DENSITOMETER I

DENSITOMETER I

308 Q19991130000008
Scientific Notebook No. 003: Densitometer I--
Thermohydrology Research Project-Separate
Effects Experiments for Use in Conjunction
with Porous Cup Liquid Tensiometer
(12/07/1989-09/21/1995)

21
150

Steve Snedeman SS
Randall Green RH
Issued To Mike Lewis
for Center Thermohydrology Project
12/6/89

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Test 6 pg 99

THERMOHYDROLOGY RESEARCH PROJECT

Notebook received: 12/7/89 Michael J. Lubo Jr

PRINCIPAL INVESTIGATORS: Dodge, F.T.
FRIETAS, C.J.
SVEDMAN, S.J
LEWIS, M.J.

ACTIVE PROJECT No. (TASK 2) 20-3704-022

* PRELIMINARY ACTIVITIES

12/22/89
Re: Digital Multimeter Calibration

Talked to B. Mabrito who recommended to send DMM to Jim Patterson X2702 → sent to Rothe

Meter: HP 3458A
Serial # 2832A02203

CALIBRATION CERTIFIED BY ROTHE DEVELOPMENT INC.
METROLOGY SERVICES DIVISION
4614 SINCLAIR RD., SAN ANTONIO
TEXAS, 78222-2099
(512) 648-3131

Certificate No. 16502
Date 12/22/89

* PRELIMINARY ACTIVITIES

Pressure Transducer Calibration

Type: Honeywell Microswitch 160PC model 1 and 5 psi pressure sensors (Integrated Circuit Type)

Purpose: Separate Effects Experiments - For use in conjunction with porous cup liquid tensiometer

SPECIFICATIONS

Installation instructions for 160PC 1 psi pressure sensors

12/13/94

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* PRELIMINARY ACTIVITIES

PRESSURE TRANSDUCER SPECS

160PC Series

160PC SPECIFICATIONS at 8.0 ± 0.01VDC, 25° C

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12/13/94

MOUNTING DIMENSIONS
(for reference only)

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Low Pressure Differential, Gage, Vacuum Gage Sensors/Amplified

ENVIRONMENTAL SPECIFICATIONS

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* PRELIMINARY ACTIVITIES

12/13/94

CALIBRATION PROCEDURES:

1. Check Xdr's for long term stability with Data Ac. System
2. Calibrate each transducer using simple manometer.
3. Account for anticipated temp. range of operation in calibration

Next PAGE BEGIN:

INITIAL ENTRY	1/19/90	LEWIS
PERIODIC ENTRY 1	2/2/90	LEWIS
PERIODIC ENTRY 2	2/16/90	LEWIS
PERIODIC ENTRY 3	3/1/90	LEWIS
" " 4	3/6/90	SVEDEMAN
" " 5	3/6/90	"
" " 6	3/19/90	"
" " 7	5/4/90	"
" " 8	5/9/90	"
" " 9	5/28/90	"
" " 10	7/2/90	"
" " 11	8/6/90	"
" " 12	3/13/91	"

CNWRA- THERMOHYDROLOGY RESEARCH PROJECT

Investigators: Frank Dodge(04), Steve Svedeman(04), Mike Lewis(06), Chris Frietas(04), Ron Green (20)

I. SEPARATE EFFECTS EXPERIMENTS

OBJECTIVES

12/13/94

The objective(s) may be found in the Letter Report "Design of Separate Effects Experiments, Thermohydrology Project" dated May 1, 1989. A description may be found in Section II (Effects to be Studied).

EQUIPMENT AND MATERIALS

A parallel plate model composed of two 24"x24"x0.5" transparent acrylic plates separated by a 3" interior dimension will be used. Two opposing boundaries will be heat controlled, the other two boundaries will be insulated. The temperature of the heated boundaries will be controlled using liquid circulating heat exchangers in conjunction with constant temperature baths. The test media will be mono-sphere glass beads ranging in particle diameter from approximately 40 to 160 micron. Fractures will be simulated in the media by emplacing a planar sheet of larger glass beads (approximately 5 times the mean media diameter) and several diameters thick within the center of the media matrix. The control of liquid flow into and out of the test cell will be accomplished through fill and drain ports in the sidewalls of the fixture. The fill and drain ports will be outfitted with continuous tubular ceramic pipe across the horizontal 24" dimension of the test fixture. The instrumentation to be used for the measurement of temperature, heat flux, matric potential, and degree of saturation consists of:

27 ea. Thermistors (measuring temperature)
2 ea. Heat Flux Sensor (measure heat flux on two surfaces)
9 ea. Liquid Tensiometer (measure matric potential)
1 ea. Gamma Densitometer (measure saturation via. density)
2 ea. Traversing System Position Sensors (measure x,y position)
1 ea. Absolute Pressure Transducer (measure Barometric pressure)

Descriptions to follow include the individual components of the test system.

Test Cell Heating System

The heat exchangers are made of aluminum plate with flow through channels milled into them. Each exchanger is made of two 3/4 in. plates which are fitted together with an O-ring seal. The plate in contact with the media has transverse channels (in the 3 in. dimension) which are spaced on 1 in. centers and are 1/4 in. deep. The exterior plate has short longitudinal channels which connect successive transverse channels. The heat exchanger is sealed against the acrylic with another O-ring seal. The thickness of aluminum between the heated fluid and the media is 1/2 inch.

Heating or cooling of the cell occurs by conduction when liquid (water and ethylene glycol mixture) is pumped through the exchanger at a desired temperature. The liquid temperature in each heat exchanger is controlled independently by NESLAB EXACAL model EX251-HT high temperature baths with 25 liter liquid volume. These baths can control the setpoint liquid temperature to approx. 0.1 degree C for temperatures above 35-40 degrees C and up to 250 degrees C.

Test Media

The glass beads for matrix and fracture simulations were obtained from FERRO CORPORATION, Cataphote Division, P.O. Box 2369, Jackson, MS 39205. The beads are Class IV, Uni-spheres and consist of soda-lime glass. They are annealed to reduce internal stresses. The manufacturer claims a maximum of 15% irregular shaped particles. The sizes obtained are listed below:

MATRIX:	#2740\	28-53 um	FRACTURE:	#608\	177-259 um
	#1420\	74-105 um		#354.5\	350-500 um
	# 812\	125-174 um		#203\	590-840 um

These beads will be characterized before use in the experiments. A statistical grain size study will be done to verify the claimed size ranges and/or sieve filtration if a narrower range is desired. A standard dry packed volume will be determined and the volumetric fraction of voids (porosity) established.

Data Acquisition and Control

An automated PC-based system has been acquired to control data collection, log data input, and analyze the logged data. The system is composed of the following products:

*IBM PS2 model 80 computer
*NATIONAL INSTRUMENTS MC-GPIB card
*MICROSOFT MOUSE
*MICROSOFT QUICKBASIC V4.5 software
*HEWLETT PACKARD model HP3458A DIGITAL MULTIMETER
*HEWLETT PACKARD model HP3488A SWITCH/CONTROL UNIT
*4 ea. HP44470A MULTIPLEXER SWITCH (10 chan. each)
*1 ea. HP44473A MATRIX SWITCH (4x4 chan.)
* assorted NATIONAL INSTRUMENTS TYPE X2 gpib cables

Calibration of the digital multimeter was performed by ROTHE DEVELOPMENT INC., Metrology Services Division, 4614 Sinclair Rd., San Antonio, Texas 78222-2099. The calibration certificate for HP3458A, SN.2832AO2203 is dated Dec. 22, 1989, Certificate No. 16502. Other components of the data acquisition system will be checked in-line with instrumentation calibration to ensure adequate system function.

Instrumentation

a) Thermistors- YSI INC., Box 279, Yellow Springs, Ohio 45387. Thermistor probe assembly 031-46031-4-RPS-120-ST. These gages will be mounted and sealed into the fixture through access ports drilled into the acrylic plate. Some specifications of the probes are given below.

Style Tubular Probes

030"
031"
032"

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Tolerance (±) % Resistance and °C

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Part No. 46030, 46033, 46034, 46036, 46037

TEMPERATURE ----- RESISTANCE ----

b) Heat Flux Sensor- RDF CORPORATION, 23 Elm Ave., Hudson, New Hampshire 03051. Heat Flux Gage # 20456-3 and application cement. These gages will be flush mounted, one on each heat exchanger surface toward the interior of the cell. Specifications are listed below.

Information potentially subject to copyright protection was redacted from this location. The redacted material is from a user manual for tubular probes.

c) Liquid Tensiometer- These must be constructed as indicated in the diagram below. These instruments will be mounted and sealed to the fixture through access ports drilled into the acrylic plate. The major components are as follows:

*HONEYWELL MICROSWITCH PRESSURE SENSOR #141PCOSG (-5 to 0 psi)
Blackburn Drives and Control, San Antonio
*SOIL MOISTURE EQUIPMENT CORP. 652X07-BIM3 porous ceramic cup
P.O. Box 30025, Santa Barbara, California 93105
*stainless steel and PVC tubing

RH
12/12/94

HONEYWELL MICROSWITCH SENSOR SPECS MAY BE FOUND IN PRELIMINARY ACTIVITIES ON PAGES 2 AND 3.

Absolute, Differential, Gage, Vacuum Gage Sensors/Amplified **140PC Series**

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TENSIOMETER

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RH 12/13/94

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PHYSICAL PROPERTIES OF POROUS CERAMICS

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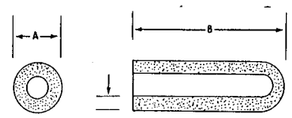
652 ROUND BOTTOM STRAIGHT WALL CUPS



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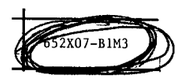


RH 12/13/94

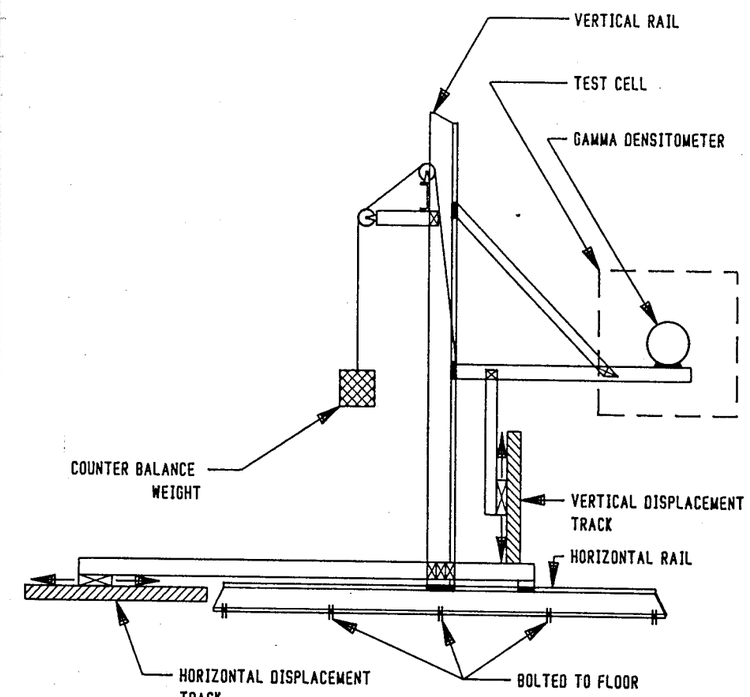
d) Gamma Densitometer- TEXAS NUCLEAR model 9700D EZ-CAL System. The gamma densitometer will traverse the exterior of the test fixture with beam directed through the test sample. The traversing system is computer controlled with feedback loop.

e) Position Sensors- HOUSTON SCIENTIFIC, 4202 Directors Row, Houston, Texas. Linear displacement transducer (string pot) # 1850-40 (40 inches travel). These sensors will be used as position feedback for the traversing system which will be used to automatically control the position of the Gamma Densitometer source and receiver. They will be mounted to a reference position on the traversing frame.

f) Absolute Pressure Transducer- HONEYWELL MICROSWITCH PRESSURE SENSOR, #141PC15G (0-15 psi vacuum). This transducer will be used to monitor barometric pressure in the laboratory for a reference standard.

Traversing System

An aluminum frame of welded structural members will be used to transport the Gamma Densitometer to required locations in the plane of the test cell. The (X,Y) positioning is accomplished with two independent, digitally controlled, linear displacement tracks. The linear displacement tracks are manufactured by VELMEX INCORPORATED, UNI-SLIDE. The horizontal track (X-position) is a model #B4024P20 and the vertical track (Y-position) is a model #B4042P20J. The two positioning sensors from HOUSTON SCIENTIFIC will be used to confirm Densitometer location. The weight of the Gamma Densitometer will be counterbalanced on the frame to allow the linear positioning tracks to function properly. A schematic drawing of the traversing system is given below.



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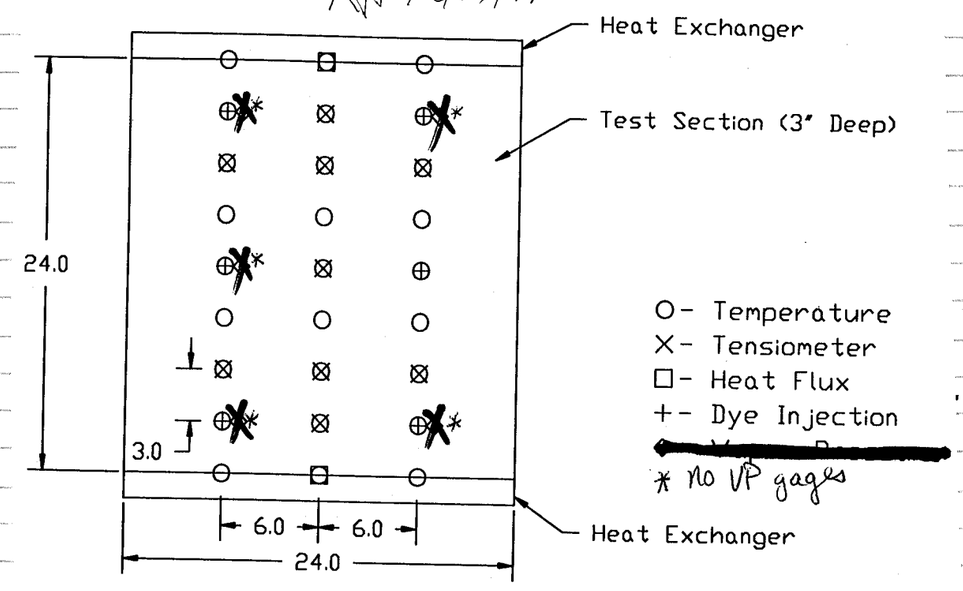


CALIBRATION AND ACCURACY REQUIREMENTS

The following is a list of the measurement parameters, instrumentation types, required accuracy, and calibration requirements.

RJA 12/13/94

Measurement Parameter	Fundamental Units	Instrument	Required Accuracy	Calibration Status (Date, Page)
Temperature	°C	Thermistor	± 0.5°C	P.32
Matric Suction	centimeter of Hg	Tensiometer	± 0.5cm	P. 28
Saturation		Gamma Densitometer	± 2%	P. 23
X-Position	centimeter	Position Sensor	± 0.5cm	P. 26
Y-Position	centimeter	Position Sensor	± 0.5cm	P. 26
Barometric Pressure	centimeter of Hg	Pressure Gage	± 0.15cm	NOT REQ'D - REF. ONLY

SPECIAL TRAINING OR QUALIFICATIONS

A Radiation Safety class will be required by all personnel having contact with the Gamma Densitometer. Personnel are required to wear radiation exposure rings which are checked on a monthly interval for exposure levels. Classes are arranged through the SwRI Radiation Safety Officer, Dave Cadena, ext.2633. To date one class has been held in association with this project, dated November 29, 1989. Attending were Steve Svedman, Mike Lewis, Marion Burzynski.

END INITIAL ENTRIES 1/19/90
Michael J. Lewis

PERIODIC ENTRY ① 2/2/90

BEAD CHARACTERIZATION ACTIVITY

- DETERMINE APPROXIMATE VOID FRACTION FOR BEAD PACKING USING WEIGHT AND VOLUME PROCEDURES

a) CALIBRATE LAB SCALE TO NATIONAL BUREAU OF STANDARDS
* Scale was not calibrated, but was checked against dead weights which were determined on an NBS traceable scale

REFERENCE WT	Scale Used (NBS)	WEIGHT
1	OHAUS Triple Beam # 5485 20# cap .002# resolution calibrated 8/9/89 Texas Scales	.336 #
2	"	1.172 #
3	"	7.107 #
4	"	11.460 #
5	METTLER E2000 # 15709 Ser. No. 830536 2000g capacity .01g resolution calibrated 6/22/89	51.50 gram
6	"	1.62 gram

Both Scales were calibrated by Texas Scales - Chris Chinni within about 6-7 months.
~~[illegible]~~ Triple Beam resolution (.002)(453.6) = .9 gram

Lab Scale = SARTOVIUS 3808 MFG. P/N B-147-73 ELECTRONIC TOP LOADING BALANCE 30kg cap. 0.1 gram resolution
SN

Michael J. Lewis 4/10/90

1# = 453.6 gram

Ref wt #	Ref. wt. (gram)	LAB SCALE (gram)	% Error	WITHIN RESOLUTION
1	152.4 ± .9	151.9 g	0.59	✓
2	531.6 ± .9	530.9	0.17	✓
3	3223.7 ± .9	3223.2	0.016	✓
4	5198.7 ± .9	5197.8	0.017	✓
5	51.50 ± .01	51.5		✓
6	1.62 ± .01	1.6		✓

b) Calibrate Volumetric Graduated Cylinder using water

KIMAX 500 ml by 10 ml Sv
No. 20024
wt = 397.6 grams

Add 200 ml of H_2O @ 1g/ml
to bottom of meniscus

Expected wt.	Actual Weight
397.6 + 200 = 597.6 gram	597.6 gm OK

c) Beads #812 (125-174 μm)

- Add 200 cc glass beads to beaker

The beads were added to the beaker using a ~~[illegible]~~ funnel with Spout such that the falling distance is equal to six inches at all times (procedure analogous to ASTM D 2049) This packing configuration should represent the same as the beads will have in the test fixture if the same procedure is used.

Total wt. of ~~beaker~~ KIMAX 200424 + beads 700.5 gm
− wt. ~~beaker~~ KIMAX 200424 −397.6
302.9 gm beads (dry)

$$\rho_{dry} = \left(\frac{1}{200\,cc}\right)(302.9\,g) = 1.515\,g/cc$$

Reported range for ρ_{dry} from Ferro Cataphote Supplier
1.45 g/cc Finer beads to 1.55 g/cc coarser beads

$$1.45 < 1.515 < 1.55 \quad \text{OK}$$

Saturate beads by titration of water (deionized) into the current bead pack
approximate flow rate of 1/2 cc / second

Add 75 cc to overfill (negligible air voids remaining) by inspection

Remove overfill by pipet − .6 cc

By volume: 75 − .6 = 74.4 cc water

By weight: 774.7 grams (saturated wt.)
- 700.5 grams (dry)

74.2 grams

or @ 1g/cc of water 74.2cc by weight

POROSITY (n) = $\frac{\text{Volume of Voids}}{\text{Volume total}} = \frac{74.2cc}{200cc}$ or $\frac{74.4cc}{200cc}$

By weight	n = 37.1%
By volume	n = 37.2%

VOID RATIO (e) $\frac{\text{volume of voids}}{\text{volume of solids}}$

$V_s = 200 - V_v =$ 200 - 74.4 = 125.6cc
or
200 - 74.2 = 125.8cc

By weight: e = .589

By volume: e = .592

CALCULATE G_s SPECIFIC GRAVITY OF BEADS

For Saturated Conditions $w\% = \frac{74.4}{302.9} = .245$

$G_s = \frac{Se}{w} = \frac{1(.59)}{.245} = \underline{\underline{2.41}}$

Compare to ~~density~~ G_s of solid glass = 2.5 ∴ spheres may have some entrapped air voids

MJL 4/10/90

MJL 4/10/90

d) Beads #1420 (74 - 105 μm)
- Use same procedures to calculate porosity n

Use beaker calibrated by water weight @ 150cc
- establish calibration level marks

Beaker wt. = 142.3 gm
H_2O add 150cc 150.0 gm

292.3 gm add water to achieve this weight

Mark calibration lines on beaker at bottom of meniscus interface.

Add beads to fill line using "raining" procedure with funnel

Total weight dry = 371.3 gm

Titrate H_2O @ ~½ cc/sec rate

Add 70.5cc
remove by pipette 13.3cc

Volume Total of water added = 57.2 cc

Saturated weight = 427.9 gram
dry wt. - 371.3

56.6g @ 1g/cc H_2O = 56.6cc

POROSITY

By weight	$n = \frac{56.6}{150} = 37.7\%$
By volume	$n = \frac{57.2}{150} = 38.1\%$

e) Beads # 2740 (28-53 μm)

Add 150cc beads

Total weight dry = 371.4 g

Add 65 ml water

Remove by pipette 8.5 ml

Total H_2O added 56.6 ml

Saturated weight = 428.1 g
dry wt. − 371.4
56.7 g

POROSITY

By weight $\eta = \frac{56.7}{150} = 37.8\%$

By volume $\eta = \frac{56.5}{150} = 37.6\%$

POROSITY appears to range between 37 → 38% using this packing procedure and is roughly independent of the size of beads used (no mixing of beads) therefore assume $\eta = 37.5\%$ for practical purposes.

END PERIODIC ENTRY ① Michael J Lewis 2/2/90

PERIODIC ENTRY ② 2/16/90

GLASS BEAD GRAIN SIZE DISTRIBUTION STUDIES

Grain size analysis performed with a sub-sieve sizing device by Gene Jones, Chemistry, Div. 01

using a Coulter Counter model TA2; orifice size 400 (2-200 μm); No dispersant; Electrolyte: Isotron 2 (NaCl)

Note: ① This procedure has not been QA qualified
② The operator has not been QA indoctrinated
③ At this time: The information is not required at an accuracy greater than presented.

Michael J Lewis 4/9/90

Small vials containing 2 samples of each #812 beads, #1420 beads, #2740 beads were obtained from differing lots at random from existing bead supplies

Results of both Population and Volume studies follow:

SAMPLE I.D.	POPULATION STATISTICS MEAN (μm)	STANDARD DEVIATION (μm)	MEDIAN (μm)	COEFF. OF VARIATION (%)	VOLUME STATISTICS MEAN (μm)	STANDARD DEVIATION (μm)	MEDIAN (μm)	COEFF. OF VARIATION (%)
#812-1	130.27	1.46	140.09	1.12	159.54	1.40	162.61	0.88
#812-2	134.95	1.46	143.51	1.08	171.25	1.42	175.79	0.83
#1420-1	82.24	1.46	88.19	1.77	106.59	1.41	108.60	1.33
#1420-2	89.42	1.46	96.31	1.64	114.64	1.40	116.90	1.22
#2740-1	58.84	1.43	62.81	2.44	78.90	1.51	78.45	1.91
#2740-2	58.97	1.44	63.00	2.43	79.49	1.52	78.91	1.91

MJL 4/10/90

END PERIODIC ENTRY ② 2/16/90 Michael J Lewis

PERIODIC ENTRY (3) 3/1/90
BEAD CHARACTERIZATION ACTIVITY
CAPILLARY PRESSURE CURVE (#812 BEADS)

NEED PRESSURE REGULATION TO HOLD ±.1 psi over long (1-2 day) time period. REGULATE WALL PRESSURE ① 150psi → 10psi

Fairchild precision regulators
- Regulator 2 ② 10 psi → ~2 psi - 3 psi
- Regulator 3 ③ .1 psi increments

PRESSURE TRANSDUCER: BK E124 # 206 0-150psi by .1psi
Digital Readout E400-341
calibrated using 4 points on mercury U-tube manometer from 0-5psi range (OK)

SATURATED WT. BEADS + CONTAINER 1555.6 gm
Dry WT. BEADS + CONTAINER 1443.2 gm
LIQUID WATER 112.4 gm
@ 1g/cc = 112.4 cc

Pressure Interval	DATE/TIME	ELAPSED TIME (MIN)	EFFLUENT (ml)
.2 psi	2/19 9:45a	0	1
	11:45a	120	2
	1:15p	210	2
	2:00p	255	2
.4 psi	2/19 2:00p	0	2
	4:00p	120	3
	5:30p	210	3
	2/20 11:30	1290	3
.7	2/20 11:30a	0	3
	12:15p	45	5.5
	2:30p	180	~~8~~ 11 ← error in effluent calculation add 3ml
	5:00p	330	~~18~~ 21
.8	2/20 5:00p	0	~~18~~ 21
	2/21 8:44a	944	~~42~~ 45
	12:00p	1140	~~45~~ 48
	3:28p	1348	~~46~~ 51

MJL 4/10/90

PRESSURE INTERVAL	DATE/TIME	ELAPSED TIME (MIN)	EFFLUENT (ml)
1.0 psi	2/21 5:10p	0	~~46~~ 51
	2/22 11:30a	1100	~~98~~ 98.5
1.2 psi	2/22 11:30a	0	~~98~~ 98.5
	3:21p	231	~~105.0~~ 108.0
	6:15p	405	~~106.5~~ 109.5
	2/23 9:18a	1308	~~107.0~~ 110
	1:20p	1550	~~107.5~~ 110.5
1.6 psi	2/23 1:30p	0	~~107.5~~ 110.5
	2/24 9:00a	1170	~~108.8~~ 111.8
2.0	2/24 9:00a	0	~~108.8~~ 111.8
	2/26 8:52a	2872	~~109.4~~ 112.4
3.0	2/26 9:00a	0	112.4
	2/27 1:00p	1680	112.4

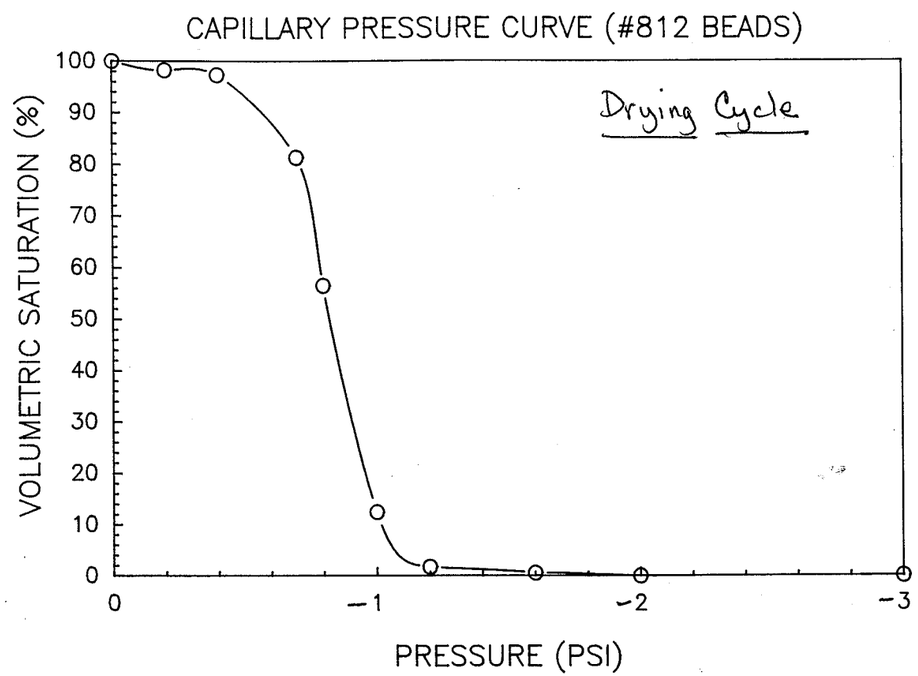
MJL 4/10/90

SATURATION $S = \frac{V_w}{V_v} = \frac{\text{EFFLUENT (cc)}}{112.4\text{cc}}$

Pressure (psi)	SATURATION (%)
.2	98.26
.4	97.31
.7	81.29
.8	56.38
1.0	12.38
1.2	1.70
1.6	.54
2.0	0
3.0	0

Procedure used in this investigation roughly follows ASTM D2325 with the exception of the apparatus size only. A Tempe pressure cell (Soil Moisture Equipment) was used with a ceramic plate having a minimum air entry value > 1 bar.

Effluent was collected in a graduated cylinder, roughly calibrated using a 3 point check with the weight of water.



This curve represents drying of the saturated bead matrix. A complimentary test for wetting will have to be performed to establish the hysteresis in the capillary relationship between wetting and drying cycles.

END PERIODIC ENTRY (3) Michael [illegible]

PERIODIC ENTRY (4) 3-6-90 [illegible]

CALIBRATION CHECK ON SENSORS USED IN SEPARATE EFFECTS EXPERIMENTS.

γ-BEAM DENSITOMETER CALIBRATION 2-17-90

TEST SETUP

ALUMINUM SHEET STOCK WAS USED TO PROVIDE VARIOUS "THICKNESS" FOR γ-BEAM DENSITOMETER CALIBRATION

DENSITOMETER: TEXAS NUCLEAR
MODEL # 9700 D E-Z Cal
Ser. # 00961

INPUT VALUES IN DENSITOMETER SETUP:

		CODE #	
PIPE I.D.	300F	—	3.00
P1 UNITS	121C	—	54
SLURRY/SINGLE PHASE	080C	—	0
STANDARDIZE			
CAL/REF	560F	—	1.0
SET SLOPE	310F	—	1.0
CAL DENSITY	180F	—	0.0

% Sol. by Vol.

GRAVITIES:	CARRIER	550F	— 0.001	
	SOLIDS	530F	— 1.0	
ABSOR. COEF:	CARRIER	130F	— .086	
	SOLIDS	140F	— .086	
CURRENT OUTPUT:	MIN	330F	— 4.00	(mA)
	MAX	320F	— 20.00	(mA)
		191C	— 2	
CURRENT CORR. FACTORS	MIN	351F	— 1.009	
	MAX	341F	— 1.006	
DYNAMIC TRACKING		090C	— 1	(DISABLE)

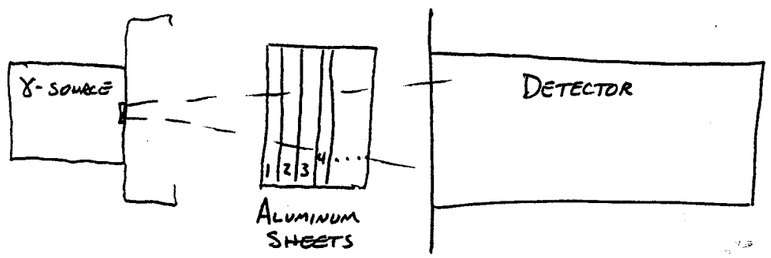
3-6-90 SS

ALUMINUM (6061-T6) CAL. BLOCKS USED

BLOCK #	THICKNESS
1	.750"
2	.750
3	.750
4	.505
5	.261
6	.032

4-4-90 SS

BLOCK THICKNESS MEASURED WITH MITUTOYA MODEL 505-626 CALIPERS



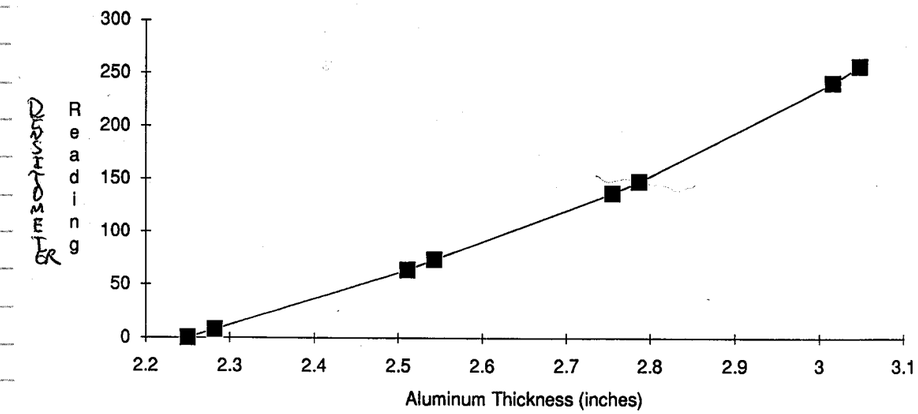
Calib. PIECES IN γ-BEAM	TOTAL SAMPLE THICKNESS	DENSITOMETER READING
1+2+3	2.250"	0.0 *
1+2+3+6	2.282	7.6
1+2+3+5	2.511	63.5
1+2+3+5+6	2.543	73.3
1+2+3+4	2.755	136.2
1+2+3+4+6	2.787	147.1
1+2+3+4+5	3.016	240.5
1+2+3+4+5+6	3.048	256.3

3-6-90 SS

* THIS WAS "0" CAL. POINT (press 79 ENTER ON DENSITOMETER AND DENSITOMETER STANDARDIZES ON THIS SAMPLE)
STANDARDIZATION VALUE ~~AFTER CAL.~~ 79OF = 4649

4-13-90 SS

SINCE THE AL PLATE THICKNESS WERE MEASURED WITH AN "UN-TRACEABLE" CALIPER SET, THE MEASUREMENTS WERE REPEATED WITH A CRAFTSMAN 6" SCALE (#40896) WITH 0.01" DIVISIONS. THE RESULS ARE:
BLOCK #1 = 0.75", BLOCK #2 = 0.75", BLOCK #3 = 0.75"
BLOCK #4 = 0.50", BLOCK #5 = 0.26" SS 4-13-90, BLOCK #6 = 0.03" SS 4-13-90



THESE READING MATCH FAIRLY WELL WITH THE PRIOR READINGS AND DO NOT CHANGE THE RESULTS IN ANY SIGNIFICANT WAY. THE CALIBRATION CHECK VERIFIES THE DENSITOMETER FUNCTIONS THROUGHOUT THE RANGE OF INTEREST IN THE EXPECTED MANNER. Steve Friedman 4-13-90.

THE ORIGINAL "COPY" OF P26-45 ARE ATTACHED TO THIS PAGE. FOR REPRODUCIBLE COPY. 9 Pages. 4-4-90.

NRC-20-3704-022
THERMOHYDRODOGY - SEA EFFECTS EXPMTS.

2-2-90

CALIBRATION OF POSITION SENSORS ON TRAVERSING SYSTEM (USED TO POSITION γ-BEAM DENSITOMETER ON TEST SECTION)

SENSOR TYPE - HOUSTON SCIENTIFIC
MODEL # 1850-040
P.N. 402707-0000-00
SPEC - LIN ± 0.1%
MAX TRAVEL = 40"
X-AXIS SER. # 6940-001
Y-AXIS " " 6940-002

10.000 VDC Power Supply (Position Sensor are voltage divider systems)

MEASURED POSITION	X-AXIS VOLTAGE	X-AXIS COMPUTER DISPLAY *	Y-AXIS VOLTAGE	Y-AXIS COMPUTER DISPLAY **
0.0"	1.2634 VDC	0.00"	8.7876 VDC	0.0053
5.0"	2.4703	5.0072"	7.5793	5.0088 ~~4.9994~~
10.0"	3.6748	10.0042	6.3655	10.0187
15.0"	4.8829	15.0162		
18.0"	5.6025	18.0015		
10.0"	3.6769	~~9.99~~ 10.0129		
0.0"	1.2655	0.0091		
20.0			3.9483	20.011
30.0			1.5337	29.994
34.0			0.5471	33.980
15.0			5.1519	15.036
0.0			8.7827	0.0258

* CONVERSION IN COMPUTER $X = 4.1482(V) - 5.2414$
** " " " $Y = -4.1341(VDC) + 36.3343$

CONTINUED FROM PAGE 57

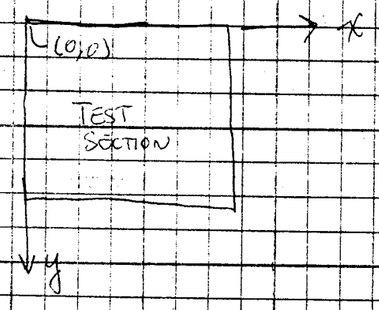
"MEASURED POSITION" WAS FROM A SCALE FIXED TO TRAVERSING SYSTEM

SCALE : L.S. STARRETT CO
ATHOL, MASS.
STEEL SCALE - 48" LONG
MODEL # C404R
~~RESULT~~ GRADUATED TO 1/64" (0.015")
2-2-90

VOLTAGE READINGS FROM: HP 3458A MULTIMETER
Sn # 2823A-02203

"COMPUTER DISPLAY READING" - VOLTAGE reading from Multimeter is transferred via Digital Signal (IEEE-488) TO IBM PS-2. AND CONVERTED TO INCHES FOR DISPLAY.

~~RESULTS~~
2-2-90



2-2-90

RESULTS - POSITIONING ACCURACY REQUIRED — 0.10"

THE CALIBRATION CHECK SHOWED THE FEED BACK SENSOR ARE ~~NOT~~ WITHIN THE ACCURACY REQUIRED 2-2-90

2-8-90 SS

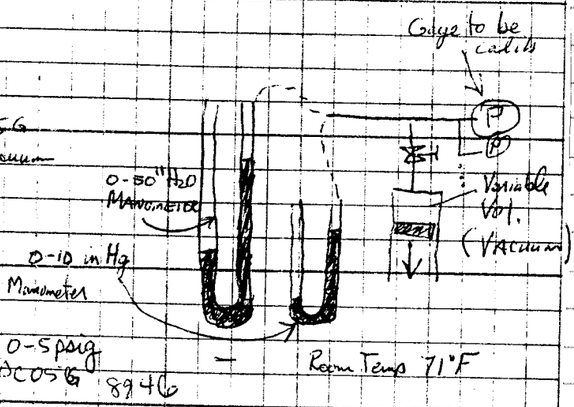
PRESSURE GAGE CALIBRATION

SETUP

PRESSURE TRANSDUCERS:

HONEYWELL MODEL 141PC05G

RANGE = 0 → 5 psig Vacuum



Pressure gages Honeywell 0-5 psig PART # 141PC05G 8946

Room Temp 71°F

RESULTS

MANOMETER PRESS Reading		CHANNEL 106 Ser# 0392-0003 VOLTS	PSI	CHANNEL 107 Ser# 0393-0102 VOLTS	PSI	Channel 108 Ser# 0373-0064 VOLTS	PSI	Channel 109 Ser# 0393-0118 VOLTS	PSI
0	0.0	ⓐ	1.282	-.0255	1.2934	-.0347	1.2744	-.0195	1.2964	-.0371
.428	11.85 in H_2O	ⓑ	1.8149	-.4520	1.8255	-.4606	1.8075	-.4461	1.8265	-.4609
.761	21.07 "	ⓒ	2.2260	-.7809	2.2360	-.7889	2.2183	-.7747	2.2347	-.7879
1.375	38.19 "	ⓓ	2.9994	-1.3996	3.0075	-1.4061	2.9905	-1.3925	3.0024	-1.4024
1.769	49.00 "	ⓔ	3.4886	-1.7909	3.4956	-1.7965	3.4788	-1.7831	3.4891	-1.7913
2.56	5.24 in Hg	ⓕ	4.5144	-2.6113	4.5185	-2.6147	4.5015	-2.6012	4.5084	-2.6067
3.29	6.73 in Hg	ⓖ	5.4207	-3.3363	5.4246	-3.3396	5.4075	-3.3269	5.4134	-3.3311
4.48	9.16 "	ⓗ	6.9201	-4.5358	6.9289	~~-5.4377~~ -4.5369	6.9044	-4.5236	6.9160	-4.5327

SS 2-8-90 SS 2-8-90

Supply Voltage TO Pressure TRANSDUCERS:

Ref = 10.001 VDC

Conversion from VDC → PSI: PSI = 0.80 VDC + 1.00

60

SS 2-19-90 2-19-90 SS

Continue Calib of Pressure gages - calibrate the rest of the sensors not completed on 2-8-90

Manometer Press. Reading		Channel 101 Ser# 0393-0133 "TENSIOMETER 1" VDC	DAS	Channel 102 0393-0131 "Tensiometer 2"	Channel 103 0393-0118 "Tensiometer 3"	Channel 104 0392-0004 "Tensiometer 4"	Channel 105 0393-0122 "Tensiometer 5"
time							
17.59	0.0 in H_2O	1.2869 VDC	.0249 psi		(1)		
18:02	19.76 "	2.1612	-.7291		(2)		
18:05	36.36 "	2.9905	-1.3223		(3)		
18:06	47.05 "	3.3877	-1.7107		(4)		
18:09	5.14 in Hg	4.3971	-2.5184		(5)		
18:10	7.47 "	5.8380	-3.6118		(6)		
18:11	10.09 "	7.4544	-4.9623		(7)		
18:14	0.0	1.2828	-0.0263		(8)		

See attached sheet for Recorded values.

From Calib. data on p 59 Max. Difference between the manometer reading and sensor reading is:

Cal. Point	Max Diff
ⓐ	.04
ⓑ	.03
ⓒ	.03
ⓓ	.03
ⓔ	.03
ⓕ	.05
ⓖ	.05
ⓗ	.05

Pressure Sensor calib. con't. 2-19-90 SS 61

		Manometer Reading	Maximum Diff (Sensor - Manometer)
(1)	Data taken: 02-19-1990 17:59:45 Tensiometer 1 -0.0335 PSIg Tensiometer 2 -0.0169 PSIg Tensiometer 3 0.0078 PSIg Tensiometer 4 -0.0059 PSIg Tensiometer 5 -0.0189 PSIg	0.0 psig (0 in H_2O)	.03 psig
(2)	Data taken: 02-19-1990 18:02:24 Tensiometer 1 -0.7292 PSIg Tensiometer 2 -0.7243 PSIg Tensiometer 3 -0.7019 PSIg Tensiometer 4 -0.7148 PSIg Tensiometer 5 -0.7255 PSIg	0.71 psig (19.76 in H_2O)	.02
(3)	Data taken: 02-19-1990 18:04:53 Tensiometer 1 -1.3203 PSIg Tensiometer 2 -1.3219 PSIg Tensiometer 3 -1.3013 PSIg Tensiometer 4 -1.3141 PSIg Tensiometer 5 -1.3230 PSIg	1.31 psig (36.36 in H_2O)	.01
(4)	Data taken: 02-19-1990 18:06:25 Tensiometer 1 -1.7099 PSIg Tensiometer 2 -1.7098 PSIg Tensiometer 3 -1.6901 PSIg Tensiometer 4 -1.7029 PSIg Tensiometer 5 -1.7109 PSIg	1.70 psig (47.05" H_2O)	.01
(5)	Data taken: 02-19-1990 18:08:44 Tensiometer 1 -2.5171 PSIg Tensiometer 2 -2.5202 PSIg Tensiometer 3 -2.5023 PSIg Tensiometer 4 -2.5155 PSIg Tensiometer 5 -2.5217 PSIg	2.51 psig (5.14" Hg)	.01
(6)	Data taken: 02-19-1990 18:10:39 Tensiometer 1 -3.6692 PSIg Tensiometer 2 -3.6677 PSIg Tensiometer 3 -3.6520 PSIg Tensiometer 4 -3.6652 PSIg Tensiometer 5 -3.6699 PSIg	3.65 psig (7.47" Hg)	.02
(7)	Data taken: 02-19-1990 18:11:56 Tensiometer 1 -4.9612 PSIg Tensiometer 2 -4.9664 PSIg Tensiometer 3 -4.9532 PSIg Tensiometer 4 -4.9645 PSIg Tensiometer 5 -4.9688 PSIg	4.93 psig (10.09 in Hg)	.04
(8)	Data taken: 02-19-1990 18:14:35 Tensiometer 1 -0.0263 PSIg Tensiometer 2 -0.0170 PSIg Tensiometer 3 0.0077 PSIg Tensiometer 4 -0.0061 PSIg Tensiometer 5 -0.0189 PSIg	0 psig (0.0 in H_2O)	.03 psig

62 Pressure Sensor Calib. Continued. 2-19-90 SS

Results

All of the pressure sensor readings are within ±1% of the manometer readings over the calibration range – for ~~our tests~~ SS 2-19-90 Separate Effects experiments. This is SS 2-19-90 acceptable. Therefore no individual calibration is required.

(NOTE – The sensor accuracy could be improved to ~ ± 0.5% FS by removing offset @ 0 psig).

2-13-90 SS

THERMISTOR CALIBRATION CHECK

SETUP: LIQUID BATH – NESLAB RTE-4 REFRIGERATED CIRCULATION BATH

REFERENCE TEMPERATURE – BROOKLYN THERMOMETER CO.
Hg in Glass Thermometers w/Calib. Certificates
THERMISTORS ARE read THRU HP3458A MULTIMETER

THERMISTORS – YSI INC. MODEL # 031-46031-4-RPS-120-ST

Hg in Glass thermometer readings

	①	CAL TEMA			
	14:05	14:25 ② 20.91°C	14:38 ③ 60.81°C	15:07 ④ 90.11°C	15:19 ⑤
THERMISTOR	53.1°F = 11.72°C	87.65°F	141.6°F	194.2°F	32.0°F
Sensor	(11.6 CHECK) 32.0 ICE CHECK	30.4°C 32.4 ✓	60.9°C 32.0 ✓	90.3°C 32.0 ✓	ICE BATH

YSI Temperature 1	11.6074 °C	30.9256 °C	60.8192 °C	90.1394 °C	-0.0511 °C
YSI Temperature 2	11.6584 °C	30.9850 °C	60.8762 °C	90.2073 °C	-0.0032 °C
YSI Temperature 3	11.7487 °C	31.0881 °C	60.9154 °C	90.2250 °C	0.0774 °C
YSI Temperature 4	11.6835 °C	30.9917 °C	60.9152 °C	90.2484 °C	0.0146 °C
YSI Temperature 5	11.6558 °C	30.9769 °C	60.8747 °C	90.1931 °C	0.0036 °C
YSI Temperature 6	11.6878 °C	31.0002 °C	60.8477 °C	90.1206 °C	-0.0001 °C
YSI Temperature 7	11.7236 °C	31.0279 °C	60.8454 °C	90.1043 °C	0.0737 °C
YSI Temperature 8	11.7024 °C	31.0492 °C	60.9134 °C	90.2455 °C	0.0393 °C
YSI Temperature 9	11.6222 °C	30.9692 °C	60.8658 °C	90.2439 °C	-0.0736 °C
YSI Temperature 10	11.7062 °C	31.0081 °C	60.8977 °C	90.1914 °C	0.0894 °C
YSI Temperature 11	11.7466 °C	31.0755 °C	60.8898 °C	90.1596 °C	0.0410 °C
YSI Temperature 12	11.7161 °C	31.0607 °C	60.8896 °C	90.1690 °C	0.0066 °C
YSI Temperature 13	11.7689 °C	31.0993 °C	60.9262 °C	90.2102 °C	0.0617 °C
YSI Temperature 14	11.7856 °C	31.1199 °C	60.8959 °C	90.2076 °C	0.0829 °C
YSI Temperature 15	11.7659 °C	31.0795 °C	60.8871 °C	90.1938 °C	0.0537 °C
YSI Temperature 16	11.6989 °C	31.0554 °C	60.8900 °C	90.2484 °C	-0.0120 °C
YSI Temperature 17	11.7384 °C	31.0859 °C	60.9314 °C	90.2752 °C	0.0409 °C
YSI Temperature 18	11.6907 °C	31.0511 °C	60.8657 °C	90.2373 °C	-0.0442 °C
YSI Temperature 19	11.6931 °C	31.0464 °C	60.8803 °C	90.2060 °C	-0.0157 °C
YSI Temperature 20	11.7313 °C	31.0929 °C	60.9482 °C	90.2845 °C	0.0175 °C

THE ABOVE DATA WERE RECORDED FROM THE HP3458A MULTIMETER AND SCALED TO READ IN °C

$$T(°C) = \frac{1}{\left(K1 + K2 * Ln(\Omega) + K3 * Ln(\Omega)^3\right)} - 273.15$$

$K1 = 1.0295 \times 10^{-3}$, $K2 = 2.3908 \times 10^{-4}$, $K3 = 1.56817 \times 10^{-7}$

Ω - Sensor Resistance in Ω

2-13-90 SS

Thermometer

①	ASTM	63F	8009-1311	SEE CERTIFICATES OF CALIB. – ATTACHED TO THIS PAGE (COPIES) (MAC WOOD HAS ORIGINALS)
②	"	"	"	
③	"	65F	7903-3787	
④	"	66F	8003-799	
⑤	Ice Bath			

Results:

Mercury in glass thermometer could be read to ~0.1°F accuracy.

The ice point readings are all within ± 0.1°C of 0.0°C

ALL OF THE OTHER Readings are with ±0.2°C OF THE Hg in glass thermometers.

Accuracy required is ± 0.5°C so a calibration check show individual sensor calibration is not required.

3-6-90 SS

NPLC 1										
Densitometer	DCV	10.0	.0001	402	% Sat.	1	12.5	-25	0	
Barometer	DCV	10.0	.0001	100	PSIa	1	2.4	-3	0	
Tensiometer 1	DCV	10.0	.0001	101	PSIg	1	-.8	1	0	
Tensiometer 2	DCV	10.0	.0001	102	PSIg	1	-.8	1	0	
Tensiometer 3	DCV	10.0	.0001	103	PSIg	1	-.8	1	0	
Tensiometer 4	DCV	10.0	.0001	104	PSIg	1	-.8	1	0	
Tensiometer 5	DCV	10.0	.0001	105	PSIg	1	-.8	1	0	
Tensiometer 6	DCV	10.0	.0001	106	PSIg	1	-.8	1	0	
Tensiometer 7	DCV	10.0	.0001	107	PSIg	1	-.8	1	0	
Tensiometer 8	DCV	10.0	.0001	108	PSIg	1	-.8	1	0	
Tensiometer 9	DCV	10.0	.0001	109	PSIg	1	-.8	1	0	
YSI Temperature 1	OHM	1e5	.01	200	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 2	OHM	1e5	.01	201	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 3	OHM	1e5	.01	202	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 4	OHM	1e5	.01	203	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 5	OHM	1e5	.01	204	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 6	OHM	1e5	.01	205	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 7	OHM	1e5	.01	206	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 8	OHM	1e5	.01	207	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 9	OHM	1e5	.01	208	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 10	OHM	1e5	.01	209	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 11	OHM	1e5	.01	300	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 12	OHM	1e5	.01	301	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 13	OHM	1e5	.01	302	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 14	OHM	1e5	.01	303	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 15	OHM	1e5	.01	304	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 16	OHM	1e5	.01	305	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 17	OHM	1e5	.01	306	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 18	OHM	1e5	.01	307	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 19	OHM	1e5	.01	308	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
YSI Temperature 20	OHM	1e5	.01	309	°C	2	1.0295e-3	2.3908e-4	1.56817e-7	
X position	DCV	10.0	.01	400	Inches	10	1.2634	3.6738	0	
Y position	DCV	10.0	.01	401	Inches	11	8.7889	6.3700	0	
Channel label	DMM Func.	DMM Range	DMM Resol.	Relay Numbers	Eng. Units	EQ. Type	K1	K2	K3	

Equation types:

0 - None..... Y = X

1 - Linear..... Y = K1 * X + K2

2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3) - 273.15

10- Linear..... Y = (X - K1) * 10 / (K2 - K1) (X position - No more than one of these)

11- Linear..... Y = (X - K1) * 10 / (K2 - K1) (Y position - No more than one of these)

CONFIGURATION FILE FOR DAS FOR TEMP. CALIB
PROVIDES SCALING TO -°C

MERCURY IN GLASS THERMOMETER CALIB. SHEETS

END OF PERIODIC ENTRY #4 Steve Sudeman
3-6-90

Brooklyn Thermometer Company Inc.

FARMINGDALE, N.Y. 11735

Factory Certificate

Liquid In Glass Thermometer

Marked: 1311

Range: 18 to 89°F in 0.2° Division

Immersion: Total

Catalog Number: 3963F

Tested For: South West Research Institute

Temperature	Thermometer Reading	Correction
23°F	23.00	0.00
32°F	32.04	-0.04
50°F	50.00	0.00
68°F	68.00	0.00
86°F	86.00	0.00

REFERENCE: NATIONAL BUREAU OF STANDARDS TEST NO. 199114

This thermometer has been tested by comparison with standards certified by the National Bureau of Standards. For applicable accuracy tolerance and factors affecting its use refer to N.B.S. Monograph 150. If the correction is + the true temperature is higher than the thermometer reading; if the correction is – the true temperature is lower than the thermometer reading. All temperatures are based on the IPTS-68. If the ice point is included, a subsequent change in its reading will change all other readings by the same amount.

November 20, 1981

Brooklyn Thermometer Company Inc.

per R.E. Teichert

R.E. Teichert

Brooklyn Thermometer Company Inc.

FARMINGDALE, N.Y. 11735

Factory Certificate

Liquid In Glass Thermometer

Marked: 3787

Range: 122 to 176°F in 0.2° Division

Immersion: Total

Catalog Number: 3965F

Tested For: South West Research Institute

Temperature	Thermometer Reading	Correction
32°F	32.04	-0.04
122°F	122.04	-0.04
140°F	140.16	-0.16
158°F	158.00	0.00
176°F	175.94	+0.06

REFERENCE: NATIONAL BUREAU OF STANDARDS TEST NO. 188922

This thermometer has been tested by comparison with standards certified by the National Bureau of Standards. For applicable accuracy tolerance and factors affecting its use refer to N.B.S. Monograph 150. If the correction is + the true temperature is higher than the thermometer reading; if the correction is – the true temperature is lower than the thermometer reading. All temperatures are based on the IPTS-68. If the ice point is included, a subsequent change in its reading will change all other readings by the same amount.

November 20, 1981

Brooklyn Thermometer Company Inc.

per R.E. Teichert

R.E. Teichert

Brooklyn Thermometer Company Inc.

FARMINGDALE, N.Y. 11735

Factory Certificate

Liquid In Glass Thermometer

Marked: 799

Range: 167 to 221°F in 0.2° Division

Immersion: Total

Catalog Number: 3966F

Tested For: South West Research Institute

Temperature	Thermometer Reading	Correction
32°F	32.08	-0.08
168°F	167.88	+0.12
185°F	184.96	+0.04
203°F	202.90	+0.10
220°F	219.80	+0.20

REFERENCE: NATIONAL BUREAU OF STANDARDS TEST NO. 188288

This thermometer has been tested by comparison with standards certified by the National Bureau of Standards. For applicable accuracy tolerance and factors affecting its use refer to N.B.S. Monograph 150. If the correction is + the true temperature is higher than the thermometer reading; if the correction is – the true temperature is lower than the thermometer reading. All temperatures are based on the IPTS-68. If the ice point is included, a subsequent change in its reading will change all other readings by the same amount.

November 20, 1981

Brooklyn Thermometer Company Inc.

per R. E. Teichert

R.E. Teichert

PERIODIC ENTRY #(5) 3-6-90 SS

SEPARATE EFFECTS TEST #1

2-13-90

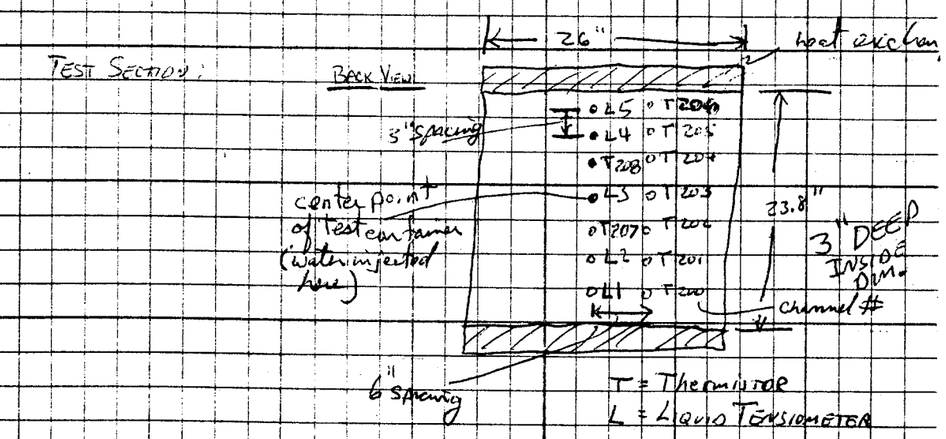
TEST DESCRIPTION - TEST 1 SEPARATE EFFECTS EXPMTS
160 μm Beads in 2'x2'x3" Test section. Pack dry beads into test section then inject water into center @ 40% saturation and monitor movement (no external heating) - then put in water for 60% sat

TEST SETUP:

PLACED "160 μm dia" beads in TEST SECTION
BEADS - CATAPHOTE INC
CLASS - 4-A
SIZE 812
BATCH - 91004

WEIGHT OF BEADS ADDED TO CONTAINER = 102 lb
WEIGHED WITH OHAUS SCALE CORP
3-BEAM BALANCE
SwRI #5485
Calib. Certified by Texas Scale
Date 8-9-89, Ser # 5485
(SCALE - DOM MASSEYS - 04)

TEST SECTION:



2-20-90 AS

12:14 PM TURNED ON DATA SYSTEM TO TAKE READINGS ON TEST SECTION WITH NO WATER – THIS WILL ESTABLISH THE "0 SATURATION" CONDITIONS READING OF THE DENSIOMETER AT EACH SAMPLE POINT. SEE TEST1 MOT FILE FOR SAMPLE LOCATIONS

2-21-90 AS

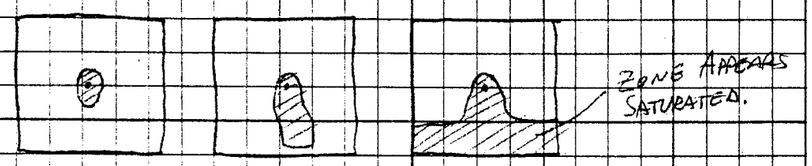
~8:00 AM TURNED OFF DAS TO INJECT WATER INTO THE TEST SECTION.

THE WATER WAS INJECTED INTO THE CENTER OF THE TEST SECTION (AT THE LOCATION OF TENSIOMETER 3. I initially tried to inject the water through the porous cup on the tensiometer but it was much to slow (~30ml per Hour under ~2' water head). I injected the water through the back of the tensiometer fitting.

WATER used was DI FROM NAC LAB ~13MΩ

BY 1:12 pm ~~[illegible]~~ 3875ml H_2O added

WATER FILLED AND FLOWED INTO Beds as follows



after a small amount of water was added it no longer spread spherically but appeared to have enough "head" to overcome capilary forces. After this point was reached the water dropped straight down to the bottom of the container and then started to spread along the bottom of the container

2-21-90 AS

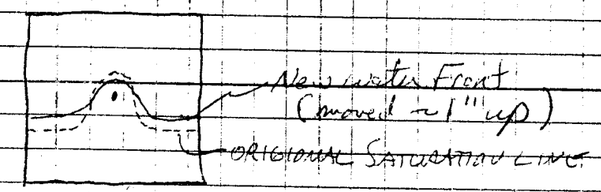
13:41 Restarted DAS

all tensiometers have just been filled with water

Photo 1 @ 2:36 pm (Y-Beam in middle of First Set.

2 @ 3:00 pm

4:22 PM

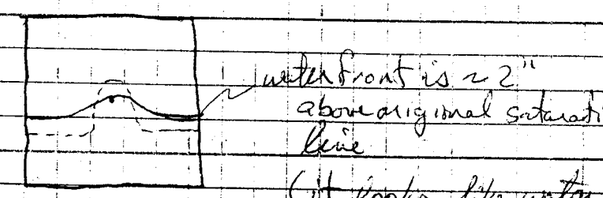


2-22-90 AS

8:45 AM STOPPED DAS – Restarted @ 8:55 am

Photo #3 8:49 am f=5.6

#4 " f=11



(it looks like water level is flattening out on the bottom of the container

11:55 Turned DAS off & on to look @ Data

Photo #5	11:56 am	f=5.6	1/4	entire test section	
6	"	"	1/8	"	"
7	"	"	1/4	Closer up	
8	"	"	1/8	"	"

2-22-90 (CON'T) [illegible]

2:28 pm DAS turned off & on to check data — O.K.

2-23-90 [illegible]

8:42 AM DAS off & on — DATA looks fine
- No visual changes to test section
- changed sample interval to 1 Hour from 30 min

2-27-90 [illegible]
~2:00 pm Checked on system — everything O.K
No Visual CHANGES

2-28-90 [illegible]

10:50 AM Turned DAS off & Back on after check data

Tensiometer # 4 and #5 appear to have dried out since they are no longer @ 5 psig suction (at full scale of sensor) — I flushed out and re-filled these tensiometers.

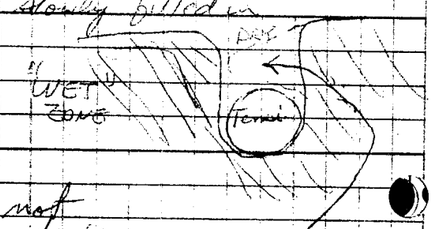
3-1-90 [illegible]

4:38 pm Turned off DAS to inject more water into the test container. (to obtain 100% Saturation point for tensiometer)

As the water level reached Tensiometer #4 it's reading went from −1.5 psig to 0 psig to positive pressure

7600 ml of H_2O Added

(Note — as water level passed the Tensiometers it left a "wake" which slowly filled in



The very top layer was not saturated — only ~ ½" at the top remained dry — This will not effect the tensiometer readings since the highest level read was at y = 3" below the top.

water later filled in from sides

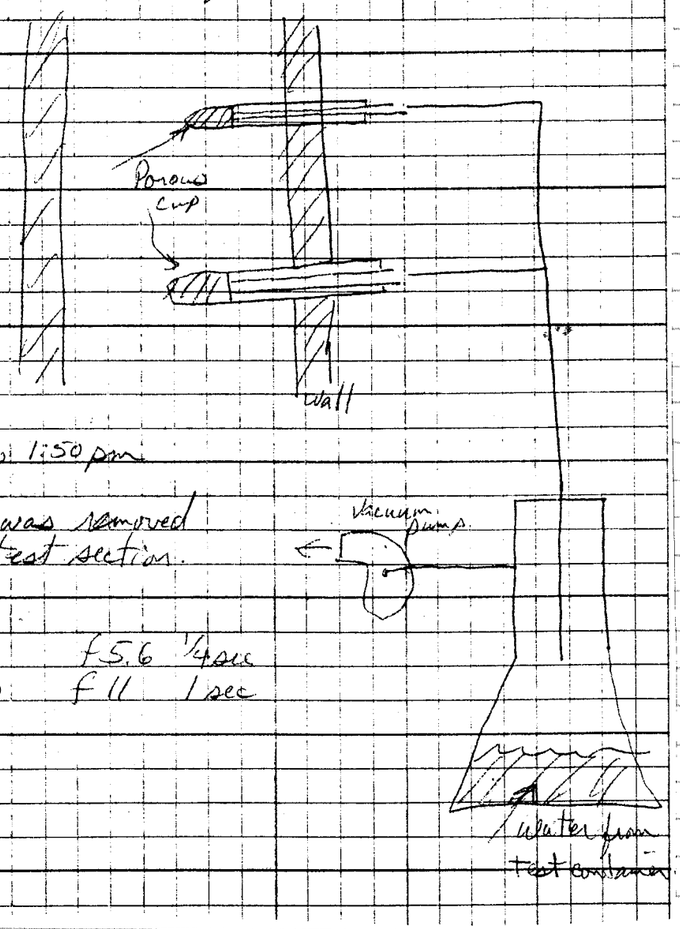
8:30 pm DAS Turned back on to obtain the 100% saturation reading at each of the tensiometer sampling locations.

3-2-90 SS

8:00AM Turned off DAS 3-2-90 SS

3-2-90 SS

For future tests, 3-2-90 SS we will need to desaturate the 3-2-90 SS media after it has been saturated. To see how this occurs water was pulled by vacuum out of Tensiometer ports #1 and 2.



FROM 8:00 AM TO 1:50 pm

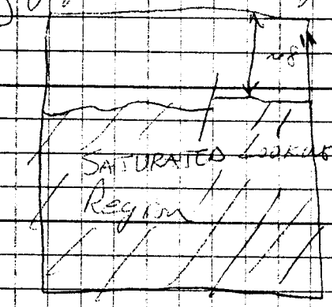
3065 ml was removed from the test section.

1:41 pm Photo #9 f5.6 1/4 sec
#10 f11 1 sec

3-2-90 (CON'T) SS

SS 3-2-90

As the water was removed from the test container a "saturation line" developed. The media appeared saturated below this line and relatively dry above the line. After the 3065 ml had been removed, the "saturation" line was ~ 1/3 of the way from the top of the container (to the bottom)



1:50 pm DAS Restarted to determine the level of saturation above and below the "saturation" line. Also to see if since the beads above the line were some what wet, if capilary action will now create a uniform water distribution.

(The tensiometers were refilled with water just before the DAS was restarted.)

3-3-90 SS

6:00 pm Turned off DAS

SHUT DOWN TEST #1

3-3-90 SS

SCALE FACTORS AND UNITS FOR PRESSURE, TEMPERATURE, AND DENSITY SENSORS.

TEST1.CFG

NPLC 1

Densitometer	DCV	10.0	.0001	402	RelSat	1	34.375	-68.75	0
Barometer	DCV	10.0	.0001	100	PSIa	1	2.4	-3	0
Tensiometer 1	DCV	10.0	.0001	101	PSIg	1	-.8	1	0
Tensiometer 2	DCV	10.0	.0001	102	PSIg	1	-.8	1	0
Tensiometer 3	DCV	10.0	.0001	103	PSIg	1	-.8	1	0
Tensiometer 4	DCV	10.0	.0001	104	PSIg	1	-.8	1	0
Tensiometer 5	DCV	10.0	.0001	105	PSIg	1	-.8	1	0
YSI Temperature 1	OHM	1e5	.01	200	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 2	OHM	1e5	.01	201	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 3	OHM	1e5	.01	202	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 4	OHM	1e5	.01	203	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 5	OHM	1e5	.01	204	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 6	OHM	1e5	.01	205	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 7	OHM	1e5	.01	206	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 8	OHM	1e5	.01	207	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 9	OHM	1e5	.01	208	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 10	OHM	1e5	.01	209	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
X position	DCV	10.0	.01	400	Inches	10	0.0582	2.4685	0
Y position	DCV	10.0	.01	401	Inches	11	6.2669	3.8480	0
Channel label	DMM Func.	DMM Range	DMM Resol.	Relay Numbers	Eng. Units	EQ. Type	K1	K2	K3

Equation types:
0 - None..... Y = X
1 - Linear..... Y = K1 * X + K2
2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3) - 273.15
10- Linear..... Y = (X - K1) * 10 / (K2 - K1) (X position - No more than one of these)
11- Linear..... Y = (X - K1) * 10 / (K2 - K1) (Y position - No more than one of these)

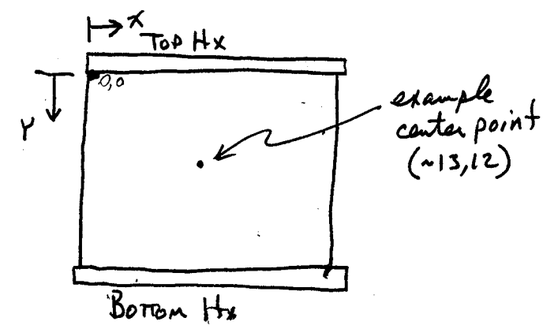
DENSITOMETER READING POSITIONS FOR TEST 1.

TEST1.MOT

DWELL TIME = 30 — AVERAGING TIME = 2 SEC
NPLC 120 — " "

5.000	-4.000	← DENSITOMETER PARK POSITION (X & Y COORDS.)
5.000	-4.000	← 1ST SAMPLE POINT (γ-BEAM CAL = 2.250" ALUM.)
11.000	-4.000	← 2nd " " (" " = 2.755" ")
5.000	3.000	
5.000	6.000	
5.000	9.000	
5.000	12.000	
5.000	15.000	
5.000	18.000	
5.000	21.000	
9.000	21.000	
9.000	18.000	
9.000	15.000	
9.000	12.000	
9.000	9.000	
9.000	6.000	
9.000	3.000	
11.000	3.000	
11.000	6.000	
11.000	9.000	
11.000	12.000	
11.000	15.000	
11.000	18.000	
11.000	21.000	
15.000	21.000	
15.000	18.000	
15.000	15.000	
15.000	12.000	
15.000	9.000	
15.000	6.000	
15.000	3.000	
17.000	3.000	
17.000	6.000	
17.000	9.000	
17.000	12.000	
17.000	15.000	
17.000	18.000	
17.000	21.000	

X & Y COORDS OF SAMPLE POINTS ON TEST CONTAINER



END OF PERIODIC ENTRY #(5) Steve Seedman 3-3-90

PERIODIC ENTRY # (6) 3-19-90 SS

SEPARATE EFFECTS TEST 2

TEST 2 WAS DOCUMENTED IN ANOTHER NOTEBOOK. COPIES OF THE PAGES FROM THE NOTEBOOK ARE ATTACHED ON THE NEXT PAGE. THE NOTES CONSIST OF 13 PAGES.

TITLE PROJECT NO. BOOK NO. 1

3-3-90 SS 1 OF 13

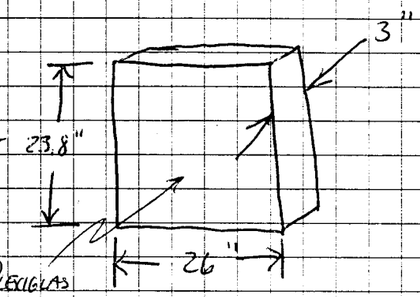
SEPERATE EFFECTS TEST # 2

DESCRIPTION

Observe water movement in 40 mm glass beads. WATER WILL BE injected in the center of a 2' x 2' x 3" Test container. The movement of the water will be recorded.

TEST SETUP:

TEST CONTAINER:
3/4" PLEXIGLASS WALLS ON FRONT AND BACK
TOP & SIDES ARE ALUMINUM PLATE



INSIDE DIMENSIONS

GLASS BEADS: CATAPHOTE INC
Class 4-A
SIZE 2740 ~ NOMINAL 40 mm
BATCH 91107

⇒ 107 # Added to container during bead packing, one end of the ~~the beads~~ in the container was lifted ~1" and dropped to pack the beads – this was done repeatedly during the addition of beads to the container. Plates on the end were then screwed on to ~~hold the beads~~ in place.

SS 3-3-90

SIGNATURE SS 3-3-90 DATE

DISCLOSED TO AND UNDERSTOOD BY | DATE | WITNESS | DATE

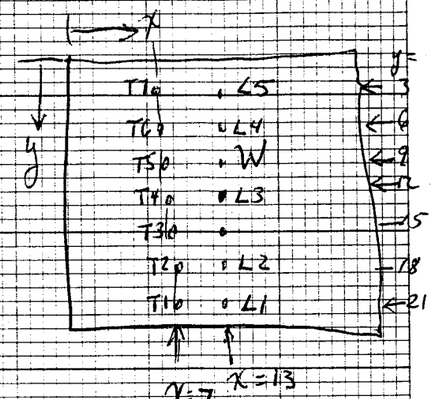
CENTURY INDEX GOODLESS CHICAGO 60606

3-3-90 [illegible]

2 of 13

INSTRUMENTATION

VIEW FROM FRONT



T = Thermistor location

L = Liquid Tensimeter location

W = WATER INJECTION PORT @ (13,9)

Temperature Sensors, Pressure sensors and the γ-Beam densitometer are all the same as used in Sep. Effects Experiment "TEST 1"

3 of 13

3-3-90 [illegible]

10.00 pm STARTED DATA ACQUISITION SYSTEM TO MAP OUT DRY BEADS

Tensimeters were dry too

3-4-90 [illegible]

2:40 PM Shut off DAS TO INJECT WATER INTO TEST CONTAINER

WATER INJECTED INTO 1/8" DIA hole @ (13",9") location

Water injection very slowly ~~with~~ [illegible] 3-4-90 under pressure of ~ 3 ft of H_2O

4:00 PHOTO #11 f.5.6 ~250 ml water injected at this time (still spreading in a ~~[illegible]~~ [illegible] 3-4-90 circular pattern)

#12 f 11

Water injection rate 4:15 pm to 7:40 pm 570 ml injected

7:45 pm Photo #13 f 5.6 1/8 sec w/ ~ 880 ml H_2O injected

#14 f 11 1/5 sec

[illegible] 3-4-90

~~9:15 pm Photo #15~~

~~#16~~

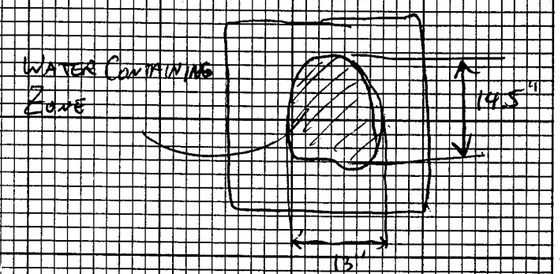
SIGNATURE | DATE

DISCLOSED TO AND UNDERSTOOD BY | DATE | WITNESS | DATE

3-4-90 (Con't) AS

TOTAL WATER INJECTED = 1100 ml 4 of 13
(WATER IS 14MΩ DI WATER)

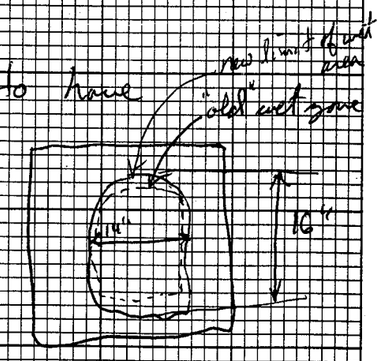
9:15 pm DAS started back up
Tensiometers were filled with water before it was started (just before)



21:42
Photo # 15 f 5.6 Took after 1st
16 f 11 Transverse w/ Densitometer.

3-5-90 AS

8:20 AM The "wet" area appears to have grown in size

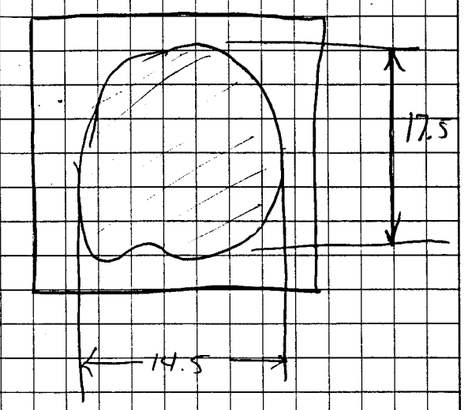


DATA ACQ. SYSTEM
STOP AND STARTED
(TO VIEW DATA)

4:50 pm DAS OFF & BACK ON — Looks O.K.
Photo 17 — f 5.6
18 — f 11

3-6-90 AS 5 of 13

9:09 AM WATER "LINE" APPEARS TO HAVE DROPPED SLIGHTLY TOWARDS BOTTOM OF CONTAINER — IT IS VERY DIFFICULT TO SEE THE WATER OUTLINE



9:15 Photo # 19 f5.6
20 f11

9:30 Restarted DATA ACQ. SYSTEM
(Changed Data interval to 1 HR from 30 min)

3-7-90 AS

9:40 AM STOPPED & STARTED DAS — EVERYTHING LOOKS OK.
TEST CONTAINER LOOKS THE SAME AS YESTERDAY

3-8-90 AS

9:10 AM TURNED DAS OFF TEST CONTAINER WATER DISTRIBUTION LOOKS THE SAME AS YESTERDAY

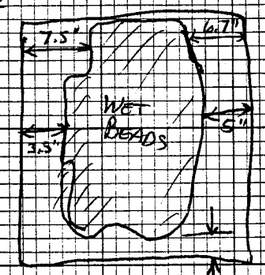
9:45 AM STARTED INJECTING MORE WATER INTO TEST CONTAINER — DI WATER - 14MΩ, INJECTED IN PORT AT (13,12)

Total water injected today is 3300 ml
injected on 3-4-90 1100 ml
TOTAL AMT OF WATER IN CONTAINER = 4400 ml.

SIGNATURE			DATE
DISCLOSED TO AND UNDERSTOOD BY	DATE	WITNESS	DATE

3-8-90 Con'T 6 OF 13

The water flowed into the test container much faster this time – it appeared to have completely saturated the wet looking zone that was previously visible. The water seemed to flow up and down more than side to side



WITH 1500 ml injected into the beads, the old "wet zone" appeared to be saturated (the water spread to fill the old wet zone and it become darker). Then the water started to spread into the dry zones.

3-8-90

Photo	21	f5.6 @ 1/4	10:49	STILL FILLING WITH WATER
	22	f5.6 1sec		Close up of saturation/
	23	" "		dry interface Photo 22 &
	24	" "		23 are from same position
				only ~20 sec apart
				24 is same as 23 (auto-fire got me)
	25	f5.6 1/4		entire test section just before stopped water injection

3-8-90

10:58 Restarted DAS (just after pulled the line from the water injection port)

3-8-90 Con'T 7 OF 13

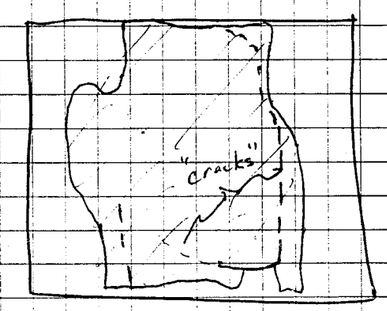
4:25pm DAS ON & OFF TO BACKUP DATA ON FLOPPY

Changed sample rate to 1 HR INTERVAL

The weight of the added water has caused the glass beads to shift in the test container.

Visiable crack lines are now present that were not ~~were~~ there just after water injection.

The water ~~stopped~~ spreading where the cracks (slip lines may be a better description) are located



3-9-90

3:00PM WATER IS CONTINUING TO spread from yesterday primarily toward the LHS of the test container and towards the bottom. There is very little water movement towards the Right Side over "Crack"

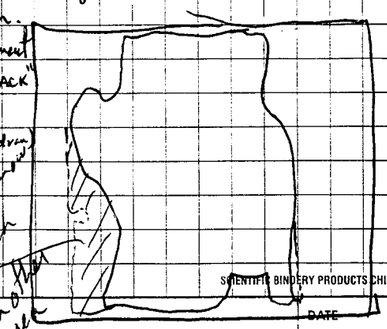
3:10pm

Photo #26 f5.6 1/4

27 Repeat of 26 ~~Goto~~ auto Advance

28 f11 1sec

looks wet but much lighter than other areas



I moved tower 1 press. gage slightly @ 3:10pm

SIGNATURE DATE

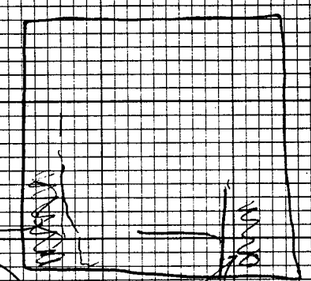
DISCLOSED TO AND UNDERSTOOD BY DATE WITNESS DATE

8 OF 13

3-13-90 SS

3:30 PM TURNED OFF DAS TO INJECT WATER INTO TEST CONTAINER (TO OBTAIN "SATURATED" READINGS)

THE WATER IN THE CONTAINER APPEARS TO HAVE SLIGHTLY REDISTRIBUTED ITSELF OVER THE LAST 4 DAYS



This zone now appears to contain a very small amount of moisture that was not visible earlier.

5:10 PM
STOPPED INJECTING WATER INTO MEDIA

3-14-90 SS

5:02 PM FINISHED INJECTING WATER INTO MEDIA AND TURNED DAS BACK ON TO READ 100% SATURATION AT EACH POINT.

AMOUNT OF WATER ADD ON 3-13-90 AND 3-14-90 IS 5870 ml

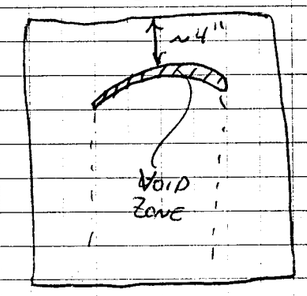
THE WATER APPEARS TO HAVE COMPLETELY SATURATED MOST OF THE MEDIA. ONLY A SMALL VOLUME ABOVE THE ~~VENT~~ AIR VENT PLUG IS NOT SATURATED. (area less than 1" x 1" in size) SS 3-14-90

9 OF 13

3-14-90 CON'T SS

After the beads were almost completely saturated they again shifted slightly. It looks like the pressure of the water has bowed out the sides (plexiglass) walls enough to let the beads settle slightly. The pressure at the tensiometer located 3" from the top of the test container was reading positive pressure of ~ 0.3 psi (because water injected w/ ~ 2 feet of head pressure) and at the bottom was ~ .6 psi higher. SS 3-14-90

It is tough to see - but it looks like a zone in the middle opened up when beads shifted. (That is - the walls bowed outward allowing the beads to move.)



3-15-90 SS

SS 3-15-90

10:15 AM TURNED OFF DAS ~~TO~~

10:30 AM STARTED TO TRY TO DE-SATURATE MEDIA
PUT 3.0 psig VACUUM ON TENSIOMETER #1 & 2

3:50 pm 220 ml OF WATER HAVE BEEN DRAINED OUT OF MEDIA - ~~PUMP~~ VACUUM PUMP STILL ON.

5:36 pm ANOTHER 55 ml OF WATER WAS REMOVED FROM THE BEADS WITH THE 3 psig VACUUM ON TENSIOMETERS #4 & 2.
THE TENSIOMETER WERE REFILLED WITH WATER AND THE DAS RESTARTED TO SEE IF THE DENSITOMETER COULD DETERMINE A SATURATION DIFFERENCE. NOTE - DESATURATION WAS NOT COMPLETE WHEN VACUUM PUMP WAS REMOVED.

3-16-90 [illegible]

10 OF 13

8:00 AM DAS OFF AT ~ 6:30 AM
(ERROR — TRAVERSING SYSTEM DIDN'T GET TO DESIRED LOCATION WITHIN 2 TRIES)

THE DENSITOMETER READINGS SHOW A SMALL DECREASE IN THE SATURATION LEVEL FROM THE 3-16-90 "REAL SATURATION" LEVELS (Because 275 ml of H_2O were removed from media). It looks like the media can be uniformly desaturated by controlling the level of the vacuum applied to pull water out

3-19-90 [illegible]

The test container was emptied of the glass beads.

NOTES: The beads were "welded" together in the regions that were outside of the region that was initially wet with the first injection of water (see 3-4-90 notes for sketch of region). The beads were hard enough 3-19-90 that they had to be "chipped" out of the test container.

3-19-90 (CON'T) [illegible]

11 OF 13

A ball (it looks like it might be used in the bead manufacturing) was found in the test container at LOCATION ~ X = 10", Y = 4", THE BALL IS Rubber and is ~ 1.5" in Diameter

SIGNATURE			DATE
DISCLOSED TO AND UNDERSTOOD BY	DATE	WITNESS	DATE

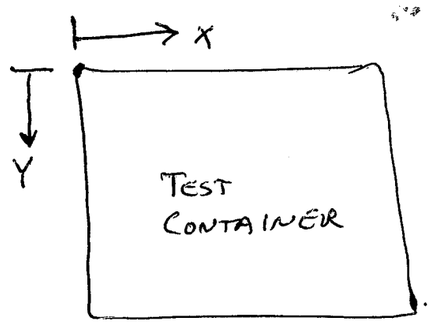
TEST 2 MOTION FILE TEST2.MOT

3-19-90 AJ

DWELL TIME = 30
NPLC 240

X-COORD	Y-COORD	
5.000	-4.000	← PARK POSITION
5.000	-4.000	← READ 2.250" THICK ALUMINUM
11.000	-4.000	" 2.755" " "
5.000	3.000	
5.000	6.000	
5.000	9.000	
5.000	12.000	
5.000	15.000	
5.000	18.000	
5.000	21.000	
9.000	21.000	
9.000	18.000	
9.000	15.000	
9.000	12.000	
9.000	9.000	
9.000	6.000	
9.000	3.000	
11.000	3.000	
11.000	6.000	
11.000	9.000	
11.000	12.000	
11.000	15.000	
11.000	18.000	
11.000	21.000	
15.000	21.000	
15.000	18.000	
15.000	15.000	
15.000	12.000	
15.000	9.000	
15.000	6.000	
15.000	3.000	
17.000	3.000	
17.000	6.000	
17.000	9.000	
17.000	12.000	
17.000	15.000	
17.000	18.000	
17.000	21.000	

DENSITOMETER SCAN POSITIONS



3-19-90 AJ

TEST 2 CONFIGURATION FILE

TEST2.CFG

```
NPLC 1
Densitometer                DCV   10.0      .0001   402   RelSat      1  34.375      -68.75     0
Barometer                   DCV   10.0      .0001   100   PSIa        1   2.4                   0
Tensiometer 1               DCV   10.0      .0001   101   PSIg        1  -.8                    0
Tensiometer 2               DCV   10.0      .0001   102   PSIg        1  -.8                    0
Tensiometer 3               DCV   10.0      .0001   103   PSIg        1  -.8                    0
Tensiometer 4               DCV   10.0      .0001   104   PSIg        1  -.8                    0
Tensiometer 5               DCV   10.0      .0001   105   PSIg        1  -.8                    0
YSI Temperature 1           OHM   1e5       .01     200   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 2           OHM   1e5       .01     201   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 3           OHM   1e5       .01     202   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 4           OHM   1e5       .01     203   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 5           OHM   1e5       .01     204   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 6           OHM   1e5       .01     205   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 7           OHM   1e5       .01     206   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
YSI Temperature 10          OHM   1e5       .01     209   °C          2  1.0295e-3   2.3908e-4  1.56817e-7
X position                  DCV   10.0      .01     400   Inches     10  0.0582      2.4685     0
Y position                  DCV   10.0      .01     401   Inches     11  6.2669      3.8480     0
*****************************************************************************************************
Channel label       DMM   DMM     DMM     Relay   Eng.    EQ.
                    Func. Range   Resol.  Numbers Units   Type    K1          K2          K3

Equation types:
0 - None........ Y = X
1 - Linear...... Y = K1 * X + K2
2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3 ) - 273.15
10- Linear...... Y = (X - K1) * 10 / (K2 - K1)   (X position - No more than one of these)
11- Linear...... Y = (X - K1) * 10 / (K2 - K1)   (Y position - No more than one of these)
```

END OF PERIODIC ENTRY #6 Steve Sredenn
3-19-90

PERIODIC ENTRY #7 3-27-90

SEPARATE EFFECTS EXPERIMENT TEST 3

DESCRIPTION

THE TEST IS TO OBSERVE WATER MOVEMENT IN A 50%-50% MIXTURE OF 40μm and 80μm glass beads. THE Beads are in the same test container as described in TEST 2.

TEST SETUP

GLASS BEADS:

"40μm" Beads ARE - CATAPHOTE INC
CLASS 4-A
SIZE 2740
BATCH 91107
"80μm" BEADS ARE - CATAPHOTE INC
CLASS 4-A
SIZE 1420
BATCH 91105

THE BEADS WERE MIXED BY STIRRING (BY HAND) EQUAL VOLUMES OF BEADS IN A BEAKER (800 ml WERE MIXED AT A TIME)

A TOTAL OF 105# WERE PUT INTO THE CONTAINER

AN AIR HAMMER WAS USED AGAINST THE OUTSIDE OF THE CONTAINER TO VIBRATE THE BEADS AND TRY TO PROVIDE A GOOD DENSE PACKING.

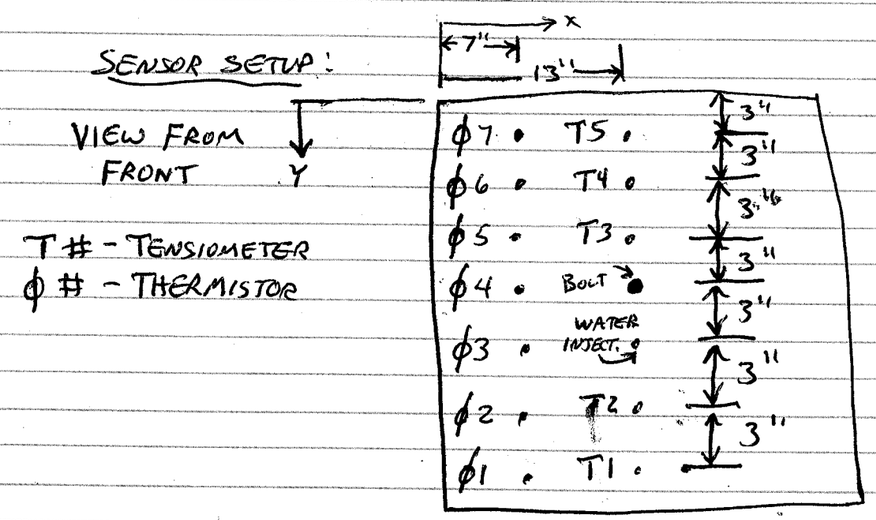
3-29-90 D

MODIFICATIONS TO THE TEST CONTAINER SINCE "TEST 2".

A BOLT WAS INSTALLED THRU THE CENTER OF THE 24"x26" PLEXIGLASS SHEETS TO KEEP THEM FROM BOWING OUT UNDER WATER PRESSURE.

3/4" THICK STYRAFOAM SHEET WAS ADDED TO COVER THE PLEXIGLASS.

SENSOR SETUP:



3-29-90 (CON'T) D

"MOTION" FILE TEST3.MOT

```
DWELL TIME =    30
NPLC 240
   5.000  -4.000
   5.000  -4.000
  11.000  -4.000
   9.000   3.000
   9.000   6.000
   9.000   9.000
   9.000  12.000
   9.000  15.000
   9.000  18.000
   9.000  21.000
  11.000  21.000
  11.000  18.000
  11.000  15.000
  11.000  12.000
  11.000   9.000
  11.000   6.000
  11.000   3.000
  15.000   3.000
  15.000   6.000
  15.000   9.000
  15.000  12.000
  15.000  15.000
  15.000  18.000
  15.000  21.000
  17.000  21.000
  17.000  18.000
  17.000  15.000
  17.000  12.000
  17.000   9.000
  17.000   6.000
  17.000   3.000
```

"CONFIGURATION" FILE TEST3.CFG

NPLC 1

Channel label	DMM Func.	DMM Range	DMM Resol.	Relay Numbers	Eng. Units	EQ. Type	K1	K2	K3
Densitometer	DCV	10.0	.0001	402	RelSat	1	50.000	-100.00	0
Barometer	DCV	10.0	.0001	100	PSIa	1	2.4	-3	0
Tensiometer 1	DCV	10.0	.0001	101	PSIg	1	-.8	1	0
Tensiometer 2	DCV	10.0	.0001	102	PSIg	1	-.8	1	0
Tensiometer 3	DCV	10.0	.0001	103	PSIg	1	-.8	1	0
Tensiometer 4	DCV	10.0	.0001	104	PSIg	1	-.8	1	0
Tensiometer 5	DCV	10.0	.0001	105	PSIg	1	-.8	1	0
YSI Temperature 1	OHM	1e5	.01	200	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 2	OHM	1e5	.01	201	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 3	OHM	1e5	.01	202	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 4	OHM	1e5	.01	203	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 5	OHM	1e5	.01	204	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 6	OHM	1e5	.01	205	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 7	OHM	1e5	.01	206	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 10	OHM	1e5	.01	209	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
X position	DCV	10.0	.01	400	Inches	10	0.0582	2.4685	0
Y position	DCV	10.0	.01	401	Inches	11	6.2669	3.8480	0

Equation types:

0 - None..... Y = X

1 - Linear..... Y = K1 * X + K2

2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3) - 273.15

10- Linear..... Y = (X - K1) * 10 / (K2 - K1) (X position - No more than one of these)

11- Linear..... Y = (X - K1) * 10 / (K2 - K1) (Y position - No more than one of these)

3-29-90 (CON'T)

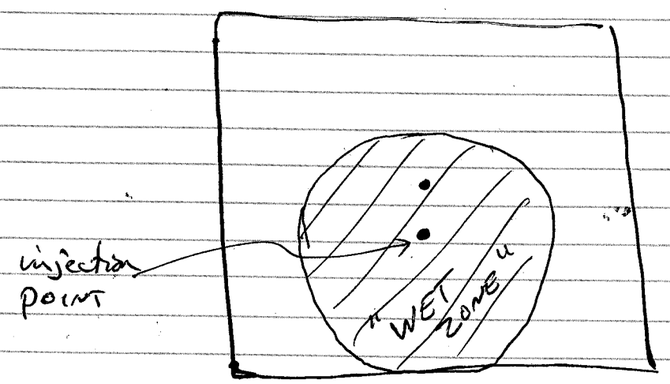
3-29-90 (CON'T) SS

4:50 PM FINISHED PUTTING 2000 ml of water into media

Photo 2 f5.6
3 f8

FILLED TENSIOMETERS WITH WATER

4:55pm Restarted DAS TO SCANN MEDIA AND SEE IF WATER MIGRATES.

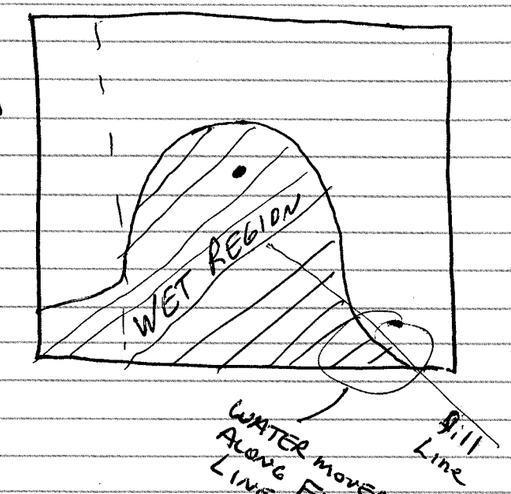


3-30-90 SS

9:00 AM DAS OFF TO LOOK AT MEDIA

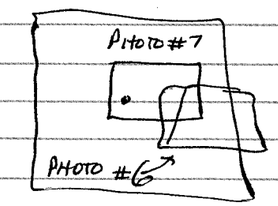
THERE HAS BEEN SOME WATER MOVEMENT

THE WET REGION IS NOT AS CLEARLY DEFINED NOW AS IT WAS RIGHT AFTER WATER INJECTION. PROBABLY BECAUSE THE WATER AT THE GLASS-BEAD INTERFACE HAS BEEN PULLED INTO THE MEDIA



9:05 AM PHOTO # 4 f5.6 1/8 entire container
5 8 1/4 " "
6 8 close up to show
7 8 fill lines.

9:15 AM CHANGED SAMPLE INTERVAL TO 1 HR
RESTARTED DAS



3-31-90 [illegible]

8:00 AM TURNED DAS OFF

BEGAN INJECTING WATER INTO MEDIA (THRU THE TUBE LOCATED AT X=13, Y=15) SO THAT THE 100% SATURATION READINGS ON THE DENSITOMETER CAN BE MADE

11:44 PM STOPPED WATER INJECTION AFTER ~ 4000 ml HAD BEEN INJECTED. MEDIA IS NOT SATURATED. INJECTION RATE HAS SLOWED FROM 15 MIN. PER 500 ml AT START TO ABOUT 45 MIN PER 500 ml NOW.

4-1-90 [illegible] TIME CHANGED TO DAYLIGHT SAVINGS TIME BUT DAS TIME WAS NOT CHANGED SO THE TEST DURATION CALCULATION WILL NOT BE OFF BY 1 HOUR.

4:09 PM RESTARTED WATER INJECTION

5:39 PM STOPPED WATER INJECTION AGAIN AFTER ~2000 ml injected. MEDIA STILL NOT SATURATED

4-2-90 [illegible]

8:00 AM WATER INJECTION RESTARTED

3:00 PM WATER INJECTION STOPPED AFTER 7610 ml (TOTAL) INJECTED SINCE 3-31-90. TOTAL AMOUT OF WATER IN MEDIA = 9610 ml. MEDIA IS NOW SATURATED.

4-2-90 (CON'T) [illegible]

3:01 PM DAS RESTARTED TO READ 100% SATURATION WITH DENSITOMETER.

~5:00 PM DAS OFF, I WENT ON TRAVEL

4-4-90 [illegible]

3:10 PM Restarted DAS to take a few more readings @ 100% SATURATION

4-5-90 [illegible]

8:30 AM DAS OFF

STARTED DESATURATING MEDIA BY APPLYING A 2 PSIG VACUUM TO THE CERAMIC CYLINDER.

5:00 PM 140 ml of water collected so far.

4-6-90 [illegible]

8:00 AM CONTINUED TO PULL WATER OUT OF BEADS overnight. - Collected 50 ml more.

INCREASED VACUUM TO 3 PSIG

2:00 PM 25 ml of water out of beads. Switched vacuum to TENSIOMETER #1 PORT. CONTINUED TO APPLY 3 PSIG.

4-6-90 (CON'T) [illegible]

8:35 pm 355 ml of water out of media since 2:00 pm (over ~7 Hours)

4-7-90 [illegible]

3:15 PM 3 PSIG VACUUM STILL ON TENSI #1
324 ml of water collected (10~18 Hrs)

SET Vacuum to 3.3 PSI

4-9-90 [illegible]

8:10AM 3.3 PSIG vacuum still on Tensiometer #1.
127 ml of water collected (over ~41 Hours)

Vacuum turned off & Tensiometer #1 Reconnected

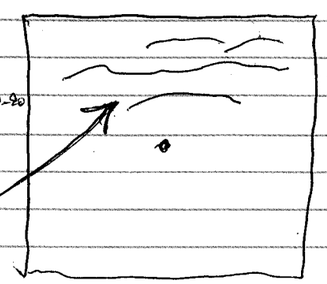
Total water removed from media
140+50+25+355+324+127 = 1021 ml

% OF TOTAL WATER IN MEDIA:

$$\frac{1021}{9610} = 10.6\%$$

8:25AM Restarted DAS to use Densitometer to determine water distribution in media.

Some bead movement has occurred. Visible cracks have formed [illegible] 4-9-90



4-9-90 (CON'T) [illegible]

3:00 PM DAS TURNED OFF

DENSITOMETER READINGS SHOW THE MEDIA IS "DRYER" AT THE TOP THAN AT THE BOTTOM. TOP IS ~60% SATURATED AND BOTTOM IS ~100% SATURATED.

3:10 PM RESTARTED VACUUM ON TENSIOMETER #1 TO SEE IF MORE WATER CAN BE PULLED OUT. VACUUM 8-9 PSIG

4-10-90 [illegible]

8:00AM TURNED OFF VACUUM ON TENSIOMETER #1

ONLY 45 ML WATER PULLED FROM MEDIA. (OVER ~17 HOURS @ 8PSIG VACUUM)
TENSIOMETER #1 REINSTALLED

8:15AM DAS RESTARTED TO DETERMINE WATER DISTRIBUTION IN MEDIA.

END OF TEST 3

4:08PM DAS OFF

START OF TEST 4

4:12PM TURNED ON HEATER BATH - PUT SETPOINT ON 60°C. BATH IS CONNECTED TO TOP HEATER PLATE.

HEATED BOUNDARY TEST. OBSERVE WATER MOVEMENT DUE TO HEATING [illegible]

CHANGED DAS SAMPLE TIME TO 1 HOUR

RESTARTED DAS - WANT TO SEE IF WATER MIGRATES DUE TO SURFACE TENSION CHANGES.

4-10-90 CON'T SS

4:28PM BATH TEMP SLOWLY RAMPING UP FROM ~25°C (NOW AT 38°C)

5:03PM HOOKED UP COOLING WATER (TAP WATER) TO LOWER HEAT EXCHANGER PLATE FOR COOLING.

4-11-90 SS

11:50 TOP PORTION OF MEDIA IS HEATING UP SLOWLY. DAS RUNNING FINE

4-12-90 SS

8:15AM DAS WAS "STUCK", TRAVERSING SYSTEM DID NOT MAKE IT TO THE DESIRED POSITION IN 2 TRIES (STEPPER MOTORS MAY HAVE "SLIPPED")
FAILURE OCCURRED 4-12-90 @ ~ 4:00AM

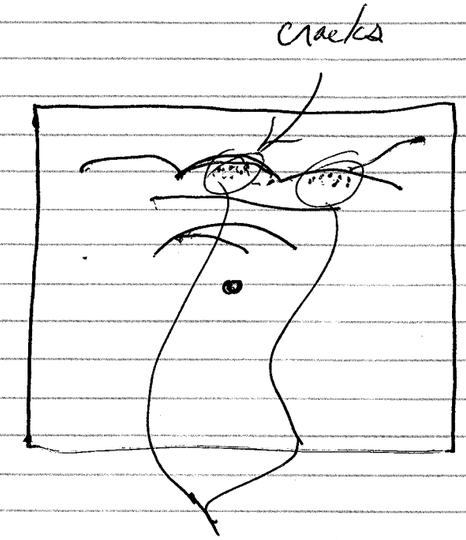
RESTARTED DAS

4:30PM DAS WAS "STUCK" AGAIN - I CHANGED COUNTER WEIGHTS ON TRAVERSING SYSTEM AND RESTARTED DAS @ 4:50

4-12-90 (CON'T) SS

4:40PM

No visiable changes in saturation have occured. The cracks appear to be more easily seen and some small condensation drops have appeared on the plexiglass.



60°C ON TOP HX Plate (still) and tap water flowing thru lower HX plate to cool.

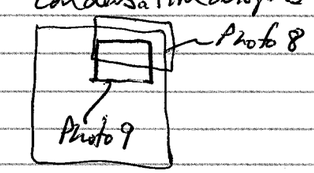


Photo #8 f8 1/2 sec
Photo #9 f8 1/2 sec.

Show "cracks" and "condensation."

4-13-90 SS

4:30PM DAS OFF.
STOP TEST WITH HEATED TOP PLATE
(TOP PLATE IS STILL @ 60°C, BOTTOM COOLED
Start SS 4-13-90 WITH "TAP" WATER)

4-13-90 (CON'T) SS

4:35 PM CHANGE TO HEAT ON BOTTOM HEAT EXCHANGER PLATE AND COOL TOP PLATE WITH TAP WATER

HEAT BATH SET @ 60°C
TAP WATER ~ 25°C

~4:45 PM RESTARTED DAS

VERY LITTLE DOWNWARD MOVEMENT OF WATER WAS RECORDED ON DENSITOMETER READINGS FOR TOP HEATED CASE.

THIS TEST WILL SEE IF FLUID WILL BE PULLED UP BY CAPILLARY ACTION TO COOLER TOP SURFACE (WITH HEAT ON BOTTOM)

4-16-90 SS

8:00 AM DAS STILL RUNNING - LOOKS LIKE IT RAN FINE OVER THE WEEKEND. HOT BATH TEMP = 60°C ON BOTTOM HX PLATE AND TAP WATER FLOWING THRU TOP HX PLATE

SET SAMPLE INTERVAL ON DAS TO 2 HOURS SO AMOUT OF DATA WOULD BE REDUCED (CHANGES ARE VERY SLOW)

The data from the densitometer readings show water is migrating towards the top (cool) HX plate

4-16-90 (CON'T) SS

4:30 PM SET HOT HX TEMP (ON BATH SET POINT) TO 80°C. THIS IS TO INCREASE THE TEMPERATURE CLOSER TO BOILING AND SEE IF MORE WATER MIGRATES TOWARDS THE COOLER TOP HX PLATE (STILL COOLED WITH TAP WATER)

4-17-90 SS

8:15AM HOT HX BATH @ 80°C (ON BOTTOM OF CONTAINER)
COLD BATH STILL HAS TAP WATER FOR COOLING

4-18-90 SS HOT HX BATH STILL @ 80°C
8:15AM COLD ~~BATH~~ SS 4-18-90 HX ON TOP STILL COOLED WITH TAP WATER

SET SAMPLE INTERVAL TO 1.5 HOURS

8:30AM INCREASED HOT BATH SET POINT TO 95°C
4:09PM INSULATION ON FRONT (BOTTOM) HAD FALLEN OFF - I put it back ON
SET HOT BATH HEAT EXCHANGER TO 95°C

4-19-90 SS

9:50 AM INJECTED 20ml OF WATER WITH RED DYE @ X=13 Y=15 (SAME PLACE WATER WAS INJECTED)
DYE DID NOT BECOME VISIBLE ON FRONT OF TEST SECTION (INSULATION WAS OFF FOR ~20 MIN)

NO CHANGES IN HOW THE BEADS LOOK EXCEPT FOR A VERY SMALL LAYER RIGHT AT THE BOTTOM THAT LOOKS LIKE IT HAS DRIED OUT

TURNED BATH TEMP ON HOT HX PLATE (BOTTOM) TO ~~100°C~~ SS 4-19-90 105°C

4-19-90 JS (CON'T)

12:45pm RED DYE IS ~~BAR~~ JS 4-19-90 VISABLE NOW
LOCATION IS 9 1/8" ABOVE BOTTOM HX PLATE
AND ON ℄ IN Y DIRECTION
DIAMETER OF DYE IS ~0.8"

PHOTO #10 f5.6 VIEW OF DYE REGION
(INSULATION ON & OFF FOR
PHOTO)

4:50 PM HOT BATH TEMP @ 105°C
TEST CONTAINER (MEDIA) STILL LOOKS ABOUT
THE SAME

PHOTO #11 f5.6. VIEW OF DYE

DYE LOCATION 9 1/8" FROM BOTTOM of JS 4-19-90 HX Plate
" DIAMETER ~ 1.0"

4-20-90 JS

9:20 AM INSULATION WAS OFF THE LOWER FRONT
OF THE TEST SECTION.

PHOTO #12 f5.6 DYE HAS SPREAD SLIGHTLY

DYE IS 9 1/8" IN. FROM TOP OF HX PLATE (BOTTOM HX PLATE)
~1.5" OD DYE CIRCLE

4-25-90 JS

8:20AM BOTTOM HX PLATE STILL @ 105°C
TOP HX " COOLED WITH TAP WATER

8:35AM TURNED HOT BATH SET POINT TO JS 3-25-90 0°C
TO ALLOW A SLOW COOL DOWN OF
LOWER HX PLATE (THE BATH IS STILL
CIRCULATING FLUID BUT NO HEATING

1:40Pm
PHOTO #13 f5.6 Photo of Test Container w/ Red DYE
14 " " " " "

RED DYE - CENTERED ~9 1/2" ABOVE THE TOP OF BOTTOM HX PLATE
DIA ~ 2.75" (THE "EDGES" ARE VERY LIGHT
AND HARD TO DEFINE

BATH TEMP = 56.3°C (COOLED OFF FROM
~8:35 AM)

5:15pm
HOT BATH TEMP AT 45.6°C

4-26-90 SS

9:39AM HOT HX BATH TEMP DOWN TO 34.4°C

3:20PM HOT BATH TEMP DOWN TO 33.6°C

PHOTO #15 f 5.6

Red DYE - Center @ 9½" above bottom HX
DIA = 2.75"

There is still a zone of "condensation drops" visable about 2" above bottom HX plate in the center of the test section. These were there during heating and have still not gone away. It may be a small gap between the beads and the wall (which means the beads have moved or the walls moved during heating or filling w/ water. I believe the plexiglass moved outward after heating started because a small lip on the HX plate can no longer support the measuring scale.)

4-27-90 SS

8:05AM HOT BATH TEMP = 32.5°C

4-30-90 SS

8:07AM HOT BATH TEMP 33.2°C
DAS STILL RUNNING (LEFT OVER WEEKEND)

3:10 PM TURNED CIRCULATING BATH OFF AND PLUMBED COOLING WATER LINE FROM TOP HEAT EXCHANGER PLATE THROUGH LOWER HEAT EXCHANGER PLATE (I.E. TAP WATER NOW CIRCULATES THROUGH BOTH HX PLATES)

5-3-90 SS

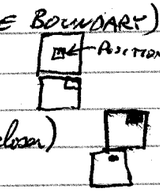
8:00AM TENSIOMETER # 5 READING IS FALLING FROM PREVIOUS VALUE. I REFILLED IT WITH WATER TO SEE IF IT WAS DRYING OUT.

5-4-90 SS

8:01AM TRAVERSING SYSTEM STUCK OVERNIGHT SO NO DATA TAKEN FROM 14:40 on 5-3-90
(I also noticed I left the shutter on the densitometer closed late yesterday so the last few densitometer reading were overrange)
PHOTO # 16 f 5.6 entire test section

DYE POSITION = 9¾" ABOVE BOTTOM HX PLATE
DIA ~ 3½" (HARD TO CLEARLY SEE BOUNDARY)

Photo #17 f 5.6 close up of "cracks" in center w/ some dye
" 18 " " " " " in upper RH corner
19 " " " " " " " " (even closer)
20 " " " even closer than #19



5-4-90 CON'T SS

8:30AM SHUT DOWN TEST 4

NOTE: COMPUTER TIME IS STILL 1 HOUR BEHIND THE TIMES RECORDED IN THIS LOG BOOK SINCE TIME CHANGE FOR DAYLIGHT SAVINGS TIME (SEE NOTES 4-1-90).

END OF PERIODIC ENTRY #7 Steve Snedeker 5-4-90

5-9-90 SS PERIODIC ENTRY #8

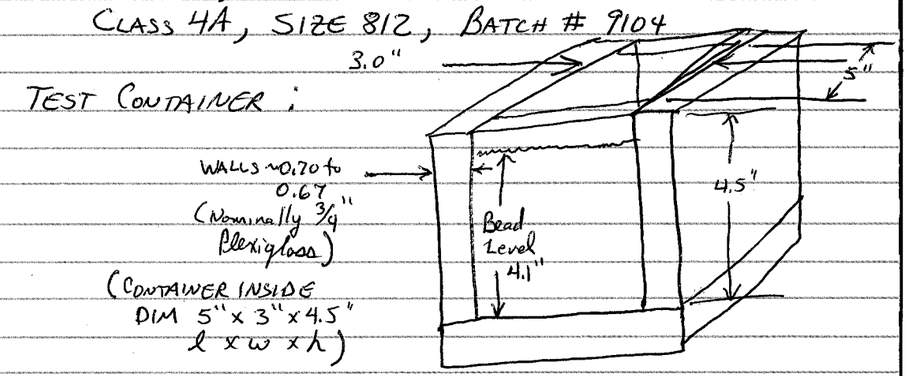
CHECK ON DENSITOMETER RESPONSE TO PARTIALLY SATURATED GLASS BEADS

OBJECTIVE: To obtain the γ-BEAM DENSITOMETER RESPONSE TO A KNOWN MIXTURE (SATURATION LEVEL) OF WATER AND GLASS BEADS

TEST SETUP:

GLASS BEADS - NOMINALLY 160μm
CATAPHOTE, INC Glass Beads
CLASS 4A, SIZE 812, BATCH # 9104

TEST CONTAINER:



DENSITOMETER: TEXAS NUCLEAR
EZ-CAL, MODEL 9700D, Ser# 00961
A lead shield on detector had a 1.3" x 1.5" WINDOW TO LIMIT VIEWING OF SOURCE.
THICKNESS OF SHIELD 1.1"

5-9-80 ds

RESULTS:

THE GLASS BEADS WERE HAND MIXED, WITH WATER AND THEN CAREFULLY PACKED INTO THE CONTAINER AND PLACED IN THE DENSITOMETER FOR READING.

1200 ml OF Beads was used (only 1000ml " " fit into the container but the entire amount was USED TO mix various saturation levels.

VOID FRACTION ASSUMED TO BE 37%

VOL. VOIDS = 1200 x .37 = 444 ml

SAMPLE SATURATION %	TOTAL AMOUNT OF WATER ADDED
0	0 ml
20	89
40	178
60	266
80	355
100	440

There is some uncertainty in this test simply due to the variation in packing densities that will occur

5-9-80 ds

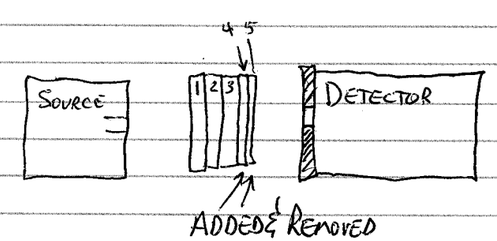
DENSITOMETER READING	SAMPLE
18.6	0% SAT
39	20%
59.3	40%
106.3	60%
133	80%
200.3	100%
1.0	2.25" THICK ALUMINUM Blocks
174.	2.75" " " "

(see p 24 for description of test setup - densitometer settings changed between tests 2 & 3 TO allow styrofoam insulation to fit (spacing between source & detector was changed))

DENSITOMETER READING THROUGH ALUMINUM

AL. Sheets	ALUMINUM THICKNESS [IN]	DENSITOMETER READING
1+2+3	2.25	1.0 ± 1
1+2+3+5	2.51	79 ± 2
1+2+3+4	2.75	175 ± 2
1+2+3+4+5	3.02	348 ± 3

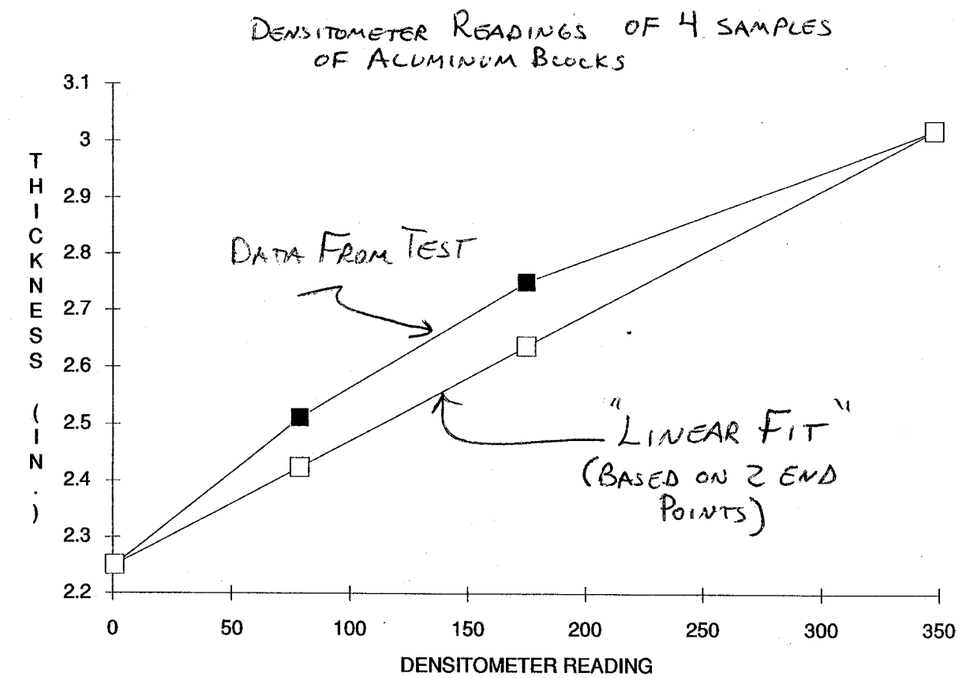
See p24

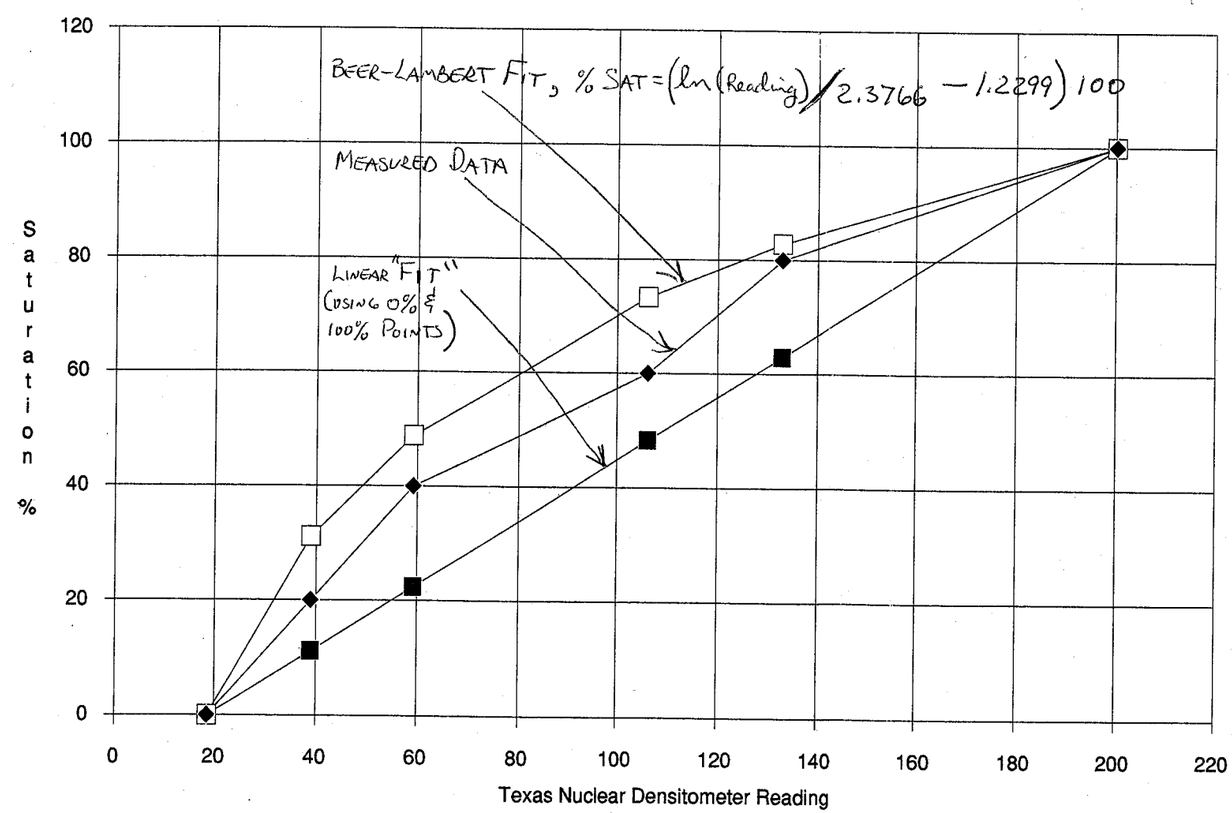


5-9-90 SS

THE ATTACHED FIGURE SHOWS THE RAW DATA PLOTTED AS Densitometer reading vs. Sample saturation (TOP LINE). ALSO PLOTTED ARE A LINEAR CURVE "FIT" (BASED ON 0 & 100% SATURATION READINGS). AND A Beer-Lambert EQN FIT (ALSO Based on the 0 & 100% saturation points). THE "DESIRED FIT" LINE SHOWS THE POSITION OF A Perfect CURVE FIT SINCE IT IS an "X=Y LINE". The Beer-Lambert fit is closer than the linear fit to the actual data. FOR THE PURPOSES OF THE PRIOR TEST, EITHER A LINEAR OR Beer-LAMBERT FIT COULD BE USED SINCE CHANGES IN SATURATION LEVELS WERE DETECTED. THE EXACT SATURATION LEVEL DID NOT NEED TO BE KNOWN.

END PERIODIC ENTRY #(8) 5-9-90 Steve Snedeker



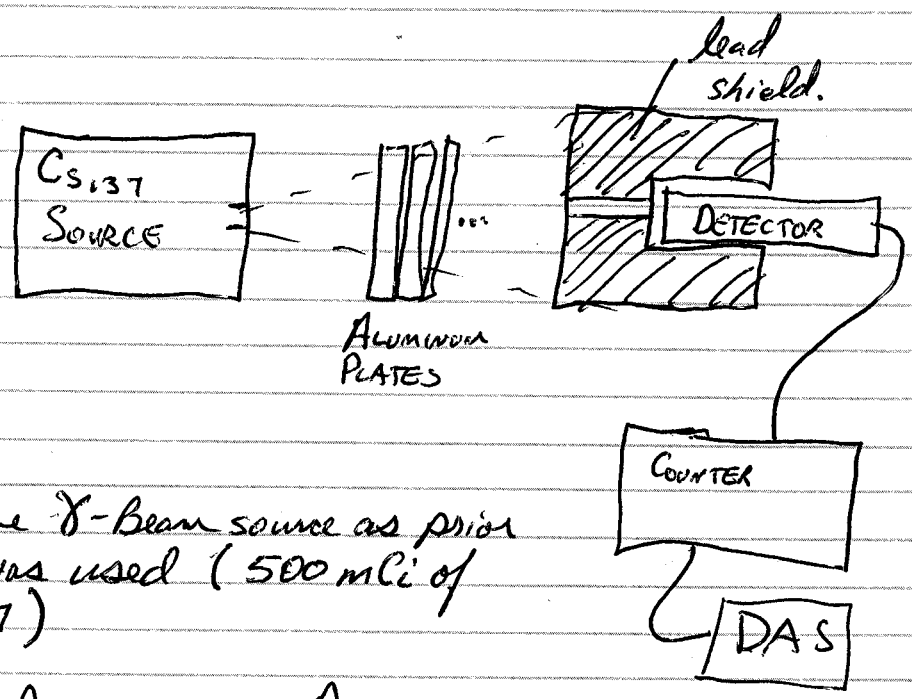


5-21-90 9-5-91

~~5-28-90~~ PERIODIC ENTRY #9

CHECK "NEW" DENSITOMETER RESPONSE

TEST SETUP



THE Same γ-Beam source as prior tests was used (500 mCi of Cs 137)

ALUMINUM PLATES WERE PLACED INBETWEEN THE SOURCE AND DETECTOR TO DETERMINE THE SYSTEMS RESPONCE. ~~to~~ 5-28-90

THE THICKNESS OF THE PLATES WAS MEASURED WITH A 6" long CRAFTSMAN SCALE #40996 WITH .01" DIVISIONS

5-28-90

THE DETECTOR IS A LUDLUM ~~I~~ MEASUREMENTS, INC 2200 Scaler Ratemeter with a NaCl Sintilation Detector. The detector output is read through the Data acquisition system. Ser.# Scaler - 72111, Serial ~~#~~ Detector PR 066881

A 2" THICK lead shield is placed over the detector. A 1/4" HOLE THROUGH THE LEAD ALLOWS ONLY A SMALL COLUMN OF γ-Beams to reach the detector

5-21-90 SS

TEST RESULTS

SETTINGS ON THE 2200 Ratemeter

THRESHOLD – 400 (see below)
WINDOW – 040
HIGH VOLTAGE – 414
Range – X 1K
WINDOW SWITCH – ON

Sweep threshold from 100 → 1000 and select operating point on "flat part" of curve.

THRESHOLD SETTING	COUNT RATE KCPM	1.5" THICK ALUMINUM PLATES
1000	9.8	
900	13.	
800	19.	
700	86.	
600	207.	
500	115.	
450	97.	
400	98.	← operating point.
350	104.	
300	107.	
200	118.	
100	117.	

5-21-90 SS

ALUMINUM PLATE THICKNESS [IN]	COUNT RATE (KCPM)
~~0.75~~ SS 5-28-90	
0.26"	187
0.31	182
0.50	164
0.55	159
0.75	142
0.80	139
1.01	125
1.25	110
1.51	98
1.76	88
2.00	79
2.26	70

THE "EXPECTED" RESPONSE IS

$$I = I_0 e^{-\mu x}$$

I_0 = INCIDENT RADIATION (KCPM)
x = THICKNESS OF SAMPLE
I = RADIATION PENETRATING SAMPLE (KCPM)
μ = absorption coefficient for Aluminum published value for .6MeV rad is 0.51/inch

TRY FITTING THE 2 END POINTS & Calc μ, I_0

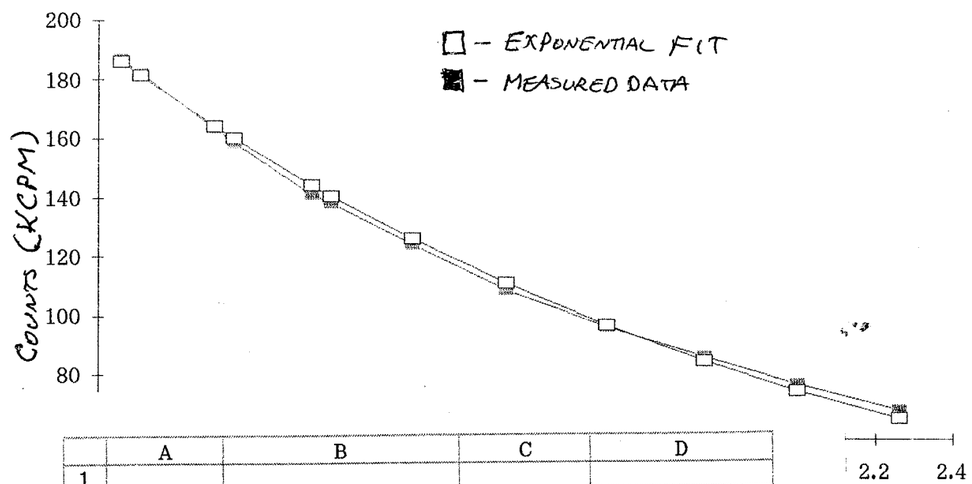
$70 = I_0 e^{-\mu(2.26)}$ $\quad \frac{70}{187} = e^{-\mu(2.00)}$ $\quad \mu = 0.491$

$187 = I_0 e^{-\mu(0.26)}$ $\quad I_0 = 212.5$

THE CALCULATED VALUE OF μ OF 0.491 IS very close to 0.51 (the published value for aluminum).

Below is a plot of the data and the curve

$$I = 212.5\, e^{-0.51x}$$



	A	B	C	D
1				
2		ALUM THICKNESS	COUNTS	EXPONENTIAL
3		(INCHES)	(KCPM)	FIT
4				MU=0.51
5		0.26	187	186.1107615
6		0.31	182	181.4249353
7		0.5	164	164.6697558
8		0.55	159	160.5237631
9		0.75	142	144.9577018
10		0.8	139	141.3080117
11		1.01	125	126.9561801
12		1.25	110	112.3301147
13		1.51	98	98.38043848
14		1.76	88	86.60365224
15		2	79	76.62642479
16		2.26	70	67.11059891

SS 9-5-91

5-21-90

END OF PERIODIC ENTRY (9) Steve Seedman ~~5-28-90~~

5-23-90 PERIODIC ENTRY #(10) SS

SEPARATE EFFECTS TEST 5

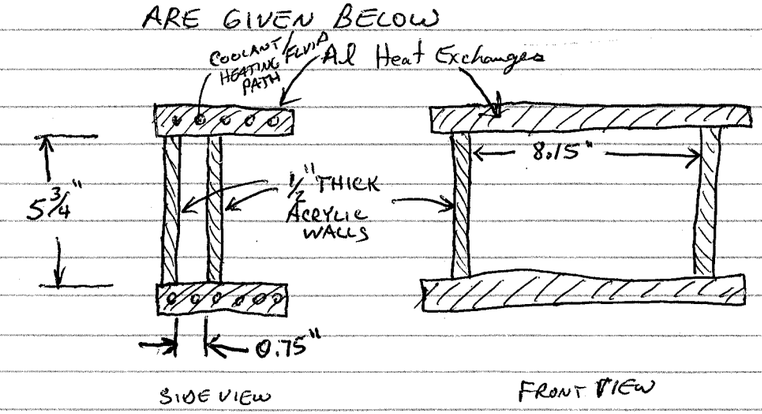
OBJECTIVE: TO "MATCH" WATER MOVEMENT IN UNIFORMLY UNSATURATED GLASS BEADS WITH A SIMULATED FRACTURE

TEST SETUP:

THE SAME RADIATION SOURCE, TRAVERSING SYSTEM, DATA AQQUISITION SYSTEM, AND INSTRUMENTATION AS "TEST 4" WERE USED FOR THIS TEST (SEE P49–66).

THE RADIATION DETECTOR FOR RECORDING γ-BEAMS WAS: LUDLUM MEASUREMENTS, INC
MODEL 2200 RATEMETER, # 72111
WITH MODEL 44-14 NaI DETECTOR, ~~#PR06688~~

THE CONTAINER USED TO HOLD THE MEDIA WAS MADE OF ACRYLIC WALLS AND ALUMINUM HEAT EXCHANGER PLATES. THE DIMENSIONS ARE GIVEN BELOW

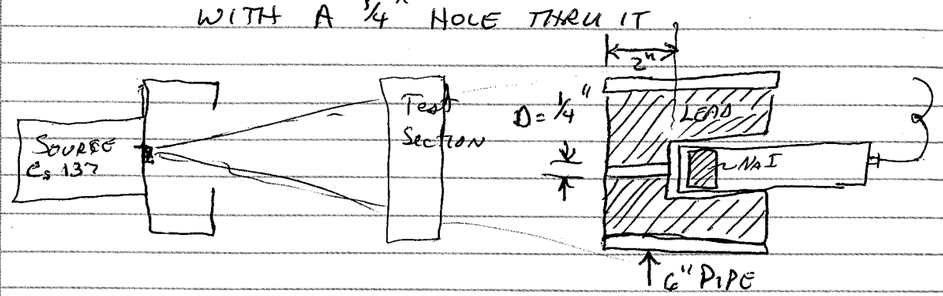


5-23-90 (CON'T) SS

DENSITOMETER SETTING:

WINDOW - 040 STABILIZATION - ON
WINDOW SWITCH - ON RATE SWITCH - S
THRESHOLD - 400
HIGH VOLTAGE - 414
RANGE X 1K

THE DETECTOR IS MOUNTED IN A LEAD SHIELD WITH A 1/4" HOLE THRU IT

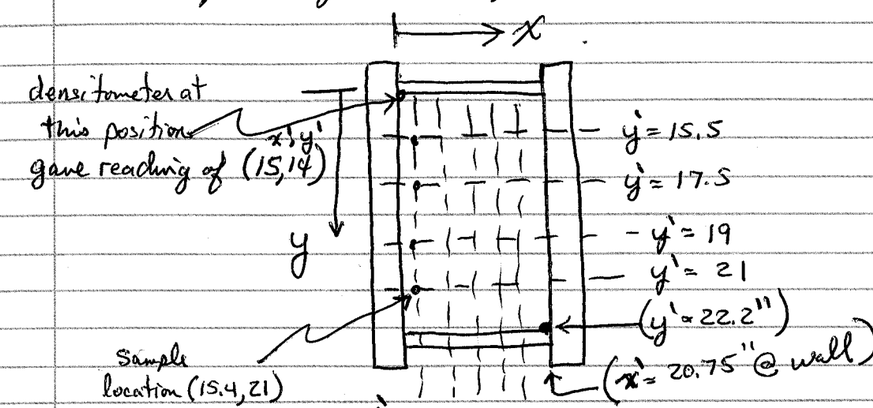


DENSITOMETER SAMPLING: 20 second dwell* (dead) time after moved into position and data is averaged for 800 PLC (power line cycles) by data system. THIS is an averaging time of 800/60 x 2 = 27 seconds. (The x2 factor is because the Multimeter skipped every other power line cycle.

Beads (media) were a 50% - 50% mixture of nominal 40 μm and 80 μm glass beads that were mixed by hand. Same beads and mixture methods as TEST 3 (see page 49 of this book)

5-23-90 (CON'T) SS

Densitometer scanning positions: To keep from changing the traversing system setup the test container was positioned as shown below & the traversing system given the positions outlined below.



position in container
x = 15.4 - 15 = 0.4"
y = 21 - 14 = 7.0"

x' = 15.4, 16.1, 16.8, 17.5, 18.2, 18.9, 19.6, 20.3
(SPACING = 0.7")

10:10AM STARTED DAS TO Record Densitometer readings ON EMPTY Plexiglass box

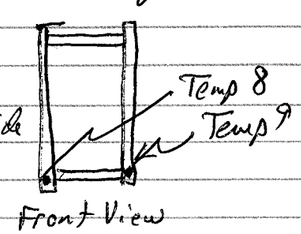
3:04PM DAS ON & OFF WHILE PUTTING HOSE FITTINGS ON Heat exchangers

3:23PM Filled container w/ Beads (dry) & started DAS

5:22PM Moved test section towards SOURCE ~1" (TO allow cooling water connects on the back of the heat exchanger)

Thermistors were installed in the HX manifolds

Channel 207 Temp 8 Left Hand Side
Channel 208 Temp 9 RHS
Channel 209 Temp 10 Ambient



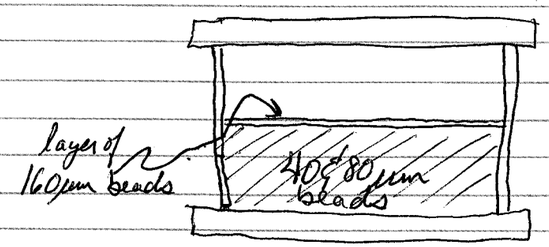
5-24-90 SS

9:00AM DAS off (HAD Been scanning ~~empty container~~ SS 5-24-90 dry glass beads)

The dry beads from the test container were mixed with enough water to form a 60% saturation mixture and then hand packed by tapping the beads in place with a thin block. A "simulated crack" was formed @ the ½ full position by lightly sprinkling 2 ml of 160 μm glass beads over the packed beads. This formed a small layer of beads in the center of the test section. Then more of the 40-80 μm mixture was carefully packed on the top to fill the container.

Bottom Layer of Beads

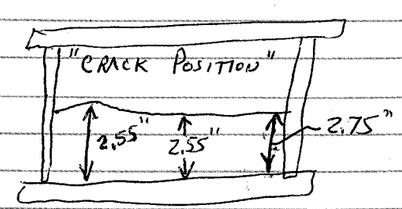
257 ml Beads
x.37 (void)
95
x.6 (Saturation)
57 ml water



Front View

Top Layer of Beads

335 ml Beads
x .37
123.95
x.6
74 ml water



after packing in beads, 35 ml were left (the packing was therefore less than dry since all the beads used here were in the container during the "dry" bead test)

5-24-90 (con't) SS

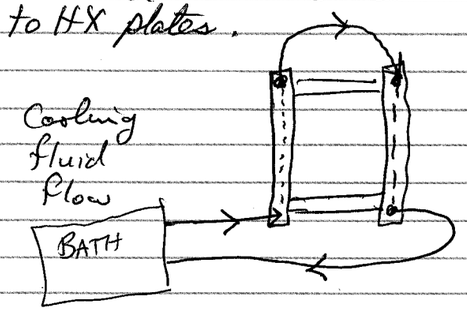
SS 5-24-90

Photos 1,2,3 During filling the ~~E~~ container - after putting in the 160 μm and some of top layer beads (but before any packing of upper layer)

Photos 4,5,6,7 After packed beads
" 8 Test section in place just before start of test.

11:50 AM Restarted DAS and hooked 20°C cooling fluid up to HX plates. (NESLABS)

COOLING/HEATING BATH: NESLABS RTE-4



16:49 (pm) Restarted DAS w/ 1 HR interval it looks like the DAS has not been sampling because the sample time interval was less than the time it takes to perform the sampling.

5-25-90 SS

9:00AM DAS not moving - the densitometer could not reach position. It looks like some data lost overnight. Restarted DAS.

5-26-90 SS

9:30 pm Hooked Hot Bath (Neslab EX-251 HT) TO THE LEFT HAND SIDE (VIEWED FROM FRONT) Heat EXCHANGER AN Put Setpoint at 60°C. LEFT THE Right Hand Side HX on 20°C Cooling fluid

5-28-90 SS

8:30 AM BOTH HEATING/COOLING Baths were off - THE PLUG-STRIP circuit breaker was "blown". They were both restarted.

DAS still running fine.

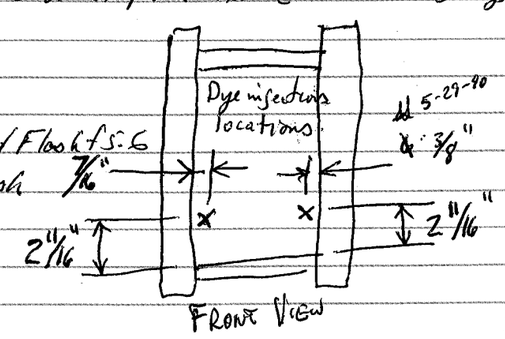
5-29-90 SS

4:00 pm Photo #9. before dye injection Flash f5.6
10 " " " "
11 " " w/o Flash "

4:40 pm injected dye near each HX plate
1cc Red dye near Hot HX plate LHS (food coloring)
1cc Blue dye " Cold HX plate RHS (Ms. Stewarts Bluing)

4:50 pm

Photo #12 after dye injection w/ Flash f5.6
13 " " " w/o Flash

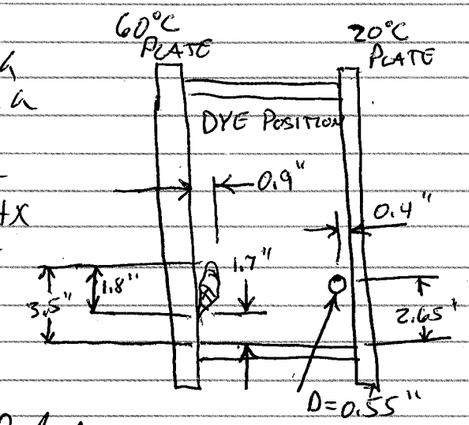


~~5-30-90~~ SS 5-29-90
5-29-90 (Con't) SS

6:03 pm STOPPED & Restarted DAS TO take more photos of dye (after it had a chance to diffuse some more)

Photo 14 screwed up photo
15 w/flash f5.6
16 w/o " "

5-30-90 SS
8:15 AM Das off & back on
SS 5-30-91
PHOTO #17 w/ Flash
18 w/o Flash



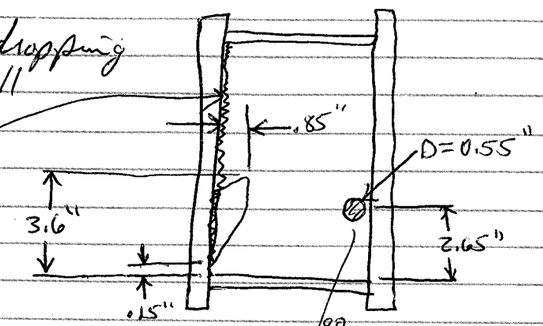
Red dye (hot side) looks like it is spreading - away from the HX it is moving upward and right next to the HX it is going downward. Blue dye (cold side) does not look like it has moved at all or diffused very much. Red dye appears to be diffusing.

3:30 pm DAS off & ON
4:00 pm Photo #19 w/ Flash f5.6 1/125 sec
20 w/o Flash " " ("screw-up")
21 w/o Flash f5.6 1/8

5-31-90 SS
8:15AM DAS off & ON

Photo #22 w/Flash f5.6 1/125
23 w/o Flash " 1/8

Red dye seems to be dropping along HX plate still



This is the side of the container with the gasket - because this is put on after the beads are in the test section, the ~~packing~~ contact here is probably poor

SS 5-31-90

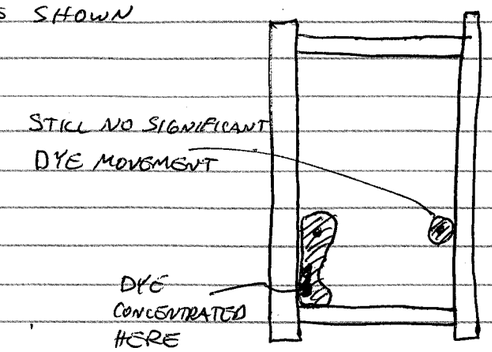
No significant dye movement

5:12 PM Found Shutter on the γ-Beam Source was left closed from photographs taken early this AM ∴ data on densitometer during this time is useless

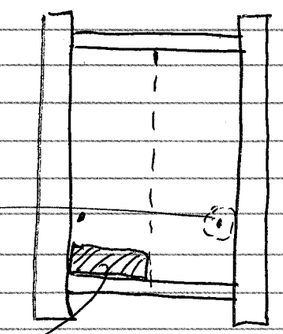
Set Sample interval to 3 Hours

5:16 PM
Photo #24 w/Flash
" #25 w/o Flash

6-1-90 SS
6:25 pm No Film to take photo but dye position is as shown



6-5-90 SS
~10:00 AM
New Roll of Film
Photo #1 w/Flash
Photo #2 w/o Flash



Blue dye is difficult to see but can see what remains (I assume it has diffused away) is still not moving

Dye all on bottom stopps at "crack"

6-6-90 SS
10:15AM Photo #3 w/Flash ~~BYE~~ SS 6-6-90
" #4 w/o Flash

Dye position same as above sketch

10:30AM Turned Hot Bath Set Point to 0°C (from 60°C) to allow media to slowly cool. This is to see if the red dye migrates upward w/ cooling. DAS Restarted @ 1 Hour interval sampling

6-7-90 S

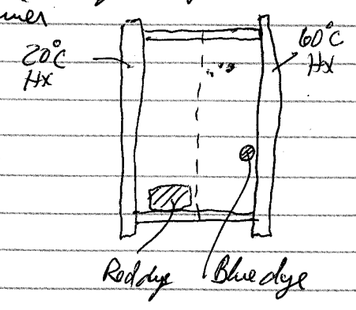
10:15AM I SWITCHED THE "HOT" FLUID BATH & "COLD" BATH CONNECTIONS TO THE HEAT EXCHANGER PLATES
Left cold bath at 20°C
" Hot Bath @ 0°C set point (So it will operate at about Room temp)

11:45AM INJECTED 1ml of blue dye (food coloring - not Ms. Stewart's "BLUING") INTO RHS port where blue dye was previously injected.

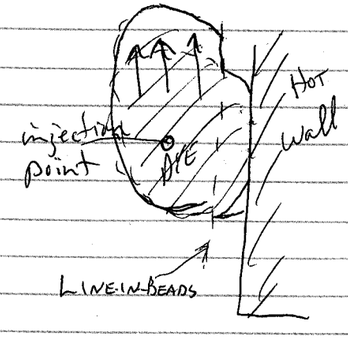
Photo #5 w/Flash showing location of the dye that was just injected

THE Red dye seems to still be migrating to the RHS of the container

11:53AM Restarted DAS
Set HOT HX Bath to 60°C
(the Right Hand Side is now connected to this bath)



5:21pm Photo #6 w/Flash
Blue dye has moved up ~ 1/4" FROM INJECTED SPOT



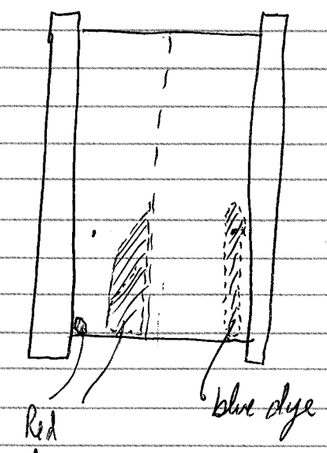
6-8-90 PHOTO # 7 w/FLASH (R. GREEN)

1:50PM Blue dye has continued to move up w/time ~ 3/4" above dot
R Green

red dye movement is arrested by the simulated fracture, but the red dye has some diffusion (or convection) upward RF

6-11-90 S
8:30AM DAS OFF - Restarted @ 2HR SAMPLE INTERVAL

PHOTO # 8 w/FLASH



4:26pm
Photo #9 w/Flash

6-12-90 S
9:25AM FOAM Insulation was left off of the front of the test container overnight
Switched Ludlum ratemeter to "F" (fast)
Photo # 10 w/Flash

Blue dye is concentrated above and below injection point in a thin line (about 0.2" away from the HX plate)

6-12-90 (Con't) SS

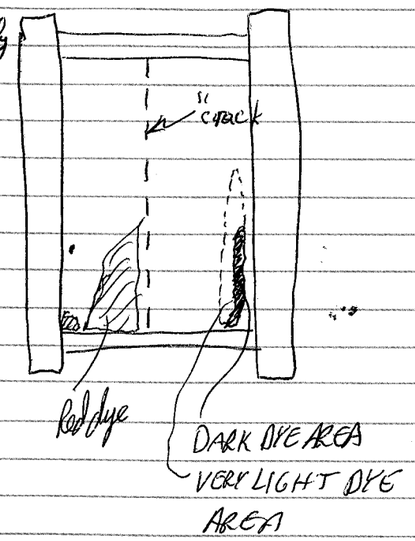
4:05 PM Photo # 11 w/Flash

6-13-90 SS

8:25 AM
Photo # 12 w/Flash

The red dye seems to be very slowly migrating up the face of the "crack"

The blue dye does not seem to be moving much from previous day



6-14-90 SS
11:30 AM Photo 13 & 14 w/Flash

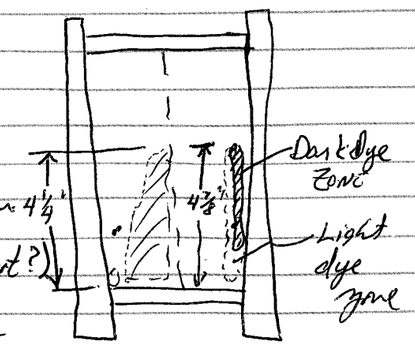
The RHS dye injection port was not covered from last dye injection so some small amount of evaporation may have occurred to dry out media - port was covered.

DAS on & off several times for extended periods - the averaging method for the γ-beam was being modified and tested to allow longer averaging times.

6-15-90 SS
4:40 pm Photo # 15

Blue dye has moved upwards along a line ~ 1/4" away from the HX plate. Top of dye is past 1/2 way up (movement started because plugged dye injection port?)

Red dye seems to be moving upward along "fracture" but the outline of the dye is difficult to see

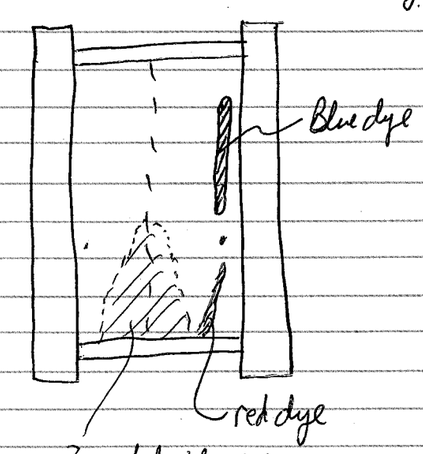


6-19-90 SS DAS SHUT OFF ON 6-18-90 (DATA FROM γ-BEAM DENSITOMETER WAS NOT meaningful)

8:44 AM Photo # 16

$T_{HOT\ BATH} = 60.1°C$
$T_{COLD\ BATH} = 20.0°C$

Both Blue and Red dye now are migrating in a counter clockwise direction



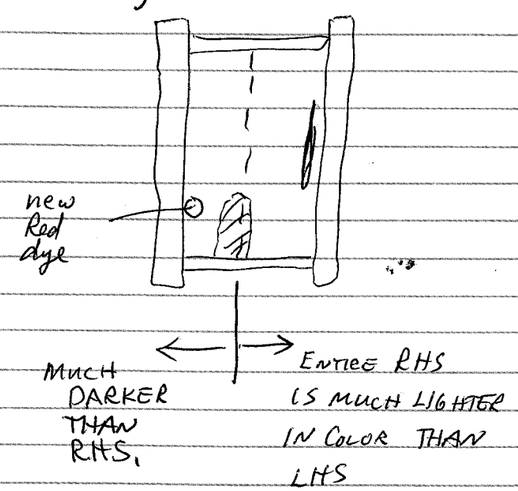
DAS Back on @ ~ 1:00 pm
(change γ-Beam reading to 106 sec average to try to limit the uncertainty in the readings)

6-20-90
8:00 AM Photo # 17

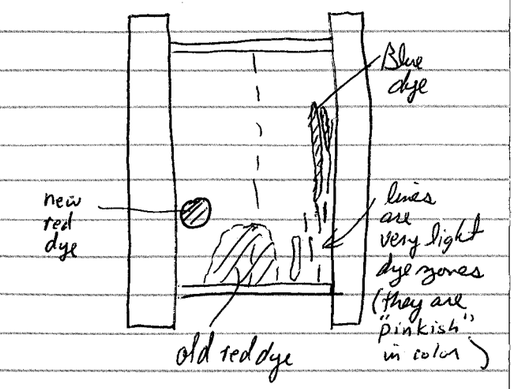
6-21-90 SS

8:52AM Photo #18
(looks about the same as yesterday)

3:25pm Injected Red dye in LHS INJECTION PORT (5cc)
TRIED TO INJECT BLUE DYE IN RHS " "
BUT IT DID NOT ABSORB INTO THE MEDIA (I THINK most OF THE 5cc OF DYE SPILLED OUT OF INJECTION PORT)
PHOTO #19
~4:30pm Restarted DAS

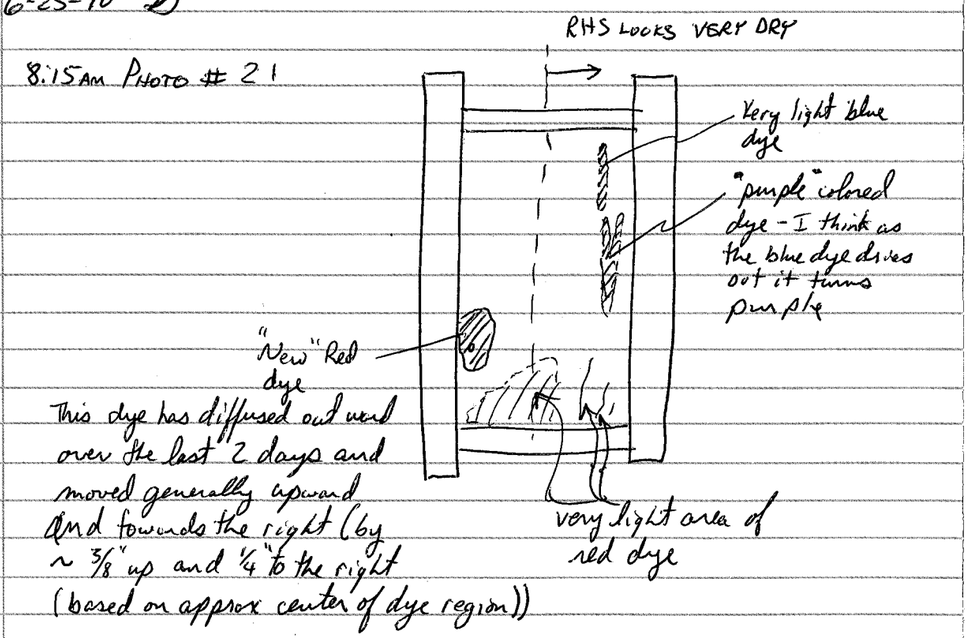


6-22-90 SS
8:15AM
Photo # 20



6-25-90 SS

8:15AM PHOTO # 21



6-26-90 SS
9:40 AM Insulation on front face had fallen off overnight.

Photo #22

6-27-90 SS

1:45 PM Photo #23

"New" red dye still seems to be going upward and to right slowly (it is next to the cold wall)
Hot HX TEMP = 60°C
Cold HX " = 20°C } No change

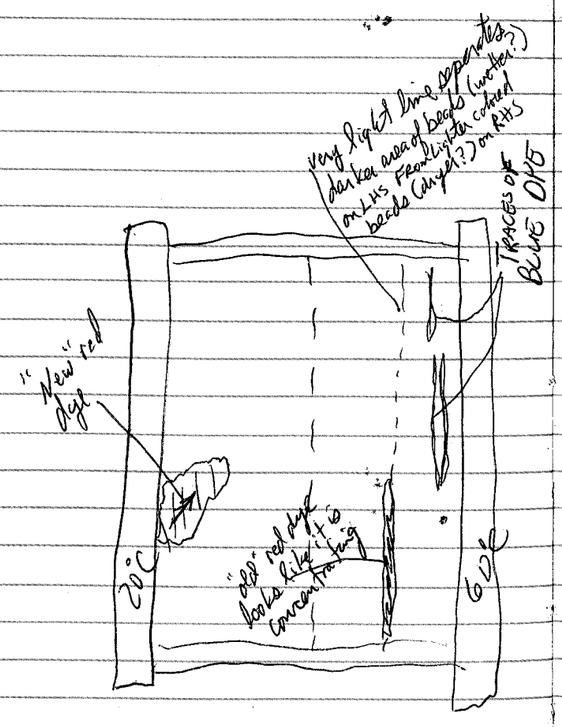
6-28-90 SS
10:32 AM Photo #24

6-29-90 SS

10:56 AM

"New" red dye still looks like it is slowly moving upward and towards the right.

The old red dye seems to be concentrating at a line ~½ way between the "crack" and the hot plate

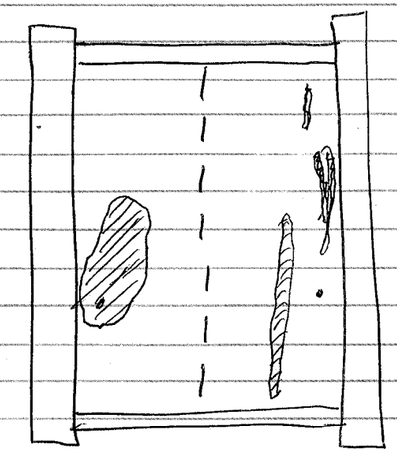


7-2-90 SS

8:12 AM SHUT DOWN DAS

INSULATION WAS LEFT OFF OF FRONT OF TEST SECTION OVER WEEKEND

PHOTO #1 ON New Roll OF FILM



I TURNED OF HOT & COLD BATH (NO LONGER ANY FLUID CIRCULATION IN HX'S)

7-2-90 SS

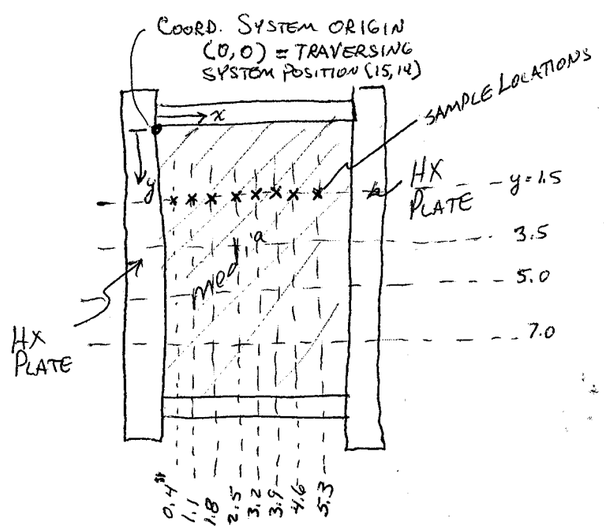
TESTS "MOTION" FILE. DEFINES DENSITOMETER SAMPLING AND "PARK" LOCATIONS

TEST5.MOT

DWELL TIME = 20 ← "Dead Time" before starting averaging (after traversing system in position)

NPLC 800 Sample average time for densitometer = 800 power line cycles × $\frac{1}{60}$ × 2 = 27 sec

5.000	22.000	← PARK POSITION
5.000	22.000	← Densitometer reading of ALUMINUM Block 1.51" THICK
10.000	22.000	← " " " " " 2.00" THICK
15.400	15.500	← " " @ position (0.4, 1.5)
16.100	15.500	← " " " " (1.1, 1.5)
16.800	15.500	← " " " " (1.8, 1.5)
17.500	15.500	
18.200	15.500	
18.900	15.500	
19.600	15.500	
20.300	15.500	
15.400	17.500	
16.100	17.500	
16.800	17.500	
17.500	17.500	
18.200	17.500	
18.900	17.500	
19.600	17.500	
20.300	17.500	
15.400	19.000	
16.100	19.000	
16.800	19.000	
17.500	19.000	
18.200	19.000	
18.900	19.000	
19.600	19.000	
20.300	19.000	
15.400	21.000	
16.100	21.000	
16.800	21.000	
17.500	21.000	
18.200	21.000	
18.900	21.000	
19.600	21.000	
20.300	21.000	



TEST 5 "CONFIGURATION" FILE. THIS FILE DEFINES THE SENSOR LINEARIZATION, UNITS, MULTIMETER SETTINGS (SUCH AS DCV, Ω, ...), AND MULTIMETER RANGE.

TEST5.CFG

NPLC 1

Channel label	DMM Func.	DMM Range	DMM Resol.	Relay Numbers	Eng. Units	EQ. Type	K1	K2	K3
Densitometer	DCV	10.0	.0001	402	KCPM	1	200.00	0.00	0
Barometer	DCV	10.0	.0001	100	PSIa	1	2.4	-3	0
YSI Temperature 8	OHM	1e5	.01	207	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 9	OHM	1e5	.01	208	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 10	OHM	1e5	.01	209	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
X position	DCV	10.0	.01	400	Inches	10	0.0582	2.4685	0
Y position	DCV	10.0	.01	401	Inches	11	6.2669	3.8480	0

Equation types:
0 - None..... Y = X
1 - Linear..... Y = K1 * X + K2
2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3) - 273.15
10- Linear..... Y = (X - K1) * 10 / (K2 - K1) (X position - No more than one of these)
11- Linear..... Y = (X - K1) * 10 / (K2 - K1) (Y position - No more than one of these)

END OF PERIODIC ENTRY (10)

7-2-90 Steve Seedman

7-31-90 SEPARATE EFFECTS TEST 5-

OBJECTIVE: TO TAKE THE 100% SATURA
READINGS ON THE MEDIA
IN TEST 5. THIS WILL PR
A REFERENCE FOR THE γ-
DENSITOMETER READINGS.

SETUP: SAME AS TEST 5

THE TEST SECTION WAS LAYED ON
LEFT HAND SIDE HEAT EXCHANGE
AND WATER INJECTED THROUGH THE
USED FOR DYE INJECTION (THAT
NOW AT THE BOTTOM OF THE C
WATER WAS GRAVITY FEED WITH ~
HEAD

9:10 AM Valve open on water line (container
9:24 AM added 3¼ cc water
10:52 AM " 8 cc "
1:06 PM " 14cc "
2:47 PM " 19cc "
4:06 PM " 13.5cc "
4:29 PM Valved off water flow - ~1" on top is
(a small amount of water is leaking
gasket - I tightened screws some
leakage)

8-1-90 SS

8:12AM Turned valve to water line to restart water flow

11:15AM Added 18cc water (the water is not uniformly saturating media near the top. It is wicking up in areas and leaving "dry" areas)

1:50PM Added 11.5 ml water (small leak at gasket again)

4:46PM Added 11cc water
test section is close to saturation but a few small "dry" areas are left near the top.
Closed valve on water injection.
Test section repositioned vertically - this may move water into dry areas

8-2-90 SS

8:30AM opened valve on water line

1:13PM added 13cc water

4:51AM ADDED 10cc "
left valve on overnight - so water might continue to wet the dry areas

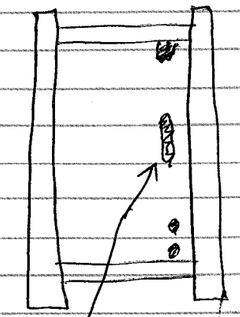
8-3-90 SS

8:30AM Connected HX bath to both heat exchanger plates & set @ 20°C to start stabilizing the temperature

8-3-90 (CON'T) SS

1:25PM Valved off water flow
Positioned container in γ-beam traversing stand
Water distribution still not entirely uniform

PHOTO # 5



STARTED DATA ACQUISITION SYSTEM TO GET 100% SAT. Readings
w/ 2 HOUR SAMPLE INTERVAL
DATA FILE NAME = TEST5END.DAT
CONFIGURATION FILE = TEST5.MOT } SAME AS
MOTION FILE = " .CFG } TEST5

3:47 Restarted DAS w/ NEW DATA FILE = TEST5-D.DAT

(STYROFOAM INSULATION WAS NOT ON TEST SECTION FOR ABOVE READINGS)

8-6-90 DAS STILL RUNNING SS
8:12AM SHUT DOWN DAS & COOLING BATH

A QUICK LOOK AT DATA SHOWS IT RECORDED THE 100% SATURATION READINGS FOR ~2 DAYS

PHOTO # 6

END PERIODIC ENTRY (11) 8-6-90 Steve Sneden

PERIODIC ENTRY (12) [illegible]

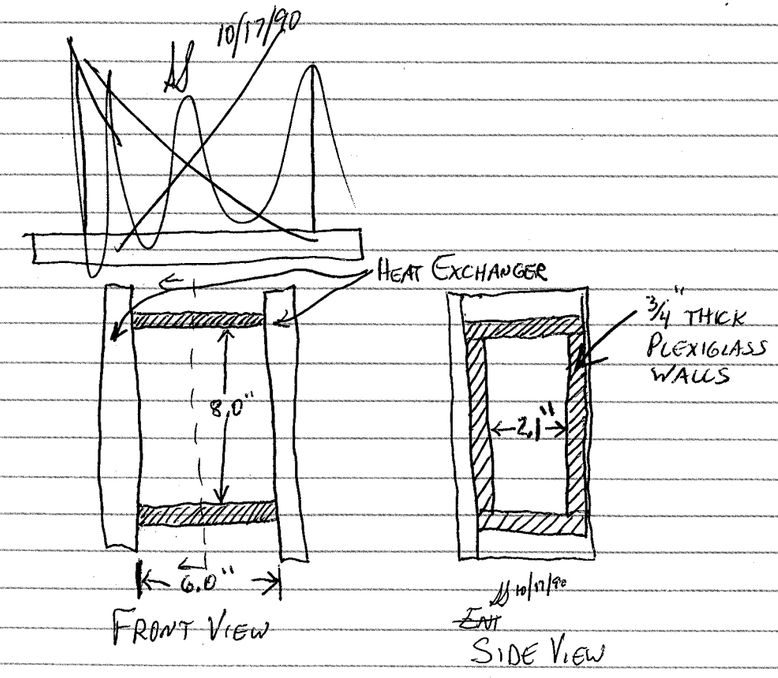
10/17/90 SEPARATE EFFECTS TEST 6

OBJECTIVE: TO REPEAT TEST #5 TO VERIFY THE RESULTS AND MAKE SOME MODIFICATIONS TO ALLOW IMPROVED QUANTATIVE RESULTS

TEST SETUP:

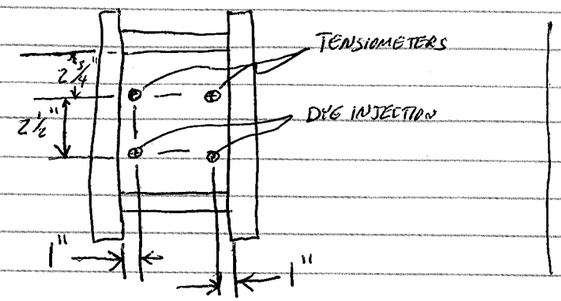
THE SAME RADIATION SOURCE, TRAVERSING SYSTEM, DATA ACQUISITION SYSTEM, AND INSTRUMENTATION AS TEST # 5 WITH THE FOLLOWING MODIFICATIONS:

MOD. 1) TEST CONTAINER DIMENSIONS



10/17/90 CON'T

MOD. 2.) DYE INJECTION PORT LOCATIONS & TENSIOMETERS

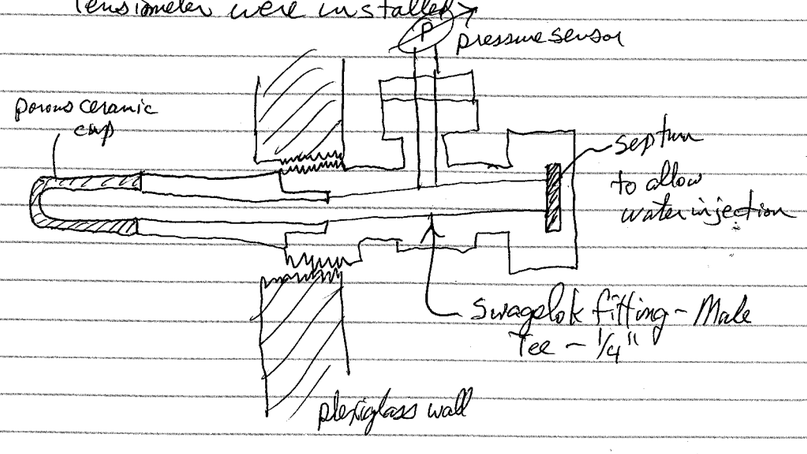


FRONT VIEW

MOD. 3.) A LEAD SHIELD WITH A 1/4" DIAMETER HOLE WAS INSTALLED IN FRONT OF THE RADIATION SOURCE. THE LEAD IS 2" THICK

MOD. 4.) TENSIOMETERS WERE ADDED TO TEST 6 (TEST 5 DID NOT USE ANY).

THE POROUS CERAMIC CUPS used for the tensiometers were the same as in Tests 1-5 and the pressure gages used for the tensiometers are the same as in Test 1-5. The following sketch shows how the tensiometer were installed.



10/17/90

MOD. 5) THICKER INSULATION WAS INSTALLED ON TEST CONTAINER. 1.5" THICK STYRA-FOAM IS USED.

MOD. 6.) THREE THERMISTORS ARE GOING TO BE INSTALLED ON THE PLEXIGLASS BOX TO MONITOR THE OUTSIDE WALL TEMPERATURE. THESE ~~ARE~~ NEED TO BE CALIBRATED. THE SENSORS ARE CONNECTED TO THE DAS SYSTEM AND WILL BE READ THRU THE DAS DURING CALIBRATION AGAINST ASTM Mercury in glass thermometer set (see p 35 of this book for the calibration sheets on the thermometers) 10-17-94

Calib. Bath Temp. THERMOMETER	°F	°C	Channel 300 Thermistor Resistance (Ω)	Channel 301 Thermistor Resist. (Ω)	Channel 302 Thermistor Resist. (Ω)
ASTM 63F, 8009-1311	72.6	22.6	10133	9770	10055
ASTM 64F, 12-3030	114.6	45.9	4339	4161	4313
65F 7903-3787	155.5	68.6	2130	2035	2122
Ice Point	32	0.0	25679	24870	25412

The above data was used to fit the following equation

$$\frac{1}{T} = a_0 + a_1 \ln R + a_2 [\ln R]^3 \qquad T \rightarrow {}^\circ K, \quad R \rightarrow \Omega$$

The following coefficients were derived

	a_0	a_1	a_2
Channel 300	8.1289×10^{-4}	2.6963×10^{-4}	1.05174×10^{-7}
301	8.3920	2.6781×10^{-4}	1.06893×10^{-7}
302	8.0865	2.7029×10^{-4}	1.05810×10^{-7}

10/31/90 SS

BEADS – Glass Beads are a 50%-50% mixture by Volume of 40 μm and 80 μm glass beads.

Beads are CATAPHOTE INC
Class H-A. No. SS 10/31/90
40 μm – SIZE = 2740, BATCH ~~SIZE~~ = 91107
80 μm – SIZE = 1420, Batch # = 91105

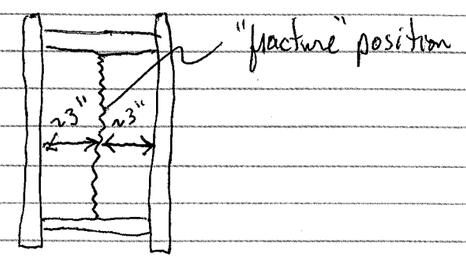
The dry beads were mixed with DI water to 65% Saturation (assuming Void Fraction = .35)

500 ml Beads
.35 ← Bead Void FRACTION
175
.65 ← Bead Saturation
113.75 ml H_2O per 500 ml Beads

The beads were mixed in 500 ml batches and then packed into the container by hand.

Bottom ½ of container held approximately 700 ml of beads

A "fracture" was simulated by putting a thin layer of 160 μm glass beads on top of bottom layer – 3 ml of beads were sprinkled on top of bottom layer



10/31/90 SS

Check on POSITION SENSOR CALIBRATION ON TRAVERSING SYSTEM

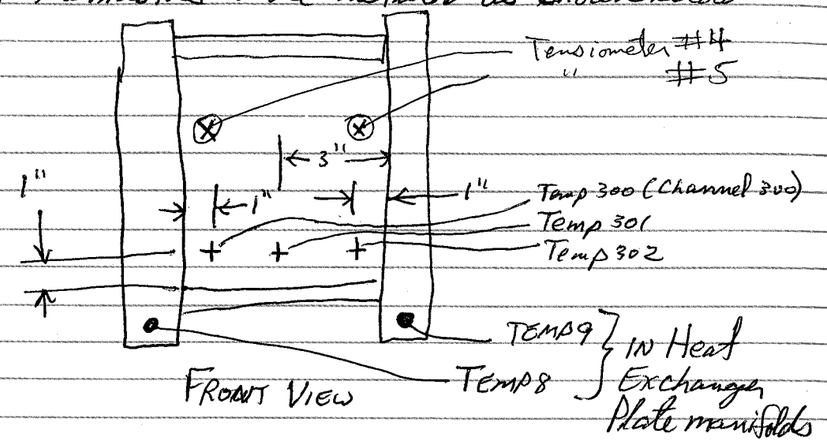
SCALE READING	SENSOR X	SCALE READING	SENSOR Y
5.00"	5.00"	22 0/64	22.00
6 0/32	5.99	21 0/64	21.00
10 0/32	10.00	17 0/64	17.00
SS 10/31/90 ~~15~~ 14 63/64	15.00	12 0/64	12.00
19 31/32	20.00	7 0/64	7.00
14 63/64	15.00	12 0/64	12.00
10 0/32	10.00	17 0/64	17.00
6 0/32	6.00	21 0/64	21.00
5 0/32	5.00	22 0/64	22.00

Scale used is a Starrett # C404R
1/64" Scale Division, Length = 48"

This check shows the traversing system position sensors are still in calibration. (Needed accuracy is ~ 1/16")

10/31/90 SS

After the beads were packed into the test chamber the 5 thermistors were installed as shown below



TEMP 10 is Room Temperature

The tensiometer's pressure transducers were not installed

12:55 PM STARTED DAS TO RECORD INITIAL WATER DISTRIBUTION WITH DENSITOMETER. Also see if water migrates toward bottom - gravity effect.
TEMPERATURE OF BOTH HEAT EXCHANGER PLATES IS 20°C (SAME FLUID THROUGH BOTH HX'S.)

Sample time interval = 3HRS
~ 3 min densitometer sample time per location

Photo # 14 taken just before start of test

11/5/90 SS

3:25 PM STOPPED DAS TO Look @ DATA. Restarted DAS.
DATA Looks O.K.

11/6/90 SS
9:00 AM STOPPE DAS TO INSTALL TENSIOMETERS
FILLED TENSIOMETERS WITH WATER
INJECTED DYE INTO DYE INJECTION PORTS 15¢/cc
~ 1/10 ml injected total (< 1" in 1/8" Tube)
Set Left side heat exchanger @ 20°C
" Right " " " @ 60°C
Injected dye @ ~ 10:15 PM
SS 11-6-90

Photo # 15 @ 10:30 AM

10:45 AM Restarted DAS @ 3 HR Sample INTERVAL
TEST6.DAT IS THE DATA FILE
When the tensiometers were 1ST Filled, they both read ~ -1.25 psig, when the data system was started they read ~ -0.75 psig.
SS 11-6-90

10:59 AM DAS STOPPED & RESTARTED (SO SCAN @ 10:45 AM WAS NOT COMPLETED OR RECORDED)

2:05 PM STOPPED DAS TO TAKE PHOTO OF DYE

Photo # 16 @ 2:15 pm

Tensiometers both reading -1.1 psig now
SS 11-6-90

Restarted DAS @ 2:20 PM

I Reset Clock time from 15:20 to 14:20
(I had not reset for Daylight savings time - 1 hr. "lost" in data)

11/7/90 SS

10:25Am Stopped DAS & Restarted after photograph

Photograph #17 @ 10:30Am

Injected more dye in Right side dye port
~6" in 1/8" O.D. Tubing or ~ 1/3 cc

Photos #18 @ 10:40Am after reinjected dye

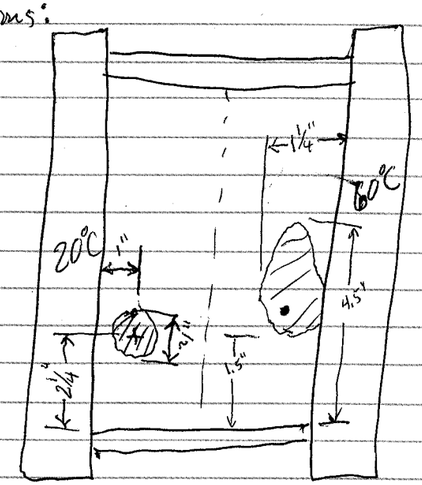
Dye on Right side diffussed away and was no longer visiable
Dye on Left side has moved down ~1/4"

11/8/90 SS

9:40Am Stopped DAS to take Photo

Photo #19 @ 10:44Am

Dye positions:



Dye on left has dropped ~1/2" since injection

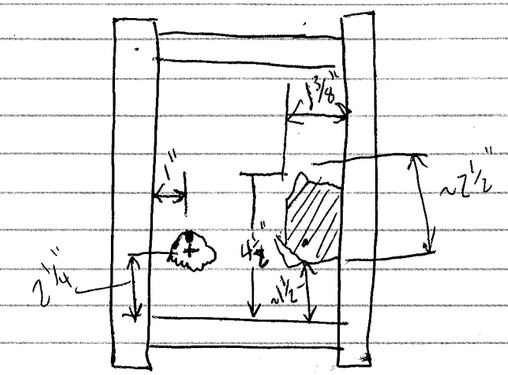
Dye on right has moved up

11/9/90 SS

8:15Am Stopped DAS to take Photo

Photo #1 (on New Roll)

Dye Position: Dye has not moved much from yesterdays position. Dye on right side appears to have moved up and towards heat exchanger a little bit.



8:25Am Restarted DAS

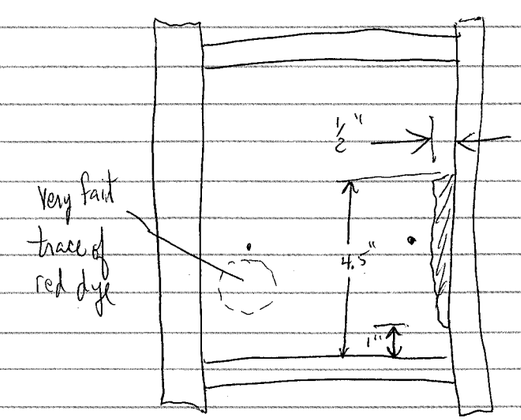
11/12/90 SS

8:15Am DAS off - Failure over weekend
(looks like failure was on 11/11/90 @ 5:20AM)

Photo #2 @ 8:20AM

Dye Locations

8:33 Am Restarted DAS



11/13/90 SS

8:22AM Cold HX Bath at 22°C – I think someone must have moved set point knob – I reset to 20°C

STOPPED DAS TO TAKE PHOTO

Photo # 3 @ 8:27am

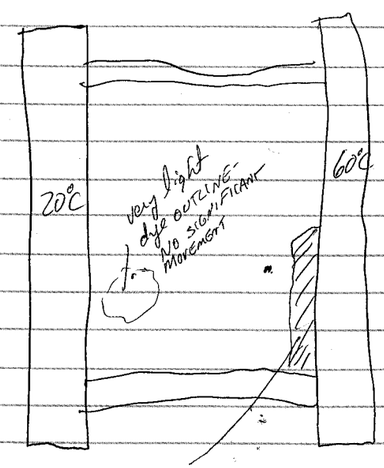
Restarted DAS @ 8:30AM

11/14/90 SS

8:10AM STOPPED DAS FOR PHOTO

Photo # 4 @ 8:15AM

Dye position



Dye has moved to the well and towards the bottom of the container

Injected ~0.1cc @ each dye port

Photo #5 @ 8:29AM

Restarted DAS @ 8:33AM

11/14/90 SS

4:53pm STOPPED DAS for Photo & Restarted DAS

Photo # 6 @ 4:55pm

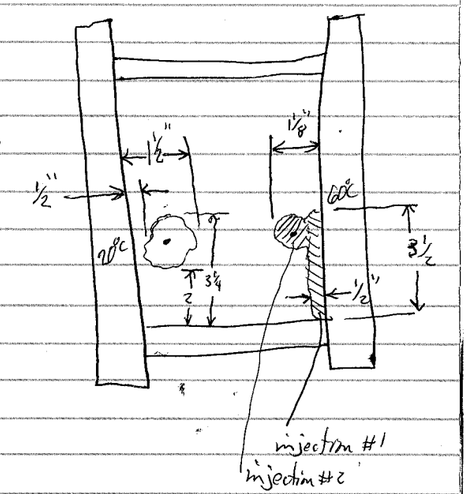
11/15/90 SS

9:00AM DAS TO TAKE PHOTO

Photo # 7 @ 9:05AM

DYE Movement:

The dye on the right side is diffusing very quickly – probably because that side is dryer



9:34am Restarted DAS

5:05PM STOPPED & Restarted DAS to Take Photo

Photo #8 @ 5:10PM

11/16/90 SS

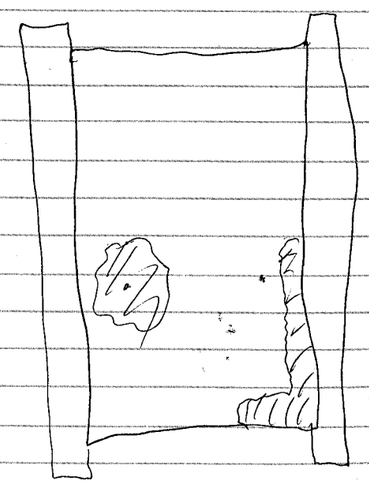
8:50AM STOPPED & Restarted DAS for Photo
Photo # 9 @ 8:51AM

4:40PM DAS off for Photo
Photo # 10 @ 4:45pm
The dye has not moved much since yesterday. The dye on the left side is about the same. The dye injected on the right side seems to have diffused toward the right and is getting hard to see (it may be diffusing back into the center of the test section).

Restarted DAS @ 4:50pm

11/19/90 SS

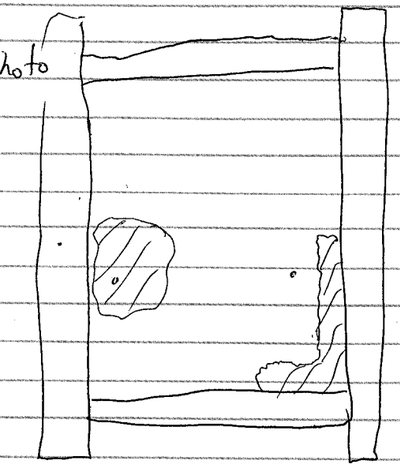
8:15AM DAS STOPPED
Photo # 11 @ 8:20AM



Dye has not moved very far over the weekend. The dye on the left side looks like it has just diffused out into a bigger area. The dye on the right has moved downward and along the bottom towards the left. The last dye injection on the right is now not visiable. it either diffused into beads or moved to the right and merged with the first dye injection
Restarted DAS @ 8:30 AM

11/20/90 SS

4:10PM Turned off DAS for Photo
Photo # 12 @ 4:15PM



Dye movement.
on left side the entire dye region is centered above the injection point (indicating some upward movement)
The dye on the right is continuing to move down and along the bottom to the left.

11/21/90 Run fan

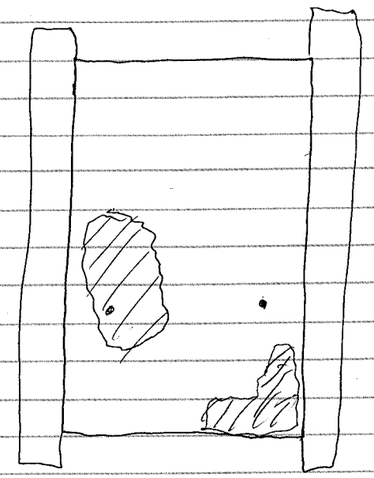
1:45 Turned off DAS for Photo
Photo # 13 @ 1:45 no flash
Photo # 14 @ 1:47 w/ flash
Turned on DAS

11/25/90 Run fan

4:45 Photo 15 @ 4:45

11/26/90 SS

8:30AM DAS off for Photo
Photo # 16 @ 8:35AM



Dye on left side has continued to diffuse and moved upward slightly
Dye on the right side has continued to move down the ~~left~~ right face to the bottom and then towards the left along the bottom

8:37AM Restarted DAS

11/27/90 SS

8:30AM DAS off

Photo # 17 @ 8:35AM

Injected ~ 1/10 cc dye into each dye port

Photo # 18 @ 8:40AM

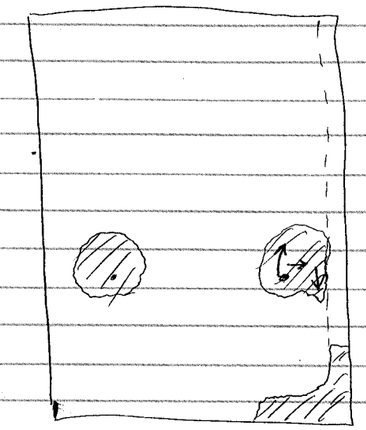
Restarted DAS @ 8:40 am

5:12PM DAS off for Photo

Photo # 19 @ 5:13PM

11/28/90 SS

8:30AM DAS off For Photo
Photo # 20



Dye on the left has moved up ~ 1/8" since injection 24 hours ago

Dye on right has moved towards the right wall and slightly upward away from the wall and next to the wall it is dropping.

A small region ~ 1/4" WIDE next to the right heat exchanger has become lighter in color - indicating it is probably drying out.

11/29/90 SS

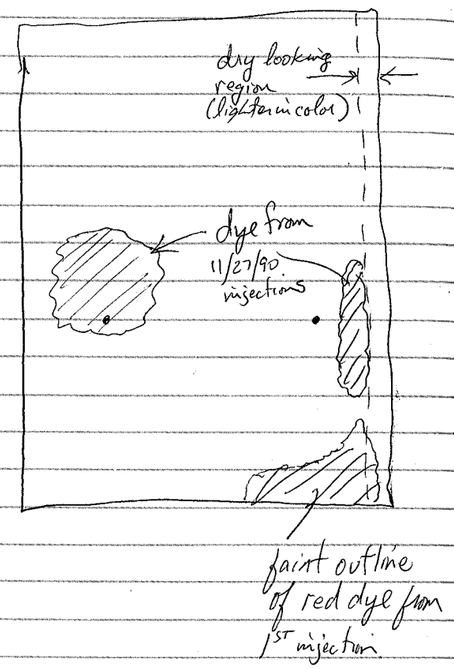
1:00PM DAS off for photo
Photo # 21

11/30/90 SS

2:00 PM DAS off FOR PHOTO
Photo # 22 @ 2:05 PM

DYE ON the left side continues to move slowly upward

Dye on the left is moving downward along the right side heat exchanger plate but ~ 1/4" away from the plate. The 1/4" wide strip along the plate appears to have dried out and is excluding moisture migration to the plate. The dye has also migrated towards the right from the injection point and is now alligned in a column



12/3/90 SS

8:50 AM DAS was not operating - went down over weekend
LAST DATA POINT was 12-2-90 @ 23:13

Photo # 23 @ 9:15 AM

DYE on Right side (near 60°C plate) has continued to move down the "dry" looking beads and along the bottom towards the left

The dye on the left side continues to move very slow upward and towards the right.

Tensiometer #5 was dried out - refilled with water.

Restarted DAS @ 9:30 AM

12/4/90 SS

3:50 PM DAS FOR PHOTO
Photo # 24 @ 3:57 PM

4:30 PM Restarted DAS.

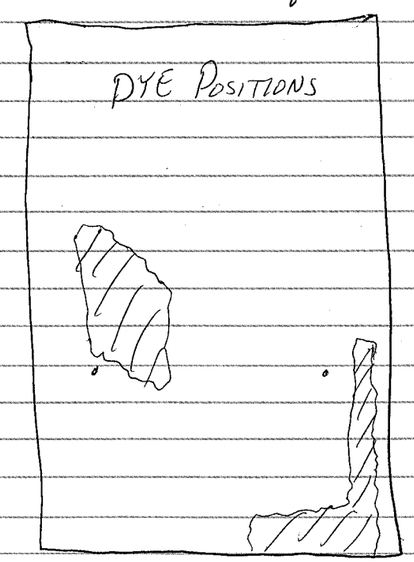
5:22 PM I STOPPED DAS AGAIN AND INSULATED THE DETECTOR (X-BEAM) WITH STYRA-FOAM INSULATION. THIS WAS AN ATTEMPT TO DAMPEN OUT TEMP. RELATED FLUXTIATIONS. DAS Restarted

12/5/90 SS

3:55 DAS off FOR PHOTO

PHOTO # 2.1 @ 4:00 PM (New Roll of Film)

4:10 AM Restarted DAS.



12/7/90 SS

1:20 PM Photo # 2.2

DAS HAS NOT Been Running - sample interval was set @ 30 min (which was less than sample time required to take data) - I Reset sample interval to 3 hours.

12/10/90 SS

10:45 AM PHOTO # 2.3

The dye is becoming very hard to see now. The movement trends look to be the same (that is, down along the right face and slowly upward along the ~~right~~ SS 12/10/90 left side).

12/12/90 SS

2:50 PM Photo # 2.4
Dye is getting very difficult to see.

12/17/90 Ron Green

4:15 PM Photo # 2.5
dye is very faint. No evidence of dye crossing fraddine. Tensometers both appear functional - Tensometer 5 is still indicating drying & there is some movement in Tensometer 4

RGreen

12-18-90 SS

3:15 PM STOPPED DAS TO INJECT DYE IN BOTH PORTS
PHOTO # 2.6 Before dye injection
3:25 PM INJECTED ~ 1/10 cc of dye into each dye port
PHOTO # 2.7 Just after dye injection.

12-19-90 SS

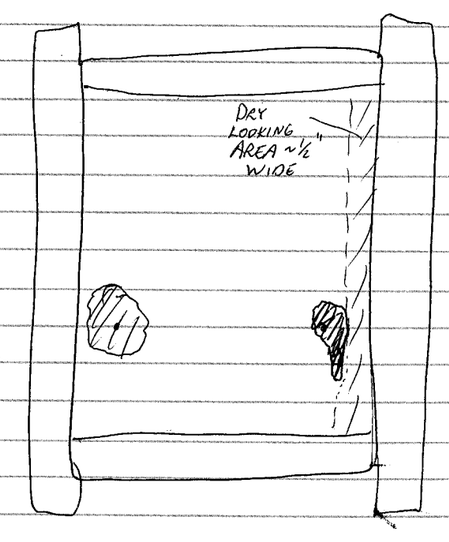
11:15 AM PHOTO # 2.8

DYE ON RIGHT SIDE HAS ALREADY MOVED DOWNWARD along the heat exchanger plate with the fluid nearer the plate moving faster. The dye on the left has not moved any noticable amount.

5:55 PM FILE OPEN ERROR ON COMPUTER SCREEN
Restarted DAS WITH DATA FILE = TEST6B.DAT

12-20-90 SS

5:43 PM Photo # 2.9



12-21-90 SS

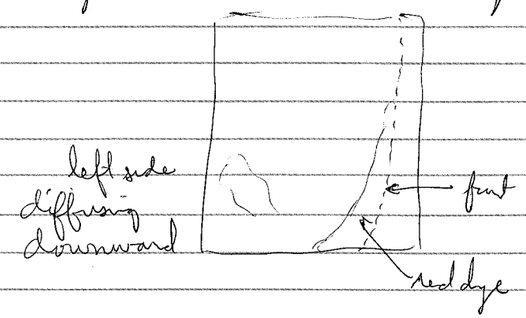
9:30AM Photo # 2.10

12-26-90

2 PM system down,

Photo # 2.11

right side, especially at bottom has appeared to completely dry out. A front appears to have been formed although there is some red dye behind the front



restarted system

1-4-90 SS 1-12-91

9:50AM Ron Green Restarted DAS on 12-26-90 and put data in TEST6.DAT (NOT TEST6B.DAT)

I Restarted DAS back on TEST6C.DAT

1-7-90 SS 1-12-91

9:00AM THE INSULATION ON THE FRONT OF THE CONTAINER WAS LEFT OFF ~~OVER~~ 1-7-90 since 1-4-90. I PUT IT BACK ON.

DAS STOPPED FOR FILLING TENSIOMETER #5 IT HAD "DRIED OUT".

9:20AM RESTARTED DAS

NOTE - WITHOUT INSULATION ON CONTAINER, THE DENSITOMETER READINGS ARE SLIGHTLY HIGHER

1-8-90 SS 1-12-91

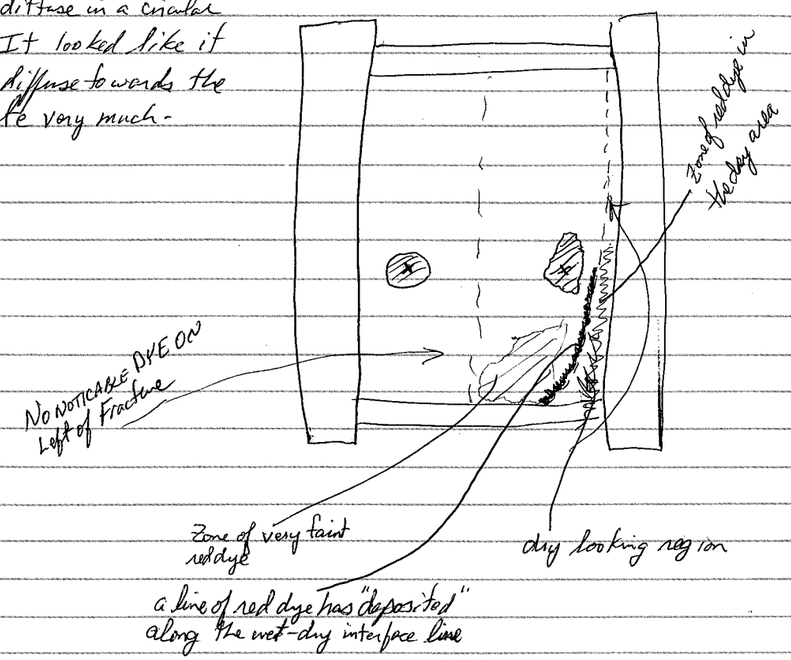
8:15AM DAS was not operating - it did not record data from yesterday. I restarted it.

11:40AM PHOTO # 2.12

INJECTED DYE INTO BOTH DYE INJECTION PORTS ~1/10 cc

1-8-90 CON'T SS 1-12-91

Dye injected into Right side (near hot plate) did not diffuse in a circular pattern. It looked like it did not diffuse towards the hot plate very much.

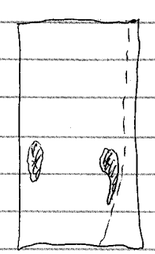


12:20 PM Photo # 2.13 just after dye injection.
Restarted DAS.

5:00 PM Photo # 2.14

1-9-90 SS 1-12-91

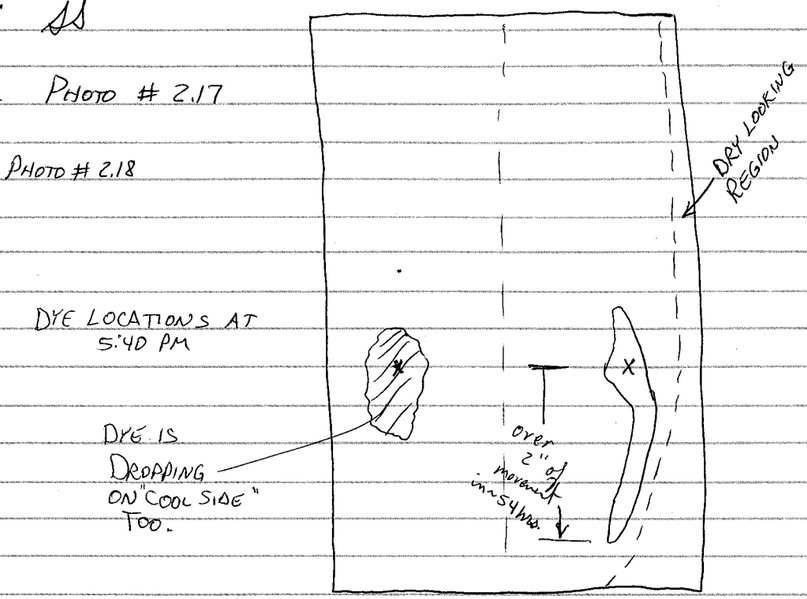
8:15 AM PHOTO # 2.15
5:40 PM " # 2.16 (Densitometer is in the edge of picture)



1-10-90 SS 1-12-91

10:20 AM PHOTO # 2.17

5:40 PM PHOTO # 2.18

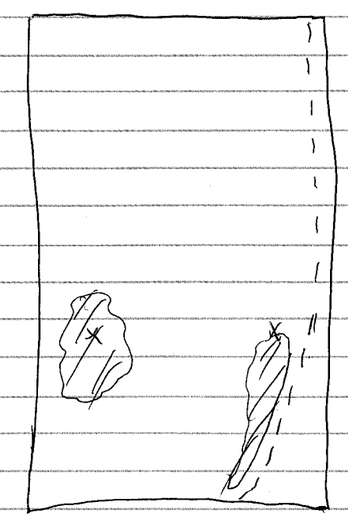


1-11-90 SS 1-12-91

8:10 AM Photo # 2.19
4:00 PM " # 2.20

1-12-91 SS

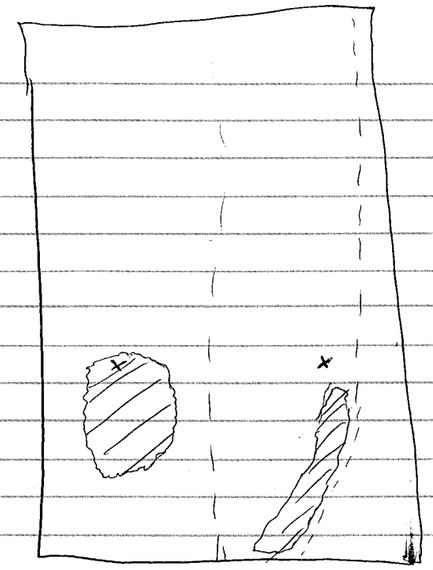
11:20 AM PHOTO # 2.21



1-14-91 SS

8:40AM Photo #2.22

9:50AM Photo #2.23 & 2.24
of experiment setup.



1-15-91 SS

10:25AM Photo #3.1 (Third Roll of Film)

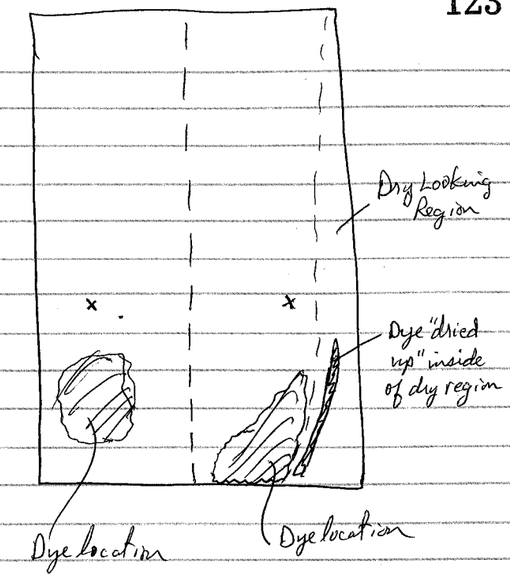
1-16-91 SS

3:30PM Photo 3.2

Both dye regions continue to move downward. The right side dye has reached the bottom of the container and is now moving along the bottom and toward the center. The dye on the left side also is migrating downward and towards the center but much more slowly.

1-17-91 SS

1:20PM Photo # 3.3



1-18-91 SS

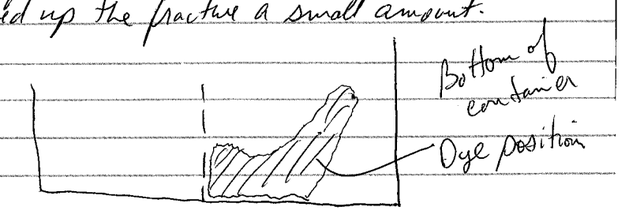
1:15PM DAS Down - Due to power failure overnight.
DAS Restarted

1:20PM Photo # 3.4

1-20-91 SS

11:08AM Photo #3.5

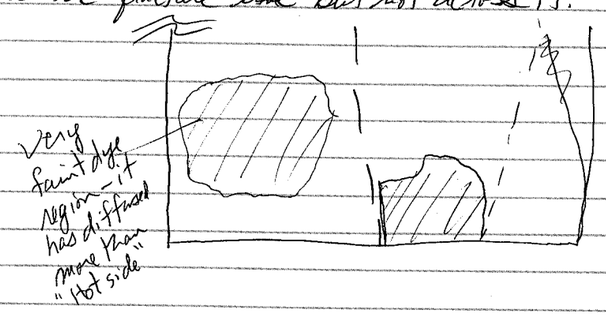
Dye from "Hot side" Right has moved to bottom of container and towards the left - it then ran into the simulated fracture. It appears the dye (which is becoming very hard to see) has moved to the fracture but has not crossed it - it may have moved up the fracture a small amount.



1-21-91 SS

9:50AM Photo #3.6
" #3.7 with 15cm long Scale in photo Vertical
" #3.8 with 6" (Snap-on) Scale 1/32" Divisions "
" #3.9 " " (Craftsman) " 1/10" " "
" #3.10 " " " " " " Horiz

The fracture is clearly acting as a barrier to dye migration from the hot plate side to the cold plate. The dye has moved to the fracture line but not across it.

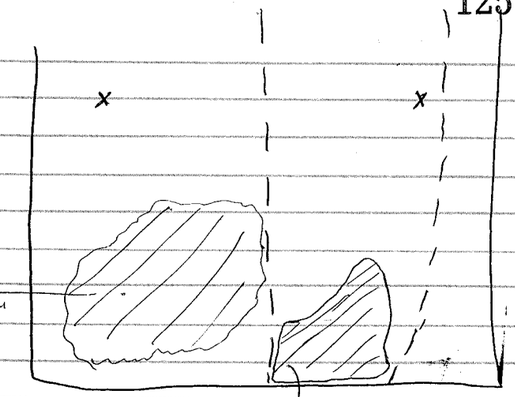


1-22-91 SS

11:15AM Photo #3.11

1-23-91 SS

8:15 AM Photo #3.12



1-24-91 SS

1:10 PM Photo #3.13

1-25-91 SS

9:00 AM DAS OFF For Starting Installation of New Interface Between Ludlum Counter & IBM-PC. Nothing on Existing DAS Software was Changed

2:00 PM Photo #3.14
DAS Restarted

1-28-91 SS

8:15AM PHOTO # 3.15

DYE IS VERY HARD TO SEE NOW. IT HAS MOVED TOWARD FRACTURE FROM BOTH SIDES

12:00 PM Changed DAS to get LUDLUM COUNT DATA THRU DIGITAL INTERFACE.

DATA FILE TEST6D.DAT

TIME INTERVAL = 2 HOURS (FOR SAMPLES)

COUNT TIME 3 MIN

PUT TRAVERSE PROGRAMS (OLD ONES) IN FILES:

TRAVERSE.BAS → TRAVERSE.OLD

TEST6.CFG → TEST6OLD.CFG

TEST6.MOT → TEST6OLD.MOT

1-31-91 SS

2:50 PM DAS WAS "STUCK". NO DATA TAKEN FROM 1-30-91 @ 10:49AM

5:10 PM PHOTO # 3.16

2-1-91 SS

12:20PM Set Sample Interval from 30 min. to 2 HOURS.

2-4-91 SS

11:45AM Refilled Tensiometer #5 with water. It had gone dry over the weekend.

1-31-91 SS (see next 2 pages)

DETERMINE THE "CONVERSION FACTOR" TO GO FROM THE ANALOG COUNTS RECORDED ON THE LUDLUM DENSITOMETER TO THE "DIGAL COUNTS" USING THE DIGITAL INTERFACE INSTALLED IN THE SYSTEM ON 1-28-91.

THE FOLLOWING READING WERE TAKEN AT 3 MIN DURATION OF SAMPLE.

ATTENUATION MEDIUM	ANALOG METHOD COUNT (KCPM)	DIGITAL INTERFACE COUNT (KCPM)
ALUMINUM SHEETS 1, 2	75.98	81.787
1, 2, 4	59.58	63.511
1, 2, 3	53.25	56.577
1, 2, 3, 5	47.20	49.9113
1, 2, 3, 4	42.20	44.725
1, 2, 3, 4, 5	37.46	39.4553
1	112.31	122.2353
NONE	180.00	199.879

ALUMINUM SHEET	THICKNESS (inches)
1	0.75
2	0.75
3	0.75
4	0.51
5	0.26

1-31-91 AJ

NRCDGTL.XLS

	A	B	C	D	E	F	G	H	I	J	K	L
1	Calibration check on the Ludlum densitometer.											
2	Compare the analog output readings with the digital interface readings.											
3	1/31/1991 Data											
4												
5	Readings are 3 min averages. Analog is averaged by HP multimeter.											
6												
7												
8	Sample	Sample	Sample	Sample	Sample	Sample	Aluminum	Analog	Digital	Ratio of	Digital	Diff btwn
9	#	#1	#2	#3	#4	#5	Thickness	Output	Output	Digital to	converted	Conv to an
10		0.75	0.75	0.75	0.51	0.26	(inches)	(KCPM)	(KCPM)	Analog	to Analog	and analog
11												(KCPM)
12	1,2	1	1	0	0	0	1.5	75.98	81.787	1.076428	75.57692	-0.403085
13	1,2,4	1	1	0	1	0	2.01	59.58	63.511	1.065979	59.33303	-0.246971
14	1,2,3	1	1	1	0	0	2.25	53.25	56.5777	1.062492	53.17065	-0.079355
15	1,2,3,5	1	1	1	0	1	2.51	47.2	49.9113	1.057443	47.24548	0.045484
16	1,2,3,4	1	1	1	1	0	2.76	42.2	44.725	1.059834	42.63585	0.43585
17	1,2,3,4,5	1	1	1	1	1	3.02	37.46	39.4553	1.053265	37.95209	0.49209
18	1,	1	0	0	0	0	0.75	112.31	122.2353	1.088374	111.5278	-0.782244
19	None	0	0	0	0	0	0	180	199.879	1.110439	180.5382	0.53823
20									Average	1.071782		
21												
22									Slope	0.88881		
23									Intercept	2.883837		
24									equation for conversion of digital			
25									to analog. Anal=0.888*dig+2.883			

Conversion of "new digital" readings to "OLD Analog" equivalents

Analog equivalent (KCPM) = 0.8888 * digital (KCPM) + 2.8838

Ludlum Digt-Anlg

2nd order least squares curve-fit of Digital to Analog reading Conversion for Ludlum γ-Beam

1

NUMBER OF POINTS = 8 NUMBER OF FUNCTIONS = 3 KWATE = 0

INPUT DATA POINTS

X-VALUES	Y-VALUES	WEIGHT
81.7870000	75.9800000	1.0000000
63.5110000	59.5800000	1.0000000
56.5777000	53.2500000	1.0000000
49.9113000	47.2000000	1.0000000
44.7250000	42.2000000	1.0000000
39.4553000	37.4600000	1.0000000
122.2353000	112.3100000	1.0000000
199.8790000	180.0000000	1.0000000

THIS 2nd ORDER CURVE FITS THE DATA MUCH BETTER (DATA FROM 1-31-91 TEST)

5-7-91 Steve Sudeman

(Data re-curve fit while reducing some of the densitometer readings for test 6)

T MATRIX

.10000D+01	.81787D+02	.66891D+04
.10000D+01	.63511D+02	.40336D+04
.10000D+01	.56578D+02	.32010D+04
.10000D+01	.49911D+02	.24911D+04
.10000D+01	.44725D+02	.20003D+04
.10000D+01	.39455D+02	.15567D+04
.10000D+01	.12224D+03	.14941D+05
.10000D+01	.19988D+03	.39952D+05

TPT MATRIX

.80000D+01	.65808D+03	.74865D+05
.65808D+03	.74865D+05	.11071D+08
.74865D+05	.11071D+08	.19033D+10

DETERMINANT OF TPT MATRIX

.635858E+13

TPTI MATRIX

.31314D+01	-.66625D-01	.26439D-03
-.66625D-01	.15131D-02	-.61813D-05
.26439D-03	-.61813D-05	.26083D-07

CHECK FOR IDENTITY MATRIX

.10000D+01	.43420D-15	-.16495D-17
-.78937D-12	.10000D+01	-.31794D-16
.61704D-10	-.34639D-11	.10000D+01

FUNCTION COEFFICIENTS

Analog Reading equivalent (KCPM) = 0.86919 + 0.935911 (Digital Rdg [KCPM]) − 0.00019875 (Digital Rdg)^2

.869190D+00
.935911D+00
-.198750D-03

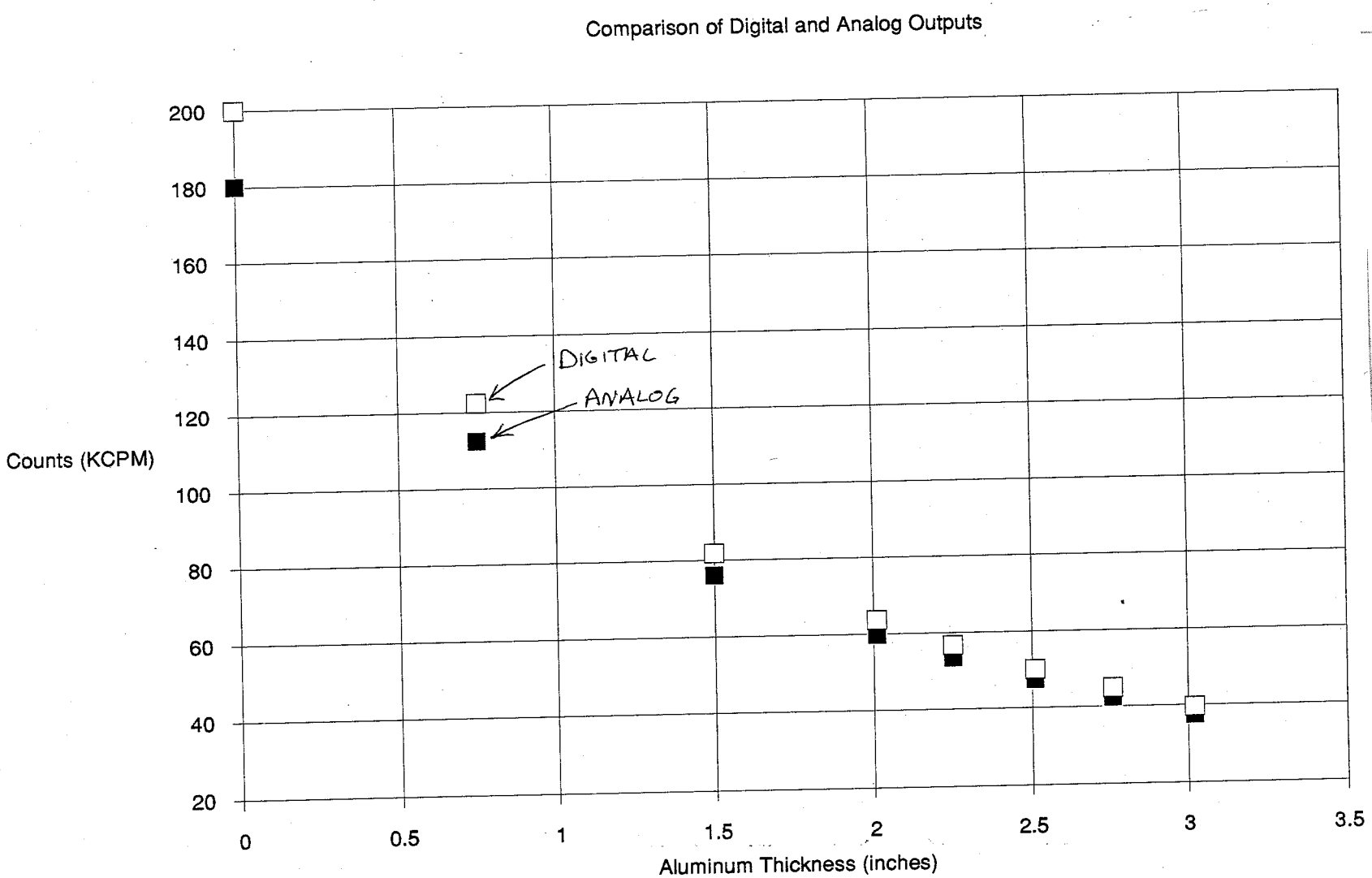
POINTS DERIVED FROM EQUATION

X	Y	YCALC	DIFFERENCE	PERCENT DIF
81.78700	75.98000	76.08509	-.10509	-.13832
63.51100	59.58000	59.50816	.07184	.12058
56.57770	53.25000	53.18468	.06532	.12266
49.91130	47.20000	47.08662	.11338	.24021
44.72500	42.20000	42.33025	-.13025	-.30865
39.45530	37.46000	37.48645	-.02645	-.07060
122.23530	112.31000	112.30095	.00905	.00805
199.87900	180.00000	179.99779	.00221	.00123

SUM OF SQUARES OF DIFFERENCES

.510794D-01

1-31-13 A


Comparison of Digital and Analog Outputs
Counts (KCPM)
200
180
160
140
120
100
80
60
40
20
0
0.5
1
1.5
2
2.5
3
3.5
Aluminum Thickness (inches)
DIGITAL
ANALOG

2-5-91 SS

8:00 AM STOPPED DAS TO WORK ON γ-Beam Densitometer

DAS Restarted with wrong setting on Ludlum COUNTER — DATA FROM 8:00 AM TO 10:00 AM ARE FOR A 0.3 MIN Sample time NOT 3.0 MIN. THIS DATA SHOULD BE DISCARDED

10:00 AM INSTALLED PULSE HEIGHT ANALYZER ON THE DENSITOMETER OUTPUT. RAN SEVERAL CHECK ON γ-BEAM SETUP. AFTER THEY WERE COMPLETE, THE SYSTEM WAS RESET TO THE INITIAL SETTINGS (THAT IS, WINDOW = 0.40, THRESHOLD = 4.00), H. Voltage was not moved - still at 4.14)

1:40 PM DAS Restarted.

2-8-91 SS

10:00 AM DAS Down when I checked System
Restarted DAS & IT FAILED TO WORK - THERE IS A PROBLEM WITH THE IBM-PC

10:05 PHOTO # 3.17

2-11-91 SS

4:00 PM PC FIXED - Harddisk controller board was replaced

4:40 PM Restarted DAS
Both Hot & Cold Heat exchangers have continued to run during the "down time" on the DAS.

2-13-91 SS

9:00 AM DAS TURNED OFF SO RADITION DETECTOR COULD BE MEASURED FOR A COOLING JACKET

~2:30 PM RESTARTED DAS

4:00 PM DAS Seemed to be "STUCK"
TURNED OFF HOT BATH HX - WAS AT 60°C AND HOOKED 20°C BATH TO BOTH HEAT EXCHANGER PLATES

PHOTO # 3.18 @ 4:06 PM

4:15 PM RESTARTED DAS - BOTH HEAT EXCHANGER PLATES AT 20°C

2-14-91 SS

9:00AM Tensiometers clearly show change in suction pressures due to the ~~SM~~ SS 2-14-91 Temperature change imposed yesterday. Hot side (right) initially increased in suction then started to drop. The left side suction increased.

THE 2ND Reading of the Aluminum Blocks (~2.25" THICK) IS "BAD" FROM 2-13-91 @ 4:15PM THRU 2-14-91 @ 9:00 Because THE ALUMINUM PLATE WAS TIPPED BACK when the HX plate lines were moved. This was not noticed until Now.

9:18AM Photo 3.19 TEST SECTION LOOKS ABOUT THE SAME AS YESTERDAY

2-15-91 SS

4:30PM PHOTO # 3.20
No visiable change in test section.

2-18-91 SS

4:20PM Tensiometer #4 dried out over the weekend - it was refilled & DAS Restarted

2-22-91 SS

9:25AM PHOTO # 3.21

TURNED OFF DAS

REMOVED TENSIOMETER #4 AND PUT A 4.PSIG SUCTION ON THE TENSIOMETER TO GET A WATER SAMPLE FOR ANALYSIS.

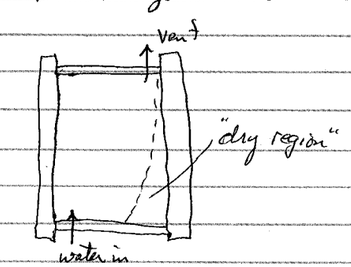
2:00PM No water has been drawn into tensiometer. I increased the suction to ~ 8psig.

5:00PM STILL NO WATER PULLED INTO TENSIOMETER –
- TENSIOMETER REFILLED
- SET UP TEST SECTION FOR SATURATING BEADS

5:04PM STARTED INJECTING WATER INTO BOTTOM OF TEST SECTION
– 1000ml of DI water in cylinder @ start

7:40PM ABOUT 125ml of water has gone into the test section. The region that looked "dryed-out" does not seem to be rewetting as quickly as the rest. I closed the valve on the water inlet to see if water will move into the dry region befor the rest saturates. Tensiometers both read -0.65psi (still suction in chamber).

DAS still off – Both Heat exchangers are still @ 20°C.



2-25-91 SS

8:15AM PHOTO # 3.22
The media next to the right Heat exchanger still is not absorbing water.

Opened valve in water feed line to re-start water injection

9:55AM TOTAL QTY WATER ADDED (NOT JUST TODAY - BUT SINCE 2-22-91) IS 200ml

PHOTO # 3.23

Media now looks almost completely saturated - even the "dry regions". Tensiometers Read +0.02psi

2:10PM TOTAL QTY WATER ADDED 210ml - MEDIA LOOKS SATURATED - A small amount of water came out of top @ vent - tensiometer reading +0.15 psig

PHOTO # 3.24

2-27-91 SS

8:45AM DAS was stuck - no data taken from 12:40pm on 12-26-91
Restarted DAS.

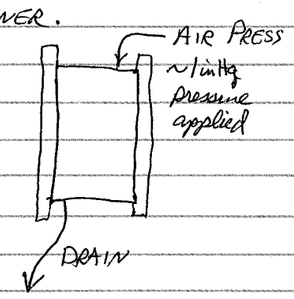
3-1-91 SS

8:15AM DAS TURNED OFF, ENOUGH DENSITOMETER READINGS OF THE SATURATED MEDIA Have been taken.

A small amount of water was sitting on top of the chamber at vent hole. So media is Saturated - some very-very small leakage past valve on the water feed line may have let this water in (it was less than a few cc's over several days)
SS 3-1-91

8:45AM PHOTO 3.25

8:50AM STARTED TRYING TO DRAIN SAMPLE OF WATER OUT OF BOTTOM OF CONTAINER.
SET UP LIKE:



12:00PM No water has come out of the beads - Overpressure increased to 2.5 in Hg

1:15PM STILL NO water comming OUT - increased overpressure to 3.0" Hg - Tensiometer reads +0.676 psi

3:30PM - ABOVE METHOD DID NOT "PUSH" OUT ANY WATER

4:30PM I was not able to get a water sample OUT - I turned off the COOLING Bath for over the weekend - DAS STILL OFF

3-13-91 The top port has had a connection to a water line (~ 3' head) for ~ 10 days trying to get water to flow through. A small amount of water has gone into container (~ 10cc) but no water has come through to bottom. May be evaporation.

Gave up on trying to extract water. STOPPED TEST 6.

TEST 6 MOTION FILE, "TEST6.MOT", AND CONFIGURATION FILE, "TEST6.CFG", ARE ATTACHED TO FOLLOWING PAGE. MOTION FILE DEFINES THE DENSITOMETER SAMPLE LOCATIONS. CONFIGURATION FILE CONTAINS THE SENSOR INFORMATION FOR CHANNEL Number, linearization, DMM FUNCTION (such as ohms or Volts), and reading units.

TEST 6


```
NPLC 1
Densitometer            DCV   10.0    .0001   402    KCPM     1
Barometer               DCV   10.0    .0001   100    PSIa     1
Tensiometer 4           DCV   10.0    .0001   104    PSIg     1
Tensiometer 5           DCV   10.0    .0001   105    PSIg     1
YSI Temperature 8       OHM   1e5     .01     207    °C       2
1.56817e-7
YSI Temperature 9       OHM   1e5     .01     208    °C       2
1.56817e-7
YSI Temperature 10      OHM   1e5     .01     209    °C       2
1.56817e-7
YSI Temperature300      OHM   1e5     .01     300    °C       2
1.05174e-7
YSI Temperature301      OHM   1e5     .01     301    °C       2
1.06893e-7
YSI Temperature302      OHM   1e5     .01     302    °C       2
1.05810e-7
X position              DCV   10.0    .01     400    Inches   10
Y position              DCV   10.0    .01     401    Inches   11
--------------------*****************************************************
*********
Channel label           DMM   DMM     DMM     Relay  Eng.     EQ
K3

                        Func. Range   Resol.  Numbers Units   Typ

Equation types:
0 - None......... Y = X
1 - Linear....... Y = K1 * X + K2
2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3 ) - 273
10- Linear....... Y = (X - K1) * 10 / (K2 - K1)  (X position - 1
11- Linear....... Y = (X - K1) * 10 / (K2 - K1)  (Y position - 1
```

END OF PERIODIC ENTRY (12) 3-13-91

3-13-91 The top port has had a connection to a water line (~ 3' head) for ~ 10 days trying to get water to flow through. A small amount of water has gone into container (~ 10cc) but no water has come through to bottom. May be evaporation.

Gave up on trying to extract water.
STOPPED TEST 6.

TEST 6 MOTION FILE, "TEST6.MOT", AND CONFIGURATION FILE, "TEST6.CFG", ARE ATTACHED TO FOLLOWING PAGE.
MOTION FILE DEFINES THE DENSITOMETER SAMPLE LOCATIONS. CONFIGURATION FILE CONTAINS THE SENSOR INFORMATION FOR CHANNEL Number, linearization, DMM FUNCTION (such as ohms or volts), and reading units.

PLC 1

ensitometer	DCV	10.0	.0001	402	KCPM	1	200.00	0.00	0
arometer	DCV	10.0	.0001	100	PSIa	1	2.4	-3	0
ensiometer 4	DCV	10.0	.0001	104	PSIg	1	-.8	1	0
ensiometer 5	DCV	10.0	.0001	105	PSIg	1	-.8	1	0
SI Temperature 8	OHM	1e5	.01	207	°C	2	1.0295e-3	2.3908e-4	
.56817e-7									
SI Temperature 9	OHM	1e5	.01	208	°C	2	1.0295e-3	2.3908e-4	
.56817e-7									
SI Temperature 10	OHM	1e5	.01	209	°C	2	1.0295e-3	2.3908e-4	
.56817e-7									
SI Temperature300	OHM	1e5	.01	300	°C	2	8.1289e-4	2.6963e-4	
.05174e-7									
SI Temperature301	OHM	1e5	.01	301	°C	2	8.3920e-4	2.6781e-4	
.06893e-7									
SI Temperature302	OHM	1e5	.01	302	°C	2	8.0865e-4	2.7029e-4	
.05810e-7									
position	DCV	10.0	.01	400	Inches	10	0.0582	2.4685	0
position	DCV	10.0	.01	401	Inches	11	6.2669	3.8480	0

****

annel label	DMM Func.	DMM Range	DMM Resol.	Relay Numbers	Eng. Units	EQ. Type	K1	K2
3								

quation types:
- None..... Y = X
- Linear..... Y = K1 * X + K2
- Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3) - 273.15
)- Linear..... Y = (X - K1) * 10 / (K2 - K1) (X position - No more than one of these)
.- Linear..... Y = (X - K1) * 10 / (K2 - K1) (Y position - No more than one of these)

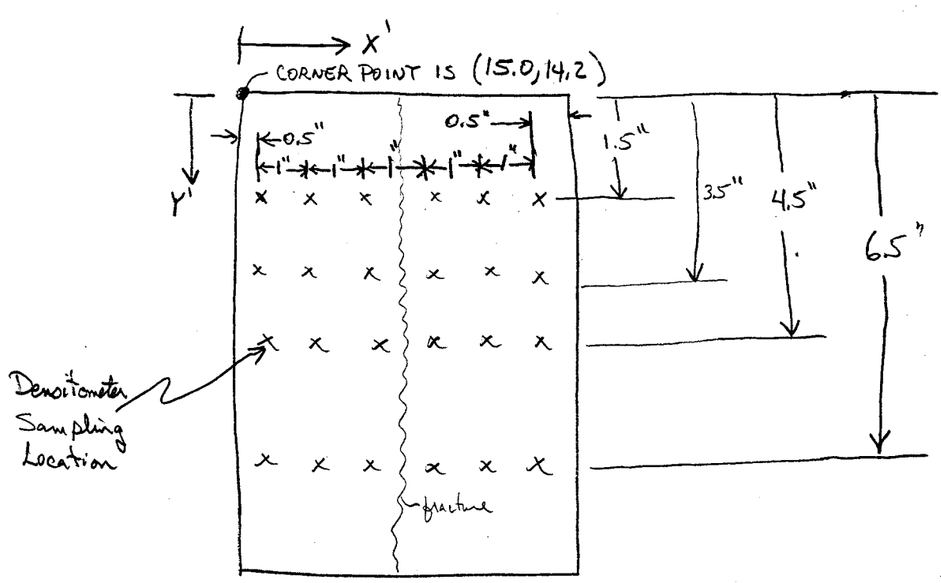
D OF PERIODIC ENTRY (12) 3-13-96
Steve Snedeman

END OF PERIODIC ENTRY (12) 3-13-96
Steve Friedman

TEST 6

DWELL TIME = 15
NPLC 800

			X'	Y'
5.000	22.000	- PARK Position		
5.000	22.000	- 1.5" THK ALUMINUM		
10.000	22.000	- 2.0" THK ALUMINUM		
15.500	15.700		0.5	1.5
16.500	15.700		1.5	
17.500	15.700		2.5	
18.500	15.700		3.5	
19.500	15.700		4.5	
20.500	15.700		5.5	
15.500	17.700		0.5	3.5
16.500	17.700		1.5	
17.500	17.700		2.5	
18.500	17.700		3.5	
19.500	17.700		4.5	
20.500	17.700		5.5	
15.500	18.700		0.5	4.5
16.500	18.700		1.5	
17.500	18.700		2.5	
18.500	18.700		3.5	
19.500	18.700		4.5	
20.500	18.700		5.5	
15.500	20.700		0.5	6.5
16.500	20.700		1.5	
17.500	20.700		2.5	
18.500	20.700		3.5	
19.500	20.700		4.5	
20.500	20.700		5.5	
X_{coord}	Y_{coord}			



Pages 1 through 137 of this Scientific Notebook were reviewed for compliance with QAP-001 in response to Corrective Action Request 94-02. Corrections and clarifications were made as appropriate. In some cases, the date of a change will reflect the date of this review rather than the date of the original Scientific Notebook entry.

Randy Folck
SwRI-QA
12/13/94

9/21/95 Notebook closed out
RH

2-2-90 JD

CALIBRATION OF POSITION SENSORS ON TRAVERSING SYSTEM (USED TO POSITION γ-BEAM DENSITOMETER ON TEST SECTION)

SENSOR TYPE - HOUSTON SCIENTIFIC
MODEL # 1850-040
P.N. 402707-0000-00
SPEC - LIN ± 0.1%
MAX TRAVEL = 40"

X-AXIS SER. # 6940-001
Y-AXIS " " 6940-002

10.000 VDC Power Supply (Position Sensor are voltage divider systems)

MEASURED POSITION	X-AXIS VOLTAGE	X-AXIS COMPUTER DISPLAY *	Y-AXIS VOLTAGE	Y-AXIS COMPUTER DISPLAY **
0.0"	1.2634 VDC	0.00"	8.7876 VDC	0.0053
5.0"	2.4703	5.0072"	7.5793 2-2-90 JD	~~4.9994~~ 5.0098
10.0"	3.6748	10.0042	6.3655	10.0187
15.0"	4.8829	15.0162		
18.0"	5.6025	18.0015		
10.0"	3.6769	~~9.99~~ 10.0129 JD 2-2-90		
0.0"	1.2655	0.0091		
20.0			3.9483	20.011
30.0			1.5337	29.994
34.0			0.5671	33.980
15.0			5.1519	15.036
0.0			8.7827	0.0258

* CONVERSION IN COMPUTER $X = 4.1482(V) - 5.2414$
** " " " $Y = -4.1341(\text{VDC}) + 36.3343$

CONTINUED FROM PAGE 57 2-2-90

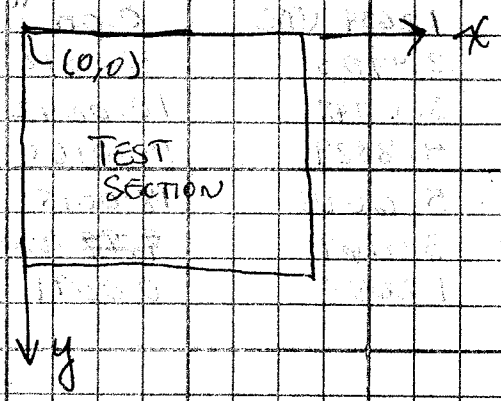
"MEASURED POSITION" WAS FROM A SCALE FIXED TO TRAVERSING SYSTEM

SCALE : L.S. STARRETT CO
ATHOL, MASS.
STEEL SCALE - 48" LONG
MODEL # C404R
2-2-90 ~~[illegible]~~ GRADUATED TO 1/64" (0.015")
4-4-90

VOLTAGE READINGS FROM: HP 3458A MULTIMETER
Sn # 2823A-02203

"COMPUTER DISPLAY READING" - VOLTAGE Reading from Multimeter is Transferred Via Digital Signal (IEEE-488) TO IBM PS-2, AND CONVERTED TO INCHES FOR DISPLAY.

4-4-90
~~RESULTS~~



4-4-90
RESULTS - POSITIONING ACCURACY REQUIRED - 0.10"

THE CALIBRATION CHECK SHOWED THE FEED BACK SENSOR ARE ~~[illegible]~~ 4-4-90 WITHIN THE ACCURACY REQUIRED

2-8-90 [illegible]

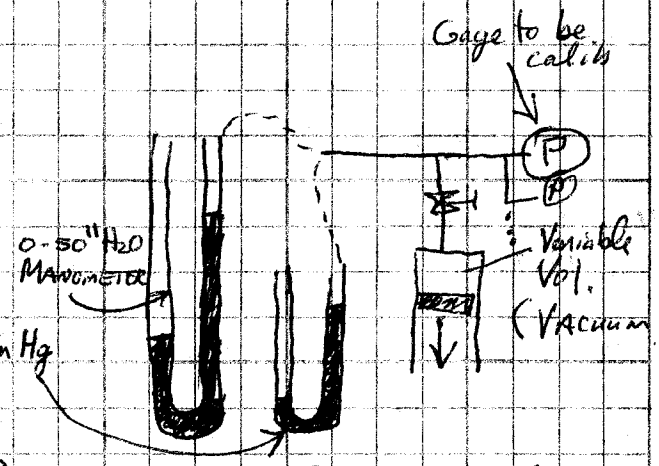
PRESSURE GAGE CALIBRATION

SETUP

Pressure Transducers

HONEYWELL MODEL 141PC05G

RANGE = 0 → 5 psig Vacuum



Pressure gages Honeywell 0-5 psig PART # 141 PC05G 8946 — Room Temp 71°F

RESULTS

MANOMETER PRESS Reading			CHANNEL 106 Ser # 0392-0003 VOLTS	PSI	CHANNEL 107 Ser # 0393-0102 VOLTS	PSI	Channel 108 Ser # 0393-0064 VOLTS	PSI	Channel 109 Ser # 0393-0118 VOLTS	PSI
0	0.0	a	1.282	-.0255	1.2934	-.0347	1.2744	-.0195	1.2964	-.0371
.428	11.85 in H_2O	b	1.8149	-.4520	1.8255	-.4606	1.8075	-.4461	1.8265	-.4609
.761	21.07 "	c	2.2260	-.7809	2.2360	-.7889	2.2183	-.7747	2.2347	-.7879
1.379	38.19 "	d	2.9994	-1.3996	3.0075	-1.4061	2.9905	-1.3925	3.0029	-1.4024
1.769	49.00 "	e	3.4886	-1.7909	3.4956	-1.7965	3.4788	-1.7831	3.4891	-1.7913
2.56	5.24 in Hg	f	4.5144	-2.6113	4.5185	-2.6147	4.5015	-2.6012	4.5084	-2.6067
3.29	6.73 in Hg	g	5.4207	-3.3363	5.4246	-3.3396	5.4075	-3.3259	5.4139	-3.3311
4.48	9.16 "	h	6.9201	-4.5358	6.9209	~~-5.4394~~ -4.5369	6.9049	-4.5236	6.9160	-4.5327

[illegible] 2-8-90 [illegible] 2-8-90

Supply Voltage to Pressure Transducers:

Ref = 10.001 VDC

Conversion from VDC → PSI : PSI = -0.80 VDC + 1.00

DD 2-19-90 DD 2-19-90

Continue Calib. of Pressure gages - calibrate the rest of the sensors not completed on 2-8-90

Time	Manometer Press. Reading	Channel 101 Ser # 0393-0133 "Tensiometer 1" VDC	DAS	Channel 102 0393-0131 "Tensiometer 2"	Channel 103 0393-0118 "Tensiometer 3"	Channel 104 0392-0004 "Tensiometer 4"	Channel 105 0393-0122 "Tensiometer 5"
17.59	0.0 in H_2O	1.2869 VDC	.0269 psi		(1)		
18:02	19.76 " DD 2-19-90	2.1612	-.7291		(2)		
18:05	36.36 "	2.9005	-1.3203		(3)		
18:06	47.05 "	3.3877	-1.7107		(4)		
18:09	5.14 in Hg	4.3971	-2.5194		(5)		
18:10	7.47 "	5.8380	-3.6718		(6)		
18:11	10.09 "	7.4544	-4.9623		(7)		
18:14	0.0	1.2828	-0.0263		(8)		

See attached sheet for Recorded values.

From Calib. data on p 59 Max. Difference between the manometer reading and sensor reading is:

Cal. Point	Max Diff
(a)	.04
(b)	.03
(c)	.03
(d)	.03
(e)	.03
(f)	.05
(g)	.05
(h)	.05

		Manometer Reading	Maximum Diff (Sensor - Manometer)
1	Data taken: 02-19-1990 17:59:45 Tensiometer 1 -0.0335 PSIg Tensiometer 2 -0.0169 PSIg Tensiometer 3 0.0078 PSIg Tensiometer 4 -0.0059 PSIg Tensiometer 5 -0.0189 PSIg	0.0 psig (0 in H_2O)	.03 psig
2	Data taken: 02-19-1990 18:02:24 Tensiometer 1 -0.7292 PSIg Tensiometer 2 -0.7243 PSIg Tensiometer 3 -0.7019 PSIg Tensiometer 4 -0.7148 PSIg Tensiometer 5 -0.7255 PSIg	0.71 psig (19.76 in. H_2O)	.02
3	Data taken: 02-19-1990 18:04:53 Tensiometer 1 -1.3203 PSIg Tensiometer 2 -1.3219 PSIg Tensiometer 3 -1.3013 PSIg Tensiometer 4 -1.3141 PSIg Tensiometer 5 -1.3230 PSIg	1.31 psig (36.36 in H_2O)	.01
4	Data taken: 02-19-1990 18:06:25 Tensiometer 1 -1.7099 PSIg Tensiometer 2 -1.7098 PSIg Tensiometer 3 -1.6901 PSIg Tensiometer 4 -1.7029 PSIg Tensiometer 5 -1.7109 PSIg	1.70 psig (47.05" H_2O)	.01
5	Data taken: 02-19-1990 18:08:44 Tensiometer 1 -2.5171 PSIg Tensiometer 2 -2.5202 PSIg Tensiometer 3 -2.5023 PSIg Tensiometer 4 -2.5155 PSIg Tensiometer 5 -2.5217 PSIg	2.51 psig (5.14" Hg)	.01
6	Data taken: 02-19-1990 18:10:39 Tensiometer 1 -3.6692 PSIg Tensiometer 2 -3.6677 PSIg Tensiometer 3 -3.6520 PSIg Tensiometer 4 -3.6652 PSIg Tensiometer 5 -3.6699 PSIg	3.65 psig (7.47" Hg)	.02
7	Data taken: 02-19-1990 18:11:56 Tensiometer 1 -4.9612 PSIg Tensiometer 2 -4.9664 PSIg Tensiometer 3 -4.9532 PSIg Tensiometer 4 -4.9645 PSIg Tensiometer 5 -4.9688 PSIg	4.93 psig (10.09 in Hg)	.04
8	Data taken: 02-19-1990 18:14:35 Tensiometer 1 -0.0263 PSIg Tensiometer 2 -0.0170 PSIg Tensiometer 3 0.0077 PSIg Tensiometer 4 -0.0061 PSIg Tensiometer 5 -0.0189 PSIg	0 psig (0.0 in H_2O)	.03 psig

Results

All of the pressure sensor readings are within ±1% of the manometer readings over the calibration range - for ~~our tests~~ Separate Effects experiments this is acceptable. 4-4-90

Therefor no individual calibration is required

(NOTE - The sensor accuracy could be improved to ~ ± 0.5% FS by removing offset @ 0 psig)

THERMISTOR CALIBRATION CHECK

SETUP: LIQUID BATH – NESLAB RTE-4 REFRIGERATED CIRCULATION BATH.
2-13-90
REFERENCE TEMPERATURE – BROOKLYN THERMOMETER CO.
Hg in Glass Thermometers w/Calib. Certificates
THERMISTORS ARE Read THRU HP 3458A MULTIMETER

THERMISTORS – YSI INC. MODEL # 031-46031-4-RPS-120-ST

Hg in Glass Thermometer readings

	CAL. TEMP				
	① 14:05	② 14:25	③ 14:38	④ 15:07	⑤ 15:19
THERMISTOR SENSOR	53.1°F = 11.72°C (11.6°C TRUE) 32.0 ICE CHECK	87.65°F 30.9°C 32.0 ✓	141.6°F 60.9°C 32.0 ✓	194.2°F 90.3°C 32.0 ✓	32.0°F ICE BATH

YSI Temperature 1	11.6074 °C	30.9256 °C	60.8192 °C	90.1394 °C	-0.0511 °C
YSI Temperature 2	11.6584 °C	30.9850 °C	60.8762 °C	90.2073 °C	-0.0032 °C
YSI Temperature 3	11.7487 °C	31.0881 °C	60.9154 °C	90.2250 °C	0.0774 °C
YSI Temperature 4	11.6835 °C	30.9917 °C	60.9152 °C	90.2484 °C	0.0146 °C
YSI Temperature 5	11.6558 °C	30.9769 °C	60.8747 °C	90.1931 °C	0.0036 °C
YSI Temperature 6	11.6878 °C	31.0002 °C	60.8477 °C	90.1206 °C	-0.0001 °C
YSI Temperature 7	11.7236 °C	31.0279 °C	60.8454 °C	90.1043 °C	0.0737 °C
YSI Temperature 8	11.7024 °C	31.0492 °C	60.9134 °C	90.2455 °C	0.0393 °C
YSI Temperature 9	11.6222 °C	30.9692 °C	60.8658 °C	90.2439 °C	-0.0736 °C
YSI Temperature 10	11.7062 °C	31.0081 °C	60.8977 °C	90.1914 °C	0.0894 °C
YSI Temperature 11	11.7466 °C	31.0755 °C	60.8898 °C	90.1596 °C	0.0410 °C
YSI Temperature 12	11.7161 °C	31.0607 °C	60.8896 °C	90.1690 °C	0.0066 °C
YSI Temperature 13	11.7689 °C	31.0993 °C	60.9262 °C	90.2102 °C	0.0617 °C
YSI Temperature 14	11.7856 °C	31.1199 °C	60.8959 °C	90.2076 °C	0.0829 °C
YSI Temperature 15	11.7659 °C	31.0795 °C	60.8871 °C	90.1938 °C	0.0537 °C
YSI Temperature 16	11.6989 °C	31.0554 °C	60.8900 °C	90.2484 °C	-0.0120 °C
YSI Temperature 17	11.7384 °C	31.0859 °C	60.9314 °C	90.2752 °C	0.0409 °C
YSI Temperature 18	11.6907 °C	31.0511 °C	60.8657 °C	90.2373 °C	-0.0442 °C
YSI Temperature 19	11.6931 °C	31.0464 °C	60.8803 °C	90.2060 °C	-0.0157 °C
YSI Temperature 20	11.7313 °C	31.0929 °C	60.9482 °C	90.2845 °C	0.0175 °C

THE ABOVE DATA WERE RECORDED FROM THE HP3458A MULTIMETER AND SCALED TO READ IN °C

$$T(°C) = \frac{1}{\left(K1 + K2 * Ln(\Omega) + K3 * Ln(\Omega)^3\right)} - 273.15$$

$K1 = 1.0295 \times 10^{-3}$, $K2 = 2.3908 \times 10^{-4}$, $K3 = 1.56817 \times 10^{-7}$

Ω - Sensor Resistance in Ω

2-13-90

Thermometer

①	ASTM-	63F	8009-1311	
②	"	"	" "	
③	"	65F	7903-3787	
④	"	66F	8003-799	
⑤	Ice Bath			

SEE CERTIFICATES OF CALIB. - ATTACHED TO THIS PAGE (COPIES) (MAC WOOD HAS ORIGINALS)

Results:

Mercury in glass thermometer could be read to ~ 0.1°F accuracy.

The ice point readings are all within ± 0.1°C of 0.0°C

ALL OF THE OTHER Readings are within ±0.2°C OF THE Hg in glass thermometers.

Accuracy required is ± 0.5°C so if calibration check shows individual sensor calibration is not required.

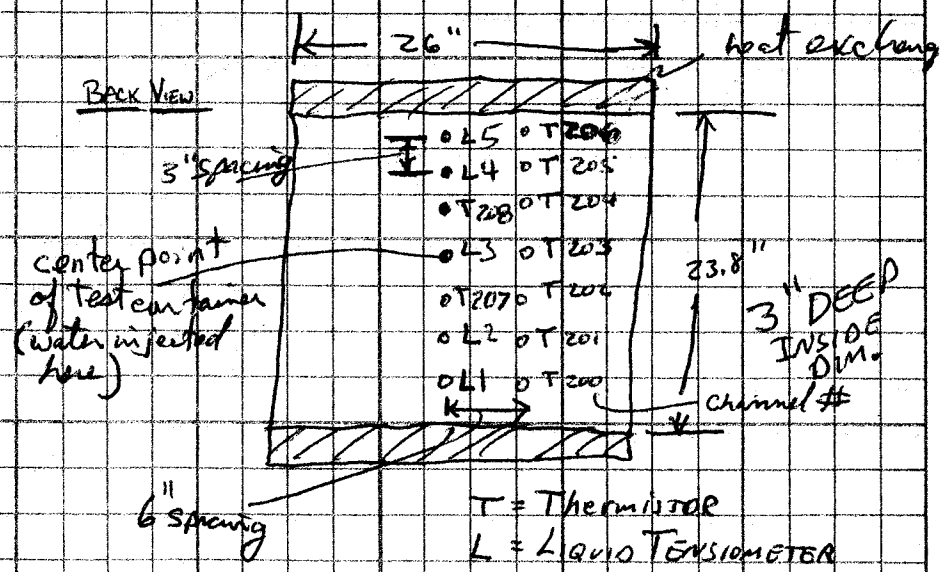
TEST DESCRIPTION - TEST 1 SEPERATE EFFECTS EXPMTS
160μm Beads in 2'x2'x3" test section. Pack dry beads into test section then inject water into center @ 40% saturation and monitor movement (no extend heating) - then put in water for 60% & 80%

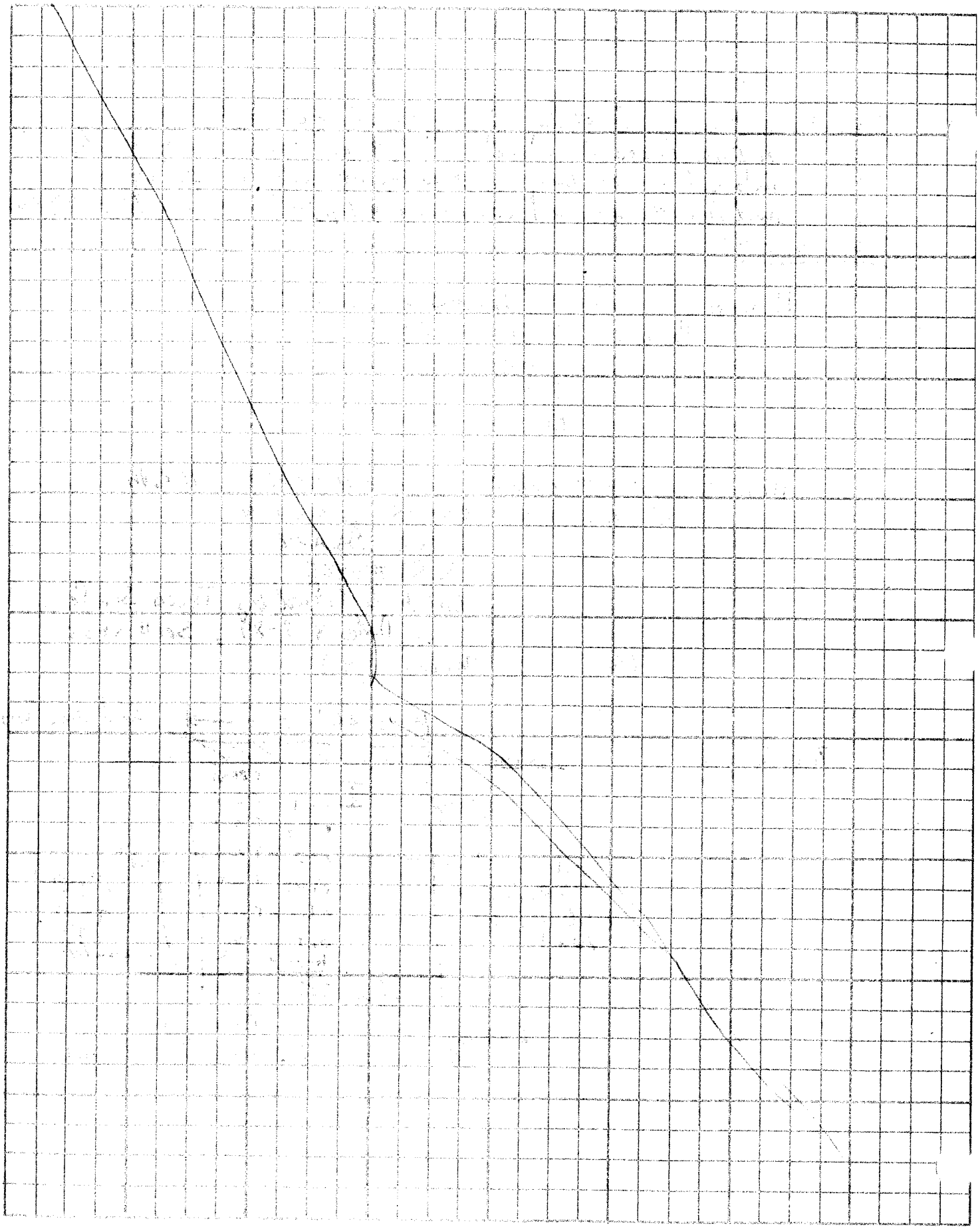
TEST SETUP:

PLACED "160 μm dia" beads in TEST SECTION
BEADS - CATAPHOTE INC
CLASS - 4-A
SIZE 812
BATCH - 91004

WEIGHT OF BEADS ADDED TO CONTAINER = 102 lb
WEIGHED WITH OHAUS SCALE CORP.
3-BEAM BALANCE
SwRI #5485
Calib. Certified by Texas Scale
Date 8-9-89, Ser # 5485
(SCALE - DON MASSEY'S - 04)

TEST SECTION:





2-20-90 JJ

12:14 PM TURNED ON DATA SYSTEM TO TAKE READINGS ON TEST SECTION WITH NO WATER - THIS WILL ESTABLISH THE "0 SATURATION" ~~CONDITIONS~~ READING OF THE DENSIOMETER AT EACH SAMPLE POINT. SEE TEST1 MOT FILE FOR SAMPLE LOCATIONS

2-21-90 JJ

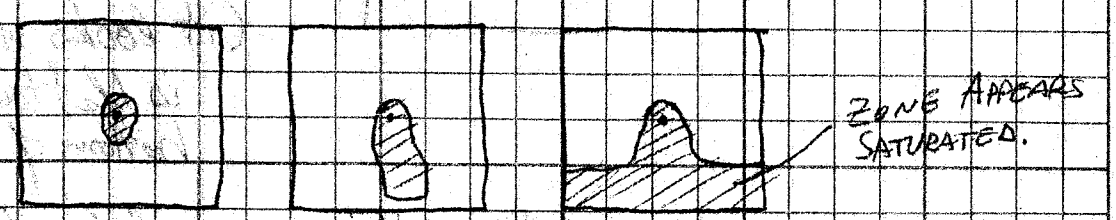
~8:00 AM TURNED OFF DAS TO INJECT WATER INTO THE TEST SECTION.

THE WATER WAS INJECTED INTO THE CENTER OF THE TEST SECTION (AT THE LOCATION OF TENSIOMETER 3. I initially tried to inject the water through the porous cup on the tensiometer but it was much to slow (~30ml per Hour under ~2' water head). I injected the water through the back of the tensiometer fitting

WATER used was DI FROM NRC LAB ~13MΩ

BY 1:12 pm ~~[illegible]~~ 3875ml H_2O added

WATER FILLED AND FLOWED INTO Beads as follows

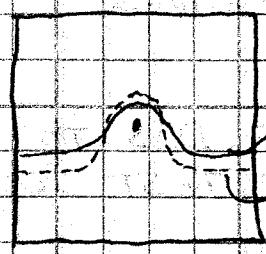


after a small amount of water was added it no longer spread spherically but appeared to have enough "head" to overcome capilary forces. After this point was reached the water dropped straight down to the bottom of the container and then started to spread along the bottom of the container

2-21-90 ll
13:41 Restarted DAS
all tensiometer have just been filled with water

Photo 1 @ 2:36 pm (Y-Beam in middle of Test Se
2 @ 3:00 pm

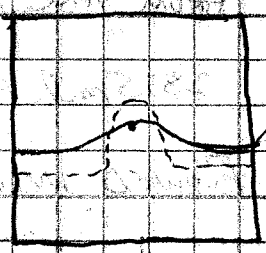
4:22 PM



New water Front (moved ~1" up)
ORIGIONAL SATURATION LINE

2-22-90 ll
8:45 AM STOPPED DAS ~Restarted @ 8:55 am

Photo #3 8:49 am f = 5.6
#4 " f = 11



water front is ~2" above original saturation line
(it looks like water level is flattening out on the bottom of the container

11:55 Turned DAS off & on to look @ Data

Photo #5 11:56 am f = 5.6 1/4 entire test section
6 " " 1/8 " " "
7 " " 1/4 Closer up
8 " " 1/8 " "

2-22-90 (CON'T) SS

2:28 pm DAS turned off & on to check data - O.K.

2-23-90 SS

8:42 AM DAS off & ON - DATA looks fine
- No visual changes to test section
- changed sample interval to 1 Hour from 30 min.

2-27-90 SS

~2:00 pm Checked on system - everything O.K
No VISUAL CHANGES

2-28-90 SS

10:50 AM Turned DAS off & Back on after check data

Tensiometer # 4 and #5 appear to have dried out since they are no longer @ 5 psig suction (at full scale of sensor) - I flushed out and re-filled these tensiometers.

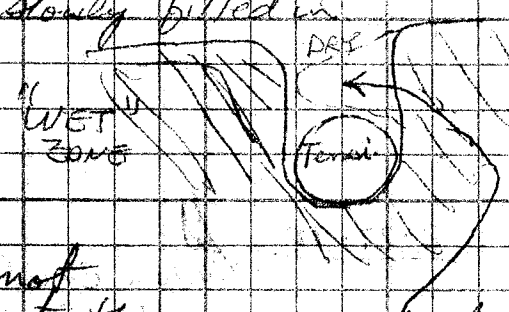
3-1-90

4:38 pm Turned off DAS to inject more water into the test container. (to obtain 100% Saturation point for densitometer)

As the water level reached Tensiometer #4 it's reading went from -1.5 psig to 0 psig to positive pressure

7600 ml of H_2O Added

(Note - as water level passed the Tensimeters it left a "wake" which slowly filled in



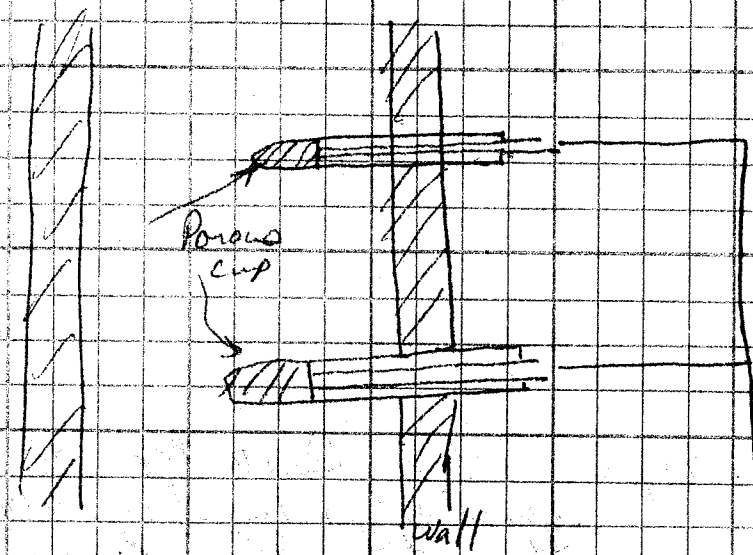
The very top layer was not saturated - only ~ ½" at the top remained dry - This will not effect the Densitometer readings since the highest level read was at y = 3" below the top.

water later filled in from sides

8:30 pm DAS Turned back on to obtain the 100% saturation reading at each of the Densitometer sampling locations.

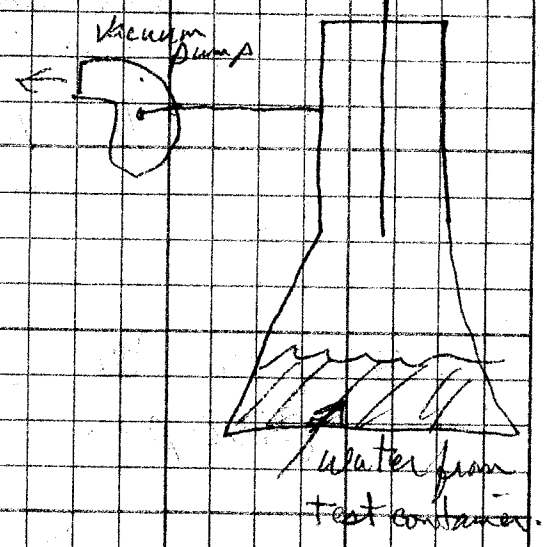
3-2-90 SJ
8:00AM Turned off DAS

~~To~~ For future tests, we will need to desaturate the ~~sa~~ media after it has been saturated. To see how this occurs water was pulled by vacuum out of Tensiometer Ports #1 and 2.



FROM 8:00AM TO 1:50pm

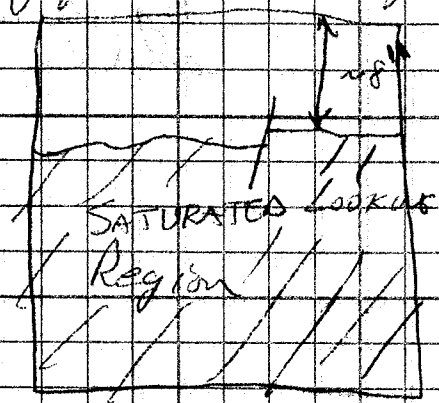
3065 ml was removed from the test section.



1:41pm Photo #9 f5.6 1/4 sec
#10 f11 1 sec

3-2-90 (Con't) DS

As the water was removed from the test container a "saturation line" developed. ~~It~~ The media appeared saturated below this line and relatively dry above the line. After the 3065 ml had been removed, the "saturation" line was ~ 1/3 of the way from the top of the container (to the bottom).



1:50 pm DAS Restarted to determine the level of saturation above and below the "saturation" line. Also to see if since the beads above the line were some what wet, if capilary action will now create a uniform water distribution.

(The tensiometers were refilled with water just before the DAS was restarted.)

3-3-90 DS

6:00 pm Turned off DAS

SHUT DOWN TEST #1

3-3-90 dd

SCALE FACTORS AND UNITS FOR PRESSURE, TEMPERATURE, AND DENSITY SENSORS.

TEST1.CFG

NPLC 1

Channel label	DMM Func.	DMM Range	DMM Resol.	Relay Numbers	Eng. Units	EQ. Type	K1	K2	K3
Densitometer	DCV	10.0	.0001	402	RelSat	1	34.375	-68.75	0
Barometer	DCV	10.0	.0001	100	PSIa	1	2.4	-3	0
Tensiometer 1	DCV	10.0	.0001	101	PSIg	1	-.8	1	0
Tensiometer 2	DCV	10.0	.0001	102	PSIg	1	-.8	1	0
Tensiometer 3	DCV	10.0	.0001	103	PSIg	1	-.8	1	0
Tensiometer 4	DCV	10.0	.0001	104	PSIg	1	-.8	1	0
Tensiometer 5	DCV	10.0	.0001	105	PSIg	1	-.8	1	0
YSI Temperature 1	OHM	1e5	.01	200	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 2	OHM	1e5	.01	201	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 3	OHM	1e5	.01	202	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 4	OHM	1e5	.01	203	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 5	OHM	1e5	.01	204	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 6	OHM	1e5	.01	205	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 7	OHM	1e5	.01	206	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 8	OHM	1e5	.01	207	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 9	OHM	1e5	.01	208	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
YSI Temperature 10	OHM	1e5	.01	209	°C	2	1.0295e-3	2.3908e-4	1.56817e-7
X position	DCV	10.0	.01	400	Inches	10	0.0582	2.4685	0
Y position	DCV	10.0	.01	401	Inches	11	6.2669	3.8480	0

Equation types:

0 - None..... Y = X
1 - Linear..... Y = K1 * X + K2
2 - Thermistor... Y = 1/(K1 + K2 * Ln(X) + K3 * Ln(X)^3) - 273.15
10- Linear..... Y = (X - K1) * 10 / (K2 - K1) (X position - No more than one of these)
11- Linear..... Y = (X - K1) * 10 / (K2 - K1) (Y position - No more than one of these)

3-3-90

DENSITOMETER READING POSITIONS FOR TEST 1.

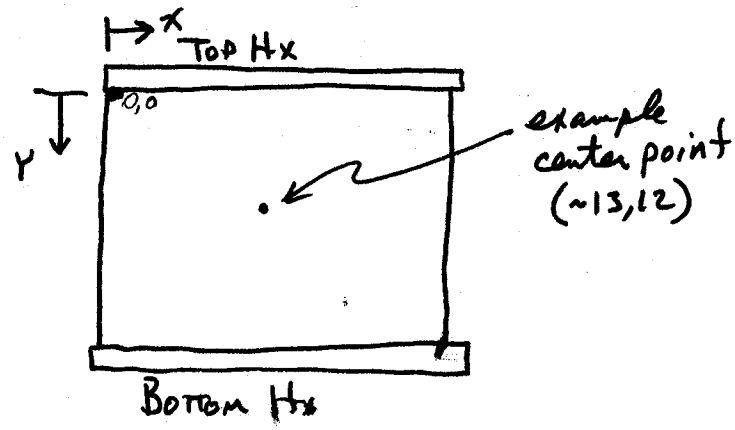
TEST1.MOT

```
DWELL TIME =    30
NPLC 120
 5.000   -4.000
 5.000   -4.000
11.000   -4.000
 5.000    3.000
 5.000    6.000
 5.000    9.000
 5.000   12.000
 5.000   15.000
 5.000   18.000
 5.000   21.000
 9.000   21.000
 9.000   18.000
 9.000   15.000
 9.000   12.000
 9.000    9.000
 9.000    6.000
 9.000    3.000
11.000    3.000
11.000    6.000
11.000    9.000
11.000   12.000
11.000   15.000
11.000   18.000
11.000   21.000
15.000   21.000
15.000   18.000
15.000   15.000
15.000   12.000
15.000    9.000
15.000    6.000
15.000    3.000
17.000    3.000
17.000    6.000
17.000    9.000
17.000   12.000
17.000   15.000
17.000   18.000
17.000   21.000
```

AVERAGING TIME = 2 SEC
" " "

← DENSITOMETER PARK POSITION (X & Y COORDS.)
← 1ST SAMPLE POINT (γ-BEAM CAL = 2.250" ALUM.)
← 2nd " " (" " = 2.755" ")

X & Y COORDS OF SAMPLE POINTS ON TEST CONTAINER



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