	NO	NO	NO	NO	YES
POCAHONTAS	NO	NO	NO	NO	YES

2.2 Calibration

All calibrations were performed at the OSHD Materials Laboratory from materials submitted for the preparation of mix design. Aggregate was processed by oven drying and separating onto designated sieve sizes, 3/4", 1/2", 1/4", #4, #10, #40, #200. Aggregate was batched to mix design proportions and asphalt content was based on percent by total weight of mix. All calibrations were performed on a three point calibration curve. The CPN gauges were calibrated on the field asphalt gauge. The Troxler gauges were calibrated on the master asphalt gauge, and a transfer routine was used to calibrate the field asphalt gauge. Calibration and transfer routines are addressed in OSHD TM 319. Appendix C

2.3 Oregon Aggregate Sources

Oregon aggregate sources are composed predominately of basaltic rock which is igneous in nature. Other igneous rock types typical to Oregon are gabbro and diabase. A report by Heinicke[11] described three rock quarries rated by Szymoniak from good to poor for representation as a cross section of Oregon quarries. The location of these sources are shown in Figure 2.

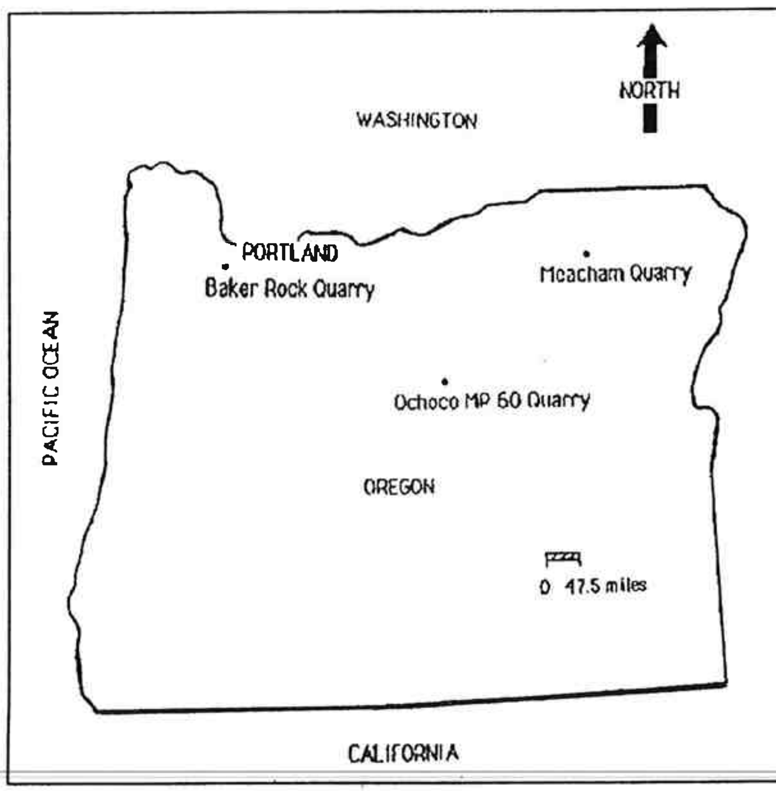

FIGURE 2 SOURCE LOCATION

Petrographic analyses were performed on these sources, and a percentage of the primary components is listed in Table 2.

TABLE 2 PETROGRAPHIC ANALYSES

	Baker Rock (unoxidized)	Baker Rock (oxidized)	Meacham	Ochoco
Plagioclase	37	52	36	54
Olivine	5	1	--	--
Pyroxene	3	19	15	9
Magnetite/Illmenite	10	7	11	7
Smetite Clay	31	3	21	30
Iron oxide	4	18	18	--
Sepiolite	10	--	--	--

These components typify the aggregate currently being used for highway construction in Oregon. The uniformity of this geological makeup is important, because a variability in minerals, e.g. iron, mica, etc. can produce a relative variability in asphalt gauge counts. This variability will adversely effect the accuracy of the asphalt gauge. Uniformity in aggregate properties is desirable, i.e. bulk specific gravity and absorption are properties which control density, retention, and residual moisture. The asphalt gauge is sensitive to changes in aggregate properties, and it is critical that job control (test) specimens match the calibration (control) specimens. Hence the unknown variable is the percent of asphalt, which can be determined when the aggregate is uniform. Five different aggregate sources were used in this study, and a review of aggregate properties was performed to determine the existing range for those properties. The aggregate properties are listed in Table 3, which demonstrate the variability by listing the high and low values within a testing period.

TABLE 3 AGGREGATE PROPERTIES

Source # /Name	Years Sampled	Fine Agg Bulk	Fine Agg Abs	Coarse Agg Bulk	Coarse Agg Abs
24-002-2	86-89	2.57	3.82	2.66	2.41
Hilroy		2.51	2.65	2.59	1.66
20-046-3	86-89	2.65	4.04	2.65	2.18
Delta		2.50	1.73	2.58	1.83
36-004-2	88-89	2.58	3.07	2.61	1.73
Dayton		2.50	2.77	2.60	1.69
20-048-3	87-89	2.92	5.17	2.64	2.39
Wildish		2.44	2.01	2.60	1.95
10-193-3	87-89	2.63	3.11	2.72	1.65
Brossi		2.54	1.79	2.65	1.38

Hilroy, Delta, Wildish, and Brossi are major suppliers of aggregate to OSHD, while Dayton is a minor supplier. A complete chronological listing of testing performed on the produced aggregate can be found in Appendix F.

2.4 Description Of Test Procedures Used

OSHD uses the vacuum extraction procedure as the acceptance test for asphalt content. This study did not substitute the asphalt gauge as the acceptance test, but did perform paired testing of samples. The asphalt gauge procedures were initially developed and modified as testing progressed.

2.4.1 Vacuum extraction

The acceptance test procedure normally used by the Oregon Highway Division to determine the asphalt content of asphaltic concrete pavement is the vacuum extraction procedure OSHD TM 309-87...a modified version of AASHTO T 164 Method E.

2.4.2 Asphalt gauge

The asphalt gauge test procedure, which was evaluated as an alternative to the vacuum extraction procedure, used in Phase I is found in Appendix A. It was developed by the OSHD Materials and Research Section laboratory personnel and was designed to be used in conjunction with the manufactures operator instruction manuals.[12,13] The moisture correction procedure was performed by the microwave method OSHD TM 311(M).

Phase II testing began with an evaluation of results from Phase I, and it was concluded that a revision of the asphalt gauge procedure was necessary to enhance the sensitivity of the gauge. The modified procedure can be found in Appendix B. This procedure changed the moisture correction to an oven dry method.

2.5 Description of Statistical Analysis

The data collected from each project was statistically analyzed to determine if the difference in asphalt contents determined by the four methods were statistically different. The statistical test used to analyze the test data was a two-tailed paired variate Student-t analysis assuming the null hypothesis. This analysis was chosen, because split samples from different sublots were tested as pairs and the total population for each project was relatively small. The differences between the observations for each pair results in a set of sample differences, which is analyzed at the 95% confidence level by determining the appropriate t critical value from the n-1 degrees of freedom. A brief description of Student-t statistic is given in Appendix E. Tank stick and metered results were calculated on a daily average.

3.0 DISCUSSION OF TEST PROGRAM

During the field testing portion of the study, several trends were observed and several situations arose which required corrective action to be taken. The following is a general description of what was encountered, especially in Phase I, and what solutions were used to alleviate the situations for Phase II.

3.1 Sample Cooling

Samples for Phase I were collected in accordance with the procedures for sampling mixtures of bituminous materials with mineral aggregate as in "Sampling Bituminous Paving Mixtures", OSHD TM 368-85. This permitted a representative portion of the sample to be collected and split for each test. Samples were obtained at the plant on two jobs, while the third job was sampled from the roadway. Difficulty was experienced in handling the increased size of the sample. At times, when the sample arrived at the lab, it was too cold for mixing and splitting. Reheating the sample became time consuming and was noted as a variation to the vacuum extraction procedure. Compacting the material into the sample pan became more difficult as the temperature decreased.

Solution Phase II sampling was performed at the plant. In all instances, the testing laboratory was within a short distance of the plant. No sample cooling problem was experienced.

3.2 Sample Weighing

Samples for Phase I were weighed on a platform balance, which was accurate to one-tenth of a pound (45 grams). The sample weight according to the manufacturers recommended procedure should be within ± 5 grams.

Solution Samples for Phase II were weighed on an electronic scale, which was accurate to 0.2 gram. No sample weighing problem was experienced.

3.3 Sample Moisture

Samples for Phase I were corrected for moisture by the microwave moisture test "OSHD TM 311M-86". This test represented the correction factor used for both tests, extraction and nuclear, even though the sample was split for testing.

Solution When performing moisture correction in Phase II, the asphalt gauge moisture correction was tested independently of the extraction moisture correction. An oven dry moisture correction procedure was developed specifically for the use with the asphalt gauge. Refinement of this procedure will continue as the asphalt gauge process is further developed.

3.4 Sample Testing

In Phase I, two asphalt determinations were scheduled for each statistical sublot (500 tons), i.e. one using the asphalt gauge and one using the vacuum extraction. Unfortunately, only one inspector was available to perform both acceptance testing and the asphalt gauge comparison testing. The vacuum extraction test was required as the acceptance test. Once testing began, the inspector became overburdened trying to perform both tests simultaneously, therefore the asphalt gauge comparison test was not completed on every sublot.

Solution The difficulty of performing simultaneous testing was anticipated in Phase II. Each project employed an additional inspector with the sole responsibility of performing the asphalt gauge testing. The project manager's inspector retained the responsibility for acceptance testing by extraction.

4.0 SUMMARY OF STATISTICAL ANALYSIS RESULTS

All projects were analyzed for significance at the 95 percent confidence level. Comparisons were performed in two categories, i.e. asphalt content and gradation. Summary tables for the asphalt analysis are in Tables 4-12, and the summary tables for the gradation analysis are in Tables 13-19. The complete Student t analysis can be found for the test results in Appendixes F & G.

4.1 Asphalt Content Comparisons.

Nine projects were evaluated for asphalt content, and the projects included test sets that ranged from five to twelve tests. The nuclear gauge readings were compared against vacuum extractions, and where available tank stick and meter readings were also analyzed. Project asphalt results are summarized in Tables 4-12, and a description of the results are as follows:

4.1.1 Phase I asphalt analysis

Detroit-Idanha

Three sets (nuclear, extraction, and tank stick) consisting of twelve tests per set were statistically different when analyzed. The mean asphalt content ranged from 6.28 for nuclear tests to 5.48 for extraction tests. Tank stick mean value was 5.84 and was approximately equidistant from the nuclear and extraction mean values.

Noti-Veneta, East Unit

Three sets (nuclear, extraction, and tank stick) consisting of nine tests per set were not all statistically different when analyzed. The extraction vs tank stick comparison was not different when analyzed while the other comparisons were. The mean asphalt content ranged from 6.49 for nuclear to 5.64 for extraction. The tank stick value of 5.75 was closest to the extraction value.

Wapato Road-N.C.L. Yamhill

Two sets (nuclear and extraction) consisting of seven tests per set were statistically different when analyzed. The mean asphalt content ranged from 7.25 for nuclear to 6.49 to extraction. The average difference was 0.76.

TABLE 4 DETROIT - IDANHA "C" MIX

n = 12	Sd	X	CV	SD / D (NUC–EXT)	SD / D (EXT–T S)	SD / D (NUC–T S)
NUC	0.18	6.28	2.9	yes		yes
EXT	0.13	5.48	2.4	0.8	yes	
T S	0.08	5.84	1.4		0.4	0.4

TABLE 5 NOTI - VENETA, EAST UNIT "C" MIX

n = 9	Sd	X	CV	SD / D (NUC–EXT)	SD / D (EXT–T S)	SD / D (NUC–T S)
NUC	0.24	6.49	3.7	yes		yes
EXT	0.12	5.64	2.1	0.8	no	
T S	0.23	5.75	4.0		0.1	0.7

TABLE 6 WAPATO ROAD - N.C.L. YAMHILL "C" MIX

n = 7	Sd	X	CV	SD / D (NUC–EXT)
NUC	0.27	7.25	3.7	yes
EXT	0.11	6.49	1.7	0.8

NUC - Percent asphalt as determined by nuclear gauge.
EXT - Percent asphalt as determined by extraction.
T S - Percent asphalt as determined by tank sticking.

n - sample size
Sd- standard deviation
X - mean
CV- coefficient of variation
SD- statistically different
D - mean difference

4.1.2 Phase II asphalt analysis

District 5 (Lime Treated)

Four sets (nuclear, extraction, tank stick, and meter) consisting of 5 tests per set (except for meter which had 4 test per set) were not all statistically different when analyzed. The nuclear vs extraction comparison was statistically different while the others were not. The mean asphalt content ranged from 5.87 for extraction to 5.21 for nuclear. Tank stick and meter values, 5.64 and 5.70, were not statistically different with the extraction value.

District 5 (No Lime)

Four sets (nuclear, extraction, tank stick, and meter) consisting of 12 tests per set were not statistically different when analyzed. All four mean asphalt contents were within 0.11 of each other.

Camas Mt. - Muns Creek

Two sets (nuclear and extraction) consisting of 5 tests per set were statistically different when analyzed. The mean asphalt content ranged from 6.27 for nuclear to 5.49 for extraction. The mean difference was 0.78.

Fish Creek - Chinquapin Creek

Two sets (nuclear and extraction) consisting of 9 tests per set were statistically different when analyzed. The mean asphalt content ranged from 5.33 for nuclear to 5.76 for extraction. The mean difference was 0.43.

E. McMinnville - Intchge Airport Rd.

Three sets (nuclear, extraction, and tank stick) consisting of 15 tests per set were not all statistically different when analyzed. The extraction vs tank stick comparison was not different while the others were. The mean asphalt content ranged from 5.64 for nuclear to 5.32 for tank stick. The extraction value, 5.35, was the closest to the tank stick value.

District 7

Three sets (nuclear, extraction, and tank stick) consisting of 12 tests per set were not all statistically different when analyzed. The nuclear vs tank stick comparison was not different while the others were. The mean asphalt content ranged from 5.27 for extraction to 5.56 for nuclear. The tank stick value, 5.49, was closest to the nuclear value.

TABLE 7 DISTRICT 5 "F" MIX (LIME TREATED)

n = 5	Sd	X	CV	SD D				
NUC	0.29	5.21	5.6	yes		no		no
EXT	0.23	5.87	3.9	0.7	no		no	
T S	0.22	5.64	3.9		0.2	0.4		
METER	0.18	5.70	3.2				0.2	0.5

TABLE 8 DISTRICT 5 "F" MIX (NO LIME)

n = 12	Sd	X	CV	SD D				
NUC	0.45	5.89	7.6	no		no		no
EXT	0.21	5.94	3.5	0.1	no		no	
T S	0.05	5.83	0.9		0.1	0.1		
METER	0.20	5.94	3.4				0.0	0.1

TABLE 9 CAMAS MT. - MUNS CREEK "B" MIX

n = 5	Sd	X	CV	SD D
NUC	0.40	6.27	6.4	yes
EXT	0.16	5.49	2.9	0.8

TABLE 10 FISH CREEK - CHINQUAPIN CREEK "F" MIX

n = 9	Sd	X	CV	SD D
NUC	0.22	5.33	4.1	yes
EXT	0.21	5.76	3.6	0.4

TABLE 11 E. MCMINNVILLE - INTCHGE AIRPORT RD "B" MIX

n = 15	Sd	X	CV	SD D		
NUC	0.23	5.64	4.1	yes		yes
EXT	0.20	5.35	3.7	0.3	no	
T S	0.11	5.32	2.1		0.0	0.3

TABLE 12 DISTRICT 7 "F" MIX

n = 12	Sd	x	CV	SD D		
NUC	0.30	5.56	5.4	yes		no
EXT	0.27	5.27	5.1	0.3	yes	
T S	0.14	5.49	2.6		0.2	0.1

4.2 Gradation Comparisons

Seven projects were evaluated for gradation comparison between the extraction and cold feed samples. The projects included test sets that ranged from 11 to 44 tests. The sieves evaluated were 1/2", 1/4", #10, #40, #200. Project gradation results are summarized in Tables 13-19, and a description of the results are as follows:

Fish Creek - Chinquapin Creek

All sets consisting of 12 tests per set were statistically different when analyzed. The mean difference ranged from 5.9 on 1/2" to 1.8 on #40 and #200 sieve.

E McMinnville - Intchge Airport Rd

Sets consisting of 14 tests per set were not all statistically different when analyzed. The #40 sieve comparison was determined different while the others were not. The mean difference ranged from 0.8 on #40 sieve to 0.0 (no difference) on the 1/2" sieve.

District 7 Paving

Sets consisting of 11 tests per set were not all statistically different when analyzed. The #200 sieve comparison was determined different while the others were not. The #40 sieve data was not available. The mean difference ranged from 1.9 on 1/2" to 0.6 on #10.

Columbia R. Br. - Old Oregon Trail

Sets consisting of 44 tests per set were not all statistically different when analyzed. The #40 sieve comparison was determined not different while the others were. The mean difference ranged from 2.5 on 1/2" to 0.2 on #40 sieve.

Cazadero - N. Fork Clackamas River

All sets consisting of 26 tests per set were not statistically different when analyzed. The mean difference ranged from 1.0 on 1/4" to 0.0 (no difference) on #40 sieve.

Queen Ave. - Corvallis/Lebanon Hwy

Sets consisting of 20 tests per set were not all statistically different when analyzed. The 1/2" and #10 comparisons were determined not different while the others were. The mean difference ranged from 0.4 on #10 sieve to 2.6 on #200 sieve.

Pocahontas - Auburn

Sets consisting of 13 tests per set were not all statistically different when analyzed. The #10 comparison was determined different while the others were not. The mean difference ranged from 2.1 on #10 to 0.1 on #200 sieve.

TABLE 13 FISH CREEK -CHINQUAPIN CREEK SECTION "F" MIX

n = 12	SIEVE	Sd	X	D	CV	SD
EXT	1/2	4.4	71.5	5.9	6.2	yes
C F	1/2	7.3	65.5		11.1	
EXT	1/4	1.4	27.6	3.3	5.1	yes
C F	1/4	3.9	24.3		16.1	
EXT	#10	2.4	15.6	2.6	15.4	yes
C F	#10	2.1	13.0		16.2	
EXT	#40	0.9	7.5	1.8	12.0	yes
C F	#40	0.9	5.7		5.8	
EXT	#200	0.3	3.3	1.8	9.1	yes
C F	#200	1.2	1.5		80.0	

TABLE 14 E MCMINNVILLE - INTCGHE AIRPORT RD SECT "B" MIX

n = 14	SIEVE	Sd	X	D	CV	SD
EXT	1/2	3.4	85.0	0.0	4.0	no
C F	1/2	1.9	85.0		2.2	
EXT	1/4	4.2	58.3	0.3	7.2	no
C F	1/4	2.4	58.0		4.1	
EXT	#10	2.1	30.1	0.7	7.0	no
C F	#10	1.2	29.4		4.1	
EXT	#40	0.8	13.5	0.8	5.9	yes
C F	#40	0.7	12.7		5.5	
EXT	#200	0.4	5.5	0.1	7.3	no
C F	#200	0.4	5.6		7.1	

EXT - Percent passing gradation by extraction
C F - Percent passing gradation by cold feed

n - sample size
Sd- standard deviation
X - mean

CV - coefficient of variation
SD - statistically different
D - mean difference

TABLE 15 DISTRICT 7 PAVING "F" MIX

n = 11	SIEVE	Sd	X	D	CV	SD
EXT	1/2	4.9	71.9	1.9	6.8	no
C F	1/2	7.8	70.0		11.1	
EXT	1/4	4.2	30.1	1.1	4.2	no
C F	1/4	6.5	28.9		22.5	
EXT	#10	2.4	14.7	-0.6	16.3	no
C F	#10	5.0	15.3		32.7	
EXT	#200	0.4	3.9	1.4	10.3	yes
C F	#200	0.6	2.5		24.0	

TABLE 16 COLUMBIA R. BR. - OLD OREGON TRAIL "B" MIX

n = 44	SIEVE	Sd	X	D	CV	SD
EXT	1/2	1.8	88.8	2.5	2.0	yes
C F	1/2	1.8	86.3		2.1	
EXT	1/4	2.0	60.8	2.3	3.3	yes
C F	1/4	2.4	58.5		4.1	
EXT	#10	1.4	31.3	-0.7	4.5	yes
C F	#10	1.7	32.0		5.3	
EXT	#40	0.6	11.4	-0.2	5.3	no
C F	#40	0.8	11.6		6.9	
EXT	#200	0.2	4.5	1.1	4.4	yes
C F	#200	0.3	3.4		8.8	

TABLE 17 CAZADERO - N FORK CLACKAMAS RIVER "B" MIX

n = 26	SIEVE	Sd	X	D	CV	SD
EXT	1/2	2.3	86.3	0.4	2.3	no
C F	1/2	2.2	85.9		2.6	
EXT	1/4	3.3	62.8	1.0	5.3	no
C F	1/4	3.5	61.8		5.7	
EXT	#10	1.7	33.8	0.4	5.0	no
C F	#10	1.8	33.4		5.4	
EXT	#40	0.8	14.8	0.0	5.4	no
C F	#40	0.8	14.8		5.4	
EXT	#200	0.7	6.1	0.1	11.5	no
C F	#200	0.4	6.2		6.5	

TABLE 18 QUEEN AVE - CORVALLIS/LEBANON HWY "B" MIX

n = 20	SIEVE	Sd	X	D	CV	SD
EXT	1/2	2.3	89.4	-0.6	2.6	no
C F	1/2	1.3	90.0		1.4	
EXT	1/4	3.2	62.3	-2.4	5.1	yes
C F	1/4	1.7	64.7		2.6	
EXT	#10	2.0	31.3	-0.4	6.4	no
C F	#10	1.1	31.7		3.5	
EXT	#40	0.7	13.4	1.4	5.2	yes
C F	#40	0.6	12.0		5.0	
EXT	#200	0.4	5.7	2.6	7.0	yes
C F	#200	0.3	3.1		9.7	

TABLE 19 POCAHONTAS - AUBURN "C" MIX

n = 13	SIEVE	Sd	X	D	CV	SD
EXT	1/2	0.8	98.1	0.3	0.8	no
C F	1/2	0.4	97.8		0.4	
EXT	1/4	4.3	63.8	0.5	6.7	no
C F	1/4	1.1	62.7		1.8	
EXT	#10	2.0	32.3	2.1	6.2	yes
C F	#10	2.0	30.2		6.6	
EXT	#40	0.8	10.8	0.3	7.4	no
C F	#40	1.3	10.5		12.4	
EXT	#200	0.4	4.0	0.1	10.0	no
C F	#200	0.6	3.9		15.4	

5.0 DISCUSSION OF TEST RESULTS

This discussion will focus on the results derived from the tests performed in both phases of this study. What results were obtained, why changes were necessary, and how the changes effected the results will be discussed.

5.1 Phase I Testing

Phase one testing included three projects that compared the CPN asphalt gauge to extraction and tank stick results. No cold feed samples were evaluated in this portion of the study.

5.1.1 Asphalt analysis

The consistent difference in asphalt contents between extraction and asphalt gauge on all three projects indicates a systematic error is present and biasing the results. Data indicates asphalt gauge values are higher than extraction values is consistent with findings made in the OSHD June 1988 report[7], however the difference is much higher in the field tests dried by microwave (approximately 0.8 percent) than in the laboratory tests dried in a 230° F oven (approximately 0.3 percent) -- see Table 28, Category 3, Table 15 and 16 on page 48 of June 1988 Report.[7] The explanation of this error can be attributed to both moisture and retention of asphalt in the aggregate.

Silbernagel showed in his report[14] a difference in moisture loss dependent upon the test method used for moisture determination. The results indicated the 250° F microwave procedure to run 47% lower than 230° F oven dry procedure, and Silbernagel also showed results for AASHTO T-110 to run 16% lower than the 250° F microwave procedure. Based on this data and since AASHTO T-110 recommends using xylene as the solvent, we do not recommend using AASHTO T-110 as the field test for moisture determination of bituminous mixtures.

TABLE 20 MOISTURE CONTENT STATISTICS

n = 8	Sd	X	CV
230° F Oven Dry	0.04	0.58	7.09
250° F Microwave	0.07	0.31	23.10
AASHTO T-110	0.06	0.26	23.62

Excess asphalt volatiles contributing to the moisture loss is of a minor concern, because this portion of the asphalt is limited by current Standard Specification for Asphalt Materials under AASHTO M 226 Table 1 (Modified). The solubility in trichloroethylene is required to meet or exceed a 99% minimum, therefore the volatiles are limited to a maximum 1% by weight of asphalt.

5.1.2 Microwave moisture correction

The microwave moisture test was used to correct both the extraction and asphalt gauge in Phase I testing. Microwave moisture has been considered an acceptable method for determining moisture in the extraction procedure, since it is relatively fast compared to oven drying. Also the extraction procedure calculates the asphalt content based on the final sample weight which is determined by the microwave procedure. Any error from moisture remaining in the sample as a result of microwave drying tends to offset the error that results from retention of asphalt in the aggregate.

The systematic error found between the two test methods can be attributed to use of the microwave procedure for moisture determination, because it will underestimate the amount of moisture accumulated into the asphalt gauge reading. Moisture correction by microwave method appears to be unacceptable for use with the asphalt gauge, because the asphalt gauge detects all asphalt, including retained asphalt, and detects all moisture as asphalt.

5.1.3 Retention

The systematic error found between the two test methods can also be attributed to asphalt retention in the aggregate, because the vacuum extraction process does not account for asphalt absorbed by the aggregate. The retention that occurs in bituminous mixture is directly related to two elements:

- Initial moisture present in the aggregate at the time of mixing.
- Absorption property of the aggregate incorporated into the mix.

The amount of retention appears to be inversely proportional to the amount of moisture present within the aggregate at mixing, but directly proportional to the absorption property of the aggregate. Retention was estimated to be within the range of 0.0 to 0.4 percent, i.e. the difference in asphalt content between extraction and tank stick results as listed in Tables 4,5,7,8,11,&, 12.

Retention will bias the vacuum extraction result lower than the true asphalt content, while it will have no effect on the asphalt gauge result. No correction for retention was applied to any of the extraction tests listed in this study.

5.2 Phase II Testing

Phase two testing included six projects to evaluate asphalt gauges and seven projects to evaluate cold feed gradation. The CPN gauge was used on two projects, while the Troxler gauge was used on five projects. Asphalt gauge projects varied in mix class, i.e. four evaluated open graded mix (OSHD Class F) and two evaluated dense graded mix (OSHD Class B).

5.2.1 Oven dry moisture correction

Since the microwave moisture correction did not measure all of the moisture as determined in phase I testing, an alternative oven dry method was developed for the second phase. This oven dry method was based on the premise---the asphalt gauge is calibrated with pre-dried samples, which were dried at 325°F; therefore the most representative method of determining sample moisture is by using a 325°F oven.

5.2.2 Asphalt analysis (open graded)

Four projects with open graded mix were evaluated. One project used lime treated aggregate, and produced results, atypical from the model, where the extraction results were 0.66% higher than the asphalt gauge. The same project, without the aggregate being lime treated, produced results where the extraction was only 0.05% higher than the asphalt gauge. The remaining two projects produced results with mean differences of 0.4% and 0.3% which were statistically different.

Open graded mixes were difficult to handle, e.g. collecting, mixing, and preparing samples due to the thick asphalt film coating. Also, asphalt migration and sample slump were observed during sample preparation. This effects the sample density which is a critical factor in proper operation of the asphalt gauge. Holmgreen of Texas stated, "Sample preparation, particularly compacting the material to be measured, is extremely important because the device performs calculations based on volume rather than weight."[10]

Currently OSHD accepts open graded cold mix based on tank stick/meter for asphalt content. The NAPA's Report[1] included eleven states that were using automatic recordation devices. The test results show little difference when comparing tank stick/meter to extraction. Only one test showed a significant difference, and the test values for that comparison were 2.5 for t observed to 2.3 for t critical. Determining asphalt content by tank stick/meter appears to be a viable system for open graded mixes.

5.2.3 Asphalt analysis (dense graded)

Two projects evaluated dense graded mixes. One project used the CPN gauge while the other project used the Troxler gauge. Both projects were statistically different. The mean differences were 0.8% and 0.3%, respectively. Moisture correction appears to be the cause of a systematic error, since an inappropriate sample vessel, one quart asphalt can, was used instead of an open flat pan. This biased the result low, because of the reduced surface area available for evaporation. Follow-up comparative analysis demonstrated the difference to be within a 0.17% to 0.26% range, and the average difference being 0.22%.

TABLE 21 FOLLOW-UP MOISTURE EVALUATION

	Flat Pan	Asphalt Can	Difference
% H_2O loss	0.45	0.28	0.17
% H_2O loss	0.52	0.28	0.24
% H_2O loss	0.49	0.28	0.21
% H_2O loss	0.58	0.32	0.26
Average	0.51	0.29	0.22

It appears with the importance of proper moisture correction that a detailed procedure be documented for specific use with the asphalt gauge.

5.2.4 Cold feed analysis

Seven projects evaluated comparisons between cold feed and extraction gradations. Thirty four separate comparisons were made, and fifteen were determined to be statistically different. Seven of the fifteen determined to be different may not have been; if the gradation was performed by AASHTO T-11, wet wash gradation test, which achieves the gradation performed on extracted aggregate. Iowa DOT has used cold feed gradation since 1987. Adam reported[15] only minor variations on 390 comparisons which averaged (0.1% on 3/4"), (1-1.6% on 1/2" to 3/8"), (0.3% on #16), and (0.7% on #30 to #200).

5.3 General Discussion

Sensitivity of the asphalt gauge can be enhanced by controlling the factors effecting the accuracy of the gauge. The greatest factors are moisture and aggregate uniformity. Other items included for discussion were operating cost relative to vacuum extraction and a comparison between the brands of gauges.

5.3.1 Moisture Correction

Proper moisture determination entails developing a moisture correction procedure which will determine the difference in moisture between the calibration and test samples. The June 88 report[7] demonstrated that during calibration a minimal amount of moisture was absorbed into the calibration samples, and this moisture content ranged from 0.8% to 0.14%. This base line moisture, moisture present during calibration, will not be read as asphalt in test specimens, because it has been incorporated into the calibration curve. Moisture correction of test specimens must determine the amount of moisture in excess of the base line moisture. This will be accomplished by controlling the temperature of calibration samples within a specific range, 250° ±10°F and by determining the moisture of test specimens by oven drying at 250° ±9°F. See OSHD TM 311(N) Appendix D.

5.3.2 Aggregate Uniformity

Aggregate uniformity can be evaluated by checking historic aggregate source data to determine the variability in aggregate properties, i.e. gravity and absorption. While this will demonstrate the expected trend for a particular source, a quantitative measurement shall be developed for application with the asphalt gauge. This shall be accomplished by determining the counts from a blank sample (base weight sample) measured on the calibration curve, and establishing an acceptable tolerance for blank test samples (final belt samples) to be within. This tolerance shall be established at 1.5% of the counts derived from the base weight sample. See OSHD TM 319 Appendix C.

5.3.3 Cost Analysis

The cost analysis compared reasonably well with the June 88 Report.[7] That report established the vacuum extraction cost per test at $27.55 and the asphalt gauge cost per test at $0.73. Cost was based on 1 gal/test of solvent priced at $9.97/gal with test time of 2 hours for extraction and 5 minutes for asphalt gauge. The detailed description can be found on pages 6 & 7 of the June 88 Report.[7] Schultz concluded vacuum extraction to use 3877 milliliter per test at 3.5 hours/test.[16] It appears that the cost analysis made in June 88 is conservative. In 1989 OSHD used 41 barrels of solvent at the expense of approximately $23,000.

The field evaluation produced similar results to the original evaluation in June 88 report[7]. The vacuum extraction evaluation remained consistent in time and cost. The exception noted involved a polymer modified asphalt. When polymer modified asphalt was used on a particular job the bituminous mixture could not be vacuum extracted with field equipment. Apparently, the filter paper would plug, and all efforts to alleviate the problem were unsuccessful. The solution was to utilize an asphalt gauge for testing. It appears the nuclear gauge is a cost effective instrument which could pay for itself within a short time frame.

5.3.4 Comparison of Asphalt Gauges

The gauges compared were the Troxler 3241-C and the CPN AC-2. Both gauges performed according to the manufacture specifications, but the Troxler gauge offers some distinct advantages. A major advantage is in the construction of the asphalt gauge. The Troxler gauge separates the sample chamber from the operator's control unit (nuclear source from electronics), while the CPN gauge is a single unit. The advantages are as follows:

- The ability to bring the control unit into an office environment where the downloading to a PC can be performed without the presence of the nuclear source.

- While operating the gauge a physical distance is created between the operator and the nuclear source, which increases both accuracy and safety aspects.

- The electronics components do not get exposed to elevated sample temperatures.

The Troxler gauge is also more user friendly. This is extremely important when considering training and operating the asphalt gauge. The Troxler gauge also offers more shielding and can store more calibrations. The Troxler gauge is more widely accepted by State Highway Departments.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- The asphalt gauge appears to be a precise and accurate instrument, but the asphalt reading must be corrected for moisture content.

- The microwave moisture procedure is not an acceptable method for correcting the asphalt gauge reading for moisture content. This procedure was designed to be used in conjunction with vacuum extraction procedure and cannot be substituted into the asphalt gauge procedure.

- Preparation of calibration samples cannot be established without the infiltration of a minimal amount of moisture, base line moisture, which is present during calibration of the asphalt gauge.

- The vacuum extraction results compares generally well with tank stick and meter results.

- It appears that cold feed aggregate gradation can be substituted for extracted aggregate gradation as the means for determining the gradation to be used in conjunction with the asphalt gauge procedure.

- Explicit procedures and proper training of personnel are necessary to produce accurate test results.

- Adequate staffing of personnel and accurate test equipment are essential to a successful testing program.

- The use of the asphalt gauge resulted in cost savings. Estimated manpower, testing cost, and contractor waiting time were substantially reduce over those obtained with the vacuum extraction method.

- Basaltic rock indigenous to Oregon has a potential for retention of asphalt due to the highly absorptive characteristic of the aggregate.

- Non-uniform aggregate sources and lime treatment of aggregate may adversely effect the accuracy of the asphalt gauge.

6.2 Recommendations for Implementation

- Proceed with immediate solvent reduction by replacing vacuum extraction testing of open graded and plant mix bituminous base mixtures with a tank stick/meter asphalt determination and by replacing extraction gradation with cold feed gradation. The gradation should be determined by AASHTO T-27 & T-11 sieve analysis of the cold feed sample taken with the automatic cold feed sampling device at the final belt.

- Proceed with the equipment purchase to outfit each region with an asphalt gauge, and insure any additional equipment required to perform the asphalt gauge procedure is obtained.

- Train region personnel in the application of OSHD TM 319 and TM 311(N) for operation of the asphalt gauge.

- Develop a plant calibration procedure for asphalt meters and belt scales to provide accurate control of asphalt content.

- Identify any non-uniform aggregate sources as part of the quality control process and recalibrate the asphalt gauge as necessary to adjust for a aggregate changes.

6.3 Recommendation for Further Study

- Conduct further field tests to evaluate the accuracy of the asphalt gauge using OSHD TM 319 and OSHD TM 311(N). Continue to use the vacuum extraction process for project acceptance testing until the accuracy of the procedure is verified.

- Field studies should carefully document actual asphalt quantities used in the mix by tank sticking or plant metering and compare these values to the asphalt gauge as well as vacuum extraction results. Verify the cause of any discrepancies to eliminate or reduce testing error to acceptable levels.

- Verify if cold feed aggregate gradation can be substituted for extracted aggregate gradation.

- Field studies should include a backup provision to recheck samples outside a given narrow band tolerance.

- Perform field studies on projects using; recycled asphalt pavement (RAP)---where (RAP) is substituted for a maximum of 20% of the aggregate, and lime treated aggregate---where the lime treatment is used as an antistrip preventive measure.

- Encourage Federal Highway Administration Demonstration Project No. 74, Field Management of Asphalt Mixes, to establish a mobile testing laboratory on an OSHD project.

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Appendix A

PROCEDURE FOR TESTS PERFORMED ON FIELD SAMPLES BY A/C CONTENT NUCLEAR GAUGE

I. Determination of Base Weight

A. Base weight is the amount of oven dried aggregate that is required to fill the sample pan level full. This establishes the weight to be used for preparation of calibration and test samples for a specific mix design. Any change in mix class will require a new base weight. This weight will generally be between 6,000 and 8,000 grams.

B. The base weight will be determined by taking oven dried aggregate which has been combined in the proportions designated by the mix design. Tare the sample pan and fill it one half full. Lift the sample pan about an inch above the table top and drop twice. After leveling materials with a spoon, overfill the sample pan and repeat dropping procedure. Fill in the corners and any void areas that might exist. Place a straight edge at one end of the sample pan and with a sawing motion strike it off. Fill in any voids that might exist after striking off. Weigh the sample to determine the base weight.

II. Calibration of Sample

It is recommended that calibration samples be fabricated at the Materials Laboratory in Salem. The nuclear A/C gauge is calibrated using three samples. Samples asphalt contents are prepared at both one percent above and below the design asphalt content, and one at the recommended asphalt content. Aggregate samples are batched out in the mix design proportions with sufficient quantity to equal base weight. Samples are dried overnight in a 325° F oven. Dry weight of aggregate is determined, and asphalt content is calculated using the following formula:

$$\text{Desired Asphalt Weight} = \frac{\text{Aggregate Weight} \times \%\ \text{Asphalt}}{100 - \%\ \text{Asphalt}} \text{X100}$$

Calibration samples are mixed and fabricated into sample pans in three lifts. Obtain base weight and level surface while filling in corners. Use a board to compact the mix into the sample pan by standing on it. Determine if sample weight is within desired tolerance, base weight ± 5 grams.

The calibration samples are run in the asphalt gauge for a 16 minute count as described in the operators manual. The calibration points should be plotted on a graph showing counts-per-minute on the Y axis versus % asphalt on the X axis. This can be used to check your calibration when running field samples.

III. Sampling Procedures for Plant Mix

Samples will be obtained and quartered by OSHD TM 368-85, Section 4.3. This covers sampling from the vehicle transporting mix from the plant. The Sample size must be large enough for a 1,000 grams moisture sample (OSHD TM 311M-87) and 8,000 grams for the A/C content gauge. The mix shall be placed in the sample pan following the same procedures used for the calibration samples.

IV. Gauge Operation for Field Samples

Standard counts shall be taken daily and whenever there is a change in the environment. Any hydrogen sources such as coffee cups, water jugs, etc., should be kept at least 10 feet away from the gauge.

The field sample will be placed in the gauge and run according to the operators manual for one four minute count. You can also use four, four-minute counts and average the results for greater accuracy. The attached form can be used to record the results.

The results shall be corrected for moisture content by subtracting the moisture content of the sample on a 1:1 basis (one percent moisture in the sample will read as 1% asphalt). The moisture shall be determined by OSHD TM 311M-87.

Appendix B

PROCEDURE FOR DETERMINING BITUMEN BY NUCLEAR ASPHALT CONTENT GAUGE

Scope

1.1 This method is to provide a procedure for determining asphalt content of bituminous mixtures by neutron moderation analysis.

Determination of Base Weight

2.1 The base weight is determined by using oven dried aggregate which has been combined to mix design proportions. Tare the sample pan and fill one-third full with dried aggregate. Lift the sample pan about an inch above the table top, drop twice, and level surface. Fill sample pan two-thirds full, drop twice, and level surface. Overfill the sample pan, place a straight edge at one end, and strike off with a sawing motion to prepare the final lift. Fill in any voids that might exist after striking off. Weigh and record base weight. Base weight is the amount of bituminous mixture required for subsequent calibration and test samples. This will generally be between 6,000 and 8,000 grams.

Calibration of Sample

3.1 The nuclear gauge is calibrated using a three point calibration curve. The three points are one percent above the design asphalt content, one percent below, and at the design asphalt content. Batch aggregate samples according to mix design proportions and dry overnight in a 325° F oven. Weigh and calculate asphalt weight using the following formula:

$$\text{Desired Asphalt Weight} = \frac{\text{Aggregate Weight X \% Asphalt}}{100 - \text{\% Asphalt}} \text{ X100}$$

Mix and prepare samples following similar procedure used for the base weight determination. To prepare the final lift, weigh bituminous mixture to equal base weight. Use metal plate to compact top lift. Verify that the sample is equal to the base weight within ±1 grams. Establish a base line moisture by maintaining the sample at 325° F. Test samples will be corrected back to this base line moisture. Establish calibration curve by performing a 16 minute count on each calibration point. Save the calibration pan that contains the design asphalt content, which is the center point of the curve, for a future field reference sample. Plot calibration curve on a graph showing counts-per-minute on the Y axis versus % asphalt on the X axis. Reference the curve when performing field samples.

Gauge Setup For Field Operation

4.1 Setup and maintain gauge out of the normal work area of the test trailer. Any hydrogen sources i.e. water jugs, personnel, are kept at least five feet away. **Walk away from the gauge while it is operating.**

4.2 Perform standard count and check chi ratio. Standard counts will be taken twice daily. Perform standard count first in the morning and once in the afternoon. Also perform standard count whenever there is a change in the environment.

4.3 Insure the gauge is on the proper calibration curve.

4.4 Check the field setup by determining the asphalt content of the known sample saved when calibration was performed. Moisture of this sample is calculated from the relative comparison of sample weight to the base weight.

Sampling & Testing Bituminous Mixture

5.1 A representative sample will be obtained and quartered by OSHD TM 368-85. The mix will be placed in a homogenous mass and transported to the testing facility in a manner that will minimize temperature loss. Expedite mixing and splitting of sample to minimize sample cooling.

5.2 Prepare the field control samples as the calibration samples were prepared.

5.3 Recommended test duration is sixteen minutes.

5.4 Split, weigh, and record, immediately after asphalt determination, a 1000 gram moisture sample taken from the test sample. Place moisture sample in 325° F oven for 24 hours.

5.5 After 24 hours weigh moisture sample, and calculate moisture content. Subtract moisture from gauge reading to determine asphalt content.

5.6 Correlate test results to all other testing e.g. vacuum extraction, tank sticking, and asphalt metering.

Appendix C **OSHD TM319**

Method of Test for

Asphalt Content of Bituminous Mixtures by Nuclear Method

GENERAL DESCRIPTION OF PROCEDURE

1. **SCOPE**

A. This method is a procedure for a rapid, safe, and accurate determination of asphalt content by utilizing neutron thermalization techniques. It encompasses both Central Laboratory Procedure and Field Operation Procedure.

2. **SIGNIFICANCE AND USE**

A. This procedure utilizes a transfer routine to calibrate Field gauges from constants derived from the Master gauge located at the Materials Laboratory (Salem). Annually every Field gauge will be standardized (cross calibrated) to the Master gauge.

B. Unless the test sample is completely free of moisture, the moisture percentage must be determined per OSHD TM 311(N) and a correction made to directly compensate the asphalt reading for moisture content.

3. **APPARATUS**

A. While exact details of construction for the apparatus may vary, the system shall consist of the following items:

1. **Neutron Source** - A double encapsulated 100mCi - 300mCi Americium - Beryllium radioactive source.

2. **Detectors** - $Helium^3$ or boron trifluoride.

3. **Read-Out** - Automatic direct sunlight LCD to display percent asphalt

4. **Printer/Computer** - Easy-to-use downloading feature compatible with printer or IBM PC computer.

5. **Precision** - Limit is ±0.050 % at four min. count and ±0.025 % at sixteen min count based on 6.0% AC.

4. **EQUIPMENT**

A. The following is a list of the equipment required to perform this test.

1. Asphalt Content Gauge (Meets ASTM D4125)

2. Sample Pans (4) four

3. Balance (Weighing capacity 10K sensitive to 0.2 g)

4. Conventional horizontal flow oven (Capable of maintaining 350° ±5°F.

5. Straightedge

6. Minimum 3/4" plywood or 3/8" metal plate sized to compact sample

7. Assorted spoons, spatulas, pans, and bowls.

MATERIALS LABORATORY PROCEDURE

5. **PROCEDURE FOR DETERMINATION OF BASE WEIGHT**

NOTE: Base weight is defined as the amount of oven dried aggregate, combined at mix design proportions, that is required to fill the sample pan level full. Henceforth all samples (calibration and test) will be prepared to equal the base weight within ±1 gram. The procedure to prepare the blank sample and determine the base weight is outlined as follows:

A. Batch aggregate to mix design proportions and oven dry overnight at 325° ±5°F.

B. Obtain sample pan tare weight, and fill pan one-third full with dried aggregate. Lift sample pan about inch above surface and drop twice.

C. Level aggregate with spoon, and fill pan two-thirds full. Lift sample pan about inch above surface and drop twice.

D. Level aggregate with spoon, and overfill the pan. Place a straight edge at one end of the sample pan and with a sawing motion strike it off. Fill in any voids.

E. Weigh and subtract tare weight. Record value to nearest 5 grams. This establishes the base weight.

F. Store blank sample at 250° ±9°F oven for use in checking aggregate uniformity.

6. **CROSS CALIBRATION**

NOTE: Cross calibration is the calibration of both Master and Field Gauges with identical samples. This establishes a relational curve for both gauges which is stored on the field gauge.

A. Heat aggregate to 325° ±5°F.

B. Calculate five samples at 0.5% asphalt content increments, ranging from 5.0 to 7.0, and proportion a minimum quantity to equal base weight.

C. Calculate the % of asphalt based on total weight of mixture. Formula for determining weight of asphalt is:

$$\text{Asphalt Weight} = \frac{\text{Aggregate weight X \% Asphalt}}{\text{\% Aggregate}} \text{ X } 100$$

D. Mix and place material into pan in three layers. Each layer is leveled with spoon to fill voids in corners.

E. Temperature of sample shall be 250° ±10°F.

F. Use plate to compact final lift. Weigh sample and adjust weight to equal base weight ±1 gram.

G. Calibrate master and field gauges with sixteen minute count by following manufacture instructions.

7. **CALIBRATION OF JOB MIX FORMULA**

NOTE: It is recommended that the initial calibration samples be fabricated at the Materials Laboratory (Salem) in conjunction with the preparation of each job mix formula. Field calibration is necessary, e.g. when the Salem lab does not perform the mix design or when a change is made in the design parameters. The gauge is calibrated using a minimum of three points. One sample shall represent the design asphalt content while the other two are one percent below and above the design sample.

A. Batch aggregate to mix design proportions and oven dry overnight at 325° ±5°F. Heat asphalt at 300° ±5°F.

B. Mix samples using desired asphalt contents and follow the same procedure as in cross calibration section (6D-6G).

C. Match base weight within ±1 gram.

D. Perform calibration on Master gauge and send calibration data to field for calibration of Field gauge.

8. **AGGREGATE UNIFORMITY**

NOTE: This is a quantitative determination of the difference in aggregate counts between blank (base weight) and blank test (final belt) samples to verify that the aggregate used in production of asphaltic concrete is substantially the same as the aggregate used for the preparation of the calibration curve.

A. Measure background count and select appropriate calibration curve.

B. Obtain blank sample saved in 5F and perform eight minute count

C. Record blank sample count. All subsequent field test shall be within ±1.5% of the blank sample count.

FIELD OPERATION PROCEDURE

9. **SETUP OF FIELD GAUGE**

A. Setup and maintain gauge out of the congested area inside the test trailer. Any hydrogen sources, e.g. water reservoirs, personnel, are kept at least five feet away. **Walk away from gauge while it is operating.**

B. Perform at least three background counts to establish an average value and determine standard deviation (sd), subsequently determine (sd) on running average. The background count shall be within 2 sd of mean before it is accepted.

10. **CALIBRATION OF FIELD GAUGE**

A. Use calibration data supplied in item 7D above, which is listed on preliminary bituminous sheet, and program field gauge via calibration transfer routine.

B. Check aggregate uniformity by running a blank test sample and comparing against value from 8C. If check does not comply within tolerance, another calibration shall be performed.

11. **FIELD GAUGE TESTING ROUTINE**

A. Perform background count twice daily, once in morning and once in afternoon, and whenever there is a sudden change in the environment.

B. Insure proper calibration curve is prompted.

C. Obtain sample of mixture from the plant, and split sample for moisture and nuclear gauge.

D. Using the split portion obtain a moisture content by OSHD TM 311(N).

E. Prepare test sample by simulating the procedure in preparing calibration samples (6D through 6F).

F. Eight minute count time shall be used to perform test.

G. The asphalt content shall be corrected for moisture content on a 1:1 basis.

Appendix D **OSHD TM311(N)**

Method of Test for

Moisture Correction for Bituminous Mixtures When Asphalt Content is Determined by Nuclear Method

1. **SCOPE**

1.1 This method describes the procedure to be used in the Central Laboratory or field for determining the moisture content of hot mixed bituminous mixtures by use of a conventional drying oven.

1.2 Results from this method are used to correct the asphalt gauge reading for moisture content.

2. **APPARATUS**

2.1 Balance capable of weighing 2000 grams to an accuracy of 0.1 gram.

2.2 Conventional oven capable of maintaining 250° ±9°F

2.3 Sample pans measuring 9" X 13" X 2" or 23cm X 33cm X 2cm

3. **SAMPLE**

3.1 One sample shall be a split to determine both asphalt and moisture content. The moisture sample shall be weighed before the preparation of asphalt sample.

3.2 Place a 1000 gram representative sample into a tared pan in an even thin layer. Weigh the sample and record the weight. Dry to a constant weight in a 250° ±9°F conventional oven. Generally this will be for 24 hours.

Note: Constant weight shall be defined as less than 0.1% loss in weight. (1 gram in 1 hour on 1000 gram sample)

4. **CALCULATION**

4.1 Moisture Loss = Initial Weight - Final Weight

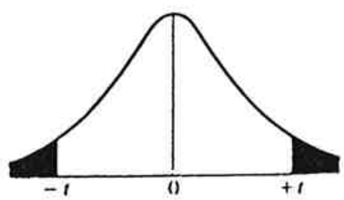
$$\% \text{ Moisture Content} = \frac{\text{Moisture Loss}}{\text{Final Weight}} \times 100$$

4.2 Moisture content percentage shall be directly subtracted from the asphalt gauge reading.

Appendix E Student t Distribution

The Student t Distribution Curve exhibits the probability that t lies between two given values as determined by the appropriate area under the curve. The degrees of freedom are listed in the first column, and the t value corresponding to various two-tail areas are listed in the other columns. For example, with 15 degrees of freedom, the t value corresponding to a confidence value of 0.05 for the two-tail area equals 2.131. This means that the probability of obtaining a mean difference between two sample populations by chance with a Student t- statistic between 2.131 or -2.131 (15 degrees of freedom) is equal to 0.05 (5 percent).

Student's *t*-Distribution



Example For 15 degrees of freedom, the *t*-value which corresponds to an area of 0.05 in both tails combined is 2131.

Degrees of Freedom	*Area in Both Tails Combined* 0.10	0.05	0.02	0.01
1	6.314	12.706	31.821	63.657
2	2.920	4.303	6.965	9.925
3	2.353	3.182	4.541	5.841
4	2.132	2.776	3.747	4.604
5	2.015	2.571	3.365	4.032
6	1.943	2.447	3.143	3.707
7	1.895	2.365	2.998	3.499
8	1.860	2.306	2.896	3.355
9	1.833	2.262	2.821	3.250
10	1.812	2.228	2.764	3.169
11	1.796	2.201	2.718	3.106
12	1.782	2.179	2.681	3.055
13	1.771	2.160	2.650	3.012
14	1.761	2.145	2.624	2.977
15	1.753	2.131	2.602	2.947
16	1.746	2.120	2.583	2.921
17	1.740	2.110	2.567	2.898
18	1.734	2.101	2.552	2.878
19	1.729	2.093	2.539	2.861
20	1.725	2.086	2.528	2.845
21	1.721	2.080	2.518	2.831
22	1.717	2.074	2.508	2.819
23	1.714	2.069	2.500	2.807
24	1.711	2.064	2.492	2.797
25	1.708	2.060	2.485	2.787
26	1.706	2.056	2.479	2.779
27	1.703	2.052	2.473	2.771
28	1.701	2.048	2.467	2.763
29	1.699	2.045	2.462	2.756
30	1.697	2.042	2.457	2.750
40	1.684	2.021	2.423	2.704
60	1.671	2.000	2.390	2.660
120	1.658	1.980	2.358	2.617
Normal Distribution	1.645	1.960	2.326	2.576

Source: Table A-6 is taken from Table III of Fisher and Yates: *Statistical Tables for Biological, Agricultural and Medical Research*, published by Oliver and Boyd Ltd., Edinburgh, and by permission of the authors and publishers.

Appendix F AGGREGATE SOURCE DATA

Hilroy 24-002-2

Date Report	Fine Agg Bulk	Fine Agg Abs	Coarse Agg Bulk	Coarse Agg Abs
890619	2.53	3.24		
890619			2.62	1.84
880902	2.52	3.11		
880902			2.63	1.79
880526	2.51	3.52		
880526			2.62	1.90
870820	2.56	2.65		
870820			2.63	1.82
870703			2.61	2.10
870716	2.53	3.07		
870716	2.55	2.82		
870713	2.52	3.46		
870713			2.61	1.94
870518	2.56	2.97		
870518			2.63	1.72
861001	2.55	2.99		
861001			2.60	2.10
860827	2.57	2.73		
860827			2.62	1.95
860728	2.53	3.26		
860728			2.66	1.66
860722	2.53	3.46		
860722			2.61	2.10
860717	2.51	3.82		
860717			2.59	2.41
860514	2.56	2.69		
860514			2.62	1.79

Delta 20-046-3

Date Report	Fine Agg Bulk	Fine Agg Abs	Coarse Agg Bulk	Coarse Agg Abs
881004	2.65	1.73		
881004	2.59	2.67		
881004			2.64	2.17
880707			2.58	2.18
871028	2.50	3.07		
871028	2.59	2.77		
871028			2.64	1.96
870720	2.52	3.67		
870720	2.56	3.16		
870720			2.65	1.95
870624			2.65	1.83
870511	2.55	3.20		
870511			2.62	2.07

Dayton 36-004-2

Date Report	Fine Agg Bulk	Fine Agg Abs	Coarse Agg Bulk	Coarse Agg Abs
890602	2.58	2.77		
890602			2.61	1.69
880705	2.50	3.07		
880705			2.62	2.07

Appendix F AGGREGATE SOURCE DATA

Wildish 20-048-3				
Date Report	Fine Agg Bulk	Fine Agg Abs	Coarse Agg Bulk	Coarse Agg Abs
890817			2.64	1.96
890810	2.60	2.71		
890727			2.61	2.26
890723			2.62	2.17
890731	2.56	3.33		
890627			2.62	2.20
880902			2.62	2.02
880907			2.61	2.39
880812	2.59	2.71		
880722	2.56	3.20		
880722			2.63	2.05
880617	2.44	5.04		
880617			2.61	2.35
880617			2.61	2.20
880330	2.45	5.17		
870831			2.62	2.20
870831	2.92	2.33		
870805	2.53	3.84		
870805			2.62	2.24
870805			2.63	1.95
870730	2.54	3.48		
870730			2.62	2.26
870730			2.60	2.32
870706			2.61	2.42
870706			2.61	2.19
870730			2.60	2.44
870716	2.57	3.48		
870610	2.57	3.24		
870629			2.63	2.23
870629			2.63	2.03

Brossi 10-193-3				
Date Report	Fine Agg Bulk	Fine Agg Abs	Coarse Agg Bulk	Coarse Agg Abs
890727	2.56	2.82		
890727	2.55	3.11		
890727			2.67	1.48
890727			2.69	1.45
890707	2.56	3.05		
890707			2.69	1.38
881205	2.57	2.54		
881205			2.67	1.62
881118	2.60	2.31		
881118			2.65	1.65
881005	2.60	2.31		
881005			2.67	1.55
880728	2.58	2.61		
880728			2.72	1.31
880718	2.63	1.79		
880718			2.70	1.41
870713	2.54	2.82		
870713			2.68	1.55

APPENDIX G

STUDENT t ANALYSIS FOR ASPHALT CONTENT

LIST OF TABLES

TABLE 1
DETROIT -IDANHA
NUCLEAR VS EXTRACTION

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	6.14	5.60	-0.54	-0.79	0.25	0.06	0.21	0.06	-13.1397
2	6.22	5.80	-0.42		0.37	0.14			
3	6.60	5.50	-1.10		-0.31	0.10			
4	5.94	5.30	-0.64		0.15	0.02			
5	6.37	5.60	-0.77		0.02	0.00			
6	6.32	5.40	-0.92		-0.13	0.02			
7	6.24	5.40	-0.84		-0.05	0.00			
8	6.21	5.50	-0.71		0.08	0.01			
9	6.36	5.50	-0.86		-0.07	0.00			
10	6.10	5.40	-0.70		0.09	0.01			
11	6.27	5.40	-0.87		-0.08	0.01			
12	6.53	5.40	-1.13		-0.34	0.11			

TABLE 2
DETROIT - IDANHA
TANK STICK VS EXTRACTION

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.81	5.60	-0.21	-0.36	0.15	0.02	0.17	0.05	-7.1745
2	5.81	5.80	-0.01		0.35	0.12			
3	5.81	5.50	-0.31		0.05	0.00			
4	5.95	5.30	-0.65		-0.29	0.08			
5	5.95	5.60	-0.35		0.01	0.00			
6	5.95	5.40	-0.55		-0.19	0.04			
7	5.95	5.40	-0.55		-0.19	0.04			
8	5.76	5.50	-0.26		0.10	0.01			
9	5.76	5.50	-0.26		0.10	0.01			
10	5.76	5.40	-0.36		0.00	0.00			
11	5.76	5.40	-0.36		0.00	0.00			
12	5.86	5.40	-0.46		-0.10	0.01			

TABLE 3
DETROIT - IDANHA
TANK STICK VS NUCLEAR

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.81	6.14	0.33	0.43	-0.10	0.01	0.20	0.06	7.3118
2	5.81	6.22	0.41		-0.02	0.00			
3	5.81	6.60	0.79		0.36	0.13			
4	5.95	5.94	-0.01		-0.44	0.19			
5	5.95	6.37	0.42		-0.01	0.00			
6	5.95	6.32	0.37		-0.06	0.00			
7	5.95	6.24	0.29		-0.14	0.02			
8	5.76	6.21	0.45		0.02	0.00			
9	5.76	6.36	0.60		0.17	0.03			
10	5.76	6.10	0.34		-0.09	0.01			
11	5.76	6.27	0.51		0.08	0.01			
12	5.86	6.53	0.67		0.24	0.06			

TABLE 4
NOTI-VENETA, EAST UNIT
NUCLEAR VS EXTRACTION

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	6.49	5.70	-0.79	-0.84	0.05	0.00	0.21	0.07	-12.0340
2	6.49	5.50	-0.99		-0.15	0.02			
3	6.64	5.80	-0.84		0.00	0.00			
4	6.81	5.60	-1.21		-0.37	0.13			
5	6.29	5.50	-0.79		0.05	0.00			
6	6.38	5.80	-0.58		0.26	0.07			
7	6.02	5.50	-0.52		0.32	0.10			
8	6.61	5.70	-0.91		-0.07	0.00			
9	6.66	5.70	-0.96		-0.12	0.01			

TABLE 5
NOTI-VENETA, EAST UNIT
TANK STICK VS EXTRACTION

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.74	5.70	-0.04	-0.10	0.06	0.00	0.24	0.08	-1.2665
2	5.74	5.50	-0.24		-0.14	0.02			
3	5.59	5.80	0.21		0.31	0.10			
4	5.59	5.60	0.01		0.11	0.01			
5	5.59	5.50	-0.09		0.01	0.00			
6	5.59	5.80	0.21		0.31	0.10			
7	5.59	5.50	-0.09		0.01	0.00			
8	6.14	5.70	-0.44		-0.34	0.11			
9	6.14	5.70	-0.44		-0.34	0.11			

TABLE 6
NOTI-VENETA, EAST UNIT
TANK STICK VS NUCLEAR

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.74	6.49	0.75	0.74	0.01	0.00	0.26	0.09	8.5064
2	5.74	6.49	0.75		0.01	0.00			
3	5.59	6.64	1.05		0.31	0.09			
4	5.59	6.81	1.22		0.48	0.23			
5	5.59	6.29	0.70		-0.04	0.00			
6	5.59	6.38	0.79		0.05	0.00			
7	5.59	6.02	0.43		-0.31	0.10			
8	6.14	6.61	0.47		-0.27	0.07			
9	6.14	6.66	0.52		-0.22	0.05			

TABLE 7
WAPATO ROAD - N.C.L. YAMHILL
NUCLEAR VS EXTRACTION

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	7.27	6.40	-0.87	-0.76	-0.11	0.01	0.29	0.11	-6.9661
~~2~~	~~6.85~~	~~6.60~~	~~-0.25~~		~~-0.51~~	~~0.26~~			
3	7.39	6.50	-0.89		-0.13	0.02			
4	7.56	6.50	-1.06		-0.30	0.09			
5	7.19	6.30	-0.89		-0.13	0.02			
6	7.52	6.60	-0.92		-0.16	0.02			
7	6.97	6.50	-0.47		0.29	0.09			

TABLE 8
DISTRICT 5 LIME TREATED
NUCLEAR VS EXTRACTION

NOTE: X1 = NUC; X2 = EXT; d = X2-X1; D = AVG d; Sd = std. dev.; SD = Sd/sq rt(N); t = D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	4.93	6.06	1.13	0.66	0.47	0.22	0.48	0.22	3.0457
2	4.88	6.10	1.22		0.56	0.32			
3	5.31	5.74	0.43		-0.23	0.05			
4	5.54	5.89	0.35		-0.31	0.09			
5	5.40	5.56	0.16		-0.50	0.25			

TABLE 9
DISTRICT 5 LIME TREATED
TANK STICK VS EXTRACTION

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.80	6.06	0.26	0.23	0.03	0.00	0.20	0.09	2.5524
2	5.80	6.10	0.30		0.07	0.00			
3	5.80	5.74	-0.06		-0.29	0.08			
4	5.40	5.89	0.49		0.26	0.07			
5	5.40	5.56	0.16		-0.07	0.00			

TABLE 10
DISTRICT 5 LIME TREATED
TANK STICK VS NUCLEAR

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.80	4.93	-0.87	-0.43	-0.44	0.20	0.49	0.22	-1.9668
2	5.80	4.88	-0.92		-0.49	0.24			
3	5.80	5.31	-0.49		-0.06	0.00			
4	5.40	5.54	0.14		0.57	0.32			
5	5.40	5.40	0.00		0.43	0.18			

TABLE 11
DISTRICT 5 LIME TREATED
METER VS EXTRACTION

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.60	6.06	0.46	0.25	0.21	0.05	0.23	0.12	2.1283
2	5.90	6.10	0.20		-0.05	0.00			
3	5.80	5.74	-0.06		-0.31	0.09			
4	5.50	5.89	0.39		0.14	0.02			

TABLE 12
DISTRICT 5 LIME TREATED
METER VS NUCLEAR

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.60	4.93	-0.67	-0.54	-0.13	0.02	0.44	0.22	-2.4208
2	5.90	4.88	-1.02		-0.49	0.24			
3	5.80	5.31	-0.49		0.04	0.00			
4	5.50	5.54	0.04		0.58	0.33			

TABLE 13
DISTRICT 5 NO LIME
NUCLEAR VS EXTRACTION

Note: X1 = NUC; X2 = EXT; d = X2-X1; D = AVG d; Sd = std dev; SD = Sd/sq rt (N); t = D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.98	6.46	0.48	0.05	0.43	0.19	0.43	0.12	0.3878
2	5.92	6.12	0.20		0.15	0.02			
3	5.61	5.83	0.22		0.17	0.03			
4	5.97	6.09	0.12		0.07	0.01			
5	5.39	5.92	0.53		0.48	0.23			
6	5.41	5.81	0.40		0.35	0.12			
7	5.63	5.81	0.18		0.13	0.02			
8	7.09	6.05	-1.04		-1.09	1.18			
9	6.17	5.85	-0.32		-0.37	0.14			
10	5.95	5.67	-0.28		-0.33	0.11			
11	5.73	5.83	0.10		0.05	0.00			
12	5.91	5.90	-0.01		-0.06	0.00			

TABLE 14
DISTRICT NO LIME
TANK STICK VS EXTRACTION

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.90	6.46	0.56	0.11	0.45	0.20	0.18	0.05	2.1360
2	5.90	6.12	0.22		0.11	0.01			
3	5.90	5.83	-0.07		-0.18	0.03			
4	5.90	6.09	0.19		0.08	0.01			
5	5.80	5.92	0.12		0.01	0.00			
6	5.80	5.81	0.01		-0.10	0.01			
7	5.80	5.81	0.01		-0.10	0.01			
8	5.80	6.05	0.25		0.14	0.02			
9	5.80	5.85	0.05		-0.06	0.00			
10	5.80	5.67	-0.13		-0.24	0.06			
11	5.80	5.83	0.03		-0.08	0.01			
12	5.80	5.90	0.10		-0.01	0.00			

TABLE 15
DISTRICT 5 NO LIME
TANK STICK VS NUCLEAR

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.90	5.98	0.08	0.06	0.02	0.00	0.45	0.13	0.4865
2	5.90	5.92	0.02		-0.04	0.00			
3	5.90	5.61	-0.29		-0.35	0.12			
4	5.90	5.97	0.07		0.01	0.00			
5	5.80	5.39	-0.41		-0.47	0.22			
6	5.80	5.41	-0.39		-0.45	0.21			
7	5.80	5.63	-0.17		-0.23	0.05			
8	5.80	7.09	1.29		1.23	1.50			
9	5.80	6.17	0.37		0.31	0.09			
10	5.80	5.95	0.15		0.09	0.01			
11	5.80	5.73	-0.07		-0.13	0.02			
12	5.80	5.91	0.11		0.05	0.00			

TABLE 16
DISTRICT 5 NO LIME
METER VS EXTRACTION

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.80	6.46	0.66	-0.02	0.68	0.46	0.32	0.10	-0.1719
2	6.00	5.83	-0.17		-0.15	0.02			
3	6.00	6.09	0.09		0.11	0.01			
4	6.20	5.92	-0.28		-0.26	0.07			
5	5.90	5.81	-0.09		-0.07	0.01			
6	6.40	5.81	-0.59		-0.57	0.33			
7	5.80	6.05	0.25		0.27	0.07			
8	5.90	5.85	-0.05		-0.03	0.00			
9	5.80	5.67	-0.13		-0.11	0.01			
10	5.80	5.83	0.03		0.05	0.00			
11	5.80	5.90	0.10		0.12	0.01			

TABLE 17
DIATRICT 5 NO LIME
METER VS NUCLEAR

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.80	5.98	0.18	-0.05	0.23	0.05	0.59	0.18	-0.2886
2	6.00	5.61	-0.39		-0.34	0.11			
3	6.00	5.97	-0.03		0.02	0.00			
4	6.20	5.39	-0.81		-0.76	0.58			
5	5.90	5.41	-0.49		-0.44	0.19			
6	6.40	5.63	-0.77		-0.72	0.52			
7	5.80	7.09	1.29		1.34	1.80			
8	5.90	6.17	0.27		0.32	0.10			
9	5.80	5.95	0.15		0.20	0.04			
10	5.80	5.73	-0.07		-0.02	0.00			
11	5.80	5.91	0.11		0.16	0.03			

TABLE 18
CAMAS MT - MUNS CREEK
NUCLEAR VS EXTRACTION

NOTE: X1 = NUC; X2 = EXT; d = X2-X1; D = Avg d; Sd = std dev; SD = Sd/sq rt (N); t = D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.78	5.30	-0.48	-0.78	0.30	0.09	0.37	0.16	-4.7335
2	6.37	5.42	-0.95		-0.17	0.03			
3	6.12	5.44	-0.68		0.10	0.01			
4	6.20	5.75	-0.45		0.33	0.11			
5	6.88	5.55	-1.33		-0.55	0.30			

TABLE 19
FISH CREEK-CHINQUAPIN CREEK
NUCLEAR VS EXTRACTION

NOTE: X1 = NUC; X2 = EXT; d = X2-X1; D = AVG d; Sd = std dev; SD = Sd/sq rt (N); t = D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.03	5.86	0.83	0.43	0.40	0.16	0.26	0.09	4.9684
2	5.44	5.98	0.54		0.11	0.01			
3	5.04	5.40	0.36		-0.07	0.01			
4	5.42	5.69	0.27		-0.16	0.03			
5	5.62	5.83	0.21		-0.22	0.05			
6	5.15	5.64	0.49		0.06	0.00			
7	5.57	5.53	-0.04		-0.47	0.22			
8	5.36	6.00	0.64		0.21	0.04			
9	5.32	5.90	0.58		0.15	0.02			

TABLE 20
E MCMINNVILLE-INTCGHE AIRPORT RD
NUCLEAR VS EXTRACTION

NOTE: X1 = NUC; X2 = EXT; d = X2-X1; D = AVG d; Sd = std dev; SD = Sd/sq rt (N); t = D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.55	5.36	-0.19	-0.29	0.10	0.01	0.13	0.03	-8.6637
2	5.44	5.13	-0.31		-0.02	0.00			
3	5.79	5.40	-0.39		-0.10	0.01			
4	5.24	4.92	-0.32		-0.03	0.00			
5	6.01	5.45	-0.56		-0.27	0.07			
6	5.78	5.38	-0.40		-0.11	0.01			
7	5.41	5.16	-0.25		0.04	0.00			
8	5.74	5.45	-0.29		0.00	0.00			
9	6.08	5.69	-0.39		-0.10	0.01			
10	5.61	5.23	-0.38		-0.09	0.01			
11	5.52	5.25	-0.27		0.02	0.00			
12	5.71	5.57	-0.14		0.15	0.02			
13	5.79	5.54	-0.25		0.04	0.00			
14	5.55	5.56	0.01		0.30	0.09			
15	5.52	5.25	-0.27		0.02	0.00			

TABLE 21
E MCMINNVILLE - INTCHGE AIRPORT RD
TANK STICK VS EXTRACTION

NOTE: d=X2-X1; D=ave. d; Sd=std.dev.; SD=Sd/sqrt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.20	5.36	0.16	0.03	0.13	0.02	0.23	0.06	0.5499
2	5.20	5.13	-0.07		-0.10	0.01			
3	5.40	5.40	0.00		-0.03	0.00			
4	5.33	4.92	-0.41		-0.44	0.20			
5	5.33	5.45	0.12		0.09	0.01			
6	5.33	5.38	0.05		0.02	0.00			
7	5.41	5.16	-0.25		-0.28	0.08			
8	5.41	5.45	0.04		0.01	0.00			
9	5.41	5.69	0.28		0.25	0.06			
10	5.20	5.23	0.03		0.00	0.00			
11	5.39	5.25	-0.14		-0.17	0.03			
12	5.39	5.57	0.18		0.15	0.02			
13	5.16	5.54	0.38		0.35	0.12			
14	5.16	5.56	0.40		0.37	0.13			
15	5.52	5.25	-0.27		-0.30	0.09			

TABLE 22
E MICMINNVILLE-INTCHGE AIRPORT RD
TANK STICK VS NUCLEAR

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.20	5.55	0.35	0.33	0.02	0.00	0.24	0.06	5.2968
2	5.20	5.44	0.24		-0.09	0.01			
3	5.40	5.79	0.39		0.06	0.00			
4	5.33	5.24	-0.09		-0.42	0.17			
5	5.33	6.01	0.68		0.35	0.12			
6	5.33	5.78	0.45		0.12	0.02			
7	5.41	5.41	0.00		-0.33	0.11			
8	5.41	5.74	0.33		0.00	0.00			
9	5.41	6.08	0.67		0.34	0.12			
10	5.20	5.61	0.41		0.08	0.01			
11	5.39	5.52	0.13		-0.20	0.04			
12	5.39	5.71	0.32		-0.01	0.00			
13	5.16	5.79	0.63		0.30	0.09			
14	5.16	5.55	0.39		0.06	0.00			
15	5.52	5.52	0.00		-0.33	0.11			

TABLE 23
DISTRICT 7
NUCLEAR VS EXTRACTION

NOTE: X1 = NUC; X2 = EXT; d = X2-X1; D = AVG d; Sd = std dev; SD = Sd/sq rt (N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	6.15	5.30	-0.85	-0.29	-0.56	0.31	0.31	0.09	-3.2718
2	5.57	5.40	-0.17		0.12	0.02			
3	5.39	5.40	0.01		0.30	0.09			
4	5.76	5.30	-0.46		-0.17	0.03			
5	5.61	5.60	-0.01		0.28	0.08			
6	5.22	4.50	-0.72		-0.43	0.18			
7	5.75	5.30	-0.45		-0.16	0.02			
8	5.09	5.30	0.21		0.50	0.25			
9	5.87	5.40	-0.47		-0.18	0.03			
10	5.36	5.10	-0.26		0.03	0.00			
11	5.31	5.20	-0.11		0.18	0.03			
12	5.63	5.40	-0.23		0.06	0.00			

TABLE 24
DISTRICT 7
TANK STICK VS EXTRACTION

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.48	5.30	-0.18	-0.25	0.07	0.01	0.30	0.10	-2.5009
2	5.48	5.40	-0.08		0.17	0.03			
3	5.82	5.40	-0.42		-0.17	0.03			
4	5.56	5.30	-0.26		-0.01	0.00			
5	5.37	5.60	0.23		0.48	0.23			
6	5.37	4.50	-0.87		-0.62	0.38			
7	5.46	5.10	-0.36		-0.11	0.01			
8	5.46	5.20	-0.26		-0.01	0.00			
9	5.46	5.40	-0.06		0.19	0.04			

TABLE 25
DISTRICT 7
TANK STICK VS NUCLEAR

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.48	6.15	0.67	0.06	0.61	0.37	0.31	0.10	0.5724
2	5.48	5.57	0.09		0.03	0.00			
3	5.82	5.39	-0.43		-0.49	0.24			
4	5.56	5.76	0.20		0.14	0.02			
5	5.37	5.61	0.24		0.18	0.03			
6	5.37	5.22	-0.15		-0.21	0.04			
7	5.46	5.36	-0.10		-0.16	0.03			
8	5.46	5.31	-0.15		-0.21	0.04			
9	5.46	5.63	0.17		0.11	0.01			

APPENDIX H

STUDENT t ANALYSIS FOR GRADATION

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TABLE 1
FISH CREEK-CHINQUAPIN CREEK SECTION
EXTRACTION VS COLD FEED 1/2"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	73.00	72.00	-1.00	-5.92	4.92	24.17	7.00	2.02	-2.9282
2	79.00	65.00	-14.00		-8.08	65.34			
3	72.00	56.00	-16.00		-10.08	101.67			
4	68.00	62.00	-6.00		-0.08	0.01			
5	72.00	53.00	-19.00		-13.08	171.17			
6	64.00	59.00	-5.00		0.92	0.84			
7	66.00	62.00	-4.00		1.92	3.67			
8	73.00	77.00	4.00		9.92	98.34			
9	67.00	68.00	1.00		6.92	47.84			
10	76.00	71.00	-5.00		0.92	0.84			
11	75.00	70.00	-5.00		0.92	0.84			
12	73.00	72.00	-1.00		4.92	24.17			

TABLE 2
FISH CREEK-CHINQUAPIN CREEK SECTION
EXTRACTION VS COLD FEED 1/4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	28.00	31.00	3.00	-3.33	6.33	40.11	4.33	1.25	-2.6640
2	31.00	21.00	-10.00		-6.67	44.44			
3	28.00	20.00	-8.00		-4.67	21.78			
4	27.00	21.00	-6.00		-2.67	7.11			
5	28.00	20.00	-8.00		-4.67	21.78			
6	27.00	23.00	-4.00		-0.67	0.44			
7	27.00	23.00	-4.00		-0.67	0.44			
8	26.00	30.00	4.00		7.33	53.78			
9	26.00	23.00	-3.00		0.33	0.11			
10	27.00	24.00	-3.00		0.33	0.11			
11	27.00	26.00	-1.00		2.33	5.44			
12	29.00	29.00	0.00		3.33	11.11			

TABLE 3
FISH CREEK-CHINQUAPIN CREEK SECTION
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	17.00	18.00	1.00	-2.58	3.58	12.84	2.94	0.85	-3.0465
2	19.00	12.00	-7.00		-4.42	19.51			
3	18.00	11.00	-7.00		-4.42	19.51			
4	17.00	13.00	-4.00		-1.42	2.01			
5	17.00	13.00	-4.00		-1.42	2.01			
6	17.00	14.00	-3.00		-0.42	0.17			
7	17.00	14.00	-3.00		-0.42	0.17			
8	12.00	14.00	2.00		4.58	21.01			
9	13.00	11.00	-2.00		0.58	0.34			
10	14.00	10.00	-4.00		-1.42	2.01			
11	13.00	12.00	-1.00		1.58	2.51			
12	13.00	14.00	1.00		3.58	12.84			

TABLE 4
FISH CREEK-CHINQUAPIN CREEK SECTION
EXTRACTION VS COLD FEED #40

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sq rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	8.00	6.00	-2.00	-1.83	-0.17	0.03	1.70	0.49	-3.7431
2	9.00	4.00	-5.00		-3.17	10.03			
3	8.00	5.00	-3.00		-1.17	1.36			
4	8.00	5.00	-3.00		-1.17	1.36			
5	8.00	5.00	-3.00		-1.17	1.36			
6	8.00	6.00	-2.00		-0.17	0.03			
7	8.00	6.00	-2.00		-0.17	0.03			
8	6.00	7.00	1.00		2.83	8.03			
9	7.00	6.00	-1.00		0.83	0.69			
10	7.00	5.00	-2.00		-0.17	0.03			
11	7.00	6.00	-1.00		0.83	0.69			
12	6.00	7.00	1.00		2.83	8.03			

TABLE 5
FISH CREEK-CHINQUAPIN CREEK SECTION
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sq rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	3.30	0.40	-2.90	-1.82	-1.08	1.17	1.25	0.36	-5.0390
2	3.60	0.30	-3.30		-1.48	2.20			
3	2.80	0.30	-2.50		-0.68	0.47			
4	2.80	0.40	-2.40		-0.58	0.34			
5	3.70	1.20	-2.50		-0.68	0.47			
6	3.70	0.40	-3.30		-1.48	2.20			
7	3.50	0.80	-2.70		-0.88	0.78			
8	3.10	2.70	-0.40		1.42	2.01			
9	3.50	3.20	-0.30		1.52	2.30			
10	3.40	2.80	-0.60		1.22	1.48			
11	3.20	2.70	-0.50		1.32	1.73			
12	3.20	2.80	-0.40		1.42	2.01			

TABLE 6
E MCMINNVILLE - INTCGHE AIRPORT RD SECT
EXTRACTION VS COLD FEED 1/2"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	78.00	83.00	5.00	0.00	5.00	25.00	2.77	0.74	0.0000
2	86.00	82.00	-4.00		-4.00	16.00			
3	84.00	85.00	1.00		1.00	1.00			
4	87.00	85.00	-2.00		-2.00	4.00			
5	89.00	85.00	-4.00		-4.00	16.00			
6	85.00	83.00	-2.00		-2.00	4.00			
7	87.00	87.00	0.00		0.00	0.00			
8	88.00	86.00	-2.00		-2.00	4.00			
9	79.00	84.00	5.00		5.00	25.00			
10	83.00	83.00	0.00		0.00	0.00			
11	84.00	85.00	1.00		1.00	1.00			
12	87.00	87.00	0.00		0.00	0.00			
13	89.00	89.00	0.00		0.00	0.00			
14	84.00	86.00	2.00		2.00	4.00			

TABLE 7
E MCMINNVILLE - INTCGHE AIRPORT RD SECT
EXTRACTION VS COLD FEED 1-4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	50.00	56.00	6.00	-0.29	6.29	39.51	2.92	0.78	-0.3661
2	59.00	60.00	1.00		1.29	1.65			
3	53.00	55.00	2.00		2.29	5.22			
4	61.00	60.00	-1.00		-0.71	0.51			
5	61.00	60.00	-1.00		-0.71	0.51			
6	58.00	55.00	-3.00		-2.71	7.37			
7	60.00	61.00	1.00		1.29	1.65			
8	65.00	59.00	-6.00		-5.71	32.65			
9	54.00	55.00	1.00		1.29	1.65			
10	60.00	58.00	-2.00		-1.71	2.94			
11	54.00	56.00	2.00		2.29	5.22			
12	60.00	61.00	1.00		1.29	1.65			
13	63.00	60.00	-3.00		-2.71	7.37			
14	58.00	56.00	-2.00		-1.71	2.94			

TABLE 8
E MCMINNVILLE - INTCGHE AIRPORT RD SECT
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	26.00	28.00	2.00	-0.71	2.71	7.37	1.86	0.50	-1.4388
2	30.00	31.00	1.00		1.71	2.94			
3	27.00	29.00	2.00		2.71	7.37			
4	32.00	30.00	-2.00		-1.29	1.65			
5	31.00	31.00	0.00		0.71	0.51			
6	30.00	29.00	-1.00		-0.29	0.08			
7	31.00	31.00	0.00		0.71	0.51			
8	34.00	29.00	-5.00		-4.29	18.37			
9	29.00	28.00	-1.00		-0.29	0.08			
10	30.00	29.00	-1.00		-0.29	0.08			
11	28.00	28.00	0.00		0.71	0.51			
12	31.00	30.00	-1.00		-0.29	0.08			
13	32.00	31.00	-1.00		-0.29	0.08			
14	31.00	28.00	-3.00		-2.29	5.22			

TABLE 9
E MCMINNVILLE - INTCGHE AIRPORT RD SECT
EXTRACTION VS COLD FEED #40

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	12.00	13.00	1.00	-0.79	1.79	3.19	0.97	0.26	-3.0154
2	14.00	14.00	0.00		0.79	0.62			
3	13.00	13.00	0.00		0.79	0.62			
4	14.00	13.00	-1.00		-0.21	0.05			
5	14.00	13.00	-1.00		-0.21	0.05			
6	13.00	12.00	-1.00		-0.21	0.05			
7	13.00	13.00	0.00		0.79	0.62			
8	15.00	12.00	-3.00		-2.21	4.90			
9	13.00	12.00	-1.00		-0.21	0.05			
10	13.00	12.00	-1.00		-0.21	0.05			
11	13.00	12.00	-1.00		-0.21	0.05			
12	14.00	13.00	-1.00		-0.21	0.05			
13	14.00	14.00	0.00		0.79	0.62			
14	14.00	12.00	-2.00		-1.21	1.47			

TABLE 10
E MCMINNVILLE - INTCGHE AIRPORT RD SECT
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	4.80	5.20	0.40	0.11	0.29	0.09	0.47	0.12	0.8593
2	5.10	5.70	0.60		0.49	0.24			
3	5.00	5.20	0.20		0.09	0.01			
4	5.70	5.70	0.00		-0.11	0.01			
5	5.70	6.00	0.30		0.19	0.04			
6	5.50	5.40	-0.10		-0.21	0.04			
7	5.10	6.00	0.90		0.79	0.63			
8	6.20	5.40	-0.80		-0.91	0.82			
9	5.40	5.20	-0.20		-0.31	0.09			
10	5.20	5.60	0.40		0.29	0.09			
11	5.30	5.60	0.30		0.19	0.04			
12	5.90	5.80	-0.10		-0.21	0.04			
13	6.00	6.30	0.30		0.19	0.04			
14	5.80	5.10	-0.70		-0.81	0.65			

TABLE 11
DISTRICT 7 PAVING
EXTRACTION VS COLD FEED 1/2"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	63.00	73.00	10.00	-1.91	11.91	141.83	10.85	3.27	-0.5836
2	72.00	70.00	-2.00		-0.09	0.01			
3	71.00	77.00	6.00		7.91	62.55			
4	72.00	77.00	5.00		6.91	47.74			
5	79.00	71.00	-8.00		-6.09	37.10			
6	65.00	68.00	3.00		4.91	24.10			
7	79.00	50.00	-29.00		-27.09	733.92			
8	70.00	77.00	7.00		8.91	79.37			
9	75.00	73.00	-2.00		-0.09	0.01			
10	72.00	70.00	-2.00		-0.09	0.01			
11	73.00	64.00	-9.00		-7.09	50.28			

TABLE 12
DISTRICT 7 PAVING
EXTRACTION VS COLD FEED 1/4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	30.00	39.00	9.00	-1.18	10.18	103.67	6.34	1.91	-0.6185
2	29.00	32.00	3.00		4.18	17.49			
3	32.00	38.00	6.00		7.18	51.58			
4	32.00	34.00	2.00		3.18	10.12			
5	36.00	28.00	-8.00		-6.82	46.49			
6	24.00	24.00	0.00		1.18	1.40			
7	36.00	24.00	-12.00		-10.82	117.03			
8	30.00	31.00	1.00		2.18	4.76			
9	32.00	27.00	-5.00		-3.82	14.58			
10	24.00	22.00	-2.00		-0.82	0.67			
11	26.00	19.00	-7.00		-5.82	33.85			

TABLE 13
DISTRICT 7 PAVING
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	16.00	23.00	7.00	0.55	6.45	41.66	4.50	1.36	0.4018
2	14.00	19.00	5.00		4.45	19.84			
3	15.00	22.00	7.00		6.45	41.66			
4	16.00	21.00	5.00		4.45	19.84			
5	18.00	14.00	-4.00		-4.55	20.66			
6	13.00	11.00	-2.00		-2.55	6.48			
7	18.00	13.00	-5.00		-5.55	30.75			
8	15.00	13.00	-2.00		-2.55	6.48			
9	15.00	13.00	-2.00		-2.55	6.48			
10	11.00	10.00	-1.00		-1.55	2.39			
11	11.00	9.00	-2.00		-2.55	6.48			

TABLE 14
DISTRICT 7 PAVING
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	3.90	2.50	-1.40	-1.45	0.05	0.00	0.52	0.16	-9.2039
2	3.40	2.80	-0.60		0.85	0.73			
3	4.00	3.10	-0.90		0.55	0.31			
4	4.00	3.20	-0.80		0.65	0.43			
5	3.90	1.80	-2.10		-0.65	0.42			
6	3.70	2.00	-1.70		-0.25	0.06			
7	4.80	3.10	-1.70		-0.25	0.06			
8	3.80	2.70	-1.10		0.35	0.13			
9	4.30	2.50	-1.80		-0.35	0.12			
10	3.70	1.70	-2.00		-0.55	0.30			
11	3.50	1.60	-1.90		-0.45	0.20			

TABLE 15
POCAHONTAS - AUBURN
EXTRACTION VS COLD FEED (1/2")

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	98.00	98.00	0.00	-0.31	0.31	0.09	0.95	0.26	-1.1711
2	99.00	98.00	-1.00		-0.69	0.48			
3	98.00	97.00	-1.00		-0.69	0.48			
4	98.00	98.00	0.00		0.31	0.09			
5	97.00	97.00	0.00		0.31	0.09			
6	97.00	98.00	1.00		1.31	1.71			
7	98.00	98.00	0.00		0.31	0.09			
8	98.00	98.00	0.00		0.31	0.09			
9	100.00	97.00	-3.00		-2.69	7.25			
10	98.00	98.00	0.00		0.31	0.09			
11	98.00	98.00	0.00		0.31	0.09			
12	98.00	98.00	0.00		0.31	0.09			
13	98.00	98.00	0.00		0.31	0.09			

TABLE 16
POCAHONTAS - AUBURN
EXTRACTION VS COLD FEED 1/4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	68.00	64.00	-4.00	-1.08	-2.92	8.54	3.45	0.96	-1.1251
2	71.00	65.00	-6.00		-4.92	24.24			
3	69.00	64.00	-5.00		-3.92	15.39			
4	60.00	62.00	2.00		3.08	9.47			
5	60.00	63.00	3.00		4.08	16.62			
6	58.00	61.00	3.00		4.08	16.62			
7	63.00	62.00	-1.00		0.08	0.01			
8	67.00	62.00	-5.00		-3.92	15.39			
9	67.00	63.00	-4.00		-2.92	8.54			
10	62.00	62.00	0.00		1.08	1.16			
11	64.00	63.00	-1.00		0.08	0.01			
12	58.00	62.00	4.00		5.08	25.78			
13	62.00	62.00	0.00		1.08	1.16			

TABLE 17
POCAHONTAS - AUBURN
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	35.00	32.00	-3.00	-2.15	-0.85	0.72	2.34	0.65	-3.3191
2	34.00	33.00	-1.00		1.15	1.33			
3	35.00	27.00	-8.00		-5.85	34.18			
4	31.00	31.00	0.00		2.15	4.64			
5	30.00	27.00	-3.00		-0.85	0.72			
6	30.00	28.00	-2.00		0.15	0.02			
7	32.00	31.00	-1.00		1.15	1.33			
8	34.00	32.00	-2.00		0.15	0.02			
9	33.00	29.00	-4.00		-1.85	3.41			
10	31.00	29.00	-2.00		0.15	0.02			
11	32.00	31.00	-1.00		1.15	1.33			
12	29.00	31.00	2.00		4.15	17.25			
13	34.00	31.00	-3.00		-0.85	0.72			

TABLE 18
POCAHONTAS - AUBURN
EXTRACTION VS COLD FEED #40

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	11.00	10.00	-1.00	-0.31	-0.69	0.48	1.89	0.52	-0.5876
2	12.00	11.00	-1.00		-0.69	0.48			
3	12.00	8.00	-4.00		-3.69	13.63			
4	11.00	10.00	-1.00		-0.69	0.48			
5	11.00	9.00	-2.00		-1.69	2.86			
6	10.00	12.00	2.00		2.31	5.33			
7	11.00	10.00	-1.00		-0.69	0.48			
8	9.00	12.00	3.00		3.31	10.94			
9	10.00	12.00	2.00		2.31	5.33			
10	11.00	12.00	1.00		1.31	1.71			
11	11.00	11.00	0.00		0.31	0.09			
12	11.00	10.00	-1.00		-0.69	0.48			
13	11.00	10.00	-1.00		-0.69	0.48			

TABLE 19
POCAHONTAS - AUBURN
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	3.80	3.90	0.10	-0.09	0.19	0.04	0.76	0.21	-0.4405
2	4.30	3.70	-0.60		-0.51	0.26			
3	4.30	3.40	-0.90		-0.81	0.65			
4	4.20	3.20	-1.00		-0.91	0.82			
5	4.30	3.20	-1.10		-1.01	1.02			
6	3.80	5.20	1.40		1.49	2.23			
7	4.10	4.00	-0.10		-0.01	0.00			
8	3.00	3.60	0.60		0.69	0.48			
9	3.40	4.10	0.70		0.79	0.63			
10	4.10	4.00	-0.10		-0.01	0.00			
11	3.90	3.20	-0.70		-0.61	0.37			
12	4.20	4.70	0.50		0.59	0.35			
13	4.40	4.40	0.00		0.09	0.01			

TABLE 20
QUEEN AVE - CORVALLIS/LEBANON
EXTRACTION VS COLD FEED 1/2"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	84.00	90.00	6.00	0.60	5.40	29.16	2.56	0.57	1.0470
2	93.00	87.00	-6.00		-6.60	43.56			
3	90.00	89.00	-1.00		-1.60	2.56			
4	88.00	92.00	4.00		3.40	11.56			
5	88.00	89.00	1.00		0.40	0.16			
6	92.00	91.00	-1.00		-1.60	2.56			
7	89.00	91.00	2.00		1.40	1.96			
8	90.00	91.00	1.00		0.40	0.16			
9	90.00	91.00	1.00		0.40	0.16			
10	92.00	91.00	-1.00		-1.60	2.56			
11	87.00	89.00	2.00		1.40	1.96			
12	90.00	89.00	-1.00		-1.60	2.56			
13	88.00	90.00	2.00		1.40	1.96			
14	88.00	89.00	1.00		0.40	0.16			
15	91.00	89.00	-2.00		-2.60	6.76			
16	88.00	91.00	3.00		2.40	5.76			
17	92.00	91.00	-1.00		-1.60	2.56			
18	88.00	88.00	0.00		-0.60	0.36			
19	87.00	90.00	3.00		2.40	5.76			
20	92.00	91.00	-1.00		-1.60	2.56			

TABLE 21
QUEEN AVE - CORVALLIS/LEBANON
EXTRACTION VS COLD FEED 1/4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	55.00	63.00	8.00	2.45	5.55	30.80	3.44	0.77	3.1843
2	67.00	62.00	-5.00		-7.45	55.50			
3	64.00	64.00	0.00		-2.45	6.00			
4	61.00	67.00	6.00		3.55	12.60			
5	63.00	65.00	2.00		-0.45	0.20			
6	63.00	65.00	2.00		-0.45	0.20			
7	63.00	64.00	1.00		-1.45	2.10			
8	65.00	68.00	3.00		0.55	0.30			
9	65.00	61.00	-4.00		-6.45	41.60			
10	65.00	67.00	2.00		-0.45	0.20			
11	61.00	64.00	3.00		0.55	0.30			
12	65.00	65.00	0.00		-2.45	6.00			
13	62.00	66.00	4.00		1.55	2.40			
14	62.00	64.00	2.00		-0.45	0.20			
15	62.00	65.00	3.00		0.55	0.30			
16	58.00	65.00	7.00		4.55	20.70			
17	65.00	67.00	2.00		-0.45	0.20			
18	55.00	64.00	9.00		6.55	42.90			
19	61.00	64.00	3.00		0.55	0.30			
20	63.00	64.00	1.00		-1.45	2.10			

TABLE 22
QUEEN AVE - CORVALLIS/LEBANON
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	28.00	30.00	2.00	0.35	1.65	2.72	2.01	0.45	0.7798
2	34.00	31.00	-3.00		-3.35	11.22			
3	36.00	32.00	-4.00		-4.35	18.92			
4	30.00	31.00	1.00		0.65	0.42			
5	31.00	32.00	1.00		0.65	0.42			
6	30.00	30.00	0.00		-0.35	0.12			
7	33.00	31.00	-2.00		-2.35	5.52			
8	33.00	34.00	1.00		0.65	0.42			
9	33.00	30.00	-3.00		-3.35	11.22			
10	32.00	33.00	1.00		0.65	0.42			
11	31.00	32.00	1.00		0.65	0.42			
12	32.00	32.00	0.00		-0.35	0.12			
13	30.00	33.00	3.00		2.65	7.02			
14	32.00	32.00	0.00		-0.35	0.12			
15	30.00	32.00	2.00		1.65	2.72			
16	29.00	30.00	1.00		0.65	0.42			
17	32.00	33.00	1.00		0.65	0.42			
18	28.00	32.00	4.00		3.65	13.32			
19	31.00	32.00	1.00		0.65	0.42			
20	31.00	31.00	0.00		-0.35	0.12			

TABLE 23
QUEEN AVE - CORVALLIS/LEBANON
EXTRACTION VS COLD FEED #40

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	12.00	11.00	-1.00	-1.40	0.40	0.16	0.68	0.15	-9.1998
2	14.00	12.00	-2.00		-0.60	0.36			
3	14.00	12.00	-2.00		-0.60	0.36			
4	13.00	12.00	-1.00		0.40	0.16			
5	13.00	12.00	-1.00		0.40	0.16			
6	13.00	11.00	-2.00		-0.60	0.36			
7	12.00	12.00	0.00		1.40	1.96			
8	14.00	13.00	-1.00		0.40	0.16			
9	14.00	12.00	-2.00		-0.60	0.36			
10	14.00	13.00	-1.00		0.40	0.16			
11	14.00	12.00	-2.00		-0.60	0.36			
12	14.00	12.00	-2.00		-0.60	0.36			
13	13.00	13.00	0.00		1.40	1.96			
14	14.00	12.00	-2.00		-0.60	0.36			
15	13.00	12.00	-1.00		0.40	0.16			
16	13.00	11.00	-2.00		-0.60	0.36			
17	14.00	12.00	-2.00		-0.60	0.36			
18	13.00	12.00	-1.00		0.40	0.16			
19	13.00	11.00	-2.00		-0.60	0.36			
20	13.00	12.00	-1.00		0.40	0.16			

TABLE 24
QUEEN AVE - CORVALLIS/LEBANON
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	5.00	3.30	-1.70	-2.58	0.88	0.77	0.52	0.12	-22.1148
2	6.00	3.30	-2.70		-0.12	0.01			
3	5.20	3.40	-1.80		0.78	0.61			
4	5.40	3.10	-2.30		0.28	0.08			
5	5.50	3.30	-2.20		0.38	0.14			
6	5.40	3.10	-2.30		0.28	0.08			
7	5.30	2.90	-2.40		0.18	0.03			
8	6.00	3.60	-2.40		0.18	0.03			
9	6.10	3.10	-3.00		-0.42	0.18			
10	5.80	3.30	-2.50		0.08	0.01			
11	5.80	2.70	-3.10		-0.52	0.27			
12	5.70	3.30	-2.40		0.18	0.03			
13	5.10	3.40	-1.70		0.88	0.77			
14	6.40	3.30	-3.10		-0.52	0.27			
15	5.90	2.80	-3.10		-0.52	0.27			
16	5.50	3.10	-2.40		0.18	0.03			
17	6.30	2.70	-3.60		-1.02	1.04			
18	5.30	2.50	-2.80		-0.22	0.05			
19	5.40	2.50	-2.90		-0.32	0.10			
20	6.10	2.90	-3.20		-0.62	0.38			

TABLE 25
COLUMBIA R. BR. - OLD OREGON TRAIL
EXTRACTION VS COLD FEED 1/2"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	90.00	88.00	-2.00	-2.52	0.52	0.27	2.47	0.37	-6.7666
2	93.00	87.00	-6.00		-3.48	12.09			
3	86.00	85.00	-1.00		1.52	2.32			
4	91.00	87.00	-4.00		-1.48	2.18			
5	88.00	84.00	-4.00		-1.48	2.18			
6	91.00	87.00	-4.00		-1.48	2.18			
7	87.00	85.00	-2.00		0.52	0.27			
8	89.00	89.00	0.00		2.52	6.36			
9	91.00	88.00	-3.00		-0.48	0.23			
10	88.00	88.00	0.00		2.52	6.36			
11	89.00	86.00	-3.00		-0.48	0.23			
12	87.00	87.00	0.00		2.52	6.36			
13	91.00	88.00	-3.00		-0.48	0.23			
14	91.00	88.00	-3.00		-0.48	0.23			
15	87.00	86.00	-1.00		1.52	2.32			
16	87.00	88.00	1.00		3.52	12.41			
17	90.00	85.00	-5.00		-2.48	6.14			
18	89.00	82.00	-7.00		-4.48	20.05			
19	90.00	87.00	-3.00		-0.48	0.23			
20	90.00	87.00	-3.00		-0.48	0.23			
21	90.00	85.00	-5.00		-2.48	6.14			
22	91.00	85.00	-6.00		-3.48	12.09			
23	87.00	87.00	0.00		2.52	6.36			
24	88.00	88.00	0.00		2.52	6.36			
25	87.00	87.00	0.00		2.52	6.36			
26	88.00	84.00	-4.00		-1.48	2.18			
27	89.00	85.00	-4.00		-1.48	2.18			
28	88.00	88.00	0.00		2.52	6.36			
29	88.00	83.00	-5.00		-2.48	6.14			
30	92.00	84.00	-8.00		-5.48	30.00			
31	89.00	90.00	1.00		3.52	12.41			
32	88.00	85.00	-3.00		-0.48	0.23			
33	89.00	87.00	-2.00		0.52	0.27			
34	89.00	86.00	-3.00		-0.48	0.23			
35	88.00	85.00	-3.00		-0.48	0.23			
36	88.00	86.00	-2.00		0.52	0.27			
37	91.00	85.00	-6.00		-3.48	12.09			
38	91.00	87.00	-4.00		-1.48	2.18			
39	89.00	87.00	-2.00		0.52	0.27			
40	87.00	88.00	1.00		3.52	12.41			
41	85.00	88.00	3.00		5.52	30.50			
42	85.00	87.00	2.00		4.52	20.46			
43	87.00	83.00	-4.00		-1.48	2.18			
44	88.00	84.00	-4.00		-1.48	2.18			

TABLE 26
COLUMBIA R. BR. - OLD OREGON TRAIL
EXTRACTION VS COLD FEED 1/4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	58.00	59.00	1.00	-2.36	3.36	11.31	2.59	0.39	-6.0563
2	59.00	60.00	1.00		3.36	11.31			
3	55.00	56.00	1.00		3.36	11.31			
4	60.00	55.00	-5.00		-2.64	6.95			
5	59.00	55.00	-4.00		-1.64	2.68			
6	64.00	55.00	-9.00		-6.64	44.04			
7	59.00	58.00	-1.00		1.36	1.86			
8	60.00	61.00	1.00		3.36	11.31			
9	62.00	60.00	-2.00		0.36	0.13			
10	61.00	60.00	-1.00		1.36	1.86			
11	61.00	58.00	-3.00		-0.64	0.40			
12	58.00	57.00	-1.00		1.36	1.86			
13	63.00	59.00	-4.00		-1.64	2.68			
14	62.00	57.00	-5.00		-2.64	6.95			
15	59.00	60.00	1.00		3.36	11.31			
16	60.00	61.00	1.00		3.36	11.31			
17	62.00	56.00	-6.00		-3.64	13.22			
18	61.00	57.00	-4.00		-1.64	2.68			
19	63.00	59.00	-4.00		-1.64	2.68			
20	59.00	59.00	0.00		2.36	5.59			
21	61.00	55.00	-6.00		-3.64	13.22			
22	63.00	59.00	-4.00		-1.64	2.68			
23	58.00	53.00	-5.00		-2.64	6.95			
24	62.00	59.00	-3.00		-0.64	0.40			
25	60.00	57.00	-3.00		-0.64	0.40			
26	60.00	56.00	-4.00		-1.64	2.68			
27	61.00	56.00	-5.00		-2.64	6.95			
28	61.00	59.00	-2.00		0.36	0.13			
29	59.00	54.00	-5.00		-2.64	6.95			
30	62.00	62.00	0.00		2.36	5.59			
31	60.00	61.00	1.00		3.36	11.31			
32	62.00	59.00	-3.00		-0.64	0.40			
33	63.00	61.00	-2.00		0.36	0.13			
34	61.00	61.00	0.00		2.36	5.59			
35	61.00	58.00	-3.00		-0.64	0.40			
36	64.00	60.00	-4.00		-1.64	2.68			
37	63.00	58.00	-5.00		-2.64	6.95			
38	60.00	60.00	0.00		2.36	5.59			
39	62.00	61.00	-1.00		1.36	1.86			
40	60.00	63.00	3.00		5.36	28.77			
41	60.00	61.00	1.00		3.36	11.31			
42	66.00	62.00	-4.00		-1.64	2.68			
43	61.00	58.00	-3.00		-0.64	0.40			
44	62.00	58.00	-4.00		-1.64	2.68			

TABLE 27
COLUMBIA R. BR. - OLD OREGON TRAIL
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	29.00	31.00	2.00	0.68	1.32	1.74	2.02	0.30	2.2384
2	30.00	33.00	3.00		2.32	5.37			
3	29.00	30.00	1.00		0.32	0.10			
4	28.00	30.00	2.00		1.32	1.74			
5	30.00	30.00	0.00		-0.68	0.46			
6	33.00	30.00	-3.00		-3.68	13.56			
7	29.00	33.00	4.00		3.32	11.01			
8	31.00	32.00	1.00		0.32	0.10			
9	31.00	32.00	1.00		0.32	0.10			
10	31.00	31.00	0.00		-0.68	0.46			
11	31.00	32.00	1.00		0.32	0.10			
12	30.00	29.00	-1.00		-1.68	2.83			
13	32.00	32.00	0.00		-0.68	0.46			
14	32.00	31.00	-1.00		-1.68	2.83			
15	30.00	34.00	4.00		3.32	11.01			
16	31.00	33.00	2.00		1.32	1.74			
17	33.00	30.00	-3.00		-3.68	13.56			
18	33.00	31.00	-2.00		-2.68	7.19			
19	33.00	33.00	0.00		-0.68	0.46			
20	31.00	31.00	0.00		-0.68	0.46			
21	31.00	32.00	1.00		0.32	0.10			
22	33.00	35.00	2.00		1.32	1.74			
23	31.00	30.00	-1.00		-1.68	2.83			
24	32.00	34.00	2.00		1.32	1.74			
25	30.00	33.00	3.00		2.32	5.37			
26	32.00	29.00	-3.00		-3.68	13.56			
27	31.00	31.00	0.00		-0.68	0.46			
28	31.00	32.00	1.00		0.32	0.10			
29	31.00	28.00	-3.00		-3.68	13.56			
30	31.00	32.00	1.00		0.32	0.10			
31	30.00	35.00	5.00		4.32	18.65			
32	33.00	32.00	-1.00		-1.68	2.83			
33	34.00	35.00	1.00		0.32	0.10			
34	30.00	34.00	4.00		3.32	11.01			
35	31.00	30.00	-1.00		-1.68	2.83			
36	32.00	33.00	1.00		0.32	0.10			
37	33.00	32.00	-1.00		-1.68	2.83			
38	31.00	32.00	1.00		0.32	0.10			
39	30.00	34.00	4.00		3.32	11.01			
40	31.00	34.00	3.00		2.32	5.37			
41	32.00	33.00	1.00		0.32	0.10			
42	33.00	32.00	-1.00		-1.68	2.83			
43	33.00	32.00	-1.00		-1.68	2.83			
44	33.00	34.00	1.00		0.32	0.10			

TABLE 28
COLUMBIA R. BR. - OLD OREGON TRAIL
EXTRACTION VS COLD FEED #40

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sq rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	11.00	11.00	0.00	0.18	-0.18	0.03	0.79	0.12	1.5350
2	11.00	12.00	1.00		0.82	0.67			
3	11.00	11.00	0.00		-0.18	0.03			
4	9.00	11.00	2.00		1.82	3.31			
5	11.00	11.00	0.00		-0.18	0.03			
6	12.00	11.00	-1.00		-1.18	1.40			
7	11.00	12.00	1.00		0.82	0.67			
8	11.00	12.00	1.00		0.82	0.67			
9	12.00	12.00	0.00		-0.18	0.03			
10	11.00	12.00	1.00		0.82	0.67			
11	12.00	12.00	0.00		-0.18	0.03			
12	11.00	11.00	0.00		-0.18	0.03			
13	12.00	11.00	-1.00		-1.18	1.40			
14	11.00	12.00	1.00		0.82	0.67			
15	11.00	12.00	1.00		0.82	0.67			
16	11.00	12.00	1.00		0.82	0.67			
17	12.00	11.00	-1.00		-1.18	1.40			
18	12.00	11.00	-1.00		-1.18	1.40			
19	12.00	12.00	0.00		-0.18	0.03			
20	11.00	12.00	1.00		0.82	0.67			
21	12.00	12.00	0.00		-0.18	0.03			
22	12.00	12.00	0.00		-0.18	0.03			
23	11.00	11.00	0.00		-0.18	0.03			
24	12.00	12.00	0.00		-0.18	0.03			
25	11.00	12.00	1.00		0.82	0.67			
26	11.00	11.00	0.00		-0.18	0.03			
27	11.00	11.00	0.00		-0.18	0.03			
28	11.00	11.00	0.00		-0.18	0.03			
29	11.00	9.00	-2.00		-2.18	4.76			
30	11.00	11.00	0.00		-0.18	0.03			
31	12.00	12.00	0.00		-0.18	0.03			
32	12.00	11.00	-1.00		-1.18	1.40			
33	12.00	12.00	0.00		-0.18	0.03			
34	11.00	12.00	1.00		0.82	0.67			
35	11.00	10.00	-1.00		-1.18	1.40			
36	12.00	12.00	0.00		-0.18	0.03			
37	12.00	12.00	0.00		-0.18	0.03			
38	11.00	11.00	0.00		-0.18	0.03			
39	11.00	12.00	1.00		0.82	0.67			
40	12.00	12.00	0.00		-0.18	0.03			
41	12.00	13.00	1.00		0.82	0.67			
42	12.00	13.00	1.00		0.82	0.67			
43	12.00	12.00	0.00		-0.18	0.03			
44	12.00	13.00	1.00		0.82	0.67			

TABLE 29
COLUMBIA R. BR. - OLD OREGON TRAIL
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	4.20	3.30	-0.90	-1.11	0.21	0.04	0.35	0.05	-21.0419
2	4.40	3.40	-1.00		0.11	0.01			
3	4.00	2.80	-1.20		-0.09	0.01			
4	3.80	3.20	-0.60		0.51	0.26			
5	4.20	3.30	-0.90		0.21	0.04			
6	4.90	3.00	-1.90		-0.79	0.63			
7	4.60	3.30	-1.30		-0.19	0.04			
8	4.60	3.80	-0.80		0.31	0.10			
9	4.60	3.80	-0.80		0.31	0.10			
10	4.40	3.80	-0.60		0.51	0.26			
11	4.80	3.70	-1.10		0.01	0.00			
12	4.70	3.30	-1.40		-0.29	0.08			
13	4.70	3.10	-1.60		-0.49	0.24			
14	4.40	3.60	-0.80		0.31	0.10			
15	4.60	3.80	-0.80		0.31	0.10			
16	4.60	3.90	-0.70		0.41	0.17			
17	4.60	3.20	-1.40		-0.29	0.08			
18	4.60	3.30	-1.30		-0.19	0.04			
19	4.80	3.50	-1.30		-0.19	0.04			
20	4.50	3.60	-0.90		0.21	0.04			
21	4.80	3.40	-1.40		-0.29	0.08			
22	4.40	3.60	-0.80		0.31	0.10			
23	4.10	3.00	-1.10		0.01	0.00			
24	4.50	3.30	-1.20		-0.09	0.01			
25	4.50	3.40	-1.10		0.01	0.00			
26	4.40	3.10	-1.30		-0.19	0.04			
27	4.10	2.90	-1.20		-0.09	0.01			
28	4.30	2.90	-1.40		-0.29	0.08			
29	4.40	3.10	-1.30		-0.19	0.04			
30	4.20	2.40	-1.80		-0.69	0.48			
31	4.80	3.20	-1.60		-0.49	0.24			
32	4.70	3.70	-1.00		0.11	0.01			
33	4.50	3.10	-1.40		-0.29	0.08			
34	4.30	3.40	-0.90		0.21	0.04			
35	4.50	3.50	-1.00		0.11	0.01			
36	4.50	3.10	-1.40		-0.29	0.08			
37	4.80	3.50	-1.30		-0.19	0.04			
38	4.30	3.60	-0.70		0.41	0.17			
39	4.30	3.30	-1.00		0.11	0.01			
40	4.70	3.30	-1.40		-0.29	0.08			
41	4.40	3.30	-1.10		0.01	0.00			
42	4.30	3.80	-0.50		0.61	0.37			
43	4.70	3.30	-1.40		-0.29	0.08			
44	4.40	4.20	-0.20		0.91	0.83			

TABLE 30
CAZADERO - N FORK CLACKAMAS RIVER
EXTRACTION VS COLD FEED 1/2"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	87.00	88.00	1.00	-0.38	1.38	1.92	2.68	0.53	-0.7306
2	88.00	86.00	-2.00		-1.62	2.61			
3	89.00	88.00	-1.00		-0.62	0.38			
4	85.00	87.00	2.00		2.38	5.69			
5	82.00	84.00	2.00		2.38	5.69			
6	90.00	86.00	-4.00		-3.62	13.07			
7	86.00	87.00	1.00		1.38	1.92			
8	85.00	81.00	-4.00		-3.62	13.07			
9	85.00	86.00	1.00		1.38	1.92			
10	87.00	85.00	-2.00		-1.62	2.61			
11	88.00	88.00	0.00		0.38	0.15			
12	85.00	86.00	1.00		1.38	1.92			
13	88.00	86.00	-2.00		-1.62	2.61			
14	90.00	81.00	-9.00		-8.62	74.22			
15	87.00	87.00	0.00		0.38	0.15			
16	84.00	86.00	2.00		2.38	5.69			
17	87.00	85.00	-2.00		-1.62	2.61			
18	88.00	88.00	0.00		0.38	0.15			
19	91.00	89.00	-2.00		-1.62	2.61			
20	83.00	83.00	0.00		0.38	0.15			
21	83.00	86.00	3.00		3.38	11.46			
22	85.00	89.00	4.00		4.38	19.22			
23	87.00	87.00	0.00		0.38	0.15			
24	85.00	86.00	1.00		1.38	1.92			
25	84.00	86.00	2.00		2.38	5.69			
26	84.00	82.00	-2.00		-1.62	2.61			

TABLE 31
CAZADERO - N FORK CLACKAMAS RIVER
EXTRACTION VS COLD FEED 1/4"

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	64.00	64.00	0.00	-1.08	1.08	1.16	3.44	0.67	-1.5963
2	67.00	63.00	-4.00		-2.92	8.54			
3	65.00	66.00	1.00		2.08	4.31			
4	63.00	65.00	2.00		3.08	9.47			
5	60.00	60.00	0.00		1.08	1.16			
6	67.00	64.00	-3.00		-1.92	3.70			
7	61.00	63.00	2.00		3.08	9.47			
8	57.00	55.00	-2.00		-0.92	0.85			
9	62.00	62.00	0.00		1.08	1.16			
10	63.00	54.00	-9.00		-7.92	62.78			
11	66.00	63.00	-3.00		-1.92	3.70			
12	61.00	62.00	1.00		2.08	4.31			
13	66.00	63.00	-3.00		-1.92	3.70			
14	65.00	54.00	-11.00		-9.92	98.47			
15	65.00	65.00	0.00		1.08	1.16			
16	57.00	58.00	1.00		2.08	4.31			
17	66.00	64.00	-2.00		-0.92	0.85			
18	66.00	65.00	-1.00		0.08	0.01			
19	68.00	66.00	-2.00		-0.92	0.85			
20	57.00	58.00	1.00		2.08	4.31			
21	60.00	63.00	3.00		4.08	16.62			
22	62.00	65.00	3.00		4.08	16.62			
23	65.00	61.00	-4.00		-2.92	8.54			
24	59.00	62.00	3.00		4.08	16.62			
25	61.00	63.00	2.00		3.08	9.47			
26	61.00	58.00	-3.00		-1.92	3.70			

TABLE 32
CAZADERO - N FORK CLACKAMAS RIVER
EXTRACTION VS COLD FEED #10

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	35.00	35.00	0.00	-0.42	0.42	0.18	1.58	0.31	-1.3661
2	34.00	33.00	-1.00		-0.58	0.33			
3	35.00	35.00	0.00		0.42	0.18			
4	34.00	33.00	-1.00		-0.58	0.33			
5	32.00	33.00	1.00		1.42	2.03			
6	35.00	34.00	-1.00		-0.58	0.33			
7	32.00	33.00	1.00		1.42	2.03			
8	30.00	29.00	-1.00		-0.58	0.33			
9	34.00	34.00	0.00		0.42	0.18			
10	33.00	30.00	-3.00		-2.58	6.64			
11	34.00	33.00	-1.00		-0.58	0.33			
12	32.00	33.00	1.00		1.42	2.03			
13	35.00	34.00	-1.00		-0.58	0.33			
14	35.00	30.00	-5.00		-4.58	20.95			
15	35.00	35.00	0.00		0.42	0.18			
16	31.00	31.00	0.00		0.42	0.18			
17	36.00	36.00	0.00		0.42	0.18			
18	34.00	35.00	1.00		1.42	2.03			
19	37.00	36.00	-1.00		-0.58	0.33			
20	32.00	32.00	0.00		0.42	0.18			
21	35.00	33.00	-2.00		-1.58	2.49			
22	33.00	35.00	2.00		2.42	5.87			
23	35.00	33.00	-2.00		-1.58	2.49			
24	32.00	35.00	3.00		3.42	11.72			
25	35.00	35.00	0.00		0.42	0.18			
26	35.00	34.00	-1.00		-0.58	0.33			

TABLE 33
CAZADERO - N FORK CLACKAMAS RIVER
EXTRACTION VS COLD FEED #40

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	15.00	15.00	0.00	-0.04	0.04	0.00	1.04	0.20	-0.1888
2	15.00	15.00	0.00		0.04	0.00			
3	16.00	16.00	0.00		0.04	0.00			
4	15.00	15.00	0.00		0.04	0.00			
5	15.00	15.00	0.00		0.04	0.00			
6	16.00	15.00	-1.00		-0.96	0.92			
7	14.00	14.00	0.00		0.04	0.00			
8	13.00	13.00	0.00		0.04	0.00			
9	15.00	15.00	0.00		0.04	0.00			
10	14.00	14.00	0.00		0.04	0.00			
11	15.00	15.00	0.00		0.04	0.00			
12	14.00	15.00	1.00		1.04	1.08			
13	15.00	15.00	0.00		0.04	0.00			
14	15.00	13.00	-2.00		-1.96	3.85			
15	15.00	15.00	0.00		0.04	0.00			
16	14.00	14.00	0.00		0.04	0.00			
17	16.00	16.00	0.00		0.04	0.00			
18	15.00	15.00	0.00		0.04	0.00			
19	16.00	14.00	-2.00		-1.96	3.85			
20	14.00	14.00	0.00		0.04	0.00			
21	16.00	14.00	-2.00		-1.96	3.85			
22	13.00	16.00	3.00		3.04	9.23			
23	15.00	15.00	0.00		0.04	0.00			
24	14.00	16.00	2.00		2.04	4.16			
25	15.00	15.00	0.00		0.04	0.00			
26	15.00	15.00	0.00		0.04	0.00			

TABLE 34
CAZADERO - N FORK CLACKAMAS RIVER
EXTRACTION VS COLD FEED #200

NOTE: d=X2-X1; D=avg d; Sd=std.dev.; SD=Sd/sg rt(N); t=D/SD

N	X1	X2	d	D	(d-D)	(d-D)^2	Sd	SD	t
1	4.30	6.30	2.00	0.15	1.85	3.42	0.74	0.14	1.0360
2	6.20	6.70	0.50		0.35	0.12			
3	6.60	6.20	-0.40		-0.55	0.30			
4	5.80	6.70	0.90		0.75	0.56			
5	6.10	6.10	0.00		-0.15	0.02			
6	5.70	5.70	0.00		-0.15	0.02			
7	5.90	5.90	0.00		-0.15	0.02			
8	5.20	5.50	0.30		0.15	0.02			
9	5.80	6.70	0.90		0.75	0.56			
10	5.20	5.70	0.50		0.35	0.12			
11	5.20	6.10	0.90		0.75	0.56			
12	5.60	6.40	0.80		0.65	0.42			
13	6.20	6.50	0.30		0.15	0.02			
14	6.90	5.50	-1.40		-1.55	2.40			
15	7.20	6.40	-0.80		-0.95	0.90			
16	6.40	6.10	-0.30		-0.45	0.20			
17	7.00	6.80	-0.20		-0.35	0.12			
18	6.40	6.30	-0.10		-0.25	0.06			
19	7.00	6.80	-0.20		-0.35	0.12			
20	6.40	6.10	-0.30		-0.45	0.20			
21	6.80	6.30	-0.50		-0.65	0.42			
22	5.30	6.50	1.20		1.05	1.10			
23	6.30	6.30	0.00		-0.15	0.02			
24	5.20	6.20	1.00		0.85	0.72			
25	6.50	5.80	-0.70		-0.85	0.72			
26	6.40	5.90	-0.50		-0.65	0.42			