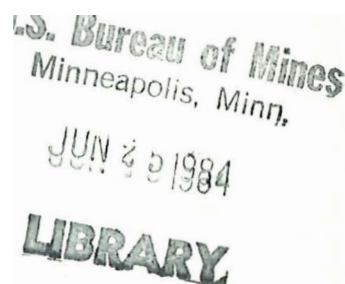


A mining research contract report
MAY 1983

DEVELOPMENT OF A CONTINUOUS SHAFT LINING SYSTEM

VOLUME III



Contract J0333915
Foster-Miller, Inc.

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

OFR
83-186 (3)



N O T I C E

This report was completed under a contract to the U.S. Department of Energy (DOE). Responsibility for the program to which the report relates has recently been transferred to the Bureau of Mines, U.S. Department of the Interior, and the report is made public under a Bureau cover. Inquiries concerning the report should be directed to the Bureau.

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FE/14223

DEVELOPMENT OF A CONTINUOUS
SHAFT LINING SYSTEM - VOLUME III

Final Technical Report
as of May 1983

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DATE PUBLISHED - MAY 1983
Prepared Under
U.S. DOE Contract No. DE-AC01-79ET14223

U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Energy Technology
Office of Coal Mining
Mining Research and Development

50772-101

REPORT DOCUMENTATION PAGE		1. REPORT NO. FE/14223	2.	3. Recipient's Accession No.
4. Title and Subtitle DEVELOPMENT OF A CONTINUOUS SHAFT LINING SYSTEM				5. Report Date MAY 1983
				6.
7. Author(s) Robert Torbin, Tom Brunsing, Douglas Ounanian, Ray Henderson, Jonathan Kelly, George Kirby				8. Performing Organization Rept. No.
9. Performing Organization Name and Address FOSTER-MILLER, INC. 350 SECOND AVENUE WALTHAM, MA 02154				10. Project/Task/Work Unit No.
				11. Contract(C) or Grant(G) No. (C) USDOE DE-AC01-79ET14223 (G) USBM J0333915
12. Sponsoring Organization Name and Address UNITED STATES DEPARTMENT OF ENERGY PITTSBURGH MINING TECHNOLOGY CENTER PITTSBURGH, PA 15236				13. Type of Report & Period Covered FINAL REPORT
				14.
15. Supplementary Notes PROGRAM TRANSFERRED MAY, 1983, TO: UNITED STATES BUREAU OF MINES PITTSBURGH MINING & SAFETY RESEARCH CENTER PITTSBURGH, PA 15236				
16. Abstract (Limit: 200 words) The objectives of the Continuous Shaft Lining (CSL) System are to reduce the costs, safety hazards, and time currently required in lining mine shafts with concrete. The CSL will line machine bored shafts downward from the shaft collar on a continuous basis using an inverted, pressurized slipforming technique. The technique for slipforming downwards has been demonstrated and refined under this program. The approach taken involved laboratory scale testing of key features of the CSL concept. These feature tests included concrete distribution, concrete sealing, concrete slipforming and development of a reliable concrete mix. Based on these results; a full scale above-ground test facility and CSL were designed and fabricated. The objectives of these tests were to demonstrate the viability of the basic concept; to establish operating limits; and to provide input data and information for the design of a second generation shaft lining system. The results of the program have led to a CSL design and operational philosophy which will need to be tested in an underground environment before industry will accept the technology. However, the next generation CSL promises to meet all the original program technical objectives.				
17. Document Analysis a. Descriptors MECHANIZED SHAFT LINING SYSTEM CONTINUOUS CONCRETE SHAFT LINING CONCRETE SLIPFORMING DOWNWARD b. Identifiers/Open-Ended Terms c. COSATI Field/Group				
18. Availability Statement		19. Security Class (This Report) UNCLASSIFIED		21. No. of Pages
		20. Security Class (This Page) UNCLASSIFIED		22. Price

APPENDIX

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APPENDIX A

TEST PLAN FOR
CONCRETE DISTRIBUTION TESTS

TEST PLAN
for
Concrete Distribution Tests
Continuous Shaft Lining System

Contract No. DE-AC01-79ET14223
U.S. Department of Energy

January, 1981

OBJECTIVES

The objectives of the laboratory scale distribution tests of the continuous shaft liner system (CSL) are to:

- Determine the feasibility of distributing concrete under pressure within a closed form above a moving curb beam.
- Determine the number of inlet ports required for full form filling.
- Determine the level of back pressure required for full form filling.
- Determine the need and extent of curb vibration.
- Assess the distribution of concrete pressure on the curb beam.
- Qualitatively assess the nature of the concrete flow patterns.
- Determine the sensitivity of concrete placement to changes in the four (4) port valve operating and switching times.

EXPERIMENTAL PARAMETERS

A number of fixed and variable parameters will be used in the distribution testing program.

FIXED PARAMETERS

The fixed parameters are:

- curb dimensions; width, length and travel zone
- concrete pumpline and inlet port diameter

Curb Dimensions

The distribution rig curb beam is a straight rectangular section comprised of built-up channel sections. The face (upper flange) of the curb beam is a flat 1/2-inch thick plate measuring 1 ft. wide and 16 ft. long. The curb can be moved through a vertical travel zone of 5 ft.

Concrete Pumpline and Inlet Port Diameter

All concrete pumplines and curb ring inlet ports are 3 inches in diameter.

VARIABLE PARAMETERS

The variable parameters are:

- concrete pumping pressure
- advance rate of curb beam
- concrete inlet ports - number and location
- vibrators - number, location, and duration and frequency of operation
- concrete mix design

Concrete Pumping Pressure

Concrete pumping pressure is developed from pipeline friction, pumping rate, and from the static pressure head against which it acts. Concrete pumping pressure can be increased artificially to simulate a pressure head by applying a back pressure force by actually pushing the curb beam up against the plastic concrete. In the distribution tests a back pressure of up to ten (10) psig can be applied to simulate conditions that would be present if the concrete was being pumped into a form through a curb beam that was supporting up to ten (10) ft. of partially set concrete.

Advance Rate of the Curb Load

In the distribution tests the average advance rate of the curb can be varied from one (1) ft./hr. to five (5) ft./hr. by changing the concrete pumping rate. Distribution tests will be performed at average advance rates of one (1) ft./hr., two (2) ft./hr., and four (4) ft./hr.

Concrete Inlet Ports

Up to five (5) inlet port configurations will be used for the distribution tests:

- one (1) end port
- one (1) mid port
- two (2) port configuration
- three (3) port configuration
- four (4) port configuration

Vibrators

The curb beam for the distribution test will be outfitted with up to four (4) pneumatically operated variable frequency vibrators. Up to five (5) different vibrator configurations will be used which correspond with the concrete inlet port configurations specified above. The frequency and duration may be varied by controlling the supply of air pressure by valves and regulators.

Concrete Mix Design

A concrete mix design will be formulated to be both workable for pumpability and rapid-stiffening for self-support. The mix design should be finalized prior to the start of the laboratory testing.

If distribution problems are encountered some minor changes will be made to mix design to improve workability. Since improvements to mix workability may jeopardize early strength behavior it is important only to change mix design in the event all other attempts to achieve distribution fail.

DATA COLLECTION

TEST MONITORING

The following data will be monitored during the test by observation or by recording instrumentation.

- curb beam position
- concrete pressure distribution over the length of the curb beam
- concrete pumping pressure
- concrete pumping rate
- form temperature
- mix water temperature
- ambient temperature
- vibrator frequency and duration.
- hydraulic fluid pressures of hydraulic power unit and curb beam cylinders
- concrete age and flow distribution

MONITORING METHODS

The instrumentation and test equipment required to collect data and the frequency of collection for each category is identified below.

Curb Beam Position

Two (2) displacement transducers will be used to monitor the location of the curb beam relative to a datum position. The output of the displacement transducers, through appropriate signal conditioning, will be recorded continuously on a strip chart recorder for permanent record. The curb beam position monitoring system will have resolution of one half (0.5) inch.

Concrete Pressure Distribution

Up to four (4) pressure transducers will be used to monitor the pressure distribution of concrete against the curb beam. The transducers will be capable of operating over a 0 to 50 psig range. The output of the pressure transducers, through appropriate signal conditioning will be continuously recorded on a strip chart recorder for permanent record. The concrete pressure distribution monitoring system will have resolution of one half (0.5) psig.

Concrete Pumping Pressure

Concrete pumping pressure will be monitored with one (1) in-line concrete pressure sensor. Reading of pressure will be made from the isolated pressure gauges on the pressure sensor and recorded on a data sheet. The sensor will be placed in the pumping line near the pump outlet or near the curb ring inlet port.

Concrete Pumping Rate

The average concrete pumping rate will be determined by dividing the filling form volume by the filling time. Filled form volume can be computed from form geometry and

information received from the curb beam position instrumentation. Pumping rate will be determined over a five (5) minute period. The rate will be calculated at fifteen (15) minute intervals and recorded on a data sheet for permanent record.

Form Temperature

Form temperature will be monitored with a thermocouple probe. Its output, through appropriate signal conditioning, will be recorded on a datasheet. The temperature will be taken once every hour.

Mix Water Temperature

Mix water temperature will be monitored with a thermometer. The temperature will be taken at 15 minute intervals and recorded on a data sheet.

Ambient Temperature

Ambient temperature will be monitored with a thermometer. The temperature will be taken once every hour and recorded on a data sheet.

Vibrator Frequency and Duration

Vibrator frequency will be monitored indirectly with an air pressure gauge. In-line air pressure will be recorded once during each operation of the vibrator and recorded on a data sheet. A relationship between air pressure and vibrator frequency will be established prior to testing. The duration of vibration will also be recorded on a data sheet.

Hydraulic Fluid Pressures

The hydraulic fluid pressures of the hydraulic power unit (HPU) and the curb beam cylinders will be monitored with the pressure gauges on the HPU. The pressures will be recorded onto a data at least once every hour and when pressure conditions change.

Concrete Age and Flow Distribution

The concrete age and flow distribution will be monitored by adding colored powdered dyes to the concrete mixer to produce batches of colored concrete prior to being delivered to the distribution rig. The color, time of addition, and length of usage will be determined based on the judgment of the test director and the results of previous testing. Distribution of the colored concrete within the cast slab will be charted and photographed following the removal of the slab from the test rig.

EXPERIMENTAL PLAN

A distribution rig was designed and fabricated to serve as a test device to study the distribution problem.

A test procedure has been formulated in the form of a decision flow chart (Figure 1). At least six (6) but no greater than twelve (12) distribution tests will be conducted. The actual number of tests conducted will depend on the number and nature of failures encountered. A test is defined as one day's placement. The test parameters may be changed during the test but all changes will be recorded. Within each square of the decision flow chart (Figure 1), the duration of vibration, frequency of vibration and amount of back pressure can be varied. If the one (1) port tests are successful a multi-port test will be performed to assess the operation of the four (4) port slide valve. The decision flow chart divides the tests into four (4) series of tests.

Test Series A will be performed at an average curb advance rate of four (4) ft./hr. which is equivalent to placing concrete at $2.4 \text{ YD}^3/\text{HR}$. Test Series B will also be performed at an average curb advance rate of 4 ft./hr., but only if the one (1) midport configuration of Test Series A is successful. Test Series C will be performed at an average curb advance rate of two (2) ft./hr. which is equivalent to placing concrete at $1.2 \text{ YD}^3/\text{HR}$. Test Series D will be performed at an average curb advance rate of one (1) ft./hr. which is equivalent to placing concrete at $0.6 \text{ YD}^3/\text{HR}$.

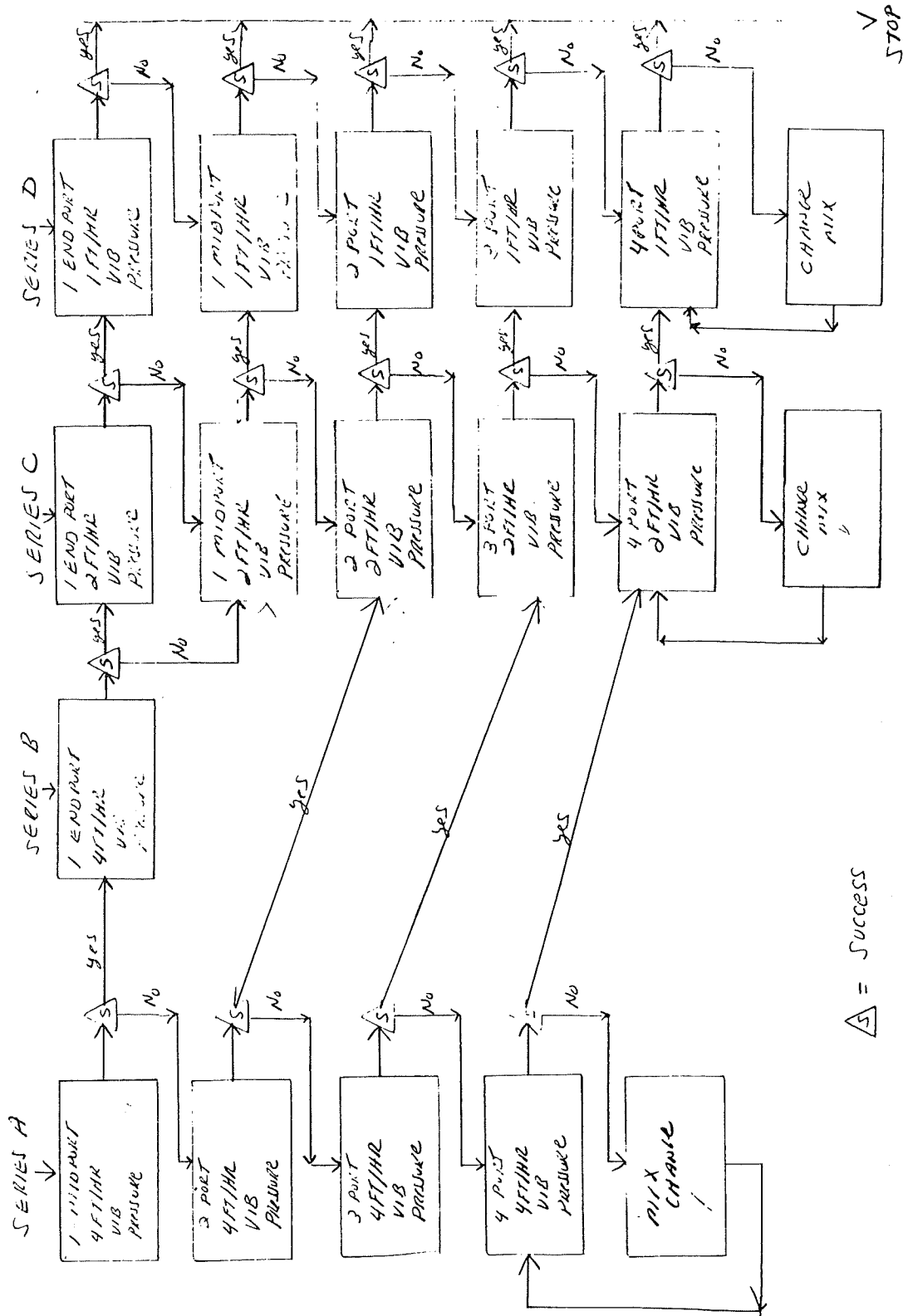


Figure 1. Decision Flow Chart

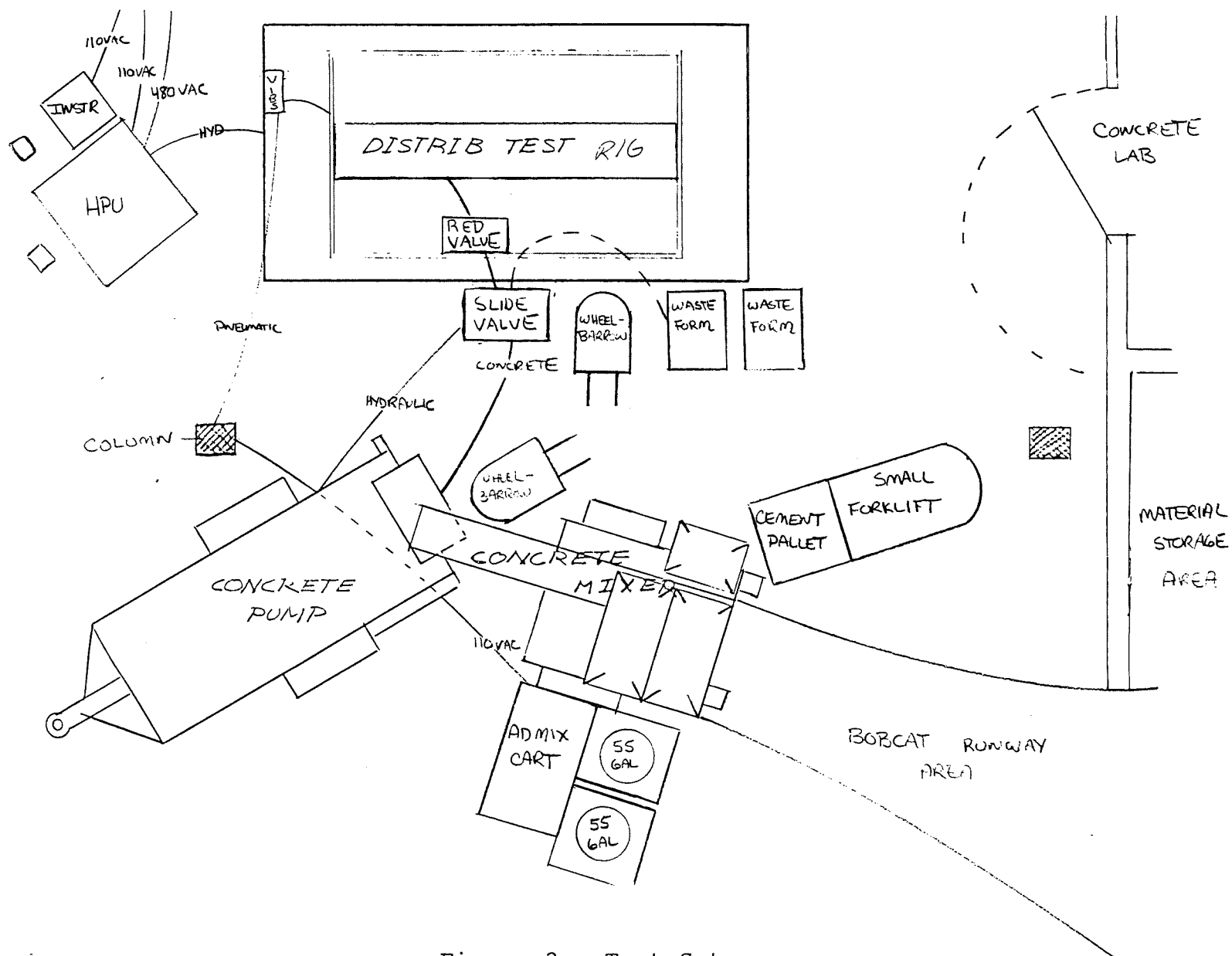
TEST APPROACH

Each distribution test involves the following systems and areas (refer to Figure 2):

- Distribution Test Rig Assembly (Structure)
- Hydraulic Power Unit (HPU)
- Pneumatic Vibrators
- Concrete Pump
- Concrete Mixer
- Admixture Cart
- Four (4) Port Slide Valve
- Pressure, Displacement and Temperature Instrumentation
- Concrete Quality Control
- Red Valve
- Materials Handling
- Slab Inspection, Demolition and Removal
- Pre-Test Setup
- Test Performance
- Cleanup
- Test Documentation and Photography

In order to ensure an orderly test and that all tasks are performed, the above systems and areas will be assigned to specific operators. All operators will report (Figure 3) directly to the test director. The test director will report to the concrete process manager and he will report to the CSL project manager. The materials handlers and cleanup crew will report to the test director through the concrete pump and mixer operators.

Each person may be assigned more than one (1) system. Nine (9) people are recommended to conduct a full functional test. The specific duties and responsibilities of each system operator are as follows:



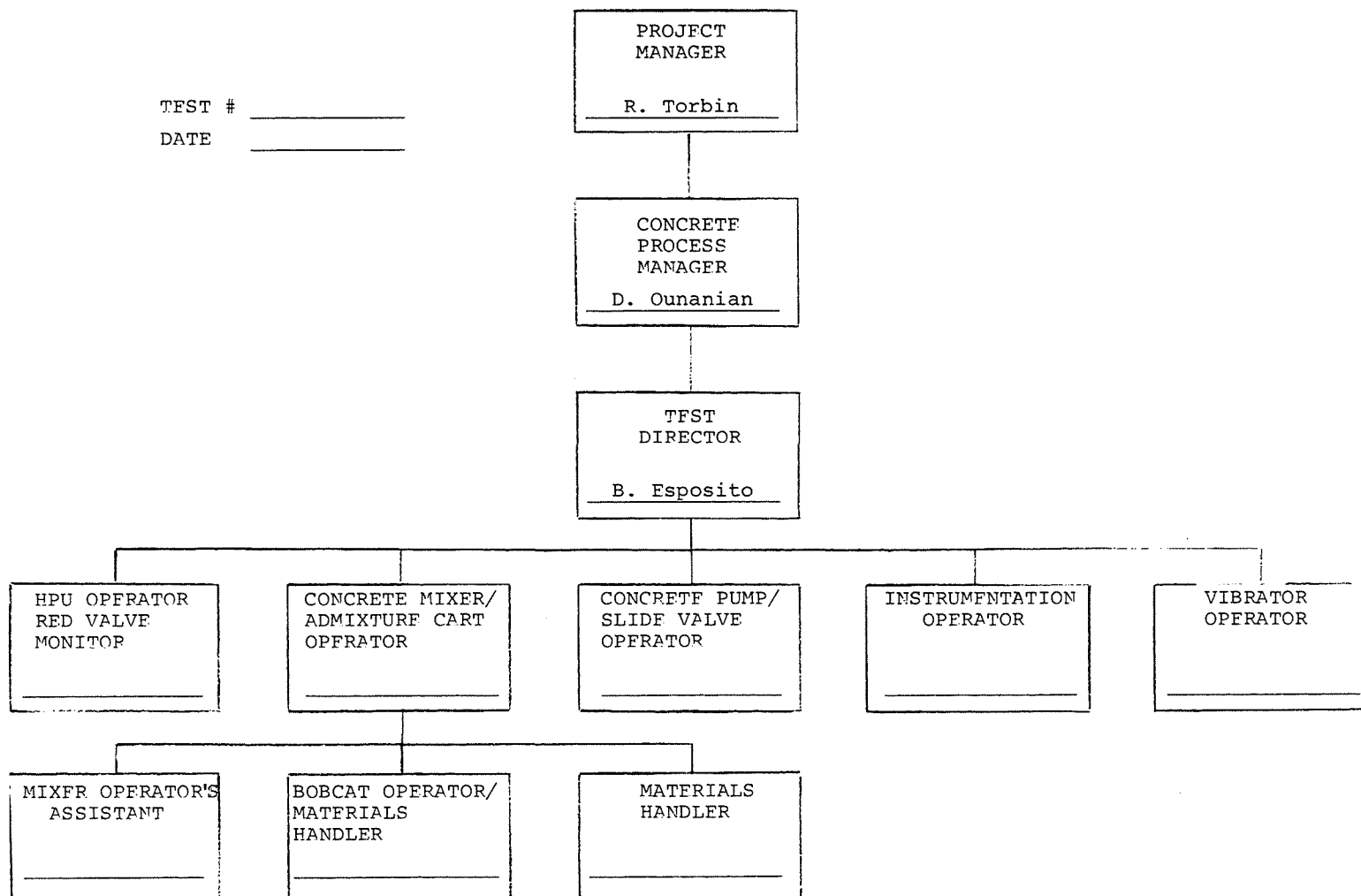


Figure 3. CSL Distribution Test Organization

TEST DIRECTOR

The test director's responsibility during the distribution tests is the specification, coordination and direction of the individual tests. His specific duties are as follows:

1.0 Pre-Test

- Details the test specification sheet which specifies the test parameters.
- Distributes the test specification sheets to the operators of the various systems.
- Coordinates all test personnel and test equipment.
- Gives pre-test "pep talk" concerning what's to be accomplished, fragility of instrumentation, danger of concrete and/or hydraulic fluid pressure build up and danger of 480 VAC power.
- Performs pre-test final inspection.

2.0 During Test

- Directs and supervises test.
- Answers questions of any system operator.
- Ensures test goes as planned.
- Ensures photos are taken.
- Resolves any problems or conflicts that may occur during the test.
- Ensures all data is being recorded.
- Ensures test is being performed safely.

3.0 Post Test

- Instructs HPU operator when curb can be pulled away.
- Instructs HPU operator when shear pins are to be installed.
- Supervises lowering of slab.
- Performs post test inspection of slab.
- Supervises demolition and removal of slab.
- Ensures all equipment is cleaned.
- Analyzes test data.
- Writes summary of test and results.

CSL DISTRIBUTION TEST SPECIFICATION SHEET

Page 1 of 3

TEST # _____ DATE _____
TEST SERIES _____ DIRECTOR _____
AVERAGE CURB ADVANCE RATE (FT./HR.) _____
AVERAGE CONCRETE PUMPING RATE (YD³/HR.) _____
CURB PORT CONFIGURATION CASE # _____
BACK PRESSURE (PSIG) _____

CONCRETE MIXER SYSTEM

MIX DESIGN _____
BIN VIBRATOR ON TIME _____
BIN VIBRATOR OFF TIME _____

COLORED DYF ADDITION

COLORS TO BE USED _____
AMOUNT OF EACH COLOR (LB) _____
TIME OF ADDITION _____
DURATION OF ADDITION (MIN) _____

HPU SYSTEM

INSTALLATION OF SHEAR PINS _____
LOWER CURB AFTER TEST _____

CLS DISTRIBUTION TEST SPECIFICATION SHEET

Page 2 of 3

TEST # _____ DATE _____

INSTRUMENTATION SYSTEM

NUMBER OF PRESSURE TRANSDUCERS _____

TRANSDUCER CURB PORT LOCATION #(s) _____

SLIDE/RED VALVE SYSTEM

NUMBER OF CONCRETE INLET PORTS _____

CONCRETE INLET CURB PORT LOCATION # _____

CONCRETE PORT CYCLING SEQUENCE _____

PUMP TIME AT EACH PORT _____

NUMBER OF CONCRETE PORTS TO WASTE _____

NUMBER OF PORTS BLANKED OFF _____

BLANKED CURB PORT LOCATION #(s) _____

NUMBER OF RED VALVES _____

RED VALVE CURB PORT LOCATION #(s) _____

CLS DISTRIBUTION TEST SPECIFICATION SHEET

Page 3 of 3

TEST # _____ DATE _____

VIBRATOR SYSTEM

NUMBER OF VIBRATORS _____

VIBRATOR CURB PORT LOCATION #(s) _____

PRESSURE TO VIBRATORS (PSIG) _____

ON TIME OF VIBRATORS _____

OFF TIME OF VIBRATORS _____

CYCLING SEQUENCE _____

ON TIME _____

OFF TIME _____

OTHER SPECIAL INSTRUCTIONS _____

CONCRETE MIXER OPERATOR

The operation of the continuous auger mixer is vital to all of the programs on which it is used. The mixer operator must be completely familiar with its operation and its maintenance requirements.

The areas of responsibility for the mixer operator can be divided into the following:

- Maintenance
- Calibration
- Pre-Test
- During Test
- Post-Test
- Problems During Mixing

Maintenance

The following maintenance procedures should be performed. See Mixer Operating Instructions for specific information.

- Lubrication of feed and main augers - weekly.
- Lubrication of drive chain - monthly.
- Check varydrive belt condition - monthly.
- Change oil in auger gear boxes - every 3 months.

In addition to mechanical maintenance,

- Maintain low inventories in material storage hoppers when not in use.
- Keep cement hopper covered with plastic when not in use.
- Keep mixer exterior clean.

Calibration

Adjust the output of individual material feed augers to match the mix design proportions. Mix proportions and total outputs can be varied by changing paradjust voltage and/or feed auger varydrive settings. A calibration program should be planned and carried out under the guidance of the test director.

Pre-Test

- Records mix design and materials identification on data sheets.
- Measures and records temperatures of water, admixtures, aggrerates, cement and color agents (if used) onto data sheets.
- Calculates and records temperature of additional mix water.
- Measures and records moisture content of aggrerates.
- Calculates and records amount of additional mix water.
- Measures and records slump, air content and mix temperature.
- Performs and records mixer calibration.
- Records parajust voltage and varydrive settings.
- Prepares admixture solutions
- Records arrangement of admixture pumps.
- Performs and records admixture cart calibration.

- Records current and control settings of admixture pump drives.
- Prepares color dyes.
- Ensures adequate supply of materials and admixtures are on-hand and in doors.
- Sets up mixer and admixture cart.
- Plugs mixer power cord into 480 VAC 30 amp service outlet on column.
- Plugs admixture cart power cord into 110 VAC outlet on column.
- Ensures wood pieces are in sand and stone bins before filling to prevent free fall of aggregate material.
- Drops lift auger boot and checks rotation of the lift auger.
- Checks for water in motor shrouds.
- Inspects electrical supply hook-up - check rotation.
- Checks operation of paradjust with all feed motors in off position.
- Before filling hoppers, checks operations of all feed augers and check for correct varydrive settings.
- Checks operation of vibrator.
- With paradjust in off position sets feed auger motor switches to on position.

- Makes final check for correct varydrive setting.
Remember: Do not change varydrive setting unless
motor is running.
- Fills material hoppers.
- Hooks-up fluid supplies from admix cart and verify proper operation.

During Test

- Measures and records temperature of water and admixtures every fifteen (15) minutes.
- Measures and records moisture content of the sand once every hour.*
- Recalculates the amount of additional mix water if the moisture content (%) of the sand changes by more than 0.25.
- Measures and records slump and mix temperature every thirty (30) minutes.
- Measures and records air content once every hour.*
- Casts three (3) cylinders once every hour.*
- Measures and records compressive strength of cylinders two (2), three (3) and four (4) hours after casting.
- Records any changes in parajust voltage or varydrive settings.
- Records any changes in current or control settings of admixture pump drives.
- Adds color dyes when specified (if used).
- Operates mixer and admixture cart.
- Ensures admixtures remain in suspension.

*Or every two (2) feet of curb advance which ever occurs first.

- Records amount of bin vibration used.
- Informs test director of any abnormalities.
- Directs and supervises the materials handlers.
- Place diversion chute in place.
- Select combination of material feed augers to be used by pushing switches to on.
- Push main auger switch to on.
- To start sequence, push paradjust switch to on and simultaneously start fluid supplies.
- Check paradjust voltage, verify operation of auger shafts.
- Visually monitor material output.
- When mix stabilizes, that is, maintains the same consistency, remove diversion chute.
- Changes to paradjust voltage or varydrive setting should not be made during a test without approval of the test director.
- Water content may be adjusted to make up for minor changes in aggregate water content.
- When changing total output of mixer, push paradjust switch to off.
- Wait 5 secs. and switch off fluid pumps.

- Turn all feed switches to off.
 - Switch on paradjust.
 - Adjust to appropriate voltage.
 - Switch off paradjust.
 - Turn on feed switches.
 - Switch on paradjust and simultaneously switch on fluid pumps.
- Remember: The feed augers should be started and stopped only by the paradjust switch. No other method is acceptable.

Post Test

- For normal shut down sequence:
 - Switch off paradjust.
 - Wait 5 secs. and shut off fluid pumps.
 - Wait one minute, then shut off main auger.
 - Move mixer free of concrete pump.
 - Cover cement hopper with plastic sheeting.
 - Drop lift auger rubber boot.
 - Wash down main lift auger.
 - Clean mixer exterior.
- Measures and records temperatures of aggrerates, cement and coloring agent (if used).
- Measures and records moisture content of aggrerates.
- Ensures mixer is properly cleaned.
- Ensures proper storage of admixtures and cart.
- Ensures proper storage of materials left in mixer.

Problems During Mixing Cycle

Following is a list of the problems that might occur during the mixing cycle accompanied by the appropriate corrective action.

- Power fails - Shut down paradjust and main switch.
- Feed auger(s) stop rotating - Turn paradjust to higher voltage until the auger is free. Turn voltage back to previous setting immediately.
- Fluid pump fails - Shut down paradjust immediately.
- Raw material supply runs out - Shut down paradjust.
- Mix auger binds or drags - Shut down paradjust and fluid pumps in normal sequence.
- Pump hopper overflows - Set up diversion chute. Do not shut down unless indicated to do so by test director or pump operator.

EQUIPMENT
REQUIRED

ETLS Admixture Cart
Six (6) 55 Gallon Plastic Drums
Thermometers
Variable Power Supplies
Multimeter
Note Pad and Writing Instrument
Concrete Mixer
Wooden Pallets
Slump Test Cone
Compressive Strength Tester
Scales
Oven
Water/Admixture Heating System
Waste Forms
Forklift, Small
Bobcat
Two (2) Wheel Barrows

SPARE PARTS & TOOLS

Varydrive Internal Plastic Piece P/N 195357

Drive Belts

Extra Tubing

Shovels

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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Page 1 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record.

Aggrerates

Sand

Source _____
Supply Date _____
Bulk Specific Gravity SSD _____
Absorption (%) _____
Percent of Total Aggrerate (%) _____
SSD Batch Weight (LB/YD³) _____

SIEVE SIZE	GRADATION (% PASSING)
3/8"	
#4	
#8	
#16	
#30	
#50	
#100	
#200	
PAN	
FM	

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 2 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record (continued).

Aggrerates (continued)

3/8" Stone

Source _____
Supply Date _____
Bulk Specific Gravity SSD _____
Absorption (%) _____
Percent of Total Aggrerate (%) _____
SSD Batch Weight (LB/YD³) _____

SIEVE SIZE	GRADATION (% PASSING)
1/2"	
3/8"	
#4	
#8	
#16	
PAN	
FM	

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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Page 3 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record (continued).

Aggrerates (continued)

3/4" Stone

Source _____
Supply Date _____
Bulk Specific Gravity SSD _____
Absorption (%) _____
Percent of Total Aggrerate (%) _____
SSD Batch Weight (LB/YD³) _____

SIFVE SIZE	GRADATION (% Passing)	
	Before Washing	After Washing
1"		
3/4"		
1/2"		
3/8"		
#4		
#8		
#16		
PAN		
FM		

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 4 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record (continued).

WATER

WATER CEMENT RATIO _____
LOCATION OF SOURCE _____
SSD BATCH WEIGHT* (LB/YD³) _____

CEMENT

TYPE _____
BRAND _____
LOT # _____
SOURCE _____
SUPPLY DATE _____
SPECIFIC GRAVITY _____
CEMENT FACTOR (SACKS/YD³) _____
BATCH WEIGHT (LB/YD³) _____

* SSD batch weight = [Water cement ratio x cement batch weight]

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 5 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record (continued).

ADMIXTURES

Admixture ID # _____
Type _____
Brand _____
Lot # _____
Source _____
Supply Date _____
Specific Gravity _____
Dose Rate (% of cement) _____
Initial Water Content (%) _____
Dilution for Test (%) _____
Total Diluted Water Content* (LB/YD³) _____

Admixture ID # _____
Type _____
Brand _____
Lot # _____
Source _____
Supply Date _____
Specific Gravity _____
Dose Rate (% of cement) _____
Initial Water Content (%) _____
Dilution for Test (%) _____
Total Diluted Water Content* (LB/YD³) _____

*Total Diluted Water Content =

Dose Rate x Cement Batch Weight x Initial Water Content
Dilution for Test

CSL DISTRIBUTION TEST DATA SHEET
CONCRFTE MIXER OPERATOR

Page 6 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record (continued).

ADMIXTURES (continued)

Admixture ID# _____
Type _____
Brand _____
Lot # _____
Source _____
Supply Date _____
Specific Gravity _____
Dose Rate (% of cement) _____
Purity (%) _____
Batch Weight* (LB/YD³) _____
Dilution for Test (%) _____
Total Diluted Water Content** (LB/YD³) _____

$$* \text{Batch Weight} = \frac{\text{Dose Rate} \times \text{Cement Batch Weight}}{\text{Purity}}$$

$$** \text{Total Diluted Water Content} = \frac{\text{Dose Rate} \times \text{Cement Batch Weight}}{\text{Dilution for Test}}$$

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 7 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record (continued).

COLORING AGENTS

Coloring Agent ID# _____
Color _____
Type _____
Brand _____
Source _____
Dose Rate (% of cement) _____
Batch Weight (LB/YD³) _____

Coloring Agent ID# _____
Color _____
Type _____
Brand _____
Source _____
Dose Rate (% of cement) _____
Batch Weight (LB/YD³) _____

Coloring Agent ID# _____
Color _____
Type _____
Brand _____
Source _____
Dose Rate (% of cement) _____
Batch Weight (LB/YD³) _____

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 8 of 21

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

COLORING AGENTS (continued)

Coloring Agent ID# _____
Color _____
Type _____
Brand _____
Source _____
Dose Rate (% of cement) _____
Batch Weight (LB/YD³) _____

Coloring Agent ID# _____
Color _____
Type _____
Brand _____
Source _____
Dose Rate (% of cement) _____
Batch Weight (LB/YD³) _____

CSL DISTRIBUTION TEST DATA SHEET
MIXER OPERATOR

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TEST # _____ OPERATOR _____
DATE _____

TEMPERATURE MEASUREMENTS:

[illegible]

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____ OPERATOR _____
DATE _____

TEMPERATURE MEASUREMENT (continued)

MEASUREMENT TYPE	TIME OF DAY	TEMPERATURE (°F)			
		AGGRERATES		CEMENT	COLORING AGENT
		FINE (SAND)	COARSE (STONE*)		
PRE-TEST					
POST-TEST					

* Temperature of mixed 3/8" and 3/4" stone in mixer bin.

Temperature Compensation Calculation

$$T_{amw} = X \div W_{amw}$$

where

T = temperature (°F)
W = batch weight (LB/YD³)
ad = admixture
amw = additional mix water
c = cement
ca = coarse aggrerates (3/8" and 3/4" stone)
co = coloring agent
fa = fine aggrerate (sand)
fw = free water
l = liquids
s = solids

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____ OPERATOR _____
DATE _____

TEMPERATURE COMPENSATION CALCULATION (continued)

and

$$W_s = W_{fa} + W_{ca} + W_c + W_{co}$$

$$W_l = W_{fw} + W_{ad} + W_{amw}$$

$$T_s W_s = T_{fa} W_{fa} + T_{ca} W_{ca} + T_c W_c + T_{co} W_{co}$$

$$T_{ad} W_{ad} = T_{ad1} W_{ad1} + T_{ad2} W_{ad2} + T_{ad3} W_{ad3}$$

$$X = 72 \left[0.22 W_s + W_l \right] - \left[0.22 T_s W_s + T_{ad} W_{ad} \right]$$

$$W_s = \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$

$$W_l = \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$

$$T_s W_s = \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$

$$T_{ad} W_{ad} = \underline{\hspace{1cm}} + \underline{\hspace{1cm}} + \underline{\hspace{1cm}} = \underline{\hspace{1cm}}$$

$$X = 72 \left[0.22 \underline{\hspace{1cm}} + \underline{\hspace{1cm}} \right] - \left[0.22 \underline{\hspace{1cm}} + \underline{\hspace{1cm}} \right] = \underline{\hspace{1cm}}$$

$$T_{amw} = X \div W_{amw} = \underline{\hspace{1cm}} \div \underline{\hspace{1cm}} = \underline{\hspace{1cm}}^{\circ}F$$

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____ OPERATOR _____
DATE _____

AGGRFRATE MOISTURE CONTENT DETERMINATION

TIME OF DAY	AGGRERATE TYPE	WEIGHT (GRAMS)			MOISTURE CONTENT* (%)
		TARE	WET	DRY	

$$*Moisture\ Content = \frac{Wet\ Weight - Dry\ Weight}{Dry\ Weight - Tare\ Weight}$$

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____ OPERATOR _____
DATE _____

$$A = B (C + 1)$$

where

A = Adjusted aggregate batch weight (LB/YD³)

B = Aggregate SSD batch weight (LB/YD³)

C = (Moisture Content (%) - Absorption (%)) ÷ 100

AGGREGATE TYPE	ABSORPTION (%)	B (LB/YD ³)	MOISTURE CONTENT (%)	C	A (LB/YD ³)
Fine (Sand)					
Coarse (3/8" Stone)					
Coarse (3/4" Stone)					

$$D = E - \Sigma (A - B + F)$$

where

D = Additional mix water batch weight (LB/YD³)

E = Water SSD Batch Weight (LB/YD³)

F = Total diluted water content of admixtures (LB/YD³)

B	E	F	A	D

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____

OPERATOR _____

DATE _____

CONCRETE QUALITY CONTROL

SLUMP & TEMPERATURE MEASUREMENTS

TIME OF MEASUREMENT	SLUMP (IN)	MIX TEMPERATURE (°F)

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____

OPERATOR _____

DATE _____

CONCRETE QUALITY CONTROL (continued)

AIR CONTENT MEASUREMENTS

TIME OF MEASUREMENT	AIR CONTENT (%)

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 16 of 21

TFST # _____ OPERATOR _____
DATE _____

CONCRETE QUALITY CONTROL (continued)
COMPRESSIVE STRENGTH MEASUREMENT

SAMPLE NO.	TIME OF DAY SAMPLE CAST

TIME AFTER CASTING (HR)	COMPRESSIVE LOAD (LB)				AVERAGE COMPRESSIVE STRENGTH (LB/IN ²) [AVG. LOAD/28.27]
	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVG.	

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____ OPERATOR _____
DATE _____

CONCRETE MIXER
CALIBRATION HISTORY (RECORD)

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

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TEST # _____ OPERATOR _____

DATE _____

MIX CONTROL

TIME OF DAY	PARAJUST VOLTAGE (VDC)	VARYDRIVE SETTING		
		SAND	STONE	CEMENT

TIME OF DAY	SAND BIN VIBRATION	
	ON TIME	OFF TIME

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 19 of 21

TEST # _____ OPERATOR _____
DATE _____

ADMIXTURE CONTROL

RECORD ARRANGEMENT OF ADMIXTURE PUMPS:

RECORD CALIBRATION:

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 20 of 21

TEST # _____

OPERATOR _____

DATE _____

ADMIXTURE CONTROL (continued)

TIME OF DAY	EXTERNAL INPUT CURRENT (MA)			FRONT PANEL SETTING (% of MAXIMUM)		
	DRIVE 1	DRIVE 2	DRIVE 3	DRIVE 1	DRIVE 2	DRIVE 3

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page 21 of 21

TEST # _____ OPERATOR _____
DATE _____COLOR DYE ADDITIONCOLOR ADDED _____
AMOUNT ADDED (LB) _____
TIME OF ADDITION _____
DURATION OF ADDITION _____COLOR ADDED _____
AMOUNT ADDED (LB) _____
TIME OF ADDITION _____
DURATION OF ADDITION _____COLOR ADDED _____
AMOUNT ADDED (LB) _____
TIME OF ADDITION _____
DURATION OF ADDITION _____COLOR ADDED _____
AMOUNT ADDED (LB) _____
TIME OF ADDITION _____
DURATION OF ADDITION _____COLOR ADDED _____
AMOUNT ADDED (LB) _____
TIME OF ADDITION _____
DURATION OF ADDITION _____

CONCRETE PUMP OPERATOR

This discussion will explain the responsibilities of the concrete pump operator. In order to understand these responsibilities we will divide the operation of the pump into four categories.

- Before Testing
- During Testing
- Termination of Testing
- Dealing with Pumping Failures

Before Testing

The pump operator should perform the following procedures before every pump usage.

- Inspect pumping tube in the pumping chamber.
Remove plexiglass ports and examine the tube for cracks and weak spots.
- Check hydraulic fluid levels - main pump and vacuum pump.
- Check hoses, belts and chains.
- Check for water in electric motor shrouds.
- Check remix hopper - note wiper blade condition and hopper side conditions.
- Check and secure hopper emergency port door.
- Verify proper electrical supply hook-up.

- Start vacuum pump. Check vacuum level and hopper remix blade operation. Check operation of hopper reposition cylinder.
- Start main pump. Operate in idle position until 20 inches of vacuum has been obtained and the hydraulic oil temperature is at least 65°F. Check operations at all speeds with variable control.
- Assemble support equipment. Locate rabbits. Place immersion vibrator and extension cord in ready position. Gather shovels and hand tools. Locate diversion chute and mortar pan. Move waste forms into position.
- Check emergency shut down - operation at both locations.

In addition, the following items should be checked at intervals specified by instructions on the nameplates attached to the side of the pump control box.

- Position of pumping hose in the pumping chamber.
- Location of high wear can be shifted by repositioning the remix hopper.
- Greasing of fittings and lubrication of chains.

During Testing

- Operate pump only when test director indicates to do so.
- Pump concrete only when you can verify at least 20 inches of vacuum and 65°F hydraulic oil temperature.

- Maintain level of concrete above the inlet port at all times.
- Change speed of pump only when test director indicates to do so.
- Keep remix hopper wiper blade rotation direction and speed consistent with pumping direction and speed. For example, when operating at slow pumping rate, operate remix hopper wiper blades slowly in the feed direction. For reverse pumping and idling, operate blades in reverse direction with slow rotation.
- Pump concrete at a slow rate when starting up to ensure complete filling of pumping lines. Increase speed slowly after successful pumping can be verified.
- Watch fluctuations in hydraulic oil pressure of the main pump. Pressure in excess of 800 psi at slow pumping rates indicates high line resistance and may indicate a pumping failure is imminent.
- If a pumping failure occurs alert both the mixer operator and test director immediately.
- Follow steps outlined in Dealing with Pumping Failures (which follows).
- Records average hydraulic fluid pumping pressure at least once every hour.
- Records hydraulic fluid temperature at least once every hour.

Termination of Testing

- Discontinue pumping when indicated to do so by the test director.
- In a normal shut down perform the following steps.
 - Relieve vacuum. Shut down vacuum pump and main pump.
 - Open remix hopper clean out hatch.
 - Empty hopper and remove as much concrete from the inlet port as possible.
 - Place rabbit in inlet port.
 - Close remix hopper clean out hatch.
 - Start vacuum pump and main pump.
 - Fill hopper with water.
 - Verify 20 in. of vacuum.
 - Pump lines clear.
 - Clear lines again by following the steps above in the same order.
 - Shut down pump.
 - Clean out hopper.
 - Clean pump exterior.

Dealing with Pumping Failures

All workers as well as the pump operator should become thoroughly familiar with the procedures outlined in this section. A pumping failure should not be regarded as a panic situation. If everyone knows what to do in case of a failure, freeing the blockage becomes just another operating procedure. Since most of us involved in the latest tests have been present when a failure occurs we should have a general feel for the level of effort required to free a plug. It is an intense effort but there is no reason why it should not be an orderly one. The following section describes how to determine whether a pumping blockage exists and if so, what to do to correct the situation. (Specific worker assignments during the operation will be outlined in a separate memo.)

How to Tell When There is a Failure or Blockage

- Abnormally high hydraulic pump pressure (over 1000 psi).
- Abnormally high concrete line pressure (over 50 psi).
- Unusual pumping sounds (thumping, high-pitched whine).
- Surging concrete pump hoses.
- Collapsed concrete pump hose.
- Water leakage at victaulic couplings.

What to do to Unblock the System

- Pump operator must immediately inform mix operator and test director of suspected problem.

- With approval from the test director try to unblock the system using the pump.
 - Try forward and reverse operation repeatedly, similar to the method one would try with an automobile that has become stuck in snow.
 - If a positive result is not obtained after 3 or 4 reversals, stop pump.
- Determine location of blockage.
 - Check for blockage in flex hose. Indicators: presence of hard spot in line under no pumping pressure.
 - Check for blockage in pump. (At inlet port or in pumping tube in the chamber.) Indicators: zero line pressure on gauge at pump outlet port location during pumping. Distinct thumping noise after each roller rotation.
 - Check for blockage in slickline. Indicators: there is no direct indicator. If checks for blockage in flex hose and pump indicate normal conditions, by deduction, the slickline is probably where the blockage exists.

Remedies

- Blockage in flex line.
 - Locate blockage point.
 - Disconnect line outbound (or beyond) blockage.

- Apply sledge hammer to "hard" spot.
- Attempt to pump concrete.
- If this fails, disconnect line inbound (or ahead) of blockage. Shake concrete out of removed line section. Reconnect inbound end. Pump concrete through line.
- Reconnect outbound end and pump concrete.

● Blockage in pump.

- Disconnect placing line at pump outlet port.
- Empty concrete hopper and leave hatch open.
- Apply water pressure to outlet port and run pump in reverse. Blockage should push out into hopper.
- If the above procedure fails:
 - A. Immediately disassemble pump line and purge by shaking out and applying water pressure by hose.
 - B. At the same time,
 - (a) Shut down vacuum system and main pump.
 - (b) Disconnect inlet reducer at flange joint.

- (c) Clean out line with hand tools and hose.
- (d) Start vacuum pump and main pump.
- (e) Pump water through outlet port while running pump in reverse. Then pump water into pump inlet and run pump forward.
- (f) Clean up hopper.

Once the pump and lines are clear proceed with operations as indicated by the test director.

EQUIPMENT REQUIRED

Concrete Pump

Concrete Lines

Two (2) Waste Forms

Two (2) Rabbits

High Pressure Water Line

110 VAC Immersion Vibrator

110 VAC Extension Cord

Diversion Chute

Mortar Pan

SPARE PARTS & TOOLS

Spare parts list to be supplied by DOT ETLIS program.

Spare parts to be purchased by DOE CSL project.

Three (3) 60 AMP 480 VAC fuses.

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE PUMP OPERATOR

Page 1 of 2

TEST # _____ OPERATOR _____
 DATE _____

HYDRAULIC FLUID
 TEMPERATURE:

TIME OF DAY	HYDRAULIC FLUID TEMPERATURE (°F)

HYDRAULIC FLUID PRESSURE

TIME OF DAY	HYDRAULIC FLUID PRESSURE (PSIG)

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE PUMP OPERATOR

Page 2 of 2

TEST # _____ OPERATOR _____
DATE _____

OTHER OBSERVATIONS AND/OR COMMENTS

HYDRAULIC POWER UNIT (HPU) OPERATOR

The hydraulic power unit (HPU) operator's responsibility during the distribution tests is the setup and operation of the hydraulic power unit. His specific duties are as follows:

1.0 Pre-test

- Ensures HPU is properly plumbed to distribution rig and that all hydraulic outlets not to be used are properly capped off.
- Ensures that the level of hydraulic fluid in the HPU is satisfactory.
- Checks for leaks of hydraulic fluid.
- Sets the pressure and flow control valves to the proper values for a particular test.
- Ensures curb seal is installed properly.
- Ensures top and end plates and gaskets are installed properly.
- Ensures form is clean and oiled.
- Sets all electrical switches on HPU control panel to off position prior to energizing control panel.
- Turns on 480 VAC circuit breakers and 110 VAC ground fault circuit breaker.
- Sets up red valve.

2.0 During Test

- Operates the hydraulic power unit.
- Monitors and records pressures and operating conditions every hour and when pressures or conditions change or are changed.
- Shuts off HPU if any hydraulic hoses fail.
- Adjusts HPU control valves to maintain desired curb back pressure.
- Installs shear pins at specified times.
- Monitors and records red valve pressure every hour.

3.0 Post Test

- After a specific time, lowers curb away from concrete slab.
- Unbolts top and end plates from stationary wall.
- Lowers sidewall after a specified time for slab inspection, demolition and removal.
- Shuts off 480 and 110 vac breakers.
- Cleans red valve.

EQUIPMENT
REQUIRED

71

One (1) HPU

Various hydraulic hoses

Distribution test rig

Ear protectors

Notepad and writing instrument

SPARE PARTS AND TOOLS

Wrenches to adjust pressure control valves

Heater elements for motor starters

Fuses 110 VAC 15 AMP

Fuses 480 VAC 30 AMP

Key to control panel

CSL DISTRIBUTION TEST DATA SHEET
HPU OPERATOR

Page 1 of 2

TEST # _____

OPERATOR _____

DATE _____

RECORD PRESSURE READINGS:

TIME OF DAY	PRESSURE (PSIG)								
	PI-6	PI-7	PI-8	PI-9	PI-10	PI-11	RED VALVE		

CSL DISTRIBUTION TEST DATA SHEET
HPU OPERATOR
Page 2 of 2

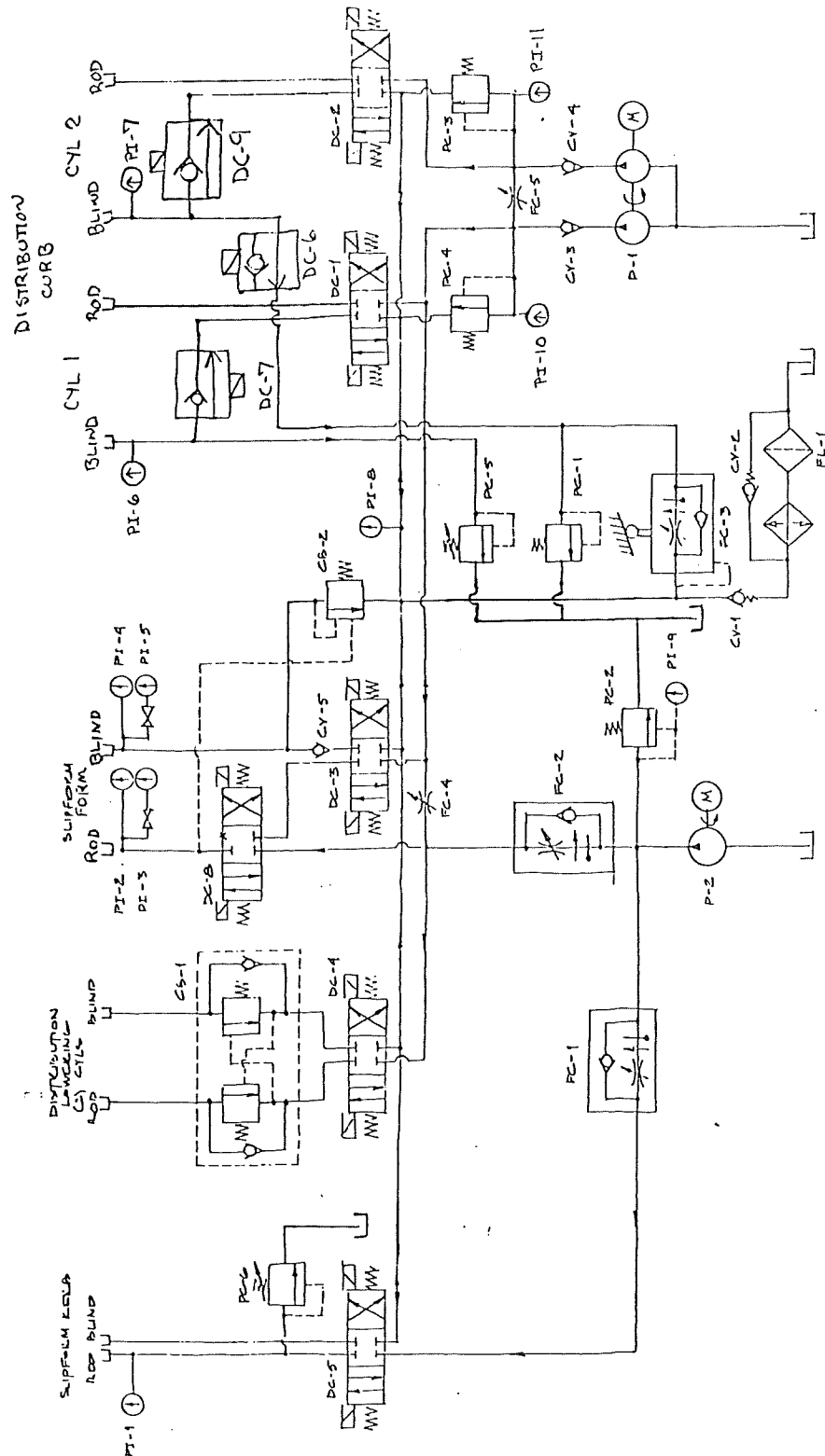
TEST # _____ OPERATOR _____
DATE _____

SHEAR PIN INSTALLATION:

TIME OF DAY	SHEAR PIN # INSTALLED

Time lowered curb away from slab : _____

OTHER OBSERVATIONS AND/OR COMMENTS:



SE-1
HYDRAULIC POWER SUPPLY
FOR CIL LAMP-1000
CONTRACT NO. - 57
JSS 6-10-80
REVISED 1-5-81 BAC

INSTRUMENTATION SYSTEM OPERATOR

The instrumentation system operator's responsibility during the distribution tests is the setup and operation of the pressure and displacement transducer instrumentation. He is also responsible for the monitoring and recording of certain temperatures. His specific duties are as follows:

1.0 Pre-test

- Ensures thermometers and/or thermocouple probes are in place or on hand for test.
- Measures and records (see data sheets) ambient and form temperature.
- Sets up pressure and displacement transducers.
- Calibrates recorder and amplifiers
- Ensures that the pressure transducers are in the proper curb ports for the particular test.
- Records pressure transducer locations on data sheet.
- Ensures proper handling of the instrumentation.
- Ensures proper protection of instrumentation wiring.
- Connects instrumentation to a "dedicated" 110 VAC outlet.
- Checks for noise on line, ground loops or other interference of the instrumentation signals.

- Warms up all instrumentation.
- Informs test director of status of instrumentation prior to test.

2.0 During Test

- Measures and records ambient and form temperature every hour.
- Monitors displacement transducers, calculates and records the average concrete pumping rate (YD^3/HR) over a five (5) minute period at fifteen (15) minute intervals.
- Maintains all instrumentation working order as best as possible.
- Annotates data where necessary.
- Records any deviation of test parameters in his control from the prescribed test conditions

3.0 Post Test

- Removes magnetic surface thermometers from form (if used) during clean up.
- Shuts off all instrumentation power.
- Ensures wiring is safely out of the way from the clean up crew.

EQUIPMENT
REQUIRED

77

One (1) chart record (6 channel).

One (1) D.C. amplifier (6 channel).

One (1) roll of recording paper.

Four (4) pressure transducers.

Two (2) displacement transducers.

One (1) thermometer (50 - 100°F minimum).

One (1) thermocouple probe or six (6) magnetic surface mount thermometers.

One (1) multimeter.

One (1) calculator.

One (1) timing device (clock, watch etc.).

Various cables and connectors.

Note pad and writing instrument.

Multi-outlet 110 VAC Extension Cord

SPARE PARTS AND TOOLS

Soldering Iron

Solder

Flux

Solderless Terminals

Wire

Wire crimper/stripper

Regular Screwdriver

Instrumentation Screwdriver

Manuals to various Instruments

Two (2) Pressure Transducers

One (1) Roll of Recording Paper

Snap Ring Pliers (for displacement transducers)

OPERATOR

DATE _____

[illegible]

* As viewed from back of distribution rig.

1	2	3
4	5	6

CSL DISTRIBUTION TEST DATA SHEET
INSTRUMENTATION OPERATOR

Page 3 of 3

TEST # _____ OPERATOR _____

DATE _____

PRESSURE TRANSDUCER #	CURB PORT LOCATION
1	
2	
3	
4	

OTHER OBSERVATIONS AND/OR COMMENTS:

SLIDE VALVE OPERATOR

The slide valve operator's responsibility during the distribution tests is the setup and operation of the slide valve system. His specific duties are as follows:

1.0 Pre-test

- Greases slide plates on slide valve.
- Connects 110 VAC power cord to outlet.
- Ensures slide valve hydraulics are plumbed to the concrete pump's hydraulic system.
- Checks for proper operation of the slide valve by operating joy stick control to all four (4) positions and observing position indicator lights.
- Ensures that the concrete lines are plumbed between the proper slide valve and curb ports (or to waste).
- Records relationship between slide valve ports and curb ports or waste receptacles.
- Records blank curb port locations.

2.0 During Test

- Operates (if required) the slide valve using the joy stick control in the proper sequence according to the test specification sheet.
- Operates the slide valve to the waste port position if required during the test due to concrete blockage.

3.0 Post Test

- Operates the slide valve to the waste port position for purging of the concrete lines with water.
- Disconnects 110 VAC power cord from outlet.
- Disconnects concrete lines from slide valve.
- Hoses down slide valve with water, taking care not to soak the control and terminal boxes.
- Disassembles slide plates and inspects for gouges (file any found), greases and reassembles slide plates.

EQUIPMENT
REQUIRED

One (1) four (4) port slide valve

Two (2) hydraulic hoses

One (1) timing device (clock, watch, etc.)

Three (3) to five (5) concrete lines

Notepad and writing instrument

SPARE PARTS & TOOLS

One (1) 9/64" allen head wrench (to adjust limit switches)

CSL DISTRIBUTION TEST DATA SHEET
SLIDE VALVE OPERATOR

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TEST # _____

OPERATOR _____

DATE _____

SLIDE VALVE PORT # *	CONNECTION **
1	
2	
3	
4	

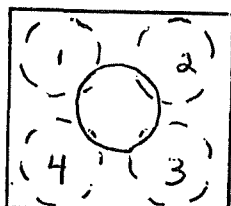
PORT CYCLING SEQUENCE: _____

PUMP TIME AT EACH PORT: _____

BLANK CURB PORT LOCATIONS _____

OTHER OBSERVATIONS AND/OR COMMENTS:

*



Viewed facing
inlet

** Specify curb port #, to waste or not used.

VIBRATOR SYSTEM OPERATOR

The vibrator system operator's responsibility during the the distribution tests is the setup and operation of the vibrator system. His specific duties are as follows:

1.0 Pre-test

- Ensures that the vibrators are in the proper curb ports for the particular test.
- Records vibrator locations.
- Sets and records air pressure at vibrator's regulator.
- Informs test director of status of vibrators.
- Fills lubricator with oil.

2.0 During Test

- Controls air pressure to vibrators and records any changes in set pressure.
- Controls and records on/off time of vibrators according to prescribed test specifications.
- Informs test director of any abnormalities during test, recording time of and a description of the abnormality.
- Ensures lubricator remains filled with oil.

3.0 Post Test

- Shuts off air pressure to vibrators.

- Cleans vibrators, manifold and lines.

EQUIPMENT
REQUIRED

Four (4) pneumatic vibrators

One (1) distribution manifold

Five (5) on/off valves

One (1) air pressure regulator/lubricator

Various connecting hoses and quick disconnects

Notepad and writing instrument

SPARE PARTS AND TOOLS

5/32 allen head wrench

Lubricating oil

CSL DISTRIBUTION TEST DATA SHEET
VIBRATOR OPERATOR

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Page 1 of 1

TEST # _____

OPERATOR _____

DATE _____

VIBRATOR #	CURB PORT LOCATION

TIME OF DAY	VIBRATOR (S) #	PRESSURE (PSIG)	TIME	
			ON	OFF

OTHER OBSERVATIONS AND/OR COMMENTS:

CSL DISTRIBUTION TEST DATA SHEET
CONCRETE MIXER OPERATOR

Page of :

TEST # _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

Mix design and materials identification record.

Aggrerates

Sand

Source _____

Supply Date _____

Bulk Specific Gravity SSD _____

Absorption (%) _____

Percent of Total Aggregate (%) _____

SSD Batch Weight (LB/YD³) _____

[illegible]

APPENDIX B

SUMMARY OF TEST RESULTS
CONCRETE DISTRIBUTION TESTS

CSL DISTRIBUTION
TEST RESULTS SUMMARY

CSL distribution test 1 was performed on January 21, 1981. Concrete was placed into the form from one (1) inlet port located at the center of the curb. A portland Type III cement concrete was used with the following admixtures:

- 1.5% (by weight of cement) Mighty 150 superplasticizer
- 1.5 fluid oz/cwt (by weight of cement) Darex air entraining agent
- 3.0% (by weight of cement) Allied Chemical calcium chloride.

Batch weights (LB/YD³) of 752 cement, 1225 sand, 600 3/8" stone and 900 3/4" stone were used with a water to cement ratio of approximately 0.42. No curb vibration was used. An improper procedure was used to slick the lines. Due to an inexperienced concrete mixer operator the initial slump was low (approximately three (3) inches).

The above two (2) problems made it extremely difficult to pump the mix through the line into the form. The test was aborted approximately thirty (30) minutes after starting due to a blockage in the pumping line. Only about two (2) ft³ of concrete were placed into the form. No dyes were added to the mix. No compressive strength measurements were made. No pressure was developed in the form.

The test indicated that the test personnel needed more familiarity with the test equipment and procedures before a successful placement could be achieved.

CSL distribution test 2 was performed on January 27, 1981. Concrete was placed into the form from one (1) inlet port located at the center of the curb. An unaccelerated portland Type I cement concrete was used with only one (1) admixture, 1.5% (by weight of cement) Mighty 150 superplasticizer. Batch weights (LB/YD³) of 752 cement, 1225 sand, 600 3/8" stone and 900 3/4" stone were used. Curb vibration was cycled five (5) seconds on and fifty-five (55) seconds off at (30) psig air supply pressure for the first thirty (30) minutes of the test. The vibration was then stopped for the next fifteen (15) minutes of placement and then back on for the remainder of the test. The initial slump was approximately eight (8) inches. A slab forty-three (43) inches high was cast at an average curb advance rate of 2.9 ft/hr with a form pressure of approximately twenty-five (25) psig. No dyes were added to the mix. No compressive strength measurements were made. The test rig was opened too soon and the upper part of the slab crumbled.

The test indicated that the form could be successfully filled with concrete from the center port.

CSL distribution test 3 was performed on February 3, 1981. Concrete was to be placed into the form from one (1) inlet port located one (1) foot to the left of the center of the curb. The one (1) foot offset was used to prevent unnecessary interference between the concrete placing line and the structural supports of the distribution rig. A portland Type III cement concrete was used with the following admixtures:

- 1.5% (by weight of cement) Mighty 150 superplasticizer
- 1.5 fluid oz/cwt (by weight of cement) Darex air entraining agent
- 1.5% (by weight of cement) Allied Chemical calcium chloride

Batch weights (LB/YD³) of 752 cement, 1225 sand, 600 3/8" stone and 900 3/4" stone were used with a water to cement ratio of approximately 0.42.

Curb vibration was cycled five (5) seconds on and fifty-five (55) seconds off at thirty (30) psig air supply pressure for ten (10) minutes of the test. The initial slump ranged from one (1) to three (3) inches. The low slump was due to an inexperienced mixer operator. The low slump caused blockages in the slide valve and the placing lines so the test was aborted. The test indicated that the mixer operator was too inexperienced and needed practice. No concrete was placed into the form, therefore no form pressure was developed. No dyes were added to the mix. No compressive strength measurements were made.

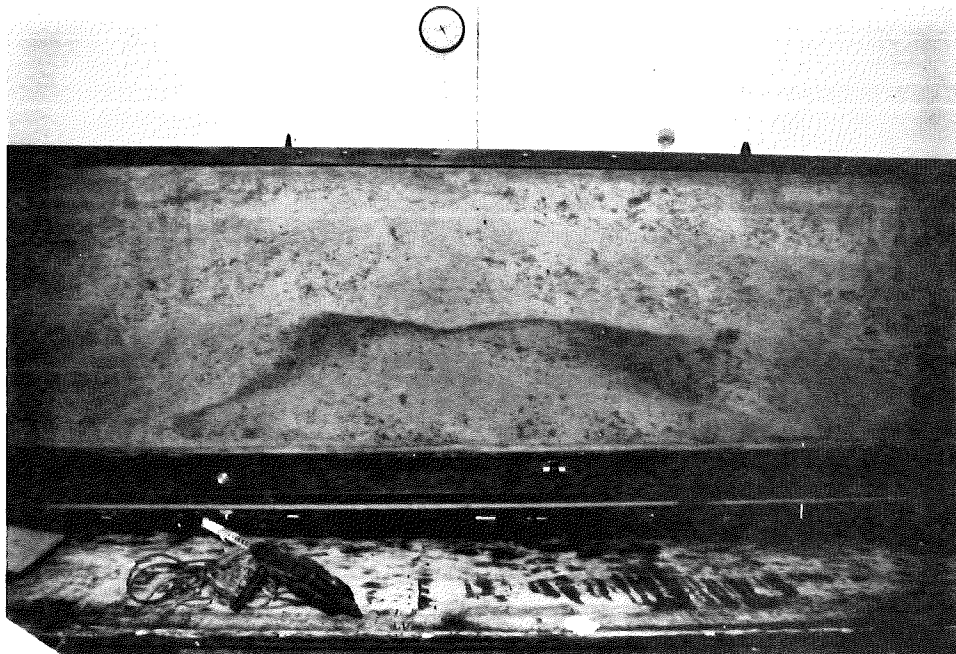
CSL distribution test 4 was performed on February 11, 1981. Concrete was placed into the form from one (1) inlet port located one (1) foot to the left of the center of the curb. The one (1) foot offset was used to prevent unnecessary interference between the concrete placing line and the structural supports of the distribution rig. A portland Type III cement concrete was used with the following admixtures:

- 1.5% (by weight of cement) Mighty 150 superplasticizer
- 1.5 fluid oz/cwt (by weight of cement) Darex air entraining agent
- 1.5% (by weight of cement) Allied Chemical calcium chloride

Batch weights (LB/YD³) of 752 cement, 1225 sand, 600 3/8" stone and 900 3/4" stone were used with a water to cement ratio of approximately 0.42.

Curb vibration was cycled five (5) seconds on and fifty-five (55) seconds off at thirty (30) psig air supply pressure. The initial slump varied from four (4) to seven (7) inches. A slab fifty-one (51) inches high was cast at an average curb advance rate of 3.25 ft/hr and a form pressure of twenty-five (25) psig. A higher form pressure of approximately thirty-five (35) psig was tried during the test but concrete leakage occurred around the curb seal so the pressure was lowered back to twenty-five (25) psig after one (1) minute. Red dye was added once to the mix. Compressive strength was 212 psi at six (6) hours and 3290 psi at twenty-four (24) hours. The concrete slab was of good quality with no voids, honey combing or segregation. The dye pattern (refer to the included photograph) indicated

good distribution with the fresh concrete only penetrating about $1\frac{1}{2}$ feet vertically.



Test 4 Distribution Pattern
Single Port Inlet, Center Location

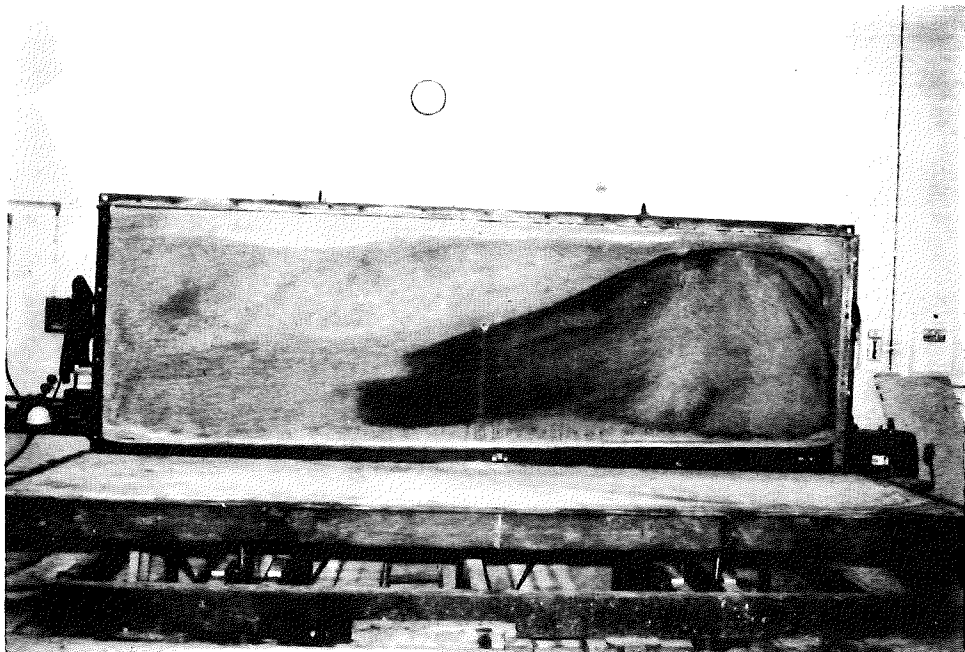
CSL distribution test 5 was performed on February 18, 1981. Concrete was placed into the form from one (1) inlet port located one (1) foot from the right end of the curb. A portland Type III cement concrete was used with the following admixtures:

- 1.5% (by weight of cement) Mighty 150 superplasticizer
- 1.5 fluid oz/cwt (by weight of cement) Darex air entraining agent
- 0.75% (by weight of cement) Allied Chemical calcium chloride

Batch weights (LB/YD³) of 752 cement, 1225 sand, 600 3/8" stone and 900 3/4" stone were used with a water to cement ratio of approximately 0.42.

Curb vibration was cycled five (5) seconds on and fifty-five (55) seconds off at thirty (30) psig air supply pressure. The initial slump varied from two (2) to ten (10) inches. A slab fifty-eight (58) inches high was cast at an average curb advance rate of 1.65 ft/hr and a form pressure of approximately twenty-five (25) psig. Yellow and black dye were added to the mix. The concentration of the calcium chloride was supposed to be 3.0% (by weight of cement), but due to an intermittent electrical connection between a power supply and the calcium chloride admixture pump drive, the actual concentration was approximately 0.75% (by weight of cement). Compressive strength was 4.0 psi at six (6) hours and 2918 psi at twenty-four (24) hours. The dye patterns (refer to the included photograph) indicated pour distribution with as much as three (3) feet vertical penetration. This excessive penetration was the result of using a concrete that ex-

hibited very little slump loss due to incorrect dosage of accelerator.



Test 5 Distribution Pattern
Single Port Inlet, Right Side

CSL distribution test 6 was performed on March 5, 1981. Concrete was placed into the form from one (1) inlet port located (1) foot from the right end of the curb. A very high early cement (VHEC) concrete was used with the following admixtures:

- 1.6% (by weight of cement & flyash) Lomar-D superplasticizer
- 0.1% (by weight of cement) citric acid retarder

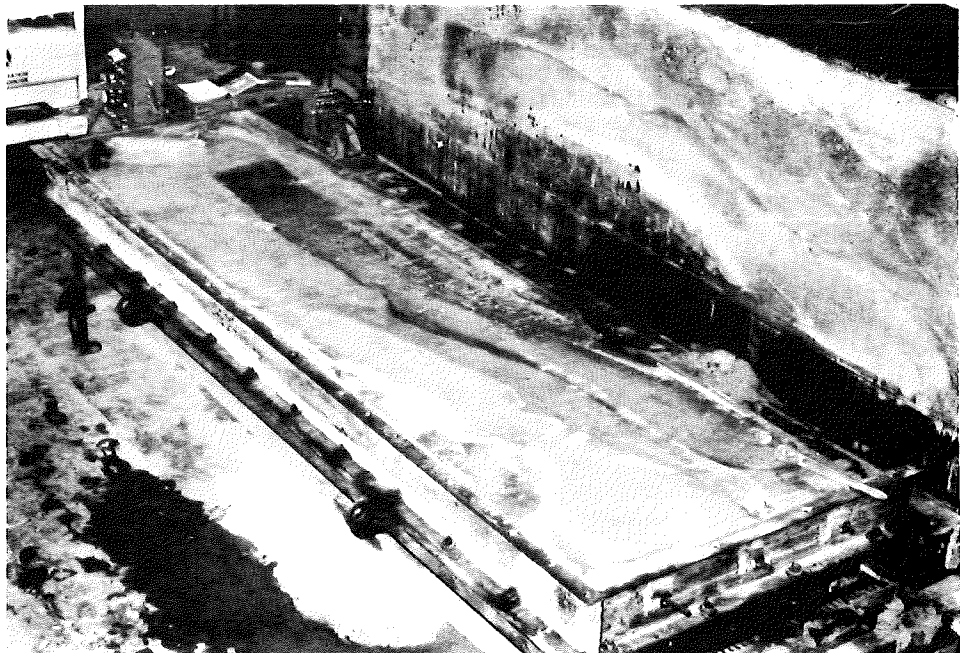
Batch weights (LB/YD³) of 611 cement, 94 flyash, 1325 sand, 570 3/8" stone and 1055 3/4" stone were used with a water to cement ration of approximately 0.40.

Curb vibration was cycled ten (10) seconds on and fifty (50) seconds off at thirty (30) psig air supply pressure. The initial slump was approximately six (6) inches. A slab fifty-one (51) inches high was cast at an average curb advance rate of three (3) ft/hr. Form pressures were varied from five (5) to fifty (50) psig near the inlet port. A typical pressure distribution during the test was fifty (50) psig near the inlet end of the curb, twenty (20) psig near the center of the curb and ten (10) psig on the left end of the curb farthest from the inlet port. This imbalance of pressures caused hydraulic problems in controlling the tilt of the curb. Thirty (30) minutes into the test curb tilt control was lost and not recovered until thirty (30) minutes later. Red and black dyes were added to the mix. Compressive strength was approximately 85 psi at 1½ hours and 1600 psi at 2 hours.

The test indicated that the curb tilt control procedure had to be changed and that the seals could withstand fifty (50) psig.

100 .

The dye patterns indicated (refer to the included photograph)
good distribution across the length of the slab.



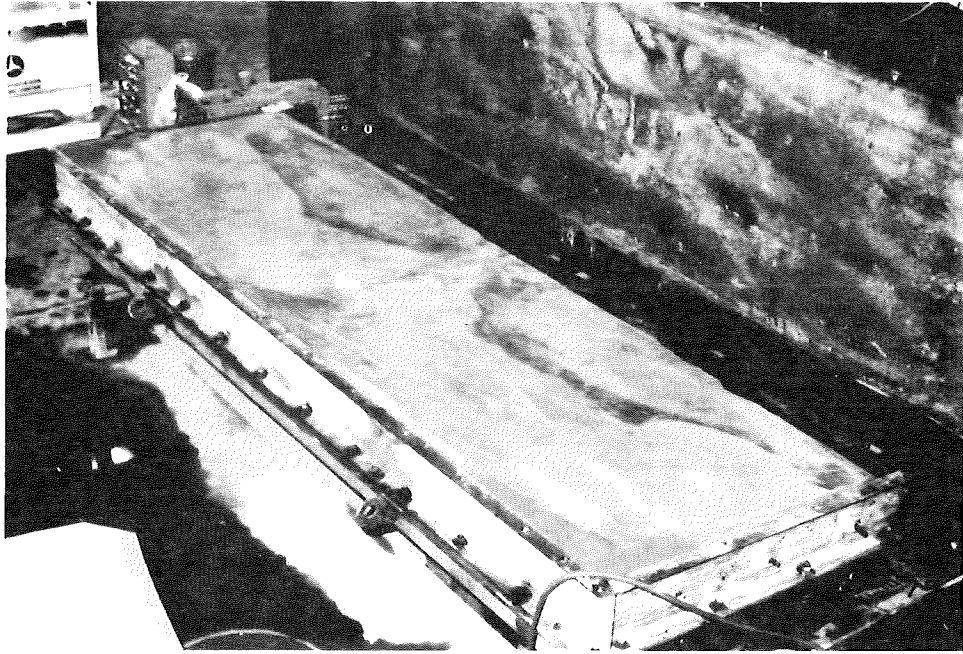
Test 6 Distribution Pattern
Single Port Inlet, Right Side

CSL distribution test 7 was performed on March 13, 1981. Concrete was placed into the form from two (2) inlet ports located five (5) feet from each end of the curb. Concrete placement was continuously cycled between the two (2) ports at one (1) minute intervals. A very high early cement (VHEC) concrete was used with the following admixtures:

- 1.6% (by weight of cement & flyash) Lomar-D superplasticizer
- 0.1% (by weight of cement) citric acid retarder

Batch weights (LB/YD³) of 611 cement, 94 flyash, 1325 sand, 570 3/8" stone and 1055 3/4" stone were used with a water to cement ratio of approximately 0.40.

Curb vibration was cycled five (5) seconds on, fifty-five (55) seconds off at thirty (30) psig air supply pressure. The initial slump was approximately eight (8) inches. A slab fifty-five (55) inches high was cast at an average curb advance rate of approximately four and one-half (4.5) ft/hr and an average form pressure of twenty-five (25) psig. Yellow and black dyes were each added twice to the mix. Compressive strength was approximately 700 psi at 1½ hours and 1700 psi at 2 hours. The test successfully proved the feasibility of using two (2) concrete inlet ports and cycling the placement of concrete between them. Good distribution across the slab was indicated by the dye patterns (refer to the included photograph).



Test 7 Distribution Pattern
Double Port Inlet

APPENDIX C

TEST PLAN FOR
CONCRETE SLIPFORM TESTS

CONTINUOUS SHAFT LINER (CSL)

SLIPFORM TEST PLAN

DOE 7957

Contract No. DE-AC01-79ET14223

Submitted by:

Foster-Miller Associates, Inc.
350 Second Avenue
Waltham, Massachusetts 02154

May 1981

1. TEST OBJECTIVES

The objectives of the continuous shaft liner (CSL) slipform tests are as follows:

- To determine the feasibility of slipforming concrete under pressure behind a moving form and above a downward moving curb
- To determine the level of concrete pumping pressure required for slipforming
- To determine the effect of coating the slipform surface on form drag
- To determine the effect of tapering the slipform on the slipforming process and on form drag
- To determine the effect of changes in slipform advance rates on the slipforming process
- To verify the suitability of different concrete mix designs to the slipforming process.

CSL SLIPFORM TEST PLAN

2. EXPERIMENTAL PARAMETERS

The following fixed and variable parameters will be used during the slipform tests.

2.1 Fixed Parameters

Fixed parameters are as follows:

- Slipform rig dimensions
- Diameter of concrete pumplines and inlet port
- Vibration of curb.

2.1.1 Slipform Rig Dimensions

The dimensions of the slipform rig are fixed. The slipform itself is 5 by 4 ft and can be moved through a vertical travel zone of 11 ft. The horizontal distance between the moving slipform and the stationary side of the form is 1 ft.

2.1.2 Diameter of Concrete Pumplines and Inlet Port

The diameter of the concrete pumplines and curb inlet port is fixed at 3 in.

2.1.3 Vibration of Curb

The vibration of the curb will be fixed. One pneumatically operated vibrator will be bolted to the curb of the slipform test rig. The frequency and duration of the vibration will be controlled by an electronic timer, electromechanical solenoid and a pressure regulator. Thirty lb/in.² air will be cycled to the vibrator at a frequency of 8 sec on, and 52 sec off each minute.

CSL SLIPFORM TEST PLAN

2.2 Variable Parameters

Variable parameters are as follows:

- Concrete pumping pressure
- Slipform surface coating
- Slipform taper
- Slipform advance rate
- Concrete mix design.

2.2.1 Concrete Pumping Pressure

Concrete pumping pressure is developed from pipeline friction, pumping rate, and from the static pressure head against which it acts. Concrete pumping pressure can be increased artificially to simulate a pressure head by applying a back pressure force by actually pushing the curb up against the plastic concrete. In the slipform tests a back pressure of up to 20 lb/in.² can be applied to simulate conditions that would be present if the concrete was being pumped into a form through a curb that was supporting up to 20 ft of partially set concrete.

2.2.2 Slipform Surface Coating

During the slipform tests, the surface of the slipform will be varied to determine the effect of coating on form drag. The slipform is 0.5 in. thick steel and for the initial tests (refer to Section 4) will be used bare with only a coat of red primer. Subsequent testing will use a removable 0.25 in. thick coating of ultra-high molecular weight polymer (UHMWP) mechanically attached to the slipform surface.

2.2.3 Slipform Taper

The angle of the slipform to the slipform rig can be varied to determine the effect of tapering the slipform. Two settings will be used during the slipforming tests. Initial tests (refer to Section 4) will be performed with no taper; defined as 0 to 0.125 in. in 10 ft. Subsequent testing will be performed at conditions of no taper and at full taper; defined as 0.375 in. in 10 ft.

2.2.4 Slipform Advance Rate

During the slipform tests the average advance rate of the slipform and curb will be varied to determine their effect on the slipforming process. Initial slipform tests will be performed at an average advance rate of 2 ft/hr when using Portland Type III cement concrete and at 4 ft/hr when using Very High Early Cement (VHEC) concrete (refer to subsection 2.2.5). Subsequent testing will be performed at the above rates and at 1 ft/hr with the Type III cement concrete and at 2 ft/hr with the VHEC concrete.

2.2.5 Concrete Mix Design

Two concrete mix designs will be formulated to be both workable for pumpability and rapid-stiffening for self-support. The two mix designs will be finalized prior to slipform tests. One mix design will be based on Portland Type III cement. The other mix design will use a VHEC.

The Portland Type III cement concrete mix design is tentatively defined as follows:

- Cement - 752 lb/yd³
- Sand - 1225 lb/yd³
- 3/8-in. stone - 600 lb/yd³
- 3/4-in. stone - 900 lb/yd³
- 0.42 water to cement ratio
- 1.5 percent* Mighty 150 superplasticizer
- 1.5 f-oz/CWT* Darex air entraining agent
- 3 percent* Allied Chemical calcium chloride.

The VHEC concrete mix design is tentatively defined as follows:

- Cement - 611 lb/yd³
- Fly ash - 94 lb/yd³
- Sand - 1325 lb/yd³
- 3/8-in. stone - 570 lb/yd³
- 3/4-in. stone - 1055 lb/yd³
- 0.40 water to cement ratio
- 0.1 percent* citric acid retarder
- 1.6 percent** Lomar-D superplasticizer.

If problems are encountered, some minor changes may be made to the mix designs to improve workability. Since improvements to mix workability may jeopardize early strength behavior it will be important to only change the mix designs in the event all other attempts to achieve slipforming fail.

*By weight of cement.

**By weight of cement and fly ash.

3. TEST MONITORING

The following data will be monitored during the slipform tests by visual observation or by instrumentation recording techniques:

- Concrete pump hydraulic fluid pressure
- Concrete pumping line pressure
- Concrete pressure in form
- Slipform and curb cylinder hydraulic pressures
- Slipform and curb positions
- Concrete mix temperature
- Mix water temperature
- Concrete pump hydraulic fluid temperature
- Admixture system flow rates
- Concrete pump rotation rate
- Concrete quality control.

3.1 Concrete Pump Hydraulic Fluid Pressure

The concrete pump hydraulic fluid pressure will be monitored by visual observation of the pressure gauge on the concrete pump. The pressure will be recorded onto a data sheet by the concrete pump operator at least once every hour.

3.2 Concrete Pumping Line Pressure

The concrete pumping line pressure will be monitored with one in-line Red Valve pressure sensor located near the curb. A pressure transducer (0 to 500 lb/in.²) will be mounted on the Red Valve pressure sensor. Its output, through appropriate signal conditioning, will be continuously recorded on a Brush chart recorder.

3.3 Concrete Pressure in Form

The concrete pressure in the form will be monitored with five pressure transducers. One pressure transducer will be located on the curb and four will be mounted in five possible locations along a vertical line of the stationary side of the form. The transducers will be capable of recording pressures up to 50 lb/in.². The output of the pressure transducers, through appropriate signal conditioning, will be continuously recorded on a Brush chart recorder.

3.4 Slipform and Curb Cylinder Hydraulic Pressure

The hydraulic pressure in the slipform and curb cylinders will be monitored by visual observation of pressure gauges on the hydraulic power unit (HPU). The pressures will be recorded on a data sheet by the HPU operator at least once every hour and when pressure changes occur.

3.5 Slipform and Curb Positions

Two displacement transducers will be used to monitor the positions of the slipform and curb. One displacement transducer will monitor the position of the slipform relative to a datum position. The other displacement transducer will monitor the relative position of the slipform to the curb. The output of the displacement transducers, through appropriate signal conditioning, will be continuously recorded on a Brush chart recorder.

3.6 Concrete Mix Temperature

The concrete mix temperature will be monitored with a temperature probe. The visual observation of its output will be recorded on a data sheet by the admixture system operator. The temperature will be recorded every 5 min.

3.7 Mix Water Temperature

The mix water temperature will be monitored with a thermometer plumbed into the admixture system. The visual observation of its output will be recorded on a data sheet by the admixture system operator. The temperature will be recorded every 5 min.

3.8 Concrete Pump Hydraulic Fluid Temperature

The hydraulic fluid temperature of the concrete pump will be monitored by visual observation of the thermometer on the concrete pump. The temperature will be recorded on a data sheet by the concrete pump operator at least once every hour.

3.9 Admixture System Flow Rates

The flow rates of the fluids in the admixture system will be monitored by visual observation of the flowmeters on the admixture system. The flow rates will be recorded on a data sheet by the admixture system operator every 5 min.

3.10 Concrete Pump Rotation Rate

The concrete pump rotation rate will be monitored by visual observation of the rotation of the rollers of the concrete pump. The rotation rate will be recorded on a data sheet by the concrete pump operator when time permits.

3.11 Concrete Quality Control

The concrete quality control will be monitored by measuring the initial slump, slump history, air content, unit weight and compressive strength of samples of the batched concrete. (Refer to subsection 5.5 for specifics.)

4. TEST SEQUENCE

A test sequence has been formulated in the form of a decision flow chart (Figure 4-1). At least 6 but no greater than 12 slipform tests will be performed. The actual number of tests conducted will depend on the number and types of failures encountered during the test program. A test is defined as one day's placement. The test parameters may be changed during the test but all such changes will be recorded.

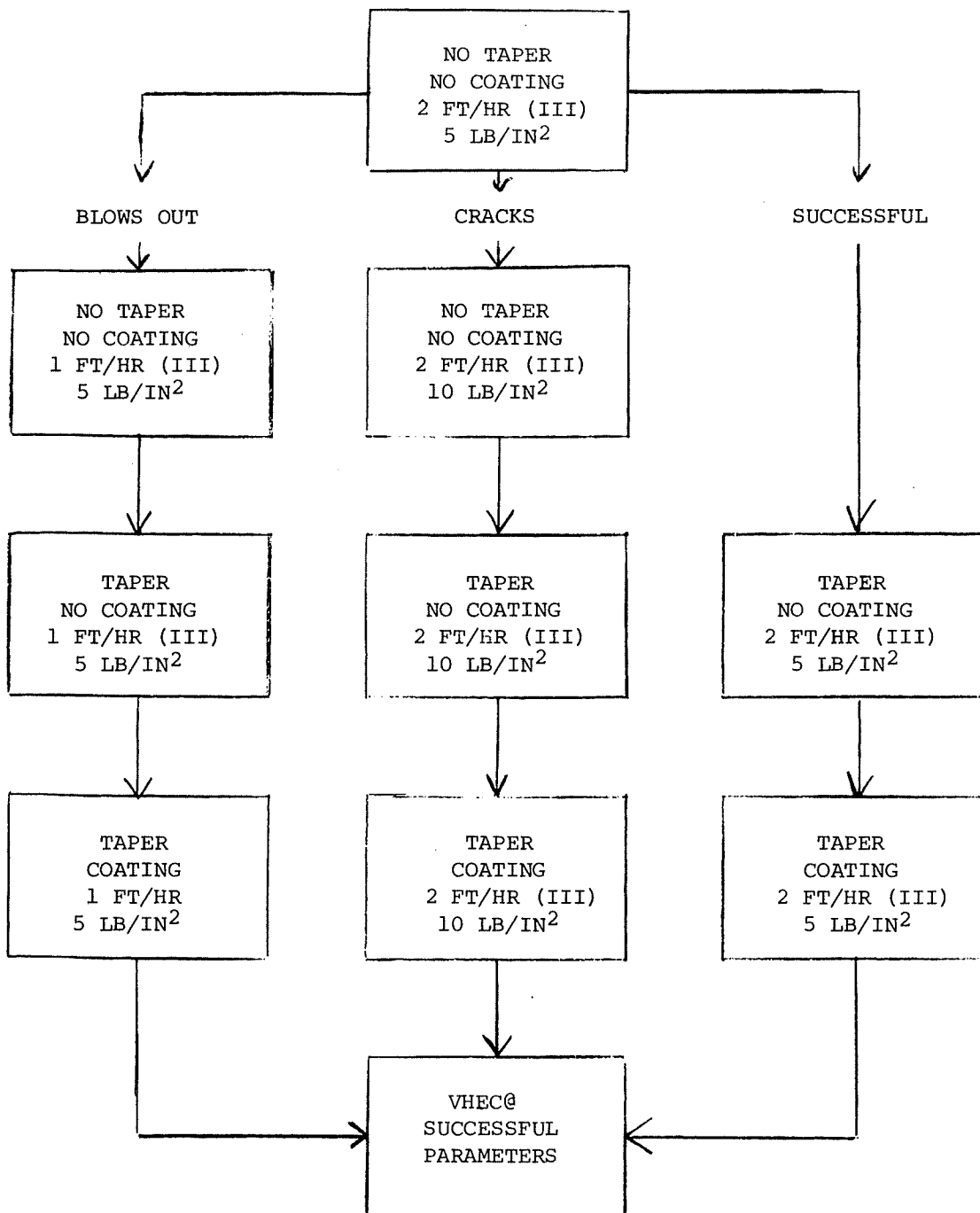


Figure 4-1. Decision Flow Chart

CSL SLIPFORM TEST PLAN

5. TEST ORGANIZATION

Each slipforming test involves the following systems:

- Concrete mixing system
- Admixture system
- Concrete quality control system
- Concrete pumping system
- Hydraulic power unit (HPU) system
- Slide valve system
- Vibration system
- Instrumentation system.

The specific duties and responsibilities of each system operator are specified in the following subsections.

Figure 5-1 shows the CSL slipform test organization.

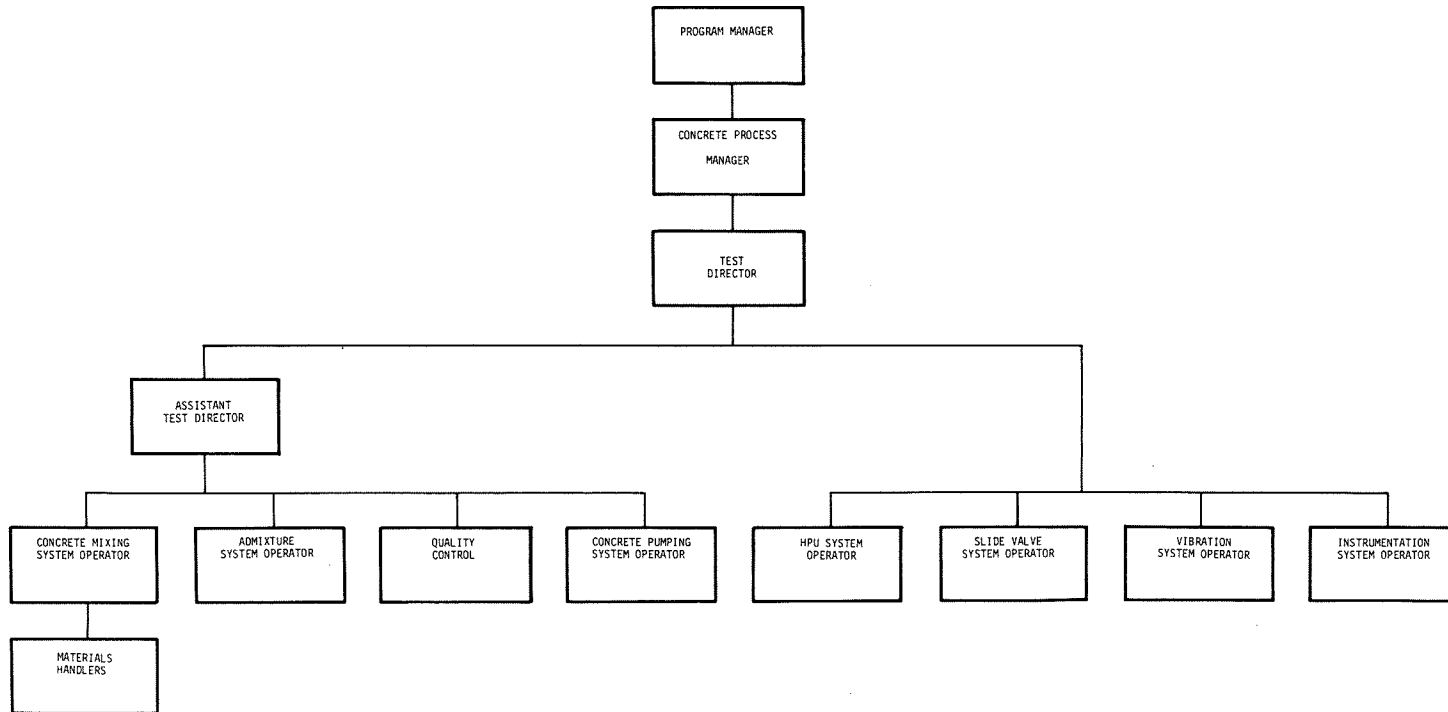


Figure 5-1. CSL Slipform Test Organization

5.1 Test Director

The test director's responsibility during the slipform tests is the specification, coordination and direction of the individual tests. His specific duties are as follows.

5.1.1 Before Test

Before test responsibilities of the test director are listed as follows:

- Details the test specification
- Distributes the test specification to the operators of the various systems
- Coordinates all test personnel and test equipment
- Gives pretest "pep talk" concerning what is to be accomplished, fragility of instrumentation, danger of concrete and/or hydraulic fluid pressure build up and danger of 480 Vac power
- Performs pretest final inspection.

5.1.2 During Test

During test responsibilities of the test director are listed as follows:

- Directs and supervises test
- Answers questions of any system operator
- Ensures test goes as planned
- Resolves any problems/conflicts occurring during test

- Ensures all data is being recorded
- Ensures test is being performed safely.

5.1.3 After Test

After test responsibilities of the test director are listed as follows:

- Performs post-test inspection of slab
- Reduces and analyzes test data
- Writes summary of tests and results.

Figure 5-2 illustrates the CSL slipform test specification.

CSL SLIPFORM TEST SPECIFICATION

PAGE 1 OF 2

TEST NUMBER _____ DIRECTOR _____
 DATE _____ ASSISTANT DIRECTOR _____

SPECIAL INSTRUCTIONS AND DETAILS

AVERAGE SLIPFORM AND CURB ADVANCE RATE (ft/hr) _____
 AVERAGE CONCRETE PUMPING RATE (yd³/hr) _____
 BACK PRESSURE IN FORM (lb/in.²) _____

CONCRETE MIXER SYSTEM

MIX DESIGN _____

MIX DESIGN CHARACTERISTICS

INITIAL SLUMP (in.) _____

15 min SLUMP (in.) _____

MIX TEMPERATURE (°F) _____

COMPRESSIVE STRENGTH (lb/in.²) _____

MIXER VIBRATION ON TIME _____

MIXER VIBRATION OFF TIME _____

Figure 5-2. CSL Slipform Test Specification

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST SPECIFICATION

PAGE 2 OF 2

TEST NUMBER _____ DIRECTOR _____
 DATE _____ ASSISTANT DIRECTOR _____

SLIPFORM RIG ASSEMBLY

SLIPFORM TAPER _____
 SLIPFORM COATING _____
 SLIPFORM EFFECTIVE LENGTH (SEL) (ft) _____

INSTRUMENTATION SYSTEM

LOCATION OF PRESSURE TRANSDUCERS _____
 RED VALVE LOCATION _____

SLIDE VALVE SYSTEM

PUMP TIME TO FORM (min) _____
 PUMP TIME TO WASTE (min) _____

VIBRATOR SYSTEM

PRESSURE TO VIBRATORS (lb/in.²) _____
 ON TIME OF VIBRATORS (sec) _____
 OFF TIME OF VIBRATORS(sec) _____

Figure 5-2. CSL Slipform Test Specification (Continued)

CLS SLIPFORM TEST PLAN

5.2 Assistant Test Director

The assistant test director's responsibility during the slipform tests is to assist the test director in the specification, coordination and direction of the individual tests. His specific duties are as follows.

5.2.1 Before Test

Before test responsibilities of the assistant test director are listed as follows:

- Ensures all systems are ready prior to testing
- Supervises raising of slipform test rig.

5.2.2 During Test

During test responsibilities of the assistant test director are listed as follows:

- Directs and supervises his system operators
- Answers questions of his system operators
- Ensures all data is being recorded by system operators
- Ensures test is being performed safely.

5.2.3 After Test

After test responsibilities of the assistant test director are listed as follows:

- Performs post-test inspection of slab
- Supervises lowering of slipform test rig
- Specifies method and supervises identification, demolition, removal, caring and disposal of slab.

5.3 Concrete Mixing System Operator

The concrete mixing system operator's responsibility during the slipform tests is the setup and operation of the concrete mixer. His specific duties are outlined in the following subsections.

5.3.1 Maintenance

The following maintenance procedures should be performed. See manufacturer's instruction manual for specific information.

- Lubrication of feed and main augers - weekly
- Lubrication of drive chain - monthly
- Check varydrive belt condition - monthly
- Change oil in auger gear boxes - every 3 months.

In addition to mechanical maintenance, he/she must:

- Maintain low inventories in material storage hoppers when not in use
- Keep cement hopper covered with plastic when not in use
- Keep mixer exterior clean.

5.3.2 Calibration

Adjust the output of individual material feed augers to match the mix design proportions. Mix proportions and total outputs can be varied by changing parajust voltage and/or feed auger varydrive settings. A calibration program should be planned and carried out under guidance of the test director. (Refer to ETLS Technical Memorandum No. 43.)

5.3.3 Before Test

- Sets up mixer on jackstands, levels mixer and removes trailer hitch tongue
- Plugs mixer power cord into 480 Vac 30A service outlet on column
- Ensures wood pieces are in prebatch and stone bins before filling to prevent free fall of aggregate material
- Checks for water in motor shrouds
- Inspects electrical supply hookup - check rotation
- Checks operation of parajust with all feed motors in off position
- Before filling hoppers, checks operations of all feed augers and checks for correct varydrive settings
- Checks operation of vibrator
- With parajust in off position, sets feed auger motor switches to on position
- Checks for proper rotation of mix auger (clockwise when viewed from motor end of auger)

- Makes final check for correct varydrive setting
Remember: Do not change varydrive setting unless
motor is running
- Fills material hoppers.

5.3.4 During Test

- Directs and supervises the materials handlers, admix cart operator and conveyor attendant
- Records any changes made in parajust voltage or vary-drive settings
- Records amount of bin vibration used
- Informs test director of any abnormalities
- Placement of the diversion chute
- Select combination of material feed augers to be used by pushing switches to on
- Push main auger switch to on
- To start sequence, push parajust switch to on and simultaneously start fluid supplies
- Check parajust voltage, verify operation of auger shafts
- Visually monitor material output
- When mix stabilizes, that is, maintains the same consistency, remove diversion chute

CSL SLIPFORM TEST PLAN

- Changes to parajust voltage or varydrive setting should not be made during a test without approval of the test director
- Water content may be adjusted to make up for minor changes in aggregate water content (adjusted by front knob on water metering pump drive)
- When changing total output of mixer, push parajust switch to off:
 - Wait 5 sec, and switch off fluid pumps
 - Turn all feed switches to off
 - Switch on parajust
 - Adjust to appropriate voltage
 - Switch off parajust
 - Turn on feed switches
 - Switch on parajust and simultaneously switch on fluid pumps
- Remember: The feed augers should be started and stopped only by the parajust switch. No other method is acceptable.

5.3.5 After Test

- For normal shutdown sequence:
 - Switch off parajust
 - Wait 5 sec, and shut off fluid pumps
 - Wait 1 min, then shut off main auger
 - Move mixer free of concrete pump
 - Cover cement hopper with plastic sheeting
 - Drop lift auger rubber boot
 - Wash down main lift auger
 - Clean mixer exterior

CSL SLIPFORM TEST PLAN

- Ensures proper cleaning and storage of all concrete mixing system equipment and materials
- Records bag count of cement used.

5.3.6 Problems During Mixing Cycle

The following is a list of the problems that might occur during the mixing cycle accompanied by the appropriate corrective action:

- Power fails - Shut down parajust and main switch
- Feed auger(s) stop rotating - Turn parajust to higher voltage until the auger is free; turn voltage back to previous setting immediately
- Fluid pump fails - Shut down parajust immediately
- Raw material supply runs out - Shut down parajust
- Mix auger binds or drags - Shut down parajust and fluid pumps in normal sequence
- Pump hopper overflows - Set up diversion chute. Do not shut down unless indicated to do so by test director or pump operator.

Figure 5-3 illustrates the concrete mixing system test data sheets.

CSL SLIPFORM TEST DATA SHEET
CONCRETE MIXING SYSTEM

PAGE 1 OF 3

TEST NUMBER _____ OPERATOR _____
DATE _____

CONCRETE MIXER CALIBRATION RECORD

MATERIAL AUGERED	PARAJUST VOLTAGE (Vdc)	VARYDRIVE SETTING	RUN NUMBER	WEIGHT (lb)			TIME (min)	FLOW RATE (lb/min)	COMMENTS (VIBRATION, etc.)
				GROSS	TARE	NET			

Figure 5-3. CSL Slipform Test Data Sheet
Concrete Mixing System

CSL SLIPFORM TEST PLAN

MATERIAL AUGERED	PARAJUST VOLTAGE (Vdc)	VARYDRIVE SETTING	RUN NUMBER	WEIGHT (lb)			TIME (min)	FLOW RATE (lb/min)	COMMENTS (VIBRATION, etc.)
				GROSS	TARE	NET			

Figure 5-3. Concrete Mixer Calibration Record
Work Sheet

CSL SLIPFORM TEST DATA SHEET
CONCRETE MIXING SYSTEM

PAGE 2 OF 3

TEST NUMBER _____ OPERATOR _____
DATE _____

MIX CONTROL (VHEC CONCRETE)

TIME OF DAY	PARAJUST VOLTAGE (Vdc)	VARYDRIVE SETTING		
		PREBATCH	3/4 in. STONE	CEMENT

TIME OF DAY	SAND BIN VIBRATION	
	ON TIME	OFF TIME

Figure 5-3. CSL Slipform Test Data Sheet
Concrete Mixing System (Continued)

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE MIXING SYSTEM

PAGE 3 OF 3

TEST NUMBER _____ OPERATOR _____
DATE _____

MIX CONTROL (PORTLAND TYPE III CEMENT CONCRETE)

TIME OF DAY	PARAJUST VOLTAGE (Vdc)	VARYDRIVE SETTING		
		SAND	STONE*	CEMENT

TIME OF DAY	SAND BIN VARIATION	
	ON TIME	OFF TIME

BAG COUNT OF CEMENT USED _____

*MIXED 3/8 AND 3/4 in. STONE

Figure 5-3. CSL Slipform Test Data Sheet
Concrete Mixing System (Continued)

CSL SLIPFORM TEST PLAN

5.3.7 Concrete Mixing System Equipment

The concrete mixing system equipment required is as follows:

- Concrete mixer
- Wooden pallets
- Waste forms
- Bobcat
- Clipboard and writing instrument
- Varydrive internal plastic piece, P/N 195357
- Drive belts
- Extra tubing
- Shovels.

5.4 Admixture System Operator

The admixture system operator's responsibility during the slipform tests is the setup and operation of the admixture system. He is also responsible for the monitoring and recording of certain data. His specific duties are as follows:

5.4.1 Before Test

- Prepares admixture solutions
- Sets up admixture system
- Records arrangement of admixture system
- Performs and records admixture system calibration
- Records control settings of admixture pump drives
- Plugs admixture cart power cord into 110 Vac outlet on column
- Hooks up fluid supplies from admixture system to concrete mixer system and verifies proper operation.

5.4.2 During Test

- Measures concrete mix temperature every 5 min
- Adjusts mix water temperature to bring concrete mix temperature to design temperature
- Measures and records temperature of mix water every 5 min

CSL SLIPFORM TEST PLAN

- Records flow rates of admixture system every 5 min
- Maintains sufficient supply of water and admixture in admixture system.

5.4.3 After Test

- Ensures proper cleaning and storage of all admixture system equipment
- Checks calibration of admixture system.

Figure 5-4 illustrates the admixture system test data sheets.

CSL SLIPFORM TEST DATA SHEET
ADMIXTURE SYSTEM

PAGE 1 OF 3

TEST NUMBER _____ OPERATOR _____
DATE _____

ADMIXTURE SYSTEM ARRANGEMENT RECORD

DRIVE #	DRIVE #	DRIVE #
A SIZE	D SIZE	G SIZE
B SIZE	E SIZE	H SIZE
C SIZE	F SIZE	I SIZE

Figure 5-4. CSL Slipform Test Data Sheet
Admixture System

CSL SLIPFORM TEST PLAN

PAGE 3 OF 3

DATE _____

[illegible]

Figure 5-4. CSL Slipform Test Data Sheet
Admixture System (Continued)

CSL SLIPFORM TEST PLAN

TIME OF DAY	MIX TEMPERATURE (°F)	MIX WATER		FLOW RATE			COMMENTS
		TEMPERATURE (°F)	FLOW RATE	ADMIXTURE	ADMIXTURE	ADMIXTURE	

Figure 5-4. Admixture Calibration Record
Work Sheet

5.4.4 Admixture System Equipment Required

Equipment required includes:

- ETLS admixture cart
- Four 55-gal plastic drums
- Thermometers
- Clipboard and writing instrument
- Water/admixture heating system
- Flow meters.

5.5 Concrete Quality Control System

The concrete quality control system personnel's responsibility during the CSL slipform tests is the monitoring and recording of concrete quality control data. His/her specific duties are as follows:

5.5.1 Before Test

Before test responsibilities include recording mix design and materials identification on data sheets.

5.5.2 During Test

5.5.2.1 VHEC Concrete

- Measures and records initial slump as often as possible
- Casts three cylinders once during test
- Measures and records compressive strength of cylinders, 1, 1.5 and 2 hr after casing
- Informs test director of any abnormalities.

5.5.2.2 Portland Type III Cement Concrete

- Measures and records initial slump as often as possible
- Measures and records slump history (slump/time measurements) at 35 min intervals
- Casts three cylinders once during test

- Measures and records compressive strength of cylinders 1, 1.5 and 2 hr after casting
- Measures and records air content and unit weight once during test
- Informs test director of abnormalities.

5.5.3 After Test

After test responsibilities include ensuring proper cleaning and storage of all concrete quality control system equipment.

Figure 5-5 illustrates the concrete quality control test data sheets.

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 1 OF 9

TEST NUMBER _____ OPERATOR _____

DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (CONTINUED).

CEMENT

TYPE _____

BRAND _____

LOT NUMBER _____

SOURCE _____

SUPPLY DATE _____

SPECIFIC GRAVITY _____

CEMENT FACTOR (SACKS/yd³) _____BATCH WEIGHT (lb/yd³) _____WATER

WATER CEMENT RATIO _____

LOCATION OF SOURCE _____

SSD BATCH WEIGHT (lb/yd³) _____Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 2 OF 9

TEST NUMBER _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (VHEC CONCRETE).

PREBATCH

SOURCE _____
SUPPLY DATE _____
ABSORPTION (%) _____
FLY ASH SSD BATCH WEIGHT (1b/yd³) _____
SAND SSD BATCH WEIGHT (1b/yd³) _____
3/8 in. STONE SSD BATCH WEIGHT (1b/yd³) _____
PREBATCH SSD BATCH WEIGHT (1b/yd³) _____

SIEVE SIZE	ACTUAL GRADATION (% PASSING)	RECOMMENDED GRADATION (% PASSING)
1/2 in.		
3/8 in.		
#4		
#8		
#16		
#30		
#50		
#100		
#200		
PAN		
FM		

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 3 OF 9

TEST NUMBER _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (PORTLAND TYPE III CEMENT CONCRETE).

SAND

SOURCE _____
SUPPLY DATE _____
BULK SPECIFIC GRAVITY SSD _____
ABSORPTION (%) _____
PERCENT OF TOTAL AGGREGATE (%) _____
SSD BATCH WEIGHT (lb/yd³) _____

SIEVE SIZE	ACTUAL GRADATION (% PASSING)		RECOMMENDED GRADATION (% PASSING)
	BEFORE WASHING	AFTER WASHING	
3/8 in.			
#4			
#8			
#16			
#30			
#50			
#100			
#200			
PAN			
FM			

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 4 OF 9

TEST NUMBER _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (PORTLAND TYPE III CEMENT CONCRETE) (CONTINUED).

3/8 in. STONE

SOURCE _____

SUPPLY DATE _____

BULK SPECIFIC GRAVITY SSD _____

ABSORPTION (%) _____

PERCENT OF TOTAL AGGREGATE (%) _____

SSD BATCH WEIGHT (lb/yd³) _____

SIEVE SIZE	ACTUAL GRADATION (% PASSING)		RECOMMENDED GRADATION (% PASSING)
	BEFORE WASHING	AFTER WASHING	
1/2 in.			
3/8 in.			
#4			
#8			
#16			
PAN			
FM			

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 5 OF 9

TEST NUMBER _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (CONTINUED).

3/4 in. STONE

SOURCE _____
SUPPLY DATE _____
BULK SPECIFIC GRAVITY SSD _____
ABSORPTION (%) _____
PERCENT OF TOTAL AGGREGATE (%) _____
SSD BATCH WEIGHT (lb/yd³) _____

SIEVE SIZE	ACTUAL GRADATION (% PASSING)		RECOMMENDED GRADATION (% PASSING)
	BEFORE WASHING	AFTER WASHING	
1 in.			
3/4 in.			
1/2 in.			
3/8 in.			
#4			
#8			
#16			
PAN			
FM			

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 6 OF 9

TEST NUMBER _____ OPERATOR _____

DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (CONTINUED).

ADMIXTURES

ADMIXTURE ID NUMBER _____

TYPE _____

BRAND _____

LOT NUMBER _____

SOURCE _____

SUPPLY DATE _____

SPECIFIC GRAVITY _____

DOSE RATE (% OF CEMENT) _____

INITIAL WATER CONTENT (%) _____

DILUTION FOR TEST (%) _____

TOTAL DILUTED WATER CONTENT* (1b/yd³) _____

ADMIXTURE ID NUMBER _____

TYPE _____

BRAND _____

LOT NUMBER _____

SOURCE _____

SUPPLY DATE _____

SPECIFIC GRAVITY _____

DOSE RATE (% OF CEMENT) _____

INITIAL WATER CONTENT (%) _____

DILUTION FOR TEST (%) _____

TOTAL DILUTED WATER CONTENT* (1b/yd³) _____

*DOSE RATE × CEMENT BATCH WEIGHT × INITIAL WATER CONTENT
DILUTION FOR TEST

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 7 OF 9

TEST NUMBER _____ OPERATOR _____
DATE _____ MIX DESIGN ID _____

MIX DESIGN AND MATERIALS IDENTIFICATION RECORD (CONTINUED).

ADMIXTURES (CONTINUED)

ADMIXTURE ID NUMBER _____
TYPE _____
BRAND _____
LOT NUMBER _____
SOURCE _____
SUPPLY DATE _____
SPECIFIC GRAVITY _____
DOSE RATE (% OF CEMENT) _____
PURITY (%) _____
BATCH WEIGHT* (lb/yd³) _____
DILUTION FOR TEST (%) _____
TOTAL DILUTED WATER CONTENT** (lb/yd³) _____

$$*BATCH\ WEIGHT = \frac{DOSE\ RATE \times CEMENT\ BATCH\ WEIGHT}{PURITY}$$

$$**TOTAL\ DILUTED\ WATER\ CONTENT = \frac{DOSE\ RATE \times CEMENT\ BATCH\ WEIGHT}{DILUTION\ FOR\ TEST}$$

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST PLAN

PAGE 8 OF 9

MIX TEMPERATURE AND SLUMP HISTORY

[illegible]

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
CONCRETE QUALITY CONTROL

PAGE 9 OF 9

TEST NUMBER _____ OPERATOR _____
DATE _____

COMPRESSIVE STRENGTH MEASUREMENT

TIME SAMPLE CAST _____

TIME AFTER CASTING (hr)	COMPRESSIVE LOAD (lb)	COMPRESSIVE STRENGTH (lb/in. ²) (LOAD/28.27)
1.0		
1.5		
2.0		

AIR CONTENT AND UNIT WEIGHT MEASUREMENT
(N/A FOR VHEC CONCRETE)

TIME OF MEASUREMENT	AIR CONTENT (%)	UNIT WEIGHT (lb/ft ³)

Figure 5-5. CSL Slipform Test Data Sheet
Concrete Quality Control (Continued)

CSL SLIPFORM TEST PLAN

5.5.4 Concrete Quality Control System Equipment Required

Equipment required includes:

- Clipboard and writing instrument
- Slump test cone
- Compressive strength tester
- Air content tester
- Shovels.

5.6 Concrete Pumping System Operator

The concrete pumping system operator's responsibility during the slipform tests is the setup and operation of the concrete pump. His specific duties are as follows.

5.6.1 Before Test

Responsibilities of the operator include the following:

- Inspect pumping tube in the pumping chamber - Remove plexiglass ports and examine the tube for cracks and weak spots
- Check hydraulic fluid levels - Main pump and vacuum pump
- Check hoses, belts and chains
- Check for water in electric motor shrouds
- Check remix hopper - note wiper blade condition and hopper side conditions
- Check and secure hopper emergency port door
- Verify proper electrical supply hookup
- Start vacuum pump - Check vacuum level and hopper remix blade operation. Check operation of hopper reposition cylinder

- Start main pump - Operate in idle position until 20 in. of vacuum has been obtained and the hydraulic oil temperature is at least 65°F. Check operations at all speeds with variable control
- Assemble support equipment - Locate rabbits. Place immersion vibrator and extension cord in ready position. Gather shovels and hand tools. Locate diversion chute and mortar pan. Move waste forms into position
- Check emergency shutdown - Operation at both locations.

In addition, the following items should be checked at intervals specified by instructions on the nameplates attached to the side of the pump control box.

- Position of pumping hose in the pumping chamber
- Location of high wear can be shifted by repositioning the remix hopper
- Greasing of fittings and lubrication of chains.

5.6.2 During Testing

- Operate pump only when test director indicates to do so
- Pump concrete only when you can verify at least 20 in. of vacuum and 65°F hydraulic oil temperature
- Maintain level of concrete above the inlet port at all times

- Change speed of pump only when test director indicates to do so
- Keep remix hopper wiper blade rotation direction and speed consistent with pumping direction and speed. For example, when operating at slow pumping rate, operate remix hopper wiper blades slowly in the feed direction. For reverse pumping and idling, operate blades in reverse direction with slow rotation
- Pump concrete at a slow rate when starting up to ensure complete filling of pumping lines. Increase speed slowly after successful pumping can be verified
- Watch fluctuations in hydraulic oil pressure of the main pump. Pressure in excess of 800 lb/in.² at slow pumping rates indicates high line resistance and may indicate a pumping failure is imminent
- If a pumping failure occurs alert both the mixer operator and test director immediately
- Follow steps outlined in Dealing with Pumping Failures (subsection 5.6.4)
- Records average hydraulic fluid pumping pressure at least once every hour
- Records hydraulic fluid temperature at least once every hour.

5.6.3 Termination of Testing

- Discontinue pumping when indicated to do so by the test director

- In a normal shut down perform the following steps:
 - Relieve vacuum. Shut down vacuum pump and main pump
 - Open remix hopper clean out hatch
 - Empty hopper and remove as much concrete from the inlet port as possible
 - Place rabbit in inlet port
 - Close remix hopper clean out hatch
 - Start vacuum pump and main pump
 - Fill hopper with water
 - Verify 20 in. of vacuum
 - Pump lines clear
 - Clear lines again by following the steps above in the same order
 - Shut down pump
 - Clean out hopper
 - Clean pump exterior.

5.6.4 After Test

Responsibilities include ensuring proper cleaning and storage of all concrete pumping system equipment.

5.6.5 Dealing with Pumping Failures

All workers as well as the pump operator should become thoroughly familiar with the procedures outlined in this section. A pumping failure should not be regarded as a panic situation. If everyone knows what to do in case of a failure, freeing the blocking becomes just another operating procedure. Since most of us involved in the latest tests have been present when a failure occurs we should have a general feel for the level of effort required to free a plug. It is an intense effort but

there is no reason why it should not be an orderly one. The following section describes how to determine whether a pumping blockage exists and if so, what to do to correct the situation. (Specific worker assignments during the operation will be outlined in a separate memo.)

How to Tell When There is a Failure or Blockage

- Abnormally high hydraulic pump pressure (over 1000 lb/in.²)
- Abnormally high concrete line pressure (over 50 lb/in.²)
- Unusual pumping sounds (thumping, high-pitched whine)
- Surging concrete pump hoses
- Collapsed concrete pump hose
- Water leakage at victaulic couplings.

What to do to Unblock the System

- Pump operator must immediately inform mix operator and test director of suspected problem
- With approval from the test director try to unblock the system using the pump
 - Try forward and reverse operation repeatedly, similar to the method one would try with an automobile that has become stuck in snow
 - If a positive result is not obtained after three or four reversals, *stop pump*

- Determine location of blockage
 - *Check for blockage in flex hose.* Indicators: presence of hard spot in line under no pumping pressure
 - *Check for blockage in pump.* (At inlet port or in pumping tube in the chamber.) Indicators: zero line pressure on gauge at pump outlet port location during pumping. Distinct thumping noise after each roller rotation.
 - *Check for blockage in slickline.* Indicators: there is no direct indicator. If checks for blockage in flex hose and pump indicate normal conditions, by deduction, the slickline is probably where the blockage exists.

Remedies

- Blockage in flex line
 - Locate blockage point
 - Disconnect line outbound (or beyond) blockage
 - Apply sledge hammer to "hard" spot
 - Attempt to pump concrete
 - If this fails, disconnect line inbound (or ahead) of blockage. Shake concrete out of removed line section. Reconnect inbound end. Pump concrete through line.
 - Reconnect outbound end and pump concrete.
- Blockage in pump:
 - Disconnect placing line at pump outlet port
 - Empty concrete hopper and leave hatch open
 - Apply water pressure to outlet port and run pump in reverse. Blockage should push out into hopper.
 - *If the above procedure fails:*

- a. Immediately disassemble pump line and purge by shaking out and applying water pressure by hose
- b. *At the same time,*
 1. Shut down vacuum system and main pump
 2. Disconnect inlet reducer at flange joint
 3. Clean out line with hand tools and hose
 4. Start vacuum pump and main pump
 5. Pump water through outlet port while running pump in reverse. Then pump water into pump inlet and run pump forward
 6. Clean up hopper.

Once the pump and lines are clear proceed with operations as indicated by the test director.

Figure 5-6 illustrates the concrete pumping system data sheets.

CSL SLIPFORM TEST DATA SHEET
CONCRETE PUMPING SYSTEM

PAGE 1 OF 1

TEST NUMBER _____ OPERATOR _____
DATE _____

TIME OF DAY	PUMP ROTATION RATE (rev/min)	HYDRAULIC FLUID	
		PRESSURE (lb/in. ²)	TEMPERATURE (°F)

OTHER OBSERVATIONS AND/OR COMMENTS

Figure 5-6. CSL Slipform Test Data Sheet
Concrete Pumping System

CSL SLIPFORM TEST PLAN

5.6.6 Concrete Pumping System Equipment Required

Equipment required includes:

- Concrete pump
- Concrete lines
- Two waste forms
- Two rabbits
- High pressure water line
- 110 Vac immersion vibrator
- 110 Vac extension cord
- Diversion chute
- Mortar pan
- Victaulic couplings
- Vehicle stands.

Spare parts and tools include:

- Spare parts list to be supplied by DOT ETLIS program
- Spare parts to be purchased by DOE CSL project
- Three 60A 480 Vac fuses.

5.7 Hydraulic Power Unit (HPU) System Operator

The hydraulic power unit (HPU) operator's responsibility during the slipform tests is the setup and operation of the HPU. His specific duties are in following subsections.

5.7.1 Before Test

Operations included in the pretest are:

- Ensures HPU is properly plumbed to the slipform rig and that all hydraulic outlets not to be used are properly capped off
- Ensures that the level of hydraulic fluid in the HPU is satisfactory
- Checks for leaks of hydraulic fluid
- Sets the pressure, flow and directional control valves to the proper settings for a particular test
- Turns on 480 Vac circuit breakers and 110 Vac ground fault circuit breaker
- Sets all electrical switches on HPU control panel to off position prior to energizing control panel.

5.7.2 During Test

Some of the operations that are performed during the test are as follows:

- Operates the HPU
- Monitors and records pressures and operating conditions every hour and when pressures or conditions change or are changed
- Shuts off HPU if any hydraulic hoses fail
- Adjusts HPU controls to maintain desired curb back pressure
- Adjusts HPU controls to maintain desired slipform effective length (SEL).

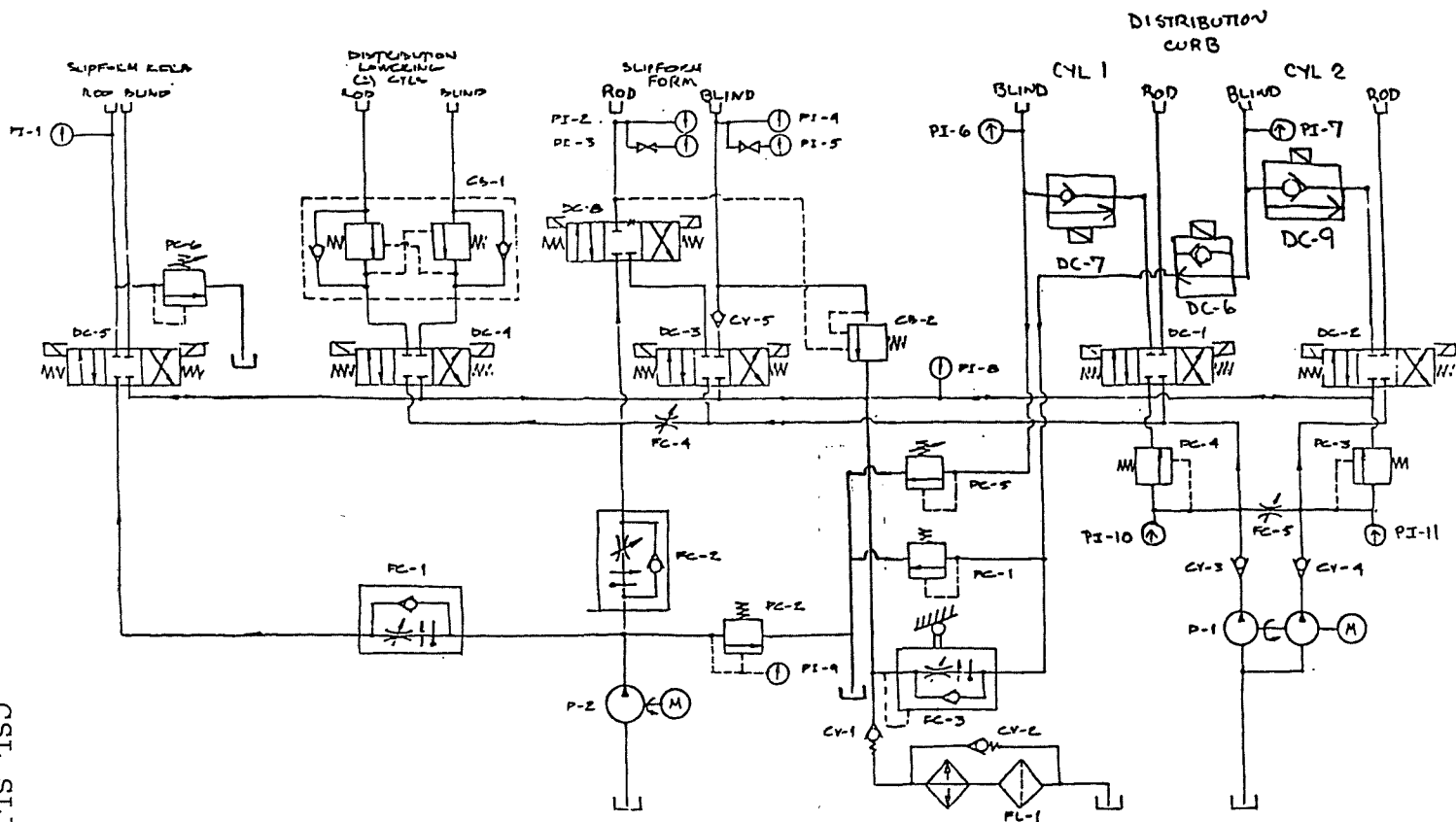
5.7.3 After Test

Post-test operations include:

- Shuts off the 480 and 110 Vac breakers
- Cleans HPU control panel, skid and hydraulic hoses.

Figure 5-7 illustrates the flow diagram of the HPU.

Figure 5-8 illustrates the HPU system test data sheet.



SL-1
 HYDRAULIC POWER SUPPLY
 FOR CSL LABORATORY
 COMPANY CODE --57
 JSE 6-10-80
 REVISED 1-5-81 BAC.

Figure 5-7. Schematic of a Hydraulic Power Supply for a CSL Laboratory

CSL SLIPFORM TEST DATA SHEET
HPU SYSTEM
PAGE 1 OF 1

TEST NUMBER _____ OPERATOR _____
DATE _____

[illegible]

Figure 5-8. CSL Slipform Test Data Sheet
HPU System

5.7.4 HPU System Equipment Required

The HPU system includes:

- One HPU
- Various hydraulic hoses
- Clipboard and writing instrument.

The list of spare parts and tools includes:

- Wrenches to adjust pressure control valves
- Heater elements for motor starters
- Fuses - 110 Vac, 15A
- Fuses - 480 Vac, 30A
- Key to control panel.

5.8 Slide Valve System Operator

The slide valve operator's responsibility during the distribution tests is the setup and operation of the slide valve system. His specific duties are in following subsections.

5.8.1 Before Test

Operations included in the pretest are:

- Greases slide plates on slide valve
- Connects 110 Vac power cord to outlet
- Ensures slide valve hydraulics are plumbed to a hydraulic system.
- Checks for proper operation of the slide valve by operating joy stick control to all four positions and observing position indicator lights
- Ensures that the concrete lines are plumbed between the slide valve and the curb and waste receptacles
- Records relationship between slide valve ports and curb port and waste receptacles
- Records blank slide valve ports.

5.8.2 During Test

During-test operates the slide valve using the joy stick control.

5.8.3 After Test

Post-test operations include:

- Operates the slide valve to the waste port position for purging of the concrete lines with water
- Disconnects 110 Vac power cord from outlet
- Disconnects concrete lines from slide valve
- Hoses down slide valve with water, taking care not to soak the control and terminal boxes
- Disassembles slide plates and inspects for gouges (file any found), greases and reassembles slide plates.

Figure 5-9 illustrates the slide valve system test data sheet.

CSL SLIPFORM TEST DATA SHEET
SLIDE VALVE SYSTEM

TEST NUMBER _____ OPERATOR _____
DATE _____

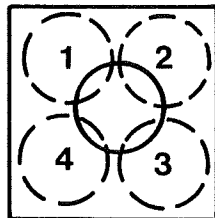
SLIDE VALVE PORT NUMBER*	CONNECTION**
1	
2	
3	
4	

PORT CYCLING SEQUENCE: _____

PUMP TIME AT EACH PORT: _____

BLANK CURB PORT LOCATIONS: _____

OTHER OBSERVATIONS AND/OR COMMENTS:



*VIEWED FACING INLET.

**SPECIFY CURB PORT NUMBER, TO WASTE OR NOT USED.

Figure 5-9. CSL Slipform Test Data Sheet
Slide Valve System

5.8.4 Slide Valve System Equipment Required

The slide valve system equipment required includes:

- One four-port slide valve
- Two hydraulic hoses
- One timing device (clock, watch, etc.)
- Three to five concrete lines
- Clipboard and writing instrument.

The spare parts and tools are one 9/16 in. allen head wrench (to adjust limit switches).

CSL SLIPFORM PLAN TEST

5.9 Vibration System Operator

The vibration system operator's responsibility during the distribution tests is the setup and operation of the vibrator system. His specific duties are in following subsections.

5.9.1 Before Test

Pretest operations include:

- Sets and records air pressure at the vibrator's regulator
- Informs test director of status of vibrators
- Fills lubricator with oil
- Checks operation of the vibrator system.

5.9.2 During Test

During-test operations include:

- Controls air pressure to vibrator and records any changes in set pressure
- Controls and records on/off time of vibrators according to prescribed test specifications
- Informs test director of any abnormalities during test, recording time of and a description of the abnormality
- Ensures lubricator remains filled with oil.

CSL SLIPFORM PLAN TEST

5.9.3 After Test

Post-test operations include:

- Shuts off air pressure to vibrators
- Cleans vibrators, manifold and lines.

Figure 5-10 illustrates the vibration system test data sheet.

CSL SLIPFORM TEST DATA SHEET
VIBRATION SYSTEM

PAGE 1 OF 1

TEST NUMBER _____ OPERATOR _____
DATA _____

TIME OF DAY	PRESSURE (lb/in. ²)	TIME	
		ON	OFF

OTHER OBSERVATIONS AND/OR COMMENTS:

Figure 5-10. CSL Slipform Test Data Sheet
Vibration System

CSL SLIPFORM TEST PLAN

5.9.4 Vibration System Equipment Required

The vibration system equipment required includes:

- One pneumatic vibrator
- One air pressure regulator/lubricator
- One timer
- One solenoid valve
- Various connecting hoses and quick disconnects
- Cupboard and writing.

The list of spare parts and tools includes:

- 5/32 in. allen head wrench
- Lubricating oil.

5.10 Instrumentation System Operator

The instrumentation system operator's responsibility during the slipform tests is the setup and operation of the pressure and displacement transducer instrumentation. His specific duties are in following subsections.

5.10.1 Before Test

Pretest operations include:

- Sets up pressure and displacement transducers
- Calibrates data acquisition system
- Ensures that the pressure transducers are in the proper location of the particular test
- Records pressure transducer locations on data sheet
- Ensures proper handling of the instrumentation
- Ensures proper protection of instrumentation wiring
- Connects instrumentation to a "dedicated" 110 Vac outlet
- Checks for noise on line, ground loops or other interference of the instrumentation signals
- Warms up all instrumentation
- Informs test director of status of instrumentation prior to test.

5.10.2 During Test

During-test operations include:

- Measures and records ambient and form temperature every hour
- Monitors displacement transducers, calculates and records the average concrete pumping rate (yd^3/hr) over a 5-min period at 15-min intervals
- Maintains all instrumentation in working order as best as possible
- Annotates data where necessary
- Records any deviation of test parameters in his control from the prescribed test conditions.

5.10.3 After Test

Post-test operations include:

- Shuts off all instrumentation power
- Ensures wiring is safely out of the way from the clean-up crew.

Figure 5-11 illustrates the instrumentation system test data sheets.

CSL SLIPFORM TEST DATA SHEET
INSTRUMENTATION SYSTEM

PAGE 1 OF 2

TEST NUMBER _____ OPERATOR _____
DATE _____

TIME OF MEASUREMENT	ADVANCE TIME (min)	CURB ADVANCE (in.)	AVERAGE CONCRETE PUMPING RATE* (yd ³ /hr)

$$*R = \frac{KH}{T}$$

WHERE: R = AVERAGE CONCRETE PUMPING RATE IN yd³/hr
 K = CONSTANT OF
 H = CURB ADVANCE IN INCHES
 T = ADVANCE TIME IN MINUTES

Figure 5-11. CSL Slipform Test Data Sheet
Instrumentation System

CSL SLIPFORM TEST PLAN

CSL SLIPFORM TEST DATA SHEET
INSTRUMENTATION SYSTEM
PAGE 2 OF 2

TEST NUMBER _____ OPERATOR _____
DATE _____

PRESSURE TRANSDUCER NUMBER	LOCATION
1	
2	
3	
4	
5	

OTHER OBSERVATIONS AND/OR COMMENTS:

Figure 5-11. CSL Slipform Test Data Sheet
Instrumentation System (Continued)

CSL SLIPFORM TEST PLAN

5.10.4 Instrumentation System Equipment Required

The list of instrumentation system equipment required includes:

- One chart record (eight-channel)
- One dc amplifier (eight-channel)
- One roll of recording paper
- Six pressure transducers (one 0 to 500 lb/in.², five 0 to 50 lb/in.²)
- Two displacement transducers (0 to 10 ft)
- One calculator
- One timing device (clock, watch, etc.)
- Various cables and connectors
- Clipboard and wiring instrument
- Multi-outlet 110 Vac extension cord.

The list of instrumentation system spare parts and tools includes:

- Soldering iron
- Solder
- Flux

- Solderless terminals
- Wire
- Wire crimper/stripper
- Regular screwdriver
- Instrumentation screwdriver
- Manuals to various instruments
- One roll of recording paper
- Snap ring pliers (for displacement transducers).

APPENDIX D

SUMMARY OF TEST RESULTS
CONCRETE SLIPFORM TESTS

C. S. L.
LABORATORY SLIPFORM TESTS
SPRING 1981
LAB REPORT SUMMARY

August, 1981

INTRODUCTION

CSL laboratory slipform testing has been successfully completed this spring. Many conclusions and design considerations can be drawn from the test results. The most significant result was the proof of concept, inverted slipforming on a laboratory scale. The data from testing also shows that form taper can dramatically reduce drag forces, while form coatings apparently have only marginal effects. The laboratory testing has also given insight into start, stop, and steady state operating procedures, data acquisition, and total systems integration and control. Laboratory testing has also shown the ability of the CSL to operate in a jump form mode, a necessary operation for spanning large slough zones in shafts.

CSL TEST PROCEDURES AND METHODS

The methods and procedures used were those discussed in the CSL slipform test plan. A listing of the experimental parameters and test data monitoring requirements can be found in the Appendix.

GENERAL TEST DESCRIPTION
AND
HIGHLIGHTS

TEST #1

- No taper in slipform, no coating
- 60" form effective length
- 25-40 psi form pressure
- 87" slab length
- 752 lb/yd³ Type III cement concrete
- 2.0 ft/hr slipforming rate

The first slipform test was considered as a shake down of the laboratory systems. These systems included the slipform test rig, hydraulic power unit, concrete pump, concrete mixer, slide valve and placement lines, instrumentation, and concrete quality control. Coordination problems that occurred between the various systems and the operators were corrected at this time. Technical problems with the equipment that occurred were also corrected during testing or prior to subsequent tests. Some of these technical problems were as follows:

- The inability of the concrete pump to pump as slow as the required rates (1/4 yd³/hr). To circumvent this, the concrete was pumped sequentially, using a multiport slide valve, with concrete being pumped either to the slipform rig or to a waste concrete form. The use of the slide valve allowed pumping rates as low as 1/4 yd³/hr to the test rig even though the instantaneous pumping rates were 1 yd³/hr. A typical timing sequence used during testing was 1 minute of concrete pumped to the slipform rig for every 3 minutes of concrete pumped to waste. The concrete pumping problems were due to the small scale of the laboratory test rig and will not occur during simulation testing.

- The hydraulic power unit and control system for the slipform rig developed problems during testing. The pressure indicating gages required calibration, and some of the solenoid valves leaked internally. Because of the leakage in the valves, the initial slipform control plan had to be changed. Specifically the slipform had to be actively held in its desired position. After this change was made no further problems occurred with the hydraulic power unit.
- During the first test the slipform shifted its position with respect to the slipform guide rails. Higher torque specifications on the bolts holding the rail-slipform assemble together solved this problem.

Additional problems occurred during testing with the slip-forming process. Two problems stand out as being significant. The first was an internal blowout of concrete. This was caused when the slipform shifted in position, with respect to the guide rail. The "blowout" was then created by concrete flowing into the newly created void. A second problem was the appearance of a "tear" or tension crack in the slipformed slab of concrete. The position of this crack was just above the trailing edge of the slipform. The crack occurred when the concrete placement line was disconnected from the curb for cleaning out. This resulted in a sudden loss of concrete volume behind the curb, and loss of pressure in the rig. In turn, this loss of pressure caused the concrete behind the slipform to fail in by tension. This problem is discussed in more detail in the summary.

In conclusion, despite the problems that occurred during this first test, a competent slab of concrete was slipformed vertically downward during the periods of steady state operation.

TEST #2

- No taper in slipform, no coating
- 60" form effective length
- 10 psi form pressure
- 104" cast slab length
- 752 lb/yd³ Type III cement concrete
- 3.0 ft/hr slipforming rate

This test was very successful for a number of reasons. First, all of the individual systems worked very well together for the first time, and second, the technical aspects of slipforming went very well. This test demonstrated the ability to slipform at a rate of 3 ft/hr, with form pressures of only 10 psi. This test also served as the first half of a comparison between the effects of drag of non-coated form vs coated form in test #3. Once again, as in test #1, a tension crack occurred above the trailing edge of the slipform. This occurred after concrete pumping operations had stopped, and during the disconnection of the concrete placement hose from the curb.

TEST #3

- No form taper, plastic coated form
- 60"-48" form length
- 10 psi form pressure
- 104 total cast slab length
- 752 lb/yd³ Type III cement concrete
- 2.2 ft/hr slipforming rate

Test #3 was very similar to test #2. Some of the minor differences were as follows: Dye was added to the concrete to examine concrete flow patterns in the rig and a pinch valve was added to the concrete placement line under the curb. The major change from test #2 to test #3 was the addition of a plastic coating to the slipform. The purpose of this coating was to reduce form drag. The primary conclusion that can be drawn comparing tests 2 and 3 is that coatings have little effect on form drag. The coatings may prove advantageous in the future as replaceable wear surfaces or for improving the surface finish of the concrete. However, at the present, coatings appear to be of marginal value.

In this test, as in past tests, the concrete slab was torn when the form pressure dropped to zero as the concrete placement line was disconnected. This pressure drop occurred despite an additional knife valve placed in the concrete line, below the curb. When the curb pressure returned to 10 psi however, the crack closed back together. This demonstrates that 10 psi is a sufficient form pressure to slipform at.

A final point to be made is that these tests demonstrated the ability to slipform vertically downward at rates of 3 ft/hr with a 5' form. This represents an exposure time of under 2 hours.

TEST #4

- 1/8" in 1' taper in slipform, plastic coatings
- 48" form effective length
- 10 psi form pressure
- 71" cast slab length
- 752 lb/yd³ Type III cement concrete
- 1.8 ft/hr slipforming rate

Test #4 was the first test of two comparing the effects of form taper on form drag. Test #5 was the second test in the series.

In test #4 there were several minor problems which hampered the operation of the test. These problems did not effect the overall results. The most significant of these were several concrete line blockages which caused the shortening of the test. Again, as in the previous tests, a tension or tear crack occurred in the concrete slab after pumping had stopped and the placement lines were disconnected. As in the previous test, when the curb was repressurized, the crack closed.

During testing, two facts were recorded. One, the slipform effective length was reduced by 10-15" automatically by the taper, and two, the coating gave an excellent finish to the concrete slipformed surface.

TEST #5

- No taper in slipform, no coating
- 48" form effective length*
- 10 psi form pressure
- 93" cast slab length
- 752 lb/yd³ Type III cement concrete
- 1.6 ft/hr slipforming rate

In this test, the principle of jump forming with the CSL was tried successfully. A gap of 3' was bridged by the form at the beginning of the test. It should be noted that the effective form length and slipforming advance rate apply only for the steady state operation. This test also provided the first experience with forming cold joints with the CSL. Physically this joint had no bonding between the two concrete surfaces. What was achieved was an excellent casting between the two concrete surfaces. As with previous tests, a tear crack occurred in the concrete slab above the slipform after concrete pumping had stopped.

The most important information gained in these tests was obtained by comparing the results of test #4 and #5. These tests suggest that form taper can significantly reduce form drag by as much as 40%. It was also shown that form taper automatically reduces the effective form length to the minimum required to form and support the concrete.

CONCLUSIONS FROM THE LABORATORY SLIPFORM TEST PROGRAM
AND RECOMMENDATIONS FOR SIMULATION TESTING

- Effects of Taper

In a comparison of drag stresses and total drag forces acting on the slipform, it was shown, on the laboratory scale, that taper reduced drag stress and total drag by 40%. This was seen in a comparison of results from tests number 4 and 5. Taper also reduces the slipform effective length to the minimum required length needed to form and support the concrete.

- Effects of UHMW Plastic Coatings

Comparing the drag stress and total drag forces acting on a coated and non-coated slipform, the effects of coatings on drag were not significant. This was determined in a direct comparison of tests numbers 2 and 3. The plastic coatings did however, improve the surface finish of the slipformed concrete. This was seen in tests 2 vs 3 and 4 vs 5.

- Tension Cracks

A major point that needs to be addressed is the cause of the tension cracks that appeared near the end of every test. It can be shown that the cracks occurred due to improper operations in part attributable to an inadequate laboratory concrete handling system. These cracks however, do lead to an important equilibrium condition that must be satisfied for proper slipforming.

$$P_c \geq P_b \geq P_a \qquad \text{eq. 1}$$

P_c = The concrete pumping pressure

P_b = The pressure of the curb on the concrete in the form

P_a = The minimum required pressure to maintain a compressive loading in the slab

It can further be shown that, $P_a \approx \rho H + \sigma_D \cdot L \cdot W$, where ρH is the weight of concrete requiring support and, $\sigma_D \cdot L \cdot W$, is the total drag force acting in a downward direction.

The cracking of the slabs in testing occurred when P_c was less than 5 psi, and $\rho H = 5$ psi so that P_a , the minimum required pressure, was 5 psi + the drag stress, or greater than P_c and no longer satisfying eq. 1.

Another conclusion that can be drawn from this equation, is that P_b max is limited by the confined compressive strength of the concrete in the form, or the partially confined compressive strength of the concrete above the form (where only one free surface exists), whichever has the lowest value.

● Other Effects and Conclusions

The initial examination of the data has shown a further need for steady state slipforming tests. Laboratory tests have demonstrated the ability to start and stop smoothly the slipforming process, along with a successful jump form mode of operation. Space constraints however, limited the ability to perform extended steady state operations.

Further study is also warranted into the effects of rate and pressure on form drag, drag stress, and overall concrete quality.

A final point to be drawn from the laboratory testing is the apparent wide range of conditions under which concrete can be slipformed successfully.

As demonstrated in test #5 the CSL jump forming mode appears to be a practical process. Its only requirements are proper sequencing and timing of events to ensure proper concrete support.

APPENDIX
EXPERIMENTAL PARAMETERS

The following fixed and variable parameters were used during the slipform tests.

2.1. Fixed Parameters

Fixed parameters are as follows:

- Slipform rig dimensions
- Diameter of concrete pumplines and inlet port
- Vibration of curb.

2.1.1 Slipform Rig Dimensions

The dimensions of the slipform rig are fixed. The slipform itself is 5 by 4 ft and can be moved through a vertical travel zone of 11 ft. The horizontal distance between the moving slipform and the stationary side of the form is 1 ft.

2.1.2 Diameter of Concrete Pumplines and Inlet Port

The diameter of the concrete pumplines and curb inlet port is fixed at 3 in.

2.1.3 Vibration of Curb

The vibration of the curb will be fixed. One pneumatically operated vibrator will be bolted to the curb of the slipform test rig. The frequency and duration of the vibration will be controlled by an electronic timer, electromechanical solenoid and a pressure regulator. Thirty lb/in.² air will be cycled to the vibrator at a frequency of 8 sec on, and 52 sec off each minute.

2.2 Variable Parameters

Variable parameters are as follows:

- Concrete pumping pressure
- Slipform surface coating
- Slipform taper
- Slipform advance rate
- Concrete mix design.

2.2.1 Concrete Pumping Pressure

Concrete pumping pressure is developed from pipeline friction, pumping rate, and from the static pressure head against which it acts. Concrete pumping pressure can be increased artificially to simulate a pressure head by applying a back pressure force by actually pushing the curb up against the plastic concrete. In the slipform tests a back pressure of up to 20 lb/in.² can be applied to simulate conditions that would be present if the concrete was being pumped into a form through a curb that was supporting up to 20 ft of partially set concrete.

2.2.2 Slipform Surface Coating

During the slipform tests, the surface of the slipform will be varied to determine the effect of coating on form drag. The slipform is 0.5 in. thick steel and for the initial tests will be used bare with only a coat of red primer. Subsequent testing will use a removable 0.25 in. thick coating of ultra-high molecular weight polymer (UHMWP) mechanically attached to the slipform surface.

2.2.3 Slipform Taper

The angle of the slipform to the slipform rig can be varied to determine the effect of tapering the slipform. Two settings will be used during the slipforming tests. Initial tests will be performed with no taper; defined as 0 to 0.125 in. in 10 ft. Subsequent testing will be performed at conditions of no taper and at full taper; defined as 0.375 in. in 10 ft.

2.2.4 Slipform Advance Rate

During the slipform tests the average advance rate of the slipform and curb will be varied to determine their effect on the slipforming process. Initial slipform tests will be performed at an average advance rate of 2 ft/hr when using Portland Type III cement concrete.

2.2.5 Concrete Mix Design

The concrete mix designs will be formulated to be both workable for pumpability and rapid-stiffening for self-support. The mix designs will be finalized prior to slipform tests.

The Portland Type III cement concrete mix design is tentatively defined as follows:

- Cement - 752 lb/yd³
- Sand - 1225 lb/yd³
- 3/8-in. stone - 600 lb/yd³
- 3/4-in. stone - 900 lb/yd³
- 0.42 water to cement ratio
- 1.5 percent* Mighty 150 superplasticizer
- 1.5 f-oz/CWT* Darex air entraining agent
- 3 percent* Allied Chemical calcium chloride.

*By weight of cement.

**By weight of cement and fly ash.

If problems are encountered, some minor changes may be made to the mix designs to improve workability. Since improvements to mix workability may jeopardize early strength behavior it will be important to only change the mix designs in the event all other attempts to achieve slipforming fail.

3. TEST MONITORING

The following data will be monitored during the slipform tests by visual observation or by instrumentation recording techniques:

- Concrete pump hydraulic fluid pressure
- Concrete pumping line pressure
- Concrete pressure in form
- Slipform and curb cylinder hydraulic pressures
- Slipform and curb positions
- Concrete mix temperature
- Mix water temperature
- Concrete pump hydraulic fluid temperature
- Admixture system flow rates
- Concrete pump rotation rate
- Concrete quality control.

3.1 Concrete Pump Hydraulic Fluid Pressure

The concrete pump hydraulic fluid pressure will be monitored by visual observation of the pressure gauge on the concrete pump. The pressure will be recorded onto a data sheet by the concrete pump operator at least once every hour.

3.2 Concrete Pumping Line Pressure

The concrete pumping line pressure will be monitored with one in-line Red Valve pressure sensor located near the curb. A pressure transducer (0 to 500 lb/in.²) will be mounted on the Red Valve pressure sensor. Its output, through appropriate signal conditioning, will be continuously recorded on a Brush chart recorder.

3.3 Concrete Pressure in Form

The concrete pressure in the form will be monitored with five pressure transducers. One pressure transducer will be located on the curb and four will be mounted in five possible locations along a vertical line of the stationary side of the form. The transducers will be capable of recording pressures up to 50 lb/in.². The output of the pressure transducers, through appropriate signal conditioning, will be continuously recorded on a Brush chart recorder.

3.4 Slipform and Curb Cylinder Hydraulic Pressure

The hydraulic pressure in the slipform and curb cylinders will be monitored by visual observation of pressure gauges on the hydraulic power unit (HPU). The pressures will be recorded on a data sheet by the HPU operator at least once every hour and when pressure changes occur.

3.5 Slipform and Curb Positions

Two displacement transducers will be used to monitor the positions of the slipform and curb. One displacement transducer will monitor the position of the slipform relative to a datum position. The other displacement transducer will monitor the relative position of the slipform to the curb. The output of the displacement transducers, through appropriate signal conditioning, will be continuously recorded on a Brush chart recorder.

3.6 Concrete Mix Temperature

The concrete mix temperature will be monitored with a temperature probe. The visual observation of its output will be recorded on a data sheet by the admixture system operator. The temperature will be recorded every 5 min.

3.7 Mix Water Temperature

The mix water temperature will be monitored with a thermometer plumbed into the admixture system. The visual observation of its output will be recorded on a data sheet by the admixture system operator. The temperature will be recorded every 5 min.

3.8 Concrete Pump Hydraulic Fluid Temperature

The hydraulic fluid temperature of the concrete pump will be monitored by visual observation of the thermometer on the concrete pump. The temperature will be recorded on a data sheet by the concrete pump operator at least once every hour.

3.9 Admixture System Flow Rates

The flow rates of the fluids in the admixture system will be monitored by visual observation of the flowmeters on the admixture system. The flow rates will be recorded on a data sheet by the admixture system operator every 5 min.

3.10 Concrete Pump Rotation Rate

The concrete pump rotation rate will be monitored by visual observation of the rotation of the rollers of the concrete pump. The rotation rate will be recorded on a data sheet by the concrete pump operator when time permits.

3.11 Concrete Quality Control

The concrete quality control will be monitored by measuring the initial slump, slump history, air content, unit weight and compressive strength of samples of the batched concrete.

APPENDIX E

SUMMARY OF TEST RESULTS
CONCRETE SEAL TESTS

CONCRETE SEAL TEST RESULTS

The seal development test consisted of a series of 37 tests in which both test rig and seal were constantly modified to obtain the desired seal behavior under conditions simulating normal sealing and slough zone sealing operations.

The major problems encountered in the test program included:

- a. Eliminating leakage around the sides of the prototype seal (this is a test apparatus problem and would not exist in the full round sealing operation of the CSL)
- b. Developing sufficient stiffness in the seal to support high concrete pressure while bridging a 3 in. gap
- c. Developing sufficient compliance in the seal to conform to three dimensional transitions into and out of slough zones.

The 37 tests are summarized in Table E-1 and the problems addressed by each test is indicated. The final four tests (tests 34 through 37) subjected the seal of the final prototype design, to two and three dimensional transition zone conditions and finally to a fully simulated three dimensional slough zone. The operation and results of these four tests are the culmination of the seal development program and are presented in detail in this section.

Side Seal Design

The new side seal design consists of a piece of plywood cut to the shape of the seal profile under pressure and lined with 1/2 in. of closed cell foam. The foam side of the seal is placed against the side of the test rig and is compressed by driving a wedge between the seal on the opposite side of the rig. An angle support attached to the side seal is bolted to the metal block supporting the main seal to maintain compression. The seal layers are then glued in place on top of the side seal. When the slough zone surface (Lexan cover) is attached a tight seal at this surface is established as shown in Figure E-1.

TABLE E-1. - Seal Test Summaries

Test No	Seal Configuration (Changes Only)	Simulated Rock Surface	Test Pressure or Pressure @ Failure	Major Problem or Area for Improvement
1	3 layer seal, ¼" x 4 Strips, Soft Rubber, 1" Wall Contact	Standard - Dry Slough Zone (Figure E-1)	10 psi Static	Seal Blow Out
2	2 Layers 4" Wall Contact	Standard - Dry	10 psi Static	Seal Clamp Failure Seepage Between Strips
3	3 Layers ¼ x 4" by 80A Polyurethane, and 2" Wall Contact	Standard - Dry	12 psi Static	Side Seal Failure
4	Improved Side Seals	Standard - Dry	30 psi Static	Test Rig Bladder Failure
5	Improved Rig	Standard - Dry	30 psi Static	Clamp Failure
6	New Seal Clamp and 45° Clamping Angle	Standard - Dry	32 psi Static	Seal Layers Separated Rig Bladder Failed
7	Seal Tips Tapered @ 45° Rig Improved	Standard - Dry	40 psi Static	Seal Layers Separated Side Seals Very Poor
8	Seal Length Staggered 1>2>3, Rig Improved	Standard - Dry	55 psi Static	Excellent Sealing Bladder Burst
9	Tip Taper Modified	Standard - Wet (Lexan wetted with concrete paste)	10 psi Static	Seal Blow Out
10	New Seal 3 Layers ¼" 85A Polyurethane No Tip Taper 1" Wall Contact	Standard - Wet	40 psi Static	Bladder Burst Side Leaks Some Seal Sliding
11	Side Seals Improved	Standard - Wet	40 psi Static	Seal Blow Out Imminent

TABLE E-1. - Seal Test Summaries (Cont.)

Test No	Seal Configuration (Changes Only)	Simulated Rock Surface	Test Pressure or Pressure @ Failure	Major Problem or Area for Improvement
12	Layers Glued Together To Within 3" of Tips	Standard - Dry	65 psi Static	Excellent Sealing
13	No Change	Standard - Wet	40 psi Static	Rig Failure Side Seal Blow Out
14	New Seal 85A Base 60A Tip, Tip Tapered 3 Layers, 3" Wall Contact	Standard - Wet	30 psi Static	Seal Blow Out
15	Seal Glued Together Within 3" of Tip	Standard - Wet	40 psi Static	Satisfactory Sealing Bladder Burst
16	Improved Rig	Standard - Wet	20 psi Static	Seal Progressively Failed With Time
17	No Change	Standard - Wet With Sandpaper Finish	20 psi Static	Seal Progressively Failed With Time
18	New Seal 3 Layers 85A Polyurethane and 1/16 By 2" Wide Internal Steel Plate Glued Into Seal, Modified Clamp Plate	Standard - Wet	20 psi Static	Seal Blow Out Imminent
19	1/8" By 2½" Steel Plate Used	Standard - Wet	12 psi Static	Seal Blow Out
20	Steel Plate Repositioned	Standard - Wet	12 psi Static	Seal Blow Out (Plate Glue Failure)

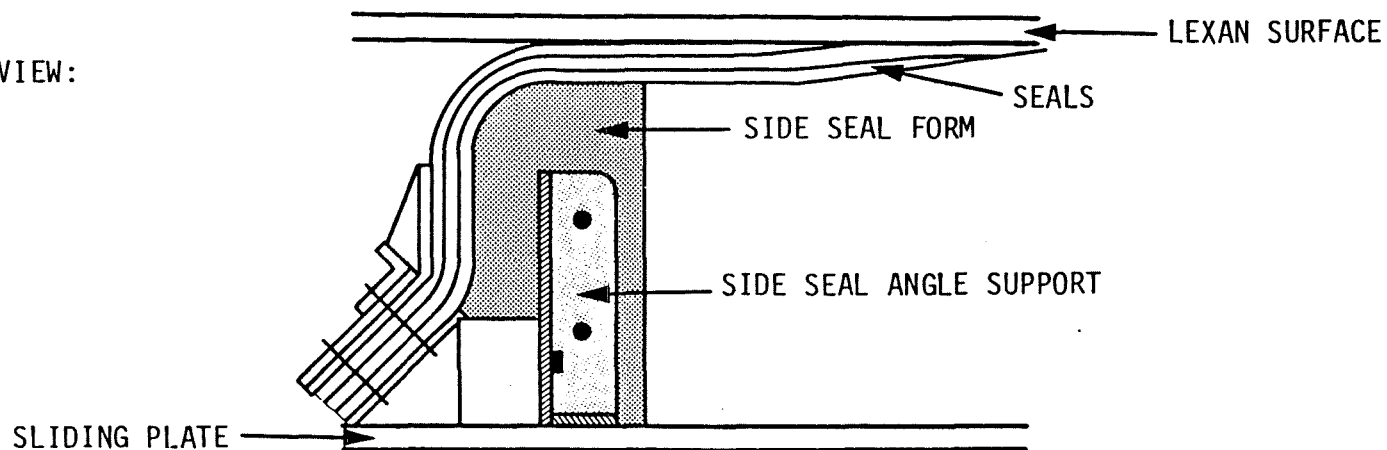
TABLE E-1. - Seal Test Summaries (Cont.)

Test No	Seal Configuration (Changes Only)	Simulated Rock Surface	Test Pressure or Pressure @ Failure	Major Problem or Area for Improvement
21	Steel Plate Reglued to 4th Seal Layer, 3 Layer Seal Glued Together Within 2" of Tips	Standard - Wet	20 psi Static	Satisfactory Sealing
22	No Change	Standard - Wet	55 psi Static	Satisfactory Sealing Rig Bladder Failed Seal Clamp Failing
23	No Change	Standard - Wet	20 psi 40 psi	Good Sealing Good Sealing
24	Seal Cut Into 3" Wide Strips 2" Deep	Roughened Surface (Figure E-2) Wet	25 psi Static	Seal Failed to Slide
25	New Clamp and Steel Support, 3 Layer Seal Composit Construction Like Seal No. 14	Standard - Wet	40 psi Static	Good Sealing, Hinge Weak
26	Seals Were Slit Into 3" Panels, Steel Support Hinge Was Improved	Standard - Wet	40 psi	Good Sealing, Hinge Weak
27	Longer Seal Made New Hinge Material Improved Test Rig	Standard - Wet	60 psi	Excellent Sealing, Side Leaks in Rig
28	Longer Seal, 9½" Long Beyond Clamp	Roughened Surface Wet	20 psi Static	Excellent Sealing, Rig Leaked When Moving Seal
29	Rig Improved	Roughened Surface Wet	30 psi Static	Bad Sealing (Poor Test Set Up)

TABLE E-1. - Seal Test Summaries (Cont.)

Test No	Seal Configuration (Changes Only)	Simulated Rock Surface	Test Pressure or Pressure @ Failure	Major Problem or Area for Improvement
30	No Change	Roughened Surface Wet	30 psi Static 30 psi Active (Moving Seal)	Satisfactory Seal Clamp Failed
31	Tightened Clamp	Roughened Surface Wet	35 psi Active	Clamp Failed
32	New Seal, Clamp, Steel Support, and Hinge	Roughened Surface	30 psi Static 30 psi Active	Good Seal Good Seal Failure of Side Seals
33	Improved Rig	Standard - Wet	30 psi Static	Rig Leaked
34	New Seal, 5 Layers New Side Seals	Roughened Wet	60 psi Static	Fair Seal Performance
35	No Change	3-Dimensional Transition Zone (Fig. E-4)	30 psi Active	Good Sealing
36	No Change	3-Dimensional Transition Zone With Roughened Surface (Fig. E-4)	60 psi Active	Very Good Sealing
37	No Change	3-Dimensional Slough Zone (Fig. E-6)	50 psi Active	Very Good Sealing

SIDE VIEW:



BACK VIEW:

SIDE OF TEST RIG

CLOSED CELL FOAM

PLYWOOD SEAL FORM

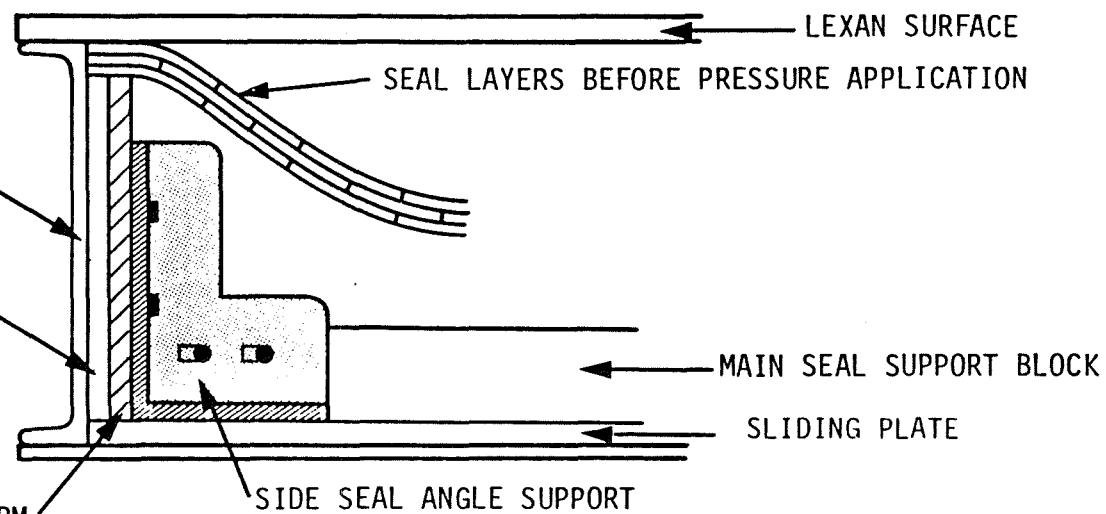


Figure E-1. Side Sealing Arrangement

Test 34 - Two Dimensional Transition Zone

A test section used to simulate the roughness and depth of a normal sealing zone was fabricated to attach to the Lexan surface. A cross section of the test rig with this section in place is illustrated below in Figure E-2.

This cross section extends the full 18 in. width of the test rig. With this section installed, and by sliding the moveable base plate back, the seal performance in transition from a normal sealing zone to a slough zone can be examined.

A similar but shorter side seal will be fabricated for testing in the normal sealing zone.

Main Seal Characteristics

The arrangement of the seal layers was modified in anticipation of testing the seal for lateral leakage when part of the seal is in a normal sealing zone and part is in a slough zone.

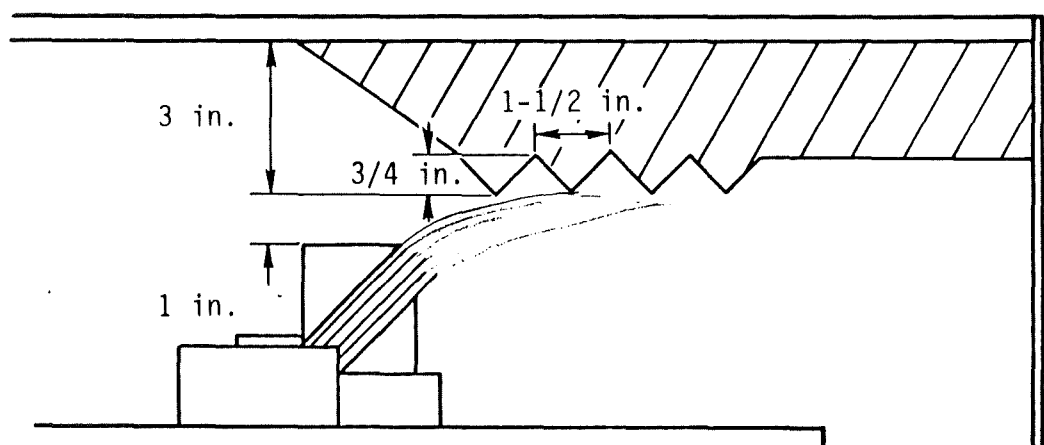


Figure E-2. Roughened Surface With Transition

In the previous tests all three seal layers were identical, with the main part of the seal of high durometer and the ends of the seal a lower durometer. This combination was selected to provide stiffness through the unsupported sealing area to prevent seal blowout and so that the seal ends could easily be tapered to eliminate gaps between the seal layers as they contacted the surface.

With the addition of the hinged seal support wedges, the requirement for seal stiffness is reduced. Also wider more pliable seal layers would be better suited to conform to lateral variations in sealing surface contours. Based on these considerations, the modified seal (from concrete side to the back side) consists of a single layer of low durometer pentathane in thin strips; followed by three layers of low durometer pentathane in wide strips; followed by one additional layer of high durometer pentathane.

Test Results

The seals were floated on top of the thinned joint compound before pressure was applied. Air pressure to the piston pump was 20 psi. At this pressure some paste leaked out through the clamp bolt holes. When the air pressure was increased to 30 psi, a slow leak developed between the two middle seal strips of the last seal layer. These two strips were not well aligned. There was no leakage around the sides of the seal at this point.

After the seal was moved forward slightly by applying pressure to the hydraulic cylinder, some side leakage was observed but it was not serious. The air pressure to the piston pump was increased to 50 psi. At this higher pressure, leakage over the seal and between the two middle strips increased although it appeared that good contact was established between the seal and the surface. The seal was well supported by the hinged wedges at this pressure and the hydraulic cylinder had to be pressurized to prevent the seal from moving forward. Some leakage also occurred from under the clamp and a small amount leaked under the sliding plate.

An attempt to pump undiluted joint compound at 50 psi air pressure was successful. The pressure was finally increased to 60 psi and although leakage increased, the seal profile held.

The resulting seal arrangement is shown in Figure E-3.

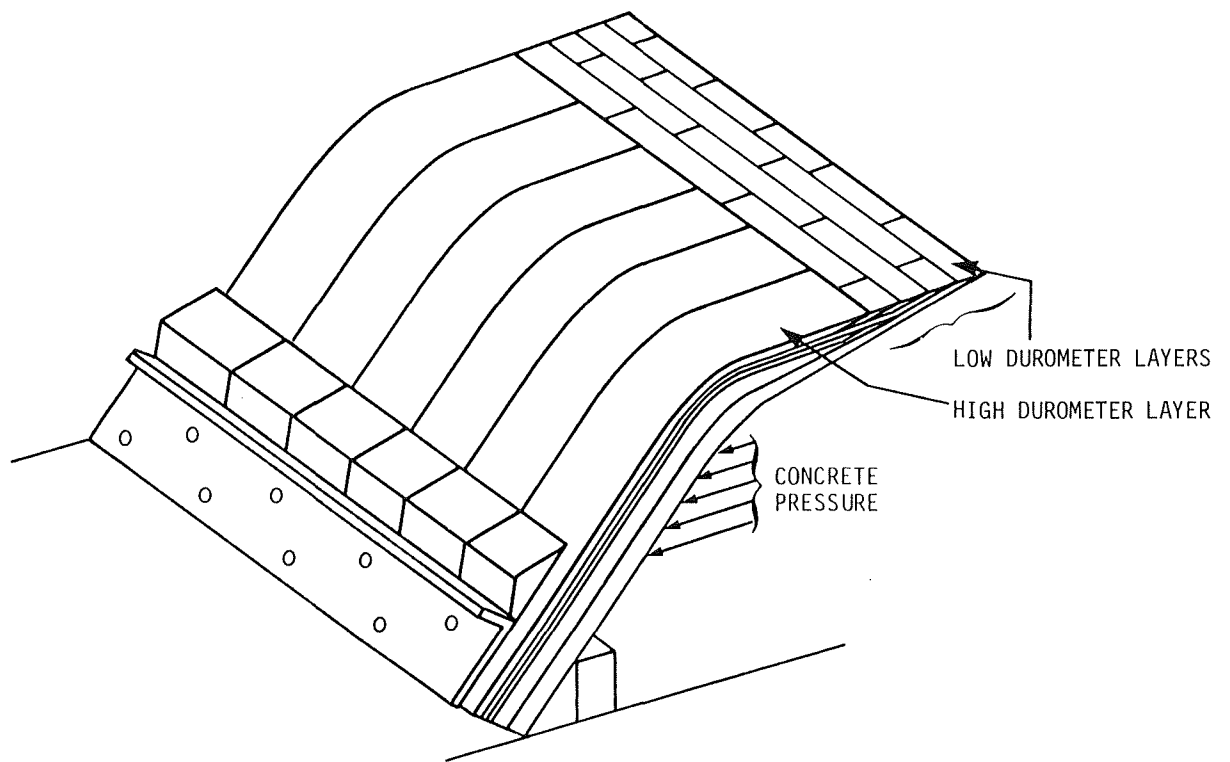


Figure E-3. - Final seal arrangement.

The edge of each seal layer was tapered as in the previous tests.

Recommendations:

Thinned joint compound is probably an extremely severe test medium for the seal compared to the concrete mixture to be used in actual application. Since the seal withstood the pressure well and the paths for paste leakage were small, the test was judged to be successful. The joint compound should not be thinned for further tests.

Test 35 - Three Dimensional Transition Zone

A surface contour to simulate lateral and axial transitions from slough zone to normal sealing zone was built. Initially, the seal would be completely in a slough zone sealing area. As the seal is moved forward under concrete pressure, the depth of the sealing zone will gradually decrease to a normal zone (3 in. change in depth). At the same time the width of the surface contour will increase to a maximum of 6 in. as illustrated below in Figure E-4.

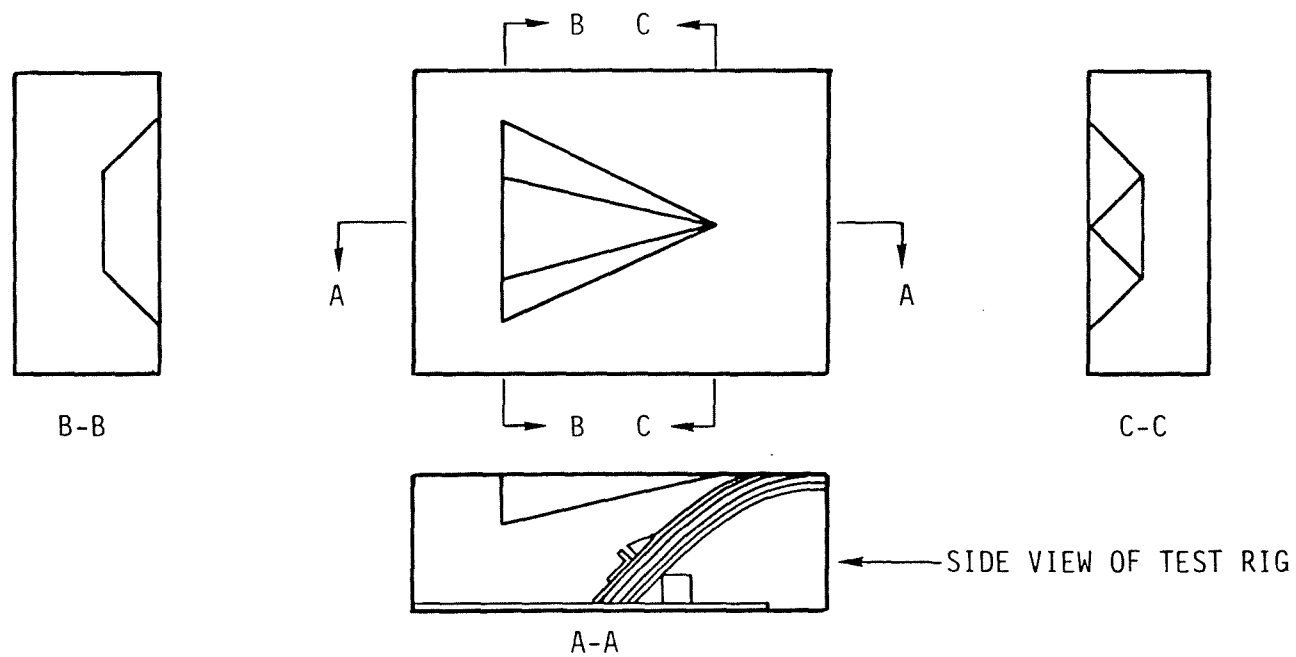


Figure E-4. Three Dimensional Transition Zone

The slope of the lateral surfaces is 45 deg while the slope in the direction of seal motion is 14 deg. This contour is mounted to the Lexan surface for testing.

A pressure transducer was mounted to the back wall of the test rig to determine the correlation between the pressure applied to the piston pump and equilibrium pressure resulting in the simulated concrete. Undiluted joint compound was used in this test of the seal performance in transition from slough zone to normal sealing depth. The surface contour described above was employed.

Results:

The relative orientation of the seal strips was better for this test resulting in reduced leakage at the main seal section. In general, the seal conformed well to the increasing obstruction of the surface contour. Some paste leaked through the top corners of the side seals and under the clamp. This leakage increased somewhat as the pressure was increased. At the end of the seal traverse, the seal was moved past the end of the surface contour, with concrete pressure at approximately 30 psi, so that an abrupt 3 in. deep surface transition was traversed. No additional leakage occurring. The following air pressure and pressure transducer readings and calculated concrete pressure were observed under equilibrium conditions (that is, essentially constant pumping and leakage rates for a stationary seal position) on Table E-2.

Test 36 - Configuration

The surface contour used in the preceding seal test was moved forward slightly on the Lexan surface. In this position, the center of the test seal section was initially in contact with the contour and not entirely in the slough sealing zone. The back end of the contour was extended about 4 in. with a 6 in. wide section simulating the normal sealing zone including the ridges resulting from the bore cutting. The resultant side view profile is shown on Figure E-5.

Undiluted joint compound was used to simulate the concrete as in the previous test. All potential leakage paths were sealed with silicon sealant.

Table E-2. - Test 35 Results

Air pressure reading (psi)	Pressure transducer reading (V)	Calculated concrete pressure (psi) *
0	0.127	0
40	0.148	8
45	0.159	12
50	0.162	13
60	0.190	25
70	0.196	27
75	0.197	27
0	0.125	0

*Offset voltage = 0.128V

Concrete pressure = 1000 (meter reading - 0.128)/2.528

Recommendation:

Duplicate the test. Seal path for leakage under clamp.

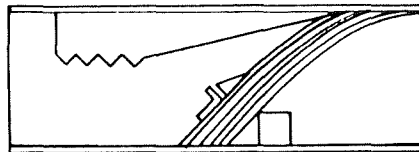


Figure E-5. Three Dimensional Transition Zone
With Roughened Surface

Results:

The air pressure was brought up to 40 psi with the seal being held in position by pressure to the hydraulic cylinder. Minor leakage occurred from the top corners of the side seals. When the pumping rate appeared to reach equilibrium the mean pressure transducer reading was recorded and then the air pressure was increased to 50 psi. A pressure transducer reading was taken at 50 psi and again the air pressure was increased and a transducer reading was recorded. The results are shown on Table E-3.

The air pressure to the piston pump was maintained at 60 psi as the seal was moved back incrementally to test the seal performance at different surface profiles. Only minor leakage was observed and it was decided that leakage with actual concrete would be insignificant under the same circumstances.

Table E-3. - Test 36 Results

Air pressure reading (psi)	Pressure transducer reading (V)	Calculated concrete pressure (psi) *
0	5.9	0
40	34	24
50	42	32
60	48	37

*Offset voltage = 0V

Concrete pressure = $0.9 \times \text{reading} - 6$

Recommendations:

The surface contour used in this trial was a good test of the seal's ability to conform to sealing zone transitions both laterally and axially. The final test of the seal should, however, use a contour in which the surface irregularity is a slough zone in a normal sealing surface. That is, the inverse of the previous surface should be used.

Test 37 - Three Dimensional Slough Zone

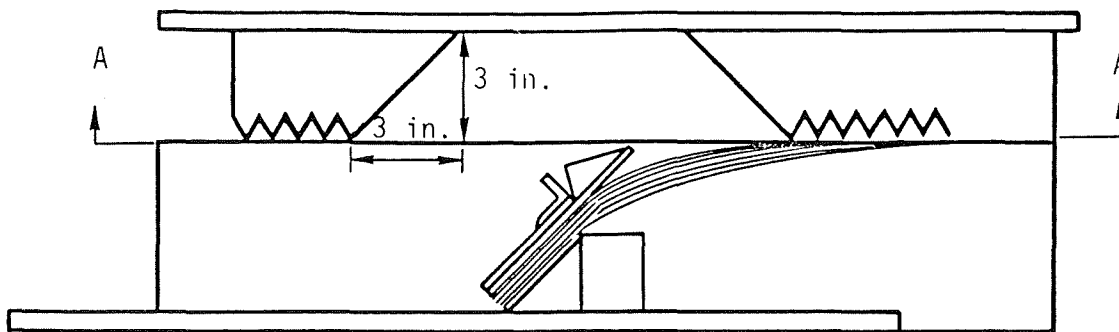
Configuration:

A new sealing surface contour to simulate a slough irregularity in a normal sealing surface was designed and built. This surface is illustrated in Figure E-6.

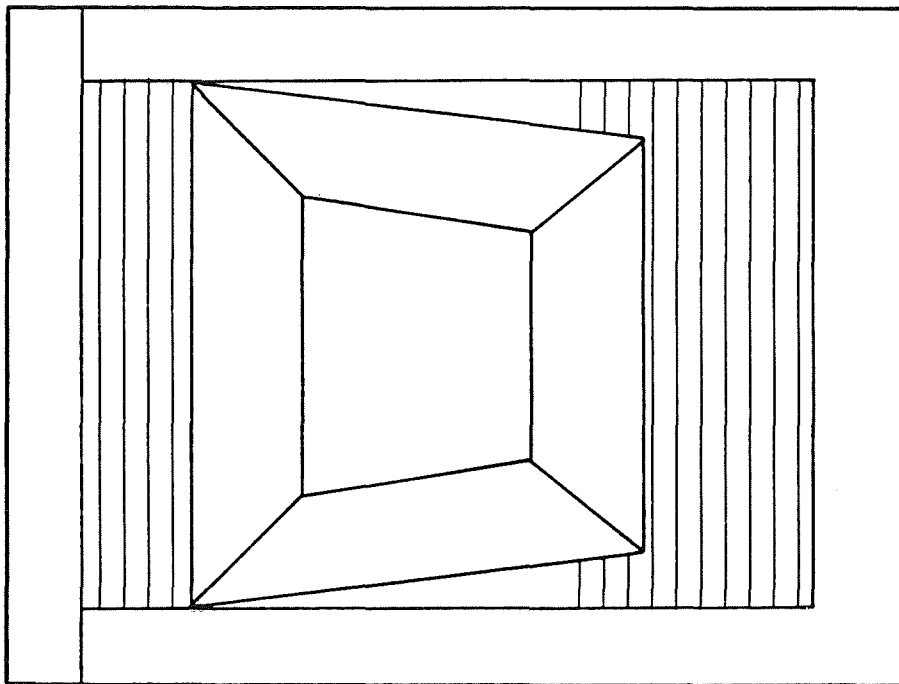
Side seals similar to those used in the previous test were fabricated to be used in the shorter, normal sealing zone. A 2 in. wide space on each side of the surface contour was maintained at a constant depth to facilitate side sealing. The established procedure of laying the seal on top of a volume of undiluted joint compound and then positioning the Lexan plate with surface contour to initiate seal contact with the surface was followed.

Results:

The seal was secured in the initial position, as illustrated in Figure E-6, and the pressure to the piston pump was brought up to 30 psi. Some leakage occurred at this pressure from the top corners of the side seals but the main sealing section did not leak. When the pumping rate appeared to be steady, the pressure transducer reading was recorded. The air pressure was then increased to 40 psi, then 50 psi with the seal remaining in the same position and concrete pressure measurements were recorded at both air pressures. Leakage did not appear to increase appreciably with pressure. The seal section was then moved through the sealing transition incrementally, allowing the system to establish equilibrium after each change in position. As the seal was moved into a position such that there was a lateral transition in the sealing contour, paste began to leak through the transition area. It appeared that the support wedges prevented adequate conformity to the surface due to the



SIDE VIEW WITH TEST RIG CENTERLINE



VIEW A-A

Figure E-6. Three Dimensional Slough Zone

relatively small gap between each wedge. The leakage was not excessive, however, and a maximum pressure transducer reading of 50 (corresponding to a concrete pressure of 35 psi) was recorded during the transition.

Final Recommendations

- a. Replace the 1/4 in. low durometer seal layer with strips of spring steel - The wide strips (6 in.) of 1/8 in. low durometer pentathane provided most of the sealing action of the last seal arrangement. The high durometer layer, on the other hand, provided the required stiffness to prevent seal blowout in the unsupported slough zone area. What remains is to supply a seal component to establish initial contact with the surface and prevent the seal edges from curling over into the concrete thus destroying the seal effectiveness. Thin spring steel strips could perform this function and could be imbedded in the layer of pentathane nearest the concrete for an integrated design.
- b. Determine the optimum method of attaching the support wedges to the flexible hinge - The support wedges for the test seal section were glued to the woven hinge with epoxy and also fastened in two places by means of screws. While this appeared to be adequate during the testing, the means of attachment should probably be reviewed and optimized.
- c. Reduce the width of the wedges - During the last test it appeared that the seals were somewhat prevented from conforming to the lateral surface variations due to interference between the wedges. By narrowing the wedges slightly this problem could be eliminated without jeopardizing their support function.

APPENDIX F

SUMMARY OF RESULTS
CONCRETE MIX DESIGN TESTS

TABLE F-1. - Chemical and physical characteristics of candidate cements

Chemical or physical characteristic	Cement (abbreviation)	Martin Marietta Type II (A)	Martin Marietta Type III (B)	Chemcomp shrinkage compensating Type K (C)	Ironclad Type III (D)	Fondu aluminous (E)	Lumnite aluminous (F)
S_1O_2 , %		21.2	20.0	-	19.3	4.5	8.6
Al_2O_3 , %		4.6	5.3	-	6.3	39.0	-
Fe_2O_3 , %		3.7	2.4	-	1.9	12.0	8.5
CaO, %		-	-	-	62.9	38.5	35.8
MgO, %		3.6	3.9	5.0	2.5	-	0.7
SO_3 , %		2.6	3.6	-	4.2	-	1.7
Specific gravity		3.15	3.15	3.15	3.15	3.25	3.02
Loss on ignition, %		0.9	1.0	1.0	1.4	-	-
Total alkalies, %		-	-	-	1.1	-	-
Insoluble residues		0.2	0.2	-	0.2	-	-
Tricalcium silicate		50.0	54.0	-	52.3	-	-
Dicalcium silicate		22.0	16.0	-	-	-	-
Tricalcium aluminate		6.0	9.0	-	13.5	-	-
Specific surface*, cm^2/g		3665 (B)	4998 (B)		5400 (B)	1500 (W)	1600 (W)
Initial set, hr:min		2:27	1:40	1:30	1:25	4:00	6:15
Final set, hr:min		4:43	3:20	-	3:15	-	-
Compressive strength, psi:							
1 day		-	3090	-	3800	3500	4700
3 days		2959	4344	-	4979	-	-
7 days		3677	-	2100	5320	-	-
ASTM type		II	III	K	III	-	-
*B = Blaine, W = Wagner							

TABLE F-2. - Results of mix design trials

Batch No.	A-1	A-2	A-3	A-4			B-1	B-2	B-3	B-4	B-5	B-6	B-7
Cement*	A	A	A	A			B	B	B	B	B	B	B
Water-cement ratio	0.43	0.43	0.43	0.39			0.46	0.46	0.46	0.48	0.48	0.48	0.50
Cement factor (lb/yd ³)	564	564	564	564			564	564	564	564	564	564	564
Fly ash factor (lb/yd ³)	94	94	94	94			94	94	94	94	94	94	94
Water reducer or plasticizer type*	-	-	-	-			-	-	-	-	-	-	-
Dosage (% wt of cement)	-	-	-	-			-	-	-	-	-	-	-
Accelerator type*	DSA	DSA	DSA	DSA			DSA	DSA	DSA	DSA	DSA	DSA	DSA
Dosage (% wt of cement)	4	4	4	4			4	4	4	4	4	4	6
Initial slump (in.)	6	5-3/4	3	1/4			2-3/4	3	3	4-1/2	4-3/4	7-3/4	5
15 min slump (in.)	3-1/2	3	2-3/4	0			1-1/2	2	2-1/4	3	2-3/4	6-1/4	2-3/4
30 min slump (in.)	2-3/4	2-1/2	2	-			1	1-1/2	1-1/2	1-3/4	-	4-1/2	1-1/4
45 min slump (in.)	3	2	0	-			3/4	1	1	-	1-1/2	3-1/2	0
Air content, %	10.6	7.3	5.3	3.9			2.9	4.6	3.9	6.0	5.0	6.2	5.9
Compressive strength* (psi)	N/D	N/D	N/D	N/D			N/D	N/D	N/D	N/D	N/D	N/D	N/D
2 hr													
2-1/2 hr													
3 hr													
3-1/2 hr													
4 hr													
*See notes for abbreviations.													

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Batch No.	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19	B-20
Cement*	B	B	B	B	B	B	B	B	B	B	B	B	B
Water-cement ratio	0.50	0.50	0.50	0.50	0.50	0.40	0.40	0.40	0.40	0.40	0.50	0.50	0.50
Cement factor (lb/yd ³)	564	564	564	564	564	564	564	564	564	564	564	564	564
Fly ash factor (lb/yd ³)	94	94	94	94	94	94	94	94	94	94	94	94	94
Water reducer or plasticizer type*	-	-	-	-	-	MTY 150	MTY 150	MTY 150	MTY 150	MTY 150	-	-	-
Dosage (% wt of cement)	-	-	-	-	-	1.2	1.5	1.75	2.50	2.5	-	-	-
Accelerator type*	DSA	DSA	-	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA
Dosage (% wt of cement)	6	6	-	5	5	5	5	5	5	5	5	6	7
Initial slump (in.)	5	6-3/4	5-1/4	7	8	1	1	1/2	1/2	3-3/4	8-1/4	8-1/4	-
15 min slump (in.)	3-1/4	3-3/4	3-1/2	6	6-1/4	0	0	0	0	1/2	-	-	-
30 min slump (in.)	1-1/2	1-1/2	-	4-1/4	3	-	-	-	-	0	-	-	-
45 min slump (in.)	0	0	0	4	2-1/2	-	-	-	-	-	-	-	-
Air content, %	5.4	6.9	5.3	8.2	6.2	3.6	5.8	-	-	-	-	-	-
Compressive strength* (psi)	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D			
2 hr											0	0	0
2-1/2 hr											0	0	0
3 hr											0	0	0
3-1/2 hr											0	0	25
4 hr											15	48	-

*See notes for abbreviations.

TABLE F-2. - Results of mix design trials (continued)

Batch No.	B-21	B-22	B-23	B-24	B-25	B-26	B-27	B-28	B-29	B-30	B-31	B-32	B-33
Cement*	B	B	B	B	B	B	B	B	B	B	B	B	B
Water-cement ratio	0.50	0.50	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.40	0.40	0.40	0.40
Cement factor (lb/yd ³)	658	658	658	752	752	752	752	752	752	752	752	752	752
Fly ash factor (lb/yd ³)	0	0	0	0	0	0	0	0	0	0	0	0	0
Water reducer or plasticizer type*	-	-	-	-	-	-	-	-	-	MTY 150	MTY 150	MTY 150	PLAST
Dosage (% wt of cement)	-	-	-	-	-	-	-	-	-	1.2	1.6	1.7	0.2
Accelerator type*	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DCI	DSA	DSA	DSA	DSA
Dosage (% wt of cement)	5	5	6	6	6	6	6	6	6	6	6	6	6
Initial slump (in.)	8	6	7	8	7	7-1/2	3-1/2	5-1/2	8	1/4	4-1/4	1-1/4	0
15 min slump (in.)	-	-	-	6	3	3-1/4	0	2-3/4	-	0	1-1/4	0	-
30 min slump (in.)	-	-	-	3-1/2	2	2	-	1-3/4	7-1/4	-	0	-	-
45 min slump (in.)	-	-	-	2	-	-	-	-	6	-	-	-	-
Air content, %	-	-	9.6	-	6.9	8.8	5.9	6.7	2.9	4.1	6.9	6.1	3.2
Compressive strength* (psi)										N/D		N/D	N/D
2 hr	0	-	-	8	-	-	11	-	7		-		
2-1/2 hr	0	10	-	23	-	14	28	-	-		-		
3 hr	0	-	13	-	42	-	-	89	16		28		
3-1/2 hr	34	-	-	-	-	-	-	-	-		44		
4 hr	-	-	24	-	-	79	142	-	-		-		
*See notes for abbreviations.													

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Batch No.	B-34	B-35	B-36	B-37	B-38	B-39	B-40	B-41	B-42	B-43	B-44	B-45	B-46
Cement*	B	B	B	B	B	B	B	B	B	B	B	B	B
Water-cement ratio	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.35	0.35	0.35	0.35	0.35	0.40
Cement factor (lb/yd ³)	752	752	752	752	752	752	752	752	752	752	752	658	658
Fly ash factor (lb/yd ³)	0	0	0	0	0	0	0	0	0	0	0	0	0
Water reducer or plasticizer type*	PLAST	PLAST	MTY RD2	MTY RD2	MTY RD2	POZZ 122R	POZZ 100XR	MTY 150	MTY RD2	PLAST	POZZ 122R	POZZ 100XR	MTY 150
Dosage (% wt of cement)	0.3	0.4	0.7	0.6	0.6	0.3	0.3	4.5	1.6	2.10	1.2	2.4	1.5
Accelerator type*	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	CaCl ₂
Dosage (% wt of cement)	6	6	6	6	6	6	6	6	6	6	6	6	4
Initial slump (in.)	2	0	7-3/4	0	0	2-3/4	5-1/2	4	5-1/2	3	5-1/2	0	3-1/2
15 min slump (in.)	0	-	7	-	-	0	-	-	3-3/4	-	3-1/4	-	1/2
30 min slump (in.)	-	-	4-3/4	-	-	-	1	0	2-1/4	0	1-3/4	-	0
45 min slump (in.)	-	-	3	-	-	-	-	-	1-3/4	-	-	-	-
Air content, %	5.5	-	7.0	-	-	4.4	5.8	2.9	9.0	-	11.8	-	5.9
Compressive strength* (psi)		N/D		N/D	N/D					N/D	N/D	N/D	
2 hr	28		-			-	7	28	0				8
2-1/2 hr	44		-			18	-	33	7				150
3 hr	-		-			-	-	57	-				315
3-1/2 hr	-		-			-	-	-	-				-
4 hr	-		25			-	-	-	-				-

*See notes for abbreviations.

TABLE F-2. - Results of mix design trials (continued)

Batch No.	B-47	B-48	B-49	B-50	B-51	B-52	B-53	B-54	B-55	B-56	B-57	B-58	
Cement*	B	B	B	B	B	B	B	B	B	B	B	B	
Water-cement ratio	0.40	0.40	0.40	0.43	0.40	0.38	0.37	0.44	0.35	0.44	0.40	0.40	
Cement factor (lb/yd ³)	658	658	658	658	658	658	658	658	658	658	658	658	
Fly ash factor (lb/yd ³)	0	0	0	0	0	0	0	0	0	0	0	0	
Water reducer or plasticizer type*	MTY 150	MTY 150	MTY RD2	POZZ 122R	MTY RD2	MTY 150	MTY 150	POZZ 122R	MTY 150	PLAST	MTY 150	POZZ 122R	
Dosage (% wt of cement)	1.75	1.6	1.5	0.4	0.5	4.5	5.5	1.0	5.5	1.0	1.7	0.4	
Accelerator type*	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	
Dosage (% wt of cement)	4	4	4	4	4	4	4	4	4	4	2	2	
Initial slump (in.)	3-1/2	5-3/4	6	2-3/4	5-3/4	9-1/4	7-1/2	0	7-1/2	0	1-1/2	3	
15 min slump (in.)	-	1	3	1/2	2	6-3/4	3	-	5-1/2	-	0	0	
30 min slump (in.)	0	0	2	0	0	0	0	-	0	-	-	-	
45 min slump (in.)	-	-	0	-	-	-	-	-	-	-	-	-	
Air content, %	5.9	11.7	11.8	6.5	9.0	16.0	16.0	-	16.0	-	7.0	4.9	
Compressive strength* (psi)								N/D		N/D			
2 hr	20	8	0	8	11	0	0		0		-	-	
2-1/2 hr	70	12	0	23	24	0	0		0		-	-	
3 hr	220	45	0	90	-	0	0		0		15	-	
3-1/2 hr	-	-	-	-	-	-	-		-		15	-	
4 hr	-	-	-	-	-	-	-		-		42	5	
*See notes for abbreviations.													

TABLE F-2. - Results of mix design trials (continued)

Batch No.	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13
Cement*	C	C	C	C	C	C	C	C	C	C	C	C	C
Water-cement ratio	0.45	0.45	0.45	0.48	0.48	0.48	0.48	0.45	0.42	0.45	0.45	0.45	0.40
Cement factor (lb/yd ³)	564	564	564	564	564	564	658	658	658	658	658	658	658
Fly ash factor (lb/yd ³)	94	94	94	94	94	94	0	0	0	0	0	0	0
Water reducer or plasticizer type*	-	-	-	-	-	-							MTY RD2
Dosage (% wt of cement)	-	-	-	-	-	-							0.6
Accelerator type*	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA
Dosage (% wt of cement)	4	3	3	3	4	3	6	6	6	6	6	6	6
Initial slump (in.)	6-3/4	3-3/4	9-1/2	2-1/4	6-1/4	6-1/4	9	8-1/2	7-1/2	6-3/4	6	8-1/4	7-3/4
15 min slump (in.)	4-1/4	2	8	0	4	4-1/2	6-3/4	7-1/2	2	2-3/4	2-1/4	3-3/4	4-3/4
30 min slump (in.)	2-1/2	0	7	-	2-1/2	3-1/2	4-1/4	3-1/2	0	2-1/4	0	1-3/4	0
45 min slump (in.)	1-1/4	-	-	-	2	3	1-3/4	3/4	-	-	-	-	-
Air content, %	7.2	3.1	2.7	3.4	5.9	5.4	6.5	5.9	9.8	9.4	8.4	5.9	8.8
Compressive strength* (psi)	N/D	N/D	N/D	N/D	N/D	N/D							
2 hr							6	0	10	15	15	20	0
2-1/2 hr							8	18	30	30	31	35	15
3 hr							42	25	58	50	60	65	45
3-1/2 hr							-	-	-	-	-	-	-

*See notes for abbreviations.

TABLE F-2. - Results of mix design trials (continued)

Batch No.	C-14	C-15	C-16	C-17	C-18	C-19	C-20	C-21	C-22	C-23			
Cement*	C	C	C	C	C	C	C	C	C	C			
Water-cement ratio	0.40	0.40	0.43	0.40	0.48	0.40	0.40	0.38	0.35	0.35			
Cement factor (lb/yd ³)	658	658	658	658	564	658	658	658	658	658			
Fly ash factor (lb/yd ³)	0	0	0	0	94	0	0	0	0	0			
Water reducer or plasticizer type*	MTY RD2	MTY RD2	POZZ 122R	POZZ 122R	-	MTY 150/ RD2	MTY 150/ RD2	MTY 150/ RD2	MTY 150/ RD2	MTY 150/ RD2			
-													
Dosage (% wt of cement)	0.6	0.7	0.3	0.45	-	1.2/0.3	1.4/0.4	3.5/0.8	3.5/1.0	4.5/0.2			
Accelerator type*	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA			
Dosage (% wt of cement)	6	6	6	6	4	6	6	6	6	6			
Initial slump (in.)	-	1-3/4	5-1/4	6-1/2	9	6-1/2	7	6-3/4	1-1/2	1-3/4			
15 min slump (in.)	-	0	2-1/4	3-3/4	7	3-1/2	3-3/4	3-1/4	0	0			
30 min slump (in.)	-	-	0	-	5	0	1-1/4	1	-	-			
45 min slump (in.)	-	-	-	-	4	-	-	-	-	-			
Air content, %	-	6.5	6.8	12.0	6.8	12.0	13.4	16.0	12.8	6.6			
Compressive strength* (psi)	N/D												
2 hr		16	5	5	0	8	0	0	34	44			
2-1/2 hr		37	5	5	0	8	0	0	50	62			
3 hr		78	8	5	-	15	8	0	60	100			
3-1/2 hr		-	-	-	-	-	-	-	-	-			
*See notes for abbreviations.													

TABLE F-2. - Results of mix design trials (continued)

Batch No.	D-14	D-15	D-16	D-17	D-18	D-19	D-20	D-21	D-22	D-23	D-24	D-25	D-26
Cement*	D	D	D	D	D	D	D	D	D	D	D	D	D
Water-cement ratio	0.40	0.44	0.40	0.40	0.40	0.40	0.42	0.42	0.40	0.40	0.40	0.40	0.39
Cement factor (lb/yd ³)	752	752	752	752	752	752	752	752	752	752	752	752	752
Fly ash factor (lb/yd ³)	0	0	0	0	0	0	0	0	0	0	0	0	0
Water reducer or plasticizer type*	LOMAR D	MTY 150	LOMAR D	MTY 150	MTY 150	MTY 150	MTY 150	MTY 150	MTY 150/ POZZ 300N	MTY 150/ WRDA HYCOL	MTY 150/ POZZ 300N	MTY 150/ POZZ 300N	MTY 150/ POZZ 122HE
Dosage (% wt of cement)	3.0	2.0	3.5	2.0	2.0	2.0	1.5	1.5	1.0/0.2	1.0/0.2	1.2/0.2	1.2/0.3	1.5/4.0
Accelerator type*	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	-
Dosage (% wt of cement)	3	3	3	3	3	3	3	3	3	3	3	3	-
Initial slump (in.)	3-1/2	2-3/4	9	6	9-1/2	9	4	6-1/2	3	3	2-1/2	2	9-1/2
15 min slump (in.)	1-1/2	1-1/4	3-1/2	3-1/2	6-1/4	-	-	-	-	-	-	0	-
30 min slump (in.)	-	-	3	3-1/4	4-1/4	2-1/2	2-1/2	2-3/4	0	0	2	-	5
45 min slump (in.)	-	-	2-1/2	3	3	2-1/2	2-1/4	2-3/4	-	-	-	-	5
Air content, %	6.0	3.0	7.0	4.9	5.8	6.5	3.5	4.9	3.5	2.7	3.5	3.2	3.5
Compressive strength* (psi)													
2 hr	-	-	-	-	-	-	-	-	-	-	-	-	-
2-1/2 hr	20	-	-	-	-	-	-	-	-	-	-	-	-
3 hr	50	45	10	15	13	13	9	7	-	-	-	10	0
3-1/2 hr	90	100	30	25	25	25	25	12	10	25	0	15	0
4 hr	-	220	60	70	70	45	45	30	20	55	-	30	0
*See notes for abbreviations.													

TABLE F-2. - Results of mix design trials (continued)

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Batch No.	D-27	D-28	D-29	D-30	D-31	D-32	D-33	D-34	D-35			E-1	E-2
Cement*	D	D	D	D	D	D	D	D	D			E	E
Water-cement ratio	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.40			0.35	0.35
Cement factor (lb/yd ³)	752	752	752	752	752	752	752	752	752			752	752
Fly ash factor (lb/yd ³)	0	0	0	0	0	0	0	0	0			0	0
Water reducer or plasticizer type*	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE	MTY 150/ POZZ 122HE			LOMAR D/ PLAST	LOMAR D/ PLAST
Dosage (% wt of cement)	1.3/4.0	1.3/4.0	1.4/4.0	1.5/4.0	1.8/4.0	2.0/4.0	2.2/4.0	1.5/4.0	1.5/5.0			2.0/0.1	2.5/0.1
Accelerator type*	-	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂	CaCl ₂			LiCO ₃	LiCO ₃
Dosage ¹ (% wt of cement)	-	1.0	2.5	1.5	1.8	1.8	1.8	1.8	1.8			9g/100#	5g/100#
Initial slump (in.)	6	4	1-1/2	4	6-1/2	5-1/2	8	3	5			0	8
15 min slump (in.)	-	-	-	2-1/2	1-1/2	2	-	-	2			-	0
30 min slump (in.)	4	-	-	1-1/4	-	-	0	0	0			-	-
45 min slump (in.)	3	-	-	-	-	-	-	-	-			-	-
Air content, %	3.0	7.3	6.2	10.0	9.4	9.4	10.0	5.6	6.0			-	10.4
Compressive strength* (psi)												N/D	
2 hr	-	-	-	-	-	-	-	-	-				25
2-1/2 hr	-	-	-	0	-	-	-	-	-				93
3 hr	0	5	50	-	-	0	-	5	30				-
3-1/2 hr	0	5	100	-	10	-	10	30	70				-
4 hr	0	-	225	-	25	-	15	80	170				-

*See notes for abbreviations. ¹Mixes E-1, E-2 - Accelerator dosage in grams per 100 lbs cement

TABLE F-2. - Results of mix design trials (continued)

Batch No.	E-3	E-4			F-1	F-2	F-3	*Notes - Abbreviations
Cement*	E	E			F	F	F	
Water-cement ratio	0.35	0.35			0.35	0.35	0.35	Cement: A - Martin Marietta Type II B - Martin Marietta Type III C - Chemcomp Expansive Type K D - Iron Clad Type III E - Fondu Aluminous F - Lumnite Aluminous
Cement factor (lb/yd ³)	752	752			752	752	752	
Fly ash factor (lb/yd ³)	0	0			0	0	0	Water-reducer or plasticizer: MTY 150 - Mighty 150 MTY RD2 - Mighty RD2 PLAST - Sika Plastiment POZZ 122R - Pozzoloth 122R POZZ 100XR - Pozzoloth 100XR POZZ 300N - Pozzoloth 300N POZZ 122HE - Pozzoloth 122HE LOMAR D - LOMAR D WRDA HYCOL - WRDA Hycol
Water reducer or plasticizer type*	LOMAR D/ PLAST	LOMAR D/ PLAST			LOMAR D/ PLAST	LOMAR D/ PLAST	LOMAR D/ PLAST	
Dosage (% wt of cement)	2.3/0.1	2.5/0.1			2.5/0.1	1.8/0.1	2.5/0.1	Accelerator: DSA - Darex set accelerator CaCl ₂ - Calcium chloride DCI - Darex corrosion inhibitor LL880 - Master builders LL880 LiCO ₃ - Lithium carbonate
Accelerator type*	LiCO ₃	LiCO ₃			LiCO ₃	LiCO ₃	LiCO ₃	
Dosage ¹ (% wt of cement)	2g/100#	1g/100#			1g/100#	1g/100#	1g/100#	Compressive strength: N/D - Not done, no specimens cast
Initial slump (in.)	5-1/4	7			1	9-1/2	2-3/4	
15 min slump (in.)	0	2			0	0	0	Sand/Aggregate Ratio: 55 Percent
30 min slump (in.)	-	0			-	-	-	
45 min slump (in.)	-	-			-	-	-	
Air content, %	10.4	7.4			-	5.5	6.0	
Compressive strength* (psi)					N/D			
2 hr	0	0				30	0	
2-1/2 hr	0	0				180	0	
3 hr	0	0				612	0	
3-1/2 hr	-	-				-	-	
4 hr	-	-				-	-	

*See notes for abbreviations. ¹Mixes E-3, E-4 and F-1 to F-3 - Accelerator dosage in grams per 100 lbs cement



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO:

WESSC

4 May 1982

SUBJECT: Tests in Support of Continuous Shaft Liner (CSL) Concept for
Mine Shafts

Mr. Robert Evans
US Department of Energy
Pittsburgh Mining Technology Center
PO Box 10940
Pittsburgh, Pennsylvania 15236

Dear Mr. Evans:

Tests have been conducted at the Waterways Experiment Station as part of contract No. DE-AI01-79ET 14338 in conjunction with Foster-Miller Associates, Inc. (FMA). The tests addressed several questions posed by FMA in connection with field trials on the continuous shaft liner (CSL) system. Correspondence with FMA and observation of the first field trial at Framingham, Massachusetts, on 12-13 November 1981 indicated that the following areas needed work.

- a. Consideration of the type, amount, cost, and setting characteristics of potential cements.
- b. Maintenance of good workability and pumpability for approximately 30 min.
- c. A lower cement factor, if possible, in order to reduce cost, thermal volume changes, and shrinkage.
- d. Higher air content and increased sulfate resistance compared to the basic FMA mixture.
- e. Consideration of combinations and modifications of cements in order to achieve a strength of 50 to 100 psi in 2 to 4 hr time and rapid strength gain during the first 72 hr after casting.

One Type III cement, designated RC-884; one Type V, RC-778; one Class F fly ash, AD-590; and two shipments of a special cement known as Very High Early (VHE) cement, RC-811 and RC-885, were secured for the test program. Fly ash was chosen for its potential capacity to increase sulfate resistance of concrete. The materials were tested according to the appropriate ASTM method for compliance with specifications. The results, given in Incl 1-5, indicate that the conventional cements and the fly ash met the required specifications. No appropriate specification was available for the VHE cement.

WESSC

Mr. Robert Evans

4 May 1982

Preliminary tests were conducted on various combinations of the cementitious materials in order to eliminate those which had little potential for use in the concrete mixtures. Since the fly ash mixture and the combination VHE-Type V mixtures (Table 1) resulted in very rapid setting times and relatively low 1-day strengths, they were discarded. The VHE used in this test series, RC-811, had been previously secured for another project. Use of this cement allowed the work to be expedited with no adverse effects to the program.

In order to provide information on the questions raised by the field trials (para 2), six concrete mixtures were proportioned and tested for compressive strength at various ages. Mixture proportions are given in Incl 6-11. All mixtures were proportioned to be pumpable and to have a slump of $6 \pm 1/2$ in. and an air content of $5 \pm 1/2$ percent. Mixture No. 5 was estimated to have an initial slump in the mixer of approximately 6 in. However due to the extremely fast setting of this mixture, some slump was lost before the slump test could be conducted.

Time of setting tests were conducted on all mixtures according to ASTM C 403. Results are given in Figure 1. Tests were also made on all mixtures for slump loss by conducting the slump test on a portion of each mixture at designated time intervals until the slump reached 0 in. The concrete was slightly agitated prior to the performance of each slump test. Results are given in Figures 2-7.

With respect to the areas of concern (para 1), it is convenient to compare each of the mixtures with the basic mixture (No. 1, Table 2). This mixture approximates the mixture used by FMA in the field trials except that mixture No. 1 contained 0.3 percent less Mighty 150 admixture which resulted in approximately 1 in. less slump. It is believed that the use of less admixture would help alleviate a problem FMA encountered in securing 5 percent entrained air in the fresh concrete. Six-inch slump concrete should be sufficiently workable for use in the slip form under normal operating conditions and should reduce any tendency for segregation of the aggregate. Mixture No. 1 has excellent early age strength and sufficient air content. The high cement factor would increase the relative cost, although not prohibitively, and may increase the thermal cracking if the heat cannot be effectively dissipated. Consequently, mixture No. 6 which contains 600 lb cement per cu yd, should be considered. Mixture No. 6 appears to meet the setting, strength, and workability criteria, although very early age strength may not be sufficient under depressed temperatures. The sulfate resistance of mixtures No. 1 and 6 would be satisfactory for most environments due to the use of Type III cement with the moderate sulfate resistance (8 percent maximum C₃A) requirement.

Mixture No. 2 with the Type V cement did not attain any measurable strength during the first 4 hr and thus cannot be considered further. It is likely that Type V cement would be needed in very few areas where shafts are contemplated. Mixture No. 3 also did not provide sufficient early age strength. Mixture No. 4 could be considered as a possibility, however, it did not provide early age strength comparable to No. 1 or 6. Mixtures No. 3 and 4 also tended to lose slump rather quickly (Figures 4 and 5). Since VHE cement costs approximately

WESSC

Mr. Robert Evans

4 May 1982

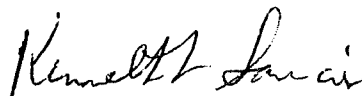
twice as much as conventional portland cement, the cost per yard of concrete would increase accordingly. There is the question of availability of special cements which should also be considered. Mixture No. 5, which contained only VHE cement, lost slump (Figure 6) and set so fast that a time of set specimen could not be secured. Consideration could be given to this mixture only where the concrete is to be handled and placed extremely fast and where equipment malfunction is highly unlikely. The sulfate resistance of VHE at present is unknown, although it is understood that FMA is investigating this problem.

Communications with FMA revealed that difficulty was encountered in securing the desired 5 percent air content in the fresh concrete during the field trial. The manufacturer of the Mighty 150 admixture has recognized this problem and developed recommendations for corrective action. In the concrete made for the tests reported herein the admixture was added after the air-entraining agent and most of the water had been charged into the mixer. Results were satisfactory. FMA could contact the manufacturer and/or conduct limited laboratory trials to address the problem.

Two additional ideas advanced at the start of the laboratory study do not appear feasible at this time. One concept consists of having a cement manufacturer grind portland cement two or three times finer than Type III cement for our exclusive use. This cement would provide ultrahigh early strength combined with the advantages of portland cement. However, the Portland Cement Association did not recommend this option due to (1) the cost, (2) the reluctance of cement manufacturers to participate, and (3) the problem of supply as needed to the field job. Another special cement, Reg-Set cement, would provide excellent early strength, but it too is very expensive and is not presently being manufactured in this country.

Based on the results of the laboratory work conducted in this study, either mixture No. 1 or No. 6 would appear to meet the requirements deemed necessary for a downward slipformed liner depending on the temperature, and hence the setting requirements, encountered at the particular site. Mixture No. 5 could be used with great care where extremely fast setting is needed. If the liner is to be installed in an area where the concrete is likely to experience freezing and thawing conditions while saturated, the mixture selected should be tested for freezing and thawing resistance according to ASTM C 494 prior to field use.

Sincerely,



KENNETH L. SAUCIER
Chief, Concrete and Grout Group
Structures Laboratory

11 Incl
As stated

Copy w/incl furnished:
FMA

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PREVIOUS EDITIONS OBSOLETE

TO: Mr. Ken Saucier Conc & Rock Prop Br Engr Mechanics Div CL	REPORT OF TESTS OF PORTLAND CEMENT RC-778	FROM: CORPS OF ENGINEERS U. S. ARMY Cem & Pozz Test Br Engr Sciences Div CL
TEST REPORT NO: WES-82-77	BIN NO.	CWT REPRESENTED: 1 Sample
SPECIFICATION: ASTM C 150-81, Type V		DATE SAMPLED: 22 Feb 77
COMPANY: Citadel	LOCATION: Birmingham, AL	BRAND:
THIS CEMENT DOES ☒ MEET SPECIFICATION REQUIREMENTS		

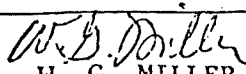
SAMPLE NO.	1						
SiO ₂ , %	23.2						
Al ₂ O ₃ , %	3.4						
Fe ₂ O ₃ , %	5.3						
MgO, %	3.1						
SO ₃ , %	1.6						
LOSS ON IGNITION, %	0.6						
ALKALIES-TOTAL AS Na ₂ O, %	0.42						
Na ₂ O, %	0.06						
K ₂ O, %	0.55						
INSOLUBLE RESIDUE, %	0.13						
CaO, %	62.5						
C ₃ S, %	43.1						
C ₃ A, %							
C ₂ S, %	34.0						
C ₃ A + C ₃ S, %							
C ₄ AF, %							
C ₄ AF + 2 C ₂ F	16.2						
HEAT OF HYDRATION, 7D, CAL/G							
HEAT OF HYDRATION, 28D, CAL/G							
SURFACE AREA, SQ CM/G (A.P.)	3270						
AIR CONTENT, %	8.9						
COMP. STRENGTH, 3D, PSI	1480						
COMP. STRENGTH, 7D, PSI	2200						
COMP. STRENGTH, 28D, PSI	4390						
FALSE SET-PEN. F/I, %							

SAMPLE NO.	1					
AUTOClave EXP., %	0.07					
INITIAL SET, HR/MIN	4:05					
FINAL SET, HR/MIN	6:05					

SAMPLE NO.					
AUTOClave EXP., %					
INITIAL SET, HR/MIN					
FINAL SET, HR/MIN					

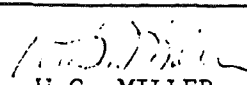
REMARKS:

Sample received from Mr. Ken Saucier, WES-CL stock, Job No. 483-CC04.17CC11.


 W. G. MILLER
 Chemist
 Chief, Cement and Pozzolan Test Branch

LABORATORY: Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P.O. Box 631 Vicksburg, MS 39180			REPORT OF TESTS ON POZZOLAN AD-590			REPORT NO.: WES-319F-79 SHEET 1 OF 1 DATE: 16 July 79 6 August 79		
CLASS (F) N		KIND OF POZZOLAN: Fly Ash						
SOURCE: Williams Bros., Atlanta, GA					BRAND:			
TEST RESULTS OF THIS SAMPLE LOT ☒ COMPLY with ASTM C-618-77, Class F								
FOR USE AT:								
CONTRACT NO.:								
DISTRICT(S):								
SAMPLED BY: Structures Branch					DATE SAMPLED: 2 July 79			
CAR NO.:			BIN NO.:					
FIELD SAMPLE NO.:				LAB SAMPLE NO.:				
DATE RECEIVED: 2 July 79				LAB JOB NO.:				
TESTED BY: Cem & Pozz Testing Branch					CHECKED BY:			
TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW								
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ %		MgO %	SO ₃ %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCCLAVE EXPANSION %	REDUCTION IN EXPANSION % (b)
REQUIREMENTS								
MIN 70.0		MAX 5.0	MAX 4.0	MAX 1.5	MIN 75	MAX 0.03	MAX 0.50	MIN 75
TEST RESULTS								
88.5		1.3	0.7	* 0.65	* 91		0.03	
TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS								
SAMPLE NO.	MOISTURE CONTENT %	LOSS ON IGNITION %	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI 2" cubes	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	—	MAX 5
TEST RESULTS								
1	0.5	2.0	21		1120	97	2.43	
AVERAGE								
(a) APPLICABLE ONLY TO CLASS N								
(b) OPTIONAL REQUIREMENT								
LABORATORY CEMENT USED Alpha, Birmingham, AL, WES-2								
LABORATORY LIME USED Chemstone								
REMARKS: Meets 7 day specification requirements. *28 day test report								
441-S920.19SC42								
W. G. MILLER Chemist Chief, Cement & Pozzolan Test Branch								
NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.								

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Mr. C. R. Sullivan C/Eng Physics Branch Structures Laboratory		REPORT OF TESTS OF PORTLAND CEMENT RC-811		(COM: CORPS OF ENGINEERS S. ARMY Structures Laboratory USAE Waterways Exp. Sta. P. O. Box 631 Vicksburg, MS 39180	
TEST REPORT NO. WES-170-78		BIN NO.		CWT REPRESENTED:	
SPECIFICATION:		DATE SAMPLED:		DATE: 23 May 78	
COMPANY: U.S. GYPSUM		LOCATION: Chicago, IL		BRAND: VHEC	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS					
SAMPLE NO.	RC-811			Preparation of normal consistency	
SiO ₂ , %	14.5			paste: 500 g cement	
Al ₂ O ₃ , %	12.3			170 ml water	
Fe ₂ O ₃ , %	1.0			8 penetration	
M ₂ O, %	1.5				
SO ₃ , %	13.1				
LOSS ON IGNITION, %	3.8				
ALKALIES-TOTAL AS Na ₂ O, %	1.19				
Na ₂ O, %	0.8				
K ₂ O, %	0.6				
INSOLUBLE RESIDUE, %	0.68				
CaO, %	51.7				
C ₃ S, %					
C ₃ A, %					
C ₂ S, %					
C ₃ A + C ₃ S, %					
C ₂ AF, %					
C ₂ AF + 2 C ₃ A, %					
HEAT OF HYDRATION, 7D, CAL/G					
HEAT OF HYDRATION, 28D, CAL/G					
SURFACE AREA, SQ CM/G (A.P.)	7020				
AIR CONTENT, %					
COMP. STRENGTH, 1hr PSI	1650	24 hr PSI :	5050	(see NOTE below)	
COMP. STRENGTH, 3hr PSI	3420				
COMP. STRENGTH, 5hr PSI	3550				
FALSE SET - PEN. F.N.C.					
SAMPLE NO.	1				
AUTOCLAVE EXP., %					
INITIAL SET, HR/MIN	12 min.				
FINAL SET, HR/MIN	21 min.				
SAMPLE NO.					
AUTOCLAVE EXP., %					
INITIAL SET, HR/MIN					
FINAL SET, HR/MIN					
REMARKS: Specific Gravity: 2.88 NOTE: Cubes prepared with a w/c of .485. Mix was extremely harsh, higher w/c would be required to produce a plastic mortar.					
CF: Mr. K. L. Saucier, SL Mr. R. A. Bendinelli, SL Mr. R. H. Denson, SL					
 W.G. MILLER Chemist Chief, Cement & Pozzolan Test Branch					

Concrete & Grout
ATTN: Ken Saucier

REPORT OF TESTS OF
PORTLAND CEMENT

RC-885

Structures Laboratory
Waterways Exp Station
ATTN: n & Pozz Group
P.O. Box 631
Vicksburg, MS 39180

TEST REPORT NO. WES-117-82 BIN NO. CWT REPRESENTED: DATE: 14 April 82

SPECIFICATION: VHE Cement DATE SAMPLED: 25 Mar 82

COMPANY: SME Cement Inc. LOCATION Middlebranch, OH BRAND:

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	1							
SiO ₂ , %	15.6							
Al ₂ O ₃ , %	13.4							
Fe ₂ O ₃ , %	2.4							
MgO, %	1.3							
SO ₃ , %	12.0							
LOSS ON IGNITION, %	2.1							
ALKALIES-TOTAL AS Na ₂ O, %	0.63							
Na ₂ O, %	0.11							
K ₂ O, %	0.79							
INSOLUBLE RESIDUE, %	1.23							
CaO, %	52.0							
C ₃ S, %								
C ₃ A, %								
C ₂ S, %								
C ₃ A + C ₃ S, %								
C ₄ AF, %								
C ₄ AF + 2 C ₃ A, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	6280							
AIR CONTENT, %								
COMP. STRENGTH, D, PSI	1 hr=1,120, 2 hr=1,910, 5 hr=2,160, 24 hr=2,960							
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
FALSE SET-PEN. F/I, %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN	0:05							
FINAL SET, HR/MIN	0:10							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS: Job #441-S952.12SC23

W/C = 0.526

CC: Frank Stewart

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

R. E. REINHOLD

Acting Chief, Cement & Pozzolan Group

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)			
PROJECT NAME: Shaft Lining Concepts (DOE)		SYMBOL: SERIAL NO.:	DATE:
CONCRETE REQUIRED FOR: Test Specimens		MIXTURE NO.: 1	
MATERIALS			
PORTLAND CEMENT, SS-C-192, TYPE: III ADDITIONS: BRAND AND MILL: Marquette Cement Co. Brandon, MS		POZZOLON OR OTHER CEMENT: TYPE: SOURCE:	AIR-ENT. ADMIXTURE: TYPE: NVR AMOUNT: 2.1 oz
FINE AGGREGATE		COARSE AGGREGATE	
TYPE: Natural SOURCE: Arkadelphia Sand & Gravel Co. Arkadelphia, AR		TYPE: Limestone SIZE: 3/4-in. SOURCE: Vulcan Materials Co. Birmingham, AL	
MATERIALS	SAMPLE SERIAL NO.	SIZE RANGE	COARSE AGGR (%)
PORTLAND CEMENT	RC - 884		
CaCl ₂	AD - 693		
Mighty 150	AD - 692		
FINE AGGREGATE	CL-20 S-1	NO.4 - 200	
COARSE AGGREGATE (A)	CL-20 MG-1	NO.4 - 3/4-in.	
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
MIXTURE DATA		SPECIMEN DATA	
MATERIALS	MIX. BY WEIGHT	S. S. D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)
PORTLAND CEMENT, III	1.00	752.0	3.826
CaCl ₂		15.0	
Mighty 150		11.3	
FINE AGGREGATE		1268.9	7.821
COARSE AGGREGATE (A)		1570.0	9.182
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
WATER		289.5	4.821*
AIR			1.350
TOTAL			27.000
W/C (WT): 0.40		S/A, % VOLUME: 46.0	
SLUMP (IN.) ⁴ : 6		THEO. UNIT WT (LB/CU FT):	
BLEEDING (%) ² :		ACTUAL UNIT WT (LB/CU FT):	
AIR CONTENT (%) ³ : 5.2		THEO. CEMENT FACT (LB/CU YD):	
AIR CONTENT (%) ⁴ :		ACTUAL CEMENT FACT (LB/CU YD): 752.0	
¹ Calculated on the basis of: CWT ² Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9. ³ In the entire batch as mixed. ⁴ In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve.			
* For "other cement," pozzolan, second size of fine aggregate, as may be required.			
REMARKS: Condition of mix, workability, plasticity, bleeding, etc.			
*Volume of water and Mighty 150, CaCl ₂ = 2.0% of cement Mighty 150 = 1.5% of cement			

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)									
PROJECT NAME: Shaft Lining Concepts (DOE)		SYMBOL: SERIAL NO.:	DATE:						
CONCRETE REQUIRED FOR: Test Specimens		MIXTURE NO.: 2							
MATERIALS									
PORTLAND CEMENT, SS-C-192. TYPE: V ADDITIONS: Citadel Cement Co. BRAND AND MILL: Birmingham, AL		POZZOLON OR OTHER CEMENT: TYPE: SOURCE: AIR-ENT. ADMIXTURE: TYPE: NVR AMOUNT ¹ : 1.7 oz							
FINE AGGREGATE		COARSE AGGREGATE							
TYPE: Natural SOURCE: Arkadelphia Sand & Gravel Co. Arkadelphia, AR		TYPE: Limestone SIZE: 3/4-in. SOURCE: Vulcan Materials Co. Birmingham, AL							
MATERIALS	SAMPLE SERIAL NO.	SIZE RANGE	COARSE AGGR (%)						
PORTLAND CEMENT	RC - 778								
* CaCl ₂	AD - 693								
* Mighty 150	AD - 692								
FINE AGGREGATE	CL-20 S-1	NO. 4 - 200							
COARSE AGGREGATE (A)	CL-20 MG-1	NO. 4-3/4-in.							
COARSE AGGREGATE (B)									
COARSE AGGREGATE (C)									
COARSE AGGREGATE (D)									
MIXTURE DATA		SPECIMEN DATA							
MATERIALS	MIX. BY WEIGHT	S. S. D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)	CYLINDERS			BEAMS		
				SIZE: 6 x 12-in.			SIZE:		
PORTLAND CEMENT, V	1.00	752.0	3.826	NO.	AGE	PSI	NO.	AGE	PSI
* CaCl ₂		15.0		9	6 hr	260			
* Mighty 150		11.3		10	1	1370			
FINE AGGREGATE		1260.0	7.766	11	2	2390			
COARSE AGGREGATE (A)		1558.8	9.117	12	3	2950			
COARSE AGGREGATE (B)				13	7	3890			
COARSE AGGREGATE (C)				14	7	3770			
COARSE AGGREGATE (D)				15	28	5750			
WATER		297.0	4.941*	16	28	5780			
AIR			1.350						
TOTAL			27.000						
W/C (WT): 0.41		S/A, % VOLUME: 46.0							
SLUMP (IN.) ⁴ : 6 3/4		THEO. UNIT WT (LB/CU FT):							
BLEEDING (%) ² :		ACTUAL UNIT WT (LB/CU FT):							
AIR CONTENT (%) ³ : 5.5		THEO. CEMENT FACT (LB/CU YD):							
AIR CONTENT (%) ⁴ :		ACTUAL CEMENT FACT (LB/CU YD): 752.0							
¹ Calculated on the basis of: CWT ² Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9. ³ In the entire batch as mixed. ⁴ In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve.									
* For "other cement," pozzolan, second size of fine aggregate, as may be required.									
REMARKS: Condition of mix, workability, plasticity, bleeding, etc. * Volume of water and Mighty 150 CaCl ₂ = 2.0% of cement Mighty 150 = 1.5% of cement									

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)			
PROJECT NAME: Shaft Lining Concepts (DOE)		SYMBOL: SERIAL NO.:	DATE:
CONCRETE REQUIRED FOR: Test Specimens		MIXTURE NO.: 3	
MATERIALS			
PORTLAND CEMENT, SS-C-192, TYPE: III ADDITIONS: BRAND AND MILL: Marquette Cement Co. Brandon, MS		POZZOLON OR OTHER CEMENT: VHE TYPE: SME Cement Co. SOURCE: Middlebranch, OH	AIR-ENT. ADMIXTURE: TYPE: NVR AMOUNT ¹ : 1.5 oz
FINE AGGREGATE		COARSE AGGREGATE	
TYPE: Natural SOURCE: Arkadelphia Sand & Gravel Co. Arkadelphia, AR		TYPE: Limestone SIZE: 3/4-in. SOURCE: Vulcan Materials Co. Birmingham, AL	
MATERIALS	SAMPLE SERIAL NO.	SIZE RANGE	COARSE AGGR (%)
PORTLAND CEMENT	RC - 884		
• VHE	RC - 885		
FINE AGGREGATE	CL-20 S-1	NO. 4 - 200	
COARSE AGGREGATE (A)	CL-20 MG-1	NO. 4 - 3/4-in.	
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
MIXTURE DATA		SPECIMEN DATA	
MATERIALS	MIX. BY WEIGHT	S. S. D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)
PORTLAND CEMENT, III	1.00	450.0	2.289
• 25% by wt. VHE		150.0	0.804
FINE AGGREGATE		1367.2	8.427
COARSE AGGREGATE (A)		1561.0	9.130
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
WATER		312.0	5.000
AIR			1.350
TOTAL			27.000
W/C (WT): 0.52		S/A, % VOLUME: 48.0	
SLUMP (IN.) ² : 6 1/2		THEO. UNIT WT (LB/CU FT):	
BLEEDING (%) ² :		ACTUAL UNIT WT (LB/CU FT):	
AIR CONTENT (%) ³ : 4.6		THEO. CEMENT FACT (LB/CU YD):	
AIR CONTENT (%) ⁴ :		ACTUAL CEMENT FACT (LB/CU YD): 600.0	
¹ Calculated on the basis of: CWT ² Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9. ³ In the entire batch as mixed. ⁴ In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve.			
* For "other cement," pozzolan, second size of fine aggregate, as may be required.			
REMARKS: Condition of mix, workability, plasticity, bleeding, etc.			

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)			
PROJECT NAME: Shaft Lining Concepts (DOE)		SYMBOL: SERIAL NO.:	
CONCRETE REQUIRED FOR: Test Specimens		DATE: MIXTURE NO.: 4	
MATERIALS			
PORTLAND CEMENT, SS-C-192, TYPE: III ADDITIONS: BRAND AND MILL: Marquette Cement Co. Brandon, MS		POZZOLON OR OTHER CEMENT: TYPE: VHE SOURCE: SME Cement Co. Middlebranch, OH	
		AIR-ENT. ADMIXTURE: TYPE: NVR AMOUNT ¹ : 1.5 oz	
FINE AGGREGATE		COARSE AGGREGATE	
TYPE: Natural SOURCE: Arkadelphia Sand & Gravel Co. Arkadelphia, AR		TYPE: Limestone SIZE: 3/4-in. SOURCE: Vulcan Materials Co. Birmingham, AL	
MATERIALS	SAMPLE SERIAL NO.	SIZE RANGE	COARSE AGGR (%)
PORTLAND CEMENT	RC - 884		
VHE	RC - 885		
FINE AGGREGATE	CL-20 S-1	NO. 4 - 200	
COARSE AGGREGATE (A)	CL-20 MG-1	NO. 4 - 3/4-in.	
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
MIXTURE DATA		SPECIMEN DATA	
MATERIALS	MIX. BY WEIGHT	S. S. D. WEIGHTS ONE CU. YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)
PORTLAND CEMENT, III	1.00	300.0	1.526
50% by wt VHE		300.0	1.608
FINE AGGREGATE		1356.7	8.362
COARSE AGGREGATE (A)		1548.7	9.058
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
WATER		318.0	5.096
AIR			1.350
TOTAL			27.000
W/C (WT): 0.53		S/A, % VOLUME: 48.0	
SLUMP (IN.) ⁴ : 6 1/4		THEO. UNIT WT (LB/CU FT):	
BLEEDING (%) ² :		ACTUAL UNIT WT (LB/CU FT):	
AIR CONTENT (%) ³ : 5.4		THEO. CEMENT FACT (LB/CU YD):	
AIR CONTENT (%) ⁴ :		ACTUAL CEMENT FACT (LB/CU YD): 600.0	
¹ Calculated on the basis of: CWT ² Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9. ³ In the entire batch as mixed. ⁴ In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve.			
* For "other cement," pozzolan, second size of fine aggregate, as may be required.			
REMARKS: Condition of mix, workability, plasticity, bleeding, etc.			

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)			
PROJECT NAME: Shaft Lining Concepts (DOE)		SYMBOL:	DATE:
CONCRETE REQUIRED FOR: Test Specimens		SERIAL NO.:	MIXTURE NO.: 5
MATERIALS			
PORTLAND CEMENT, 55-C-192, TYPE: ADDITIONS: BRAND AND MILL:		POZZOLON OR OTHER CEMENT: TYPE: VHE SOURCE: SME Cement Co. Middlebranch, OH	
		AIR-ENT. ADMIXTURE: TYPE: NVR AMOUNT ¹ : 1.5 oz	
FINE AGGREGATE		COARSE AGGREGATE	
TYPE: Natural SOURCE: Arkadelphia Sand & Gravel Co. Arkadelphia, AR		TYPE: Limestone SIZE: 3/4-in. SOURCE: Vulcan Materials Co. Birmingham, AL	
MATERIALS	SAMPLE SERIAL NO.	SIZE RANGE	COARSE AGGR (%)
PORTLAND CEMENT VHE	RC - 885		
FINE AGGREGATE	CL-20 S-1	NO. 4 - 200	
COARSE AGGREGATE (A)	CL-20 MG-1	NO. 4 - 3/4-in.	
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
MIXTURE DATA		SPECIMEN DATA	
MATERIALS	MIX. BY WEIGHT	S. S. D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)
PORTLAND CEMENT VHE	1.00	600.0	3.216
FINE AGGREGATE		1342.7	8.276
COARSE AGGREGATE (A)		1533.0	8.966
COARSE AGGREGATE (B)			
COARSE AGGREGATE (C)			
COARSE AGGREGATE (D)			
WATER		324.0	5.192
AIR			1.350
TOTAL			27.000
W/C (WT): 0.54		S/A, % VOLUME: 48.0	
SLUMP (IN.) ² : 4 1/4		THEO. UNIT WT (LB/CU FT):	
BLEEDING (%) ³ :		ACTUAL UNIT WT (LB/CU FT):	
AIR CONTENT (%) ³ : 5.0		THEO. CEMENT FACT (LB/CU YD):	
AIR CONTENT (%) ⁴ :		ACTUAL CEMENT FACT (LB/CU YD): 600.0	
¹ Calculated on the basis of: CWT ² Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9. ³ In the entire batch as mixed. ⁴ In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve.			
* For "other cement," pozzolan, second size of fine aggregate, as may be required.			
REMARKS: Condition of mix, workability, plasticity, bleeding, etc.			

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C 3)									
PROJECT NAME: Shaft Lining Concepts (DOE)		SYMBOL: SERIAL NO.:	DATE:						
CONCRETE REQUIRED FOR: Test Specimens		MIXTURE NO.: 6							
MATERIALS									
PORTLAND CEMENT, SS-C-192, TYPE: III ADDITIONS: BRAND AND MILL: Marquette Cement Co. Brandon, MS		POZZOLON OR OTHER CEMENT: TYPE: SOURCE:	AIR-ENT. ADMIXTURE: TYPE: NVR AMOUNT: 2.0 oz						
FINE AGGREGATE		COARSE AGGREGATE							
TYPE: Natural SOURCE: Arkadelphia Sand & Gravel Co. Arkadelphia, AR		TYPE: Limestone SIZE: SOURCE: Vulcan Materials Co. Birmingham, AL							
MATERIALS	SAMPLE SERIAL NO.	SIZE RANGE	COARSE AGGR (%) BULK SP GR (SSD) ABSORP %						
PORTLAND CEMENT	RC - 884								
CaCl ₂	AD - 693								
Mighty 150	AD - 692								
FINE AGGREGATE	CL-20 S-1	NO. 4 - 200	2.60 1.4						
COARSE AGGREGATE (A)	CL-20 MG-1	NO. 4 - 3/4-in.	2.74 0.4						
COARSE AGGREGATE (B)									
COARSE AGGREGATE (C)									
COARSE AGGREGATE (D)									
MIXTURE DATA		SPECIMEN DATA							
MATERIALS	MIX. BY WEIGHT	S. S. D. WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)	CYLINDERS			BEAMS		
				SIZE: 6 x 12-in.	SIZE:				
PORTLAND CEMENT, III	1.00	600.0	3.053	NO.	AGE	PSI	NO.	AGE	PSI
CaCl ₂		12.0		41	4 hr	220			
Mighty 150		9.0		42	6 hr	730			
FINE AGGREGATE		1415.4	8.724	43	1	2960			
COARSE AGGREGATE (A)		1615.8	9.450	44	2	3700			
COARSE AGGREGATE (B)				45	3	4190			
COARSE AGGREGATE (C)				46	7	4810			
COARSE AGGREGATE (D)				47	28	5910			
WATER		267.0	4.423*	48	28	5850			
AIR			1.350						
TOTAL			27.000						
W/C (WT): 0.46		S/A, % VOLUME: 48.0							
SLUMP (IN.) ⁴ : 6 1/2		THEO. UNIT WT (LB/CU FT):							
BLEEDING (%) ² :		ACTUAL UNIT WT (LB/CU FT):							
AIR CONTENT (%) ³ : 5.0		THEO. CEMENT FACT (LB/CU YD):							
AIR CONTENT (%) ⁴ :		ACTUAL CEMENT FACT (LB/CU YD): 600.0							
¹ Calculated on the basis of: CWT ² Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C 9. ³ In the entire batch as mixed. ⁴ In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve.									
* For "other cement," pozzolan, second size of fine aggregate, as may be required.									
REMARKS: Condition of mix, workability, plasticity, bleeding, etc.									
* Volume of water and Mighty 150. CaCl ₂ = 2.0% of cement Mighty 150 + 1.5% of cement									

Table 1

Results of Tests of Cements

	<u>Type III</u>	<u>25% VHE 75% V</u>	<u>50% VHE 50% V</u>	<u>50% VHE 50% Fly Ash</u>	<u>50% VHE 50% III</u>	<u>25% VHE 75% III</u>
1 day, psi	2070	1330	1300	1130	3050	2490
3 day, psi	3550	3260	2780	1740	4640	4340
Initial Set Gillmore, min	200	35	20	20	25	45
Final Set Gillmore, min	295	190	45	70	40	155

Note: ASTM requirements for Type III cement: 1 day - 1800 psi, 3 day - 3500 psi.

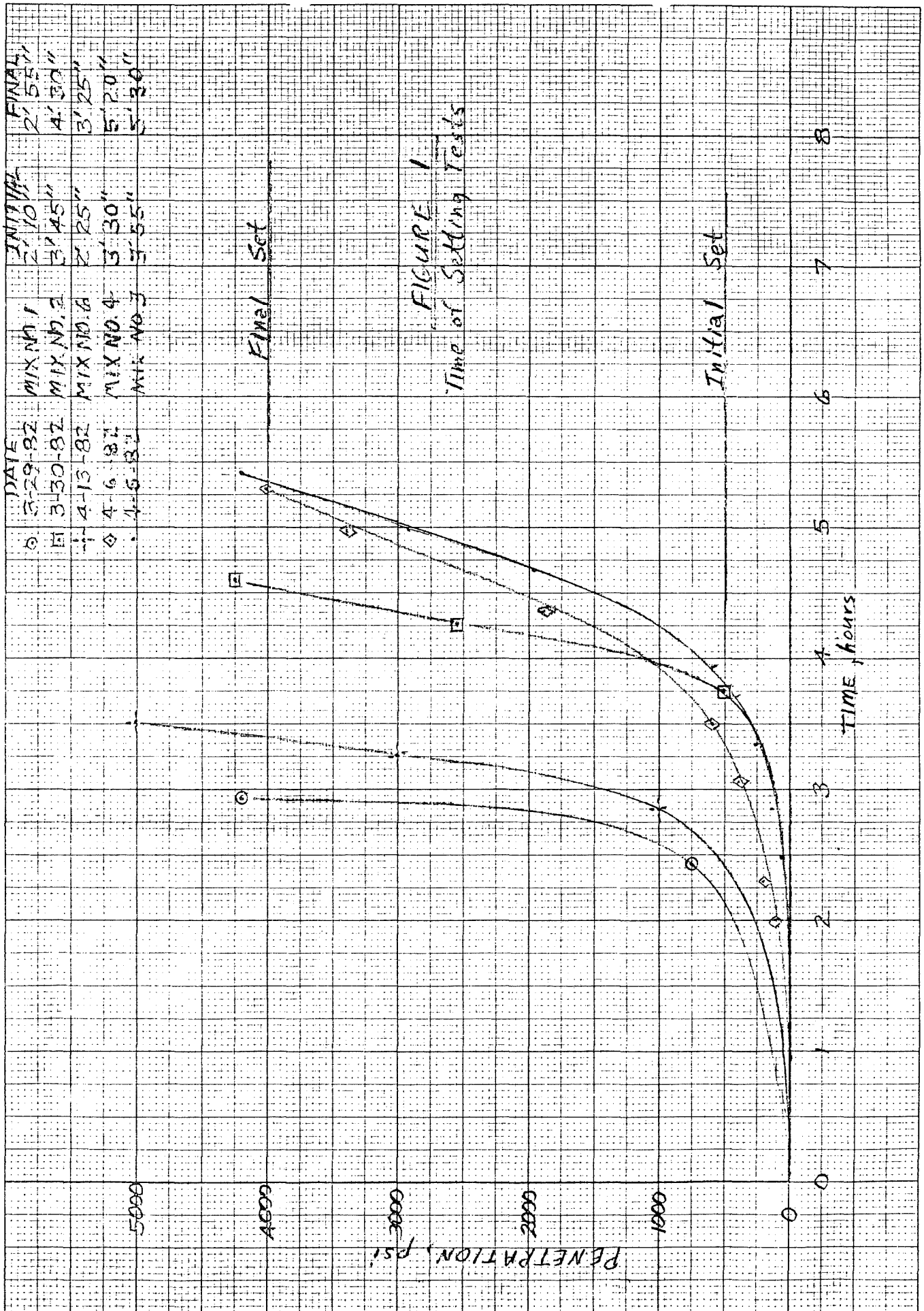
Table 2

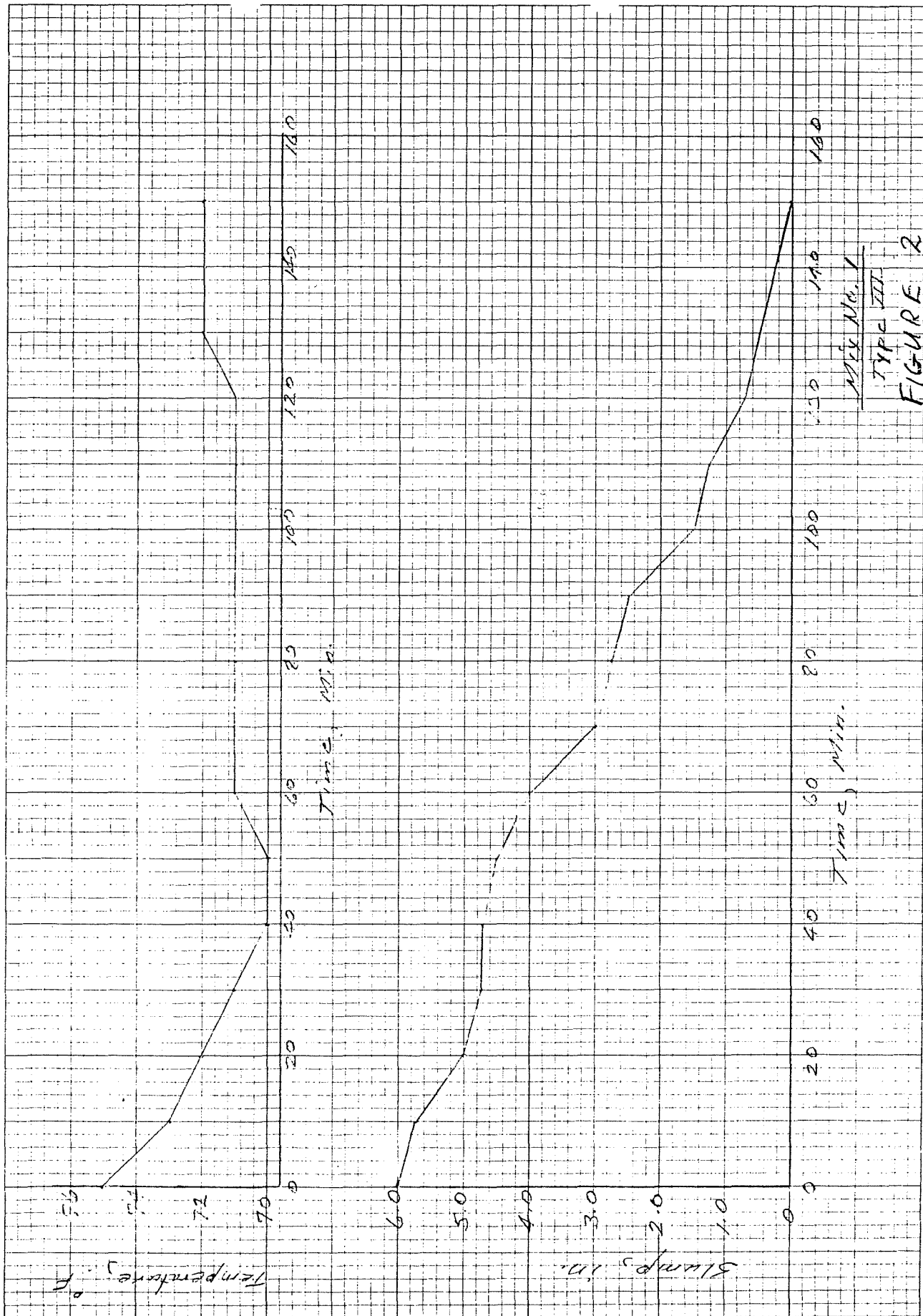
Results of Compressive Strength Tests of Concrete

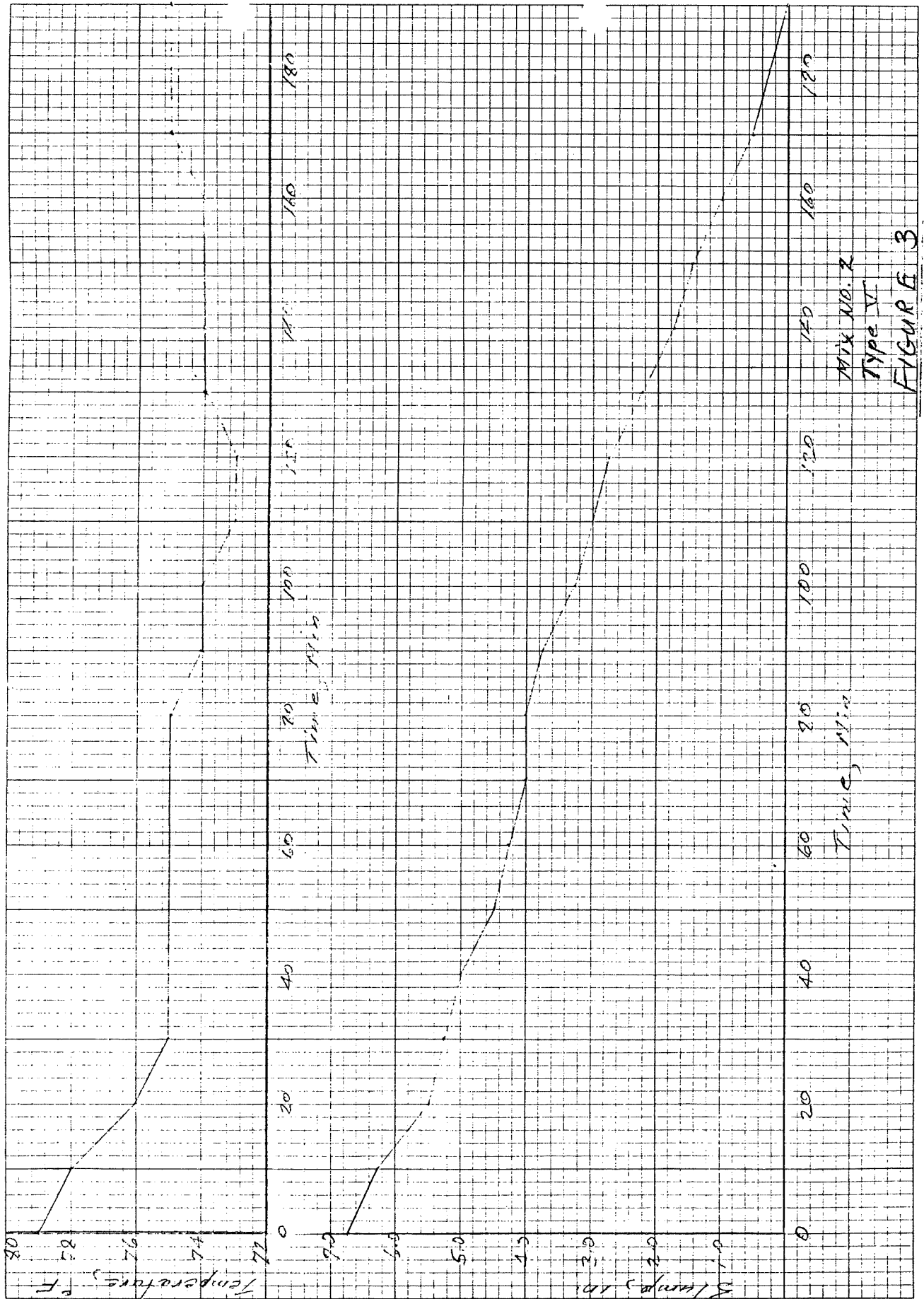
<u>Mixture Data</u>	<u>Mix 1</u>	<u>Mix 2</u>	<u>Mix 3</u>	<u>Mix 4</u>	<u>Mix 5</u>	<u>Mix 6</u>
Cement, lb/cu yd	752.0	752.0	600.0	600.0	600.0	600.0
Portland Cement	III	V	75% III	50% III	--	III
VHE Cement	--	--	25% VHE	50% VHE	100% VHE	--
S/A	46.0	46.0	48.0	48.0	48.0	48.0
W/C	0.40	0.41	0.52	0.53	0.54	0.46
Mighty 150, %	1.5	1.5	--	--	--	1.5
CaCl ₂ , %	2.0	2.0	--	--	--	2.0
Slump, in.	6	6-3/4	6-1/2	6-1/4	4-1/4	6-1/2
Air Content, %	5.2	5.5	4.6	5.4	5.0	5.0

<u>Age</u>	<u>Compressive Strength, psi</u>					
4 hr	510	--	--	50	1610*	220
6 hr	1120	260	120	140	1840	730
1 day	3380	1370	1630	1670	2320	2960
2 day	4720	2390	2400	2090	2760	3700
3 day	4860	2950	2810	2490	2990	4190
7 day	5800	3830	3670	3180	3590	4810
28 day	6900	5760	4460	3980	4600	5880

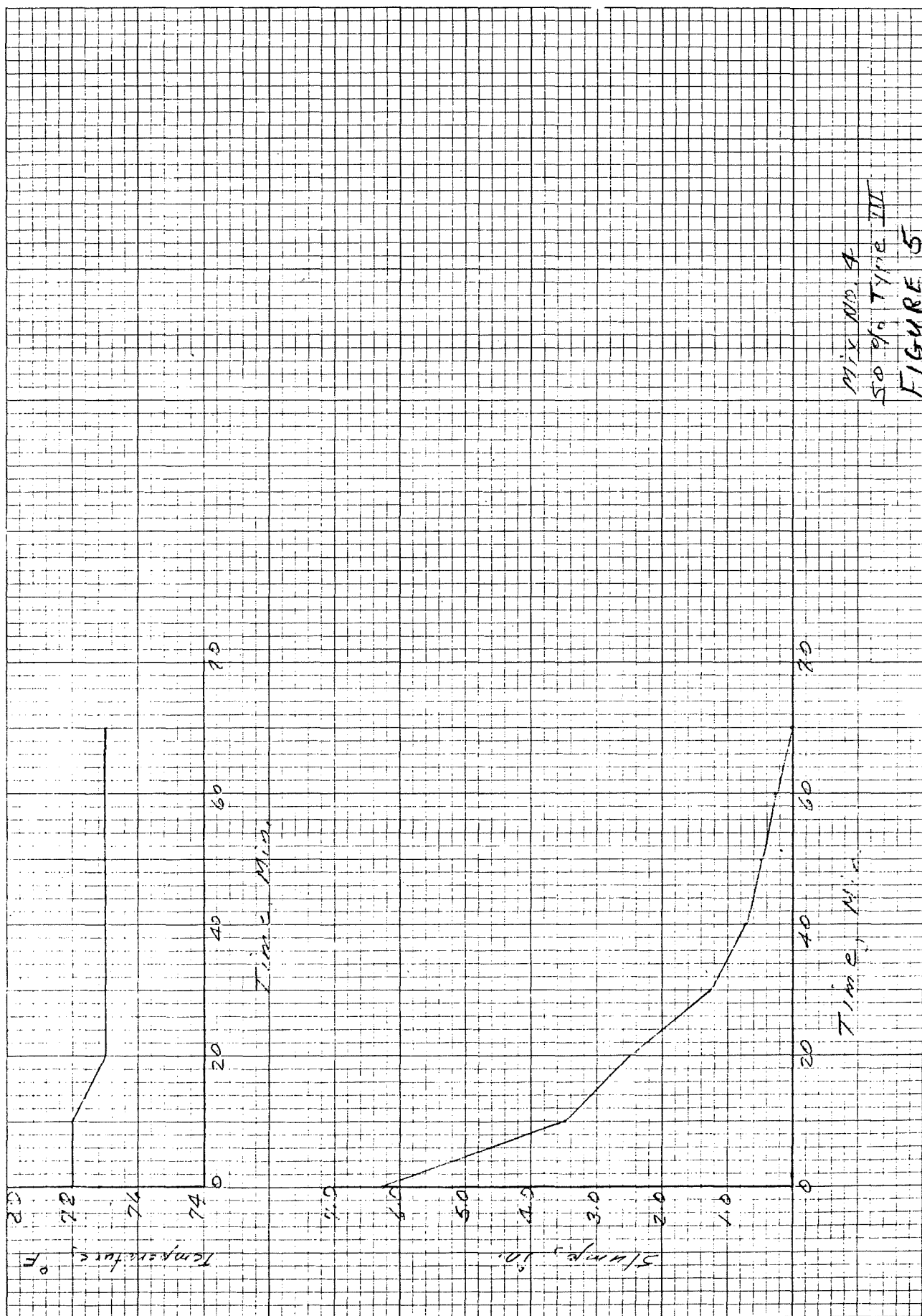
* 3-hr strength; 1-hr strength was 950 psi.

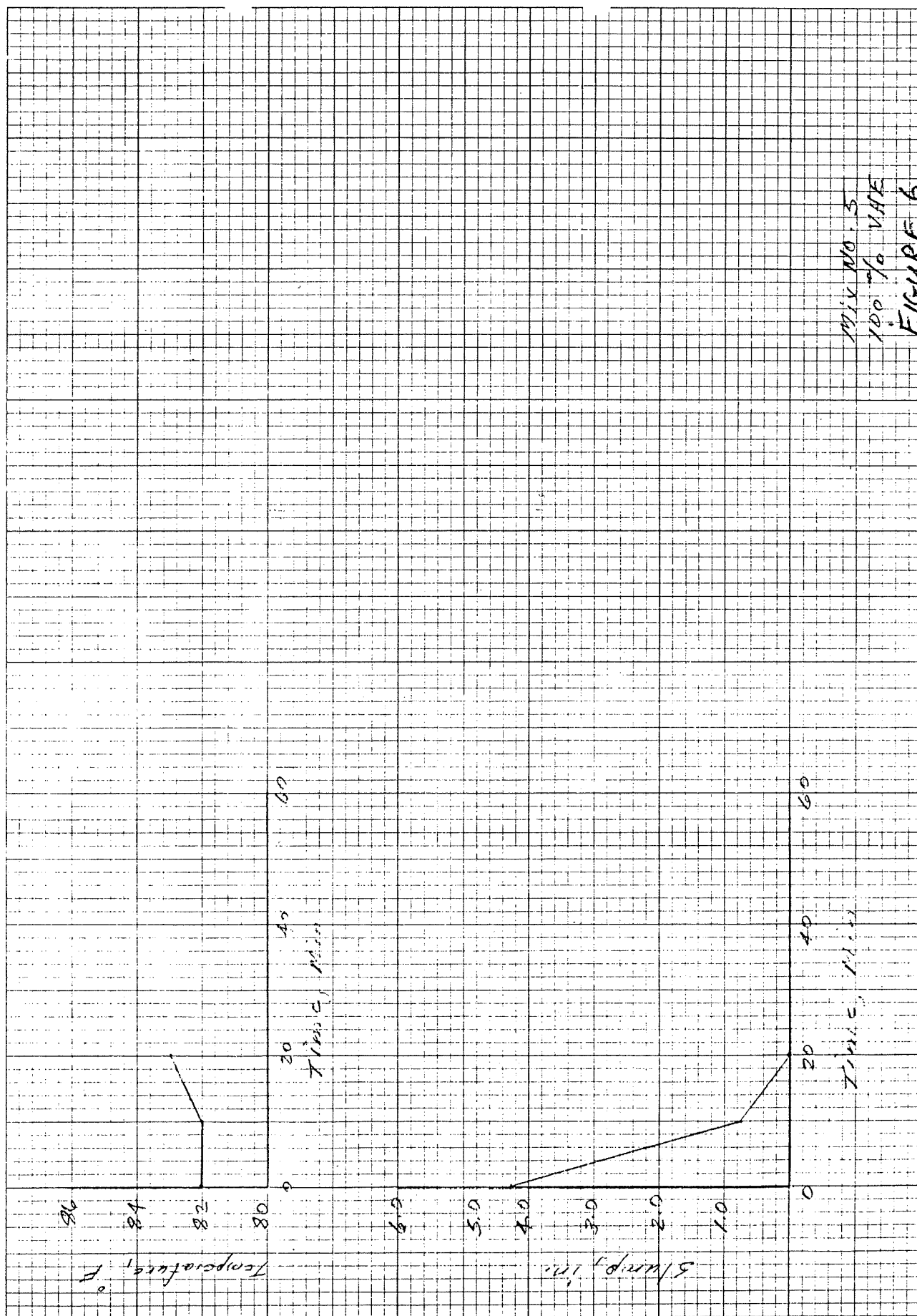














APPENDIX G
DESIGN SPECIFICATION FOR SIMULATION CSL

Specification
for
Design and Fabrication
of
Curb Ring, Slipform and
Jack Frame Assemblies

Prepared by:

Foster-Miller Associates, Inc.
Contract No. DE-AC01-79ET14223
(FMA No. 7957)

for:

Dravo Corporation
Pittsburgh, PA

Rev. No.	Prepared by	Checked by	Approved by
Original Issue	<i>M.P. Thangaraj</i> 11/26/80 (M.P. Thangaraj)	<i>Horvath</i> 11/26/80	<i>Robert J. ...</i> 11/26/80
1			
2			
3			
4			

1.0 General

1.1 Scope of Supply

This specification covers the requirements for detail design fabrication and delivery of the following:

<u>Description</u>	<u>Quantity</u>
Curb ring assembly	1
Slipform assembly	1
Jack frame assembly	1
Curb ring actuators (Hydraulic cylinders with connecting details)	4
Slipform actuators (Hydraulic cylinders with connecting details)	4
Slipform guidance	1 set
Jack frame guidance	1 set

The component parts included in the items mentioned above are explained elsewhere in the specification.

The items referred to above will be used in testing a Continuous Shaft Lining System (CSL), which is being developed by Foster-Miller Associates, Inc. (FMA) under a contract to the United States Department of Energy (DOE). The CSL System is being developed to demonstrate the effectiveness of lining a vertical circular shaped mine shaft with concrete using a slipforming technique from the shaft top downwards.

Work performed by Dravo Corporation will be limited to detail engineering and design, procurement and supply F.O.B. fabrication site, of the items mentioned above, and transmittal of final design specifications and as-built drawings.

1.1.1 Work Performed by Others

Preparation of test site and foundation, unloading and erection of CSL at the FMA test site will be done by others. FMA is responsible for supply of the hydraulic power package, interconnecting hoses and climber jacks.

1.2 General Requirement

No modification to or deviation from this specification or FMA approved drawings shall be made, unless specifically authorized in writing by FMA. Any conflicting requirement in this specification shall be brought to the attention of FMA in writing for their resolution.

2.0 Correspondence and Drawing Submittals

All correspondence shall be clearly identified with FMA purchase order number, and sent to the attention of the Program Manager - DOE-7957. Four sets of all drawings and design calculations should be submitted to FMA for approval.

Approval by FMA of drawings submitted by Dravo Corporation shall apply only to general arrangement and shall not relieve Dravo Corporation from entire responsibility for correctness of details, design and dimensions.

3.0 Codes and Standards

The most recent revision of the following codes and standards and any other standards which Dravo Corporation feels appropriate shall apply.

American Institute of Steel Construction, Inc.
1221 Avenue of Americas
New York, N.Y. 10020

American Welding Society (AWS D1.14 or D1.1)
2501 N.W. 7th Street
Miami, Florida 33125

Steel Structure Painting Council
Pittsburgh, PA 15213
SSPC-SP-3
SSPC-SP-2

4.0 Reference Drawings

Dravo Dwg. 206-513-001
FMA Dwg. 7957-TS-D-001 - Rev. 2, 7957-TS-D-005, and
7957-TS-D-006.

5.0 Functional and Design Requirement

5.1 Operation (Refer Dwg. 206-513-001, 7957-TS-D-001- Rev. 2)

The CSL Simulation Test Arrangement consists of the following major functional equipment.

Outer Casing Assembly: 15 feet diameter cylindrical shell with supports and top lid.

Slipform: 13 feet diameter and 10 feet long cylindrical form.

Curb Ring: A toroidal ring approximately 15 feet OD/13 feet ID, one foot thick with inflatable seals and concrete inlet ports.

Jack Frame: Square type frames to support climber jacks and curb ring and slipform hydraulic cylinders.

Inner Column Assembly: Four tubular columns rigidly interconnected and designed to support the complete weight of CSL moving parts with concrete lining.

The outer casing and inner column assemblies will be erected upright. The slipform will be positioned inside the outer casing assembly and the curb ring will be positioned in the annulus formed between the outer casing and the slipform. The slipform and curb ring will be connected to the jack frame through hydraulic cylinders and the jack frame in-turn will be hung from the inner column assembly with the use of hydraulic climber jacks and rods. The climber jack rods will be embedded continuously in the concrete as the slipform operation progresses. The curb ring is moved downwards, while green concrete is being placed under pressure from below the curb ring. Force created by the concrete pressure on the curb ring will be used to assist in propelling the curb ring and slipform downwards.

Adjustable roller or friction pad guides are provided on the jack frame and on the slipform top to guide the system along the outer casing during the full trial stroking of the slipform and curb ring. During lining operation, the slipform guides will be removed and the system will be guided by the set concrete and the outer casing. The jack frame will be capable of being locked to the inner column assembly at any height. This will facilitate:

- a) Partial lining operation
- b) In-situ maintenance on the curb ring or slipform
- c) Powered downward slipform movement in the event of form drag loads in excess of net downward CSL load.

At the end of lining operation, the jack frame will be locked to the inner column assembly to carry the lining weight and the curb ring and slipform weight. This may occur at any point along the casing length. The casing shell will be stripped off and the concrete lining will be split and lifted out. Following demolition of the concrete liner, the casing shell will be re-erected for further lining tests.

5.2 Loadings

5.2.1 Curb Ring Assembly

Total maximum downward load:	197920#
(excluding its self-weight)	(uniformly distributed)
Seal drag maximum upward:	40,000#
(both inside and outside)	(uniformly distributed)

5.2.2 Slipform Assembly

Radial Load:

External concrete pressure = 20 psig

Axial Load: (Per cylinder)

Downward load	2800#
Upward load	
(pull to compensate drag	
force if slipform	20,000#
actuators are used)	

5.2.3 Jack Frame Assembly

At curb ring actuator support:	51,300#
(downward)	
At slipform actuators support:	2,800#
(downward)	
Drag force upward:	20,000#
(if seen)	
At climber jack support:	40,000#
(upward)	
At locking point to inner columns	
(total load):	206,800#

(Load and load position on jack frame depends on type of loading system used.)

5.3 Dimensional Tolerances:

5.3.1 Curb Ring Assembly (Refer dwg. 7957-TS-D-006)

Top Flange:	
	$+\frac{1}{2}$
Inner diameter	$156\frac{1}{4} - 0$
	$+0$
Outer diameter	$179\frac{1}{2} - \frac{1}{2}$

Inner and outer surfaces of curb ring should be substantially circular and concentric to each other within $\frac{1}{4}$ inch. Four pad surfaces used for mounting hydraulic cylinders clevis brackets should be perpendicular to the axis of curb ring within $\frac{1}{4}$ inch.

5.3.2 Slipform Assembly (Refer Dwg. 7957-TS-D-005)

Outside diameter

156⁺⁰_{- $\frac{1}{4}$}

The outside diameter of the slipform should be smooth and substantially circular. The difference between maximum and minimum diameter at any gross section shall not exceed $\frac{1}{4}$ inch. The waviness of the external surface in the longitudinal direction should be within $\frac{1}{8}$ inch. The surface where slipform actuators are mounted should be perpendicular to the axis of the slipform within $\frac{1}{4}$ inch in 60 inches. On the assembled condition, the slipform shall have 60 percent contact on longitudinal and horizontal joints and the maximum gap on the rest (40 percent) shall be within $\frac{1}{16}$ inch.

5.3.3 Jack Frame Assembly (Refer Dwg. 7957-TS-001- Rev. 2)

Actuator mounting surfaces should be perpendicular to the plane of the jack frame within $\frac{1}{4}$ inch in 60 inches.

5.3.4 Sub-Assembly Sizes

Sizing of any individual piece shall not exceed the maximum permissible sizes for road transportation.

5.4 Materials

All items except actuators shall be fabricated from low carbon structural steel rolled sections of ASTM grade.

5.5 Construction

5.5.1 Curb Ring

The basic construction features of the curb ring will be as shown in the referenced drawing.

Ports: 24 ports are provided in the curb ring and the ports will be used either for feeding concrete, installing instruments or attaching vibrators. Unused ports will be blanked with cover plates or plugs.

Sealing: Curb ring is fitted with bulb seals and inflatable seals. The inflatable seals are back-up seals. The tube of the inflatable seal will be in multiple sections (sausage type) and each piece will be inflated by its air feeder hose. The striker block (rubbing piece) will be spliced in-situ during assembly to a full circle. The inflatable seals will be held in place by the retainer rings.

Bulb Seal

Manufactured by: Kirkhill Seals
Brea, California 92621
Type: S-13735
Quantity: 2

Inflatable Seal

Manufactured by: Seal Master Corporation
Material: EDPM
Pressure: 100 psig max.
Inner Tube: 1 piece (sausage type)
Striker Block one piece (to be spliced
during assembly)
Quantity: 2 (one inner and one outer
seal)

Climber Jack Rod Seal

Manufactured by: (later)
Material: Hard rubber bushing
Quantity: 32

Vibrators

Pneumatic (cartridge type) vibrators may be used to facilitate distribution of concrete around the curb ring.

5.5.2 Slipform

The general constructional features of the slipform will be as shown in the referenced drawing. This form should be stiff

in the axial direction to avoid buckling or hour-glassing while concrete is pressurized. Hinges shall be provided to facilitate assembling and disassembling the form inside the casing and to make the form collapsible for disengaging it from the concrete in the event of form freeze-up. The form segments should be bolted together at their joints during slipforming operation. The form shall be straight for the bottom 5' length and tapered for the top 5' length. The diametral taper will be $\frac{1}{2}$ " on 5' length. This taper is provided to reduce the drag force during slipforming operation. The possibility of adding or subtracting the straight or taper length of the slipform should be considered during design of the form.

5.5.3 Jack Frame

The jack frame will be as shown in the referenced drawing.

Main function:

- Provides mount structure for curb ring activators, slipform actuators and climber jacks.
- Provides lateral CSL guidance off the casing wall and its columns and rotational guidance off the inner columns. Rotational guidance is used to counteract the torsional forces, if created, during slipforming operation.
- Works as interconnecting structure to transfer the complete concrete lining weight and CSL moving parts weight to the inner columns.

- Provides interconnecting structure to operate the CSL system in pull down mode in the event that a net upward force exists during slipforming operation. For pull down case the connection between jack frame and inner columns should be effected within (later) minutes of the time jack frame reaches the required position.

A service deck shall be provided on the jack frame for actuators and concrete hose access.

5.5.4 Curb Ring Actuators

Curb ring actuators are double acting hydraulic cylinders with central flange mount. Actuators will be rigidly mounted to the jack frame and will have pin connection with curb ring.

Bore	6"
Rod Diameter	3½"
Stroke	11'-0" (Sufficient to traverse full slipform length and provide curb ring maintenance access from top.)
Quantity	4
Fluid	FR (MSHA certified permissible FIRE resistant fluid)
Port Size	1" tapered NTPF.
Accessories	Female rod clevis and eye bracket. (eye bracket will be fixed to the curb ring)
Pressure	1,500 psi (maximum)

5.5.5 Slipform Actuator ~~(Tentative)~~

Slipform actuators are double acting hydraulic cylinders with head rectangular flange mount. Actuators will be rigidly mounted to slipform and will have pin connection with jack frame.

Bore	6"
Rod Diameter	3½"
Stroke	30"
Quantity	4
Fluid	FR
Port	1" tapered NPTF
Accessories	Female rod eye and clevis bracket. (clevis bracket will be fixed to jack frame)
Pressure	1,500 psi maximum

5.5.6 Climber Jacks (to be supplied by FMA)

Quantity	4
Capacity	20 short tons.
Manufacturer:	Linden-Alimak
Type	2510-50-UD-EQ
Gripper Rod	
Size	2" square (tentative)
Length	12' lengths
Stroke	
Gripper cylinder	4"
Equalizer cylinder	4"

The climber jacks will operate on stationary rods with a moving load.

5.5.7 Slipform Guidance

Slipform will have two sets of friction or roller guides—one set of temporary guides at the trailing end of the slipform and one set of permanent guides at the leading end of the slipform. The temporary guides will be used only during trial stroking of the CSL system, for aligning the slipform top with the casing wall. During slipforming operation, the form will be guided by the permanent guides on the jack frame at the leading end and by the set concrete at the trailing end.

Jack frame guidance will only operate when the slipform actuators are operated in the event of high form drag loads. Under normal planned operation, the slipform will be locked to the jack frame and slipform nose guidance will be provided through the jack frame from off the casing wall.

5.5.8 Jack Frame Guidance

Jack frame will have two guidance sets—one with inner columns for rotational stability and the other with the casing wall for aligning the CSL system with casing. The guides shall be of friction pad types. Guidance pads shall be adjustable.

5.6 Witness Fit-up and Dimensional Test

Dravo's engineer or representative shall witness assembly of curb ring, slipform, jack frame and guides on fabricators shop floor to verify that final assembly can be made at FMA test site without resort to such methods as localized heating use of come-alongs, hammering with sledges or other substantial application of force.

5.7 Painting

Painting to conform to the most recent standards of the steel structures painting council (SSPC). All surfaces shall be sand-blasted, cleaned and painted. All painted surfaces shall be cleaned as per SSPC-SP 2 or 3 and shall have a minimum of two coats of red lead iron oxide primer (SSPC-Paint 14). (Final DFT greater than 18 mils.)

5.8 Shipping

Items covered by this specification shall be shipped to Foster-Miller Associates, Inc., New England Sand and Gravel, Saxonville Plant, Framingham, Massachusetts 01701.

Dravo Corporation shall provide to FMA 48 hours advance notice of ship date, carrier, route and estimated time of arrival to FMA test site.

APPENDIX H
DESIGN SPECIFICATION FOR SIMULATION TEST TOWER

Specification
for
Design and Fabrication
of
Outer Casing and Inner
Column Assembly

Prepared by:

Foster-Miller Associates, Inc.
Contract No. DE-AC'01-79ET14223
(FMA No. 7957)

for:

Dravo Corporation
Pittsburgh, PA

Rev. No.	Prepared by	Checked by	Approved by
Original Issue	<i>W. Hanger</i> 10/6/80	<i>W. Hanger</i> 10-6-80	<i>Robert J. Hanger</i> 10/6/80
1			
2			
3			
4			

1.0 General

1.1 Scope of Supply (Refer dwg. WD-10, 7957-TS-C-005)

This specification covers the requirements for detail design, fabrication and delivery of component parts for one complete outer casing assembly and one complete inner column assembly. The outer casing and inner column assembly will be used in testing a Continuous Shaft Lining System (CSL), which is being developed by Foster-Miller Associates, Inc. (FMA) under a contract to the United States Department of Energy (DOE). The CSL system is being developed to demonstrate the effectiveness of lining a vertical circular shaped mine shaft with concrete using a slipforming technique from the shaft top downwards.

The outer casing assembly consists primarily of the casing, supporting ring, top lid and six supporting columns each with caps and base plates.

The inner column assembly includes four columns with base plates, two upper cross beams, peripheral access platforms to be operated by cable climbers for rigging and disassembly of the casing shell, one materials handling jib crane with traveling 2000# capacity wire rope hoist for auxiliary material hoisting operations. The jib crane is optional.

Work performed by Dravo Corporation will be limited to detail engineering and design, procurement and supply F.O.B. fabrication site of one complete outer casing assembly and one complete inner column assembly, and transmittal of final design specifications and as-built drawings.

1.1.1 Work Performed by Others

Preparation of test site and foundation, unloading and erection of CSL at the FMA test site will be done by others.

1.1 General Requirement

No modification to or deviation from this specification or FMA approved drawings shall be made, unless specifically authorized in writing by FMA. Any conflicting requirement in this specification shall be brought to the attention of FMA in writing for their resolution.

2.0 Correspondence and Drawing Submittals

All correspondence shall be clearly identified with FMA purchase order number, and sent to the attention of the Program Manager - DOE 7957. Four sets of all drawings and design calculations should be submitted to FMA for approval.

Approval by FMA of drawings submitted by Dravo Corporation shall apply only to general arrangement and shall not relieve Dravo Corporation from entire responsibility for correctness of details, design and dimensions.

3.0 Codes and Standards

The most recent revision of the following codes and standards and any other standards which Dravo Corporation feels appropriate shall apply.

American Institute of Steel Construction, Inc.
1221 Avenue of Americans
New York, N. Y. 10020

American Welding Society (AWS D1.14)
2501 N. W. 7th Street
Miami, Florida 33125

American Waterworks Association (AWWA)
D100

Steel Structure Painting Council
Pittsburgh, PA 15213
SSPC-SP-3
SSPC-SP-2

4.0 Reference drawings

Dravo Dwg. WD-10.
FMA Dwg. 7957-TS-C-005

5.0 Functional and Design Requirement

5.1 Operation (Refer Dwg. WD-10, 7957-TS-C-005)

The CSL Simulation Test Arrangement consists of the following major functional equipment.

Outer Casing Assembly: 15 feet diameter cylindrical shell with supports and top lid.

Slipform: 13 feet diameter and 10' long cylindrical form.

Curb Ring: A toroidal ring approximately 15 feet OD/13 feet ID one foot thick with inflatable seals and concrete inlet ports.

Jack Frame: Square type frames to support climber jacks and curb ring and slipform hydraulic cylinders.

The outer casing and inner column assemblies will be erected upright. The slipform will be positioned inside the outer casing assembly and the curb ring will be positioned in the annulus formed between the outer casing and the slipform. The slipform and curb ring will be connected to the jack frame through hydraulic cylinders and the jack frame in-turn will be hung from the inner column assembly with the use of hydraulic climber jacks and rods. The climber jack rods will be imbedded continuously in the concrete as the slipform operation progresses. The curb ring is moved downwards, while green concrete is being placed under pressure from below the curb ring. Force created by the concrete pressure on the curb ring will be used to assist in propelling curb ring and slipform downwards.

Adjustable and removable roller or friction pad guides are provided on the jack frame to guide it along the inner columns during the trial stroking of the slipform and curb ring. During the lining operation, the guides will be removed and the system will be guided by the concrete lining and the outer casing.

The jack frame will be capable of being locked to the inner column assembly at any height to facilitate partial lining operation and/or to do in situ maintenance on curb ring and slipform.

At the end of lining operation, the jack frame will be locked to the inner column assembly to carry the lining weight and the curb ring and slipform weight. The casing shell will be

stripped off and the concrete lining will be split and lifted out. Following demolition of the concrete liner, the casing shell will be re-erected for further lining tests.

5.2 Loadings

5.2.1 Outer Casing Assembly

Internal concrete pressure: 20 psig maximum
10 psig average

Maximum downward load: 233,000#
(excluding its self weight)

Wind loading: 25 PSF

5.2.2 Inner Column Assembly

Maximum downward load
(excluding self weight
and locking arrangement
weight)

a)	At 10' from ground level	241,000#
b)	At 30' from ground level	109,000#
c)	At 35' from ground level	76,000#
d)	At cross beam level	10,000#

(loading a, b and c include d and loading a, b and c do not occur simultaneously)

Wind Load: 25 PSF

In addition moment created by jib crane loading on the cross beams should be taken into consideration.

5.3 Dimensional Tolerances

5.3.1 Outer Casing Assembly

Inner diameter:

Outer Casing Shell	$180^{+\frac{1}{2}}_{-0}$ inches
Top Lid	$156^{+\frac{1}{4}}_{-0}$ inches

Inner surface of outer casing shell shall be substantially circular. Deviation from verticality (plumb line) of the inner surface of outer casing shell shall not exceed $\frac{1}{2}$ inch.

Maximum allowable gap at the mating surfaces of any two courses (dwg. 7957-TS-005) shall not exceed $\frac{1}{16}$ inch. Maximum allowable gap at the mating surfaces of any two sectors of a course shall not exceed $\frac{1}{16}$ inch. Maximum allowable step between courses shall not exceed $\frac{1}{4}$ inch.

5.3.2 Inner Column Assembly

Deviation from verticality (plumb line) of the inner columns shall not exceed $\frac{1}{2}$ inch.

5.3.3 Sub-Assembly Sizes

Sizing of any individual piece shall not exceed the maximum permissible sizes for road transportation.

5.4 Materials

The outer casing and inner column assemblies shall be fabricated from low carbon structural steel rolled sections of ASTM grade.

5.5 Construction

5.5.1 Outer Casing Assembly (Refer dwg. WD-10, 7957-TS-C-005)

Outer casing assembly consists of casing, supporting ring and columns with base and cap plates.

5.5.1.1 Casing

Casing is made up of six courses of 4 to 6 feet high cylindrical flanged shells. Each course is split into three or four flanged sectors for easy assembly and disassembly. All flanged connections shall be bolted. Jib crane may be used to handle the sectors during rigging.

5.5.1.2 Supporting Ring

Supporting ring should be preferably made in three pieces, so as to align the joints at the column cap. Convenient bolting arrangement for the joints should be incorporated into the design. Bottom course flange may be adequately stiffened to replace the supporting ring. Provisions for shimming should be made to allow for foundation settlement (not expected to exceed $\frac{1}{2}$ inch.).

5.5.2 Inner Column Assembly (Refer dwg. WD-10, 7957-TS-C-005)

Inner column assembly consists of four columns with base plates, cross beams with walkway, peripheral access platforms to be

hung by cable climbers from the cross beams and a materials handling jib crane.

5.5.2.1 Cross Beams with Walkways

The cross beams should have bolted connection with the inner columns. Four feet wide walkway with handrailing should be provided on the cross beam for easy access to the jack rod attachment points. The attachment arrangement shall be designed for 2 inch square rods to be supplied by Linden-Alimak.

5.5.2.2 Access Platforms

Access platforms should be of light weight design to carry two persons and to be operated by cable climbers.

5.5.2.3 Electric Jib Crane (Optional)

Post Height: approximately 5'-0"

Boom length: 10'-0"

Wire rope hoist capacity 2000#

Wire rope hoist lift 60 ft.

Motorized boom rotation with positive braking arrangement.

5.6 Welding

All welding shall be as per AWS D1.14 specification. All finished welds shall be visually inspected.

5.7 Witness Fit-up and Dimensional Test

Dravo's engineer or representative shall witness assembly of each outer casing course to the supporting ring on fabricators shop floor to verify the final assembly can be made at FMA test site without resort to such methods as localized heating use of come-alongs, hammering with sledges or other substantial application of force.

5.8 Painting

Painting to conform to the most recent standards of the steel structures painting council (SSPC). All surfaces shall be sand-blasted, cleaned and painted. All painted surfaces shall be cleaned as per SSPC-SP 2 or 3 and shall have a minimum of two coats of red lead iron oxide primer (SSPC-Paint 14). (Final DFT greater than 18 mils).

5.9 Shipping

Outer casing assembly and inner column assembly shall be shipped to Foster-Miller Associates, Inc., New England Sand and Gravel, Saxonville Plant, Framingham, Massachusetts 01701.

Dravo Corporation shall provide to FMA 48 hours advance notice of ship date, carrier, route and estimated time of arrival to FMA test site.

Weight Break-downOuter Casing Assembly:

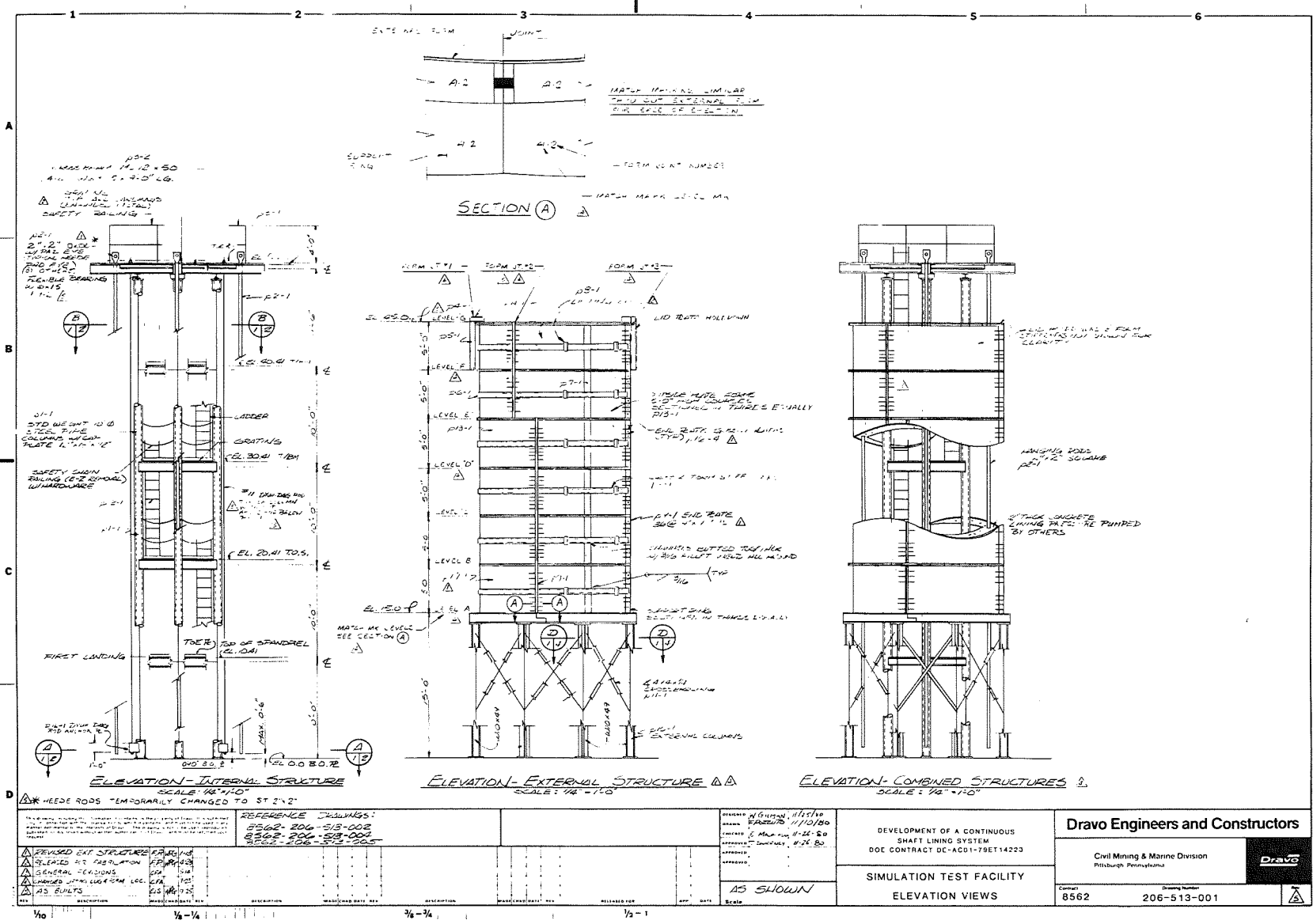
Slipform ($\frac{1}{2}$ " plate, $\emptyset$ 13'-0" and 10' long)	10,000#
Curb ring	4,000#
Jack frames	5,000#
Hydraulic cylinders 8 nos (11' stroke $3\frac{1}{2}$ " rod, 6" bore)	6,400#
Hydraulic climber jacks 40,000# capacity (25-10-50-UD-EQ of Linden Alimak type) 8 nos. (4 nos. for pull mode and 4 nos. for push mode)	3,000#
Hydraulic climber jack rods 2" square section 50' long. 4 nos.	2,800#
Service personel 5 men @200#	1,000#
Portable equipment (drills; welding m/c.etc)	3,000#
Concrete lining $\emptyset$ 15'/ $\emptyset$ 13' and 30' long @ 150# per CFT	197,920#

Inner Column Assembly:

Cable climber arrangement.	1,000#
Electric jib crane 2000# capacity 60' lift, 5' high post and 10' long boom, wire rope hoist	4,000#

APPENDIX I

DESIGN DRAWINGS OF
SIMULATION CSL AND TEST TOWER







BILL OF MATERIAL			
MARK	QTY.	ITEM	DIMENSIONS
A1-1	4	10" Ø STD. STEEL PIPE COL.	50' ± 3/8"
A2-1	4	STD. 30 HANGING BRGS. UP/DN BR.	2" x 3" x 3/16" (SUP. BY OTHERS)
A3-1	376.6	1/2" STD. STEEL PLATE JUSTY BUILDING	4'0" HIGH 8'1/4" x 1/4" TIE BR.
A4-1	18	WELDED LID PLATE HANG DOWN	CG 40.2 x 1/2" x 1/2"
A5-1	18	SIDE LID PLATE HANG DOWN	CG 40.2 x 5/8" x 1/2"
A6-1	36	WELDED FORM STIFFENERS	CG 40.2 x 7/8" x 1/2"
A7-1	36	VERT. FORM STIFFENERS	1/16" (1/16") CG 40.2 x 1/2" x 1/2"
A8-1	36	LIFTING LUGS	40.2 x 3/4" x 1/2"
A9-1	36	END PLATES	1" x 4" x 3/8"
A10-1	12	EXTERNAL COLUMN	WIDENED 1/2" x 1/2"
A11-1	12	EXTERNAL K-BRACES	2" x 1/2" x 1/2" x 1/2"
A12-1	5	LADDER ASSEMBLY	1/2"
A13-1	12	CYLINDRICAL STEEL FORM RATE	3/4" x 5/8" x 1/2" x 1/2"
A14-1	5	CYLINDRICAL STEEL FORM RATE	3/4" x 5/8" x 1/2" x 1/2"
A15-1	4	SYNDICAS DOGS	1/2" x 1/2" x 1/2" (1/2")
A16-1	4	SYNDICAS ANCHOR ASSEMBLY	3/4" x 1/2" x 1/2" x 1/2"
A17-1	4	STEEL FORM RATE	3/4" x 1/2" x 1/2" x 1/2"
A18-1	4	CONNECTION BRACES	1" x 1/2" x 1/2" x 1/2"
A19-1	4	MAIN CROSS CHANNEL	1/2" x 5/8" x 1/2" x 1/2"
A20-1	4	TOP SPANDREL BEAMS	1/2" x 5/8" x 1/2" x 1/2"
A21-1	4	HANGING ROD THE RATE	1/2" x 1/2" x 1/2" x 1/2"
A22-1	4	STD. PIPE ANCHOR ASSEMBLY	1/2" x 5/8" x 1/2" x 1/2"
A23-1	4	PIPE COLUMN CAP PLATES	1/2" x 1/2" x 1/2" x 1/2"
A24-1	4	CHANNEL WEB STIFFENERS	3/4" x 1/2" x 1/2" x 1/2"
A25-1	4	FLEXIBLE BEARING BEAM	1/2" x 1/2" x 1/2" x 1/2"
A26-1	4	BEARING BEAM STIFFENERS	3/4" x 1/2" x 1/2" x 1/2"
A27-1	4	SPANDREL BEAMS	1/2" x 5/8" x 1/2" x 1/2"
A28-1	4	CENTER BEAM	1/2" x 5/8" x 1/2" x 1/2"
A29-1	4	MAIN CHANNEL STEEL CONNECTION	1/2" x 5/8" x 1/2" x 1/2"
A30-1	4	SPANDREL BEAM RIGID SIDE PLATE	1/2" x 5/8" x 1/2" x 1/2"
A31-1	4	SPANDREL BEAM RIGID SIDE RATE	1/2" x 5/8" x 1/2" x 1/2"
A32-1	4	CHANNEL BRACES	1/2" x 5/8" x 1/2" x 1/2"
A33-1	4	TOP SPANDREL BEAM CONNECTION	1/2" x 5/8" x 1/2" x 1/2"
A34-1	4	FAST ANGLE	1/2" x 5/8" x 1/2" x 1/2"
A35-1	4	DOWN THE DOWN PLATE	1/2" x 5/8" x 1/2" x 1/2"
A36-1	4	BOLTS 1/2" x 5/8" x 1/2" x 1/2"	1/2" x 5/8" x 1/2" x 1/2"
A37-1	4	BOLTS 1/2" x 5/8" x 1/2" x 1/2"	1/2" x 5/8" x 1/2" x 1/2"
A38-1	4	EXTERNAL COLUMN CAP PLATES	1/2" x 5/8" x 1/2" x 1/2"
A39-1	4	SUPPORT RIGID BRACES	1/2" x 5/8" x 1/2" x 1/2"
A40-1	4	ASPS 1/2" x 5/8" x 1/2" x 1/2"	1/2" x 5/8" x 1/2" x 1/2"
A41-1	4	SUPPORT RIGID SIDE RATE ANGLE	1/2" x 5/8" x 1/2" x 1/2"
A42-1	4	SUPPORT RIGID SIDE RATE OUTER	1/2" x 5/8" x 1/2" x 1/2"
A43-1	4	GUIDE PLATE	1/2" x 5/8" x 1/2" x 1/2"
A44-1	4	LID RATE	1/2" x 5/8" x 1/2" x 1/2"
A45-1	4	HORIZONTAL MATING BARS	1/2" x 5/8" x 1/2" x 1/2"
A46-1	4	LID RATE HANG DOWN CONNECTION	1/2" x 5/8" x 1/2" x 1/2"
A47-1	4	RIGID STIFFENERS GUSSETS	1/2" x 5/8" x 1/2" x 1/2"
A48-1	4	RIGID STIFFENERS GUSSETS	1/2" x 5/8" x 1/2" x 1/2"
A49-1	4	HORIZONTAL MATING BARS	1/2" x 5/8" x 1/2" x 1/2"
A50-1	4	COLUMN BASE RATE BOTTOM	1/2" x 5/8" x 1/2" x 1/2"
A51-1	4	COLUMN BASE RATE TOP	1/2" x 5/8" x 1/2" x 1/2"
A52-1	4	PIPE COLUMN BASE RATE	1/2" x 5/8" x 1/2" x 1/2"
A53-1	4	BASE RATE GUSSETS	1/2" x 5/8" x 1/2" x 1/2"
A54-1	4	CHAM BRACES	1/2" x 5/8" x 1/2" x 1/2"
A55-1	4	EXTERNAL COLUMN BASE RATE	1/2" x 5/8" x 1/2" x 1/2"
A56-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A57-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A58-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A59-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A60-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A61-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A62-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A63-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A64-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A65-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A66-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A67-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A68-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A69-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A70-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A71-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A72-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A73-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A74-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A75-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A76-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A77-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A78-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A79-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A80-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A81-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A82-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A83-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A84-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A85-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A86-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A87-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A88-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A89-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A90-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A91-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A92-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A93-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A94-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A95-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A96-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A97-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A98-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A99-1	4	EXTERNAL COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"
A100-1	4	PIPE COLUMN ANCHOR BOLTS	1/2" x 5/8" x 1/2" x 1/2"

- GENERAL NOTES:
- STRUCTURAL STEEL SHALL CONFORM TO THE ASTM SPECIFICATIONS: A-36 AND A-57.
 - WELDING SHALL CONFORM TO AWS STANDARDS: D1.1 AND WELDERS SHALL HAVE CURRENT CERTIFICATION.
 - DESIGN, FABRICATION AND ERECTION SHALL CONFORM TO THE AISC SPECIFICATION: "DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS".
 - PAINTING OF STRUCTURES SHALL CONFORM TO THE MOST RECENT STANDARD OF THE STEEL STRUCTURES PAINTING COUNCIL (SSPC). ALL SURFACES SHALL BE CLEANED (PER SSPC-SP-6 AND SP-13) AND PAINTED WITH 2 COATS OF STANDARD RED OXIDE PRIMER AND A FINISH COAT OF TYPE 1 WHITE (SAF-T-GARD ENAMEL). INSIDE OF STEEL PLATE FORM DOES NOT REQUIRE FINISH COAT.
 - SHOP CONNECTIONS SHALL BE BOLTED OR WELDED.
 - FIELD CONNECTIONS SHALL BE BOLTED; NO FIELD WELDING WILL BE PERMITTED EXCEPT WHERE NOTED.

- BOLTS TO BE A325 3/4" FULL THREAD EXCEPT WHERE NOTED.
- ALL BOLT HOLES TO BE 1/16 INCH LARGER THAN BOLT DIAMETER EXCEPT AS NOTED.
- ALL HIGH STRENGTH BOLTS ARE TO BE TIGHTENED TO MINIMUM TENSION BY EITHER CALIBRATED WRENCH OR TURN-OF-TURN METHOD AS DISCUSSED IN ASTM SPECIFICATION FOR A325 OR A490 BOLTS.

- EDRUP BASE PLATES SHALL BE ANCHORED WITH 1/2" Ø, ASTM A307 ANCHOR BOLTS, PIPE SLEEVES AND MECHANICAL ANCHORAGE AS SHOWN ON DRAWINGS. BASE PLATE HOLE DIAMETERS = 2".
- BOTTOM OF BASE PLATE IS TAKEN AS ELEVATION ZERO. ELEVATIONS ARE TAKEN TO TOP OF SPANDREL BEAM.

- DIMENSIONAL TOLERANCES
- | | |
|-------------------------------|-----------------------|
| EXTERNAL FORM | 1.0 - 1.80 INCHES |
| LID PLATE | 1.0 - 1.56 INCHES |
| SUPPORT RING FILLER PLATE | 1.0 - 1.80 INCHES |
| SUPPORT RING SIDE PLATE INNER | 1.0 - 1.80 3/8 INCHES |

- INNER SURFACE OF EXTERNAL FORM SHALL BE SUBSTANTIALLY CIRCULAR. DEVIATION FROM PLUMB LINE SHALL NOT EXCEED 1/8 INCH.
- BOLT HOLES OF EVERY STEEL PLATE FORM COURSE SHALL LINE UP WITH BOLT HOLES OF THE SUPPORT RING.
- ALL COURSES OF THE EXTERNAL FORM EXCEPT THE TOP 4-0 (4000) COURSES, SHALL BE INTERCHANGEABLE.
- WELDED CONNECTIONS USE E70XX ELECTRODES.
- GUSSET PLATES = 5/16 INCH MINIMUM, WELDED BOTH SIDES.
- HANDRAIL AND LID PLATES ARE REQUIRED. SEE DRAWINGS FOR LOCATIONS AND DETAILS.
- MAXIMUM SPACING OF POSTS FOR HANDRAIL SHALL BE 5'-0" FOR TOP FLOOR.
- HANDRAIL AT LOWER FLOORS SHALL BE WIRE ROPE TYPE OR CHAIN WITH HOLES AND EYES AT EACH COLUMN FOR EASY REMOVAL.
- ALL SHARP EDGES AND CORNERS WILL BE FILED OR GROUNDED SMOOTH.
- DESIGN LOADINGS

EXTERNAL STRUCTURE	INTERNAL CONCRETE PRESSURE*	10 PSIG MAXIMUM
	WORKING PRESSURE	10 PSIG AVERAGE
	MAXIMUM COMPRESSIVE LOAD	
ON COLUMNS		236,000#
WIND LOAD		25 PSF
INTERNAL STRUCTURE	MAXIMUM COMPRESSIVE LOAD	
AT BASE DURING:		236,000#
WIND LOAD		25 PSF
LIVE LOAD PER FLOOR		100 PSF

*WASHERS WERE NOT USED FOR FIELD ERECTION ON 3/4" A325 BOLTS. BOLTS WERE PLACED SNUG TO STRUCTURAL STEEL. THIS IS PERMITTED BY AISC SPECIFICATION FOR A325 BOLTS - SECTION 5.6.

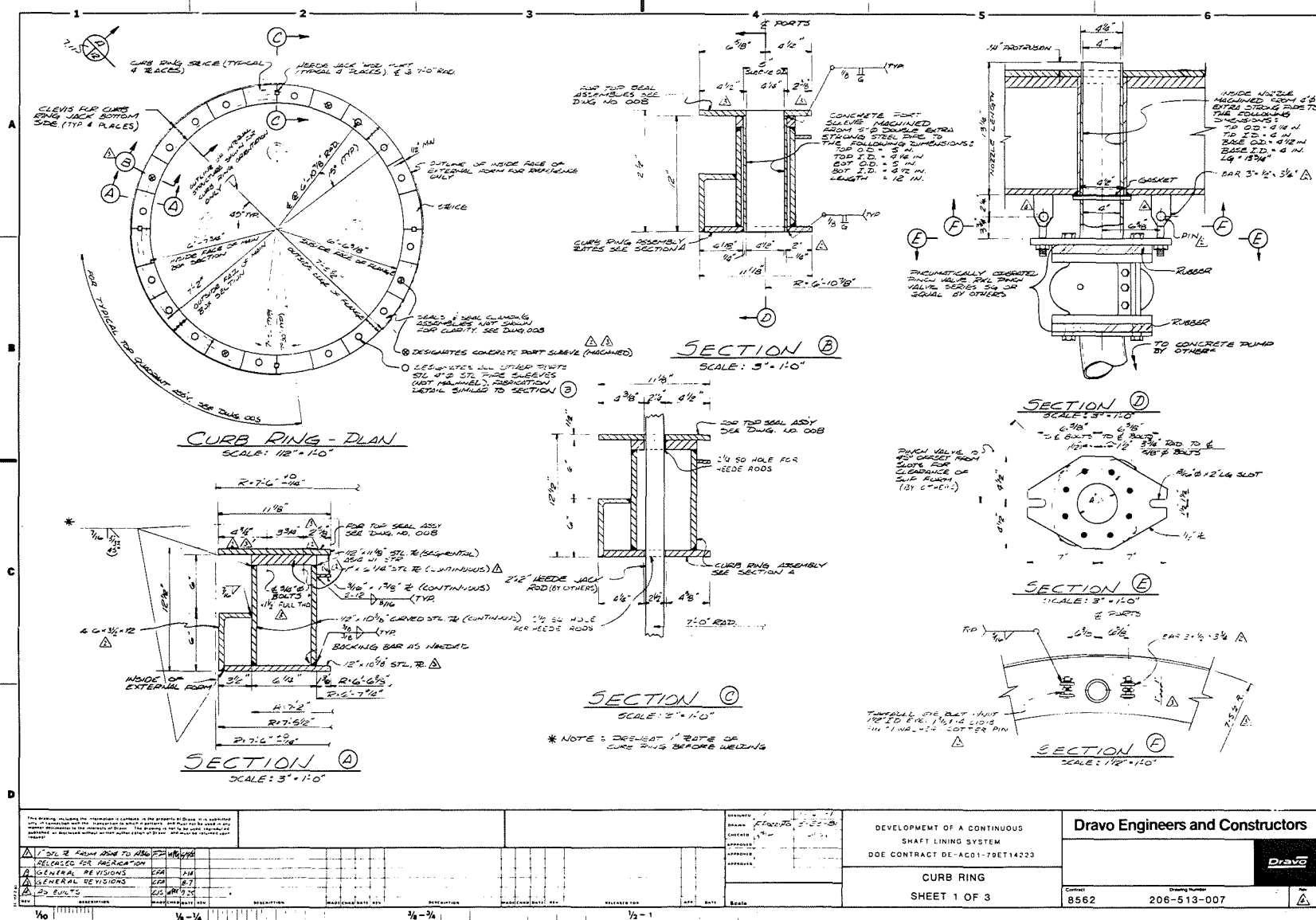
- GENERAL NOTES (CONT.):
- DRAGO'S ENGINEER OR REPRESENTATIVE SHALL WITNESS ASSEMBLY OF THE BOTTOM EXTERNAL FORM COURSE TO THE SUPPORT RING AND EACH INTERCHANGEABLE COURSE TO THE ANOTHER ON FABRICATIONS SHOP FLOOR TO VERIFY PROPER ASSEMBLY.
 - ALL ASSEMBLIES SHALL BE SHIPPED TO FOSTER-MILLER ASSOCIATES, INC., NEW ENGLAND SAND AND GRAVEL, SAKONVILLE PLANT, FRAMINGHAM, MASSACHUSETTS 01701.

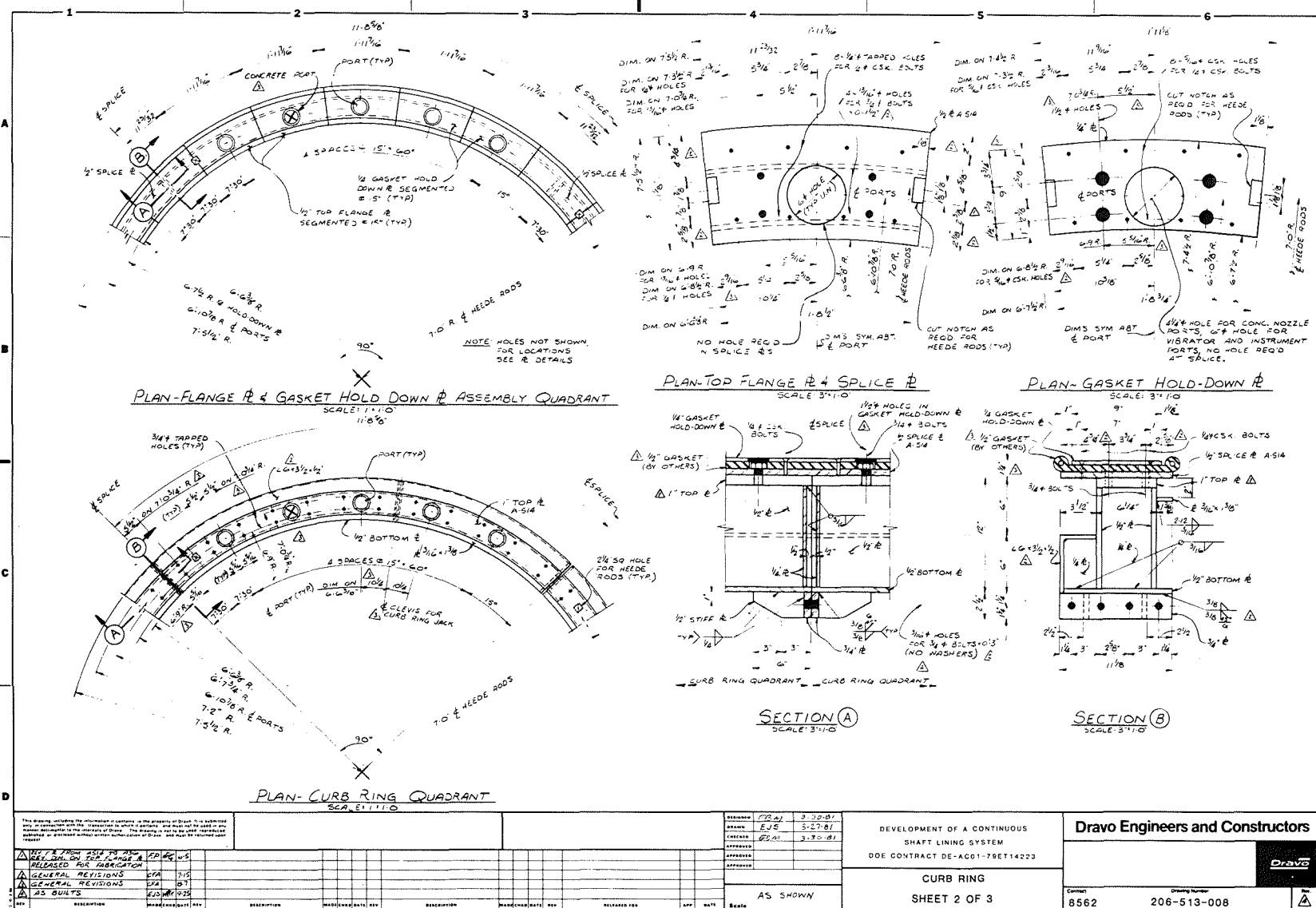
ADDITIONAL MATERIAL REQUIRED		
QTY.	ITEM	DIMENSIONS
0	GRATING SUPPORT CHANNELS	CG 6.0 x 2.0 x 1/2"
32	BOLT CLIP FOR TOE R/S	BAR 3/4 x 1/4
16	TOE R/S	BAR 4/8 x 4/8
8	SUPPORT STRUCTURE SPRUCE R/S	BAR 2 x 3/8 x 1/0
0	DO	BAR 2 x 3/8 x 1/0
0	DO	BAR 2 x 3/8 x 1/0
3	GRATING SUPPORT	BAR 2 x 3/8 x 1/1/2
0	GUSSET FOR GRATING SUPPORT	BAR 5/16 x 1/0
0	CLIP FOR GRATING SUPPORT ANGLE	BAR 3/8 x 6
0	DO	BAR 3/8 x 6
8	GRATING SUPPORT ANGLES	CG 3 x 1/4 x 1/0 x 8
0	DO	CG 3 x 1/4 x 1/0 x 8
10	BOND BREAKING ASSEMBLY	

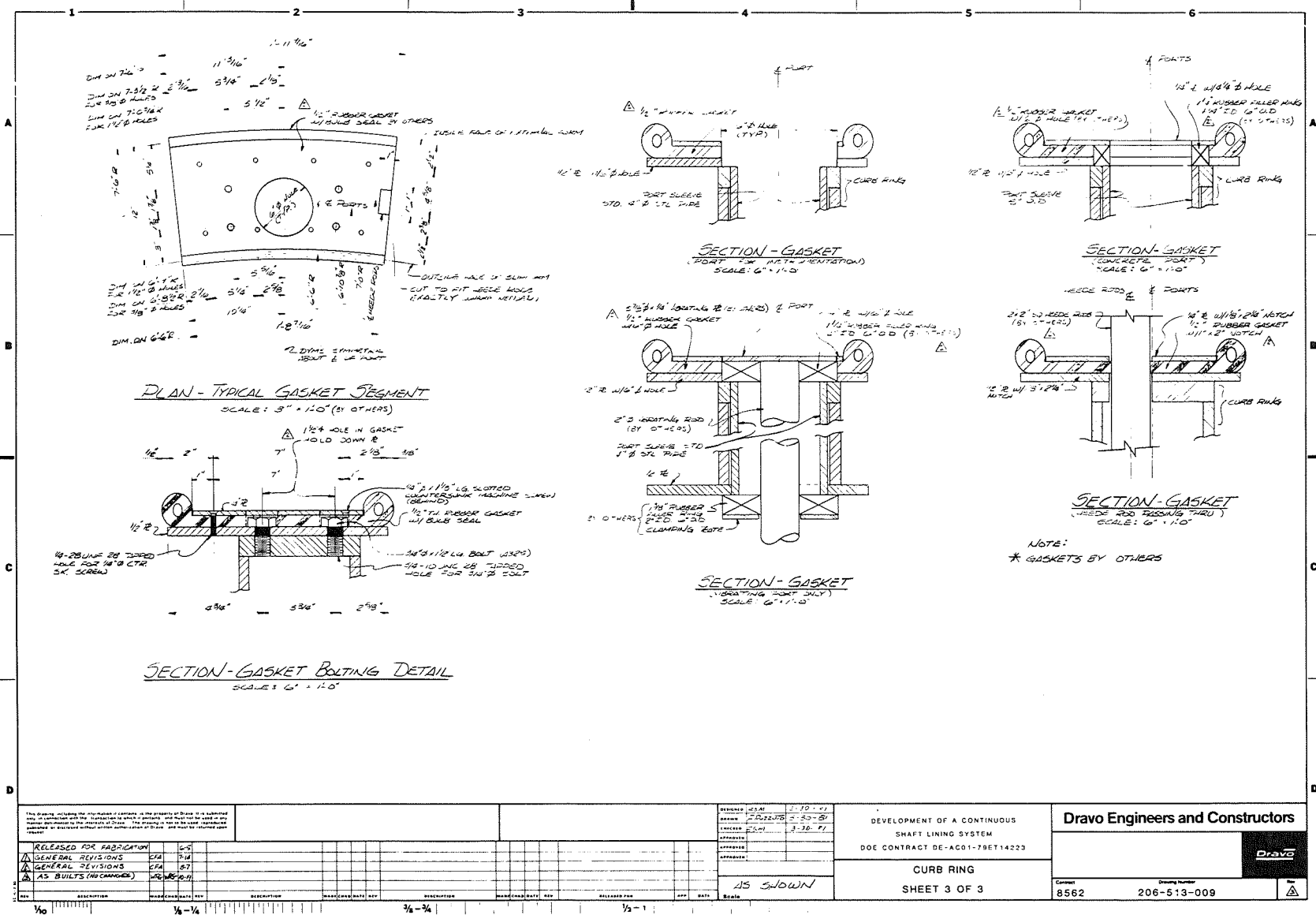
5562-206-513-001 5562-206-513-002 5562-206-513-003 5562-206-513-004		REVISIONS 1. 11-15-80 2. 11-20-80 3. 11-26-80 4. 12-80		DEVELOPMENT OF A CONTINUOUS SHAFT LINING SYSTEM DOE CONTRACT DE-A001-79ET14223		Dravo Engineers and Constructors Civil Mining & Marine Division Pittsburgh, Pennsylvania	
BILL OF MATERIAL & GENERAL NOTES		8562		206-513-005		1/2 - 1	

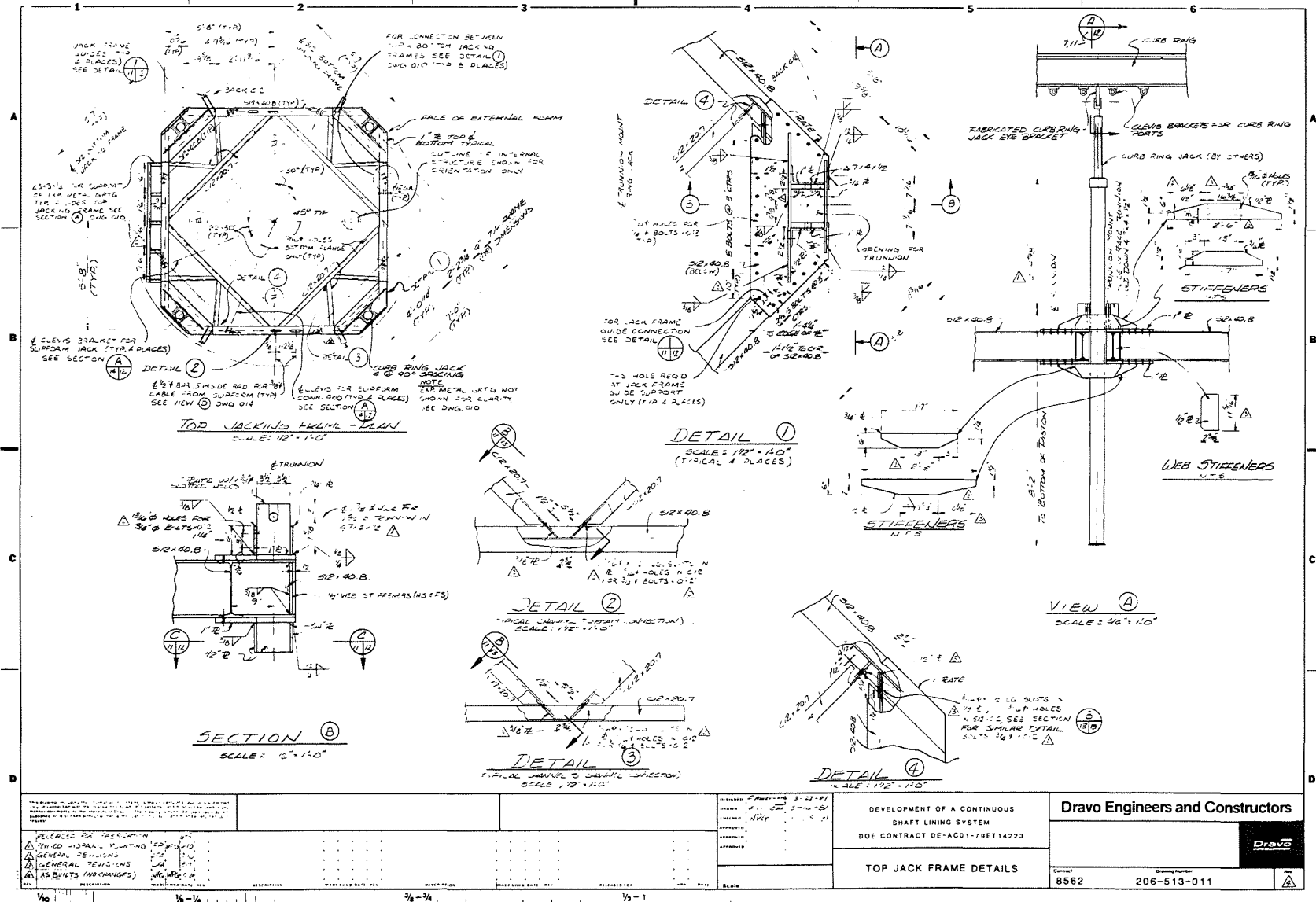


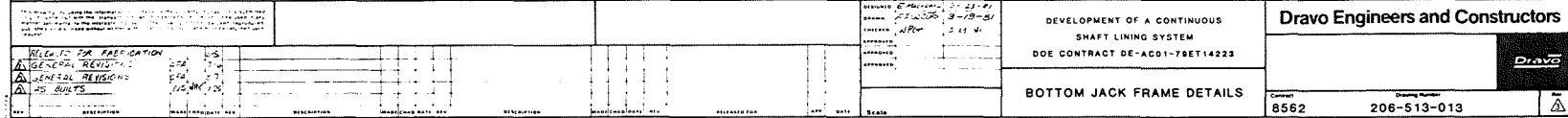
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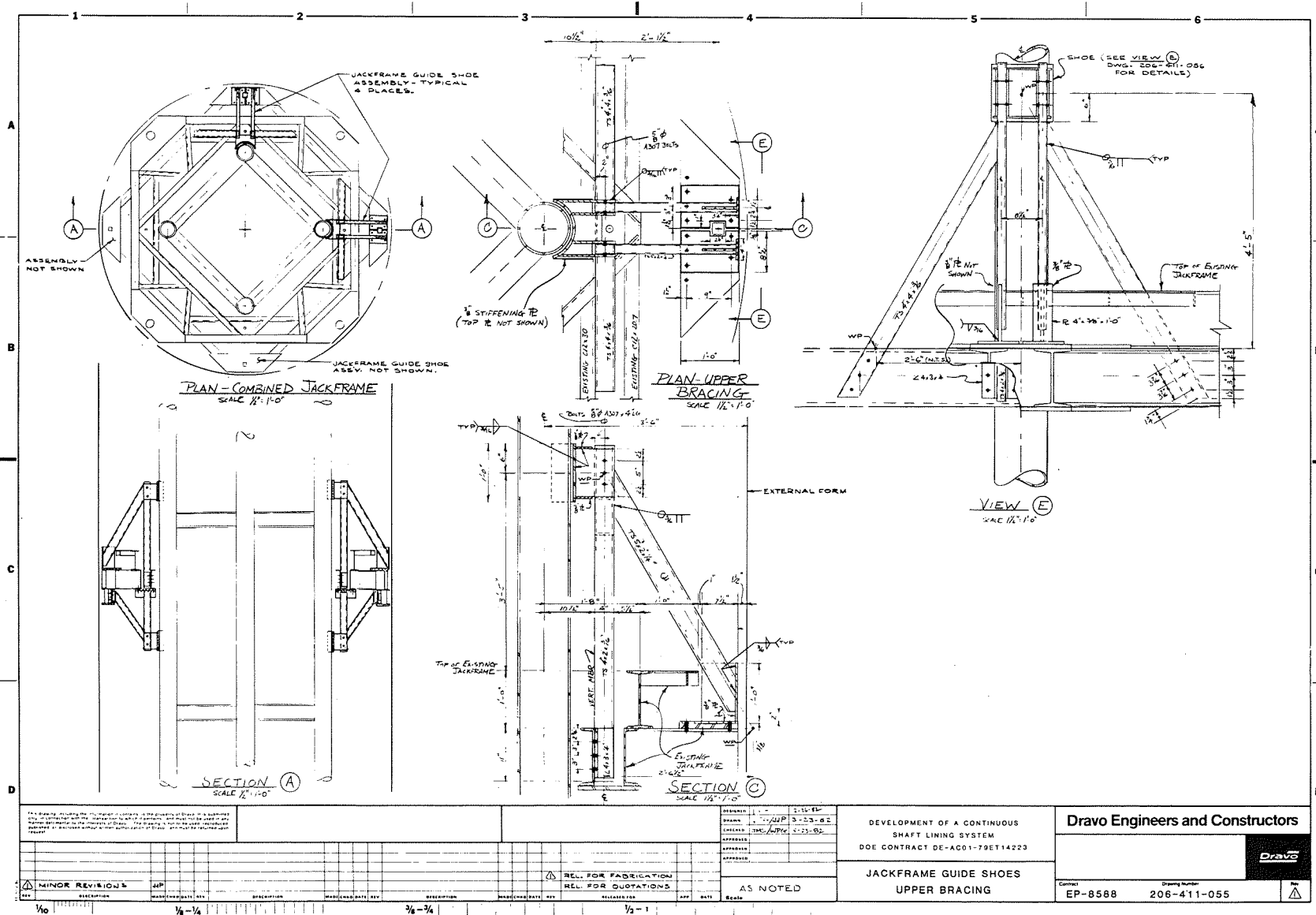


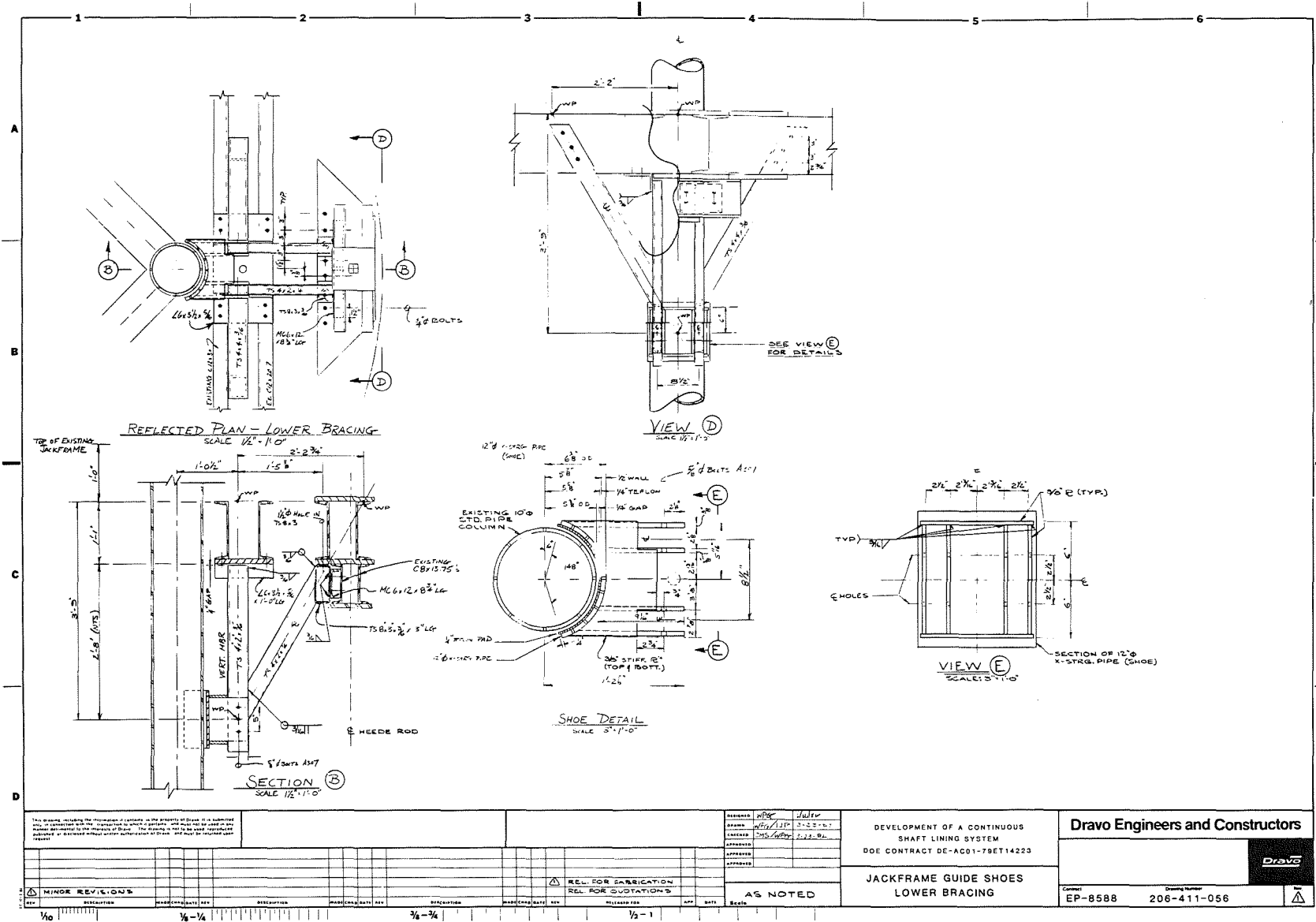


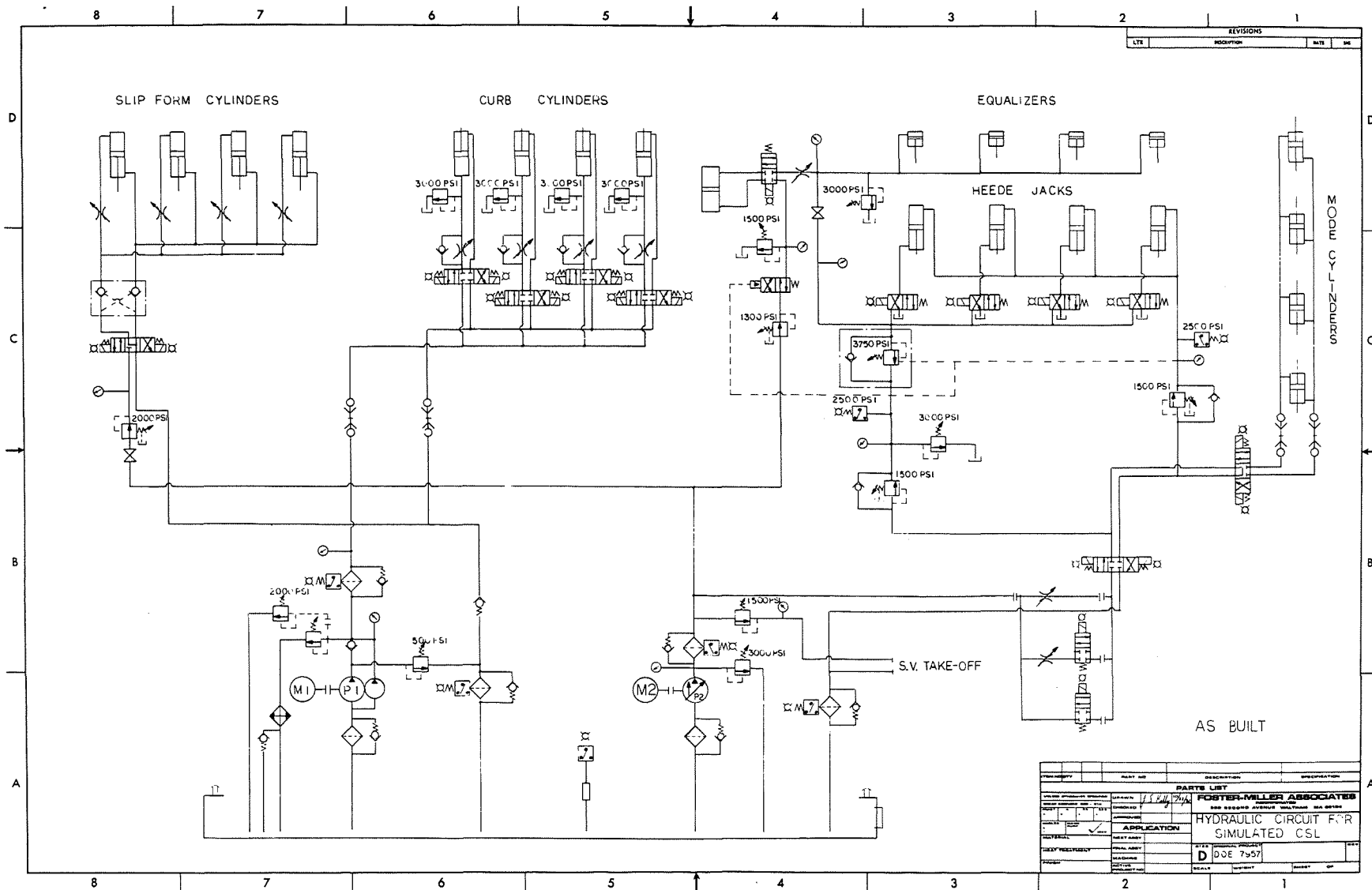


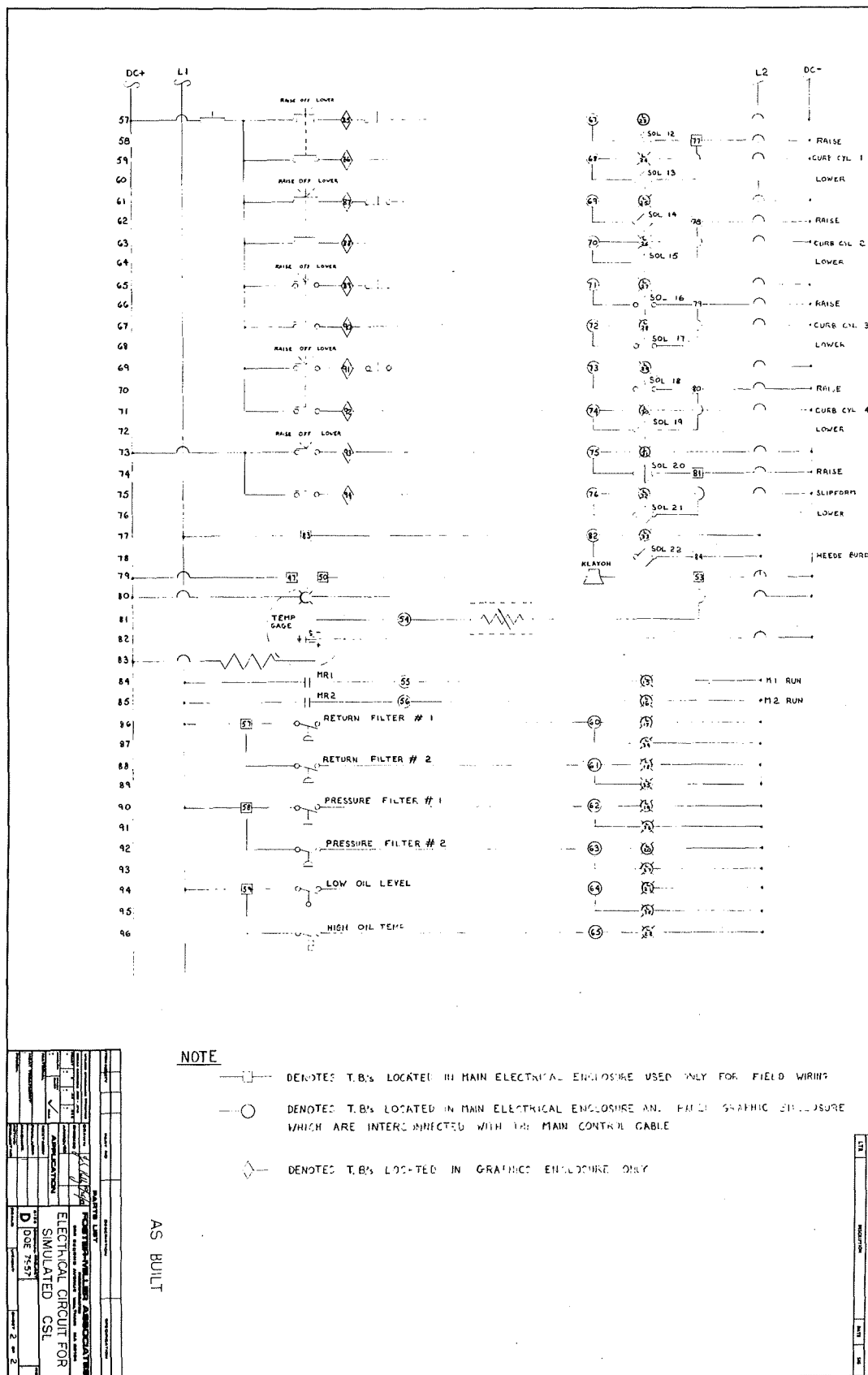












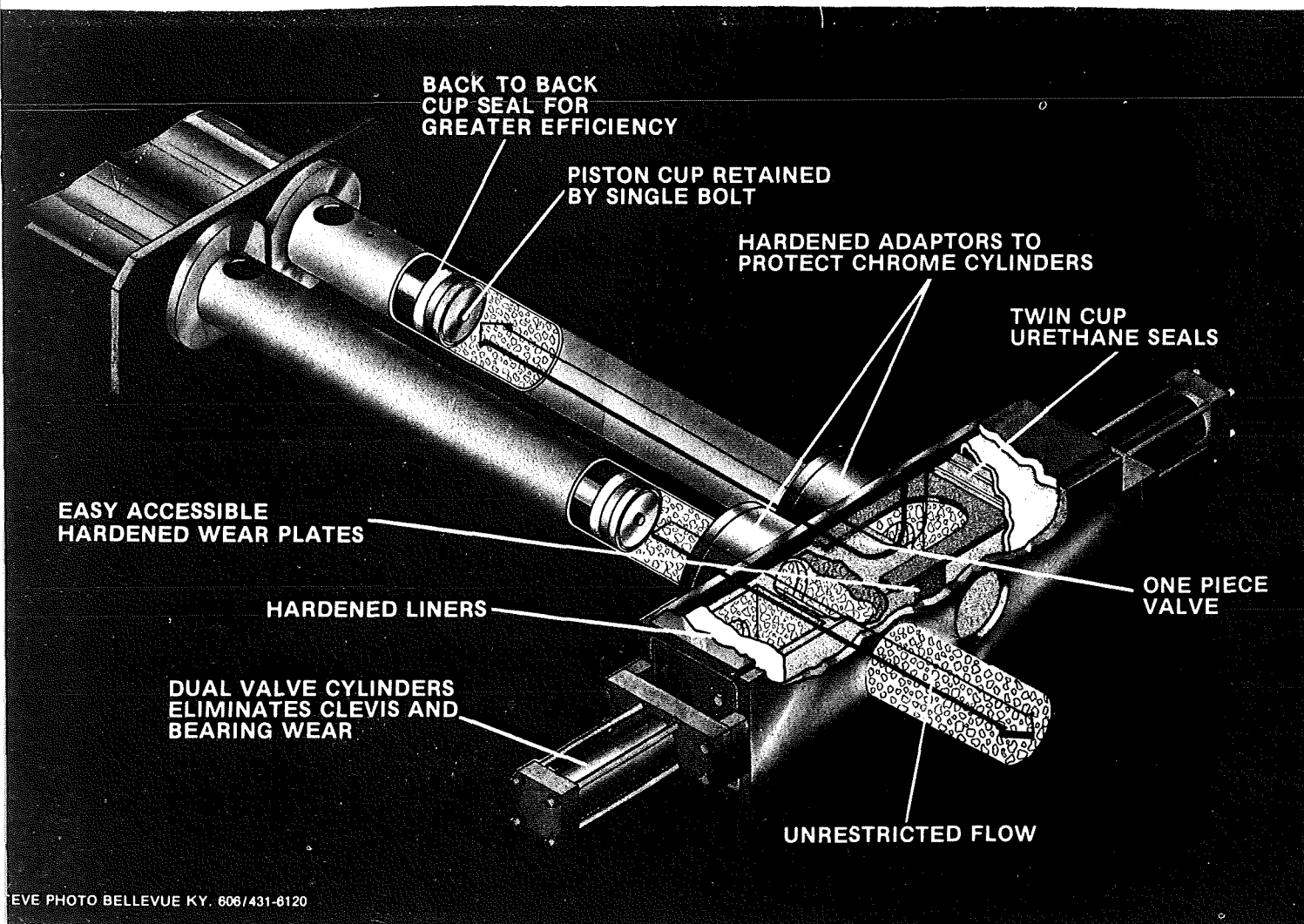
APPENDIX J
SPECIFICATIONS FOR
CONCRETE PUMP

SPECIFICATIONS

305

Pumping Data.....	
Hopper Capacity.....	7 cu. ft.
Discharge Diameter.....	up to 6 in.
Piston Head Pressure (Max).....	600 PSIG
Maximum Aggregate Size.....	1"
Hopper Height.....	108"
Width.....	44"
Lenght.....	72"

Power Units:	Electric Motor
Pump:	Balanced vane, double hydraulic pump.
Cylinders:	Two 3¼ x 12" main ram cylinders w/internal pilot valves.
Valves:	Mobile type 4-way pilot operated (RACINE)
Filter:	One, 100 mesh suction strainer.
Oil Reservoir:	35 gallon pressurized.
Material Cyl:	Dual 6" x 12" honed and hard chrome-plated steel cylinders with replaceable piston seals.
Material Valves:	Indexing Box Valve.



APPENDIX K
SPECIFICATIONS FOR
CONCRETE PLANT

Report to
Foster-Miller Associates Inc.
on
Concrete Batch Plant Specifications

Submitted by:

Dravo Corporation
One Oliver Plaza
Pittsburgh, Pa. 15222

25 September 1980

INDEX

- A. Summary of Recommendations**
- B. Introduction**
- C. Initial Requirements**
- D. Parameters from CSL Specifications**
- E. Batch Plant Components**
- F. Commercial Plants**
- G. General Conclusions**

Specifications

1. 3 bins are required for 2 course aggregates and 1 sand
2. Bulk cement will be used.
3. Up to 3 admixtures will be required.
4. The plant should be compact and portable.
5. The mixer must be capable of producing an uniform mix at the various required rates.
6. Design maximum batching rate 20cy/hr.
7. Design minimum batching rate 1cy/hr.
8. Minimum cement silo capacity 250 barrels.
9. Minimum water tank capacity (if required) 12,000 GAL.
10. Minimum fluidizer tank capacity 2,000 GAL.
11. Air entraining agent to be supplied by the barrel.
12. Aggregate supply belts should be sized to meet the maximum instantaneous demand.
13. Aggregate should be apportioned with controlled feed augers or accumulative weight batching.
14. Meters should be used for water apportioning.
15. Dispense admixtures with properly sized and controlled impulse meters.
16. The concrete plant should be fully automatic in order to adequately control the output volume to meet the needs of the CSL.
17. The mixer should be a continuous auger type or a tilting or non-tilting rotating drum.
18. The silo type should be chosen considering availability and cost.

SPECIFIC RECOMMENDATIONS

- Option 1 - Purchase or lease an automatic commercial batch with the proper mixing capacity
- Option 2 - Extensively modify a Comixo batcher to develop a custom batching unit to meet the needs of the CSL

INTRODUCTION

September 17, 1980

The CSL system requires a concrete mix with well defined, controlled properties. The supply rate requirements of the system are small in comparison to normal placing rates. Therefore, the project requires a batch plant that is capable of consistently producing top quality concrete in small amounts. Unfortunately there is small demand for units with these characteristics. The purpose of this report is to define the batch plant requirements of the CSL system, identify the various equipment options, and make recommendations for action or for course of further study.

INITIAL BATCH PLANT REQUIREMENTS

At this time it is reasonable to assume the following characteristics are required:

1. 3 bins are required for 2 course aggerates and 1 sand.
2. Bulk cement will be used.
3. Up to 3 admixtures will be required.
4. The plant should be compact and portable.
5. The mixer must be capable of producing a uniform mix at the various required rates.

PARAMETERS GENERATED FROM THE CSL SPECIFICATIONS

Shaft Diameters - 12 to 26 ft.

Lining Thickness - 10 to 18 inches.

Lining Rates - 1-5 ft/hr, 50-100 ft/day.

ASSUMED MIX DESIGN -

700 lb Cement

1500 lb Sand

750 lb 3/4 AGG.

750 lb 3/8 AGG.

4 oz. Air (Assumed amount for 5%)

280 oz Fluidizer

30 gal Water

MAXIMUM REQUIREMENTS -

26 ft dia. t = 18 in. 100 ft/day

Batching Rate = 20 cy/hr, 480 cy/day

COMPONENT REQUIREMENTS

	<u>Per - Hr</u>	<u>Per - Day</u>
Cement	14,000 lb	168 TON 8.4 trucks
Sand	30,000	360 TON
3/4	15,000	180 TON
3/8	15,000	180 TON
Air entraining liquid	80 Oz	15 GAL
Fluidizers	44 GAL	1,050 GAL
Water	600 GAL	14,400 GAL

MINIMUM REQUIREMENT -

12 ft dia. t = 10 in. 50 ft/day

Batching Rate = 2.7 cy/hr, 65 cy/day

COMPONENT REQUIREMENTS

	<u>Per - Hr</u>	<u>Per - Day</u>
Cement	1,890 lb	22.6 TON 1.1 Trucks
Sand	4,050	48.6 TON
3/4	2,025	24.3 TON
3/8	2,025	24.3 TON
Air entraining liquid	11 Oz	2 GAL
Fluidizers	6 GAL	142 GAL
Water	81 GAL	1,944 GAL

NOTE: The minimum instantaneous requirement of 1 ft/hour would equal approximately $\frac{1}{2}$ of the hourly rates above.

AVERAGE REQUIREMENT -

19 ft dia. t = 14 in. 75 ft/day

Batching Rate = 8.4 cy/hr, 202 cy/day

COMPONENT REQUIREMENTS

	<u>Per - Hr</u>	<u>Per - Day</u>
Cement	5,908 lb	71 TON 3.5 trucks
Sand	12,600	151 TON
3/4	6,300	76 TON
3/8	6,300	76 TON
Air entraining liquid	34 Oz	7 GAL
Fluidizers	18 GAL	441 GAL
Water	252 GAL	6,048 GAL

Batch Plant requirements concluded from the CSL Specifications:

1. Design maximum batching rate 20 cy/hr.
2. Design minimum batching rate 1 cy/hr.
3. Minimum cement silo capacity 250 barrels
4. Minimum water tank capacity (if required) 12,000 GAL.
5. Minimum fluidizer tank capacity 2,000 GAL
6. Air entraining agent to be supplied by the barrel.
7. Aggregate supply belts should be sized to meet the maximum instantaneous demand.

BATCH PLANT COMPONENT

The following is an outline of the normal components in a concrete plant along with the various alternatives. Some of the characteristics of the alternatives are noted.

MIXERS

1. Continious Auger Type
 - a) Used by Comixo or Concrete Mobile
2. Tilting Mixer
 - a) More expensive than non-tilting
3. Non-tilting rotating drum
4. Vertical shaft turbine mixer
 - a) Good for low slump
 - b) High wear factors
 - c) High horse power

CEMENT SILOS

1. Overhead
2. Ground mounted, auger discharge

AGGREGATE APPORTIONING

1. Volumetric batching through a orifice
 - a) Used on concrete mobile units.
2. Volumetric batching with controlled feed auger
 - a) Used on Comixo Unit
3. Accumulative weight batching
 - a) Commonly used on commercial plants
4. Individual weight batching
 - a) Used on high volume plants

WATER BATCHING

1. Volumetric measuring
2. Water meters

ADMIXTURE DISPENSING

1. Adjustable orifice
 - a) Inexpensive but unreliable
2. Closed chamber positive displacement
 - a) Used on batch-type apportioning
3. Impulse meter
 - a) good positive system
4. Weigh hopper
 - a) most accurate, most expensive

CONTROL SYSTEMS

1. Fully automatic
 - a) Fully interlocked, will not allow an incomplete batch
2. Manual
 - a) all measuring must be viewed, controlled and adjusted by the plant operator
3. Semi-automatic
 - a) designed to suit the user

The following recommendations are made based on a review of the options above.

1. The mixer should be a continuous auger type or a tilting or non-tilting rotating drum.
2. The silo type should be chosen considering availability and cost.
3. Aggregate should be apportioned with controlled feed augers or accumulative weight batching.
4. Meters should be used for water apportioning.
5. Dispense admixtures with properly sized and controlled impulse meters.
6. The concrete plant should be fully automatic in order to adequately control the output volume to meet the needs of the CSL.

COMMERCIALLY AVAILABLE PLANTS

The following information outlines some of the commercial plants available. The list is not intended to be complete but is representative. Approximate costs are included.

Ross Umimix Model 60 -

Cost - \$143,000.

Semi-automatic, 3 aggregates, low profile w/250 barrel cement hopper, should be equipped with 1 c.y. mixer or less for small batching

Johnson-Mobile Mixer 224 -

Cost - \$103,000.

Automatic batching, 3 aggregates, over-head 350 barrel cement silo - should be equipped with less than a 2 cy mixer

Daffin - Concrete Mobile SP Series -

Cost - \$65,000

Skid Mounted - 25 cy/hr, two aggregates, orifice - type agg. apportioning, maximum component storage - materials for 10 cy of concrete. The system was basically designed for redi-mix concrete at remote site.

Sunrise Systems - The Sun Master -

Cost \$54,000.

Capacity 10-12 cy/hr, one aggregate bin, 200 barrel silo, not portable, designed for a small concrete supplier, manual batch controls, 1 cy mixer

U-Cart Concrete Systems MK-10 -

Cost \$64,000.

7 cy/hr, two aggregates, 1 c.y. mixer not portable - 20' wide X 14' long X 48 high. Silo holds material for 55 cy of concrete

Comixo - Model 18-CP -

Cost \$21,000.

18 cy/hr. auger mix, two aggregates, auger apportioning. Air or electric operated, designed for under-ground use. Requires additional equipment for continuous materials supply.

The CSL System must have concrete with consistent properties at the required rate. With this in mind along with the proceeding specifications, it seems reasonable to recommend two possible courses of action to provide suitable concrete.

Option 1 -

Buy or lease an automated commercial plant capable of producing batches of 1/8 cy on a 5 minute interval. Unfortunately the smallest automatic commercial plant available has a design capacity of 60 cy/hr. It will be necessary to derate this capacity to meet the CSL requirements. A small mixer will have to be substituted for the normal 2 cy size. This odd size mixer and the fact that the project will require a relatively small volume of concrete, in three locations, over a span of three years, will make it difficult to arrange a suitable lease.

Budget Estimate for Commercial Batch Unit

C. S. Johnson Mobile 224 with 350 BBL Silo	96,430
Three Component Admix System	9,900
Hopper and Aggregate Charging Conveyor	10,000
Discharge Hopper & Slick Line Charging Belt	5,000
	<u>121,330</u>
Misc. Adder	3,670
Estimated Total Cost	<u>\$125,000</u>

Option 2 -

Adopt the Comixo continuous batching principle and custom design the plant to meet the specific needs of the CSL System. The custom features would be as follows:

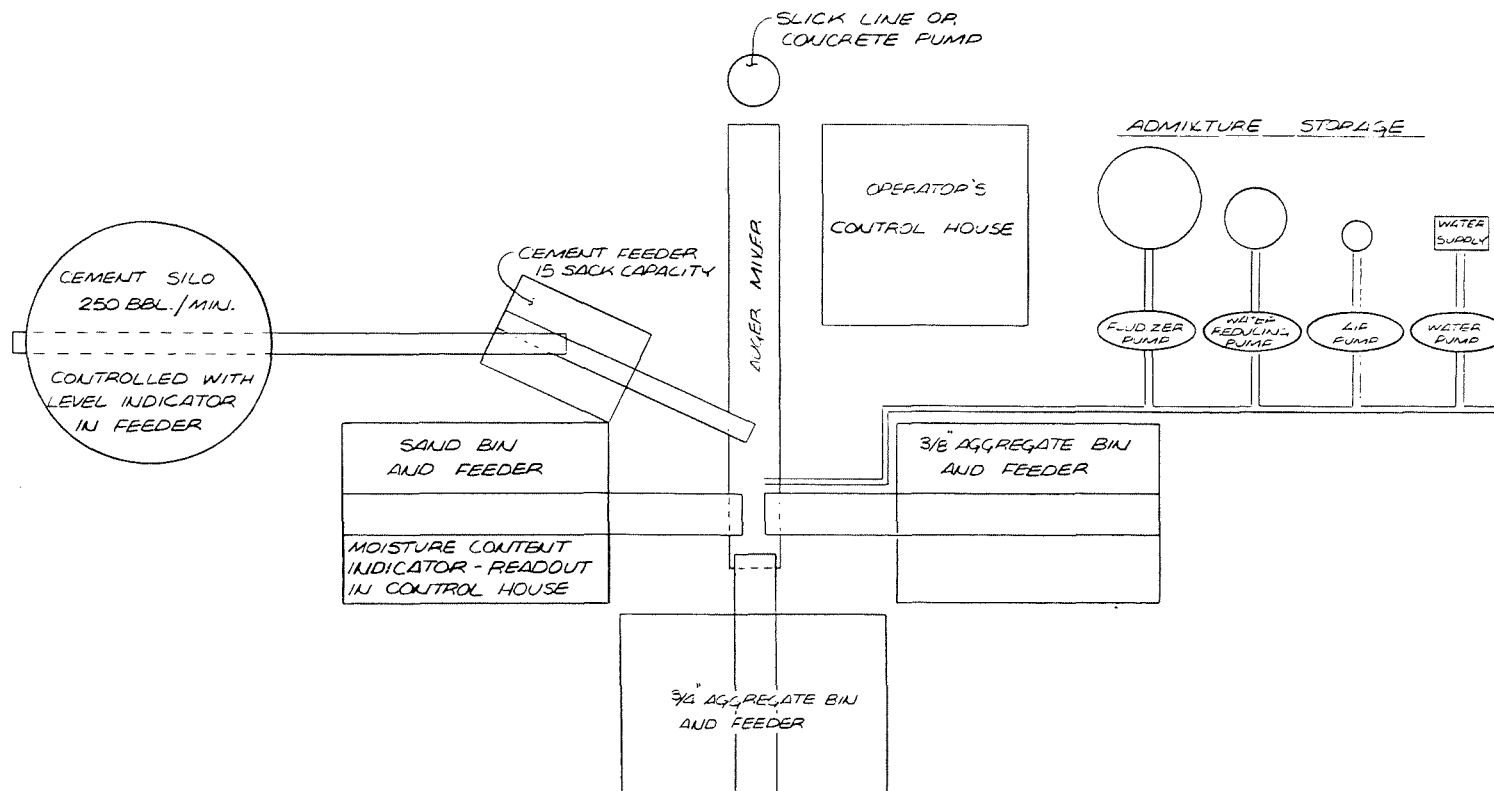
1. Purchase from Comixo 3 aggregate bins and a cement bin each with a feed auger powered with an AC motor. These units would feed a auger mixer similiar to the 18-LP. (See the attached layout).

2. Provide a cement silo for additional storage.
3. Provide 4 variable flow pumps for admixture and water.
4. Control the RPM's of the AC feed motors with frequency controllers for accurate dispensing
5. Connect all functions of the plant to a programmer to provide the correct mix at the rate required by the CSL.

Budget Estimate for Continuous-Mixing Plant

Cement	Bin	6,260	
Sand	Bin	8,920	
Fine Agg.	Bin	8,920	Quote from Comix
Course Agg.	Bin	8,920	with D.C. motors
Mixing Auger		5,718	
		<u>38,738</u>	
Convert DC to AC		-7,000	Man Hours
		<u>\$31,738</u>	
Variable Frequency Drives		17,450	60
Programmable Controller		8,592	200
Cement Silo		12,000	40
Admixture Pumps		4,000	40
Control House		3,000	
Water Pump		2,000	30
Power Panels		2,000	40
		<u>\$80,780</u>	<u>410</u>
Misc. Adders		\$ 4,220	190
		<u>\$85,000</u>	<u>600 X 25 = 15,000</u>

Approximate cost of plant on site, ready to operate, \$100,000 plus freight.



Foster Miller Associates Inc.
 Quote: Semi Automatic 5-15 Yard Per
 Hour Batch and Mixing System

A & B Fabrication
 March 19, 1981

1. Fine aggregate feed system	\$ 9,780
2. Pea rock feed system	\$ 9,780
3. 3/4 inch rock feed system	\$ 9,780
4. Cement feed system	\$ 7,500
5. Fly ash feed system	\$ 6,700
6. Mixing auger	\$ 5,718
7. Control cabinet	\$ 3,500

Fine Aggregate

1. Two yard free standing bin.
2. 9 inch diameter 9 inch pitch hard faced auger.
3. 5 H.P. A.C. drive motor, 240 volt, 3 phase.
4. 5 H.P. gearbox, 25-1 reduction.
5. A.C. variable speed controller.
6. Magnetic starter.

Pea Rock

1. Two yard free standing bin.
2. 6 inch diameter half pitch auger.
3. 5 H.P. A.C. drive motor, 240 volt, 3 phase.
4. 5 H.P. gearbox, 25-1 reduction.
5. A.C. variable speed controller.
6. Magnetic starter.

3/4 Inch Rock

1. Two yard free standing bin.
2. 9 inch diameter 9 inch pitch hard faced auger.
3. 5 H.P. A.C. drive motor, 240 volt, 3 phase.
4. 5 H.P. gearbox, 25-1 reduction.
5. A.C. variable speed controller.
6. Magnetic starter.

Cement

1. Fifteen sack bin free standing.
2. 6 inch diameter half pitch auger.
3. 3 H.P. A.C. drive motor, 240 volt, 3 phase.
4. 3 H.P. gearbox, 25-1 reduction.
5. A.C. variable speed controller.
6. Magnetic starter.
7. Bin level indicator activating feed from storage silo.

Flyash

1. Ten cubic feet bin free standing.
2. 6 inch diameter half pitch auger.
3. 3 H.P. A.C. drive motor, 240 volt, 3 phase.
4. 3 H.P. gearbox, 25-1 reduction.
5. A.C. variable speed controller.
6. Magnetic starter.
7. Bin level indicator activate alarm on low level.

Foster Miller Associates Inc.
Quote: Semi Automatic 5-15 Yard Per
Hour Batch and Mixing System

B & B Fabrication
March 19, 1981
Page 2

Mixing Auger

1. 9 inch diameter 9 inch pitch with N1-Hard replaceable wear shoes.
2. Drive motor 15 H.P., 240 volt, 3 phase.
3. Gearbox shaft mount, 6.23 reduction.

Water System Valving

1. Mounted on mixing auger.
2. Pressure reducing valve.
3. Solenoid valve.
4. Hand adjustable needle valve.
5. Inline flow rate valve.
6. Water meter.

Control Cabinet and Control Station

1. Enclosure with double door front.
2. 50 H.P., 100 AMP main breaker.
3. All A.C. controllers and magnetic starters will be installed in NEMA 4 enclosure.
4. All adjusting potentiometers for motor speed will be mounted externally, on the side of control cabinet, with a hinged cover over controls.
5. All motor tachometers mounted externally, on side of control cabinet.

Motor Control

Each drive motor will have a pulse gear mounted on the motor shaft for read-out to an electric tachometer mounted in the control panel.

Tach dial face will be calibrated to auger R.P.M. Tachs will have high/low adjustable set points connected to alarm horn for monitor.

A.C. Motor Speed Control

Adjustment for speed control will be by potentiometer.

A ten turn dial will drive the potentiometer. 999 numbers are available on the ten turn dial, for coming back to a specific auger R.P.M. for accuracy.

Items Needed For Checking Ratios

1. Two (2) boxes at least three cubic feet.
2. One each 1000 lb platform scale.
3. Water supply to fill 100 gallon surge tank at least ten gallon per minute.
4. Power to our panel, 240 volt, 3 phase at least 80 AMP.
5. Front-end loader.

Foster Miller Associates Inc.
Quote: Semi Automatic 5-15 Yard Per
Hour Batch and Mixing System

B & B Fabrication
March 19, 1981
Page 3

Ratios

Feeding of the different combinations of aggregates and cement is accomplished in the R.P.M. Batcher by metering the materials by metering augers.

Since an auger feeds material from the back of the bin through the material in the bin, a constant density of the material is discharged into the mixing auger due to consistent packing of material in the auger.

Each material auger is driven by variable A.C. motors with A.C. variable controller.

Infinite ratios are available by dialing in a desired speed of each auger.

Determining the R.P.M. of each auger is accomplished by batching from each material feed auger into a container for one (1) minute intervals and weighing the results of each batch.

There is no shortcut to finding ratios other than above method.

EXAMPLE

SAND

1. Fill the material bin.
2. Dial in 20 R.P.M. auger speed.
3. Place a container under the auger discharge.
4. Start auger feed and time for one (1) minute.
5. Weigh the results.
6. Repeat at least three times logging each batch weight.
7. Divide the weight of each batch by 20 R.P.M. Results are lbs of material discharged per R.P.M.
8. Average sands around the country will be 16.5 lbs per turn. however there are some lighter and heavier sands and the 16.5 lb figure cannot be assumed.
9. Experience has shown that different speeds will discharge slightly different weights per turn. 20 R.P.M. will give the same weight as 15 R.P.M. and 20 R.P.M. 30 R.P.M. will vary slightly, so again weights cannot be assumed. Increments of 5 R.P.M. is suggested when looking for weights per turn.
10. Finding weights per revolution on rock and cement have to follow the above procedure.
11. The above information is true with any type of volumetric batch plant on the market today bar none, whether it is an auger feed, gate and belt feed or pocket wheel feed. All ratios have to be proven on the jobsite with the materials being used.

Foster Miller Associates Inc.
Quote: Semi Automatic 5-15 Yard Per
Hour Batch and Mixing System

E & B Fabrication
March 19, 1981
Page 4

Water

Normally in our shotcrete application, water is adjusted to pumping conditions existing on the jobsite. We go after as low a slump that the concrete pump will operate with. This means from a 1" slump up to a 3" slump in different pumps. With this type of application the Batcher operator is eye-balling the slump.

Your application calls for a 6" slump with additives, so a more accurate water control is needed.

Again the ratio will have to be proven by trial method and logging results.

EXAMPLE

1. Batcher has been set for 10 yards per hour.
2. Additive pumps have been set for your amount needed for 10 yards per hour.
3. Your formula calls for 30 gallon per yard.
4. The water bar on the mix auger is supplied with a block valve and a by-pass valve for testing purposes.
5. Water is introduced into the bar by going through a water meter into an adjustable in-line flow rate valve with visual read-out into the pressure reducer into the solenoid operated water shut-off into a needle valve and discharging into the mix auger or by-pass test line.
6. By filling a measured container for one (1) minute the calibrated needle valve can be adjusted for numerous gallons per minute for your various mixes.

Operation

After ratios have been set Batcher is ready for operation.

1. Start the mixing auger.
2. Start all feed motors by pushing each of the individual breakers to ON position.
3. All auger drive motors, water pump, chemical pumps are now running.
4. There is one switch marked FEED SYSTEM that has not been activated. This switch will open a solenoid valve to the:
 - A. Water bar.
 - B. Air vibrator in the sand bin.
 - C. To each additive lines.
5. While operating the Batcher this is the only switch the operator will turn ON and OFF to mix material.

When the feed system is shutdown the mixing auger will continue to run discharging all of the mix in the auger.

APPENDIX L
TEST PLAN FOR
CSL SIMULATION TESTS

Test Plan
for
Continuous Shaft Lining System
Simulation Studies

Contract No. DE-AC01-79ET14223

Submitted to:

U.S. Department of Energy
Carbondale Mining Operations
P.O. Box 2587
Carbondale, IL. 62901

Submitted by:

Foster-Miller Associates, Inc.
350 Second Ave.
Waltham, MA. 02154

Revision Number	Prepared By	Checked By	Approved By	Date
Original Issue	<i>John J. Lutz</i>	<i>J. Lutz</i>	<i>Robert J. Lutz</i>	11/26/80
Revision 1	<i>John J. Lutz</i>	<i>Ray Anderson</i>	<i>Robert J. Lutz</i>	2/14/81

1. INTRODUCTION

Above ground simulation tests of the continuous shaft lining system (CSL), will be carried out at the FMA outdoor test facility in Framingham, Massachusetts. The test facility (Figure 1) includes a 45-foot test assembly, a three component concrete delivery system, and appropriate ancillary equipment.

The test assembly consists of a 55-foot high central tower and external form, which is comprised of a 30-foot high cylindrical steel casing supported by six 15-foot high steel columns (Figure 2). The 15-foot diameter casing is comprised of six 5-foot long flange mounted cylindrical sections together simulating a 30-foot section of mine shaft. The entire tower assembly is located above ground.

Within the casing, a 13-foot diameter, cylindrical slipform and multiported curb ring are independently linked by means of hydraulic jacks to a movable jack frame (Figure 3). The jack frame translates vertically on climbing jacks, which transmit the load through equally spaced vertical rods located in the annular space between the casing and slipform, and running the full height of the tower.

The slipforming system places concrete through the curb ring while the curb ring and slipform traverse downward through the casing. The concrete is placed under controlled pressure and vibration, and is supported by the slipform for a predetermined time to allow the concrete to set and gain sufficient strength to be self-supporting upon leaving the form.

Simulation tests will be performed in two parts. First, Proof of Concept tests will be carried out in the fall of 1981 and early spring of 1982. Then, Extended Reliability testing will be conducted from spring into the summer months of 1982 as required.

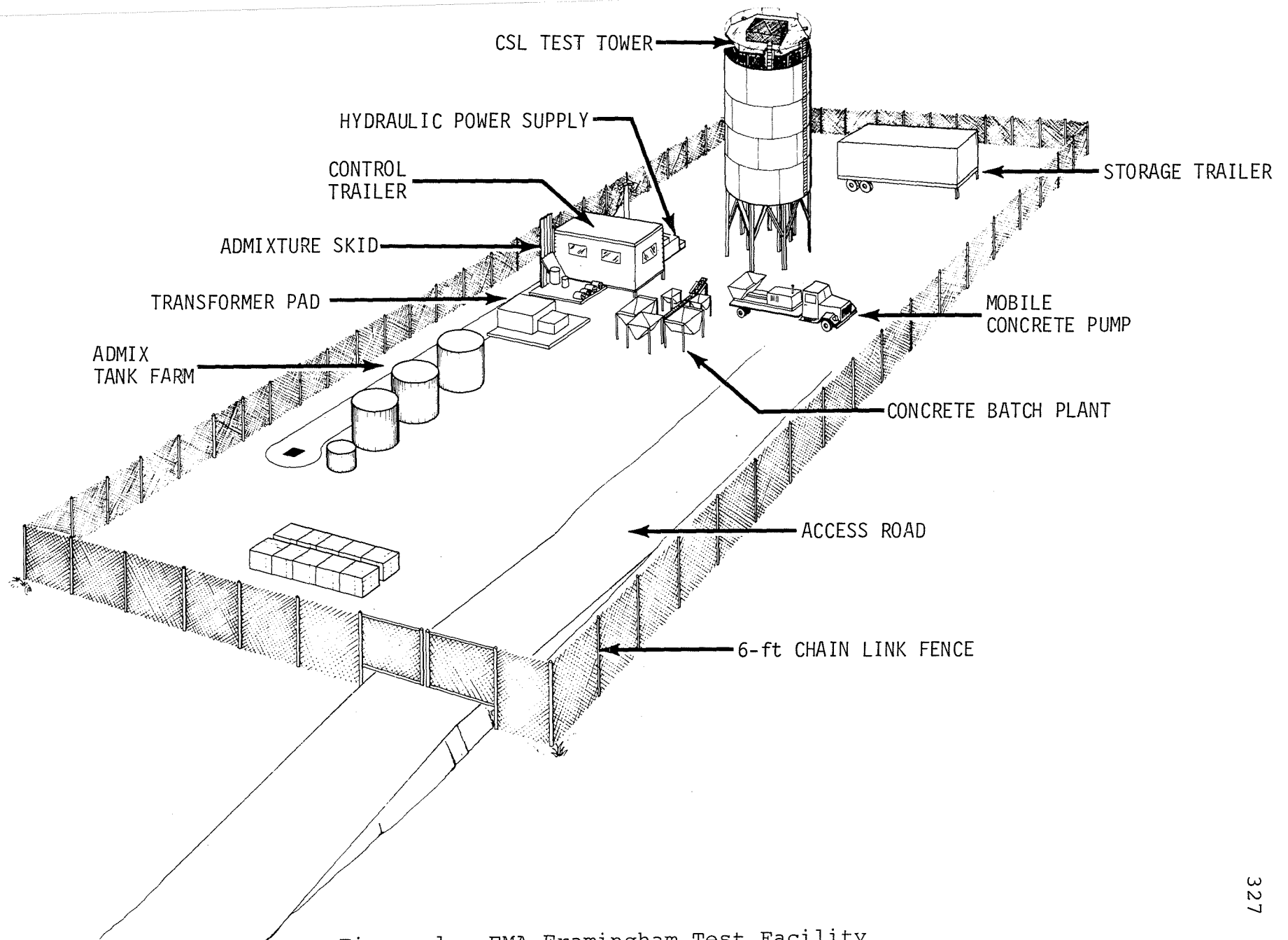


Figure 1. FMA Framingham Test Facility

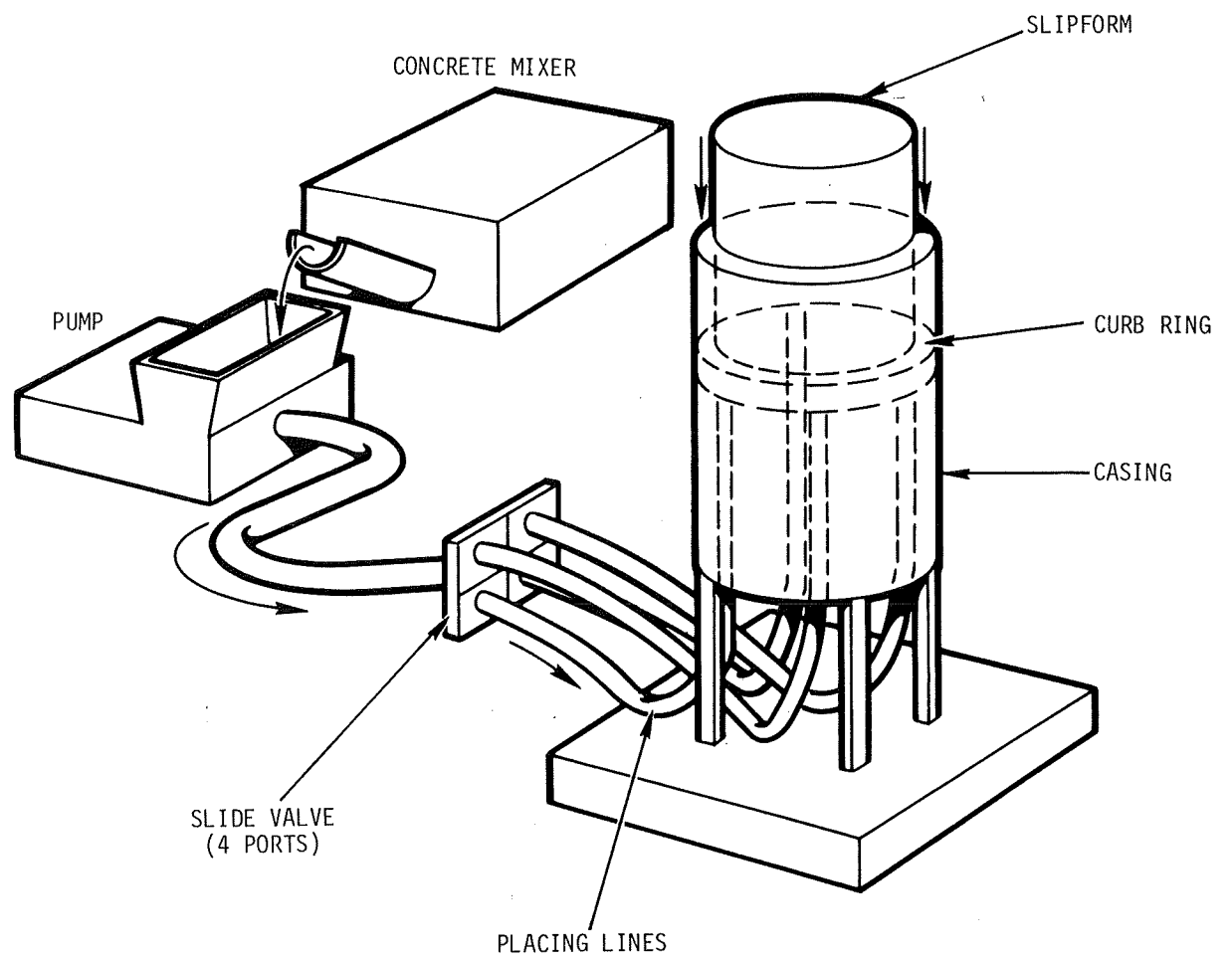


Figure 2. Simulation Test Rig

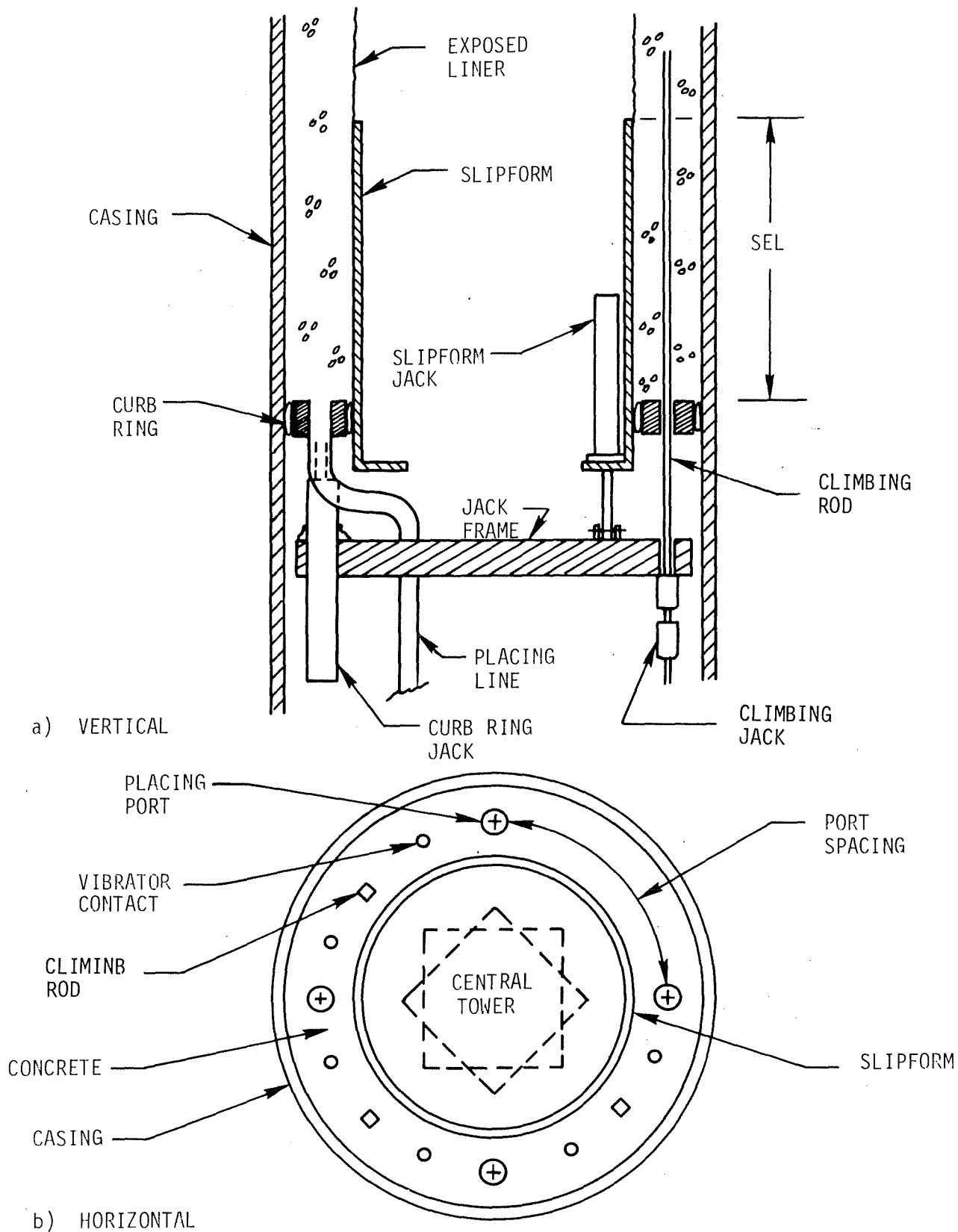


Figure 3. Simulation Test Rig Cross-Section

Proof of Concept testing during the fall of 1981 will evaluate concrete placing and concrete distribution under various modes of operation (see Section 3.5.1). Proof of Concept testing during the spring of 1982 will demonstrate slip-forming at various advance rates and the operation of a curb ring seal designed for underground use (see Section 4.1).

Extended Reliability testing will demonstrate component resistance to wear or fatigue, the effect of concrete build-up and the system's ability to negotiate slough zones (see Section 4.2).

2. TEST OBJECTIVES

The fundamental objective of the simulation tests is to demonstrate the viability of both the process and the CSL equipment required to continuously slipform a concrete shaft lining in the downward direction, utilizing a full-sized prototype.

The specific objectives of the program include:

- Placing uniformly distributed concrete through multiple ports evenly spaced around a complete circular curb ring
- Continuously forming a vertically standing cylindrical concrete liner which supports itself upon exiting the slipform
- Determining the allowable variations in advance rate which the system can sustain
- Determine the most effective startup and stopping procedures
- Evaluating the system's adaptability to the step form mode of operation
- Evaluate performance of the alignment control systems for the curb ring and slipform
- Demonstrating the prototype seal performance on a complete circular curb ring.

In order to successfully place a lining, the mixing system must batch a pre-selected concrete mix design within tolerances

defined under Section 3.3.1. The placing system must then expediently transport and distribute the mix to the curb ring ports in equal proportions and maintain pressure on the wet concrete mix (while held within the confines of the shaft wall and the moving slipform and curb ring). The control system must maintain alignment within the shaft in order to place a liner of uniform thickness, and must sufficiently support the previously placed concrete immediately above the slipform to ensure worker safety and to ensure that liner distortion/cracking does not exceed the standard liner design requirements.

3. TEST PARAMETERS

The broad range of performance specifications combined with the complex nature of the CSL yields a tremendous number of potentially variable parameters. Practicality and laboratory test results have enabled us to fix a number of these variables. Still, there are 10 variable parameters with over 1000 potential combinations, necessitating an adaptive experimental program which will allow these parameters to be sequentially fixed as testing progresses.

3.1 Fixed Parameters

3.1.1

Based on CSL performance specifications (Appendix A) the following parameters will be fixed during CSL testing:

- Shaft diameter (O.D.) 15 feet
- Liner thickness 12 inches

3.1.2

Based on laboratory tests conducted in the concrete lab, and slipform and distribution test rigs (Appendices B), the following parameter will be fixed during CSL testing:

- Design of the concrete mix will remain constant (Section 3.3.1)
- Four concrete ports will be placed symmetrically around the curb ring (Figure 3)
- Eight vibrators will be symmetrically placed around the curb ring (Figure 3)

- Four hydraulic actuators will be symetrically located around the curb ring
- Four pressure transducers will be symetrically placed around the curb ring.

3.2 Variable Parameters

3.2.1 Concrete Placement Parameters

- Concrete pressure at curb ring
- Degree of concrete vibration
- Frequency of slide valve operation
- Number of active placing ports.

3.2.2 Slipforming Parameters

- Curb ring/slipform advance rates
- Concrete age when exiting the slipform
- Slipform taper

3.2.3 Operational Control

- Curb ring and alignment control method
- Slipform alignment control method
- Start/stop method

3.3 CSL Concrete

3.3.1 Concrete Mix Design

The concrete mix criteria based on pumping requirements and desired range of CSL advance rates is as follows:

- Initial slump: 6 to 8 inches
- 45 minute slump: 1 to 3 inches

- Strength at 2 hours: 50 psi
- Strength at 3 hours: 100 psi
- Minimum concrete ultimate strength: 3000 psi

Based on slipform testing and laboratory tests of various concretes using Type I, Type II, Type III, aluminous, and very high early cements, the following concrete mix design was selected for CSL testing:

BATCH QUANTITIES

<u>Material</u>	<u>lbs/yd³</u>	<u>Tolerance</u> (percent)
Type III Cement	752	2
Sand	1230	3
3/4-in Stone	905	3
3/8-in Stone	605	3
Water	290	2
Mighty 150 Superplasticizer	11.28	3
Darex Air Entraining Agent	0.70 (11.3 Floz)	3
Calcium Chloride	22.56	3

Minor changes to mix design quantities may be required in the simulation testing to account for cement brand, variation in aggregate gradation, and ambient temperature.

Concrete will be continuously volumetrically batched on site by auger metering materials to a transfer conveyor which in turn feeds a mix auger (Figure 4). Water and admixtures will be metered by flow control valves from constant pressure sources to the auger mixer (Figure 5). The auger mixer will transfer the freshly batched concrete to the remix hopper feeding a twin cylinder reiprocating concrete pump. The concrete will then be pumped via 40 feet of 4-inch slick line to a 4-way slide valve (Figure 6), which will distribute the concrete via 4-inch rubber hoses to the 4 concrete ports on the CSL curb ring.

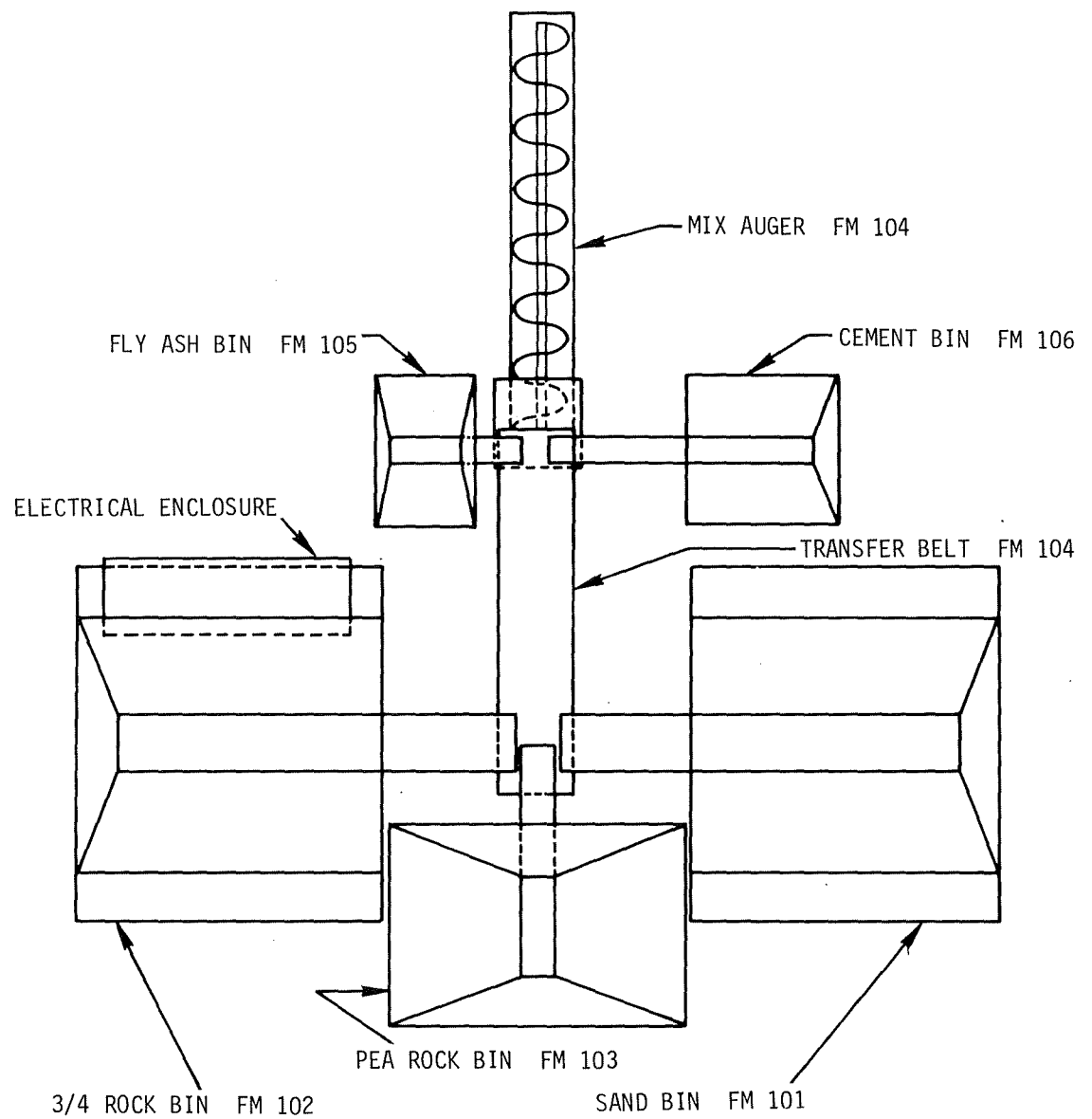


Figure 4. Concrete Batch Plant

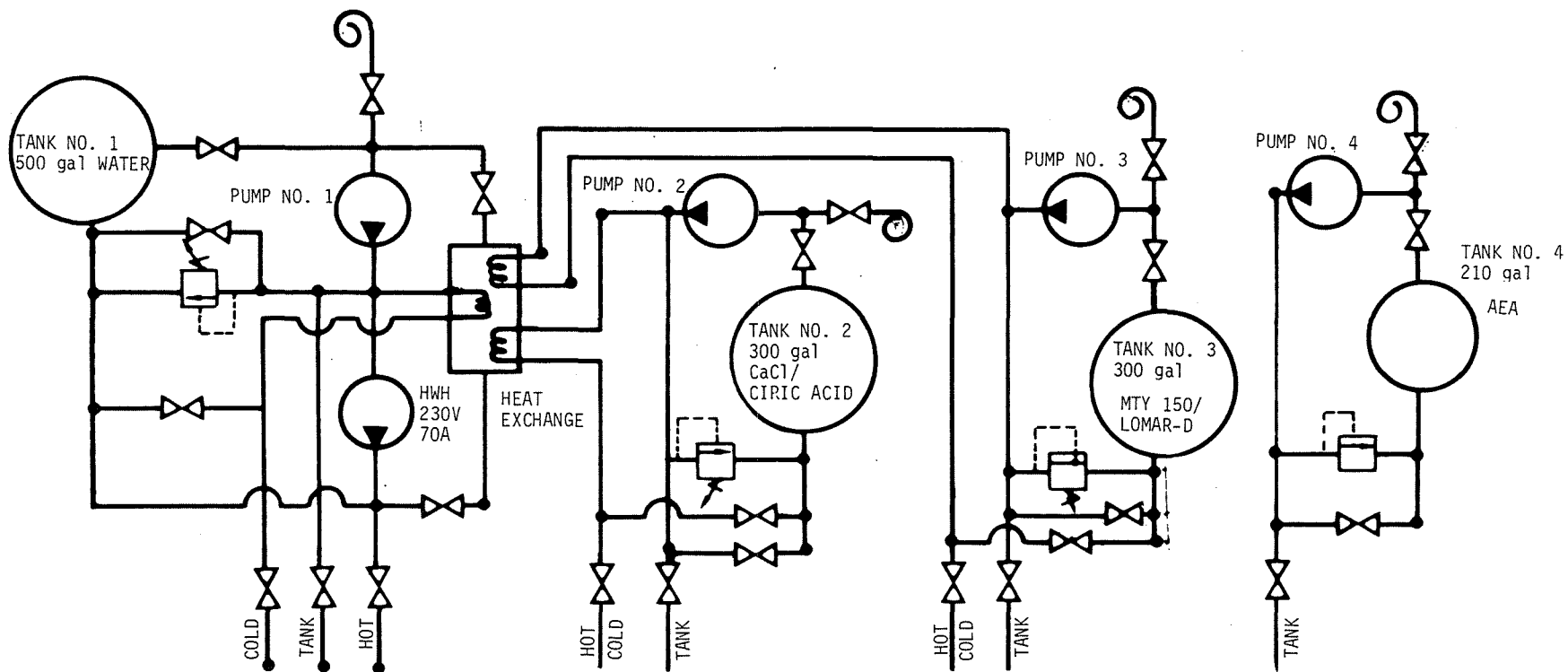


Figure 5. Addmix System

3.3.2 Concrete Batching Hardware

The concrete batching system is a portable unit which can be easily transported around the CSL site. The system consists of the following components:

- Three two-yard free standing aggregate bins (for 3/4", 3/8" stone and sand) with 9-inch diameter, 9-inch pitch metering augers, driven by 5 H.P. variable speed A.C. motors
- A fifteen sack free standing cement bin with a 6-inch diameter half pitch metering auger driven by a 3 H.P. variable speed A.C. motor
- An 8-foot long transfer conveyor
- A 10-foot long mixer with 9-inch diameter, 9-inch pitch mixing auger, driven by a 15 H.P. variable speed A.C. motor.

The concrete batch system requires 80 amps of 220 volt 3 phase 60 cycle power.

3.3.3 CSL Admixture System

The CSL admixture system is designed (in conjunction with) the CSL continuous concrete batching plant. The admixture system design is based around 4 stainless steel pumps that deliver all required fluids to the concrete mixer. These fluids include water, calcium chloride solution, superplasticizer, and air entrainment agent. The admixture system also has an additional pump which supplies all wash down water for the CSL facility. The system can be divided into two units—a tank farm for storage of various fluids and a skid unit containing all

mechanical systems. The specific components of each unit are listed below:

- Tank Farm:

- 1 1500 gal water tank
- 1 1100 gal solution tank
- 1 1100 gal water tank
- 1 500 gal solution tank

- Skid Unit:

- Base 6-ft x 10-ft welded steel frame
- 4 stainless steel pumps rated at a minimum of 5 gpm. The flow from these pumps is pressure regulated through a 20' combination pressure relief/regulation standard pipe system. The flow to the mixer system is controlled by needle valves and monitored by flow meters. The unused portions of pumped fluids are returned to the tank.
- 1 150 gal hot water heater
This heater is capable of 100°, 100 gph temperature rise. It is used to heat the mix water and other solutions through a heat exchange system.
- Heat Exchange System
This system is used for heating or cooling solution(s) as necessary, to control the concrete mix temperature.
- Wash Down Water Pump
This pump is used to supply the facilities wash water. It is capable of providing 15 gpm at 80 psi.

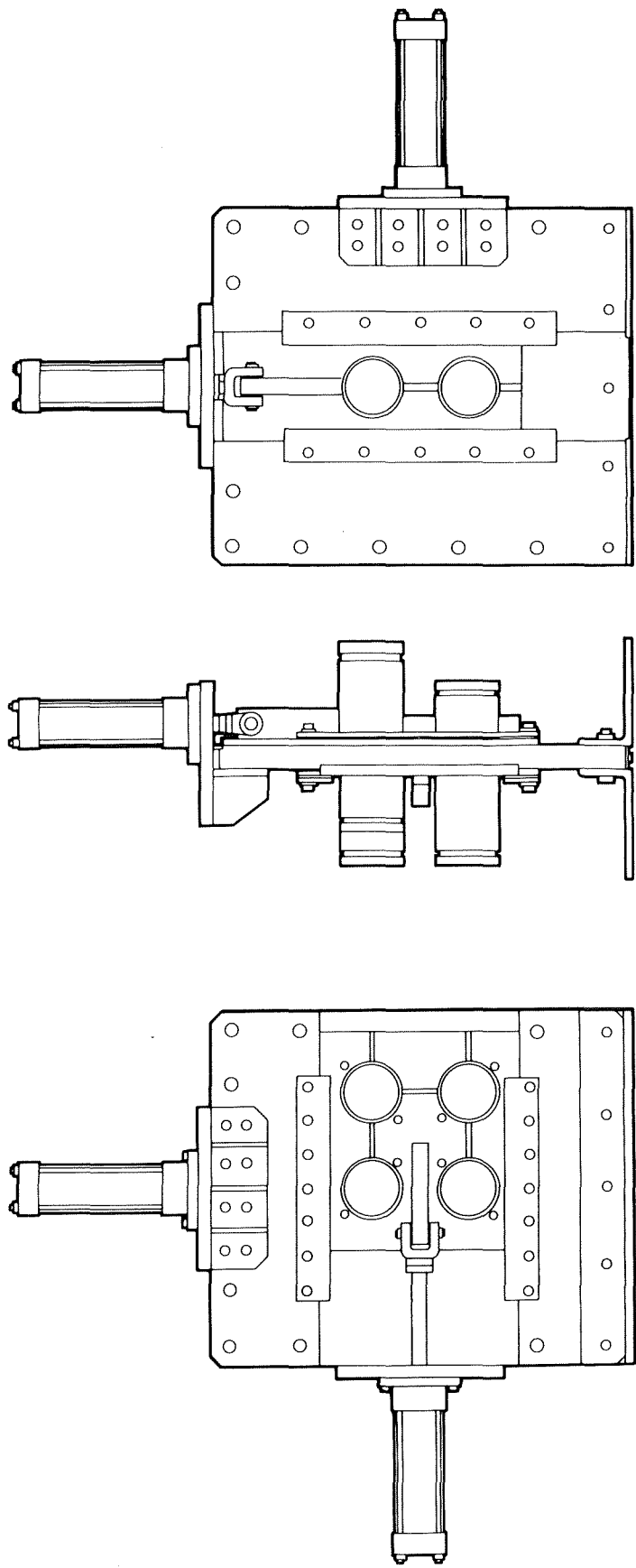


Figure 6. Four-Way Slide Valve

3.3.4 Four Port Slide Valve

The four port slide valve is designed either to direct concrete to any one (1 of 4) port on the curb ring when fed by a single input feeder line, or to two (2 of 4) ports simultaneously when fed by dual input feeder lines (Figure 7). The valve is hydraulically actuated by two 2½-inch diameter, 7½-inch stroke hydraulic cylinders operating under a pressure of 800 to 1000 psi. The valve is manually controlled by a "joy stick" located in the CSL control trailer (Section 4.1).

The system is plumbed into the hydraulic circuit of the CSL Hydraulic Power Unit (HPU) (Appendix C). The valve can be cycled at a variable rate. The transfer time between positions is approximately 2 seconds when the valve is operated at 500 psi. This can be reduced to less than 1 second by increasing the actuator pressure. The minimum cycle time (time per port including transfer) is approximately 5 seconds.

The slide valve will be fixed on the first landing of the CSL central tower and will distribute concrete to the 4 curb ring ports through 4-inch rubber hoses.

3.4 CSL Slipforming Hardware

3.4.1 CSL Curb Ring

The curb ring is a box design toroidal ring, 12 inches deep and 11½ inches thick with ½ inch nominal diametrical clearance between the curb ring and the slipform and between the curb ring and the outer casing (simulated shaft) (Figure 8). The curb ring contains the following components:

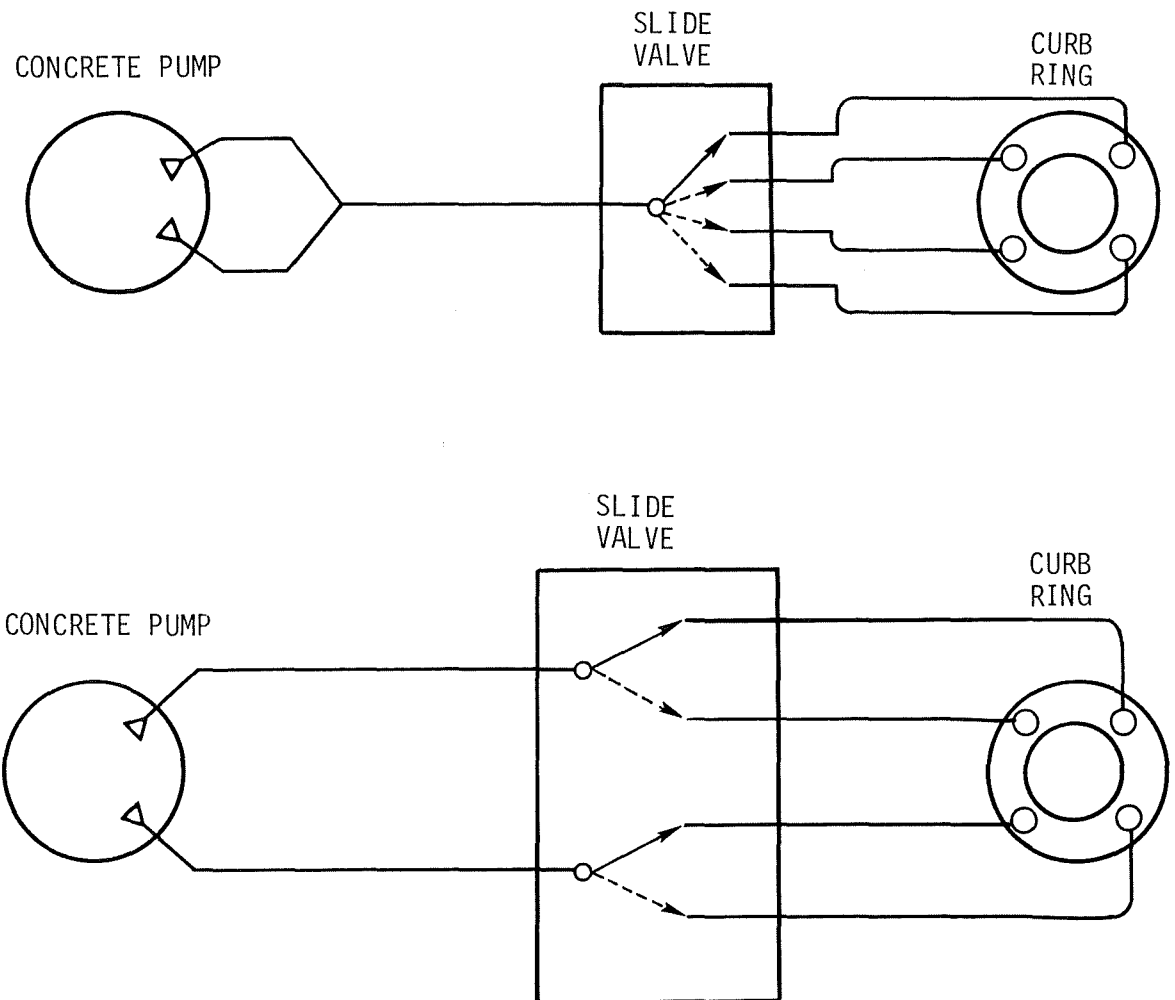


Figure 7. Optional Pumping Arrangements

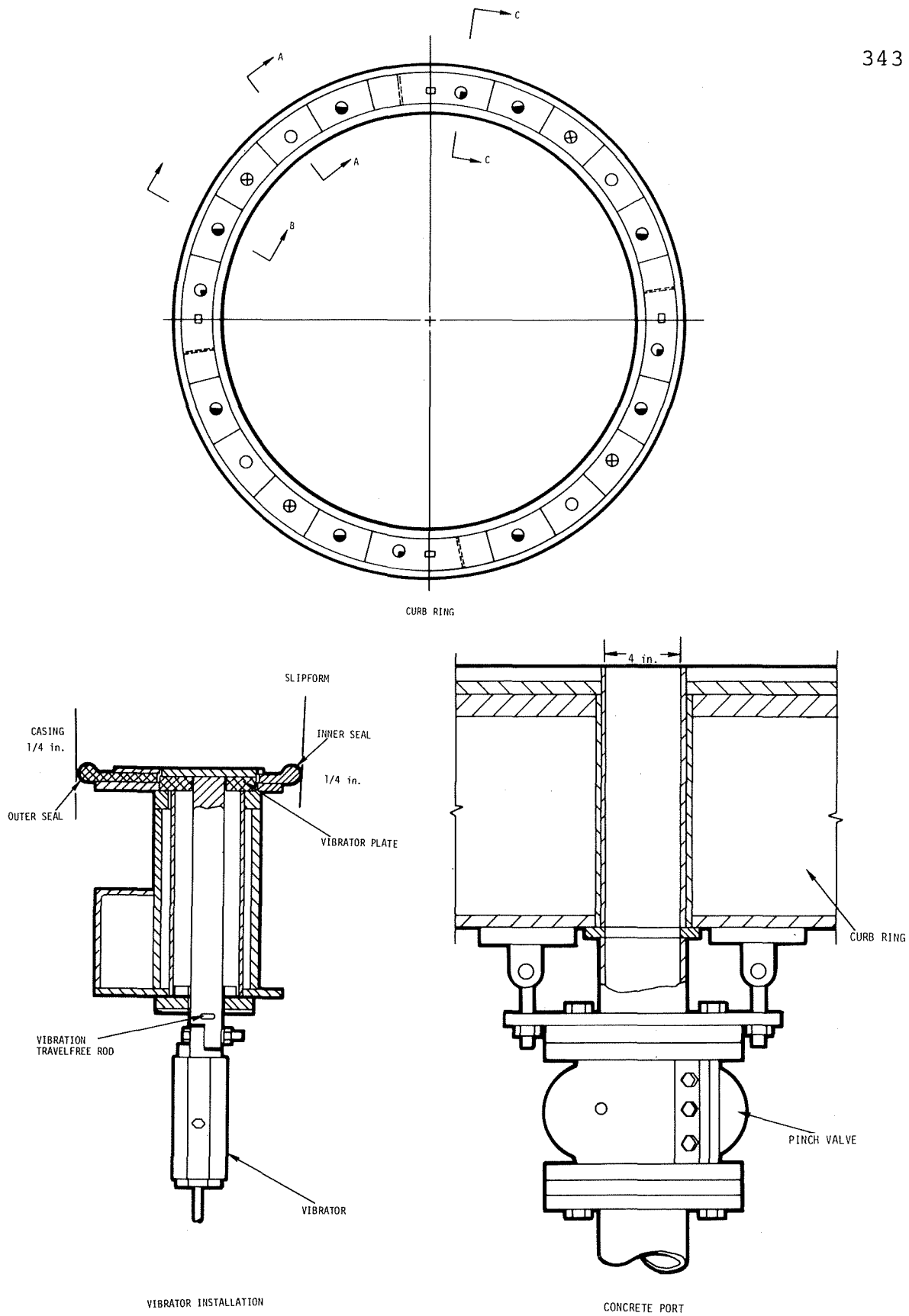


Figure 8. CSL Curb Ring

- 4 clearance holes for 2-inch square imbedded jacking rods (Figure 8a)
- 4 concrete pressure transducers (Figure 8a)
- 4 placing ports with removable sleeves and pneumatically operated pinch valve for cutting off concrete flow (Figure 8b)
- 8 pneumatic vibrators connected to the vibrating transfer plate on top of the curb (Figure 8c)
- Inner and outer curb ring seals (Figure 8c)
- Mounts for 4 pinned rod ends of the 132-inch stroke curb ring hydraulic actuators (6 inch cylinders with 3 inch rods). The cylinders are toroidal mounted at mid cylinder to the CSL jacking frame.

The pneumatic pinch valves will be closed when concrete pumping is discontinued at the end of a test.

The pneumatic vibrators will be cycled in any designed pattern (multiples of 2) which will be automatically actuated by a timer during testing.

3.4.2 CSL Slipform

The 10-foot long slipform is designed to have either a tapered (truncated cone) or straight cylindrical slope. Tapering in at the top is accomplished by inserting four symmetrically spaced axial wedges in the slipform circumference (Figure 9). The wedge inserts can be replaced by straight inserts to make the slipform a straight cylinder.

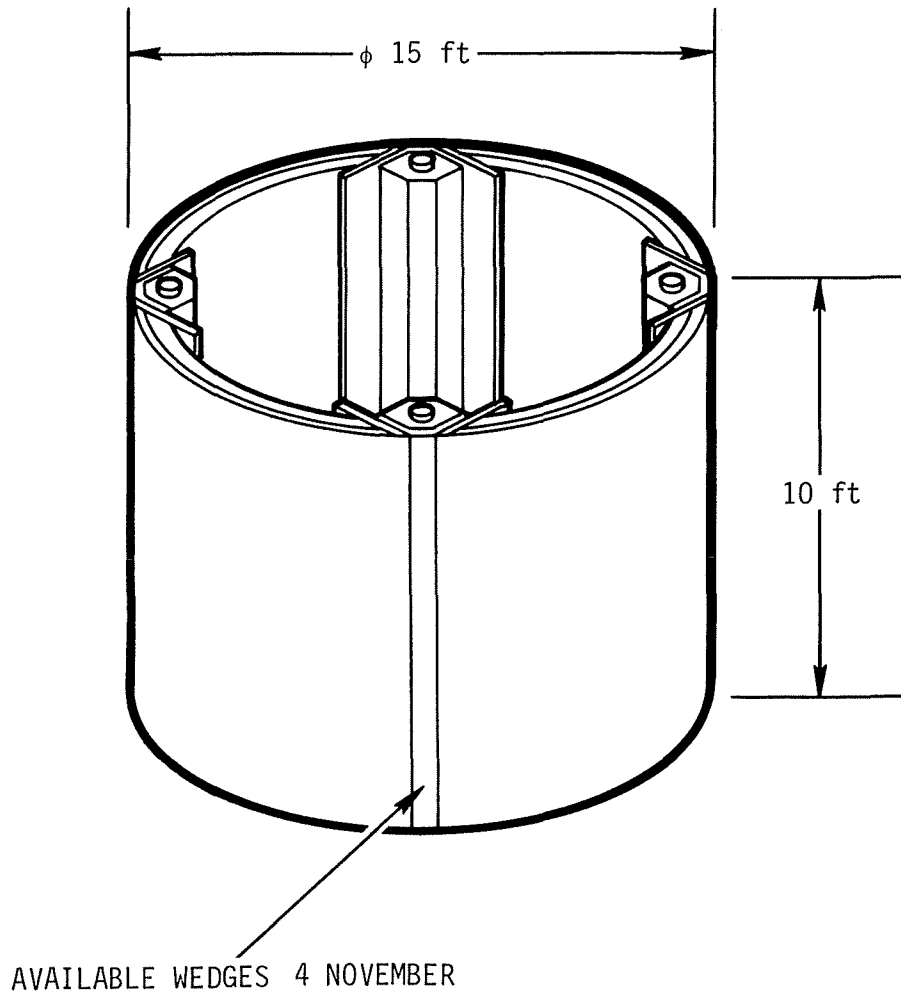


Figure 9. CSL Slipform (Showing Wedges)

The slipform is connected to the jacking frame by four 30-inch stroke hydraulic actuators (6-inch cylinders with 3-inch rods). There are also four pinned linkage connectors which work in parallel to the hydraulic actuators when collapsing the slipform for form release or changing taper.

3.5 Operation of the CSL

The overall system operates as follows:

1. The concrete batch plant is set to produce an output of concrete which corresponds to the desired advance rate. The concrete pump must pump at whatever rate the batch plant outputs (the pump remix hopper allows for a slight surge control).
2. The curb ring advances downward at a rate dictated by the inflow of concrete while maintaining as constant and as uniform a concrete pressure as is possible, by means of hydraulic pressure in the curb ring hydraulic actuators.
3. The cycling of vibrators and slide valve transferring of concrete delivery to each of the concrete ports in the curb ring help to maintain uniform pressure and attain uniform concrete distribution.
4. Under normal operation, the slipform is directly linked to the jacking frame so that these two components move as one. The slipform is therefore advanced downward by lowering the jacking frame on the four 2-inch square climbing jack rods. Concrete age when exiting the slipform is controlled by adjusting the slipform advance rate.

As an alternative to lowering the jacking frame, a limited stroke slipform advance can be attained by lowering the slipform relative to a locked in place jacking frame by activating the 30-inch stroke slipform hydraulic actuators. This option will be used on tests conducted during fall of 1981.

During a full slipform test the sequence of operation is as follows:

1. Concrete pumping is initiated, forcing the curb ring to advance downward (Figure 10b). The slipform advances at an extremely slow rate.
2. When the initially placed concrete reaches the exposure age (approximately 2 hours) the slipform and jacking frame begin advancing at a rate comparable to that of the curb ring, (Figure 10c), thus maintaining a constant slipform effective length (distance from top of curb ring to top of slipform).
3. Upon discontinuation of concrete pumping, the curb ring stops advancing while the slipform and jacking frame continue to descend until the concrete has been fully exposed (Figure 10d).

3.5.1 Alternative Modes of Operation

Initial Proof of Concept testing will require an adaptive experimental approach as all aspects of CSL behavior are not known at this time. In spite of diligent laboratory testing, analysis, and design efforts, certain unknowns still exist which can only be answered by information obtained from CSL testing. Consequently, optional operating modes must be available and a flexible experimental plan must be devised to solve problems that might arise during testing.

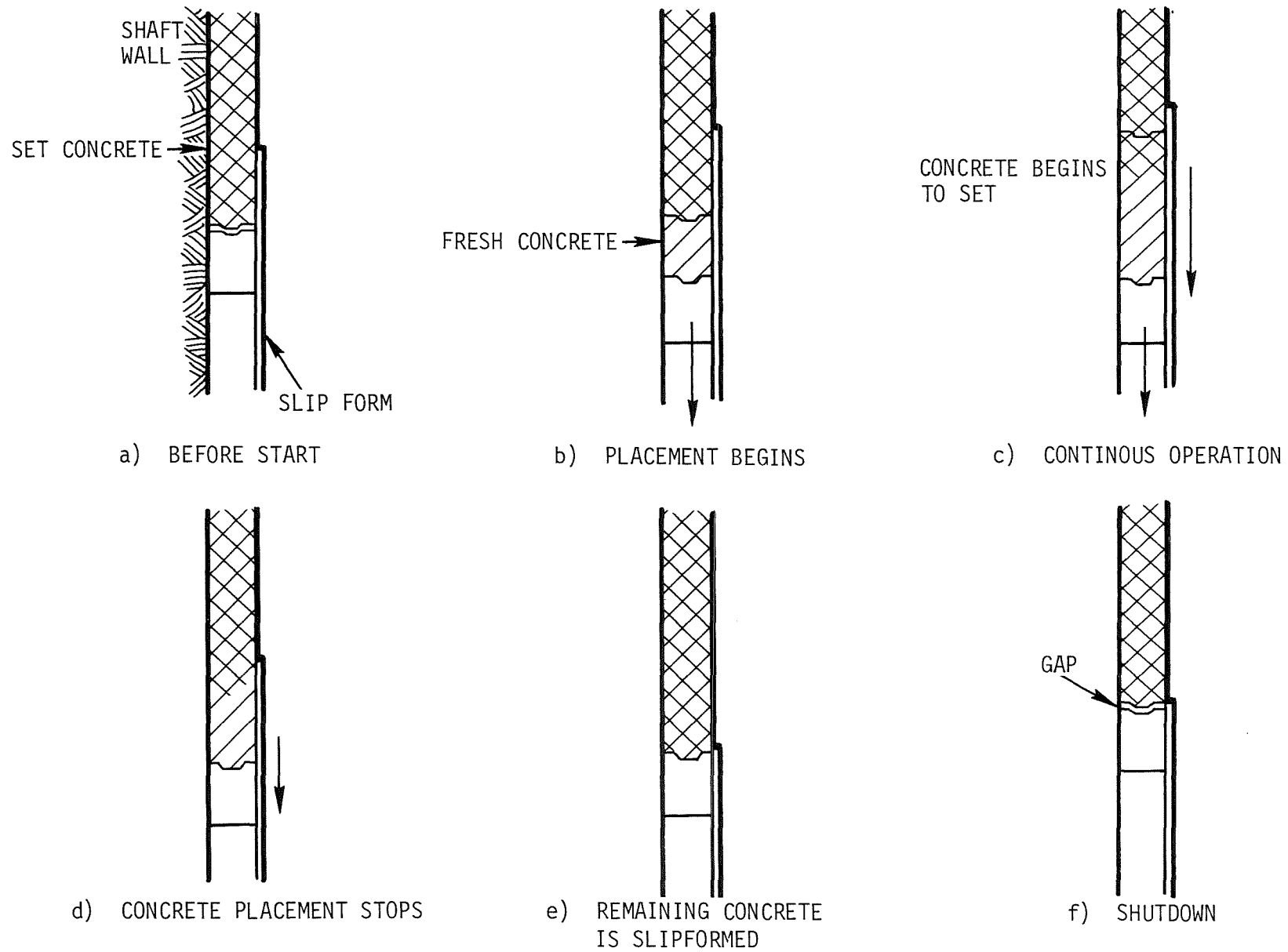


Figure 10. CSL Operating Sequence

We have determined that there are 4 practical operating modes of the concrete placing system including curb rig advance. The modes are the following:

Mode 1 - Concrete will be placed at each of the four ports sequentially. Concrete pressure will be maintained at the curb ring by setting a common blind end pressure to all four curb ring hydraulic actuators.

Curb ring alignment will be manually maintained by observing alignment indicators and directing concrete to the appropriate concrete port for a sufficient period of time to correct the misalignment.

Mode 2 - Concrete will be placed at each of the four ports sequentially. Alignment will be automatically maintained by independent flow metering to two of the curb ring hydraulic actuators based on feedback signals from alignment indicators. Concrete pressure will be maintained at the curb ring by setting a common blind end pressure to the two adjacent curb ring hydraulic actuators. Uniform pressure will be maintained at other locations on the curb ring by regulating the frequency and pattern of slide valve operators.

Mode 3 - Similar to Mode 2 with the exception that pressure control to the two adjacent hydraulic actuators will be accomplished by servo feedback from concrete pressure transducers located near the place ports.

Mode 4 - Similiar to Mode 1 except that concrete will be simultaneously pumped to two opposing ports. The slide valve will thus alternate curb ring ports between two sets of two ports.

In the event that directing concrete to the appropriate port is not a sufficient means of controlling alignment in Modes 1 and 4, hydraulic flow can be temporarily isolated from one or more of the four curb ring hydraulic actuators in order to force realignment.

3.5.2 Slipform Alignment Control

Initial slipform alignment control will consist of fixed rollers extending from the jacking frame loosely contacting the casing (shaft wall). Since the system operates in a vertical orientation, gravity should help to maintain a stable alignment. In the event that the loose fixed rollers are not adequate, the system design allows substitution with actively positioned rollers. Hydraulically actuated rollers would be positioned by remote manual operation based on a continuously monitored optical alignment survey.

4. EXPERIMENTAL PLAN

Simulation testing is divided into two series of tests to correspond to contractual tasks 3.15, Proof of Concept Testing, and 3.2.5, Extended Reliability Testing.

Proof of Concept testing will begin in September, 1981, with simultaneous shake down tests of (a) the concrete batching and placing system, and (b) the hydraulically controlled CSL.

Shake down tests will be followed by a series of tests to determine the following:

- The simplest acceptable curb ring control mode
- An acceptable combination of variable concrete placement parameters for proper concrete distribution
- Smooth start up/shut down operations

Proof of Concept testing will continue with slipforming tests in the spring as soon as weather permits. Slipforming tests will include the following:

- Determination of the simplest acceptable slipform alignment control technique
- Proof of liner self-support
- Verification of performance of prototype curb ring seal
- Range of advance rates at which the system is capable of operating

Extended Reliability Testing will begin upon completion of Proof of Concept testing and is expected to continue into the summer of 1982. Extended studies will investigate the following phenomena:

- Concrete build-up on the curb ring, curb ring seals, pinch valves, and slipform due to repeated operation of the CSL.
- Wear due to concrete abrasive action on concrete pressure transducers and slipform.
- Wear due to abrasive action of shaft wall on curb ring seal.
- Curb ring seal performance when negotiating small slough zones and roughened wall surfaces.
- The step form mode of operation used for transgressing large slough zones.
- Permissible slipform alignment deviation.

4.1 Proof of Concept Testing

The concrete batch plant will be calibrated and adjusted to produce 4.9 yds/hr which corresponds to a CSL advance rate of 3 ft/hr. Auger and admixture calibration will be accomplished by repeated weighing of individual outputs for 2 minute intervals.

Shake down tests of the hydraulically controlled CSL will begin with transducers, string pot calibration, and an optical alignment survey of the tower, casing, and slipform. An optical survey will then be set up for slipform alignment during tests.

Prior to placing concrete in the simulated shaft, the curb ring will be cycled full stroke, and the CSL will be partially filled with water to check for leakage in the seal, slipform joints, casing joints, and placing system.

The curb ring will be cycled under water pressure and seal drag will be evaluated. By moving the slipform with the curb ring, outer seal drag will be determined. By moving the curb ring alone, the combined inner and outer seal drag will be determined. If seal drag is determined to be significant, pressure dependence of seal drag will be investigated.

4.1.1 Distribution Tests

Full system testing will combine concrete batching and placing with CSL hardware operations, utilizing a 9 member team (as shown in Figure 11) comprised of the following:

- 1 Test Director
- 1 Instrumentation Engineer
- 5 Operators
- 2 Support Technicians

The first 10 tests will each place 3 vertical feet of CSL design mix concrete at 3 ft/hr. This series of tests will investigate the uniformity of concrete pressure control and distribution behind the curb ring. The system will initially be set up to operate as follows:

- Concrete will be sequentially placed to each of the 4 placing ports for 1 minute intervals.
- The curb ring control will be set for Mode 1 operation (Section 3.5.1)

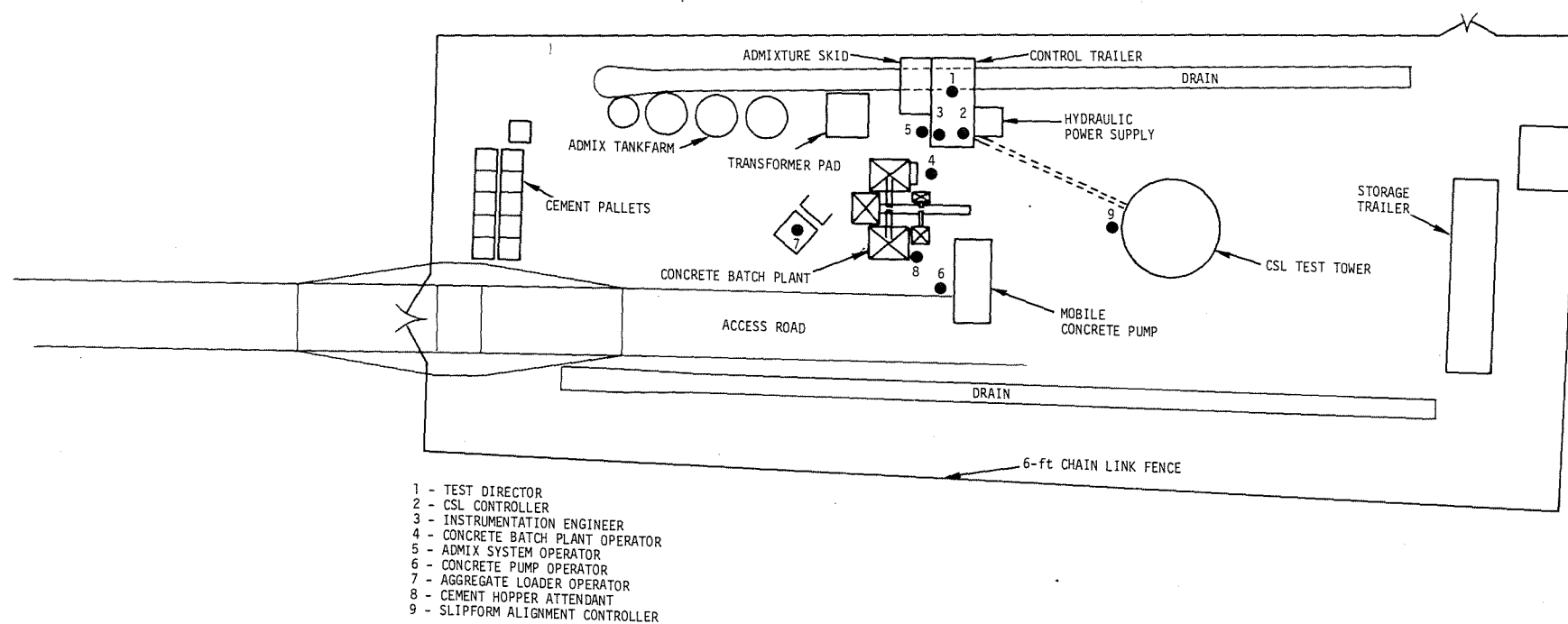


Figure 11. Test Operation Positions

- The jack frame will be locked off to the control tower.
- Slipform movement will be accomplished by the controlling hydraulic flow to the slipform actuators.
- Vibrators will operate for 10 second intervals every minute.
- Concrete pressure at the curb ring will be set at 30 psi.

In the event that curb ring pressure distribution is not sufficiently uniform (varies more than 15 psi from point to point along the curb ring), the frequency of slide valve sequencing will be increased. Should higher frequency slide valve sequencing not produce satisfactory results, ring vibration will be increased. If satisfactory pressure distribution is not attainable at slide valve maximum operating frequency with vibrators full on, concrete will be simultaneously placed to two ports at a time. Both adjacent and opposing port configurations will be investigated.

Upon completion of 30 feet of liner, the CSL casing will be disassembled and the liner will be demolished. Cores will be taken from the various sections of the liner for further analysis of concrete quality.

4.1.2 Self-support Tests

CSL design mix concrete will be placed at 4.9 yds/hr, corresponding to an advance rate of 3 ft/hr. Slipform effective length will be set at 6 feet which will expose concrete after the concrete has reached an age of 2 hours. An operating mode (Section 3.5.1) will be selected based on earlier performance.

The curb ring seal will be replaced by a prototype seal design based on laboratory seal test results.

During initial testing 6 feet of liner will be placed at a concrete pressure of 30 psi and degree of vibration selected from the distribution experiment results. If cracking occurs as a result of the liner being exposed, the concrete pressure will be increased at the curb ring. If the exposed liner begins to bulge, the slipform effective length and, therefore, the residence time behind the form will be increased.

The self-support experiments will initially require 12 feet of liner. An additional 18 feet of liner is projected for use in subsequent tests conducted during these experiments. Upon completion of the first 30 feet of liner, data will be analyzed and the test plan for subsequent experiments will be reviewed. At this time, core samples will be taken from the existing liner and laboratory tested for strength. The liner will then be demolished.

4.1.3 Advance Rate Tests

Initial advance rate tests will include a low speed (1 ft/hr) test, followed by a high speed (5 ft/hr) test. During the slow advance test slipform effective length will be progressively increased up to an estimated 10 feet. The increases in slipform effective length will be terminated if increased form drag reaches a level requiring concrete pressure at the curb ring to exceed 60 psi. The concrete pressure limit will be based on maximum permissible curb ring seal pressure derived during earlier tests. The initial slow advance rate tests will demonstrate the ability to produce quality concrete at the lower placing rate, while yielding pertinent data for developing an empirical understanding of the parameters effecting form drag. During the test, form length, form velocity relative to the concrete, and

concrete pressure will be varied.

During initial testing, up to 10 feet of liner will be placed at 1 ft/hr, while maintaining form velocity at 1 ft/hr and concrete pressure at the maximum level determined from prior tests. With both form and curb descending at 1 ft/hr, SEL will increase at 1 ft/hr; thus, no concrete will be exposed during this portion of the test. Upon reaching the maximum permissible form drag or 10 feet of form length, the pumping and curb descent will be discontinued and form will continue to descend and commence to expose the setting liner. During this phase of the test, the form velocity will be incrementally increased to 5 ft/hr over a short distance for various slipform effective lengths. After a portion of the concrete has been exposed and form drag has been sufficiently reduced, concrete pressure will be cycled by increasing the pressure on the curb ring through a permissible range for a short period. The cycling of form velocity and concrete pressure will be repeated at selected intervals corresponding to selected slipform effective lengths. The results of this test should yield quantitative input regarding the effects of four parameters (form length, form velocity, concrete pressure, and concrete age) on total form drag.

Initial high advance rate testing will be designed based on the results of previous tests. Earlier laboratory test data combined with data from the self-support experiment will indicate the minimum permissible concrete age needed for self-support. The initial slow advance rate tests should yield sufficient slipform drag information to estimate the maximum permissible form length that can be used at high advance rates. An apparent maximum advance rate will then be calculated for an initial high advance rate test. During this test, sufficient liner will be placed to mobilize the full slipform effective length required for continuous placing.

The results of the advance rate tests should yield data indicating maximum and minimum attainable advance rates for the concrete mix design used. In addition, the data will yield information regarding the slipform drag characteristics and the range in slipform effective length necessary to accommodate the full range of advance rates. A full 30 feet of liner is projected for use in the advance rate experiment.

4.2 Extended Reliability Testing

4.2.1 Sustained Slipforming

A full 30 feet of liner will be placed at the maximum attainable advance rate to verify steady state self-support of the liner upon exiting the slipform. System reliability and operational manpower requirements will also be evaluated during this experiment.

4.2.2 Step Form Operation

Concrete placing will commence in a step form mode by starting with the curb ring a distance of $2/3$ of the slipform effective length below the normal starting position. This yields a step form cavity which will be filled from the bottom at a placing rate corresponding to the maximum pumping rate of the system. During this phase, the form and curb ring will not move. Upon completion of filling, the placing system will be purged. The curb ring will be released shortly after the concrete sets. The slipform will be released after the concrete has attained self-support age.

4.2.3 Alignment Deviation

Due to the inherent deviations from plumb that are encountered in bored and drilled shafts, the effects of slipform misalignment on the slipforming process must be investigated. De-

viation from plumb may result from an abrupt offset of shaft alignment or may develop as a more gradual change in shaft inclination.

In order to assess the CSL system's ability to negotiate these changes, the slipform will be intentionally incrementally misaligned while slipforming at a nominal advance rate; 10 to 15 feet of liner will be slipformed while varying inclination through a small angle. The variation in inclination will be increased until slipform drag becomes critical or until the concrete lining is damaged. The SEL will affect the permissible deviation in inclination. A predetermined value of SEL will be selected for the alignment test based on previous test results. Upon reaching critical slipform drag or liner damage, the SEL will be reduced to see if further misalignment can be tolerated.

A total of 5 complete liners, each 30 feet in height are planned for the entire test program. A decision tree for conducting simulation test experiments is shown in Figure 12.

5. DATA COLLECTION

Data acquisition required during simulation testing has been compiled in tabular form (Table 1). The data can be categorized into the following groups:

- Concrete properties
- Test rig loads
- Stress, vibration and movement of concrete
- Alignment and relative positions of moving components

During all tests, concrete slump will be measured and test cylinders will be prepared for compressive strength tests. Compressive strength will be measured at the anticipated self-support age, and after 7 and 28 days.

Test rig loads that will be measured include forces on slipform and curb ring actuators monitored by means of two hydraulic pressure transducers.

Concrete pressure will be monitored at multiple points in the placing system. Diaphragm pressure transducers will monitor pressure at 4 locations on the curb ring and at 2 locations in the placing lines. A record will be kept of the operations of the slide valve and vibrators.

Curb ring alignment and motion will be monitored by means of 3 linear potentiometers connected between the curb ring and jack frame. The slipform and jack frame alignment will be monitored by means of optical survey, and jack frame elevation will be measured by a linear potentiometer connected between it and the tower structure. Instrument locations are shown in Figure 13.

In total there will be 12 channels of electronically re-

CSL SIMULATION TESTING
TABLE 1 - DATA ACQUISITION REQUIREMENTS

DATA REQUIRED	INSTRUMENT USED	RANGE OF MEASUREMENT	ACCURACY	READING FREQUENCY	NUMBER OF INSTRUMENTS
<u>Concrete Properties</u>					
Workability	Slump Test	0, 3/4, 1½ hrs. old	±½ in.	Every 45 mins.	—
Strength	Test Cylinders	2 hr. 3 hr. 7 day 28 day	±5%	1 set each test	4 cylinders /test
<u>Test Rig Loads</u>					
Jack pressure	Hydraulic transducers	0 - 1500 psi	±10 psi	Continuous	2
Heede system	Hydraulic gages	0 - 3000 psi	±30 psi	5 minute	8
<u>Stress Vibration & Movement of Concrete</u>					
Placing line Pressure	Pressure diaphragm gage	0 - 100 psi	±2 psi	Continuous	2 - 4
Curb ring Pressure	Pressure transducers	0 - 50 psi	±5 psi	Continuous	4
Vibrator Operation	Air pressure gage	40 - 80 psi	±5 psi	1 time during test	8 vibrators
Slide valve Operation	Micro Switches	Position Indication		Switching Frequency 12 cycl./mix	
<u>Alignment and Relative Position of Moving Components</u>					
Curb ring	Linear potentiometers	0 - 500 in.	±0.2 in.	Continuous	3
Jack frame Alignment	Optical Survey	±1 in.	±0.1 in.	Continuous	1
Jack frame Position	Linear potentiometers	0 - 500 in.	±0.2 in.	Continuous	1

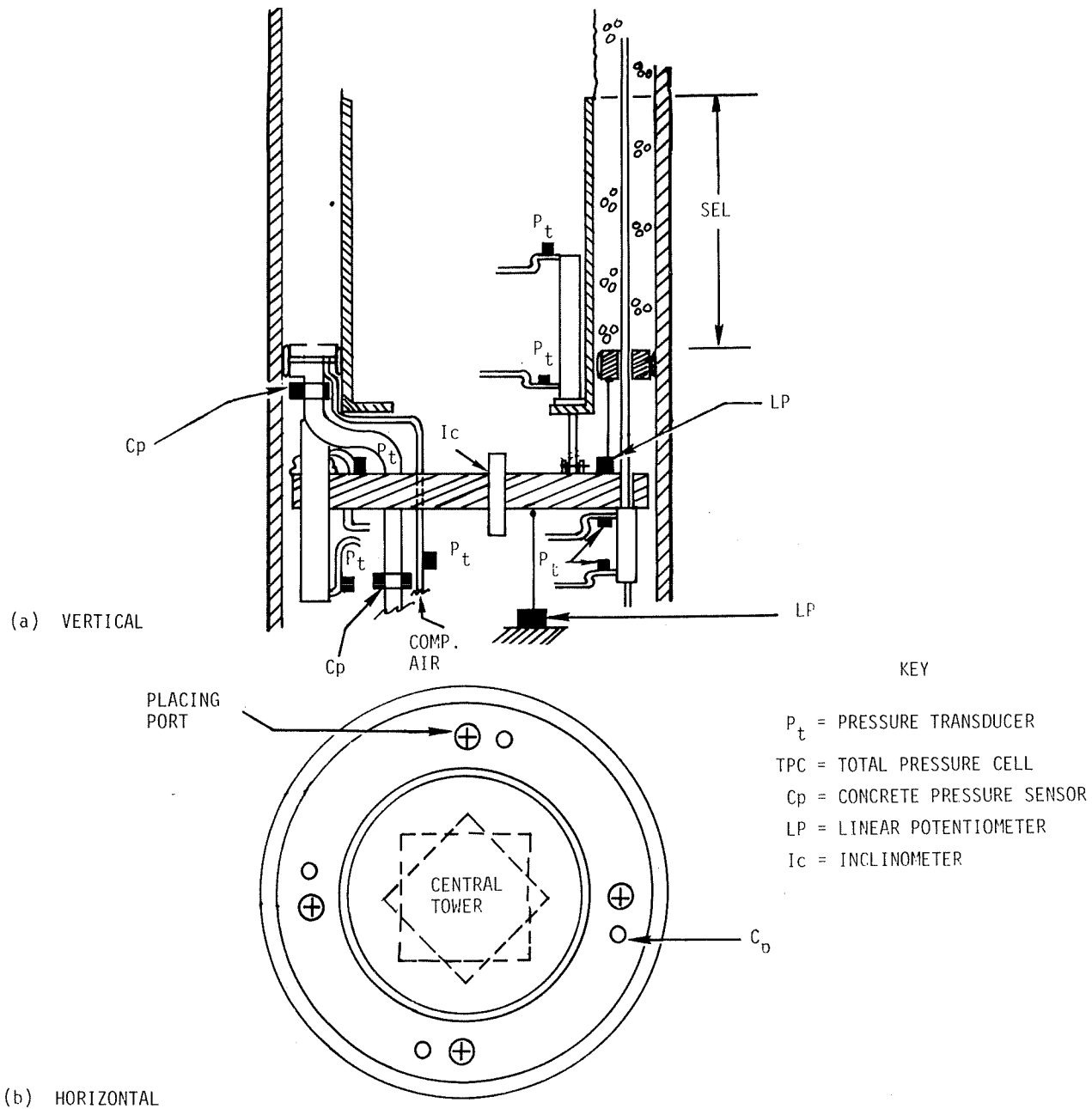


Figure 13. Simulation Test Instrumentation

corded data as follows:

- curb ring position (1 channel)
- curb ring alignment (2 channels)
- concrete pressure at curb ring (4 channels)
- concrete pressure in placing line (2 channels)
- slipform position (1 channel)
- curb ring hydraulic pressure (1 channel)
- slipform hydraulic pressure (1 channel)

APPENDIX A

PERFORMANCE SPECIFICATIONS

FOR THE

CONTINUOUS SHAFT LINING SYSTEM

Contract No. DEAC01-79ET14223

1. SUMMARY

Specifications have been established for the performance of the CSL and will be used to develop design specifications for the aboveground simulation tests. The performance specifications stipulate the types and sizes of shafts which the CSL system should be capable of lining, and the expected ranges of liner thickness and strength. The specifications include lining rate, alignment tolerance and cost constraints.

Performance specifications are summarized as follows:

- Types of applicable shafts
 - Blind drilling
 - Downhole boring
 - Raise drilling.
- Range of bored shaft diameters (unlined)
 - Minimum 12 ft
 - Maximum 26 ft.
- Range of bored shaft depths
 - Minimum 400 ft
 - Maximum 2000 ft.
- Concrete lining strength range
 - Minimum 3000 lb/in.²
- Range of nominal lining thicknesses
 - Minimum 10 in.
 - Maximum 18 in.
- Shaft alignment tolerances
 - Follow alignment of excavation, smoothing out abrupt shifts.

- Range of lining rates
 - Instantaneous 1 to 5 ft/hr
 - Average 50 to 100 ft/day.
- Lining costs
 - Matching conventional methods which are:
 - \$800/ft for 12-ft diam shaft
 - \$1750/ft for 25-ft diam shaft
 - Cost benefit is incurred from reduced construction time.

2. TYPES OF APPLICABLE SHAFTS

There are three generic types of shafts which are conducive to continuous shaft lining:

- Blind hole drilled shafts
- Downhole bored shafts
- Raise drilled shafts.

Unlike conventionally sunk shafts, all of these shaft types have a circular cross-section of extremely consistent diameter and are relatively smooth walled, a necessary characteristic for the CSL system.

2.1 Blind Drilling

The method of blind drilling has its roots in oil-field technology. In the late 1950's the Atomic Energy Commission started a drilling program at the Nevada test site. Also, at

this time some ventilation shafts were being drilled in the uranium mines in New Mexico. The first shafts were drilled with slightly modified oil field type rigs using direct mud circulation. These units lacked adequate circulation capabilities. Modifications were made on methods and equipment, and by 1964, 6-ft diam holes up to 4500 ft deep were being drilled.

Figure 2-1 shows the components of an oil field rig. The thrust on the cutterhead is provided by the weights above the bit. The total weight exceeds the required thrust, therefore the draw-works is constantly under load and the drill pipe is in tension. Torque is provided by the rotary table and transmitted to the drill pipe via a kelly.

It is unlikely that the CSL would be lining simultaneously with blind hole drilling, as the presently designed drill head could not be retracted past the lining. Temporary support is obtained if needed by keeping the hole filled with drilling mud. When lining a blind drilled shaft, the drilling mud or water may be removed simultaneously with lining in order to keep the length of unsupported shaft to within acceptable limits. The shaft wall would be covered with a thin coat of mud cake and may have significant ground water inflows with which the CSL system must contend.

2.2 Downhole Boring

A downhole boring machine is essentially a tunnel borer arranged in a vertical mode. The design of the basic machine has been well tested. There is no question about the ability of the borer to break the rock. However, the problem of effective rock removal has not been solved. The maximum cutter advance rate can only be achieved with "perfect cleaning" of the fractured rock. Each piece must be swept away from the cutters and removed from the face before it can be regrounded.

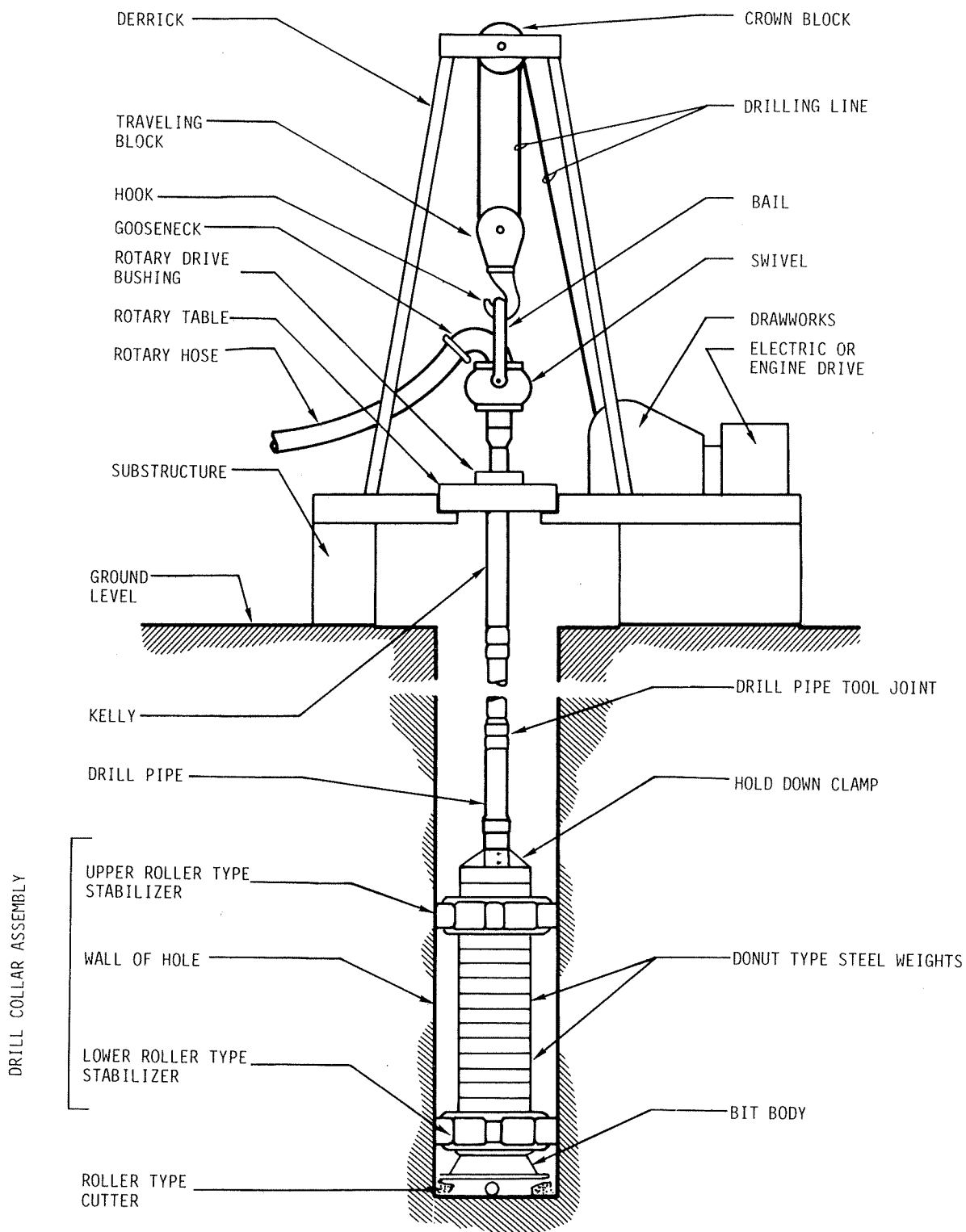


Figure 2-1. Blind Drill

The Robbins Company is presently running a DOE-funded shaft borer development in Oak Grove, AL. The machine has a 24-ft, 5-in. diam cutterhead arrangement similar to a tunnel machine with a mechanical muck removal system. The mechanical system is ineffective and 80 percent of the machine effort is spent regrinding the retained muck. The retrofit of a vacuum pickup system, feeding an air slugger-type system for muck removal from the shaft, is presently under consideration. There is general agreement that the mechanical pickup system will never be sufficiently effective.

The Robbins machine has a capacity of 2.06 million ft-lb of torque and 1.43 million lb of thrust. These capabilities are higher than those of the other drilling modes requiring drill stems. The drilling accuracy of the Robbins machine is remarkable. Tolerances of 1/2 in. from true centerline appear to be routinely obtainable. It would appear that the downhole borer will attain common usage as soon as an effective muck removal system is developed. The final choice of muck removal system will impact the CSL in terms of mucking system clearance requirements and borer to CSL lag distance constraints.

2.3 Raise Drilling

Raise drilling is a method by which a shaft is drilled from an existing mine working upwards to the collar. The drill machine is situated at the collar and the cuttinghead is unmanned. Torque is applied through a power swivel and the thrust is applied by vertical hydraulic cylinders. The hole geometry that a machine is capable of is determined by drill stem weight, cutterhead weight, and the optimum thrust balance against the torque requirements. The rock characteristics determine the required thrust. The thrust can be limited by torque availability.

In raise drilling the accuracy of the shaft is determined by the pilot hole. The pilot hole is drilled with the raise machine with a tricone type bit. With proper care, good rock, and a little bit of luck a hole accuracy of 0.25 percent of depth is possible. Often, however, shafts raised over significant distances, exceeding 1000 ft, will deviate from vertical alignment in excess of 1 diam. The pilot hole accuracy can be determined prior to raising if necessary.

3. RANGE OF BORED SHAFT DIAMETERS (UNLINED)

Shaft diameter is dependent on the purpose of the shaft. Production shafts are as large as 26 ft in diameter while ventilation shafts are typically 12 ft in diameter. There is a trend toward increased shaft diameter as mines develop higher production rates and manufacturers develop more productive equipment. The development of shaft boring machines may lead to standardization of shaft diameters.

A performance range of 12 to 26 ft in unlined diameter has been established based on construction limitations and on the range of existing shaft sizes. The maximum diameter is constrained by present boring technology at 24 ft, 5 in., which encompasses the present size of the DOE-Robbins blind shaft borer. The minimum diameter is constrained by space requirements for lining equipment and lining crews.

4. RANGE OF BORED SHAFT DEPTHS

A performance range of 400 to 2000 ft has been established based on maximum coal seam depth for an upper bound and economic consideration as a lower bound. Shafts shallower than 400 ft have been deemed uneconomical because fixed mobilization and demobilization costs would overshadow cost savings per linear foot of shaft. Mobilization and demobilization time would actually exceed shaft sinking time in shallower shafts. The maximum depth of presently mined seams in the eastern United States is approximately 2000 ft as indicated in Figure 4-1.

5. CONCRETE LINING STRENGTH RANGE

The minimum concrete strength has been set at 3000 lb/in.² based on industry standards. Strength requirements for design consideration are dependent on liner thickness and hydrostatic head developed behind the liner in undrained aquifers.

Concrete quality is of prime importance in shaft construction. Placement conditions are often very adverse. A "normal" problem in surface concreting can be very traumatic on the shaft bottom. Every consideration should be given to develop an efficient mix that meets production and serviceability requirements. Listed below is a suggested priority list for concrete characteristics for use with the CSL:

1. Workability
2. Initial and final set control
3. Strength
4. Shrinkage control
5. Sulfate resistance.

PERCENT
ACTIVE
DEEP
MINES

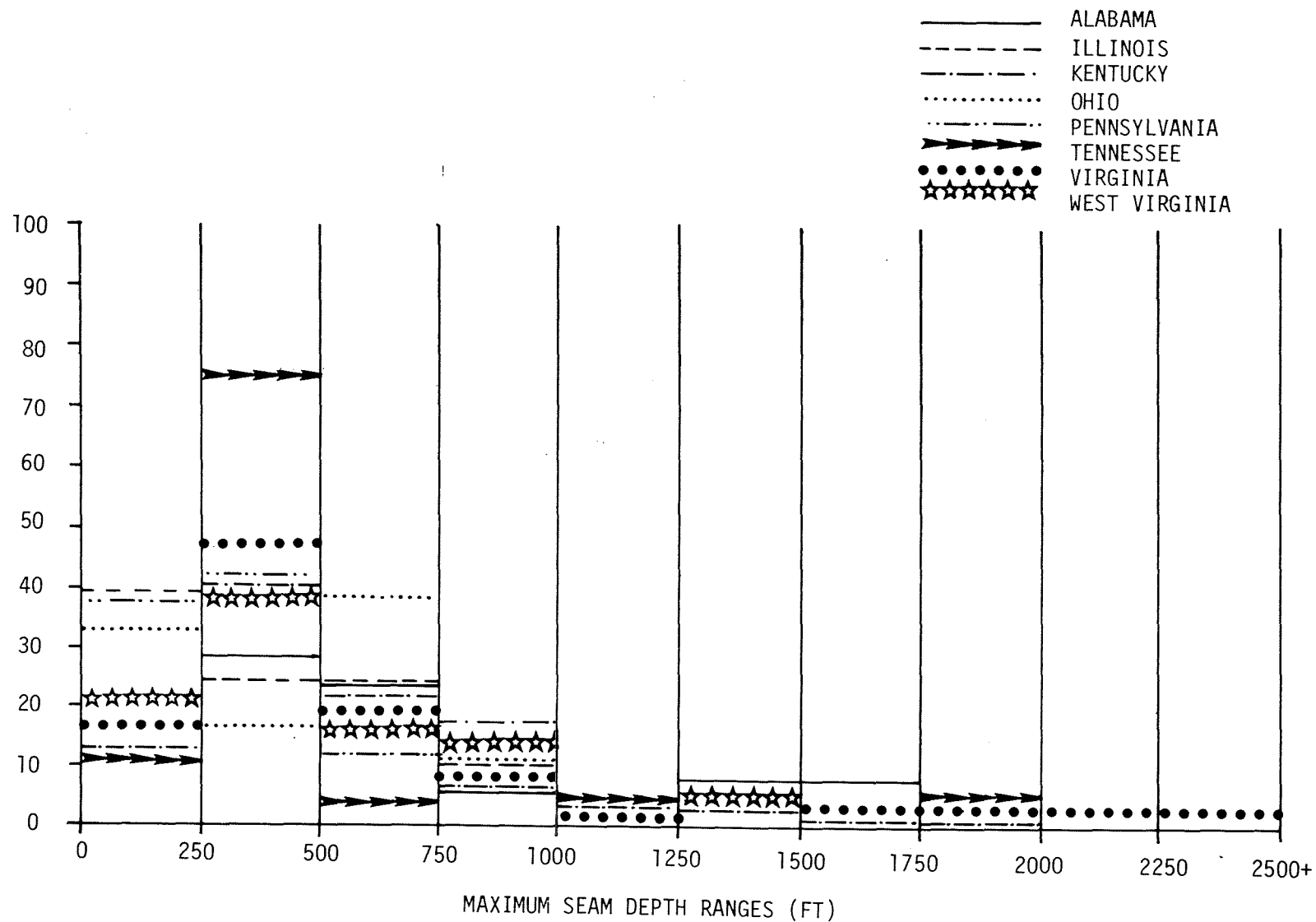


Figure 4-1. Depth of Mined Seams in the Eastern United States

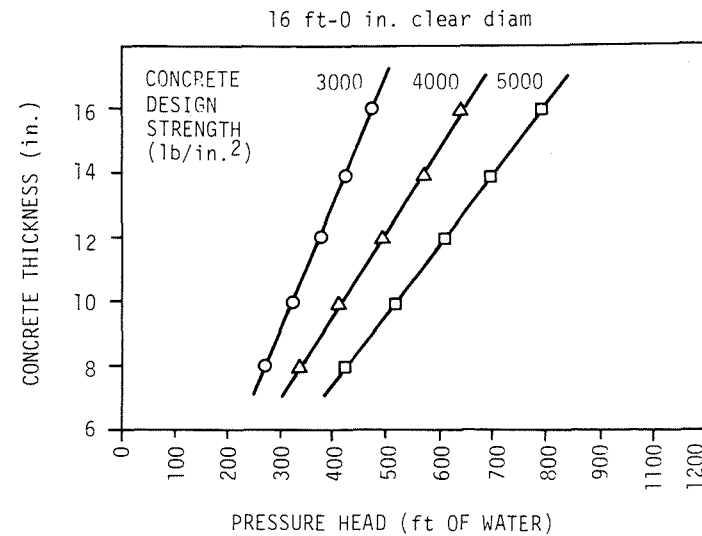
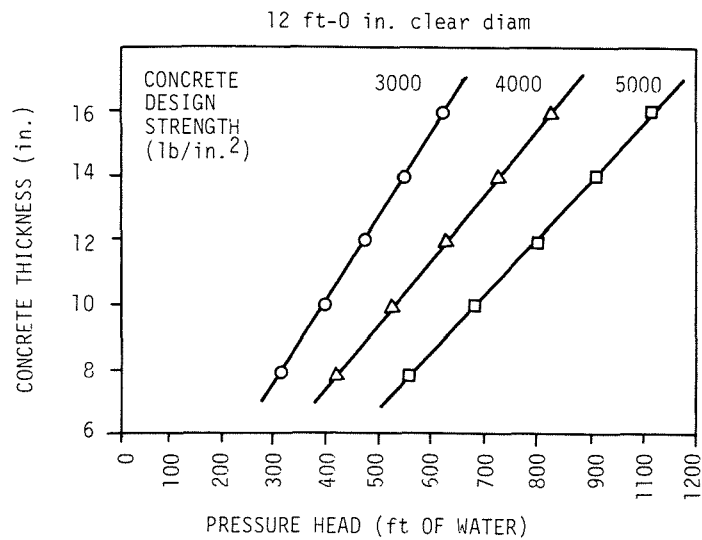
It is advisable to alter standard mixes to meet ground and water conditions. As conditions become adverse, it is sometimes advisable to increase cement content and slump to optimize workability.

6. RANGE OF NOMINAL LINING THICKNESSES

The nominal thickness of concrete shaft linings has typically been 12 in. The choice of liner thickness has historically been based on prior shaft designs in a mining area and is often the result of construction expedience. Design considerations typically assume negligible ground loading but do account for hydrostatic head in aquifers. A 12-in. liner of 3000 lb/in.² concrete can withstand a hydrostatic head ranging from 250 ft in a 22-ft diam shaft to 450 ft in a 12-ft diam shaft (see Figure 6-1).

The range of nominal liner thickness has been set at 10 to 18 in. The lower limit is based on design limitations of CSL while the upper limit is the maximum design thickness experienced in the industry.

Nominal thickness has been specified since, in practice, the liner may deviate substantially above or below the design thickness for limited distances to smooth out irregularities in the shape of the excavation.



MAXIMUM CONCRETE STRESS $0.45 f_c$

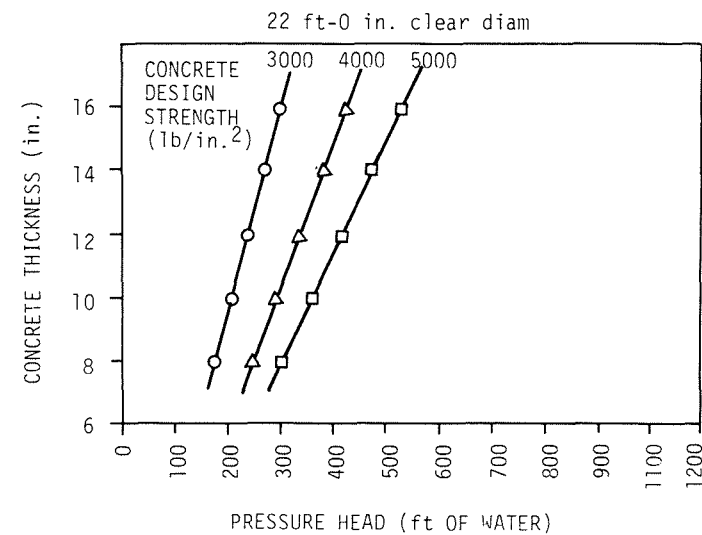
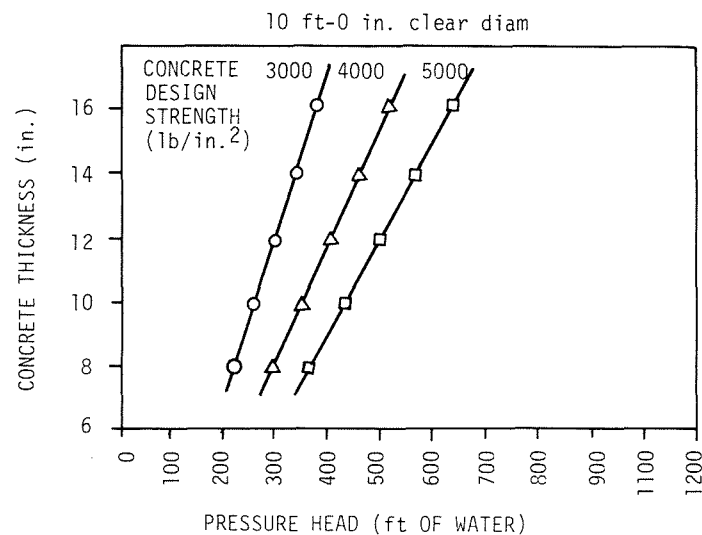


Figure 6-1. Suggested Water Head to Lining Thickness Relationship

7. SHAFT ALIGNMENT TOLERANCES

Shaft alignment error varies substantially, depending on the method of shaft sinking, as mentioned in the section on shaft types. The relatively large alignment errors in many raise drilled shafts could not be compensated for in the lining without requiring an exceedingly thick liner.

By contrast, downhole bored shafts are extremely accurate and would, therefore, require extremely little alignment compensation, even if stringent finished diameter alignment performance specifications were imposed.

Consequently, no alignment performance specifications have been included at this time other than to stipulate that abrupt shifts in shaft alignment must be smoothed out over a reasonable transition distance.

8. RANGE OF LINING RATES

Specifications for CSL lining rates are based on compatibility with the DOE-Robbins blind shaft boring machine, DRSB. Instantaneous advance rate should span a range of 1 to 5 ft. Shafts sunk by other means such as drilling or raising would, of course, be lined at the most cost-effective rate. The cost per foot is reduced with increased advance rate. Preliminary total unit cost estimates of a 1000-ft deep 16-ft diam raise bored shaft in problem-free ground are as follows:

<u>Advance Rate (ft/hr)</u>	<u>Cost/ft</u>
1	\$ 902
2	708
3	643
4	611

This trend is bounded by an upper limit based on increased initial cost and crew size as advance rate exceeds 5 ft/hr.

9. LINING COSTS

Potentially the CSL system can be used in three modes:

- Lining a raised drilled shaft
- Lining a blind drilled shaft
- Following a downhole boring machine.

The direct operating costs of these three modes will be very similar. The plant setup and overhead costs of the three modes will vary widely.

The setup costs associated with the CSL/DRSB system would be significantly higher than lining after the drilling is complete. It would be difficult to isolate what setup charges are applicable to the CSL and what belongs to the DRSB. It really would not be necessary to separate charges because the two systems complement each other. A failure in one system will affect the costs in the other. The DRSB might not be a cost-effective system without the CSL.

The estimated total unit costs for placing a 12-in. liner in a 1000-ft deep, 16-ft diam raise bored shaft are shown in the preceding section.

The direct costs of conventionally lining a problem-free shaft range from \$800/ft for a 12-ft diam shaft to \$1750/ft for a 25-ft diam shaft. Although initial CSL lining cost estimates are well below these conventional costs, a more significant factor is the indirect cost benefits obtained using CSL by completing shaft construction in a shorter period of time. The cost criteria has therefore been set at matching conventional direct costs with significant benefit being incurred from indirect costs associated with earlier start of, or increase in, mine production.

APPENDIX B

SUBJECT: CSL Project Review Meeting
July 14 & 15, 1981
Waltham, MA

ATTENDEES: Department of Energy: T. Zeigler; G. Jernberg
Dravo: J. Sweeney
FMA: K. Maser*, D. Hoadley, D. Ounanian,
T. Brunsing*, B. Esposito*, R. Henderson*,
R. Torbin

*part-time

Purpose

The purpose of the meeting was to review the technical results of the laboratory testing programs; to discuss the current technical direction of the CSL Simulation Studies, and to plan the upcoming Task II activities.

Discussion1. Distribution Test Results

The Summary of Results report on the distribution tests was handed out at the start of the discussions. In all seven tests were conducted, however only five tests resulted in useable information.

Each test was presented individually with its own operating conditions and rig configuration discussed in detail. The impacts of the distribution tests on the program, in general, and the CSL simulation studies, in particular, are as follows:

- A. Concrete will distribute latterally along a horizontal, downward moving curb under pressurized conditions.
- B. Lateral distribution will be limited due to the viscous, plastic nature of the material. It is expected that a minimum of 3 concrete ports but probably 4 ports will be required on the 15 ft dia CSL.
- C. Advance rate appears to have little, if any, affect on distribution—always got good concrete quality slab.
- D. Intermittent vibration along the curb will be required.

- E. Operational problems with hydraulic power unit (HPU) and operation of the rig will be factored into CSL HPU.
- F. Experience was gain on concrete plant operations and use of multi-port valve.

2. Slipform Test Results

In all five tests were conducted. Each test was presented individually with its own operating conditions and rig configuration discussed in detail. The impacts of the slipform tests on the program, in general, and the CSL simulation studies, in particular, are as follows:

- A. Concrete can be slipformed vertically downward behind a downward moving, pressurized curb.
- B. A Portland Type III concrete mix was shown to meet the CSL operational specifications in regard to strength gain and workability.
- C. Form taper was shown to reduce form drag.
- D. Form coating improved concrete quality however its impact on form drag is still uncertain.
- E. The jump mode was demonstrated successfully however more study of cold joints is required.
- F. Advance rate of 3 ft/hr are obtainable with this concrete mix. It may be possible to achieve 5 ft/hr in the CSL simulation facility.
- G. Operational problems with the HPU and control instrumentation will be factored into the CSL HPU control design.
- H. Concrete plant operation and rig operation procedures will be modified and factored into the CSL design to prevent tension cracking upon shutdown.

A Summary of Results report on the slipform tests will be issued in late July.

3. Seal Tests

The seal tests are a separate laboratory program (not defined in contract) to study and evaluate potential prototype seal candidates. FMA has issued a seal specification which set the performance requirements which we believe are obtainable.

Since seal wear will not be a problem (due to slow advance rates), a rolling seal concept was eliminated due to its otherwise complicated configuration. Inflatable seals lack flexibility to seal in two directions which would be common through slough zones. Therefore, we are investigating lip and brush type seals. Current design is a multi-layer

(3) concept using a composite arrangement of 85 and 70 durometer polyurethane. The design pressure is 60 psi with 30 to 40 psi as the maximum operating pressure. There are overlapping radial cuts made in each layer to give the necessary bi-directional flexibility. To add stiffness to the seal when it is fully extended across a gap, a metal stiffener is added to act as a hinge. This also prevents the seal from folding over backwards under maximum loading.

The present seals are being designed to bridge a 1 to 3 inch gap between the shaft wall and the edge of the curb ring. The material being evaluated is a visco-elastic material which will maintain a constant volume when stretched (up to 5 times its length). The testing has progressed from a smooth wall surface to an artificially roughened one. The configuration of the roughness is based on FMA's own observations of machine bored shafts as well as conversations with shaft sinking contractors. The surface represents that typically expected from gage cutters, however with some abrupt and gradual changes due to slough zones. There is cost sharing on this program with DOT which also has a similar need for the tunnel lining system.

The best prototype seal will be tested with concrete in the slipform rig. Eventually, it will be evaluated in the CSL simulation facility.

4. Concrete Mix Design

The requirements of the concrete mix to meet the performance specifications of the CSL were discussed. Workability versus strength gain is the prime concern. The current Portland Type III cement mix is giving us the desired concrete quality in about 2 to 3 hours residence time behind the slipform. We are currently doing long term strength tests on this mix. The potential drawbacks with this mix are the lower free thaw and sulfate resistance properties of Type III as compared to other cements. Also shrinkage is greater. This situation will not cause concern in every application, and the mix can be altered to deal with situation where these concerns are problems. Ken Saucier at WES may be available to help do some concrete work for the CSL program provided it is limited in scope.

APPENDIX M

SUMMARY OF TEST RESULTS
CSL SIMULATION TESTS

CONTINUOUS SHAFT LINING SYSTEM
SIMULATION TESTS
FALL 1981

SUMMARY

The fall series of Simulation Tests for the development of a rapid shaft lining system have been successfully completed. In a combined effort, Foster-Miller Associates and Dravo Engineers conducted four tests on October 28, October 30, November 5, and November 12, 1981. These "Proof of Concept" tests verified the Continuous Shaft Liner's operating mode in a full scale 15 ft. diameter simulated mine shaft. The tests also demonstrated that a concrete lining can be placed by continuous slipforming beginning at the top of the shaft and progressing downward.

I. Test Results

Three fundamental hypotheses were proven by the fall tests. First, the demonstrations proved that a Portland Type III concrete mix can be pumped under pressure and uniformly distributed within a toriodal void with no segregation above the curb ring. Second, the demonstrations proved that this concrete will remain in place while the curb ring descends away from it providing that pressure and the continuous inflow of fresh concrete is maintained. Third, the testing proved that the concrete can be slipformed and has enough strength at less than three hours to be exposed and remain self-supporting.

Distribution of concrete around the 15 foot diameter simulated shaft was accomplished by pumping fluid concrete under pressure through four symmetrically located ports into a void above the curb ring. Concrete was pumped in a steady cycle clockwise around the shaft through ports #1, #2, #3, #4 sequentially. Cycling was accomplished by a hydraulically controlled slide valve. By maintaining the pumping pressure within the void between 5 and 15 psi, and with the aid of pneumatic vibrators, good distribution of aggregate was obtained. When the pressure in the void was interrupted, a rift developed.

During testing it was discovered that tilt of the curb ring away from level was less significant than expected. During the third test, the curb ring was as much as seven inches out of level yet its descent was not greatly affected. Slipform drag also appeared to be insignificant as the weight of the slipform itself was sufficient to overcome drag and allow exposure of concrete. The hydraulic cylinders which were originally provided to pull the slipform down if necessary, were actually used to restrain the slipform from descending too fast. Finally the range of acceptable concrete slumps was greater than expected. Although the design mix of concrete was specified as having an initial 6-8 inch slump, there often were times when a concrete mix with a three inch slump was pumped through the lines.

The problems encountered during testing were involved with minor mechanics of the CSL operating mode and were not problems related to the continuous slipform lining concept. The primary source of difficulties was directly attributable to the use of pneumatic pinch valves. The pinch valves, located beneath the curb ring port on the four inch diameter concrete lines, were intended to prevent reverse flow of concrete from above the curb ring void when the lines below were disconnected. However, these valves caused numerous line blockages. The pinch valves were removed for Test #4, conducted on November 12, 1981, and the line blockage problem was eliminated.

A second source of problems was provoked by the lack of Heede jacks. The original design of the CSL required the Heede rod climber jacks to be the main propulsion of the jack frame. The jacks however, were unavailable for the fall series of tests so, an alternate method of moving the jack frame was employed. This method involved manually walking the jack frame down Dywidag rods supplied adjacent to the test tower columns. The method was time consuming but effective until Test #4 when the jack frame became lodged between the pressurized concrete above and a Dywidag support nut below. Because the jack frame bound up, no further testing could be accomplished. Test #4 was prematurely terminated.

Several other minor difficulties were encountered, the most notable being:

- controlling the output from the cement hopper,
- making a good cold joint, and
- obtaining accurate readouts of the CSL position in the shaft.

The output of cement from the cement hopper was found to be variable for a fixed RPM of the discharge auger. Compaction of cement due to an overloaded hopper caused a greater discharge of cement. As the hopper depleted its supply, the cement discharge varied. To control the output, a constant volume of cement and a uniform rate of replenishing the cement in the hopper was required. The incorporation of vibrators and/or aerators to the cement hopper, for the spring tests, may potentially be the solution of this matter.

The cold joints obtained during the fall tests were affected by three factors:

- the amount of grout used to slick up the concrete lines; grout should be removed from behind the slipform before placing design mix concrete;
- the radius of the trailing flange on the slipform, a smooth breakaway radius in addition to the taper should prevent tearing of the concrete;

- the behavior of the curb ring seal; the seal used for the fall tests was not the prototype seal.

The position displacement transducers (string pots) used to measure the curb ring and slipform position were discovered to be too fragile for use in the Simulation Tests without some means of protection. No protection was provided in the fall tests which inevitably resulted in a broken string pot and the loss of electronic digital readouts in the control trailer.

III. Recommendations

Recommendations for spring testing are listed below:

- Concrete lines must be fully greased prior to pumping design mix concrete.
- A method of removing grout used for greasing the lines must be investigated. Removing the grout would tend to improve cold-joints.
- Immediately proceed to pumping the design mix after being satisfied that all lines are greased properly.
- To improve concrete appearance, include a form finish such as UHMW polyurethane.

- Pressure, greater than the static head of fluid concrete, must be maintained above the curb ring to prevent sagging and tearing of the concrete.
- Determine the location relative to the curb ring where the concrete is self supporting.

IV. Log of Activities - Testing of the CSL

Below is a brief diary of activities beginning with pre-test preparations and leading to the conclusion of fall Simulation Tests.

October 28, 1981

This was the first day of testing. All preparations were made prior to this date. The concrete pump arrived on site at 9:30 a.m. and the FMA technicians made the hook-up.

A series of problems developed that caused numerous line blockages and eventual termination of this test. The occurrences listed below are not necessarily in sequence:

- The concrete pump operator only ran one hopper of grout through the concrete lines. This was not enough grout to effectively slick up all the lines to the curb ring.

- The initial concrete slump was only 2 to 3 inches. Design mix requires a 6-8 inch initial slump.
- The pinch valve at port #3 was partially closed due to compression of the rubber gasket. This prevented any flow of concrete through port #3 into the curb ring void.
- The auger in the feed system of the cement hopper bound up and would not discharge cement. Probable cause of binding may have been a wet bag of cement.
- The 6 inch start-up void above the curb ring may not have been sufficient to allow proper dispersion of fluid concrete around the shaft.

October 29, 1981

The entire day was spent cleaning up from Test #1 and preparing for Test #2. The pinch valve at port #3 was replaced with the spare pinch valve.

October 30, 1981

The second simulation test was conducted. Concrete pumping began at approximately 10:00 a.m. During pumping, several plugged lines occurred primarily in lines #2 and #3. Approximately 70-72 inches of concrete were placed.

The slipform descended at a slow rate until concrete pumping stopped. No concrete was exposed since the top of the slipform was still above the lid. During cleanup the slipform bonded to the concrete and would not descend further. The slipform surface had not been prepared with any form coating.

November 2, 1981

Foster-Miller Associates used the wedges to collapse the slipform and expose the set concrete. Cleanup and Test #3 preparations are underway.

November 4, 1981

Preparations were made for Test #3. The curb ring was positioned 12 inches below the bottom of the set concrete from the previous pour.

November 5, 1981

The third simulation test was conducted. Pumping began at 11:45 a.m. and terminated at 1:49 p.m. Lines #2 and #3 plugged and were cleared a few times. Approximately 60 inches of concrete were placed although the curb ring descended nearly 7 inches out of level.

Slipforming of concrete was accomplished, exposing three hour old concrete with enough strength to remain self-supporting.

November 11, 1981

Preparation for Test #4 was underway. A few changes to the instrumentation were implemented. The pinch valves were removed and replaced by C-clamps and blocks of wood.

November 12, 1981

Operations ran smoothly as 110 inches of concrete were placed and slipformed in the fourth simulation test. The test was prematurely terminated while beginning to expose concrete due to locking the jack frame between the concrete above and Dywidag support nut below.

By the time the jack frame was freed, the slipform had bonded to the concrete preventing any further advance.

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Test No. 1

Test Date: October 28, 1981

Test Summary:

Test aborted due to start up problems. No concrete placed
behind slipform.

B. Gorbin

CSL SIMULATION TEST
SUMMARY DATA SHEET

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TEST NUMBER: 1 DATE: 10/28/81 COMPILED BY: TPB

TEST PURPOSE: Shake down system; verify operating mode;
evaluate distribution

DURATION OF TEST: _____

DISTANCE LINED: 4 in.

CONCRETE MIX USED: CSL TYPE III DESIGN (Reduced C_{cl} by 20%)

PUMPED CONCRETE SLUMP (VARIATION): 3"

CONCRETE PRESSURE AT CURB (VARIATION): —

CURB RING VIBRATORS a) NO: 8

b) CYCLE: 5 sec/min

CURB RING ADVANCE RATE: —

CONCRETE/SLIPFORM GAP AT TAIL: —

SLIPFORM ADVANCE RATE a) SLOW: —

b) FAST: —

DISTANCE SLIPFORMED: —

SLIDE VALVE a) FREQUENCY: 1 minute/port $\rightarrow$ 30 sec/port

b) CYCLE: 1, 2, 3, 4

TEMPERATURE a) AMBIENT _____ b) CASING _____

c) CURB _____ d) CONCRETE AT PUMP _____

REASON FOR TEST TERMINATION: blockage in port

1 & 3 (first 3 Men 1). followed by break lower
of cement auger

PROBLEMS ENCOUNTERED: #3 pinch valve not fully open,
insufficient slick in lines, cement auger tripout
(thermal protection) after short shut down period (3 min.); cement bags damp

RECOMMENDED MITIGATION: increase volume of slick,
verify pinch valves open prior to test, avoid batch plant
shut downs, increase starting gap between curb & top,
increase slide valve frequency, increase vibration. Use
fresh cement

Test No. 2

Test Date: October 30, 1981

Test Summary:

Seventy-two inches of concrete was placed behind the slip-form in 2 hours and 28 minutes. This translates to a curb advance rate of 2.4 feet per hour. No slipforming was attempted. Objective of test was to evaluate concrete distribution. Test stopped due to concrete pumping and delivery problems. One of the pinch valves failed, allowing several cubic feet of concrete to flow out from behind the form. This caused a large void to occur in the finished lining.

B. Jorbin

CSL SIMULATION TEST
SUMMARY DATA SHEET

395

TEST NUMBER: 2 DATE: 10/30/81 COMPILED BY: TRB

TEST PURPOSE: Shake down system; verify operating mode
evaluate distribution

DURATION OF TEST: pumped concrete for 3 hrs. / clean-up 3 hrs.

DISTANCE LINED: ≈ 72 inches

CONCRETE MIX USED: 2 3/4 hrs CSL design mix w/reduced CaO; 1/4 hr. full design mix

PUMPED CONCRETE SLUMP (VARIATION): 4 - 7 inch

CONCRETE PRESSURE AT CURB (VARIATION): 10 psi ± 3 psi

CURB RING VIBRATORS a) NO: 8

b) CYCLE: 5 sec / min

CURB RING ADVANCE RATE: —

CONCRETE/SLIPFORM GAP AT TAIL: —

SLIPFORM ADVANCE RATE a) SLOW: 0.1 - 0.3 in. / min.

b) FAST: —

DISTANCE SLIPFORMED: ≈ 15 inches

SLIDE VALVE a) FREQUENCY: 30 sec / port

b) CYCLE: 1, 2, 3, 4 (delayed on problematic ports)

TEMPERATURE a) AMBIENT 48°-50°F b) CASING —

c) CURB — d) CONCRETE AT PUMP est. 60°F

REASON FOR TEST TERMINATION: plan was for ≈ 60 in to be
placed. 60 × 12 inch initial void = 72" total

PROBLEMS ENCOUNTERED: plugged port #2 at start; —
mix too rich, apparent miscalibration; lost 4 cu. ft. at end due to
air pressure loss at pinch valve #1; clean-up too slow, slipform stuck.

RECOMMENDED MITIGATION: delay 3/4" stone to mix at start to ease
initial pumping; check cal on all augers; detail cleanup routine;
maintain constant slipform movement throughout test. Tie off conc.
hoses at pinch valve, at shut down snap off V-couplings
immediately, wash out pinch valve bottoms, open pinch valves
after 1 1/2 hrs → 2 hrs. & wash out with 10' probe.

TEST DATE 10/30/81

Concrete was mixed in the auger mixer and placed in the pump hopper at 10:04 a.m.
All instrumentation was turned on. All concrete port meters read 0 psig.

The "Concrete Placed" meter reads + 12.3 inches

The "Concrete Exposed" meter reads +40.8 inches

<u>TIME</u>	<u>EVENTS</u>
10:09 a.m.	Tilt meters: C1 to C3 reads 0" Level C2 to C4 reads 1" Low towards C4 Red valve reads = 0 psig Curb ring cyl. reads approx. 325 psig Slipform cyl. reads approx. 675 psig At this time the concrete is filling hoses.
10:17 a.m.	We noticed the red valve meter was stuck. Tapping on the meter freed the needle. It now reads 20 psig and ranges to 30 psig.
10:23 a.m.	Port #2 clogged and apparently cleared itself.
10:25 a.m.	Port #2 pulsed - pump was shutdown temporarily by the operator until the slide valve could be changed to another port. Apparently line #2 is plugged.
10:28 a.m.	Blew concrete feed line on line #2 after trying one more time to clear the plug - pressure @ slide valve decreasing due to loss of concrete from line #2.
10:30 a.m.	We began pumping into line #3.

TIMEEVENTS

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10:32 a.m. Line to port #1 increased concrete pressure slightly.

10:33 a.m. Test operator began cycling between ports #1 and #3
pumping into each port for 30 seconds.

10:36 a.m. Pressured indicators at the curb ring indicate some
pressure buildup (2 psi) near ports 1 and 3.

10:38 a.m. Line #2 has been disconnected and cleared of concrete.
Line #2 was reconnected.

10:39 a.m. Concrete line #2 plugged again.

10:44 a.m. All curb ring pressure indicators are showing low pressures.

10:45 a.m. Curb ring cylinders were actuated to lower curb. Curb
ring pressure meter reads 500 psi.

10:47 a.m. Jog Cylinder #4 to control tilt.
Jog Cylinder #2 to control tilt.
The "Concrete Placed" meter now reads 11.7"
Port #3 pressure indicator on curb ring shows 5 psi.
Port #1 pressure indicator shows 6 psi.
Tilt meter at C4 reads 5" low.

10:51 a.m. Concrete line #2 has been cleared. Tilt meter is settling
back to a level indication.
The "Concrete Placed" meter reads 13.0"
All curb ring pressure indicators are reading low pressures.

10:53 a.m. Tilt meter C1 to C3 indicates C3 is 2½" low and meter
C2 to C4 shows that C4 is 2" low.

<u>TIME</u>	<u>EVENTS</u>
10:56 a.m.	Line #3 pulsed. Apparently the pump operator was adjusting pumping rate.
10:58 a.m.	At this time all tilt meters read level. The "Concrete Placed" meter reads 18.2". This shows 6" of concrete has been placed.
10:59 a.m.	We began moving the slipform down at an arbitrarily slow rate. Port #3 developed line pressure problems. The pump power was cut back. All port curb pressures read 6 psi.
11:04 a.m.	"Concrete Placed" meter reads 21.6". Tilt indicators read level. All "jog" mushroom buttons for the curb ring actuators are being operated on a continuous basis now.
11:06 a.m.	Pressure indicators on curb ring read as follows: Port #1 reads 6 psi concrete pressure Port #2 reads 4 psi concrete pressure Port #2 reads 6 psi concrete pressure Port #4 reads 6 psi concrete pressure
11:07 a.m.	Curb ring concrete pressure was increased to approximately 10 psi at all ports.
11:09 a.m.	The slipform was adjusted to a slower rate of decent.
11:09 a.m.	"Concrete Exposed" meter reads +37.2"
11:13 a.m.	"Concrete Exposed" meter reads 36.9"

TIMEEVENTS

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11:15 a.m.

"Concrete Exposed" meter reads 36.6

Rate of slipform travel

$$36.9" - 36.6" = 0.3"$$

$$\frac{3"}{10} \quad 2 \text{ min.} \times \frac{1 \text{ min.}}{60 \text{ sec.}}$$

$$\text{RATE} = 0.0025"/\text{sec. or } 0.15 \text{ in./min. approx. } 1/8" \text{ min.}$$

11:19 a.m.

Curb ring pressures read as follows:

to

Port #1 11 psi

11:20 a.m.

Port #2 8 psi

Port #3 10 psi

Port #4 9 psi

Tilt meter C1 to C3 read 0" (level)

C2 to C4 read 2 3/4" towards C2 low

"Concrete Placed" meter reads 32.2 inch

"Concrete Exposed: meter reads 35.4 inch

At slide valve:

Port #3 indicates 50 psig line pressure inside red valve

11:21 a.m.

Curb ring cyl. internal pressure reads 500 psi

Slipform cyl. internal pressure reads 0 psi

11:27 a.m.

Black dye injected in concrete to show a change in concrete mix.

11:27 a.m.

"Concrete Placed" meter reads 35.3"

Rate of curb ring advance

$$\begin{array}{r} 35.3" \\ -12.3 \text{ (initial)} \\ \hline 23" \end{array} \quad \begin{array}{r} 11:27 \\ 10:45 \\ \hline 42 \text{ min.} \end{array}$$

<u>TIME</u>	<u>EVENTS</u>
11:27 a.m. (cont.)	$\frac{23 \text{ in.}}{42 \text{ min.}} = \frac{0.548 \text{ in.}}{\text{min.}} \times \frac{60 \text{ min.}}{\text{hr.}} = \frac{32.857 \text{ in.}}{\text{hr.}} \times \frac{\text{ft.}}{12 \text{ in.}} = 2.74 \frac{\text{ft.}}{\text{hr.}}$
11:32 a.m.	We changed the rate of speed for the slipform. Micrometer at control panel now reads 0.326 medium speed. This indicates that the slipform is running too fast. We want slipform to move at approximately 3/8" min.*
11:35 a.m.	Red dye is injected in the concrete to show change of concrete mix. "Concrete Placed" meter reads 41.4"
11:36 a.m.	30.3 inch on "Concrete Exposed" meter.
11:37 a.m.	29.5 inch on "Concrete Exposed" meter
11:38 a.m.	29.0 inch "Concrete Exposed" meter
11:39 a.m.	28.7 inch "Concrete Exposed" meter
11:45 a.m.	#2 port pulsed. Apparently operator was adjusting the concrete pump.
11:50 a.m.	A 4" slump for the concrete mix was taken at the batch plant.
11:52 a.m.	"Concrete Exposed" meter reads 24.1"
11:55 a.m.	HPU pump to slide valve cut off. The slide valve was stuck. The operator manually reset the circuit and restarted the pump.

* SET MICROMETER FOR MEDIUM SPEED AT 0.224. THIS MAKES
SLIPFORM MOVE AT APPROXIMATELY 3/8"/MIN.

TIMEEVENTS

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11:59 a.m. "Concrete Placed" meter reads 57.5 inches.

12:05 p.m. Blue dye injected. Mix design changed to slow set mix.
(low calcium chloride).

12:18 p.m. Slipform rate of advance was stopped.
"Concrete Exposed" meter reads 16.4 inches.

12:27 p.m. The concrete plant has discontinued batching concrete.

12:29 p.m. Concrete pump began slowing down. A loss of pressure at
the curb ring is seen.

12:32 p.m. Stop pump. Pinch valves are closed.

12:34 p.m. Curb ring cyl. locked off and turned off.

12:36 p.m. HPU turned off.

12:37 p.m. Visicorder off!
Pinch valve #1 opened: concrete let out from behind form
for 30 sec. before under control - pinch valve at 80 psi
to keep closed.

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Test No. 3

Test Date: November 5, 1981

Test Summary:

Fifty-seven inches of concrete was placed behind the slipform in 1 hour and 40 minutes. Concrete placement stopped due to delivery system problems. Entire sixty inches was exposed by moving slipform at a rate which exposed the in-place concrete at an average age of 2 hours and 50 minutes.

B. Jorkin

CSL SIMULATION TEST
SUMMARY DATA SHEET

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TEST NUMBER: 3 DATE: 11/5/81 COMPILED BY: TPB

TEST PURPOSE: Place uniformly dist. conc. through 4 ports, slipform 60" concrete. observe effect of slipform drag.

DURATION OF TEST: conc. placement 2 hrs.

DISTANCE LINED: 55 - 60 inches

CONCRETE MIX USED: 1st 10 min low fall - Remainder design mix *

PUMPED CONCRETE SLUMP (VARIATION): 3 1/2 - 5 (dropped to 2 1/2 - 3 in 5 min)

CONCRETE PRESSURE AT CURB (VARIATION): 10 psi

CURB RING VIBRATORS a) NO: 8

b) CYCLE: 5 sec 'min'

CURB RING ADVANCE RATE: ≈ 30 in. 'hr

CONCRETE/SLIPFORM GAP AT TAIL: 1/8" - 1/4 inch

SLIPFORM ADVANCE RATE a) SLOW: 0.2 inch/min

b) FAST: 1 inch/min

DISTANCE SLIPFORMED: 55 - 60 inches

SLIDE VALVE a) FREQUENCY: 30 sec 'port

b) CYCLE: 1, 2, 3, 4; 1, 3, 4; 1, 4; 1

TEMPERATURE a) AMBIENT 50 b) CASING 55 - 60

c) CURB 55 - 60 d) CONCRETE AT PUMP 65°

REASON FOR TEST TERMINATION: placed 60 inches, having

trouble pumping, high pressure at relief valve 60-80 psi, lost ports
2 & 3 due to plugging.

PROBLEMS ENCOUNTERED: mix too rich, apparent prob with cement auger cal.;
pump operator kept hopper level too low; plug were at pinch valves.

CURB pressure was allowed to drop off due to HPU relay kickouts; concrete had horizontal
cracks & 6" separation at cold joint above port #2; injured tech due to unexpected con.
RECOMMENDED MITIGATION: pressure at port being de-plugged.

Recal mixer augers, determine if auger RPM carrying; cal all augers
under sustained load; make sure pump hopper is kept 1/2 full; slide valve
must be cycled sequentially during plug clearing operation to avoid
inadvertent pumping to the port being cleared. HPU break amp adjust must
be turned up, check inst. cables for connection & clearance.

CSL - SIMULATION TEST
CONCRETE SYSTEM DATA SHEET

TEST NO.: 3 DATE: 11/5/81 COMPILER: TPB
MIX DESIGN: CSL - TYPE II + CaCl₂, OUTPUT: 5 yds/hr (actual 4.5)

MIX COMPONENT	Designed OUTPUT	POTENTIOMETER SETTING METER READING	MOISTURE/ CONTENT/ CONCENTRATION
Cement	62.7 ^{lb} /min	295	—
Sand	102.5 ^{lb} /min	249	2%
3/8 stone	50.5 ^{lb} /min	273	55 D
3/4 stone	75.5 ^{lb} /min	392	55 D
CaCl ₂	1.47 gal/min		20% solution
Mighty	426 gms/min		50% "
AEA	5.5 gal/hr.		10% "

Ambient Temp. 50°F Aggregate Temp. _____

TIME	CONCRETE AGE	SLUMP	TEMP	COMMENT
	INITIAL	5 "	65°F	1/3 Ca Cl ₂ of Design mix too Rick (10 sacks by bag count)
	5 MIN	4		
	10 "	3 1/2		
	15 "	3 1/4		
	20 "	3 1/4		
	25 "	2 3/4		
	INITIAL	3 1/2	65°F	
	5 MIN.	2 3/4		
	10 "	2 3/4		
	15 "	2 1/2		
	20 "	2 1/2		
	25 "	2 1/4		
	30 "	2		
	INITIAL	3 1/4		
	5 MIN.	3		
	10 "	2 3/4		
	5 "	2 1/2		
	20 "	2 1/2		
	25 "	2 1/2		
	30 "	2 1/4		

CONTINUOUS SLIPFORM LINER DEVELOPMENT PROGRAM

NOVEMBER 5, 1981

LOG OF SIMULATION TEST #2

Basic start readings on string pots

Curb readings 12.70 inches (calculated 13.25")

Slipform reading - 44.10 inches

<u>TIME</u>	<u>EVENTS</u>
11:37	Took basic start readings
11:45	Lubricating grout being mixed
11:55	Start of grout pumping
	Curb ring (C.R.) meter reading indicates 13.00" is start location (this is distance from bottom of previously placed concrete to top of C.R.)
	Form reading still -44.10"
11:58	At start of test, top of slipform was 42" above the bottom of the existing concrete placed on October 30, 1981. Form lowering rate should be $42/3 = 14"/\text{hr.} = 0.23"/\text{min.}$
12:02	Concrete being mixed and being discharged into pump hopper.
	C.R. tilt meters indicate:
	Port #1 (P#1) is 1" Low
	Port #2 (P#2) is 1" Low
12:05	<u>START OF PUMPING CONCRETE</u>
	No pressure yet showing on red valve (R.V.)
	Checking operation of slide valve (S.V.)
	C.R. hydraulic actuator pressure at ± 200 psig
12:10	Pressure beginning to show on R.V.
	S.V. on P#3 - line being filled

TIMEEVENTS

12:12 S.V. to P#4 - R.V. pressure dropped down - lines being filled.

12:13 S.V. to P#1 - R.V. pressure still down

12:15 Lines are still being filled. No pressures are showing on any of the Curb Ring Transducers(C.R.T.)

12:16 R.V. pressure coming up to approximately 40 psig

12:21 Line #4 showed a jump in R.V. pressure up to 100 psig but immediately dropped back to 40 psig

12:22 START OF DESIGN MIX BEING PUMPED
Design mix marked with introduction of black dye.

12:27 S.V. stickening and not sliding quickly. S.V. being cleaned.

12:28 S.V. back to normal operation.

12:29 -
12:31 Curb Ring Transducers (C.R.T.) are beginning to show light (1 psig) pressure.

12:32 R.V. pressure jumped from 50 psig to 75 psig - attributed to slow travel of S.V.

12:35 S.V. being lubricated and is now back to normal operation.

12:36 C.R.T. pressures are all increasing to acceptable levels.

12:37 CURB RING STARTED DOWN

12:38 C.R.T. #1 8 psig
C.R.T. #2 7 psig
C.R.T. #3 8 psig
C.R.T. #4 7 psig

12:39 Tilt meter rapidly moved off scale

12:40 Tilt meter back to normal
C.R. meter showing only 13.5"

TIMEEVENTS

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12:42 C.R. meter now showing 14.2"
Black eye again being introduced

12:45 C.R.T. #1 9 psig
C.R.T. #2 8 psig
C.R.T. #3 9 psig
C.R.T. #4 8 psig
R.V. Showing 50 to 60 psig. C.R. meter at 14.9"

12:46 Visicorder stopped. Starts and stops of the visicorder
from now on will be noted on the recording paper roll.

12:47 C.R. meter at 16.5"
5 minutes (16.5" - 14.2" = 2.3")
 $2.3"/5 \text{ min.} = 0.46"/\text{min.}$
If concrete is being placed at 5 yards/hr, C.R.
advance rate should be $\frac{5 \times 27 \times 12}{44 \times 60} = 0.61"/\text{min.}$
This equals 36.8 inches per hour.

12:52 The CSL was started down, but was moving too fast so it
was stopped.

12:56 R.V. pressure jumping up in line #3.

12:57 C.R. at 21.9"
At 12:42 C.R. at 14.2", then in 15 minutes the C.R. advanced
 $21.9 - 14.2 = 7.7 \text{ inches}$ or $7.7 \times 4 = 30.8 \text{ in/hr.}$
Concrete production rate at this time is $\frac{30.8}{36.8} \times 5 = 4.2 \text{ yds/hr.}$
C.R. hydraulic cylinder pressure was reduced from 600 to
300 psig.

12:59 R.V. pressures seem to show a block in lines #2 and #3.
C.R.T. #2 dropped to 5 psig. Ports #1 and #4 are still
clear.

TIMEEVENTS

13:01 C.R. at 25.0"

13:08 Line #3 unplugged and hooked up again. Now pumping into
line #3.
C.R. at 33.0"
CSL at -39.8"

13:12 C.R. at 33.3"
CSL at -39.7"

13:13 S.V. being cycled between ports #1 and #3, line #2 plugged.

13:16 C.R.T. #1 6 psig
C.R.T. #2 3 psig
C.R.T. #3 6 psig
C.R.T. #4 5 psig
Line #2 disconnected and being unplugged.

12:19 Pumping into line #3

13:20 Line #2 connected and pumping into line #2 resumed.

13:22 R.V. again went too high while trying to pump through
line #2. Blockage probable.

13:24 Line #2 seems to have cleared, all ports now working.
C.R. 37.4"
CSL -39.6"

13:25 Line #2 giving trouble again

13:26 Line #2 seems to still be plugged

13:28 Lines #2 and also #3 not working.
CSL started down.
C.R. 40.1
CSL -39.4

<u>TIME</u>	<u>EVENTS</u>	409
13:31	Lines #2 and #3 are plugged C.R.T. #1 7 psig C.R.T. #2 2 psig C.R.T. #3 5 psig C.R.T. #4 6 psig	
13:34	CSL jogged down	
13:37	C.R. meter reading 51.5". CSL meter -38.3" Pumping concrete through lines #1 and #4 only.	
13:38	C.R. at 53.3" CSL at -37.2" C.R.T. #1 5 psig C.R.T. #2 2 psig C.R.T. #3 3.5 psig C.R.T. #4 3.5 psig	
13:43	C.R. at 57.0" CSL at -35.4" C.R.T. #1 6 psig C.R.T. #2 2 psig C.R.T. #3 4 psig C.R.T. #4 3 psig	
13:45	C.R. at 60.0" CSL at -34.5" Still pumping through lines #1 and #4 only. Lines #2 and #3 are plugged.	
13:49	<u>CONCRETE MIXER SHUTDOWN</u> C.R. at 62.5" CSL at -33.7"	

<u>TIME</u>	<u>EVENTS</u>
13:52	Attempts are being made to level up the C.R. and bring the C.R.T. pressures back up to uniform acceptable levels.
13:54	Pressure in the curb ring hydraulic cylinders increased to 800 psig. C.R.T. #1 5 psig C.R.T. #2 4 psig C.R.T. #3 3.5 psig C.R.T. #4 4 psig
13:56	Curb ring hydraulic cylinder pressure was lowered to 700 psig and the curb ring locked off. C.R.T. #1 5.5 psig C.R.T. #2 3.0 psig C.R.T. #3 4.5 psig C.R.T. #4 4.5 psig C.R. at 62.4" CSL at -31.7"
14:02	Curb ring meter shows 61.8" CSL at -29.8" CSL average advance rate was 30" in 14:02 - 12:52 = 1 hr. and 11 min. = 71 minutes. At this rate the concrete will be exposed in $\frac{42}{30} \times 71 = 99$ min
14:10	CSL locked off at -25.4"
14:20	CSL started down again
14:55	CSL locked - both frames tight against Dywidag nuts.
15:05	CSL freed and jackframe lowered.
15:09	CSL again being lowered and concrete being exposed.
16:45	CSL descent stopped. Curb ring tilted so that seal is exposed near port #3 and totally covered near port #1.

November 13, 1981

FOSTER-MILLER ASSOCIATES, INC.
WALTHAM, MASSACHUSETTSINSPECTION OF CONCRETE
THE TOWER PROJECT

REFERENCE NUMBER 81C-2222

DATE OF INSPECTION 11-5-81

TEST SPECIMENS	Series No.	1A-E	2A-D	3A-E
	Class, psi	3000	3000	3000
	Slump, in.	5	3½	3¾

PLACEMENT OF The Tower

REMARKS Prior to batching of the concrete we observed the calibration of the batching plant. The calibration was based on the flow of material on the belt at a constant rate for 2 minutes.

<u>Constituent</u>	<u>Design Rate</u>	<u>Approx. Actual</u>
Cement	125.3 lbs.	123 lbs.
Sand	205 "	210 "
¾" Gravel	151 "	152 "
⅜" Gravel	101 "	101½ "

After calibration the concrete pump was set up directly under the mixing auger and pumping commenced. The slump was adjusted visually by the batchman to 6" to 8" at the auger.

As requested by Foster-Miller we took a sample directly from the auger every 1/2 hour. Slumps were performed every 5 minutes throughout each half hour. Cylinders were fabricated after the first slump test. Two 6x12 steel molds were made on sets 1 and 3 for 3 hour tests. We were informed by Foster-Miller after the sampling of Series #1 that this mixture contained approximately 30% below the design amount of calcium chloride. All concrete after this contained the proposed design mix. Our results for slumps and temperature are shown on the appended sheet.

Our observations of the data were as follows: Although the initial slump taken on each of the 3 series is below the proposed 6" to 8", the initial slump directly out of the auger was in fact higher. We found that in the time it took us to take the sample and take the first slump was in fact the time of the greatest slump loss. The concrete did appear to have a slump of from 6" to 8" at the auger but our first actual slump was appreciably below that.

Due to the slump loss in pumping the concrete, any delay in pumping or hold-up could easily clog the lines. As a result it would be necessary to keep the concrete moving and have no long delays in pumping. This was easily

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demonstrated when it was necessary to break down the lines in the tower when they became clogged after minimal delays.

INSPECTION TIME 8 Hours (8:00AM - 2:30PM + travel)

INSPECTOR D. Duncan

Sample #1 (Series # 1A-E)

<u>Time</u>	<u>Temp.</u>	<u>Slump</u>
12:20PM	65°F	5 "
12:25	65	4
12:35	65	3½
12:40	65	3½
12:45		3½
1:50		2¾

Sample #2 (Series #2A-D)

1:00PM	68°F	3½ "
1:05		2¾
1:10		2¾
1:15	65	2½
1:20		2½
1:25		2½
1:30	65	2

Sample #3 (Series #3A-E)

1:35PM	68°F	3¼ "
1:40		3
1:45	68	2¾
1:50		2½
1:55		2½
2:00	68	2½
2:05		2¼

HERMAN G. PROTZE

MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

(617) 332-8460

November 13, 1981

TEST OF CONCRETE SPECIMENS

CLIENT FOSTER-MILLER ASSOCIATES, INC., WALTHAM MASS.
 PROJECT THE TOWER PROJECT

Reference Number	81L-1572AB
Date Received	11-5 & 6-81
Date Sampled	11-5-81 by us
Location of Placement	The Tower
Truck Number	On Site Mix
Load Number	" " "
Ticket Number	" " "
Class Concrete	3000 ψ @ 28 days
Cubic Yards	1/6 approximately
Cement	752 lbs/cu.yd. Iron Clad Type III
Fine Aggregate	1230 " New England Sand
Coarse Aggregate	1510 " " 3/4" Gravel
Water	No data
Admixture	0.7 oz/cu.yd. Darex + 15.7 lbs/cu.yd. Calcium Chloride + ? oz/cu.yd. Mighty 150
Time Sampled	12:20PM
Weather	Fair 60°F
Concrete Temperature	65°F
Slump	5"
Entrained Air	Not determined
Appearance	Good
Storage	Job trailer, then laboratory fog room
Date of Test	11-5-81 11-12-81
Age at Test	3 1/2 hours 7 days
Specimen Number	1A 1B
Dimensions	6x12" 4x8"
Density, lbs/cu.ft.	147 1/2 144
Compressive Strength	80 ψ 5130 ψ
Remarks	

Respectfully submitted,

Herman G. Protze
 Herman G. Protze

November 13, 1981

TEST OF CONCRETE SPECIMENS

CLIENT FOSTER-MILLER ASSOCIATES, INC. WALTHAM, MASS.
PROJECT THE TOWER PROJECT

Reference Number 81L-1573A
Date Received 11-6-81
Date Sampled 11-5-81 by us
Location of Placement The Tower

Truck Number On Site Mix
Load Number " " "
Ticket Number " " "
Class Concrete 3000 ψ @ 28 days
Cubic Yards 1/6 approximately
Cement 752 lbs/cu.yd. Iron Clad Type III
Fine Aggregate 1230 " New England Sand
Coarse Aggregate 1510 " " " 3/4" Gravel
Water No data
Admixture 0.7 oz/cu.yd. Darex + 22.56 lbs/cu.yd. Calcium Chloride + ? oz/cu.yd. Mighty 150
Time Sampled 1:00PM
Weather Fair 60°F
Concrete Temperature 70°F
Slump 3 1/2"
Entrained Air Not determined
Appearance Good
Storage Job trailer, then laboratory fog room
Date of Test 11-12-81
Age at Test 7 days
Specimen Number 2A
Dimensions 4x8"
Density, lbs/cu.ft. 145 1/2
Compressive Strength 6080 ψ
Remarks

Respectfully submitted,

Herman G. Protze 1/14
Herman G. Protze

HERMAN G. PROTZEMATERIALS ^{- INC. -} TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

(617) 332-8460

November 13, 1981

TEST OF CONCRETE SPECIMENS

CLIENT FOSTER-MILLER ASSOCIATES, INC., WALTHAM, MASS.
 PROJECT THE TOWER PROJECT

Reference Number	81L-1574AB
Date Received	11-5 & 6-81
Date Sampled	11-5-81 by us
Location of Placement	The Tower
Truck Number	On Site Mix
Load Number	" " "
Ticket Number	" " "
Class Concrete	3000 ψ @ 28 days
Cubic Yards	1/6 approximately
Cement	752 lbs/cu.yd. Iron Glad Type III
Fine Aggregate	1230 " New England Sand
Coarse Aggregate	1510 " " 3/4" Gravel
Water	No data
Admixture	0.7 oz/cu.yd. Darex + 22.56 lbs/cu.yd. Calcium Chloride + ? oz/cu.yd. Mighty 150
Time Sampled	1:35PM
Weather	Fair 60°F
Concrete Temperature	68°F
Slump	3 1/4"
Entrained Air	Not determined
Appearance	Good
Storage	Job trailer, then laboratory fog room
Date of Test	11-5-81 ' 11-12-81
Age at Test	3 1/2 hours 7 days
Specimen Number	3A 3B
Dimensions	6x12" 4x8"
Density, lbs/cu.ft.	147 1/2 145 1/2
Compressive Strength	510 ψ 5780 ψ
Remarks	

Respectfully submitted,

Herman G. Protze
 Herman G. Protze

Test No. 4

Test Date: November 12, 1981

Test Summary:

One-hundred and twenty inches of concrete was placed behind the slipform in 3 hours and 35 minutes. The average rate of advance of the curb ring was 2.7 ft/hr. Slipforming not accomplished due to mechanical lock up of the jack frame.

B. Jolter

CSL SIMULATION TEST
SUMMARY DATA SHEET

TEST NUMBER: 4 DATE: 11/12/81 COMPILED BY: TPB

TEST PURPOSE: Verify pumpability of CS2 design mix, preliminary evaluation of slipform drag at steady state slipforming

DURATION OF TEST: 6 hrs.

DISTANCE LINED: 10 ft.

CONCRETE MIX USED: CS2 design with 1% CaCl₂, 15 min; 2% CaCl₂, 15 min; 3% CaCl₂ remainder

PUMPED CONCRETE SLUMP (VARIATION): 7"-8" initial

CONCRETE PRESSURE AT CURB (VARIATION): 10-15 psi

CURB RING VIBRATORS a) NO: 8

b) CYCLE: 5 sec/min.

CURB RING ADVANCE RATE: 2.7 ft/hr.

CONCRETE/SLIPFORM GAP AT TAIL: none apparent

SLIPFORM ADVANCE RATE a) SLOW: stopped for 1st 1/2 hr.

b) FAST: 2.5 - 3 ft/hr.

DISTANCE SLIPFORMED: 24 inches

SLIDE VALVE a) FREQUENCY: 20 sec/port

b) CYCLE: 1, 2, 3, 4

TEMPERATURE a) AMBIENT 42° - 46°F b) CASING CLOSE TO AMBIENT

c) CURB d) CONCRETE AT PUMP 59° - 64°F

REASON FOR TEST TERMINATION: Locked up jack frame on dewie lag with curb jacks fully retracted; 1 hr. delay in slipform movement while freeing jack frame caused slipform/concrete lock-up

PROBLEMS ENCOUNTERED: with removal of pinch valves $\Rightarrow$ no problems with blockage (initial block due to improper slide valve cleaning removed early); Raj frame/jack frame walking requires more observers; cement auger output still not staying in cal. we had to count cement bags; some sloughing of early non-design mix when exposed

RECOMMENDED MITIGATION: stop for fall - install heede system in spring - vibrate cement auger bin; Radine trailing edge of slipform; divert grout from placement & go immediately to full design mix following grout. Protect or eliminate tilt string pots.

CSL - SIMULATION TEST
CONCRETE SYSTEM DATA SHEET

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TEST NO.: 4 DATE: 11/12/81 COMPILER: M. D. L.

MIX DESIGN: CSL Type II OUTPUT: 7.5 yds/hr

MIX COMPONENT	#/MIN. OUTPUT	POTENTIOMETER SETTING METER READING	MOISTURE/ CONTENT/ CONCENTRATION
Cement	62.7	202.6	-
Sand	102.5	157.0	~2.5%
3/8 stone	50.0	24.1	SSD
3/4 stone	75.0	450.5 - 500.0	SSD
CaCl	13.16	1.53 ± 0.2 GPM	15.4% solution
Mighty	2.36	17.0 ± 1.6 GPM	50.0% solution
AEA	0.047	6.1 GPM	1.09% solution

Ambient Temp. @ 10:45 AM = 42°F Aggregate Temp. ~ Ambient
@ 12:45 PM = 47°F

TIME	CONCRETE AGE	SLUMP	TEMP	COMMENT
10:40 AM	0 MIN 5 MIN 10 MIN 15 MIN	7 1/4" 8 1/4" 7 3/4" 7 1/4"	50°F ~42°F	SERIES I @ 1% CaCl ₂
11:40 AM	0 MIN 5 10 15	6" 4 1/2" 4 1/4" 3 3/4"	69°F	SERIES II @ 2% CaCl ₂
12:40 PM	0 MIN 5 10 15	6 3/4" 5 1/4" 4 1/2" 4"		SERIES III @ 3% CaCl ₂ = DESIGN MIX
CYLINDER STRENGTHS:				
SERIES I: 13 PSI @ 5 hrs.				
SERIES II: 170 PSI @ 4 hrs.; 6840 PSI @ 7 days				
SERIES III: 30 PSI @ 3 hrs.; 6250 PSI @ 7 days				

CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
NOVEMBER 12, 1981

LOG OF SIMULATION TEST #4

BASIC INFORMATION

- Curb ring (CR) and Continuous Slipform Liner (CSL) are tilted approximately 5" out of level and must be leveled and placed in a known position.
- Kenneth L. Saucier of the Corps of Engineers in Vicksburg was present for the test representing the D.O.E.

<u>TIME</u>	<u>EVENT</u>
10:12	CR and CSL being leveled and positioned to start test.
10:31	Bottom of CR set at 89½" above second horizontal joint line in outside form coursing. This elevation places the top of the CR an average of 12+" below the bottom of the previously placed concrete. The bottom of the CSL set at 18 3/4" above the same second horizontal joint line. This provides an average lap of 24-" over the previous concrete slab.
10:35	Lubricating grout being mixed.
10:42	Start of grout pumping into port #1.
10:44	Lubricating grout being cycled through ports #1, 2, 3 and 4.
10:49	Curb ring transducer (CRT) #3 giving bogus pressures. Decision made to omit readings from CRT #3 throughout this test.
10:50	<u>START OF PUMPING CONCRETE</u>
10:53	Cycle time set at 20 seconds per port to reduce dormant periods of concrete in pumping lines. Pump operator instructed to try to "even out" the pump

<u>TIME</u>	<u>EVENT</u>
10:56	CR location meter malfunctioned (string pot broken) and meter readings will not be taken. CR hydraulic cylinder rods were calibrated in inches and the relative position of the CR will be located from these marks. CSL meter adjusted to read +25.7" (estimated lap of CSL over previous concrete slab).
10:58	Red valve (RV) showing 25 PSIG and steady.
11:02	RV at 30 PSIG. No pressure showing on CRT #1,2 and 4.
11:09	Pumping in port #1. CRT #1 showing 1 PSIG. Nothing on other two. RV showing 25 to 30 PSIG.
11:11	CRT #4 now showing 1 PSIG.
11:13	<u>CURB RING STARTED DOWN</u>
11:14	RV showing signs of blockage in line #3.
11:15	Line #3 blocked. CR hydraulic pressure increased to raise pressure in concrete above the CR. CRT #1 10 PSIG CRT #2 10 PSIG CRT #3 Reading to be omitted. CRT #4 11 PSIG RV at 40 PSIG on lines #1, 2 and 4.
11:16	CRT #1 12.5 PSIG CRT #2 12.5 PSIG CRT #4 13.0 PSIG RV at 45 PSIG on lines #1 and #2.
11:23	CR cylinders (CRC) read CRC #1 3" down

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<u>TIME</u>	<u>EVENT</u>
11:23 (cont.)	CRC #2 1½" down
	CRC #3 1½" down
	CRC #4 0" down
11:24	CRT #1 13 PSIG
	CRT #2 12 PSIG
	CRT #4 13 PSIG
11:25	CRC #1 4"
	CRC #2 3"
	CRC #3 0"
	CRC #4 2"
11:26	CRC #1 5"
	CRC #2 3"
	CRC #3 1"
	CRC #4 3"
	Pumping into port #1 temporarily halted.
11:29	Line #3 cleared and operating again. A small amount of concrete from the previous test had set up in the slide valve and triggered the blockage of port #3 in the valve.
	CRT #1 12 PSIG
	CRT #2 12 PSIG
	CRT #4 12 PSIG
	CRC #1 6"
	CRC #2 4½"
	CRC #3 3"
	CRC #4 6"
	RV at 45 PSIG
11:31	Calcium chloride in concrete mix increased to 2%.

<u>TIME</u>	<u>EVENT</u>
11:32	CRC #1 7"
	CRC #2 6"
	CRC #3 6"
	CRC #4 7½"
	CRT #1 12 PSIG
	CRT #2 12½ PSIG
	CRT #4 12 PSIG
	RV at 40 PSIG
11:36	CRC #1 8"
	CRC #2 7½"
	CRC #3 9"
	CRC #4 9"
	CRT #1 12½ PSIG
	CRT #2 13 PSIG
	CRT #4 13 PSIG
	RV at 40 PSIG
11:38	Number 4 CRC locked off to level the curb ring.
11:40	CRT #1 11 PSIG
	CRT #2 12 PSIG
	CRT #4 12 PSIG
	CRC #1 10"
	CRC #2 8"
	CRC #3 11½"
	CRC #4 13½"
	RV at just under 50 PSIG
11:43	CRT #1 6½ PSIG
	CRT #2 8 PSIG
	CRT #4 8 PSIG

424 <u>TIME</u>	<u>EVENT</u>
11:43 (cont.)	CRC #1 12" CRC #2 12" CRC #3 12" CRC #4 16" Curb ring locked off to build the concrete pressure back up.
11:45	Concrete pressure increasing. CRT #1 11 PSIG CRT #2 12 PSIG CRT #4 11½ PSIG Curb ring still locked off. RV pressure at 55 PSIG. Curb ring hydraulic pressure increased to 900 PSIG. CRC #1 13" CRC #2 12" CRC #3 14" CRC #4 16½"
11:49	CR descent reactivated. Hydraulic pressure in curb ring cylinders reduced to 700 PSIG. CRC #1 14½" CRC #2 13" CRC #3 16" CRC #4 18"
11:52	Curb ring cylinder lowered to level up the ring. CRT dropped to 6 PSIG.
11:53	Relief valve setting for cylinder #4 increased to improve resistance force of cylinder #4. Cylinder #4 locked off.
11:55	CRT #1 10 PSIG CRT #2 11½ PSIG

<u>TIME</u>	<u>EVENT</u>
11:55 (cont.)	CRT #4 11 PSIG CRC #1 17" CRC #2 16½" CRC #3 18" CRC #4 20"
11:57	Concrete pump output rate increased to reduce the volume of concrete in the pump hopper.
11:59	CRC #1 19½" CRC #2 20½" CRC #3 21" CRC #4 21" CRT #1 10 PSIG CRT #2 12 PSIG CRT #4 10 PSIG RV at 50+ PSIG
12:01	Curb ring hydraulic pressure increased to 800 PSIG. CRT #1 13 PSIG CRT #2 14 PSIG CRT #4 13½ PSIG
12:01	<u>CSL STARTED DOWN</u> Micrometer speed control will be adjusted to obtain desired advance rate.
12:05	Movement of CSL reported from tower, but not noted on control house meter.
12:06	<u>CONCRETE MIX CHANGED TO "DESIGN MIX"</u>
12:07	CSL control meter shows 24.8"

<u>426</u> <u>TIME</u>	<u>EVENT</u>
12:08	CRT #1 17 PSIG CRT #2 18 PSIG CRT #4 17 PSIG CRC #1 23" CRC #2 27" CRC #3 26" CRC #4 22½"
12:10	Curb ring cylinders #2 and #3 were locked to level up. CRT #2 and #3 increased to 22 PSIG each. Curb ring started down again and all CRT pressures went down.
12:12	Curb ring hydraulic pressure increased. CRT #1 14 PSIG CRT #2 17 PSIG CRT #4 13 PSIG CRC #1 27" CRC #2 29" CRC #3 32" CRC #4 28" CSL reading 25.0"
12:17	CSL reading 24.3". CSL speed micrometer increased to #2 setting.
12:18	CRC #1 29" CRC #2 31" CRC #3 33" CRC #4 32"
12:22	CSL meter at 21.1". Micrometer set back to #1 setting.

<u>TIME</u>	<u>EVENT</u>
12:23	CRT #1 18 PSIG CRT #2 22 PSIG CRT #4 15 PSIG
12:25	Curb ring cylinders #3 and #4 locked off. CRT #1 16 PSIG CRT #2 19 PSIG CRT #4 15 PSIG Curb ring leveling. RV at 50 to 60 PSIG.
12:27	CRT #1 15 PSIG CRT #2 17 PSIG CRT #4 14 PSIG Cylinder #3 locked off.
12:29	CRC #1 36" CRC #2 37" CRC #3 37½" CRC #4 37"
12:32	CSL at 21.3" CRT #1 15 PSIG CRT #2 17½ PSIG CRT #4 14 PSIG
12:36	CRC #1 39" CRC #2 40½" CRC #3 43" CRC #4 42"
12:40	CSL at 20.1". Micrometer set up to #1.5.
12:42	CRC #1 44½" CRC #2 44½"

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<u>TIME</u>	<u>EVENT</u>
12:42 (cont.)	CRC #3 45"
	CRC #4 45½"
	CRT #1 15 PSIG
	CRT #2 18 PSIG
	CRT #4 14 PSIG
	CSL at 19.2"
12:47	CRC #1 48½"
	CRC #2 46½"
	CRC #3 47½"
	CRC #4 49½"
	Approximately 21" of travel remaining in the curb ring cylinder stroke.
	CRT #1 15 PSIG
	CRT #2 21 PSIG
	CRT #4 14 PSIG
	CSL at 17.5"
12:56	It was reported that 80 bags of cement have been used.
	CRC #1 52½"
	CRC #2 50½"
	CRC #3 51"
	CRC #4 53"
	CRT #1 14 PSIG
	CRT #2 18 PSIG
	CRT #4 14 PSIG
	CSL at 14.2"
13:00	CRC #1 54"
	CRC #2 53"
	CRC #3 54"

<u>TIME</u>	<u>EVENT</u>
13:00 (cont.)	CRT #1 14 PSIG CRT #2 19 PSIG CRT #4 13½ PSIG CSL at 11.5"
13:07	CRC #1 57" CRC #2 56½" CRC #3 57" CRC #4 58½" CRT #1 15 PSIG CRT #2 18 PSIG CRT #4 14 PSIG CSL at 8.3" RV indicates slightly above 50 PSIG
13:11	CRC #1 60" CRC #2 59" CRC #3 59½" CRC #4 61½" CRT #1 15 PSIG CRT #2 18 PSIG CRT #4 14 PSIG CSL at 6.1" RV remaining relatively steady, jumping only during slide valve movement from port to port.
13:13	CRC #1 61½" CRC #2 60" CRC #3 60" CRC #4 63"

<u>430</u> <u>TIME</u>	<u>EVENT</u>
13:15	Spurt of lubricating grout occurred near curb ring port #3.
13:18	CSL raised to stop blow-by of grout past the previously placed concrete slab. CRT #2 had increased to 30 PSIG. Curb ring cylinder jogged down to reduce concrete pressure. All concrete pressure dropped.
13:20	Concrete pressure regaining desired level. CRT #1 13 PSIG CRT #2 15 PSIG CRT #4 14 PSIG CRC #1 66" CRC #2 63½" CRC #3 62" CRC #4 66"
13:22	CRT pressures easily brought down by lowering the curb ring. CRC #1 68" CRC #2 65" CRC #3 63½" CRC #4 67½" CSL pushed back up to 10"
13:25	CRC #1 69" CRC #2 66" CRC #3 65" CRC #4 68"

<u>TIME</u>	<u>EVENT</u>
13:25 (cont.)	CRT #1 14 PSIG CRT #2 16 PSIG CRT #4 15 PSIG
13:30	CRT pressures on all three meters dropped to 10 PSIG.
13:31	CRT #1 14 PSIG CRT #2 19 PSIG CRT #4 14 PSIG CSL at 9.0"
13:33	<u>START OF LOWERING JACKFRAME</u>
13:36	Exact distance that the jackframe was lowered is not known at this time. CRT pressures on all three meters dropped again. CRT #1 8 PSIG CRT #2 6 PSIG CRT #4 6 PSIG
13:40	Curb ring hydraulic pressure increased to 750 PSIG. CRT #1 10 PSIG CRT #2 11 PSIG CRT #4 9 PSIG
13:41	CRC #1 63" CRC #2 61" CRC #3 62½" CRC #4 63½"
13:42	CRT #1 15 PSIG CRT #2 14 PSIG CRT #4 13 PSIG
13:43	CSL moving down again, meter reads 10.3"

432 <u>TIME</u>	<u>EVENT</u>
13:43 (cont.)	CRT #1 14 PSIG
	CRT #2 14 PSIG
	CRT #4 14 PSIG
13:46	CRC #1 65"
	CRC #2 64½"
	CRC #3 66"
	CRC #4 66"
	All concrete lines are flowing smoothly.
13:53	CRC #1 69"
	CRC #2 68"
	CRC #3 68"
	CRC #4 70½"
	CRT #1 15 PSIG
	CRT #2 15 PSIG
	CRT #4 14 PSIG
13:59	CRC #1 72"
	CRC #2 71"
	CRC #3 71"
	CRC #4 73"
	CRT #1 14 PSIG
	CRT #2 14 PSIG
	CRT #4 13 PSIG
14:04	CRC #1 74 "
	CRC #2 74"
	CRC #3 74"
	CRC #4 75½"
14:07	CRT #1 13½ PSIG
	CRT #2 13½ PSIG
	CRT #4 11 PSIG

<u>TIME</u>	<u>EVENT</u>
14:09	CSL slowed down. Meter reading -5.2" (top of CSL below bottom of previous slab). CRT #1 12 PSIG CRT #2 14 PSIG CRT #4 12 PSIG CRC #1 80" CRC #2 79" CRC #3 78½" CRC #4 80½"
14:13	CSL descent rate increased.
14:13	CSL at -8.5"
14:18	CSL at -9.8" CRT #1 13 PSIG CRT #2 15 PSIG CRT #4 13 PSIG
14:19	The pressure gauge on the RV indicates 60 to 80 PSIG when the remote readout in the control room reads 40 to 50 PSIG.
14:20	Concrete pressure dropped. CRT #1 8 PSIG CRT #2 7 PSIG CRT #4 11 PSIG Concrete mix started to use cement out of storage.
14:22	Concrete pressure increasing. CRT #1 15 PSIG CRT #2 9 PSIG CRT #4 15 PSIG

<u>434</u> <u>TIME</u>	<u>EVENT</u>
14:24	<u>CONCRETE MIXER AND PUMP STOPPED</u>
14:25	CSL at -10.0"
	CSL stopped at -10.7"
14:32	CRT #1 4½ PSIG
	CRT #2 6 PSIG
	CRT #4 11 PSIG
	CSL meter reads -9.8"
14:35	Jackframe jamed when the curb ring cylinders ran out of stroke and both support frames chaired on the Dywidag rods. Test terminated.

Test No. 5
Test Date: May 26, 1982
Test Summary:

Sixty inches of concrete was placed behind the slipform. The special slough zone panel was installed and was successfully negotiated by the prototype seal. The seal traversed a $3\frac{1}{2}$ inch deep zone under concrete pressure of 20 psig without evidence of concrete blow by. The slough zone panel also included a piece of corrugated sheet metal used as water panning. The test was terminated due to problems with the new vertically mounted concrete pump and the new Heede jack suspension system.

CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
MAY 26, 1982

LOG OF SIMULATION TEST "A"

BASIC INFORMATION

- All components of the system are in position as directed by T. Brunsing, Assistant Program Manager.

Curb Ring (CR) Position	+011" (Below Lid)
Slipform Liner (CSL)	-049" (Above Lid)
Slipform Effective Length (SEL)	+060" (Top of CR to Top of CSL)
All Pressure Gauges at 0.00	

- Guests in Attendance

1. Robert Stephan	D.O.E. - T.P.O.
2. Dennis Hall	Cementation - Project Engineer
3. Gunther Mattheis	Thyssen Mining

STARTING SPEEDS

Curb Ring (CR)	36"/1 Hour - 1" in 100 sec.
Slipform (CSL)	6"/1 Hour = 1" in 10 Min.

<u>TIME</u>	<u>EVENT</u>
8:40	Start pumping lubricating grout.
<u>8:45</u>	Start pumping design mix concrete.
8:50	Slide Valve 15 PSIG
	Curb Cylinder 125 PSIG
	Heede Jack 300 PSIG
	Slipform 300 PSIG
	SWITCH TO AUTO SLIDE VALVE AT 8:47 (30 Sec. for Each Port)
8:55	All gauges about the same.
8:57	Trouble with pump slide valve.
8:59	Trouble still exists.
9:02	Slide valve opened up to be cleaned out.
9:03	Valve still giving trouble.
9:08	Mixer Purged (sand hopper bridged over auger).

TIMEEVENTAbout 20 Mins.
Down

9:10	Still purging mixer.
9:16	Concrete being put in hopper (pump slide valve being operated manually).
9:18	Red valve up to 45 PSIG
9:23	Concrete moving up hoses.
9:24	Vibrators turned on (no pressures showing on port pressure gauges).
9:27	No noticeable change in red valve pressure when slide valve changes.
9:36	Beginning to show pressures on transducers. Curb position showing +12" SEL 62"
9:39	Curb position to 13"
9:40	C.R. pressure up to 250 PSIG P-1 at 5 PSIG P-2 at 4 PSIG P-3 at 3 PSIG P-4 at 1 PSIG (Curb tilted toward Port #1 - +2")
9:43	P-1 4 PSIG P-2 3 PSIG P-3 5 PSIG P-4 5 PSIG
9:44	Curb at 14" Conc. Exp. (C.E.) at -49" (Above lid) SEL at 63"
9:45	Pressures on port gauges seem to also show where we are pumping (which port is being pumped to).
9:46	Curb ring hydraulics raised to 450 PSIG Concrete pressures to: P-1 - 6 PSIG P-2 - 5 PSIG P-3 - 10 PSIG P-4 - 8½ PSIG
9:49	Concrete pressures behaving very well.

<u>TIME</u>	<u>EVENT</u>
9:50	C.R. at +16" SEL at +65" Red (conc.) valve still about 50 PSIG. CR going slightly out of level.
9:52	Curb Ring hydraulics raised to 600 PSIG Concrete P-1 15 PSIG P-2 9 PSIG P-3 11 PSIG P-4 11 PSIG
9:54	Heedes being activated (slow)
9:56	P-2 dropped to $\pm$ 4 PSIG Came back to 7 PSIG C.R. at 17" CSL at -48" SEL at 67"
9:58	All cone pressures about 10 PSIG. Slipform cylinders at $\pm$ 450 PSIG.
10:00	Hydraulic Unit shut off for few seconds.
10:02	Pressures P-1 10 PSIG P-2 10 PSIG P-3 8 PSIG P-4 7 PSIG
10:03	CSL moving down to -46" 1 1/16" in 35 sec. 1.0625" in 35 sec. $\frac{1.0625}{35} \times 60 \times 60/12 = 9.1 \text{ ft./hr.}$ 1.82"/Min. = 109.3"/hr.
10:07	Pressures still about $\pm$ 10 PSIG C.R. at 20" CSL at -45" SEL at 67" Curb tilted about 3" to 3 2 1/2" to 4

<u>TIME</u>	<u>EVENT</u>
10:08	Hydraulics jogged again.
10:10	Red valve still around 40 to 50 PSIG.
10:12	C.R. at +22" CSL at -45" SEL at +69"
10:15	Tom manually locking out #3 cylinder to level curb.
10:17	Conc. P-1 13 PSIG P-2 8 PSIG P-3 11 PSIG P-4 10 PSIG C.R. +26" CSL -45" SEL +73"
10:22	Conc. P-1 8 PSIG P-2 6 PSIG P-3 8 PSIG P-4 10 PSIG C.R. +27" CSL -44" SEL +73"
10:26	P-1 9 PSIG P-2 7 PSIG P-3 11 PSIG P-4 7 PSIG C.R. +29" CSL -38" SEL + 69
10:32	Slide valve on manual on #4 P-1 10 PSIG P-2 8 PSIG P-3 12 PSIG P-4 15 PSIG #3 cylinder locked off Tilt way out

<u>TIME</u>	<u>EVENT</u>
10:35	<u>SLOUGH ZONE AT PORT #4</u> P-1 6 PSIG P-2 9 PSIG Tilt being leveled. P-3 4 PSIG P-4 5 PSIG
10:37	One vibrator dropped out of curb.
10:39	P-1 3 PSIG P-2 4 PSIG P-3 5 PSIG P-4 5 PSIG C.R. +38" CSL -28" SEL +67"
10:49	P-1 15 PSIG P-2 14 PSIG P-3 20 PSIG P-4 12 PSIG C.R. +40" CSL -20" SEL +62" C. R. Hydraulic pressure lowered to 400 PSIG.
10:51	Bob suggests we protect string pots.
10:52	P-1 10 PSIG P-2 2 PSIG P-3 4 PSIG P-4 4 PSIG Curb hydraulic press up to 800 C.R. +42" CSL -18" SEL +62"
10:56	P-1 15 PSIG P-2 14 PSIG P-3 15 PSIG P-4 13 PSIG C.R. +43" CSL -15" SEL +60"

<u>TIME</u>	<u>EVENT</u>
11:00	P-1 14 PSIG P-2 10 PSIG P-3 16 PSIG P-4 9 PSIG C.R. +43" CSL -15" SEL +60"
11:03	Heede auto level adj. giving some trouble - working on it.
11:04	P-1 15 PSIG P-2 10 PSIG P-3 20 PSIG P-4 8 PSIG C.R. +44" CSL -15" SEL +61" Tilt out 2" each way toward #3 and #4
11:26	C.R. +51" CSL -15" SEL +69"
11:46	Still having Heede trouble.
11:49	Problems with pump and Heedes curb locked off. P-1 - 6 PSIG P-2 - 10 PSIG P-3 - 5 PSIG P-4 - 10 PSIG C.R. +58" CSL -16" SEL +75"
2:00	Test Aborted

CSL PROGRAM
 CONCRETE DATA SHEET
Person MARK D. LUTHERDate 5/26/82Time 8:35 AM. - 11:49 AM.Temp. 77°F @ 10:12 - 82°F @ 11:29Weather PLEASANT, SUNNY

TABLE I (Cement and Aggregates)

MATERIAL	DELIVERY RATE lbs/min.	BATCH PLANT DIAL SETTING	TEMPERATURE (°F)	MOISTURE CONTENT (%)
CEMENT	65.3	420 INITIALLY 410 @ 10:52 AM.	-	NA.
SAND	99.7	235	-	4 ASSUMED
3/8 STONE	52.8	216	-	3 ASSUMED
3/4 STONE	74.8	480	-	2 ASSUMED

TABLE II (Admixtures)

MATERIAL	DELIVERY RATE	FLOW METER	TEMPERATURE (°F)	SOLUTION STRENGTH PARTS MTL:PARTS WATER
¹⁵⁰ MIGHTY SOLUTION	2.82 #/min	20 + 1/16 TURN	-	1 : 2
DAREX SOLUTION	0.629 #/min	5.8 GPH.	-	1 : 10
CaCl ₂ SOLUTION	12.47 #/min	1.46 GPM	-	1 : 4

TABLE III (Fresh Concrete Data)

SERIES	START TIME AM.	SLUMP @ SOME TIME X" @ t = X min	UNIT WEIGHT	AIR CONTENT (%)	CONCRETE TEMPERATURE (°F)
I	9:36	7 1/4" @ 3 min.	-	-	~ 68°F
II	11:01	5 1/2" @ 4 min.	-	2.6	71°F

TABLE IV

SERIES	STRESS @ SOME TIME
I	3950 @ 1d
II	5190 @ 1d

NOTES: SERIES I SERIES II

TIME	SLUMP	TIME	SLUMP
3 min	7 1/4	4 min	5 1/2
10	6 3/4	15	2 3/4
15	6 1/2	25	3 1/4
22	6 1/2	30	2 3/4
25	6 1/2	37	2 3/4
35	7		
41	5 1/2		
60	5		

TEST OF CONCRETE SPECIMENS

June 2, 1982

June 23, 1982

CLIENT FOSTER-MILLER ASSOCIATES, WALTHAM, MASSACHUSETTS
PROJECT CSL

Reference Number 82L-977ABC
Date Received 5-27-82
Date Sampled 5-26-82 by us
Location of Placement CSL

Truck Number Not determined
Load Number No data
Ticket Number No data
Class Concrete "
Cubic Yards Not determined
Cement 752 lbs/cu.yd. Iron Clad type III
Fine Aggregate 1225 " New England Sand
Coarse Aggregate 1500 " " 3/4" Stone
Water No data
Admixture 3% CaCl₂ + 1.5% Mighty 150 + 1 1/2 oz/cu.yd. Darex
Time Sampled 9:36AM
Weather Fair, 70°F
Concrete Temperature 68°F
Slump 7 1/4"
Entrained Air Not determined
Appearance Satisfactory
Storage Outside on Pallet, then laboratory fog room

Date of Test	5-27-82	6-2-82	6-23-82
Age at Test	24 hours	7 days	28 days
Specimen Number	1A	1B	1C
Dimensions	6x12"	6x12"	6x12"
Density, lbs/cu.ft.	148	148	147 1/2
Compressive Strength	3950ψ	5330ψ	6740ψ
Remarks			

Respectfully submitted,

David R. Mitchell
David R. Mitchell 193

HERMAN G. PROTZE- INC. -
MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

(617) 332-8460

TEST OF CONCRETE SPECIMENS

June 2, 1982

June 23, 1982

CLIENT FOSTER-MILLER ASSOCIATES, WALTHAM, MASSACHUSETTS
PROJECT CSL

Reference Number 82L-978ABC
Date Received 5-28-82
Date Sampled 5-26-82 by us
Location of Placement CSL

Truck Number Not determined
Load Number No data
Ticket Number "
Class Concrete "
Cubic Yards Not determined
Cement 752 lbs/cu.yd. Iron Clad type II
Fine Aggregate 1225 " New England Sand
Coarse Aggregate 1500 " " ¾" Stone
Water No data
Admixture 3% CaCl₂ + 1.5% Mighty 150 + 1½ oz/cu.yd. Darex

Time Sampled 11:00-11:25AM
Weather Fair, 82°F
Concrete Temperature 70°F
Slump 5½" @ 11:01AM, 3¼" @ 11:25AM
Entrained Air Not determined
Appearance Satisfactory
Storage Outside on Pallet, then laboratory fog room

Date of Test	5-27-82	6-2-82	6-23-82
Age at Test	24 hours	7 days	28 days
Specimen Number	2A	2B	2C
Dimensions	6x12"	6x12"	6x12"
Density, lbs/cu.ft.	150	151½	150
Compressive Strength	5190ψ	6200ψ	7770ψ
Remarks			

Respectfully submitted,

David R. Mitchell
David R. Mitchell 195

Test No. 6
Test Date: June 3, 1982
Test Summary:

One-hundred and five inches of concrete was placed behind the form. Jack frame ran out of level and locked up inside tower causing termination of test.

CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
JUNE 3, 1982

LOG OF PART #2 - SIMULATION TEST "A"

BASIC INFORMATION

- Position of CSL components at start of test.

Curb Ring (CR) Position	+ 075 ¼"	(Below Lid)
Slipform Liner (CSL)	+029½"	(Below Lid)
Slipform Effective Length	+045 ¾"	(Top of CR to Top of CSL)

Approximate Void Height is 18".

Reinert Pump will be discharging into a mobile pump rented from Guerini.

Pumping rate approximately 5 yards/hr. (Void should be filled in about 30 minutes).

<u>TIME</u>	<u>EVENT</u>
10:01	Start pumping lubricating grout.
10:03	Grout being pumped to Guerini Hopper.
10:10	Guerini pumping.
10:13	Concrete to Guerini pump. Reinert Pump set at "5" (Slide valve set on auto).
10:16	Reinert Pump working O.K. with low to no back pressure.
10:17	8" slump on concrete.
10:20	Grout slowing above curb.
10:21	Slide valve cycling 30 sec./port.
10:22	Reinert pump operating at 150 PSIG. Red Valve (RV) at 30 to 40 PSIG.
10:26	4 way slide valve stuck. Pressure too low - Jonathan Kelley had set pressure low to prevent overheating.
10:27	All O.K. when pressure raised.
10:29	RV at 40 PSIG. CR at 200 PSIG. Heede Equalizer (HE) at 400 PSIG.

<u>TIME</u>	<u>EVENT</u>	447
10:30	Reinert Pump at - 300 PSIG. Slump low concrete sticky - valve moving slowly, has problem - concrete not moving around elbows in line.	
10:32	CR at +075" CSL at +030" SEL at +045" } Rounded	
10:34	Concrete slump 5". Both pumps seem to be working O.K.	
10:37	All gauges reading the same as above. (#4 pressure transducer is not working according to R.T.) May be repaired later.	
10:39	Pressure transducer P#3 is beginning to show slight pressure.	
10:43	Pressures showing on all ports. CR hydraulic pressure at 200 PSIG.	
10:44	P1 - 1 PSIG P2 - 1 PSIG P3 - 4 PSIG RV 40 PSIG HE 500 PSIG CR 200 PSIG	
10:47	Slide valve set to manual and pumping to Port #1 to level CR - Process working. P1 - 2 PSIG P2 - 1½ PSIG P3 - 2 PSIG	
10:50	Concrete Temp. 76°F CR at +77" CSL at +30" CSL at +47"	
10:52	Concrete Slump 4"	
10:53	CR at 400 PSIG Hydraulic P1 - 3 PSIG P2 - 4 PSIG P3 - 8 PSIG	
10:54	P1 - 6 PSIG P2 - 6 PSIG P3 - 6 PSIG CR Level at +79" RV at 50 PSIG	
10:56	CR at 500 PSIG P1 - 8 PSIG (P4 broken) P3 - 8 PSIG CR Level at +80" Heede Equalizer pressure at 800 PSIG	

<u>TIME</u>	<u>EVENT</u>
11:00	CR at +82" CSL at +30" SEL at +51" P1 - 8 PSIG P2 - 7 PSIG P3 - 8 PSIG Tilt slightly out. Pumping manually between Ports 1 and 2.
11:06	CR at +86" CSL at +30" SEL at +56" P1 - 8 PSIG P2 - 7 PSIG P3 - 8 PSIG CR Level RV about 50 to 60 PSIG
11:12	CR at +89" CSL at +30" SEL + 59" P1 - 8½ PSIG P2 - 7 PSIG P3 - 7½ PSIG CR tilt within 1" both ways. RV 50 PSIG to 60 PSIG Heede Equalizer 850 PSIG CR Pressure 500 PSIG
11:19	Problems with Reinert Pump. Concrete sticky - no reading on slump - concrete will not fall through 3 x 3 grating.
11:22	Concrete pumping again.
11:23	CR at 93" P1 - 9 PSIG P2 - 7 PSIG P3 - 8 PSIG CR tilted to #3 again. (Maybe due to seal)
11:26	CR at +96" CSL at +30" SEL at +66" P1 - 10 PSIG P2 - 7 PSIG P3 - 12 PSIG Vibrator broke off. Heede 900 PSIG
11:28	Reinert Pump problems again. Diverting concrete from mixer. Mix dried up and stuck in 3 x 3 grid - concrete sticky.

<u>TIME</u>	<u>EVENT</u>	449
11:34	CR pressure raised to 700 PSIG. P1 - 11 PSIG P2 - 17 PSIG P3 - 11 PSIG CR at +100" CSL at +30" SEL at +70" Heede 1100 PSIG	
11:40	CR at +104" CSL at + 30" SEL at + 74" P1 - 13½ PSIG P2 - 11 PSIG P3 - 11 PSIG Heede 1100 PSIG Concrete slump 6"	
11:45	CR at +106" CSL at + 30" SEL at + 76" P1 - 14 PSIG P2 - 11 PSIG P3 - 14 PSIG	
11:51	Going to start slipform CR at +110" CSL at + 30" SEL at + 80" P1 - 13 PSIG P2 - 15 PSIG P3 - 10 PSIG	
11:54	Heedes correcting. Slipform not moving down as it should.	
11:58	Concrete blockage.	
12:01	Concrete lines cleared. Trying to power CSL down. CSL showing +31".	
12:04	CSL moving O.K. CR at +119" CSL at + 32" SEL at + 86" P1 - 12 PSIG P2 - 13 PSIG P3 - 13 PSIG RV + 60 PSIG HE 850 PSIG Curb close to level.	
12:08	64" of concrete pumped.	

450

<u>TIME</u>	<u>EVENT</u>
12:10	CR at +122" CSL at + 32" SEL at + 90" P1 - 14 PSIG P2 - 12 PSIG P3 - 13 PSIG
12:18	CSL Slipforming. CR at +126" CSL at + 32" SEL at + 93" P1 - 2 PSIG P2 - 8 PSIG P3 - 8 PSIG
12:20	CR pressure 800 PSIG <u>THE SYSTEM IS WORKING</u>
12:25	CR at +128" CSL at + 35" SEL at + 93" P1 - 9 PSIG P2 - 10 PSIG P3 - 9 PSIG Curb closed to level. RV 58 PSIG HE 900 PSIG
12:30	CR at +131" CSL at + 37" SEL at +94" P1 - 11 PSIG P2 - 12.5 PSIG P3 - 12 PSIG Curb close to level. RV 62 PSIG HE 400 PSIG
12:35	CR at +135" CSL at + 39" SEL at + 96" P1 - 13 PSIG P2 - 16 PSIG P3 - 11 PSIG Tilt O.K. RV 63 PSIG HE 0 PSIG (Trouble)
12:40	CR at +136" CSL at + 39" SEL at + 98" P1 - 14 PSIG P2 - 18 PSIG P3 - 18 PSIG Tilt returning to level. RV 62 PSIG HE 0 PSIG (One Heade may be walking away)

<u>TIME</u>	<u>EVENT</u>	451
12:45	CR at +137" CSL at + 39" SEL at +100" P1 - 9 PSIG P2 - 17 PSIG P3 - 13 PSIG Tilt O.K. HE 600 PSIG	
12:50	CR at +146" CSL at + 45" SEL at +102" P1 - 4 PSIG P2 - 15 PSIG P3 - 13 PSIG Tilt Close RV 50 PSI + HE 200 PSIG	
12:52	CR at +150" CSL at + 48" SEL at +103" P1 - 9 PSIG P2 - 15 PSIG P3 - 10 PSIG Heedes not coordinating.	
12:55	We seem to have more slipform drag than expected. Curb ring concrete pressure not pushing the system down. System hanging up.	
12:58	CR at +163" CSL at + 57" SEL at +107" P1 - 9 PSIG P2 - 15 PSIG P3 - 9 PSIG	
1:04	CR at +162"	
1:14	Test ended. We pulled one hose (#2 Port) off the nozzle.	
1:15	The jackframe and curb ring are stuck again. We need a method of keeping the jackframe level.	

Person MARK D. LUTHEDate 6/3/82Time 10:11 AMTemp. 77°F @ 11:37Weather PLEASANT

TABLE I (Cement and Aggregates)

MATERIAL	DELIVERY RATE lbs/min.	BATCH PLANT DIAL SETTING	TEMPERATURE (°F)	MOISTURE CONTENT (%)
CEMENT	62 ^{bac} _{COVET}	330	63°F @ 9:27	-
SAND	106 ^{CALIX}	300	59°F @ 9:27	ASSUMED 4
3/8 STONE	52 ^{CALIX}	216	59°F @ 9:27	ASSUMED 3
3/4 STONE	77 ^{CALIX}	480	59°F @ 9:27	ASSUMED 2

TABLE II (Admixtures)

MATERIAL	DELIVERY RATE #/MIN	FLOW METER	TEMPERATURE (°F)	SOLUTION STRENGTH PARTS MTL:PARTS WATER
150 MIGHTY SOLUTION	SERIES I 2.78 SERIES II 2.70	23 22 GPH	68	1 : 2
DAREX SOLUTION	0.776	8.2 GPH	-	1 : 10
CaCl ₂ SOLUTION 77% FUSK	12.5	1.46 GPH	78	1 : 4

TABLE III (Fresh Concrete Data)

SERIES	START TIME	SLUMP @ SOME TIME X" @ t = X min	UNIT WEIGHT	AIR CONTENT (%)	CONCRETE TEMPERATURE (°F)
I	10:27	5 3/4" @ 5 min.	ND	3.1	73°F @ 10:24 ⁺
II	12:53	5 1/4" @ 3 min	ND	3.2	75°F @ 12:53

NOTES: Below are Slump Histories

SERIES I SERIES II
 5 3/4" @ 5 min 5 1/4" @ 3 min
 4" @ 23 min 4 1/4" @ 12 min
 3 1/4" @ 26 min 3 3/4" @ 24 min
 2 3/4" @ 34 min 3 @ 30 min
 2 1/4" @ 40 min 3 @ 35 min

TABLE IV

SERIES	STRESS @ SOME TIME
I	1220 PSI @ 5 hrs 18 min 4140 PSI @ 1 day
II	23 PSI @ 5 hrs 56 min 3630 PSI @ 1 day

Calculated w/c SERIES I = 0.46X

SERIES II = 0.46X

TYPICAL w/c ratio = 0.46X

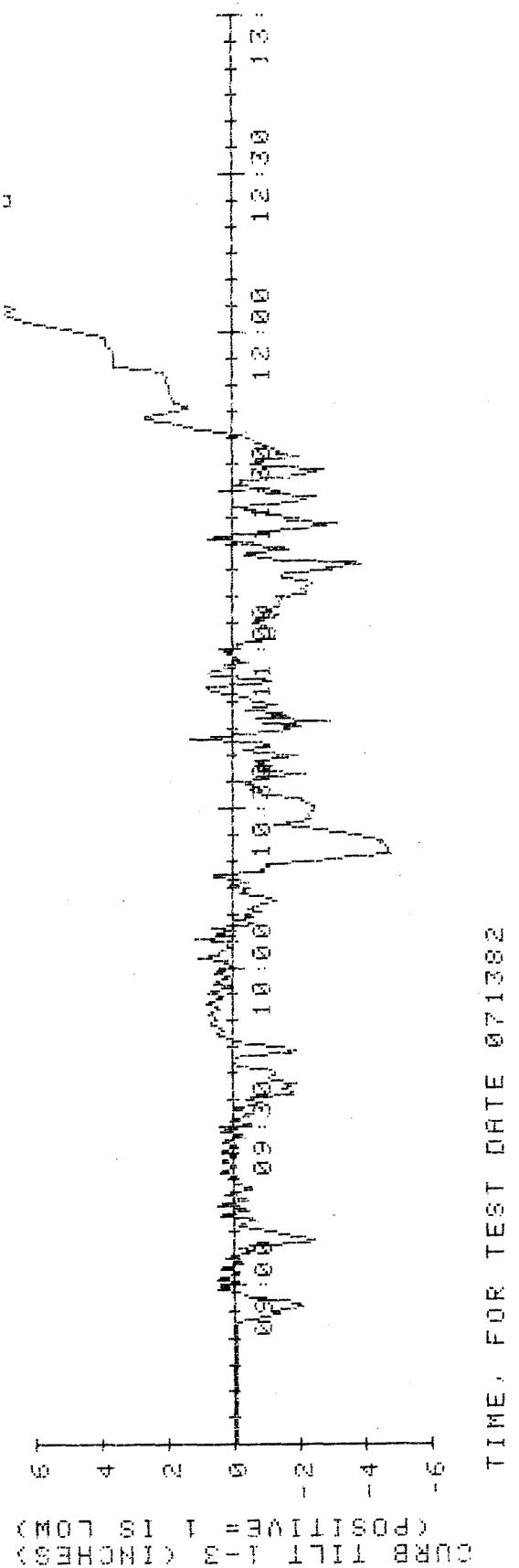
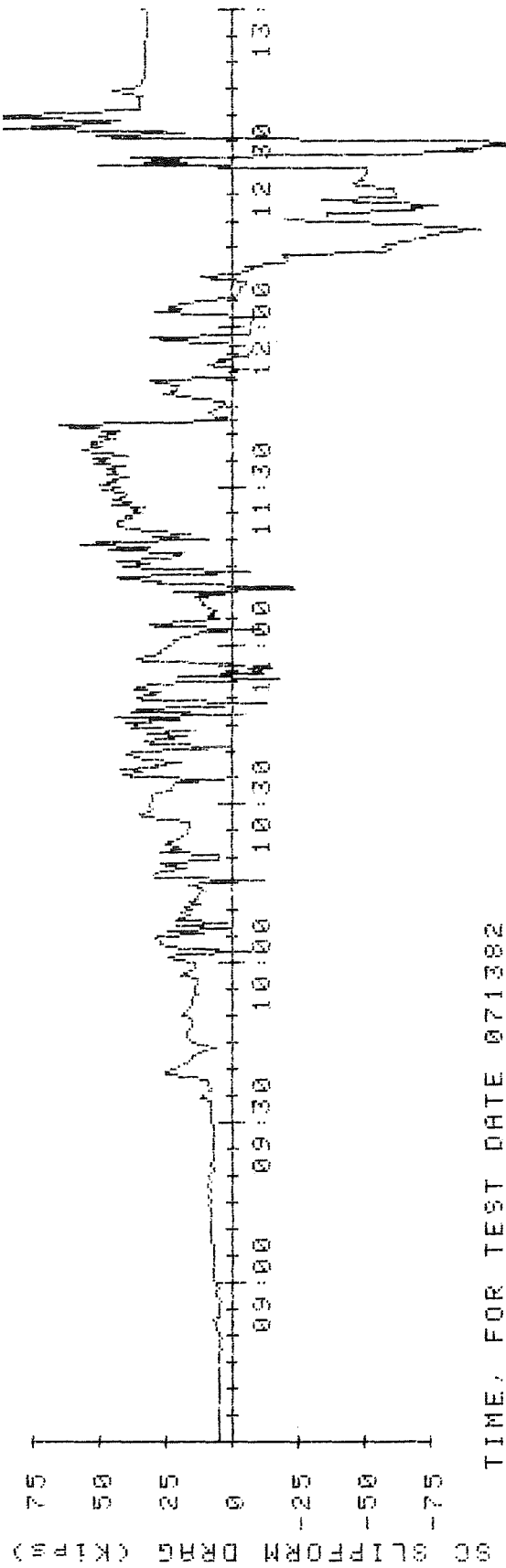
Test No. 7

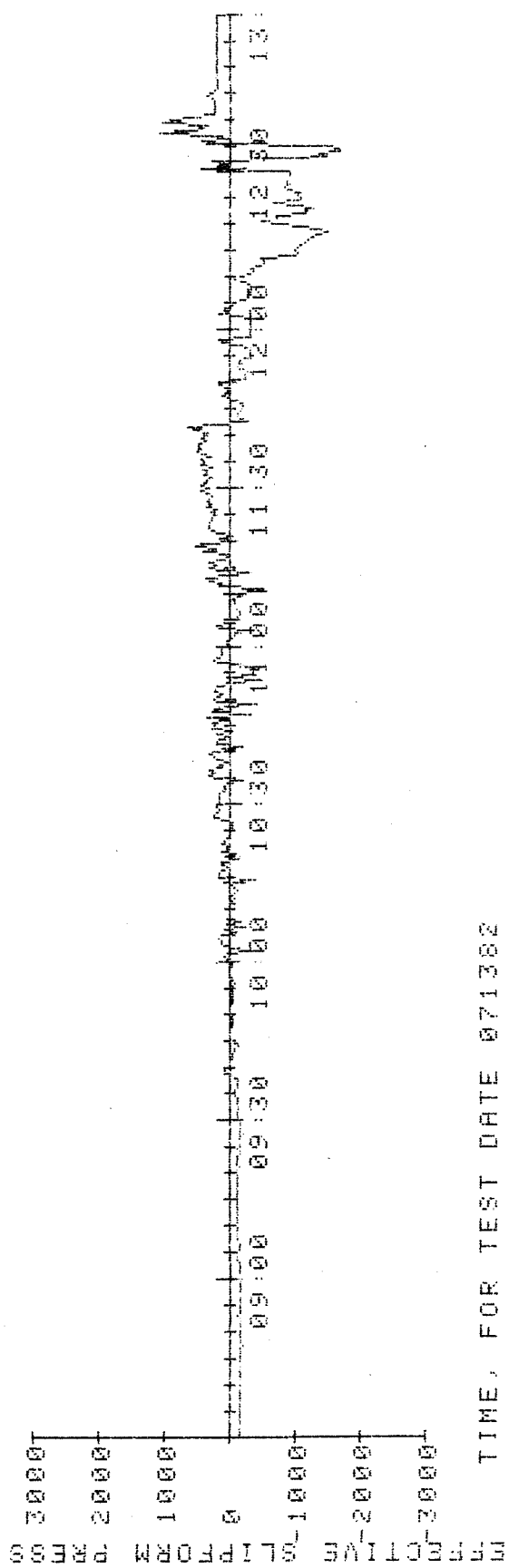
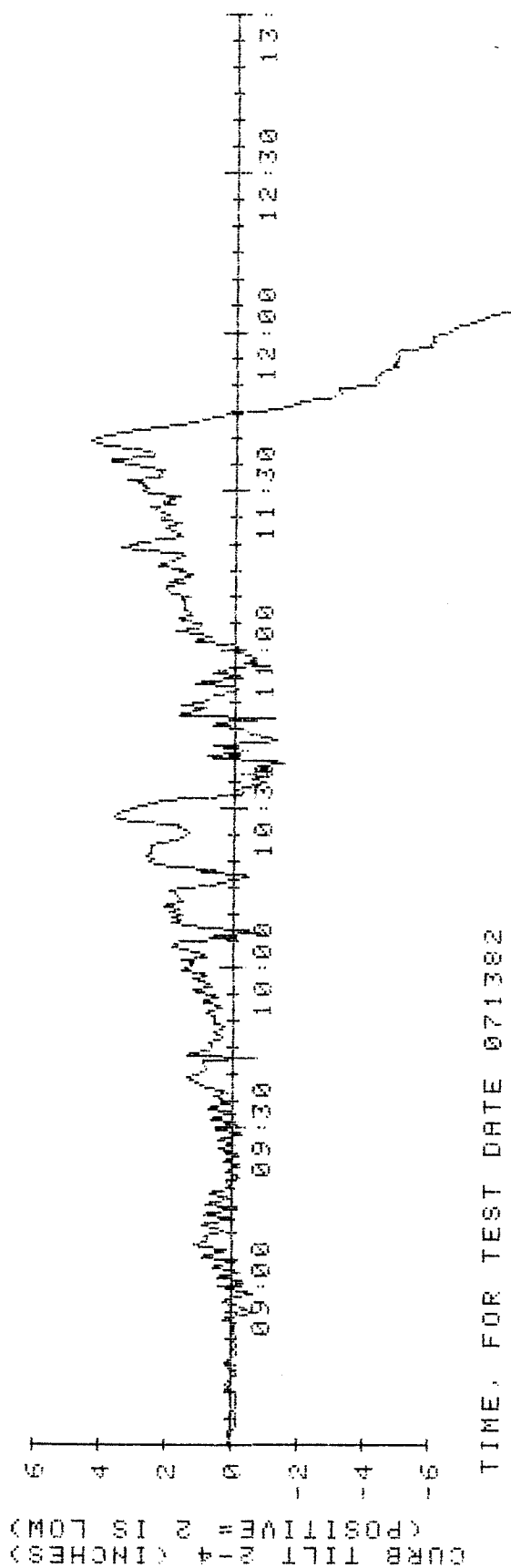
453

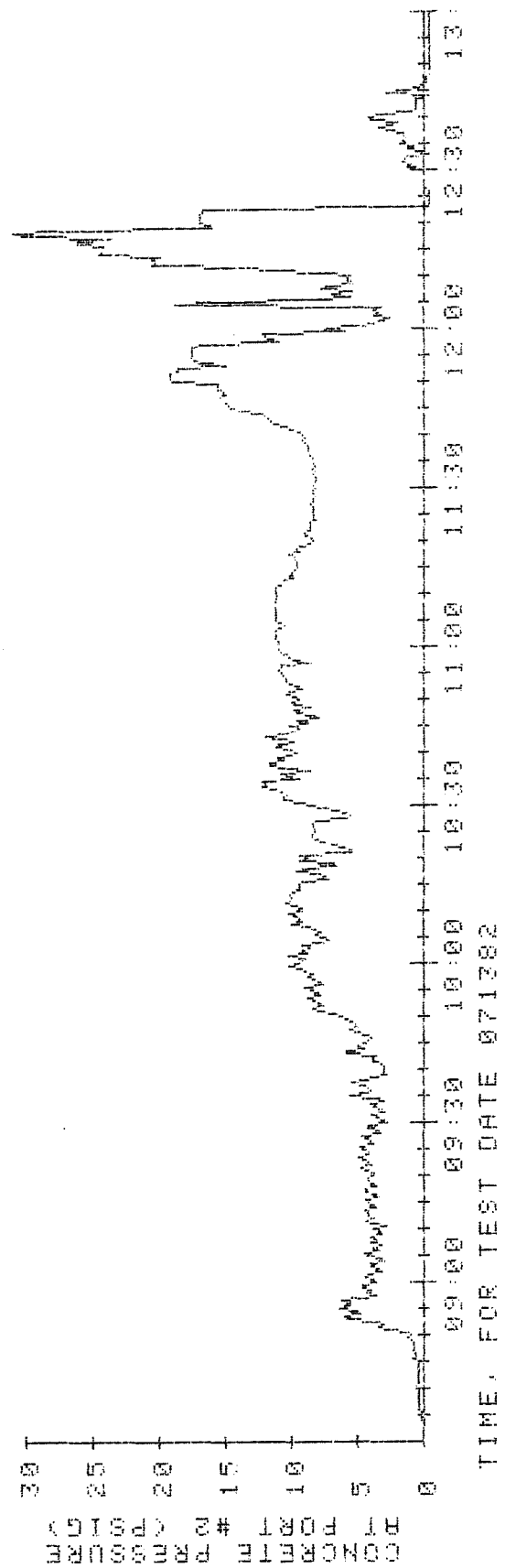
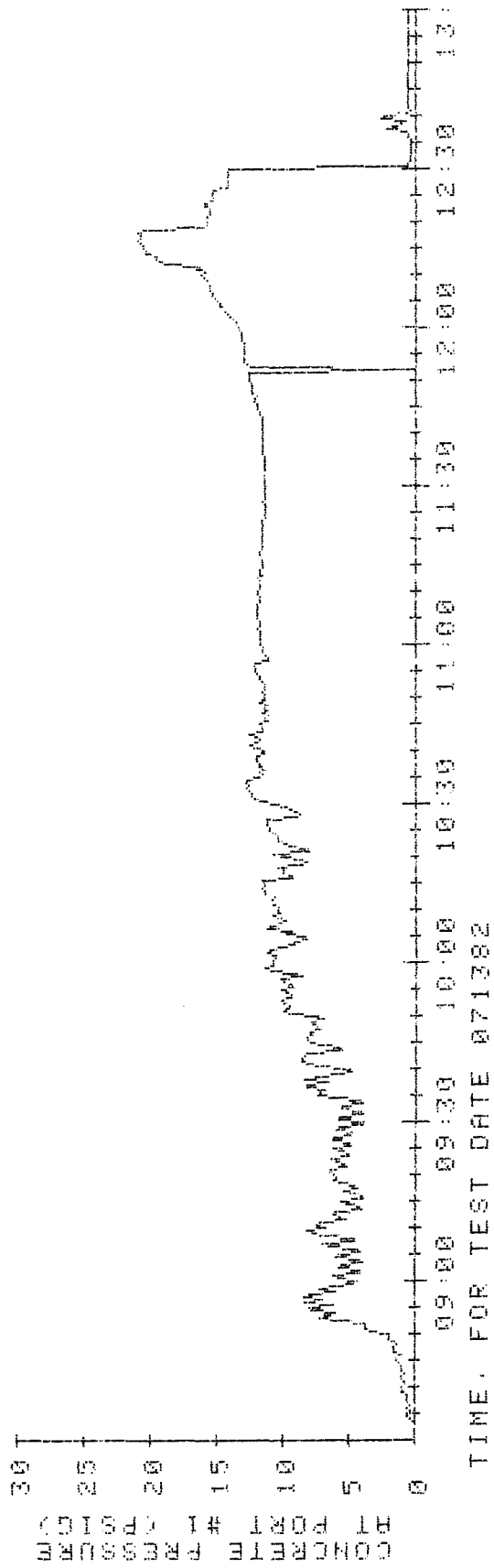
Test Date: July 13, 1982

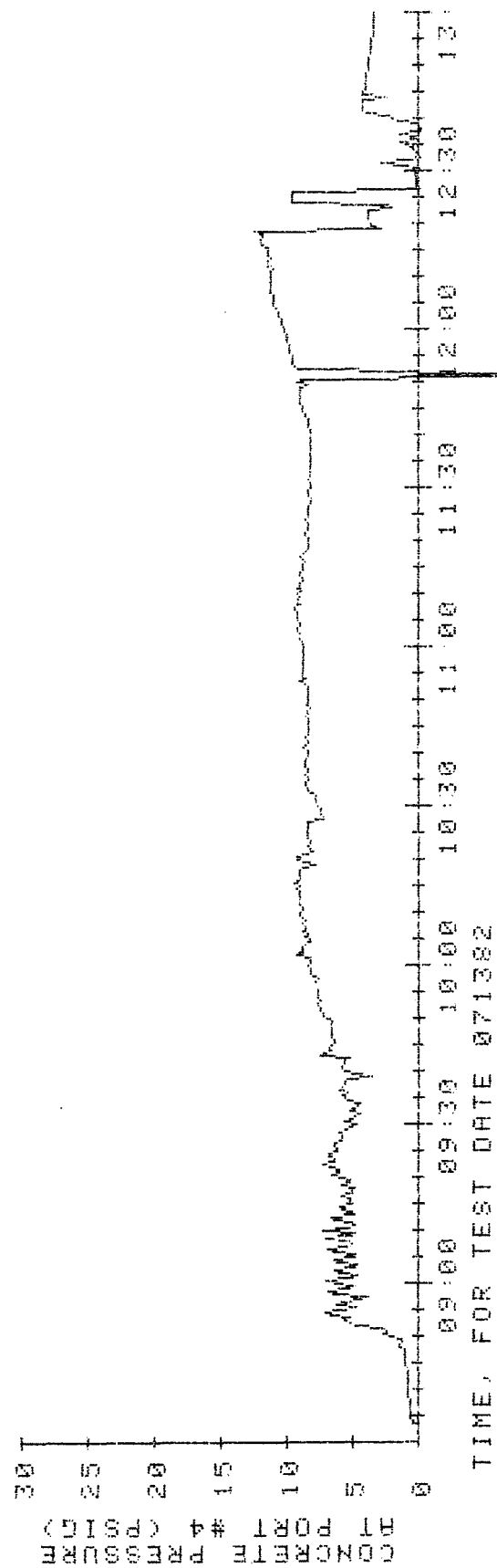
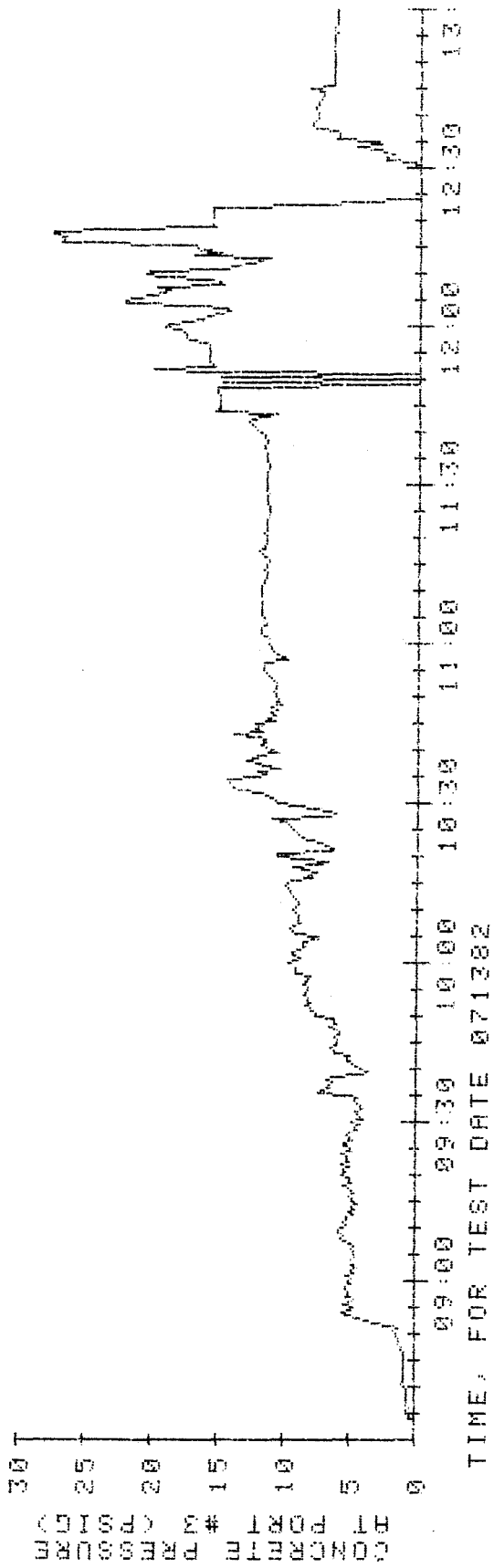
Test Summary:

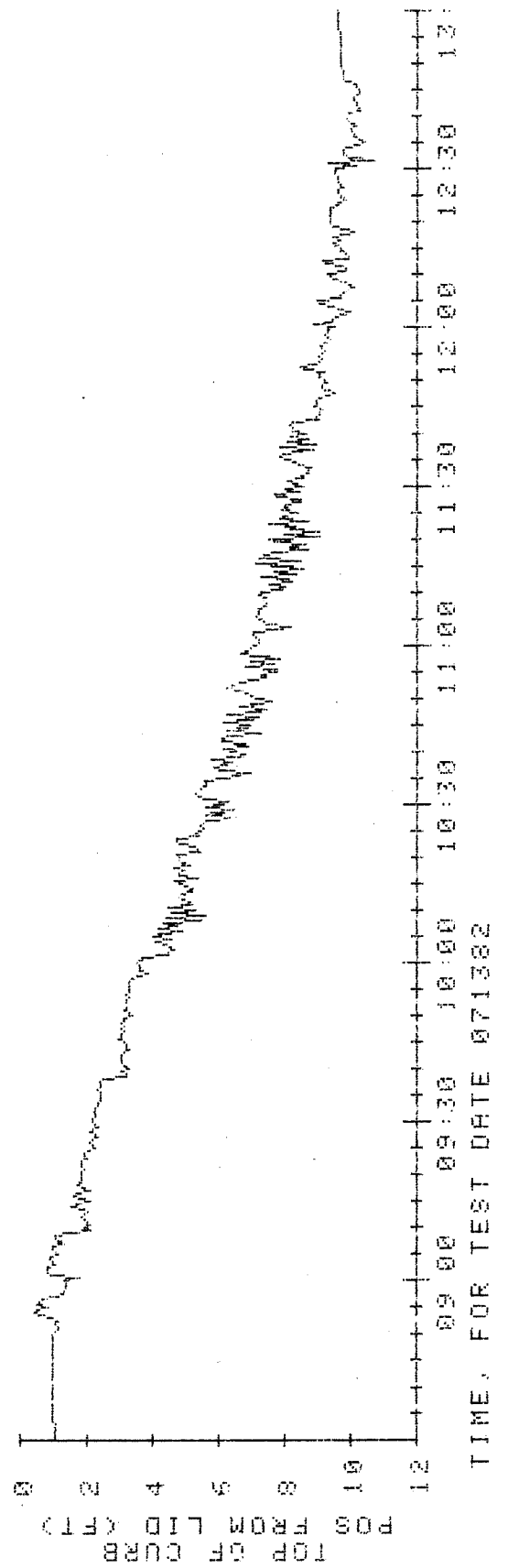
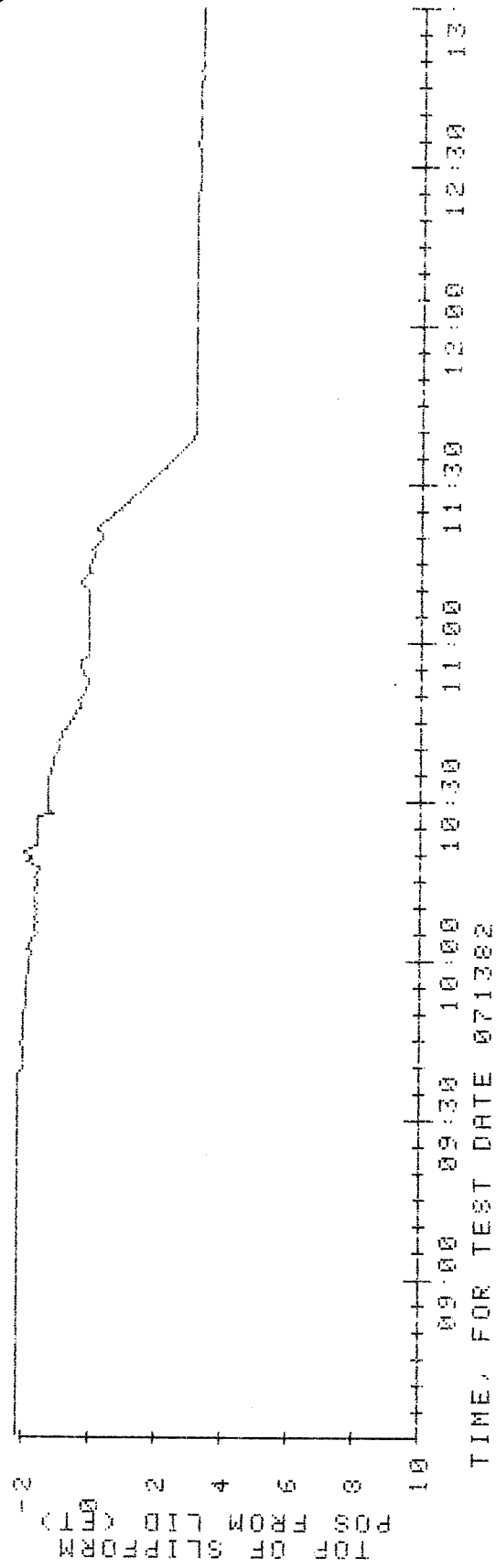
One-hundred and five inches of concrete was placed behind the slipform. Approximately 3 feet were slipformed before the test was prematurely ended. Curb ring jammed between slipform and outer form causing curb ring to break at two of its four joints.

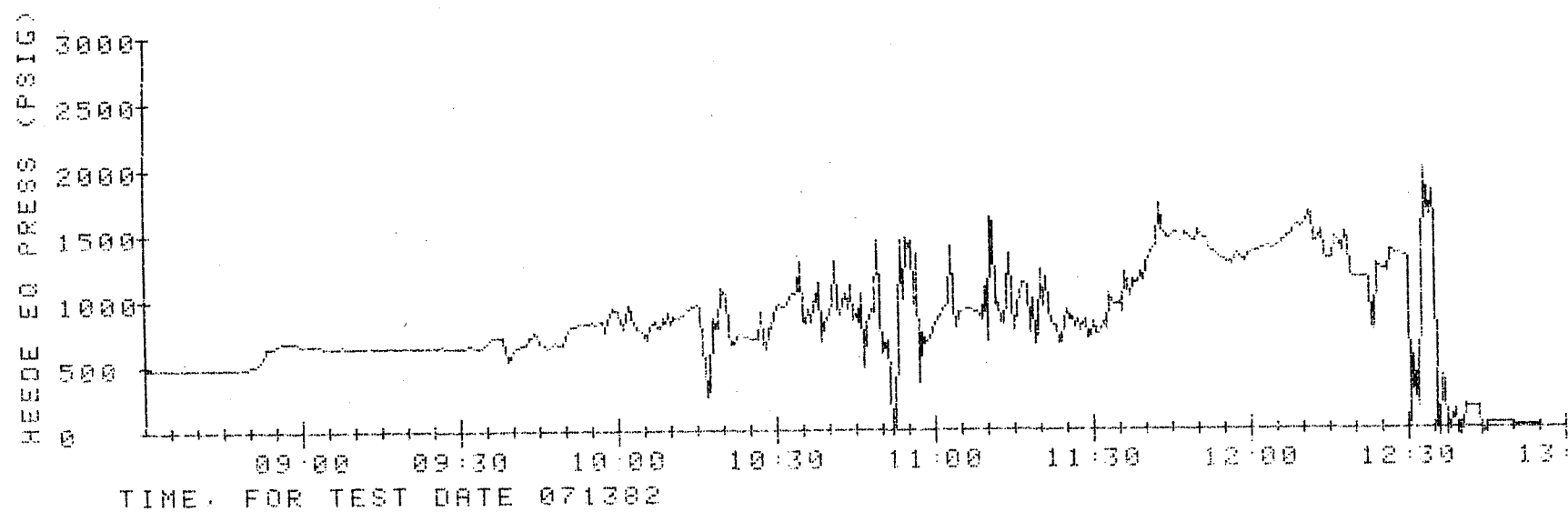
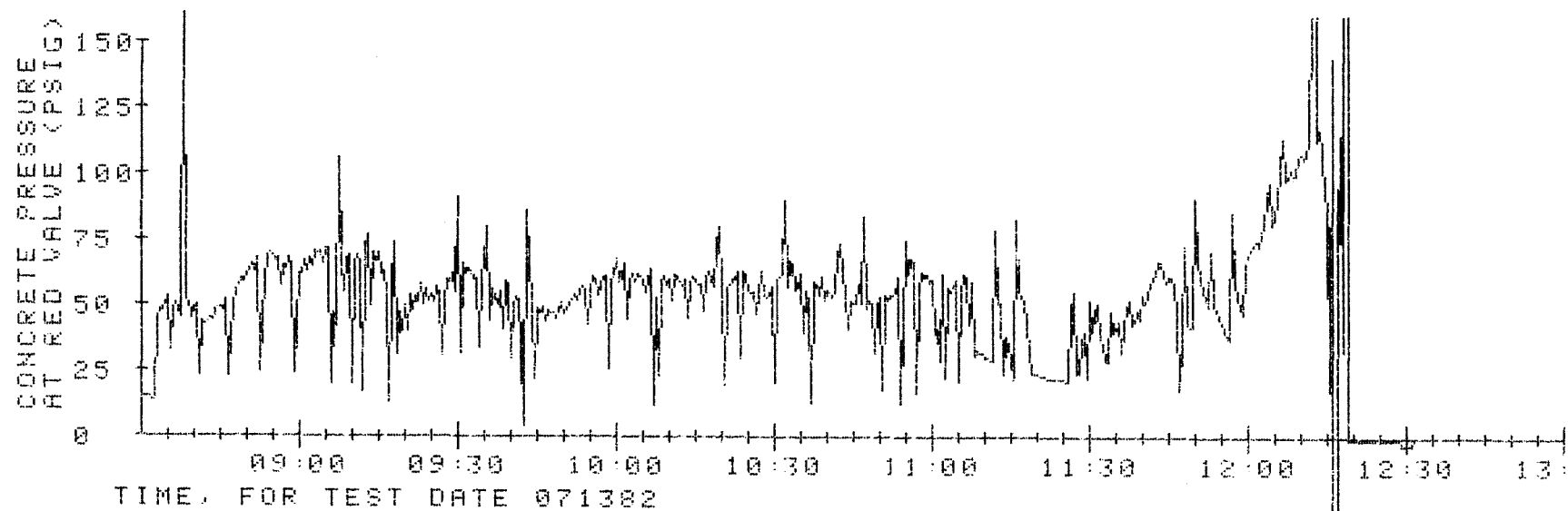


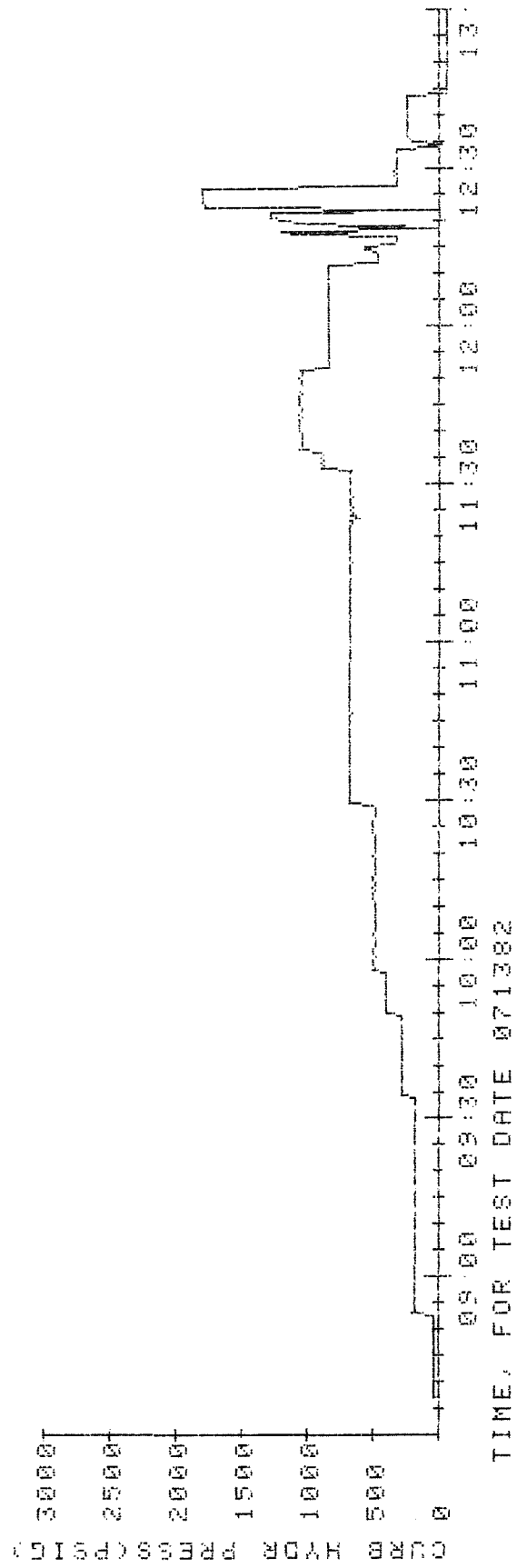












CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
JULY 13, 1982

461

LOG OF PART #1 - SIMULATION TEST "B"

BASIC INFORMATION

- Position of CSL components at start of test.

Curb Ring (CR) Position	+ 014"	(Below Lid)
Slipform Liner (CSL)	- 027"	(27" Above Lid)
Slipform Effective Length (SL)	+ 041"	(Top of CR to Top of CSL)
- Guest in Attendance
 1. Robert Stephan D.O.E. - T.P.O.
 2. Kenneth L. Saucier Corps of Engineers was present on July 14, 1982 during the test review and start of data analysis.
- Weather clear and 72⁰ at 7:30 A.M.

<u>TIME</u>	<u>EVENT</u>
7:45	Instruments being calibrated and Heede equalizers (HE) being filled. Equalizer pressure set at 400 PSIG.
8:01	Lubrication grout being made and pumped.
8:07	Slide valve (SV) hydraulic pressure set at 2000 PSIG and will be held constant.
<u>8:11</u>	Start pumping concrete. SV set on auto - cycle 30 sec/port.
8:15	Red Valve (RV) up to 20 PSIG.
8:17	RV at 30 PSIG.
8:18	Grout showing below curb ring on Heede rod.
8:20	Reinert Pump not performing - taken off line. Guerini Pump will be used.
8:24	RV back to 15 PSIG.
8:29	C.D. Dobson reported that Heede rod between Ports #1 and #4 - lowest joint - is out of alignment.
8:32	Guerini's Thompson Pump is operating - RV at 50 PSIG.

12 Minutes
Downtime

TIMEEVENT

8:34	Concrete flowing well in hoses.
8:36	Reinert Pump could not keep up supplying 5 yds/hr against the head with RV at 20 to 30 PSIG. Seems to work with no back pressure (only pumping into Guerini Hopper). Reinert Pump keeping up at 40% operating capacity.
8:44	Calculate start to pressurize at 8:55 (This time estimate was off because downtime was only 12 min. Not 21 min. - should be 8:46 (8:55 - 0:09)).
8:45	Reinert Pump keeping up at 35% capacity.
8:47	Seeing 1 PSI on Ports #2, 3 and 4. Probably dead load of concrete. RV about 50 to 60 PSIG.
8:50	Pressure starting to build. P1 - 2 PSIG P2 - 3 PSIG P3 - 3 PSIG P4 - 4 PSIG
8:52	Concrete showing at lid all the way around. Curb activated. P1 - 5 PSIG P2 - 5 PSIG P3 - 5 PSIG P4 - 6 PSIG
8:54	CR meters show tilt but we will not lock off cylinders - trying to level by pumping the concrete to specific ports - it worked.
8:56	CR at +015" CSL at -027" SL at +043" HE at 600 PSIG Lost #2 vibrator (hose disconnected)
8:58	Slide valve back on auto.
9:00	P1 - 5 PSIG P2 - 4 PSIG P3 - 5 PSIG P4 - 5 PSIG CR at +018" CSL at -027" SL at +045" HE at 600 PSIG RV at 50 PSIG Jack frame ¼" out of level curb tilt meters look O.K.

TIMEEVENT

463

9:07

P1 - 5 PSIG
P2 - 4 PSIG
P3 - 5 PSIG
P4 - 5 PSIG
CR at +022"
CSL at -026"
SL at +050"
HE at 600 PSIG
RV at 50 to 65 PSIG
Curb ring being leveled by pumping to specific ports.
Back on auto at 9:10

9:16

Red valve pressure periodically drops to 20 to 30 PSI on every port from average of 50 to 60.
CR at +029"
CSL at -026"
SL at +056"

9:20

P1 - 5 PSIG
P2 - 5 PSIG
P3 - 5 PSIG
P4 - 5 PSIG
CR at +031"
CSL at -026"
SL at +058"
Tilt - Level
HE at 600 PSIG
RV at 50 PSIG

9:28

P1 - 5 PSIG
P2 - 4 PSIG
P3 - 4 PSIG
P4 - 4½ PSIG
CR at +035"
CSL at -025"
SL at +061"
Curb - Level
HE at 600 PSIG
(Concrete pressure seems too low)

9:30

CR at +036"
Heedes are activated.
HE at 600 PSIG.
Concrete pressure increased by raising the curb ring cylinder hydraulic pressure.

9:34

P1 - 6 PSIG
P2 - 4 PSIG
P3 - 5 PSIG
P4 - 5 PSIG
CR at +038"
CSL at -026"
SL at +065"
HE at 600 PSIG
Meters show slight tilt - #3 low pumping to Port #1.

TIMEEVENT

9:38	Port pressures at 2 and 4 dropped to 3 PSIG P3 - 3 PSIG CR at +041 Concrete pressure too low.
9:45	P1 - 6 PSIG P2 - 4 PSIG P3 - 6 PSIG P4 - 5 PSIG CR at +046" CSL at -023" SL at +070" HE at 600 PSIG Meters show level jack frame and curb ring.
9:48	Concrete P1 - 6 PSIG P2 - 6 PSIG P3 - 7 PSIG P4 - 6 PSIG CR at +048" CSL at -023" SL at +073" HE at 700 PSIG Tilt looks good.
9:53	P1 - 8 PSIG P2 - 7 PSIG P3 - 8 PSIG P4 - 7 PSIG
9:58	Curb Concrete Pressure going up. P1 - 9 PSIG P2 - 8 PSIG P3 - 9 PSIG P4 - 7 PSIG CR at +052" CSL at -022" SL at +076"
10:08	Heedes not working as they should - not moving together. P1 - 9 PSIG P2 - 9 PSIG P3 - 9 PSIG P4 - 8 PSIG
10:09	CR at +059" CSL at -019" SL at +080" HE at 700 PSIG

TIMEEVENT

465

10:16 Heedes not working properly.
Jackframe levels show fairly good readings.
CR meters only 1" out.
CR at +063"
CSL at -021"
SL at +086"
RV at 70 PSIG
P1 - 9 PSIG
P2 - 9 PSIG
P3 - 9 PSIG
P4 - 8 PSIG
HE at 900 PSIG

10:28 P1 - 8 PSIG CR hydraulic pressure at 800 PSIG
P2 - 6 PSIG (increased 200 PSIG)
P3 - 7 PSIG
P4 - 6 PSIG

P1 - 9 PSIG
P2 - 7 PSIG
P3 - 10 PSIG
P4 - 7 PSIG

10:32 Jackframe walking down Heede rods.
P1 - 10 PSIG
P2 - 11 PSIG
P3 - 14 PSIG
P4 - 7 PSIG
CR at +074"
CSL at -014"
SL at +090"
RV at 50 PSIG
HE at 900 PSIG
Tilt looks good.

10:40 Heedes now working as they are supposed to work.

10:43 P1 - 10 PSIG
P2 - 9 PSIG
P3 - 12 PSIG
P4 - 7½ PSIG
CR at +081"
CSL at -008"
SL at +089"
Tilt looks within 1".

10:50 Getting ready to expose concrete.
CR at +083"
CSL at -002"
SL at +086"

10:51 Lost equalizer pressure - one Heede jack must have walked away.

TIMEEVENT

10:57

System still not working.
Heede jack hanging up.

10:59

P1 - 10 PSIG
P2 - 10 PSIG
P3 - 10 PSIG
P4 - 8 PSIG
CR at +089"
CSL at -000"
SL at +091"
HE at 750 PSIG
Tilt within 1" all ways.

11:06

All activities slowed down to work on Heede.
CR at +091"
CSL at -001"
SL at +095"
P1 - 10 PSIG
P2 - 10 PSIG
P3 - 11 PSIG
P4 - 8 PSIG
HE at 750 PSIG

11:15

Still having problems controlling the Heede jacks.
Concrete pressures O.K.
Tilt reasonable.
P1 - 10 PSIG
P2 - 9 PSIG
P3 - 11 PSIG
P4 - 8 PSIG
CR at +094"
CSL at +000"
SL at +097"
Tilt looks about 1" off.
#4 is high (Edit. Note: This checks with computer printout)
HE at 600 PSIG

11:18

Meter shows that concrete should be exposed.

11:22

Plant shut down - curb being held - slipform coming down.

11:24

Plant started up again.

11:32

Concrete hydraulic pressure up to 1000 PSIG.
P1 - 10 PSIG
P2 - 8 PSIG
P3 - 11 PSIG
P4 - 8 PSIG
CR at +098"
CSL at +027"
SL at +072" (Bob wants to go to an SL of 60" and raise pressure to induce in incipient bulge)

TIMEEVENT

467

11:36 Concrete hydraulic pressure raised to 1200 PSIG.
P1 - 10 PSIG
P2 - 8 PSIG
P3 - 11 PSIG
P4 - 8 PSIG
Concrete pressures are not going up as they usually do -
don't know why.

11:43 Concrete bulging with 66" slipform length.
CR at +105"
CSL at +036"
SL at +070"
P1 - 10 PSIG
P2 - 13 PSIG
P3 - 15 PSIG
P4 - 8 PSIG
HE at 1300 PSIG
Tilt seems to be O.K.

Recorded after test terminated -----

The Heede jacks do not move down uniformly.

At 11:45 the slipform was slowed way down and curb ring speeded up to regain SEL. Curb ring ran too far out of level while we were concerned with the Heede jacks. Curb ring quadrant between splices #1 and #2 jamed between the outside form and slipform before we knew what was happening. The concrete being pumped forced the other 3 quadrants down and broke both #1 and #2 splices in negative bending. Broken curb was discovered on Wednesday, July 14, 1982.

12:18 RV shows pressures above 200 PSIG.
Concrete hose parted and a substantial amount of concrete flowed back out of the form.
Curb ring hopelessly jammed up.
Test terminated. Jackframe stayed quite level.

Preliminary measurements indicate that the curb ring is approximately 18 3/4" out of level (measured from the jackframe).

Measurements on July 14, 1982 taken from the horizontal joints of the outside form indicate that the curb ring is 19 1/4" out of level.

Person MARK D. LUTHERDate 7/13/82, TUESDAYTime 8:08 AM - 12:16 PMTemp. 79°F - 85°FWeather SUNNY, NICE

TABLE I (Cement and Aggregates)

MATERIAL	DELIVERY RATE lbs/min.		BATCH PLANT DIAL SETTING		TEMPERATURE (°F)	MOISTURE CONTENT (%)
CEMENT	3LF/hr 63	1.5LF/hr 32	3LF/hr 435-440	1.5LF/hr 140	83	- 0 -
SAND	102	51	210	120	76	ASSUMED 1.96-SSD
3/8 STONE	50	25	250	130	76	ASSUMED 1.15-SSD
3/4 STONE	74	37	480	252	74	ASSUMED 0.71-SSD

TABLE II (Admixtures)

MATERIAL	DELIVERY RATE	FLOW METER	TEMPERATURE (°F)	SOLUTION STRENGTH PARTS MTL:PARTS WATER
150 MIGHTY SOLUTION	100% DESIGN 1.6% CMT WT.	19.75 / 10.06	76	1 AS-BOUGHT 58% V/GRA: 2 (VOL)
DARVAIK DAREX SOLUTION	100% DESIGN 1.51162/100% CMT	5.25 / 2.75	75	1 AS-BOUGHT: 9 (WT)
CaCl ₂ SOLUTION	69% DESIGN OR 2% CMT WT.	1.0 / 0.5	74 @ 9:45 AM 66 @ 11 AM	1 AS-BOUGHT 77% FLAKE: 4 (WT)

TABLE III (Fresh Concrete Data)

SERIES	START TIME	SLUMP @ SOME TIME X" @ t = X min	UNIT WEIGHT	AIR CONTENT (%)	CONCRETE TEMPERATURE (°F)
I	9:00 AM	4 1/4" 5 min	ND	* 5%	75
II	11:00 AM	4 3/4" 2 min	ND	* 5%	76

* Air content = 4.8% @ 8:35; 5.1% @ 8:47. 5% Air for Series I
AND Series II is inferred from these data.

TABLE IV

NOTES: SLUMP-TIME HISTORIES:

SERIES I

SERIES II

4 1/4" @ 5 min 4 3/4" @ 2 min

3 1/2" @ 10 min 4 1/4" @ 5 min

3" @ 15 min 4" @ 10 min

2 3/4" @ 20 min 4" @ 15 min

2 1/4" @ 25 min 3 1/2" @ 20 min

SERIES	STRESS @ SOME TIME		
I	5900 @ 6 hr	3910 @ 28 hr	5840 @ 7 d
II	710 @ 4 hr	4070 @ 36 hr	5340 @ 7 d

37° V/AIR @ 9:40 & 11:00

CHRONOLOGICAL EVENTS WERE: 7:58 BEGIN

MAKING GROUT; 8:08 MAKING CONCRETE @ 3LF/hr

8:19 ALL OFF; 8:28 ALL ON @ 3LF/hr; 11:05 SWITCH TO 1.5 LF/hr; 11:15 ALL OFF - AIR LINE
TO SAND BROKEN - SAND CIRCUITS OVERHEATING; 11:30 ALL ON @ 1.5 LF/hr; 11:32 SWITCH
TO 3 LF/hr; 11:43 SWITCH TO 1.5 LF/hr; 12:00 NOON SWITCH TO 3 LF/hr; 12:10
LINE PARTED BENEATH TOWER (CONCRETE LINE), BULKHEAD TRIMMED, ALL OFF.

HERMAN G. PROTZE

— INC. —
MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

469

(617) 332-8460

TEST OF CONCRETE SPECIMENS

July 14, 1982
July 20, 1982
August 10, 1982

CLIENT FOSTER-MILLER ASSOCIATES, WALTHAM, MASSACHUSETTS
PROJECT VERTICAL SLIPFORM TESTING

Reference Number 82L-1431ABC
Date Received 7-14-82
Date Sampled 7-13-82 by us
Location of Placement C.S.L.

Truck Number N/A
Load Number "
Ticket Number "
Class Concrete "
Cubic Yards "
Cement 752 lbs/cu.yd. Ironclad Type III
Fine Aggregate 1225 " New England Sand
Coarse Aggregate 1500 " " " ¾" Gravel
Water No data
Admixture 11.28 oz/cu.yd. Daravair AEA + 1.5% wt.ct.Mighty 150
+ 2.14% wt.ct.CaCl₂

Time Sampled 9:00AM
Weather Fair, 80°F
Concrete Temperature 79°F
Slump 4½"
Entrained Air Not determined
Appearance Satisfactory
Storage Outside, covered with wet burlap, then
laboratory fog room
Date of Test 7-14-82 7-20-82 8-10-82
Age at Test 28 hours 7 days 28 days
Specimen Number IB IC ID
Dimensions 6x12" 6x12" 6x12"
Density, lbs/cu.ft. 145½ 146 145½
Compressive Strength 3910ψ 5840ψ 6730ψ
Remarks

Respectfully submitted,

David R. Mitchell
David R. Mitchell *gs*

HERMAN G. PROTZE

— INC. —
MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

(617) 332-8460

TEST OF CONCRETE SPECIMENS

July 14, 1982

July 20, 1982

August 10, 1982

CLIENT FOSTER-MILLER ASSOCIATES, WALTHAM, MASSACHUSETTS
 PROJECT VERTICAL SLIPFORM TESTING

Reference Number	82L-1432ABC		
Date Received	7-14-82		
Date Sampled	7-13-82 by us		
Location of Placement	C.S.L.		
Truck Number	N/A		
Load Number	"		
Ticket Number	"		
Class Concrete	"		
Cubic Yards	"		
Cement	752 lbs/cu.yd. Independent type III		
Fine Aggregate	1225	"	New England Sand
Coarse Aggregate	1500	"	" " ¾" Gravel
Water	No data		
Admixture	11.28 oz/cu.yd. Daravair AEA, + 1.5% wt.ct. Mighty 150, + 2.14% wt.ct. CaCl ₂		
Time Sampled	11:00AM		
Weather	Fair, 86°F		
Concrete Temperature	81°F		
Slump	4¾"		
Entrained Air	Not determined		
Appearance	Satisfactory		
Storage	Outside, covered with wet burlap, then laboratory fog room		
Date of Test	7-14-82	7-20-82	8-10-82
Age at Test	26 hours	7 days	28 days
Specimen Number	IIB	IIC	IID
Dimensions	6x12"	6x12"	6x12"
Density, lbs/cu.ft.	145	145½	144
Compressive Strength	4070ψ	5430ψ	5950ψ
Remarks			

Respectfully submitted,

David R. Mitchell
 David R. Mitchell *SS*

Test No. 8

Test Date: August 11, 1982

Test Summary:

One-hundred and sixty-six inches of concrete was placed behind the slipform. Because of line blockages, concrete was placed through only two ports during most of the test. This caused excessive cracking in the lining, difficulty in controlling curb ring level, and generally minimally acceptable concrete distribution. A deeper and large slough zone panel was installed and successfully negotiated by the prototype seal. The zone was 4 inches deep and the seal subject to 30 psig concrete pressure as it traversed the panel. Both the five and four leaf seal sections prevented any concrete blow by.

CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
AUGUST 11, 1982

LOG OF SIMULATION TEST "C"

BASIC INFORMATION

- Position of CSL components at start of test.

Curb Ring (CR)	+ 011 ½"	(Below Lid)
Slipform Liner (CSL)	- 045"	(Above Lid)
Slipform Effective Length (SEL)	+ 056 ½"	(Top of CR to Top of CSL)
Jackframe Level		

- Guests in Attendance

1. Robert Stephan	D.O.E. - T.P.O.
2. G. Mattes	Thyssen

- Weather rainy.

<u>TIME</u>	<u>EVENT</u>			
8:30	Tilt meter indicates CR to be ½" low at #3 on the 1/3 axis and 7/8" low at #4 on the 2/4 axis. Measurements verify meter readout.			
8:50	Gauge readings at start of test. P1 - 0 PSIG P2 - 0 PSIG P3 - 0 PSIG P4 - 0 PSIG Red Valve (RV) - 4 PSIG (Tare) Heede - 475 PSIG (Hydraulic) CR - 0 PSIG (Hydraulic) CSL - 100 PSIG (Hydraulic) SEL Limits set at: Upper Alarm at 80" Lower Alarm at 85"			
9:06	Start Mixing grout.			
9:09	Start pumping grout.			
9:10	Stop pumping. Hoses rotated 90°. <table style="margin-left: 20px; border-collapse: collapse;"> <tr> <td style="border: none;"> Port #1 is curb port #4 Port #2 is curb port #1 Port #3 is curb port #2 Port #4 is curb port #3 </td> <td style="font-size: 3em; vertical-align: middle; padding: 0 10px;">}</td> <td style="border: none; vertical-align: middle;">Use curb ring numbers</td> </tr> </table>	Port #1 is curb port #4 Port #2 is curb port #1 Port #3 is curb port #2 Port #4 is curb port #3	}	Use curb ring numbers
Port #1 is curb port #4 Port #2 is curb port #1 Port #3 is curb port #2 Port #4 is curb port #3	}	Use curb ring numbers		

TIMEEVENT

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9:12 Pumping grout slowly. We renumbered the panel board.

9:15 Pumping to Port #1. The pump has a hard time trying to pump the grout (loosing suction).

9:23 Pump is not pumping the grout.
Lines will be broken to clean system and we will start over.
All joints and voids around the slide valve clean out and "Y" connection were caulked to help air pressure loss.

9:46 Mixing grout - Clean up completed.

9:47 Start pumping again to Port #1 (CR).
CR at +011"
CSL at -046"
SEL at +057

9:51 Pea stone being added to lubricating grout.

9:56 Mixing concrete and pumping slowly.

9:57 Speeded up to normal mixing rate.

9:59 Slide valve on auto.
Grout showing on Heede rod at Port #1.
Vibrators turned on.

10:01 RV moving between 30 PSI to 40 PSI.

10:02 Grout at Port #2.

10:05 Still not seeing any pressure on CR transducers.

10:06 Beginning to show pressure at curb.

10:12 RV 60 to 70 PSIG pump not cycling properly.

10:15 Temporary plug in line #1 - Blown out immediately.

10:17 CR at +011"
CSL at -046"
SEL at +057"
P1 - 0 PSIG
P2 - 1 PSIG
P3 - 1 PSIG
P4 - 1 PSIG

10:19 P1 - 2 PSIG
P2 - 4 PSIG
P3 - 2 PSIG
P4 - 2 PSIG

<u>TIME</u>	<u>EVENT</u>
10:21	P1 - 3 PSIG P2 - 5 PSIG P3 - 2 PSIG P4 - 2 PSIG CR at +012" CSL at -046" SEL at +057"
10:26	R. Torbin reports plug in line or lines.
10:30	All lines will be checked for plugs - Thompson pump being brought into use. Raining again.
10:43	Concrete being pumped from Reinert to Thompson Hopper. Manually cycling slide valve. Thompson hooked up (Thompson pump has 9" Ø piston with 30" stroke).
10:45	CR pulled down using cylinders.
10:48	All lines may be blocked up at top - all lines are blocked.
10:58	Blockage found between RV and SV - as predicted from RV pressure.
11:06	Back pumping again.
11:09	P1 - 0 PSIG P2 - 7 PSIG P3 - 3 PSIG P4 - 5 PSIG CR at +017" CSL at -046" SEL at +062" Still having problems with blocked lines (#3 may be blocked).
11:17	CR at +032" Level CSL at -045" SEL at +077"
11:29	Curb going out of level - Levelled but CR at +035" CSL at -045" SEL at +080" Still trying to get blockage out of line #3.
11:34	CR at +037" CSL at -045" SEL at +082"

TIMEEVENT

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11:37 CR at +039"
CSL at -045"
SEL at +083"
PL - 4 PSIG
P2 - 1 PSIG
P3 - 0 PSIG
P4 - 9 PSIG
Port #3 still plugged.
Pumping to other 3 ports.
Tilt 1 & 4 slightly out of level.

11:42 CR hydraulic pressure increased to 400 PSIG.

11:44 Heedes started down.

11:48 Line 3 still blocked.
Pumping to #1, 2, and 4.
Heedes walking down.
Curb being leveled manually.

11:50 Curb hydraulic pressure at 600 PSIG to 800 PSIG.
CR at +046"
CSL at -040"
SEL at +085"
Concrete pressures don't show anything meaningful -
Concrete placed will probably be poor.

11:54 CR at +045"
CSL at -034"
SEL at +078"
P1 - 10 PSIG
P2 - 9 PSIG
P3 - 2 PSIG
P4 - 13 PSIG

12:00 Heedes stopped.

12:04 CR at +050"
CSL at -031"
SEL at +080" (going to 86")
P1 - 6 PSIG
P2 - 10 PSIG
P3 - 1 PSIG
P4 - 0 PSIG
Heedes 900 PSIG (Hydraulic)

12:11 CR at +054"
CSL at -031"
SEL at +084"
P1 - 10 PSIG
P2 - 14 PSIG
P3 - 0 PSIG
P4 - 7 PSIG
Curb hydraulic pressure 900 PSIG.
Heede hydraulic 1100 PSIG.

476	<u>TIME</u>	<u>EVENT</u>
	12:15	CR at +056" CSL at -030" SEL at +085" P1 - 10 PSIG P2 - 16 PSIG P3 - 0 PSIG P4 - 12 PSIG Heede back to 650 PSIG. CR press at 850 PSIG.
	12:17	Trying line #3 to see if we have block out - NO!
	12:20	CR at +057" CSL at -030" SEL at +083" P1 - 10 PSIG P2 - 10 PSIG P3 - 5 PSIG P4 - 3 PSIG
	12:22	Line still blocked.
	12:23	Line #1 to be clamped off, disconnected and cleaned - We will pump to ports #2 and 4 for duration of test.
	12:27	Dropped curb at #2 which lowered pressure. CR at +060" CSL at -027" SEL at +086" P1 - 9 PSIG P2 - 20 PSIG P3 - 0 PSIG P4 - 5 PSIG RV at 50 to 70 PSIG
	12:34	One Heede walked away.
	12:36	CR at +065" CSL at -021" SEL at +085" P1 - 0 PSIG P2 - 10 PSIG P3 - 10 PSIG P4 - 0 PSIG
	12:40	Heedes giving problems. CR at +066" CSL at -020" SEL at +086" P1 - 0 PSIG P2 - 20 PSIG P3 - 1 PSIG P4 - 0 PSIG

TIMEEVENT

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12:57 Having problems with Heedes.
CR at +077"
CSL at -008"
SEL at +084"
P1 - 2 PSIG
P2 - 2 PSIG
P3 - 3 PSIG
P4 - 2 PSIG
2 loud bangs in tower - Welds on guides broke.

1:07 Slipform below lid and Bob Torbin reports that top of
concrete is:
13" below lid
21" below at port #3

Measurements - lid to T/Concrete.
Port #1 #2 #3 #4
13" 14" 18" 14"

1:12 Going to walk down with Heedes.
P1 - 5 PSIG
P2 - 25 PSIG
P3 - 2 PSIG
P4 - 0 PSIG

1:21 Cylinder Port #1 #2 #3 #4
19" 19 3/4" 19 1/2" 20 3/4"

1:38 Cylinder Port #1 #2 #3 #4
Moved to 15 1/2" 15 1/4" 15" 15"
When slipform was lowered, jackfram raised - hydraulic
pressure in CR raised - pushed concrete up - broke bond
on form.

1:41 CR at +109"
CSL at +017"
SEL at +092"
Heedes walking - pumping to ports 2 and 4 only.

1:48 CR at +111"
CSL at +020"
SEL at +090"
Heedes giving some problems.
Tilt fair at 3 2" low
Tilt fair at 4 1/2" low
Computer tape ended.

478	<u>TIME</u>	<u>EVENT</u>																				
	2:20	CR at +123" CSL at +041" SEL at +081" P1 - 2 PSIG P2 - 32 PSIG P3 - 1 PSIG P4 - 0 PSIG Heede 700 PSIG Curb 900 PSIG Slipform 2000 PSIG																				
	2:26	Slipform cylinders extended to $\pm$ 20" Going to retract to 15" <table border="0" style="width: 100%;"> <thead> <tr> <th style="text-align: left;">Cylinders</th> <th style="text-align: left;"><u>#1</u></th> <th style="text-align: left;"><u>#2</u></th> <th style="text-align: left;"><u>#3</u></th> <th style="text-align: left;"><u>#4</u></th> </tr> </thead> <tbody> <tr> <td></td> <td>15 1/8"</td> <td>14 1/2"</td> <td>14 3/4"</td> <td>15 1/4"</td> </tr> <tr> <td>Moved to</td> <td>14 3/4"</td> <td>14 3/4"</td> <td>15 1/2"</td> <td>15 1/2"</td> </tr> <tr> <td>Moved to</td> <td>14 5/8"</td> <td>14 3/4"</td> <td>15"</td> <td>15 1/4"</td> </tr> </tbody> </table> CR at +129" CSL at +058" SEL at +070"	Cylinders	<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>		15 1/8"	14 1/2"	14 3/4"	15 1/4"	Moved to	14 3/4"	14 3/4"	15 1/2"	15 1/2"	Moved to	14 5/8"	14 3/4"	15"	15 1/4"
Cylinders	<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>																		
	15 1/8"	14 1/2"	14 3/4"	15 1/4"																		
Moved to	14 3/4"	14 3/4"	15 1/2"	15 1/2"																		
Moved to	14 5/8"	14 3/4"	15"	15 1/4"																		
	2:38	Tilt #3 2 1/2" low #4 1" low																				
	2:45	CR at +134" CSL at +058" SEL at +075" Port pressures meaningless. Curb tilt controlled by pumping at 2 and 4 in the 2/4 axis - 1/3 axis controlled manually using CR hydraulic cylinders.																				
	2:55	CR at +142" CSL at +058" SEL at +084"																				
	3:02	CR at +146" CSL at +058" SEL at +087" Curb pressure 750 PSIG (hydraulic).																				
	3:08	Getting ready to lower jack frame. CR at +149" CSL at +058" SEL at +090"																				
	3:11	Heedes being activated. CR at +151" CSL at +058" SEL at +092" Heede pressure 1100 PSIG. Curb ring pressure 750 PSIG.																				

TIMEEVENT

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3:19 We have been able to control the tilt of the curb very well. CR works well at 750 PSIG. Crew making tower safe.

3:28 Cement hopper auger plugged up. Mixer down.

3:36 Mixer started.

3:38 CR at +152"
CSL at +059"
SEL at +094"

3:45 Trying to move slipform with hydraulic cylinders.
Measurements of rod extension.

	<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>
Slipform				
Cylinders	13 3/4"	13 1/2"	13 1/2"	14 1/2"

3:50 CR at +162"
CSL at +067"
SEL at +096"

3:54 CR at +162"
CSL at +069"
SEL at +094"
Going to SEL under +090"

3:57 Slipform cylinder pressure up to 3,000 PSIG.

4:05 RV seems to have gone out.

4:10 Trying to get CR past bottom of slough zone.

4:15 Slipform broken free.
Rod extensions back to 15" on CSL cylinders.
CR at 167"
CSL at +074"
SEL at +092"

4:28 Concrete mixing ended.
CR at +166"
CSL at +174"
SEL at +092"

4:41 Slipform broken loose using CR pressure (pushing down) and slipform pressure (pulling down).
Heede's locked off.

CR bottom splice plates hung up on lower joint of slough zone. TEST ENDED.

CSL PROGRAM
 CONCRETE DATA SHEET
Person W. A. O. LutzDate 8/11/82Time 1:55 PM - 4:00 PMTemp. 66°F 71°FWeather DRY, B, D, C

TABLE I (Cement and Aggregates)

MATERIAL	DELIVERY RATE lbs/min.	BATCH PLANT DIAL SETTING	TEMPERATURE (°F)	MOISTURE CONTENT (%)
CEMENT	63 LF/Hr @ 1.5 LF/Hr 64 → 62 / 32.6 → 32	63 LF/Hr @ 1.5 LF/Hr 565 → 510 / 220 → 200	AMBIENT ~65°	NA
SAND	105 / 51	250 / 120	"	4
3/8 STONE	50 / 25	230 / 130	"	3
3/4 STONE	77.9 / 37.3	360 / 160	"	2

TABLE II (Admixtures)

MATERIAL	DELIVERY RATE $\frac{1}{\text{min}}$	FLOW METER	TEMPERATURE (°F)	SOLUTION STRENGTH PARTS MTL:PARTS WATER
¹⁵⁰ MIGHTY SOLUTION	1365/682	20/9.9	67	1 AS BOUGHT : 2 BY VOLUME
~~DAREX~~ AEA DAREX SOLUTION	280/140	5.75/3	ND	1 AS BOUGHT : 9 BY WEIGHT
CaCl ₂ SOLUTION	5538/2769	1.43/0.5	64	1 AS BOUGHT : 4 BY WEIGHT

TABLE III (Fresh Concrete Data)

SERIES	START TIME	SLUMP @ SOME TIME X" @ t = X min	UNIT WEIGHT	AIR CONTENT (%)	CONCRETE TEMPERATURE (°F)
RS*	12:45	5 1/4 @ 2	ND	4.2	78
I	1:40	4 1/4 @ 5	ND	4.4	78

TABLE IV

NOTES: *RS = RANDOM SAMPLE

SERIES I		AS THE TEST
TIME (MIN)	SLUMP	PROCESSED THE
5	4 1/4"	CEMENT BAG COUNT
15	3"	CHECK SHOWED THE CEMENT OUTPUT WAS TOO HIGH, WE
20	2 1/2"	TURNUED THE CEMENT DOWN FROM 565 TO 510,
25	3"	
30	2 1/2"	

SERIES	STRESS @ SOME TIME		
I	3380 @ 1d	6870 @ 7d	8040 @ 28d

HERMAN G. PROTZE

MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

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(617) 332-8460

TEST OF CONCRETE SPECIMENS

August 18, 1982
September 8, 1982
November 9, 1982

CLIENT FOSTER-MILLER, INC. WALTHAM, MASSACHUSETTS
PROJECT DOE 7957.106

Reference Number 82L-1754A B C
Date Received 8-17-82
Date Sampled 8-11-82 by you
Location of Placement No data

Truck Number No Data
Load Number "
Ticket Number "
Class Concrete "
Cubic Yards "
Cement "
Fine Aggregate "
Coarse Aggregate "
Water "
Admixture "

Time Sampled No data
Weather "
Concrete Temperature "
Slump "
Entrained Air "
Appearance "
Storage " , then laboratory fog room

Date of Test	8-18-82	9-8-82	11-9-82
Age at Test	7 days	28 days	90 days
Specimen Number	A	B	C
Dimensions	6x12"	6x12"	6x12"
Density, lbs/cu.ft.	146	145½	147
Compressive Strength	6870ψ	8040ψ	8040ψ
Remarks			

Respectfully submitted,

David R. Mitchell

3-F-M

Mark D. Luther

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Test No. 9

Test Date: August 18, 1982

Test Summary:

A six foot jump mode test was successfully conducted. The large void was completely filled from the curb ring up to the ragged edge of the previously cast lining (August 11 test).

Test No. 10

Test Date: September 21, 1982

Test Summary:

One-hundred and thirty-two inches of concrete was placed behind the slipform. Test was terminated when curb ring jammed against side of outer form. Slipforming was successfully demonstrated over 3 feet of lining.

CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
SEPTEMBER 21, 1982

LOG OF SIMULATION TEST "D"

BASIC INFORMATION

- o Position of CSL components at start of test.

Curb Ring (CR)	+ 010"	(Below Lid)
Slipform Liner (CSL)	- 036"	(Above Lid)
Slipform Effective Length (SEL)	+ 046"	(Top of CR to Top of CSL)

- o Guests in Attendance

1. Thomas Steel	R. A. Hanson Co.
2. Robert Bird	R. A. Hanson Co.
3. Kenneth Saucier	Corps of Engineers

- o Weather very overcast and 52° at 6:15.

Tom Brunsing prepared a set of curves which relate P_c (curb ring hydraulic pressure) to P_s (slipform hydraulic pressure). Each SEL has its own limits determined by the weight of the concrete above. The "Y" intercept is the dead load of the slipform plus the cylinders. The pressure relationship must stay above the curve to prevent tension in the concrete.

Both tilt meters indicate level. Heede equalizer pressure (P_h) at 1500 PSIG.

P_c = 250 PSIG.

P_s = 500 PSIG.

Both sets of cylinders locked off.

Curb ring transducer #3 out of action.

<u>TIME</u>	<u>EVENT</u>
8:05	Meters reset because slipform settled 4" over night.
8:10	Slide valve (SV) cycled.
8:45	Start mixing grout.
8:56	Slipform 1 1/4" and 5/16" (plumb lines) CR at +011" CSL at -035" SEL at +046"
9:00	Slipform being plumbed.
9:02	Start Pumping grout. Slipform 1" and 5/16" (plumb lines).

TIMEEVENT

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9:03 Slide valve (SV) being moved manually lubricating lines.

9:06 Start mixing concrete.

9:14 Things seem to be running smoothly. SV on auto for 3 minutes.

9:28 Concrete temperature 75° F.

9:37 Void above CR is full, pressure showing on transducers.

9:39 No movement showing on curb.
CR at +011"
CSL at -034"
SEL at +046"

9:41 Curb moved to +012".

9:42 Pc to 300 PSIG.
P1 - 4 PSIG
P2 - 5 PSIG
P4 - 5 PSIG

9:44 Manually operating the SV to level CR.

9:48 P1 - 5 PSIG
P2 - 5 PSIG
P4 - 6 PSIG
Concrete at 80° F.
CR at +016"
CSL at -034"
SEL at +050"
Pc at 300 PSIG.

9:51 Plumbing the slipform.
Ps to 800 for positioning.

9:55 Slipform cylinder extension 14".
Ps locked off.

9:58 Ps to 500 PSIG.

10:03 CR at +024"
CSL at -034"
SEL at +058"
P1 - 9 PSIG
P2 - 9 PSIG
P4 - 11 PSIG

10:04 Heedes being walked down.
Timing Heede speed 1" in 23 seconds.

10:08 Heedes slowed down - taking second step.

<u>TIME</u>	<u>EVENT</u>
10:09	Concrete pressures holding. P1 - 5 PSIG P2 - 5 PSIG P4 - 7 PSIG
10:15	Checking tilt in tower.
10:20	Rechecking CSL extension reading 13".
10:21	CR at +037" CSL at -023" SEL at +060" Slipform plumb. CR close to level. P1 - 9 PSIG. P2 - 8 PSIG P4 - 10 PSIG Concrete 76° 6 3/4" slump.
10:38	CR at +047" CSL at -018" SEL at +066" P1 - 6 PSIG P2 - 8 PSIG P4 - 8 PSIG
10:46	Pc to 700 PSIG.
10:48	Pc to 800 PSIG. P1 - 13 PSIG P2 - 14 PSIG P4 - 14 PSIG CR at +053" CSL at -015" SEL at +068"
10:56	Increasing Heede equalizer pressure.
11:00	All seems to be going well. CR at +060" CSL at -013" SEL at +073" P1 - 15 PSIG P2 - 16 PSIG P4 - 16 PSIG CR level
11:05	Concrete pump 900 PSIG (hydraulic) at the pump. RV showing about 70 to 90 PSIG.
11:16	Pc up to 1000 PSIG. P1 - 18 PSIG P2 - 18 PSIG P4 - 18 PSIG

TIMEEVENT

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11:23 Heede rod broke (stud broke at eye fitting on top).
Concrete pressure dropped to:
P1 - 10 PSIG
P2 - 10 PSIG
P4 - 10 PSIG

11:46 Heede repaired and test back on track.

12:02 Adjusting slipform to plumb.
Ps - 1050 PSIG
Pc - 1200 PSIG
This is marginal on critical plot with 9'-0" of concrete.
We are now in a cracked concrete position.
P1 - 20 PSIG
P2 - 21 PSIG
P4 - 18 PSIG

12:09 Pc = 900 PSIG.

12:18 About 1" of concrete is exposed.
Meters are still not functioning.
All systems (?) still "GO".

12:24 P1 - 16 PSIG
P2 - 16 PSIG
P4 - 10 PSIG

12:30 6 1/2" of concrete exposed - Tom reports concrete looks great.

12:31 Black dye put in concrete.

12:33 Dye is going through pump.
P1 - 10 PSIG
P2 - 15 PSIG
P4 - 16 PSIG

12:34 9'-0" concrete in form.
Slipform being pulled down.
Ps - 1250 PSIG.

12:38 9 1/2" concrete exposed.
Ps - 1250 PSIG
Pc - 800 PSIG

12:50 Pc - 1500 PSIG
Ps - 1000 PSIG
P1 - 9 PSIG
P2 - 23 PSIG
P4 - 11 PSIG

12:59 Pc back to 1000 PSIG.
P1 - 4 PSIG (Moved back to 13 PSIG when SV shifted)
P2 - 24 PSIG
P4 - 21 PSIG

<u>TIME</u>	<u>EVENT</u>
13:01	Heedes walking and have dropped the pressure at #1 to 0 PSIG. We must stop the Heedes and readjust.
13:26	Heedes giving problems - Jackframe out of tile - Guide broke - Trying to level up.
13:29	Hose broke - Concrete pressure above CR went to 0 on all transducers - $P_c = 250$.
13:45	Things critical with CR at bottom of CSL and lines plugging at the curb ring.
13:49	CSL appears to be hung up somehow.
13:54	CSL and CR are now freed up. Concrete being pumped again. Might have plug.
14:04	Red valve and concrete pump indicate a block in the slide valve or all ports plugged.
14:05	Jackframe, CSL and CR hung up. No pressure showing on the CR transducers. TEST ENDED.

CSL PROGRAM
 CONCRETE DATA SHEET
Person MAH D. LUTHERDate 9/21/32Time 5:45 AM - 2:09 PMTemp. 60°F @ 10 AMWeather OVERCAST

TABLE I (Cement and Aggregates)

MATERIAL	DELIVERY RATE lbs/min.	BATCH PLANT DIAL SETTING	TEMPERATURE (°F)	MOISTURE CONTENT (%)
CEMENT	62.7	434	~ 60	NA
SAND	102	228	~ 60	~ SSD = 1.76
3/8" STONE	50	244	~ 60	~ SSD = 1.15
3/4" STONE	75	370	~ 60	~ SSD = 0.71

TABLE II (Admixtures)

MATERIAL	DELIVERY RATE (%)	FLOW METER	TEMPERATURE (°F)	SOLUTION STRENGTH PARTS MTL:PARTS WATER
150 MIGHTY SOLUTION	1136	19.6 GPH	62	1 AS SIGHT : 2 LY VOLUME
EMULSIFIER DRINK SOLUTION	1136	19.6 GPH	60	1# AS SIGHT : 9# WATER
CaCl ₂ SOLUTION	5538	1400 GPH	92	100# AS SIGHT : 400# WATER

TABLE III (Fresh Concrete Data)

SERIES	START TIME	SLUMP @ SOME TIME X" @ t = X min	UNIT WEIGHT	AIR CONTENT (%)	CONCRETE TEMPERATURE (°F)
I	9:30 AM	4 @ 5	ND	7	76
II	12:10 PM	5 3/4 @ 2	ND	3.8	81

TABLE IV

NOTES:

SERIES I	SERIES II	SERIES	SLUMPS @ SOME TIME
5 4"	2 5 3/4"	I	5 3/4 @ 2
14 3 1/2"	10 4 1/2"	II	5 3/4 @ 2
24 2 3/4"	20 4 1/2"	TYPICAL CONCRETE SLUMP = 6 1/2"	
29 2 3/4"	25 4"	TYPICAL CONCRETE TEMP = 80°F	
	30 3 3/4"	3 1/2" of concrete was tested at 42.5	
	35 3 3/4"	a la Portland Cement at 11:25 AM	
		75% of sand was 55% at 3 1/2"	

This was the result of test, in
the field.

HERMAN G. PROTZE

— INC. —
MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

(617) 332-8460

TEST OF CONCRETE SPECIMENS

September 24, 1982

September 28, 1982

October 19, 1982

December 20, 1982

CLIENT FOSTER-MILLER ASSOCIATES, WALTHAM, MASSACHUSETTS
 PROJECT CONTINUOUS SHAFT LINER

Reference Number 82L-2163ABC D
 Date Received 9-22-82
 Date Sampled 9-21-82, by us
 Location of Placement Continuous shaft liner

Truck Number None
 Load Number "
 Ticket Number "
 Class Concrete No data
 Cubic Yards "
 Cement 752 lbs/cu.yd. Iron Clad type III
 Fine Aggregate 1225 " New England Sand
 Coarse Aggregate 1500 " " 3/4" Gravel
 Water No data
 Admixture 3% CaCl₂ wt.ct. + 13½ oz/cu.yd. Darex
 + 1.5% Mighty 150 wt.ct.

Time Sampled 9:40AM
 Weather Cloudy, 66 °F
 Concrete Temperature 75 °F
 Slump 4"
 Entrained Air 5.6% by Acme Air Meter
 Appearance Satisfactory
 Storage Outside, covered with wet cloths, then laboratory fog room

Date of Test	9-22-82	9-28-82	10-19-82	12-20-82
Age at Test	30 Hours	7 days	28 days	3 months
Specimen Number	1A	1B	1C	1D
Dimensions	6x12"	6x12"	6x12"	6x12"
Density, lbs/cu.ft.	142	141	141½	141
Compressive Strength	3260ψ	6300ψ	6870ψ	6980ψ
Remarks				

By David R. Mitchell

TEST OF CONCRETE SPECIMENS

September 24, 1982

September 28, 1982

October 19, 1982

December 20, 1982

CLIENT FOSTER-MILLER ASSOCIATES, WALTHAM, MASSACHUSETTS
 PROJECT CONTINUOUS SHAFT LINER

Reference Number	82L-2164A BC D			
Date Received	9-22-82			
Date Sampled	9-21-82 by us			
Location of Placement	Continuous shaft liner			
Truck Number	None			
Load Number	"			
Ticket Number	"			
Class Concrete	No data			
Cubic Yards	"			
Cement	752 lbs/cu.yd. Iron Clad type III			
Fine Aggregate	1255 "	New England Sand		
Coarse Aggregate	1500 "	"	3/4" Gravel	
Water	No data			
Admixture	3% CaCl ₂ wt.ct. + 13½ oz/cu.yd. Darex + 1.5% Mighty 150 wt.ct.			
Time Sampled	12:00N			
Weather	Cloudy, 66 °F			
Concrete Temperature	81 °F			
Slump	5¾"			
Entrained Air	3.8% by Acme Air Meter			
Appearance	Satisfactory			
Storage	Outside, covered with wet cloths, then laboratory fog room			
Date of Test	9-22-82	9-28-82	10-19-82	12-20-82
Age at Test	27½ Hours	7 days	28 days	3 months
Specimen Number	2A	2B	2C	2D
Dimensions	6x12"	6x12"	6x12"	6x12"
Density, lbs/cu.ft.	147½	147½	147½	147½
Compressive Strength	2990ψ	6500ψ	7100ψ	6580ψ
Remarks				

By David R. Mitchell

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Test No. 11

Test Date: September 29, 1982

Test Summary:

One-hundred and twelve inches of concrete placed behind the slipform. Test was conducted as mechanized step form to examine affects of water inflow, and to determine the forces necessary to steer the slipform. Both low (1 gpm) and high (5 gpm) inflow were examined.

CONTINUOUS SLIPFORM LINER
DEVELOPMENT PROGRAM
SEPTEMBER 29, 1982

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LOG OF SIMULATION TEST "E"

BASIC INFORMATION

- Primary objectives of the test are to observe the effects of various water inflow conditions and to control the descent direction of the slipform. The location and direction of the slipform will be determined by successive vertical measurements from arbitrary scratch marks in the concrete above (S1, S2, S3, and S4) and successive horizontal measurements from the outside form (G1, G2, G3, and G4). These measurements will be given in centimeters (CM). The measurements will be taken at the slipform cylinders numbers 1, 2, 3, and 4. The slipform will be rotated about the 1/3 axis.
- Standard design mix having a 6 1/2" slump and 80° F temperature will be used. The concrete pumping rate will start at 2 ft/hr for 20 minutes then increase to 3 ft/hr.
- Position of CSL components at start of test.

Curb Ring (CR)	+ 146"	(Below Lid)
Slipform Liner (CSL)	- 128 1/2"	(Above Lid)
Slipform Effective Length (SEL)	+ 017 1/2"	(Top of CR to Top of CSL)

Jackframe chaired on Dywidag rods and level.

- Guest in Attendance
1. Robert Stephan T.P.O.
- Weather - slight drizzle - temperature 57°.

<u>TIME</u>	<u>EVENT</u>
9:42	Instrumentation being checked. Guerini (Thompson) pump hooked up and ready to start. Concrete plant calibrated. Water inflow manifold O.K. Slipform has a nominal 9" overlap (bottom of previously placed concrete is irregular).
10:32	Start mixing grout (no CaCl.).
10:42	Start pumping grout to Port #1.
10:48	Slipform being plumbed.
<u>10:49</u>	Concrete being made (78°). <u>RAINING HARDER</u>

<u>TIME</u>	<u>EVENT</u>										
10:52	Revised S & G (after plumbing).										
	<table border="1"> <thead> <tr> <th><u>S</u></th> <th><u>G</u></th> </tr> </thead> <tbody> <tr> <td>1</td> <td>31.5 CM</td> </tr> <tr> <td>2</td> <td>29.5 CM</td> </tr> <tr> <td>3</td> <td>32.0 CM</td> </tr> <tr> <td>4</td> <td>30.5 CM</td> </tr> </tbody> </table>	<u>S</u>	<u>G</u>	1	31.5 CM	2	29.5 CM	3	32.0 CM	4	30.5 CM
<u>S</u>	<u>G</u>										
1	31.5 CM										
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1 23.7 CM	30.4 CM										
2 18.1 CM	31.6 CM										
3 32.7 CM	33.4 CM										
4 26.4 CM	28.4 CM										
11:03	11 1/2" x 2.54 = 29.2 CM is critical.										
11:07	Black dye being added. CR at +145" Base locations CSL at +128" SEL at + 17"										
11:09	Reports 6" concrete on curb.										
11:12	Concrete pumping rate being speeded up.										
11:13	Concrete transducers showing pressure. P1 - 2 PSIG P2 - 2 PSIG P4 - 3 PSIG										
11:15	P1 - 2 PSIG P2 - 4 PSIG P4 - 5 PSIG										
11:16	P1 - 6 PSIG P2 - 4 PSIG P4 - 5 PSIG RV running about 30 PSIG.										
11:18	CR at +147" CSL at +129" SEL at + 18"										
11:26	Concrete is being pushed out over the top of the slipform.										
11:28	CR at +149" CSL at +130" SEL at + 19"										
11:29	Trying to raise slipform. CR at +150" CSL at +129" SEL at + 21"										

TIMEEVENT

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11:31 P1 - 11 PSIG
P2 - 4 PSIG
P4 - 5 PSIG

11:35 Ray Henderson called me out to see the Reinert pump -
it does not seem to be filling on the suction stroke.
Rain slacked back to drizzle.

11:42 CR cylinder tape readings.
#1 - 98"
#2 - 97 3/4"
#3 - 97 1/2"
#4 - 98 1/4"

11:46 CR at +160"
CSL at +129"
SEL at + 30"

11:47 Water inflow turned on (60 PSIG at ground level).
80° concrete.
CR hydraulic pressure increasing to 500 PSIG.

11:52 Concrete pressure at Port #1 has been running high (about
30 PSIG).
Went up to 36 PSIG.

<u>S</u>	<u>G</u>
1	33.0 CM
2	29.8 CM
3 No "S" Measurements	30.8 CM
4	30.8 CM

11:58 P1 - 45 PSIG
P2 - 9 PSIG
P4 - 11 PSIG
G2 now 30.4 CM.
S1 - moved 25" counterclockwise.

<u>S</u>	<u>G</u>
1 45.4 CM	
2 24.8 CM	
3 38.8 CM	No "G" Measurements
4 35.4 CM	

12:00 Slipform moved down.

12:02 Green dye being added.

12:03 Concrete mixing stopped - slide valve not moving to
Port #1, going to #2 and 3.
May be aggregate in the guides. Limit switches not
lighting lights on control panel.
Tom Brunsing cleaned to permit full stroke.

<u>TIME</u>	<u>EVENT</u>														
12:08	Valve O.K. now - resume making concrete.														
12:10	Stop pumping - push slipform back up.														
12:13	Start pumping concrete again.														
12:14	CR at +168" CSL at +129" SEL at +038" Port Pressures. P1 - 40 PSIG P2 - 9 PSIG P4 - 12 PSIG														
12:18	Tom wants to move up on slipform #3 cylinder.														
12:25	<table border="0" style="width: 100%;"> <thead> <tr> <th style="text-align: center;"><u>S</u></th> <th style="text-align: center;"><u>G</u></th> </tr> </thead> <tbody> <tr> <td>1 43.4 CM</td> <td>35.8 CM</td> </tr> <tr> <td>2 20.8 CM</td> <td>29.6 CM</td> </tr> <tr> <td>3 33.4 CM</td> <td>28.0 CM</td> </tr> <tr> <td>4 31.6 CM</td> <td>30.4 CM</td> </tr> </tbody> </table>	<u>S</u>	<u>G</u>	1 43.4 CM	35.8 CM	2 20.8 CM	29.6 CM	3 33.4 CM	28.0 CM	4 31.6 CM	30.4 CM				
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1 43.4 CM	35.8 CM														
2 20.8 CM	29.6 CM														
3 33.4 CM	28.0 CM														
4 31.6 CM	30.4 CM														
12:30	Curb pressure going to 750 PSIG.														
12:31	CR at +179" CSL at +130" SEL at +048"														
12:34	Black dye being added. Red was added about 15 minutes ago. P1 - 37 PSIG P2 - 18 PSIG P4 - 15 PSIG G1 at 35.8 CM (no change)														
12:37	Slipform being moved. Concrete temperature 85° F. 5" to 6" slumps. Moving slipform. #3 open - moved down.														
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1 43.9 CM	33.1 CM														

TIMEEVENT

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12:46 Concrete pressure at Port #1 is 49 PSIG.

12:57 Red dye added.
P1 - 39 PSIG
P2 - 15 PSIG
P4 - 15 PSIG
CR at +183"
CSL at +119"
SEL at + 64"
Pressure at #1 dropped off when CR jogged.

13:01 P1 - 35 PSIG
P2 - 14 PSIG
P4 - 14 PSIG

13:02 S G
1 43.8 CM 32.3 CM
2 23.7 CM 29.8 CM
3 38.8 CM -
4 34.4 CM -

13:05 Slipform moved down 1"±
1 46.4 CM 32.0 CM
2 26.6 CM 30.1 CM
3 41.1 CM -
4 36.9 CM -
CR at +190" - Base 134 = 56" of concrete.
CSL at +120"
SEL at + 70"

13:22 Slipform moved down 1"
 S G
1 52.2 CM 32.8 CM
2 31.7 CM 30.2 CM
3 45.8 CM 30.5 CM
4 42.0 CM 30.4 CM
CR at +200"
CSL at +121"
SEL at + 78"

13:37 Slipform down.
 S G
1 56.2 CM 32.2 CM
2 36.2 CM 30.2 CM
3 50.2 CM -
4 46.4 CM -

TIMEEVENT

13:50

Slipform down.

SG

1 59.6 CM
 2 40.2 CM
 3 54.1 CM
 4 49.6 CM

32.0 CM = 12.60"
 30.6 CM = 12.05"
 31.8 CM = 12.52"
 29.4 CM = 11.57"

13:58

We calculate 92.5" concrete 7'-9"±.

13:59

Slipform down - calculated SEL 89".
 Slipform sticking.

SG

1 60.4 CM
 2 41.1 CM
 3 54.6 CM
 4 50.3 CM

32.0 CM
 31.2 CM
 31.8 CM
 28.8 CM

14:04

Black dye added.

14:05

Pull all slipform cylinders down.

14:06

SG

1 71.0 CM
 2 51.0 CM
 3 65.4 CM
 4 61.2 CM
 P1 - 14 PSIG
 P2 - 18 PSIG
 P4 - 16 PSIG

32.2 CM = 12.68"
 30.2 CM = 11.89"
 31.6 CM = 12.44"
 29.8 CM = 11.73"

14:14

Pull slipform down (all 4 cylinders).

SG

1 76.6 CM
 2 57.2 CM
 3 71.0 CM
 4 66.8 CM

32.2 CM
 30.3 CM
 31.6 CM
 29.7 CM = 11.69"

1 81.6 CM
 2 61.4 CM
 3 75.2 CM
 4 71.6 CM

32.6 CM
 30.0 CM
 31.2 CM
 30.0 CM

14:20

Red dye added.

14:22

#1, 2, and 3 open valves - down.

SG

1 85.9 CM
 2 68.2 CM
 3 82.2 CM
 4 78.0 CM

32.2 CM
 30.2 CM
 31.6 CM
 30.2 CM

TIMEEVENT

499

14:27

SG

1 88.5 CM
2 69.0 CM
3 82.6 CM
4 78.3 (26.4)

No "G" Measurements

14:28

Will try to move jackframe.
This did not work.

SGFORM TO BOTTOM OF CR

1	88.8 CM	32.6 CM	14"	at P1
2	70.2 CM	30.0 CM	9 3/8 "	at P2
3	83.6 CM	30.6 CM	10"	at P3
4	79.0 CM	30.0 CM	14 1/4"	at P4

14:36

Green dye added.

14:43

RV pressure going high on all ports.
Stopped pumping concrete.

14:45

Test completed.
Water test seems to be working out O.K.

14:50

Tilt meters
1 - 3 shows 2.3" Low on #3
2 - 4 shows 1.1" Low on #4
CR at +249"
CSL at +135" (concrete exp.)
SEL at +113"
Placed 112" of concrete.

TABLE I (Cement and Aggregates)

MATERIAL	DELIVERY RATE lbs/min.	BATCH PLANT DIAL SETTING	TEMPERATURE (°F)	MOISTURE CONTENT (%)
CEMENT	62.6	434	60	NA
SAND	102	230	60	~ SSD = 1.96
3/8 STONE	50	228	60	~ SSD = 1.15
3/4 STONE	75	350	60	~ SSD = 0.71

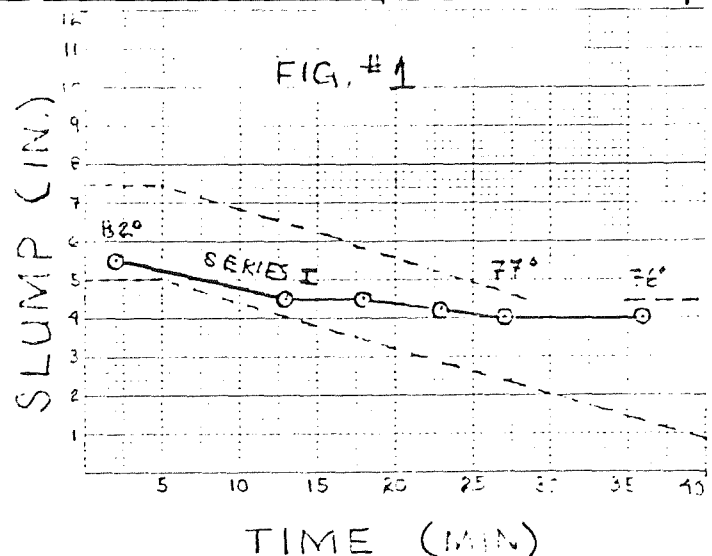
TABLE II (Admixtures)

MATERIAL	(GM/MIN) DELIVERY RATE	FLOW METER	TEMPERATURE (°F)	SOLUTION STRENGTH PARTS MTL:PARTS WATER
¹⁵⁰ MIGHTY SOLUTION	1136	19.6 GPH	64	1 : 2 VOLUME
~~PARAVAIR~~ ~~DAREX~~ SOLUTION	250	6.5 GPH	60	1 : 9 WEIGHT
CaCl ₂ SOLUTION	5538	1480 GPH	93	77% FLAKE 1 : 4 WEIGHT

TABLE III (Fresh Concrete Data)

SERIES	START TIME	SLUMP @ SOME TIME X" @ t = X min	UNIT WEIGHT	AIR CONTENT (%)	CONCRETE TEMPERATURE (°F)
I	11:34	5 1/2" @ 2 MIN	ND	4.8	82
SEE FIG. #1 FOR SLUMP-TIME FOR SERIES I.					

NOTES: CONCRETE PRODUCTION WAS
UNIFORM. PRODUCTION RATE
WAS 5 CY/HR = 3 LF/HR.
TYPICAL VIBRATOR WAS
1.2 GPM @ 160°F. THIS
GIVES A W/C = 0.37. THE
SLUMP-TIME WAS VARYING
FOR EACH CYCLE.



APPENDIX N
PATCHING AND SEALING MATERIALS

TABLE 1

RAPID-SETTING PATCHING MATERIALS

Brand and Manufacturer	Basic Material	Other Materials	Approximate handling time - minutes at:					Compressive strength/Time at:					Agencies that have used the product
			20 F	40 F	60 F	80 F	100 F	20 F	40 F	60 F	80 F	100 F	
Burke Non-Metallic Grout Burke Conc. Access. San Mateo, Calif.	Portland cement	Special cements	-	-	40	-	-	-	-	-	(73 F) 4000/24 hr	-	-
Exide Resurfacer 100 Atlas Minerals & Chem. Div., ESB Inc. Mertztown, Pa.	Portland cement	Polymers, silica	-	-	-	120	-	-	-	-	1000/ 7 day 4000/14 day	-	-
Exide Resurfacer 200 Atlas Minerals & Chem. Div., ESB Inc.	Portland cement	Latex, silica	-	-	-	45-60	-	-	-	-	1000/24 hr 4000/ 7 day	-	-
Fast-Fix Cement (P) Custom-Crete, Inc. Dallas, Texas	Portland cement	Calcium sulfate, calcium aluminate	-	40-60	25	15	5-10	-	250/40 min 500/75 min 1000/ 2 hr 2000/ 2 day 4000/45 day	250/20 min 500/50 min 1000/90 min 2000/24 hr 4000/28 day	250/15 min 500/40 min 1000/75 min 2000/24 hr 4000/28 day	250/10 min 500/30 min 1000/60 min 2000/24 hr 4000/ 7 day	Texas
Fix-A-Crete Custom Bldg. Products Bell, Calif.	Portland cement	Barium chloride, latex (optional)	NR	25-35	25-35	25-35	15	-	-	-	1525/60 min 7250/28 day	-	-
Mirament The Seddon Co. Springfield, Ohio	Portland cement	Calcium aluminate	20	-	-	6	-	-	-	385/30 min 400/60 min 3910/24 hr 5580/ 7 day 6040/28 day	-	-	Ind., Ky., & W. Va.; Cities of Pittsburgh and Indianapolis
Set Instant Concrete Set Products, Inc. Macedonia, Ohio	Portland cement	Silica	-	-	12	5	-	-	-	-	500/ 2 hr 2000/24 hr 4000/ 7 day	500/60 min 2000/24 hr	Illinois; Ohio
Sikaset Road Patch (P) Sika Chemical Corp. Lyndhurst, N. J.	Portland cement	-	-	-	-	(75 F) 17	-	-	-	-	(75 F) 500/45 min 1000/ 2 hr 2000/ 5 hr	-	-
Fondu Lone Star LaFarge Co. Norfolk, Va.	Calcium aluminate	-	-	15	15	15	-	-	-	-	(73 F) 2200/ 4 hr 5000/ 6 hr 6300/24 hr	-	Calif., La., Ore., Va. and Wash.; FHWA (G.W. Pkwy.)
FS-16 Pre-Krete Pocono Fabricators E. Stroudsburg, Pa.	Calcium aluminate	Fillers and additives	12	11	11	10	8	-	-	-	1430/60 min 2200/ 3 hr 3100/24 hr 4600/ 7 day	-	N.J., Pa., and Va.; Mass. and Pa. Tpk.; Balto. Co. Md. & Nassau Co., N.Y.
Bostik 275 (P)* The Upco Company Cleveland, Ohio	Magnesia-phosphate	Silica or dolomitic limestone	(30F) 150	-	(55 F) 25	(72 F) 7	(90 F) 5	-	(35 F) 1000/2.5hr 2000/ 5 hr	-	(70 F) 250/30 min 500/45 min 1000/60 min 2000/ 2 hr 4000/ 7 day	-	Calif., Ohio, & Wash.; Indianapolis Airport Authority
FC-100 (P)* Steelcote Mfg. Co. St. Louis, Mo.	Magnesia-phosphate	-	-	10-15	-	7-10	-	-	-	-	2000/ 2 hr 4000/24 hr	-	Ohio

TABLE 1 (Continued)

Brand and Manufacturer	Basic Material	Other Materials	Approximate handling time - minutes at:					Compressive strength/Time at:					Agencies that have used the product
			20 F	40 F	60 F	80 F	100 F	20 F	40 F	60 F	80 F	100 F	
Set - 45 Set Products Inc. Macedonia, Ohio	Magnesia - phosphate	-	-	30	20	12	6	500/ 2 hr 2000/24 hr	1000/60 min 4000/24 hr	2000/60 min 4000/ 6 hr	2000/60 min 4000/ 4 hr	2000/60 min 4000/ 4 hr	Ill., Ind., Mich., Ohio & Pa.; Cook Co. Ill., Wayne Co. Mich.
Colma Dur LV Sika Chemical Corp. Lyndhurst, N.J.	Epoxy resin	-	-	-	35	16	(90 F) 10	-	(35 F) 2000/24 hr 4000/36 hr	1000/7 hr	(75 F) 1000/ 4 hr 2000/4.5 hr 4000/ 6 hr	(90 F) 1000/3 hr	Missouri, N.J., Pa., & Virginia; Corps of Engineers
Cono/Crete and Cono/Crete FS Con/Chem, Inc. Gardena, Calif.	Epoxy resin	Bauxite	240	120	60	30	15	-	-	250/ 3 hr 500/ 6 hr 1000/ 8 hr 2000/10 hr 4000/16 hr	250/ 2 hr 500/ 3 hr 1000/ 4 hr 2000/ 8 hr 4000/10 hr	500/60 min 1000/ 2 hr 2000/ 3 hr 4000/ 5 hr	Cuyahoga Co. Ohio; Port Auth. N.Y. & N.J.
Exide Surfacer 300 Atlas Minerals & Chem. Div., ESB Inc. Mertztown, Pa.	Epoxy resin	Asphalt, silica	-	-	45	30	10	-	-	4000/24 hr	250/ 2 hr 500/ 4 hr 4000/24 hr	250/60 min 500/ 2 hr 1000/ 6 hr 4000/12 hr	-
Tufchem (Epoxy) Grout Pennwalt Corp. Philadelphia, Pa.	Epoxy resin	-	-	(50 F) 180	180	60	60	-	(50 F) 17,500/ 7 day	17,500/ 5 day (Min. setting temp.: 50 F)	17,500/ 2 day	17,500/ 1.5 day	-
Gold Label (P) Preco Plainview, N. Y.	Polyester resin	-	120	120	5-120	18-75	10-40	4000/6 hr	4000/90 min	4000/90 min	4000/60 min	4000/60 min	New York; NYC Transit Authority
Radgrout-H ^r Road & Industrial Concrete Radiation Tech., Inc. Rockaway, N. J.	Polyester resin	-	60	35	40	15	5	10,000/ 90 min	10,000/ 70 min	10,000/ 40 min	10,000/ 30 min	10,000/ 10 min	New York; Pa. Tpk.; Port Auth. NY & NJ; Triboro Bridge & Tun. Auth.; City of Phila.
Vitrobond Atlas Minerals & Chem. Div., ESB Inc. Mertztown, Pa.	Sulfur	Silica	(Hot-melt material)					-	-	-	4000/ 5 min	-	-
Duracal (P) U.S. Gypsum Co. Chicago, Ill.	Calcium sulfate	Portland cement	-	35-40	20-35	20-35	15-30	-	2000/60 min	2000/60 min	2000/60 min 4000/ 3 day 5600/ 7 day 7200/28 day	2000/60 min	Colo., Conn., Del., Ga., Mass., N.Y., Okla. Texas, & Va.; Illinois Tollway.
Mari-Crete Atlas Minerals & Chem. Div., ESB Inc. Mertztown, Pa.	Calcium sulfate	Portland cement, silica	-	-	10-15	3-5	-	-	-	-	-	500/ 8 hr 1000/16 hr 2000/24 hr 4000/48 hr	New York; Virginia
DP Concrete Additive Pennwalt Corp. Philadelphia, Pa.	-	-	-	-	-	-	-	(Accelerating additive for any patching Formula. Provides 3:28 reduction in time to strength.)					-
Gill #33 B&P Superbond Gill Chemical Co. Hamlin, W. Va.	-	Calcium chloride	60	-	-	30	-	1000/3 hr	-	1000/2 hr 4000/24 hr	2000/2.5 hr	-	Georgia, W. Va.; U.S. Bureau of Mines

(P) Patented * Licensee of Republic Steel Corp.
Data from survey of manufacturers, October 1975.

NR Not Recommended

MINE SAFETY AND HEALTH ADMINISTRATION

LIST OF CURRENTLY ACCEPTABLE MINE SEALANTS

<u>Company/Address</u>	<u>Trade Name</u>	<u>Acceptance Number</u>
Acme Chemicals and Insulation Co. P. O. Box 1404 New Haven, CT 06505 PHONE: 203/562-2171	HydrEpoxy 156 HydrEpoxy 300	
American Energy Group 608 Montecito Drive San Gabriel, CA 91776 PHONE: 213/	Mine-Gard 76	(IC 44)
Benco Industrial Supply, Inc. Washington and Ludwick Streets Greensburg, PA 15068 PHONE: 412/836-2160	B-Bond Bencoat	(IC 36) (IC 36/1)
Burrell Construction and Supply Co. One Fifth Street New Kensington, PA 15068 PHONE: 412/362-4600	Steel Bond Fibercrete	(IC 18) (IC 18/1)
Celtite, Inc. 13670 York Road Cleveland, OH 44133 PHONE: 216/237-3232	Celtite-10	(IC 29)
CISCO--Coal Industry Services Company P. O. Box 134 Pounding Mill, VA 24637 PHONE: 703/964-6755	Aero Seal No. 1 Aero Seal No. 2 CISCO-Bond Aero-Seal Aero Seal Steel Fiber	(IC 66) (IC 66/1) (IC 66/2) (IC 66/3)
Conproco P. O. Box 368 Hookset, NH 03106 PHONE: 603/668-8810	Mine Seal Raleigh Mine Supply Mine Bond	

LIST OF CURRENTLY ACCEPTABLE MINE SEALANTS

<u>Company/Address</u>	<u>Trade Name</u>	<u>Acceptance Number</u>
Gill Chemical Company 6230 MacCorkle Avenue, S.W. St. Albans, WV 25177 PHONE: 304/727-6343	Gill #33 B&P/ Superbond ^{1/}	
Harris Mining Company P. O. Box 628 Spruce Pine, NC 28777 PHONE: 704/765-4251	Harris Mine Sealant	(IC 29)
International Vermiculite Company P. O. Box 66 Girard, IL 62640 PHONE: 217/627-2193	Mine Sealant-1 Mine Sealant-2	
J. P. Austin Associates, Inc. Mandoseal Corporation 300 Mt. Lebanon Boulevard Pittsburgh, PA 15234 PHONE: 412/563-3300	Mandoseal P Fibercoat	(IC 72) (IC 72/1)
Johnston-Morehouse-Dickey and Co. P. O. Box 173 5401 Progress Boulevard Bethel Park, PA 15102 PHONE: 412/833-7100	JMD Fibre-Bond	
Michael-Walters Industries 2801 Circlewood Court Louisville, KY 40207 PHONE: 502/892-6300 or 456-2100	M-W Stoppit	
Morton Chemical Company 110 North Wacker Drive Chicago, IL 60606 PHONE: 312/621-5551	Mor-Ad S-8005	

^{1/}Liquid additive to Portland cement-sand mixtures to improve adhesion and water-proofing.

MINE SAFETY AND HEALTH ADMINISTRATION

LIST OF CURRENTLY ACCEPTABLE MINE SEALANTS.

<u>Company/Address</u>	<u>Trade Name</u>	<u>Acceptance Number</u>
Stone Mountain Manufacturing Co., Inc. Lafayette Executive Ctr., Suite 304 P. O. Box 7320 5750 Chesapeake Boulevard Norfolk, VA 23509 PHONE: 804/853-7451	Fiberbond	(IC 39)
Strataseal, Inc. 163 Orchard Drive McMurray, PA 15317 PHONE: 412/941-6444	Strataseal MS-1 Strataseal MS-2 Stratalite Safetyseal	(IC 49) (IC 49/1) (IC 49/2) (IC 49/3)
The Carborundum Company P. O. Box 808 Niagara Falls, NY 14302 PHONE: 716/278-2296	Fiberfrax/Gypsum	
The INCA Company Stanton and Empire Streets Wilkes-Barre, PA 18702 PHONE: 717/822-2191	INCA 1000	(IC 1)
Thermocoat, Inc. 5910 Wellesley Pittsburgh, PA 15206 PHONE: 412/	Minescalant	(IC 35)
Therm-O-Rock Division of Allied Block Chemical Co. P. O. Box 455 New Eagle, PA 15067 PHONE: 412/258-3670	Tite-Seal Tite-Bond	(IC 16) (IC 16/1)
Thomas Company 203 Third Street Rainelle, WV 25962 PHONE: 304/438-6242	Thomas Fiberglass Bonding Mix	

LIST OF CURRENTLY ACCEPTABLE MINE SEALANTS

<u>Company/Address</u>	<u>Trade Name</u>	<u>Acceptance Number</u>
U. S. Gypsum Company Tool and Casting Division 101 South Wacker Drive Chicago, IL 60606 PHONE: 312/321-4000	Airtrol Rib and Roof Cement	
U. S. Mineral Products Company Stanhope, NJ 07874 PHONE: 201/347-1200	CAFCO Structural #3 CAFCO Type D-4 C/F	
W. R. Bonsal Company 4083 Bonsal Road P. O. Box 127 Conley, GA 30027 PHONE: 404/622-1956	Surewall	(IC 30)
W. R. Grace and Company 1716 Towpath Court Naperville, IL 60540 PHONE: 312/355-5545	Zonolite Mine Sealant	
Western Chemical and Mfg. Co. 3270 East Washington Boulevard Los Angeles, CA 90023 PHONE: 213/269-0191	Fire-Guard BM Mine-Guard	
Zonolite Construction Products Div. W. R. Grace and Company 62 Whittemore Avenue Cambridge, MA 02140 PHONE: 617/876-1400	STAK-N-BOND	