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Scientific Notebook No. 643:Laboratory Tests to Verify the Water Transport Models Added to the Flow3D Computational Fluid Dynamics (CFD) Code (02/20/2004 through 04/15/2005

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

20.06002.01.091

CNWRA
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COPY 643

Steve Svedeman

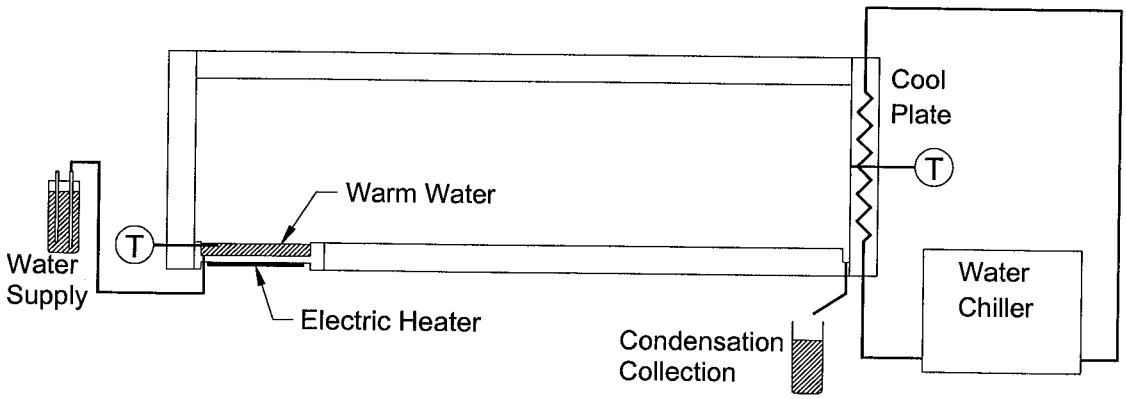
2-20-2004 Steve Svedeman SS

CFD Water Transport Model Verification Testing

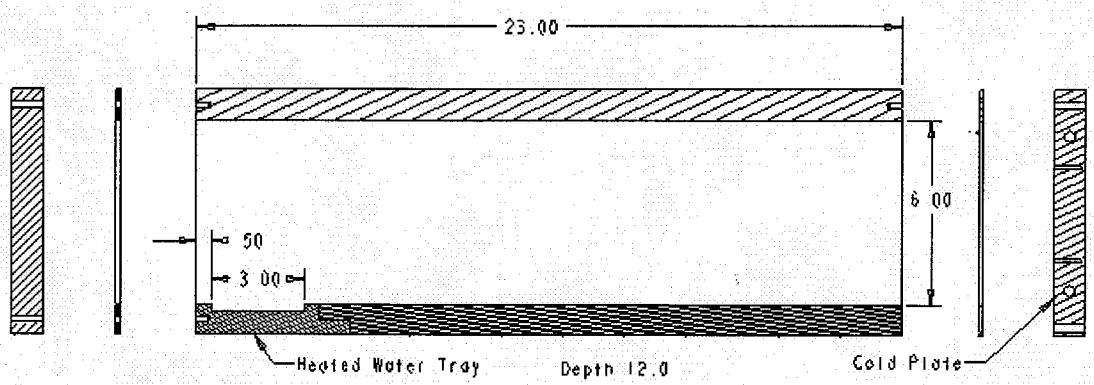
Test Objective: Laboratory tests will be conducted to verify the water transport models added to the Flow3D computational fluid dynamics (CFD) code. The models were added to simulate water evaporation at a heat source and water condensation on cool surfaces. Tests will be conducted to measure water evaporation and water condensation rates in a natural convection flow. Comparisons will be made between the measured water transport rates and the rates predicted by the CFD model.

Test Plan: Tests will be conducted to measure the amount of water transported from the water source to the condensation plate. Tests will be conducted by varying the heat rate to the water source and measuring the steady state temperatures and water transport rate.

Test Rig: A schematic of the test rig is given below. The enclosure is made of polycarbonate sheet, acrylic sheet, and aluminum. Water is condensed and collected on the aluminum plate shown on the right side of the test enclosure. Water evaporates from the pan shown on the bottom-left of the enclosure. Instrumentation is included to measure the evaporator (water) temperature, condenser temperature, air temperatures, and the water condensation rate.



Schematic diagram of the test rig.



Dimensions of the test chamber. The test chamber depth is 12.0 inches.

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Calibration Check on thermocouples

Objective: check the thermocouples that will be used to measure temperature in the test chamber.

Method: Compare thermocouple temperature readings at several temperatures to a calibrated thermometer

Equipment:

- Thermocouples - Type K, OMEGA Type K - Cat. No. 5TC-TT-K-30-72
- Calibrated thermometer, ASTM 91C, 20 to 50°C, 0.1°C increments, S/N 1709, Cal Due 3-5-04
- Fisher stirred water bath
- Fluke data logger, Hydra, S/N 5832651
- Fluke data logger software & personal computer
- Excel software to average temperature readings & tabulate results

Procedure:

- Thermocouples ~~conne~~ wired to Fluke 2-20-2004 SS
- Thermocouples and calibrated thermometer were placed in the water bath a different temperatures (20°C to 50°C)
- when water bath reached a stable temperature, the reading of the calibrated thermometer was recorded. The Fluke data logger was then used to record the thermocouple readings ~ 10 readings.
- the thermocouple average temperature readings were then compared to the calibrated thermometer readings.

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DATA FILE WITH THERMOCOUPLE READINGS	CALIBRATED THERMOMETER READING
TC_Cal1.DAT	20.7°C
" 2.DAT	28.65°C
" 3.DAT	32.5°C
" 4.DAT	44.5°C
" 5.DAT	47.65°C
" 6.DAT	39.3°C

The data from the above files are attached on the following pages

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TC_cal1.dat													
	Temp Std	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 10	Chan 11	Chan 12
	(C)	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"
		20.6	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.6	20.6
		20.6	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.6	20.7	20.6	20.6
		20.6	20.7	20.7	20.7	20.7	20.7	20.6	20.7	20.6	20.7	20.6	20.6
		20.6	20.7	20.7	20.6	20.7	20.7	20.6	20.7	20.6	20.7	20.6	20.6
		20.7	20.7	20.7	20.6	20.7	20.7	20.6	20.7	20.6	20.7	20.6	20.6
		20.6	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.6	20.7	20.6	20.6
		20.6	20.7	20.7	20.7	20.7	20.7	20.6	20.7	20.6	20.7	20.6	20.6
Avg Reading (C)	**20.7**	20.6143	20.7	20.7	20.6714	20.7	20.7	20.6429	20.7	20.6143	20.7	20.6	20.6
Tstd-T (C)		0.09	0.00	0.00	0.03	0.00	0.00	0.06	0.00	0.09	0.00	0.10	0.10

TC_cal2.dat													
	Temp Std	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 10	Chan 11	Chan 12
	(C)	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"
		28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.5	28.6
		28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6
		28.6	28.6	28.6	28.6	28.6	28.6	28.7	28.6	28.7	28.6	28.6	28.6
		28.6	28.7	28.6	28.7	28.6	28.6	28.7	28.7	28.7	28.6	28.6	28.6
		28.6	28.7	28.6	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.6	28.6
		28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.6	28.7
		28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.6	28.7
		28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.6	28.7
		28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.6	28.7
		28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7
		28.7	28.7	28.7	28.7	28.7	28.7	28.8	28.8	28.8	28.7	28.7	28.7
Avg Reading (C)	**28.65**	28.6545	28.6727	28.6545	28.6727	28.6636	28.6636	28.6909	28.6818	28.6909	28.6636	28.6091	28.6545
Tstd-T (C)		0.00	-0.02	0.00	-0.02	-0.01	-0.01	-0.04	-0.03	-0.04	-0.01	0.04	0.00

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TC_cal3.dat													
	Temp Std	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 10	Chan 11	Chan 12
	(C)	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"
		32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.3	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.5	32.4	32.3	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.3	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.5	32.4	32.3	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.5	32.5	32.4	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.3	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.5	32.4	32.4	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.5	32.4	32.4	32.4
		32.4	32.4	32.4	32.4	32.4	32.4	32.5	32.4	32.5	32.4	32.4	32.4
		32.4	32.4	32.4	32.5	32.4	32.4	32.5	32.4	32.5	32.4	32.4	32.4
Avg Reading (C)	**32.5**	32.4	32.4	32.4	32.41	32.4	32.4	32.47	32.4	32.5	32.41	32.35	32.4
Tstd-T (C)		0.10	0.10	0.10	0.09	0.10	0.10	0.03	0.10	0.00	0.09	0.15	0.10

TC_cal4.dat													
	Temp Std	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 10	Chan 11	Chan 12
	(C)	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"
		44.4	44.4	44.4	44.5	44.4	44.4	44.5	44.4	44.6	44.5	44.3	44.5
		44.4	44.4	44.4	44.5	44.4	44.4	44.5	44.4	44.6	44.5	44.3	44.4
		44.4	44.4	44.4	44.5	44.4	44.4	44.5	44.4	44.6	44.5	44.3	44.4
		44.4	44.4	44.4	44.4	44.4	44.4	44.5	44.4	44.5	44.4	44.3	44.4
		44.4	44.4	44.4	44.4	44.4	44.3	44.5	44.4	44.5	44.4	44.3	44.4
		44.4	44.4	44.4	44.4	44.3	44.3	44.5	44.4	44.5	44.4	44.3	44.4
		44.4	44.4	44.4	44.4	44.3	44.3	44.5	44.4	44.5	44.4	44.3	44.4
		44.4	44.3	44.3	44.4	44.3	44.3	44.5	44.4	44.5	44.4	44.3	44.4
		44.3	44.3	44.3	44.4	44.3	44.3	44.4	44.3	44.5	44.4	44.3	44.4
		44.3	44.3	44.3	44.4	44.3	44.3	44.4	44.3	44.4	44.4	44.2	44.3
		44.3	44.3	44.3	44.3	44.3	44.3	44.4	44.3	44.4	44.3	44.2	44.3
Avg Reading (C)	**44.5**	44.3727	44.3636	44.3636	44.4182	44.3455	44.3364	44.4727	44.3727	44.5091	44.4182	44.2818	44.3909
Tstd-T (C)		0.13	0.14	0.14	0.08	0.15	0.16	0.03	0.13	-0.01	0.08	0.22	0.11

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TC_cal5.dat													
	Temp Std	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 10	Chan 11	Chan 12
	(C)	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"
		47.5	47.5	47.5	47.5	47.5	47.4	47.6	47.5	47.7	47.5	47.4	47.6
		47.5	47.5	47.5	47.5	47.5	47.5	47.6	47.5	47.6	47.6	47.4	47.6
		47.5	47.5	47.5	47.5	47.5	47.5	47.6	47.5	47.7	47.6	47.4	47.5
		47.5	47.5	47.5	47.5	47.5	47.5	47.6	47.5	47.7	47.6	47.4	47.6
		47.5	47.5	47.5	47.6	47.5	47.5	47.6	47.5	47.7	47.6	47.5	47.5
		47.5	47.5	47.5	47.6	47.5	47.5	47.6	47.5	47.7	47.6	47.5	47.6
		47.6	47.5	47.5	47.6	47.5	47.5	47.7	47.5	47.7	47.6	47.5	47.6
		47.6	47.6	47.5	47.6	47.5	47.5	47.7	47.6	47.7	47.6	47.5	47.6
		47.6	47.5	47.5	47.6	47.5	47.5	47.7	47.6	47.7	47.6	47.5	47.6
		47.6	47.6	47.5	47.6	47.5	47.5	47.7	47.5	47.7	47.6	47.5	47.6
Avg Reading (C)	**47.65**	47.54	47.52	47.5	47.56	47.5	47.49	47.64	47.52	47.69	47.59	47.46	47.58
Tstd-T (C)		0.11	0.13	0.15	0.09	0.15	0.16	0.01	0.13	-0.04	0.06	0.19	0.07

TC_cal6.dat													
	Temp Std	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Chan 7	Chan 8	Chan 9	Chan 10	Chan 11	Chan 12
	(C)	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"	"C"
		39.3	39.3	39.3	39.3	39.3	39.2	39.3	39.3	39.4	39.3	39.2	39.3
		39.3	39.3	39.3	39.3	39.2	39.2	39.3	39.2	39.4	39.3	39.2	39.2
		39.3	39.2	39.2	39.3	39.3	39.2	39.3	39.2	39.3	39.3	39.2	39.3
		39.2	39.2	39.3	39.3	39.2	39.2	39.3	39.2	39.3	39.3	39.2	39.2
		39.2	39.3	39.3	39.3	39.3	39.2	39.3	39.2	39.3	39.3	39.2	39.3
		39.2	39.3	39.3	39.3	39.3	39.2	39.3	39.2	39.3	39.3	39.2	39.3
		39.3	39.3	39.3	39.3	39.2	39.2	39.3	39.2	39.3	39.3	39.2	39.3
		39.3	39.3	39.3	39.3	39.2	39.2	39.3	39.3	39.3	39.3	39.2	39.3
		39.3	39.3	39.3	39.3	39.3	39.2	39.3	39.2	39.4	39.3	39.2	39.2
		39.2	39.3	39.3	39.3	39.3	39.2	39.3	39.3	39.4	39.3	39.2	39.3
Avg Reading (C)	**39.3**	39.26	39.28	39.29	39.3	39.26	39.2	39.3	39.23	39.34	39.3	39.2	39.27
Tstd-T (C)		0.04	0.02	0.01	0.00	0.04	0.10	0.00	0.07	-0.04	0.00	0.10	0.03

2-20-2004

Thermocouple Calibration Check
Channels 1-12 were Type K Thremocouples
Channel 13 was a thermistor, 10,000 ohm at 25 C.
Standard thremometer was a mercury in glass thermometer

	Average of ~10 Temperature Reading												
Temp Std (C)	Chan 1 "C"	Chan 2 "C"	Chan 3 "C"	Chan 4 "C"	Chan 5 "C"	Chan 6 "C"	Chan 7 "C"	Chan 8 "C"	Chan 9 "C"	Chan 10 "C"	Chan 11 "C"	Chan 12 "C"	Chan 13 "C"
20.70	20.61	20.70	20.70	20.67	20.70	20.70	20.64	20.70	20.61	20.70	20.60	20.60	20.74
28.65	28.65	28.67	28.65	28.67	28.66	28.66	28.69	28.68	28.69	28.66	28.61	28.65	28.74
32.50	32.40	32.40	32.40	32.41	32.40	32.40	32.47	32.40	32.50	32.41	32.35	32.40	32.52
39.30	39.26	39.28	39.29	39.30	39.26	39.20	39.30	39.23	39.34	39.30	39.20	39.27	39.36
44.50	44.37	44.36	44.36	44.42	44.35	44.34	44.47	44.37	44.51	44.42	44.28	44.39	44.51
47.65	47.54	47.52	47.50	47.56	47.50	47.49	47.64	47.52	47.69	47.59	47.46	47.58	47.63

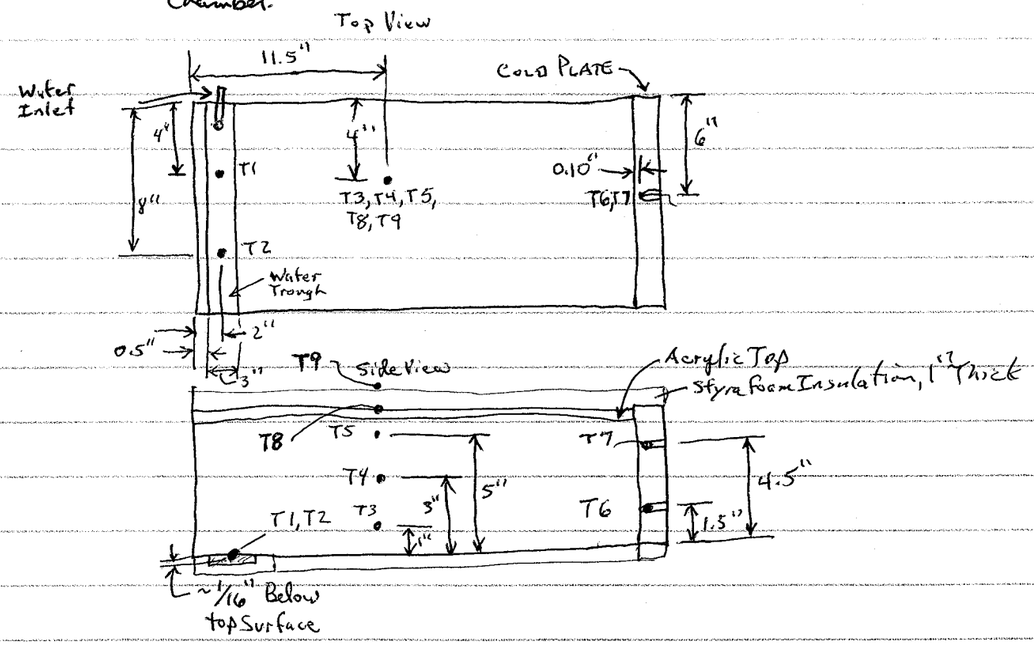
	Difference Between "Standard Temperature" and Recorded Temperature														
Temp Std (C)	Chan 1 "C"	Chan 2 "C"	Chan 3 "C"	Chan 4 "C"	Chan 5 "C"	Chan 6 "C"	Chan 7 "C"	Chan 8 "C"	Chan 9 "C"	Chan 10 "C"	Chan 11 "C"	Chan 12 "C"	Chan 13 "C"	Max. Diff "C"	Min. Diff "C"
20.70	0.09	0.00	0.00	0.03	0.00	0.00	0.06	0.00	0.09	0.00	0.10	0.10	-0.04	0.10	-0.04
28.65	0.00	-0.02	0.00	-0.02	-0.01	-0.01	-0.04	-0.03	-0.04	-0.01	0.04	0.00	-0.09	0.04	-0.09
32.50	0.10	0.10	0.10	0.09	0.10	0.10	0.03	0.10	0.00	0.09	0.15	0.10	-0.02	0.15	-0.02
39.30	0.04	0.02	0.01	0.00	0.04	0.10	0.00	0.07	-0.04	0.00	0.10	0.03	-0.06	0.10	-0.06
44.50	0.13	0.14	0.14	0.08	0.15	0.16	0.03	0.13	-0.01	0.08	0.22	0.11	-0.01	0.22	-0.01
47.65	0.11	0.13	0.15	0.09	0.15	0.16	0.01	0.13	-0.04	0.06	0.19	0.07	0.02	0.19	-0.04

Result: All measured temperatures were within 0.22 C of the standard thermometer.
This is acceptable accuracy for the tests.

2-20-2004 SS

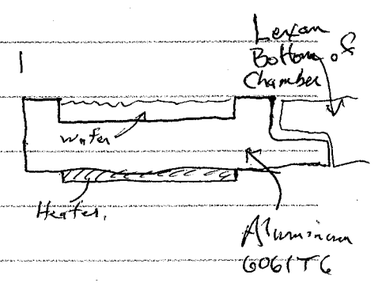
TEST SETUP

Set up thermocouples on test chamber as shown below. Labels given as T1 = Fluke Channel 1, T2 = Channel 2, ...
Sensors 10, 11, 12 not used (measuring ambient temperature beside chamber.



The box (chamber) was insulated on the top & sides with 1" thick styrafoam, 2 layers of styrafoam sheet were placed under the chamber.

The heater element was bonded to the bottom of the water tray. The heater pad dimensions are 3"x12". The heater is 90 Watts at 120 VAC.
McMaster-Carr part No. 35765K177.
The heater power setting is changed using a Variac 0-120 VAC.



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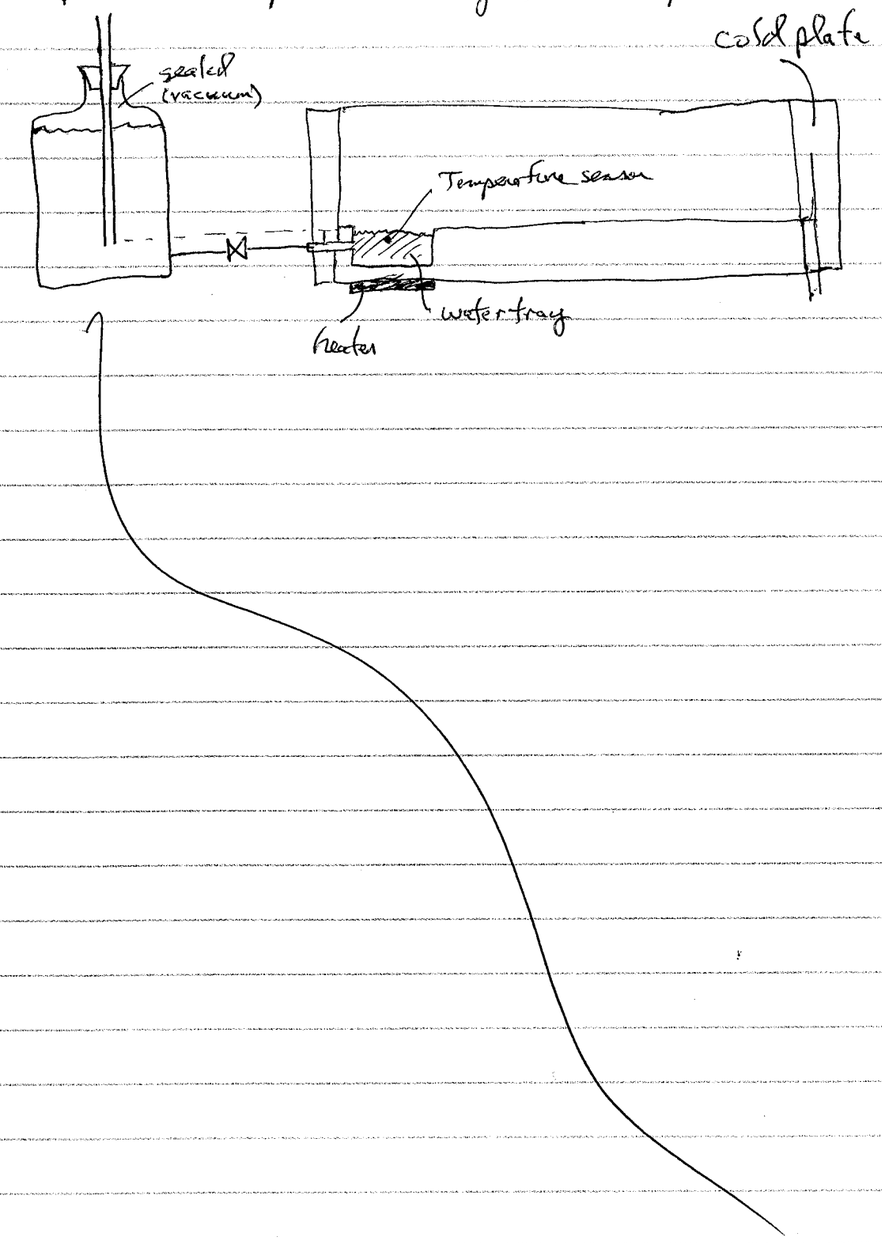
A water supply was set up as below to keep the water tray full. Water draining out of the chamber at the cold plate was captured in a graduated cylinder.



2-24-2004 SS

Initial Test

8:20 AM

Heater Variac Set to "35" setting.

Chiller used to cool the cold plate set to 10°C

data acquisition system started to log temperatures

12:40 PM

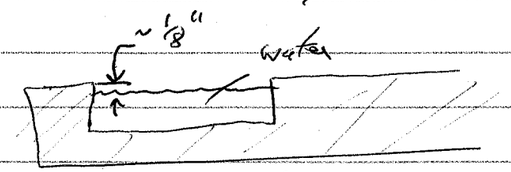
Drained water from graduated cylinder that is collecting condensate to start a test. Reset Computer Time 2-14-04, 12:40 → 2-24-04, 12:40.

14:51 16.2 ml captured in grad. cylinder (25 ml cylinder with 0.2 ml graduations)

Water tray (heated) temp = 36°C

Cold plate Temp ~ 10.6°C

Adjusted water level slight - to get higher water level in tray (it is ~ 1/8" below bottom of chamber)



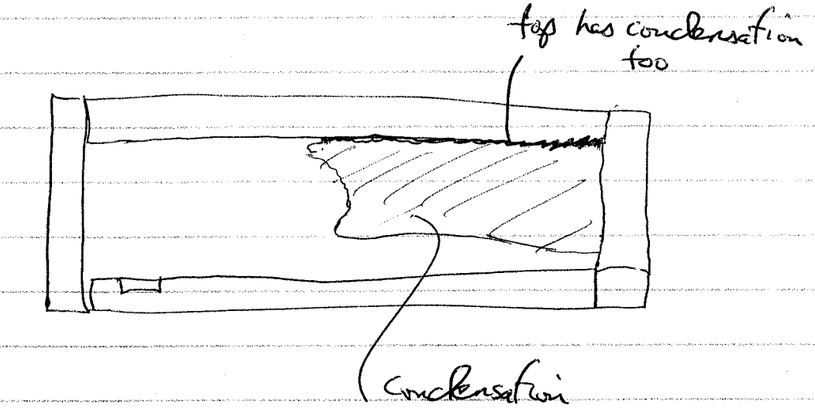
15:01 Drained graduated cylinder - 18.4 ml drained

16:45 14.3 ml collected in grad cylinder (total accumulated water since 12:40 = 32.7 ml)

Cold plate T = 10.6°C, Water Temp ~ 38°C

Inspected box, there is condensation covering ~ 1/2 of the top cover on inside

2-24-2004 SS



17:34 graduated cylinder level = 19.0 ml (Total liq. accum since 12:40 pm = 37.4 ml)

Drained cylinder water out

Put 500 ml beaker to catch condensate, 5 ml graduations

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8:54 AM Liquid collected = 135 ml (Since Start of test total liquid = 172.4 ml)

Set data system to log at 10 sec

Cold plate T = 10.6°C Water Temp = 38.7°C

Some water has accumulated on the bottom of the chamber next to the cold plate - looks like condensation

9:10 Touched 3 thermocouples that are measuring ambient temperature (temperature readings probably changed) I put them closer together.

9:14 AM Stopped Test at Variac setting of 35

Data acquisition File name: "Var-35.dat"

Water collected in grad. cylinder = 138 ml

(total collected during test = 138 + 37.4 = 175.4 ml)

2-25-04 ~~Noon~~

2-25-2004 SS

9:20 AM START TEST WITH VARIAC SETTING AT 45
COLD PLATE FLUID Temp Setting = 10°C
Drained condensate collection graduated cylinder
13:04 Drained graduated cylinder out to start test
(had collected 50 ml while reaching steady state)
Water Temperature = 46.4°C , Cold Plate T = 10.7°C
17:15 Condensate Collected = 59 ml since 9:20 AM
Drained water from cylinder
Water Temp = 46.7°C Cold Plate T = 10.8°C

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8:20 Water collected 262 ml
T water = 46.6°C , T cold plate = 10.8°C
11:40
Water collected = 320 ml
T water = 47°C T cold plate = 10.8°C
END TEST WITH VARIAC AT "45" Setting
DATA FILE VAR_45.DAT

11:49 START TEST WITH VARIAC SET TO "55"
17:00 Opened insulation on top of box to see inside
Water has puddled on bottom - condensation covers most of top + sides.
Even the thermocouple wires have condensation drops on them.
Water collected = 89 ml (end of tube in water - may have backed up flow) dumped water from cylinder
T water = 53.4 (Ch1) & 35.6 (Ch2)
T cold plate = 10.9°C

2-26-2004 SS
17:00 Water level in tray was low - adjusted water level control higher.
17:10 Closer inspection showed TC on Channel 2 had the tape holding it down come loose (due to heat + water I suppose) and it is above the top of the water surface
17:13 Drained fluid from grad. cylinder to start overnight fluid collection.
Also made hose on condensate drain shorter.

2-27-2004 SS
~9:29 AM Water level over discharge tube - water backed up in box. Inside box has a lot of condensation on walls.
Water collected = 418 ml
T water = 34.3°C - both TCs came loose in water bath.
T cold plate = 10.9°C
END Test
DATA File VAR_55.DAT

3-1-04 SS

Bonded thermocouple wires down into water tray with RTV sealant. This is an attempt to keep temperature sensors in place when water tray gets hot.

3-2-04 SS

~9:30 Refilled water supply.

STARTED "TEST 4" - Data file "Test4.dat"

Set cold plate T=5°C (this is to keep "average" chamber temp closer to ambient temp & reduce condensation on the box.

Set variac setting to 35

15:01 Added another 1" thick layer of polystyrene foam insulation to the top, sides & ends. Bottom already has 2 layers (each 1" thick)

17:18

Drained water from graduated cylinder to start the test (65ml)

T_{water} = 31.5°C $T_{coldplate}$ = 5.3°C

3-3-04 SS

9:08 AM T_{water} = 28°C $T_{coldplate}$ = 5.3°C

Water collected in grad cylinder = 42 ml

Drained water

Water level in water tray is low - some areas are dry.

Condensation is visible on top + side walls within ~6" of cold plate.

Some water collected on bottom near cold plate.

Adjusted water level up to refill tray & re-start test.

3-3-04 SS

15:45 Temperature sensor T8 was pulled loose. Replaced it only a few ml of water collected in grad. cylinder since 9:08 AM. It looks like gasket on cold plate is leaking. Screws were tightened (they were loose).

17:52 Drained water from graduated cylinder to start test

T_{water} = 32.1°C $T_{coldplate}$ = 5.4°C

3-4-04 SS

8:49 AM Liquid in grad. cylinder = 108 ml

Drained cylinder

T_{water} = 32.6°C , $T_{coldplate}$ = 5.4°C

Water level looks OK, condensation on inside chamber walls within ~6" of cold plate

END Test

Data File = Test4.dat

8:56 Start next test with Variac set to 45, cold plate ~5°C

Data File = "Test5.dat"

~1:00 Filled Water supply bottle with DI water

16:35 T_{water} = 39°C , $T_{coldplate}$ = 5.3°C

Drained water out of grad cylinder to start steady state test (84ml)

Condensation now covers top + sides of chamber (inside surface) to a distance of ~12" from the cold plate.

3-5-04 SS

8:45AM $T_{water} = 39°C$, $T_{cold\ plate} = 5.3°C$

Condensate collected = 195 ml

END Test 5; but turned data collection rate to every 5 seconds to see any time varying nature to the flow (Insulation removed before start scan + at 8:49AM to check water level)

Water level OK. Condensation covers ~ 12" of inside surface of chamber close to cold plate.

8:51AM Restart data system at 5 sec scan interval

9:18 AM Stopped data collection for Test 5.

3-8-04 SS

9:15AM Setup for Test 6

Filled water supply bottle

Set Variac to "55", cold plate set to 5°C

12:54 Reset Clock on DAS - time on Computer ~~Seems~~ off by 12 hours -

Restarted data collection

Inside of chamber is covered with condensation

only ~ 85 ml water collected as condensate drained liquid from grad. cylinder

Water level OK.

15:11 30 ml condensate collected. ~~(did not drain)~~ SS 3-8-04

Drained out water

$T_{Hot\ Water} = 45°C$, $T_{cold\ plate} = 5.3°C$

3-9-04 SS

8:33 AM $T_{Hot\ water} = 46.4$, $T_{cold\ plate} = 5.5°C$

Condensate collected = 330 ml (drained water)

Water level OK

Condensation has cleared up some above the heater section (I guess box warmed up)

11:49 $T_{hot\ water} = 48°C$ $T_{cold\ Plate} = 5.5°C$

Condensate collected = 70 ml

13:30 $T_{hot\ water} = 47.7°C$ $T_{cold\ plate} = 5.5°C$

cond. collected = 109 ml

Refilled water supply bottle.

Level keep dropping

13:55 Finished adding water to water supply bottle

Cond. collected = 115 ml

17:10 $T_{Hot\ water} = 46.5°C$ $T_{cold\ plate} = 5.4°C$

Condensate collected = 178 ml (drained cylinder)

Set water level up a little bit.

3-10-04 SS

8:12 AM Condensate collected = 312 ml

$T_{Hot} = 47.9°C$ $T_{cold\ plate} = 5.4°C$

STOP TEST 6 Data file "Test 6.dat"

8:14AM START TEST 7 - Repeat of Test 5 since water level went low during the test

Set Variac setting to "45" - cold plate set to 5°C

Data File - "Test 7.dat"

The chamber has quite a bit of water condensed on bottom + top & sides, except near heated water tray.

3-10-04 SS

11:05 AM AFTER REVIEWING TEST DATA DECIDED TO RUN TEST 7 AT A LOWER POWER SETTING.

SET VARIAC TO "25"

Drained condensate ~ 57 ml

3-11-04 SS

8:41 AM Condensate collected = 120 ml (drained)

$T_{hot\,water}$ = 25.3°C, $T_{cold\,plate}$ = 5.3°C

12:50 Condensate collected = 19 ml

$T_{hot\,water}$ = 25.5°C, $T_{cold\,plate}$ = 5.2°C

5:20 Cond. collected = 37 ml (drained)

T_{hot} = 25.6°C T_{cold} = 5.3°C

3-12-04 SS

8:22 Condensate Collected = 75 ml

$T_{hot\,water}$ = 25.1°C $T_{cold\,plate}$ = 5.3°C

11:38 Condensate Collected = 90 ml

T_{hot} = 25.1°C, T_{cold} = 5.2°C

END Test 7, Data File "Test7.dat"

11:53 START TEST 8

VARIAC SET "15"

16:56 Drained Grad. Cylinder = 18 ml

$T_{hot\,water}$ = 20.3°C $T_{cold\,plate}$ = 5.2°C

3-15-04 SS

10:23 $T_{hot\,water}$ = 18.5°C $T_{cold\,plate}$ = 5.3°C

Condensate Collected = 178 ml ± 2.6 ml (500 ml beaker) Drained

Condensate inside box is much less

Water level in tray is low - air bubbles may have stopped up line

3-15-04 SS

17:05 Water collected = 15 ml (100 ml cylinder) drained

$T_{hot\,water}$ = 19.8°C $T_{cold\,plate}$ = 5.1°C

3-16-04 SS

8:45 AM Condensate collected = 39.5 ml (100 ml cylinder)

$T_{hot\,water}$ = 19.5°C $T_{cold\,plate}$ = 5.2°C

10:00 Stopped Test 8 - Data File "Test8.dat"

10:05 START TEST 9

COLD PLATE SET TO 20°C

VARIAC POWER SETTING = 15

DATA SYSTEM LEFT OFF UNTIL TEMPERATURES CHANGE

13:02 Turned on Data collection system to start test.

13:24 $T_{hot\,water}$ = 25°C $T_{cold\,plate}$ = 25.5°C

15:33 $T_{hot\,water}$ = 25.7°C $T_{cold\,plate}$ = 19.1°C

Condensate Collected = 0 ml

Noted time wrong on computer

Changed from 15:35 → 17:20

3-17-04 SS

8:54 Condensate collected = 26.5 ml (100 ml beaker)

T_{hot} = 26.4°C $T_{cold\,plate}$ = 19.1°C

11:40 T_{hot} = 26.4°C T_{cold} = 19.1°C

Condensate Collected = 31.0 ml (100 ml beaker)

END Test 9 - Data File "Test9.dat"

Start Test 10.

Varic Set to 35, Cold Plate set to 20°C

3-17-04 SS

16:52 Started DAS - Test10.DAT
$T_{coldplate}$ = 19.1°C, $T_{Hot\ water}$ = 37.7°C
Emptied grad. cylinder.

3-18-04 SS

10:26 T_{HOT} = 38.2°C T_{cold} = 19.1°C
Condensate collected = 116 ml (250 ml cylinder)

11:57 END TEST 10.
Cond Level = 125 ml (250 ml cylinder) - Drained

11:59 Start up Test 11.
Variac Set to 55, cold plate T = 20°C

17:17 Started Das - Data File Test11.dat
$T_{Hot\ water}$ = 50.2°C $T_{cold\ plate}$ = 19.2°C
Condensate collected = 87 ml (250 ml cylinder)
Drained water out

3-19-04 SS

9:13 Condensate Collected = 331 ml (500 ml cylinder) drained
T_{Hot} = 50.4°C $T_{cold\ plate}$ = 19.3°C

17:08 Condensation = 167 ml
T_{Hot} = 51.4°C T_{cold} = 19.3°C
End Test 11

3-22-04 SS

10:31 AM Set Varic to "45", Cold Plate T set to 20°C

15:45 Cleaned condensed water off walls inside of chamber.

3-22-04 SS

17:30 START TEST 12. DATA FILE TEST12.dat
VARIAC SET TO 45, COLD PLATE T = 20°C
$T_{Hot\ water}$ = 43.8°C, $T_{COLD\ PLATE}$ = 19.1°C

3-23-04 SS

8:55 $T_{HOT\ water}$ = 45.1°C $T_{COLD\ PLATE}$ = 19.2°C
Condensate collected = 166 ml (Drained, 250 ml cyl'n).

17:26 $T_{Hot\ water}$ = 44.8°C $T_{coldplate}$ = 19.2°C
Condensate = 107.8 ml (250 ml cylinder) drained

3-24-04 SS

8:35 $T_{HOT\ water}$ = 45.4°C $T_{cold\ plate}$ = 19.2°C
Condensate Collected = 194 ml (250 ml cylinder) drained

13:50 STOPPED TEST 12

13:52 START TEST 13 SETUP
COLD PLATE SET TO 30°C
VARIAC (Heater Power) Set to "20"

17:15 SS 3-24-04
~~15:T~~ STARTED DATA LOGGING, Drained Grad. cylinder
$T_{HOT\ water}$ = 35.6°C $T_{cold\ plate}$ = 29.4°C

3-25-04 SS

8:38 $T_{HOT\ water}$ = 34.3°C $T_{cold\ plate}$ = 29.4°C
Condensate Collected = 7.5 ml (100 ml cylinder) drained

17:13 $T_{Hot\ water}$ = 34.4°C $T_{cold\ plate}$ = 29.4°C
Condensate Collected = 4 ml (100 ml cylinder)

3-29-04 SS

8:35 AM Condensation level above drain hose -
Stopped test to clean condensation out of the chamber

3-29-04 SS

8:54 AM Closed up chamber after cleaning condensation off walls

10:40 Decided to record both inlet + outlet water flow rates. Brought over scale to weigh water supply.
Initial weight: 5527.3g Feed water
Drain cylinder

11:02 Moved scale, Re-weigh Feed water container = 5495.0

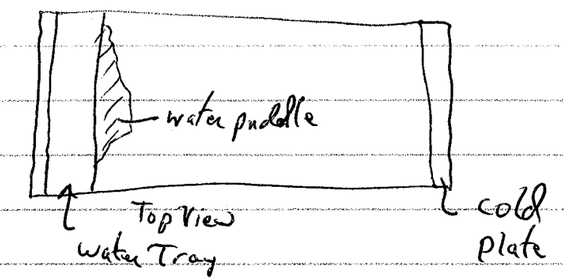
17:24 Restarted Data system for Test 13
Drained grad cylinder, only a couple of drops since 11:00
Water supply = 5391.2g
$T_{hot\ water}$ = 33.4°C $T_{cold\ plate}$ = 29.4°C
Some water overflowed water tray - happened when I picked up water source to weigh

3-30-04 SS

8:41 No condensate collected in grad. cylinder
Supply Tank (water) weight = 5353.7g
Water level still over tray.
To get test started Turned Variac to "40"
INSIDE of Box is covered with a thin layer of condensation. Condensation covers almost all of inside of chamber except small areas near heater.

3-30-04 SS

17:37 $T_{hot\ water}$ = 45.6°C, $T_{cold\ plate}$ = 29.4°C
Condensate Collected = ~~35.5~~ 34.0 ml (100ml cylinder) Drained 3-30-04
Water Supply Weight = 5316.9g
There is still some water "puddled" near heater tray



3-31-04 SS

8:27 $T_{Hot\ water}$ = 46.6°C, $T_{cold\ plate}$ = 29.5°C
Condensate Collected = 120.0ml (250ml cylinder) Drained
Water Supply Weight = 5251.8g
Water "puddle" by heater is gone

13:52 $T_{Hot\ water}$ = 46.7°C $T_{cold\ plate}$ = 29.4°C
Condensate Collected = 47ml (250ml cylinder)
Water Supply Tank Weight = 5189.1g

17:06 $T_{Hot\ water}$ = 46.5°C $T_{cold\ plate}$ = 29.5°C
Condensate Collected = 70.5ml (250ml cylinder) Drained
Water Supply Tank Weight = 5187.6g
(I had left it valved off from 13:52 reading)

4-1-04 SS

8:41 $T_{Hot\ water}$ = 46.5°C $T_{cold\ plate}$ = 29.5°C
Condensate Collected = 139ml (250ml cylinder)
Water Supply Tank Weight = 4971.5g

4-1-04 SS

12:35 Condensate Collected = 168.5 ml (250 ml cylin) Drained
Water Supply Weight = 4935.5 g
Stop Test 13.

12:39 Set Variac to "30" - Start Test 14

17:21 T_{Hot} = 40.5°C T_{cold} = 29.4°C
Cond. collected = 54 ml (250 ml cylinder) drained
Water Supply Weight = 4899.8 g

4-2-04 SS

8:11 AM T_{Hot} = 39.6°C T_{cold} = 29.4°C
Condensate Collected = 45.5 ml (250 ml cylinder)
Water Supply Weight = 4824.1 g

14:56 T_{Hot} = 39.5°C T_{cold} = 29.4°C
Cond. Collected = 82 ml (250 ml cylinder)
Water Supply weight = 4824.0 g (left water supply valve closed earlier - 8:11)

17:37 Cond Collected = 88 ml (250 ml cylinder) drained

4-5-04 SS

9:00 DAYLIGHT SAVINGS TIME SWITCH over weekend - computer updated today?
T_{Hot} = 39.5°C T_{cold} = 29.4°C
Condensate Collected = 260 ml (500 ml cylinder)
Water Supply Weight = 4464.8

12:45 END TEST 14
Set Variac to "20" - Start Test 15
Refilled water tank

4-5-04 SS

17:45 Drained Condensate
Water Supply Weight = 6504.6 g
Started data collection
T_{hot} = 34.7°C T_{cold} = 29.4°C

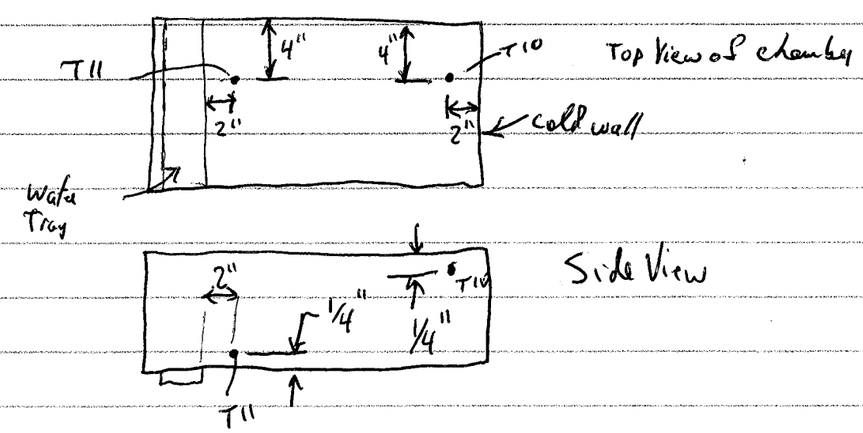
4-6-04 SS

12:15 T_{Hot} = 33.6°C T_{cold} = 29.4°C
Condensate Collected = 12.5 ml (250 ml cylinder)
Weight water supply = 6504.5 g

4-7-04 SS

8:07 AM $T_{Hot\ Plate}$ = 34.3°C $T_{cold\ plate}$ = 29.4°C
Condensate Collected = 19 ml (250 ml cylinder)
Water Supply Weight = 6406.4 g
STOPPED TEST 15
Dried out chamber to remove all water. water supply valve closed

Thermocouple #1 Taped down to bottom of heater Tray
Added TC #10 & 11 to chamber



4-7-04 SS

8:59AM Set Variac setting to "40"
Set cold plate circulating bath to 20°C
No water in water Tray
START TEST 16 - Dry test to
get chamber temperatures without
any condensation - to provide
data to compare with CFD calculations.

14:30 Added a power meter to check heater power.
Ohio Semitronics Watt meter
Range 0-100 W, Model PC5-1030, 0-10VDC out
SwRI Cal, An: 010469, Sn 03080278
Cal Due 9-29-04
Voltmeter used to read Watt meter
FLUKE 87 III . SwRI cal Lab An: 009508,
Sn: 81420256, Cal Due Aug 20, 04

Variac setting = 40, 1.385VDC out of
Wattmeter Power = $1.385 \frac{100W}{10VDC}$ = 13.85 Watts

4-8-04 SS

10:11 T_{HOT} = 57.6°C T_{cold} = 19.3°C
Heater Power ~~Vo~~ SS 4-8-04 : Wattmeter Voltage = 1.365VDC ± 0.005VDC
Power to heater = 13.65 Watts
Set scan interval to 5 seconds to record any transients

10:30 END TEST 16 - Data file Test16.dat
Set Variac to "30" - Start Test 17
Wattmeter Voltage = VDC Power = watts

4-9-04 SS

8:32AM T_{HOT} = 44.20 T_{cold} = ~~18~~ SS 4-9-04 19.3
8:50AM END TEST 17 - Data File "Test17.dat"
Wattmeter V = 0.754V → Power = 7.54 watts
8:53 START TEST 18
VARIAC Setting = ~~0.75~~ SS 4-9-04 20
Wattmeter V = 0.327 VDC → Power = 3.27 Watts
4-12-04 T_{HOT} = 32.3°C T_{cold} = 19.3°C
11:45 Wattmeter V = 0.332 VDC → Power = 3.3 watts
11:52 STOPPED TEST 18
DATA FILE = "TEST18.DAT"

5/26/2004 Steve Svedeman SS
Graduated cylinders were used to catch the water that condensed on the cold plate.
The three cylinders were checked for accuracy by adding a known mass of water to the cylinder and then reading the water volume in the cylinder.

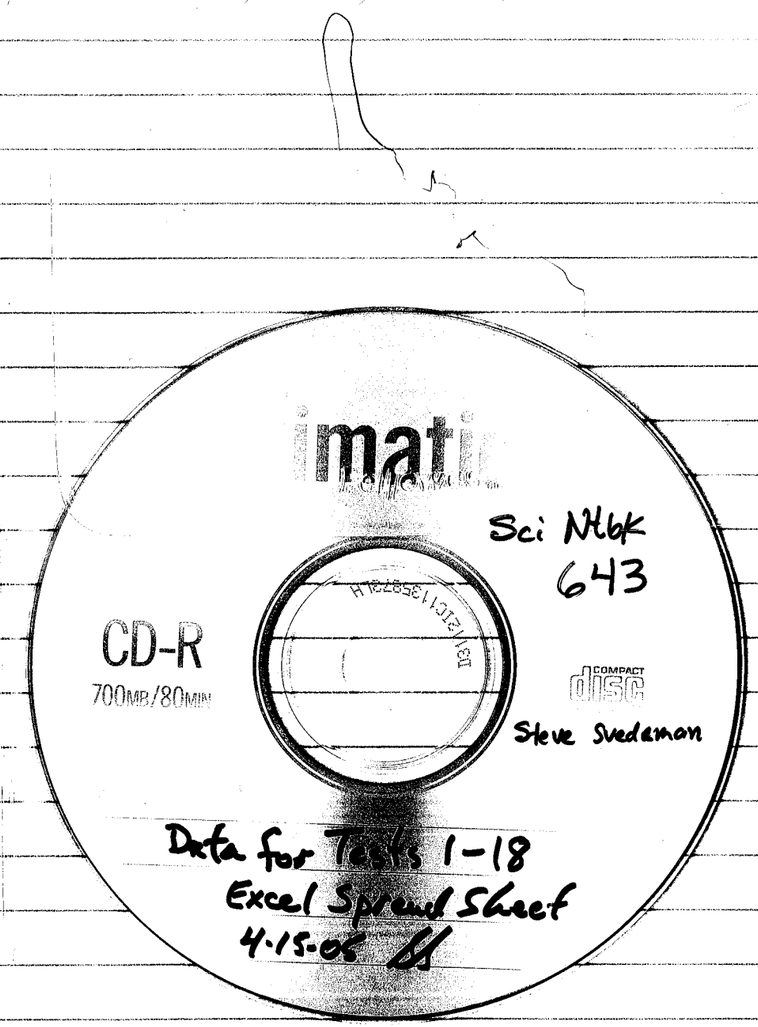
Balance used to measure the water added to the graduated cylinder:
Mettler PM480 Delta Range, SN N405601
Calibration due date: Aug 9, 2004
Water temperature measured with mercury in glass thermometer:
ASTM 91C, 20-50 deg C, 0.1 deg C increments, S/N 1709
SwRI cal due: Aug 23, 2004

Water Temperature (C)	24.1
Water Density (g/ml)	0.997
Weight Scale Density,SS (g/cc)	7.85
Air Density (g/cc)	0.001156

Scale Reading Water Added (g)	Graduated Cylinder Reading (ml)	Corrected Water Mass (g)	Added Water Vol. (ml)	Total Water Added (ml)	% Difference, Weighed vs. Grad Cyln.	Diff Weighed - Grad Cyln
0-100 ml Graduated Cylinder, 1 ml graduations, Pyrex No. 3022, ASTM						
34.981	35	35.016	35.12	35.12	0.35	0.12
34.999	70.1	35.034	35.14	70.26	0.23	0.16
28.934	99.3	28.963	29.05	99.31	0.01	0.01
0-250 ml Graduated Cylinder, 2 ml graduations, Pyrex No. 3022						
52.046	53.5	52.099	52.26	52.26	-2.38	-1.24
52.231	106	52.284	52.44	104.70	-1.24	-1.30
54.559	160.3	54.614	54.78	159.48	-0.52	-0.82
51.01	212	51.062	51.22	210.69	-0.62	-1.31
33.239	246	33.273	33.37	244.06	-0.79	-1.94
0-500 ml Graduated Cylinder, 5 ml graduations, Kimax No. 20024, Tol. +/-2.6 ml						
100.605	104	100.707	101.01	101.01	-2.96	-2.99
91.912	195	92.005	92.28	193.29	-0.88	-1.71
93.368	287	93.463	93.74	287.04	0.01	0.04
90.458	379	90.550	90.82	377.86	-0.30	-1.14
96.957	475	97.055	97.35	475.21	0.04	0.21

Each graduated cylinder is more accurate than the graduations on the cylinder.

4-15-2005 SS
CD containing Test data attached below.
Final Entry in Scientific Notebook.
SS 4-15-2005



I have reviewed this SN and find that it complies with QAP-001.

Andrew Wittmeyer
4/15/2005

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 643

Document Date:	02/20/2004
Availability:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, Texas 78228
Contact:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, TX 78228-5166 Attn.: Director of Administration 210.522.5054
Data Sensitivity:	■"Non-Sensitive" □ Sensitive □"Non-Sensitive - Copyright" □ Sensitive - Copyright
Date Generated:	04/15/2005
Operating System: (including version number)	Windows NT
Application Used: (including version number)	Excel 97
Media Type: (CDs, 3 1/2, 5 1/4 disks, etc.)	1 - CD
File Types: (.exe, .bat, .zip, etc.)	xls
Remarks: (computer runs, etc.)	Media contains the electronic data for Tests 1–18 files.