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QUARTERLY PROGRESS REPORT

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March 27, 1996 - June 26, 1996

FOR PROJECT ENTITLED

DEVELOP APPARATUS AND PROCESS FOR SECOND-STAGE DRYING

ASSISTANCE INSTRUMENT NO. DE-FG01-94CE1555R

DR. FRED TAYLOR
PRINCIPAL INVESTIGATOR

DR. C. W. BOUCHILLON
CONSULTANT

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FOREST PRODUCTS LABORATORY
MISSISSIPPI STATE UNIVERSITY
MISS STATE, MS 39762

July 3, 1996

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July 3, 1996

Dr. Fred Taylor and Dr. C. W. Bouchillon

I. INTRODUCTION

This is the seventh quarterly progress report for this project. The effort this quarter has been directed toward the some additional experiments and evaluation of the experimental results for the laboratory scale heat exchanger models. Also, additional work has been done on the computer predictive model for dry kiln performance.

II. PROGRESS ON TASKS

Progress on several tasks has been made during this quarter of the conduct of this project. A description of the efforts and a summary of some of the results are presented below.

TASK 1. COMPUTER SIMULATION REFINEMENT AND EXTENSION

Task 1A. Verification of Computer Model Simulation of the Drying Process for Lumber in a Superheated Steam Kiln.

Additional modifications have been made to the predictive program for dry kiln performance in order to improve the predictions. An introduction of the energy requirements for the venting of conventional dry kilns, heat losses from the kiln, and estimates of heatup energy requirements have been made to the computer model.

Task 1B. Establish Energy Loss Predictions for Specific Kiln Designs for the First Stage Kiln

Additional efforts to compare the results of the computer model with the energy consumption schedule previously obtained from a kiln company for a conventional kiln design. By addition of the factors described in Task 1A, improvements in predictions have been made.

Task 1C. Establish Energy Loss Predictions for Specific Kiln Designs for the Second Stage Kiln.

The second stage kiln will be operated at lower temperatures than the first stage and consequently, the kiln will have to be vented. The improvements in the predictive capabilities described in Tasks 1A and 1B will enhance the predictive capabilities for the Second Stage Kiln. More detail will be presented in the Final Technical Report.

TASK 2. DETAILED HEAT EXCHANGER EQUIPMENT DESIGN

The experimental results obtained in Task 4 will be used in full scale design of the heat exchangers to be used for latent heat recovery from the exhaust of the first stage kiln.

TASK 3. PILOT SCALE DESIGN AND FABRICATION

Task 3A. Establish Three Different Designs for Heat Exchanger Geometries to be Tested in the Pilot Scale System.

Configurations of commercially available rolled metal sheeting typically used in metal building construction, right angle deep grooved metal sheeting, and a deep "V" groove heat exchanger panel have been fabricated for use in the pilot scale test apparatus.

Detailed designs were made for insertion into three chambers which are inserted into the steam coil dry kiln of the Mississippi Forest Products Laboratory. The designs incorporate a catch basin for the condensate on the surface of the heat exchanger surfaces.

Two of the designs used galvanized steel material and one used an aluminum coated steel panel. The galvanized steel material oxidized rather quickly during the tests. The aluminum coated steel sheet only corroded where the surface was scratched.

Two stainless steel heat exchanger surfaces have been fabricated and further testing of these designs has been accomplished. Experimental results were presented in the Fifth Quarterly Progress Report.

In order to better understand the water vapor condensation process, the test chambers were modified to allow liquid water spray onto the outside surfaces. This greatly enhanced the heat transfer rates from the surfaces, thereby giving additional experimental evaluation of the expected condensation process of heat transfer. Results of these tests are presented below on Figures 1, 2, and 3.

Task 3B. Fabrication of the Pilot Scale Equipment

The stainless steel test panels for the pilot scale experimental apparatus were installed in the general apparatus for the performance of the tests at different first stage kiln conditions. This apparatus was modified to allow liquid water spray onto the outside surfaces of the test panels in order to gain a better understanding of the condensation process expected in the final design.

The existing dry kiln at the Forest Products Laboratory was been used to simulate the first stage kiln. The three different heat exchanger configurations were used in the tests. Collection of the condensate from the heat exchanger surfaces allowed approximate determination of the energy recovery from each of the three heat exchanger designs.

Task 3C. Assembly of the Pilot Scale System

The Pilot Scale System has been fabricated and testing was extended in order to ascertain additional information on the heat recovery potential from the condensation process.

TASK 4. EXPERIMENTAL EVALUATION OF THE PILOT SCALE SYSTEM

Additional progress was made on this TASK with the heat exchanger panels being used as test panels with liquid water spray onto the exterior surface. This allowed additional information on the heat exchange process to be obtained. A summary of the results are presented on Figures 1, 2, and 3 below. A more detailed presentation of results will be made in the Final Technical Report.

Determination of Velocities in the Three Test Chambers.

No further testing of the velocity distributions in the test cells have been made.

Testing of the Heat Transfer in the Test Cells

Testing of the heat transfer in the test cells has been extended for the determination of heat transfer with liquid water sprayed onto the outside surface of the panels. Again, as expected, the convoluted heat exchanger surfaces did yield a higher heat transfer rate than did the surface of classical metal building sheeting.

TASK 5. PRELIMINARY DESIGN OF A PROTOTYPE SYSTEM

No progress to report on this task. Efforts to complete this task will be made during the next quarter.

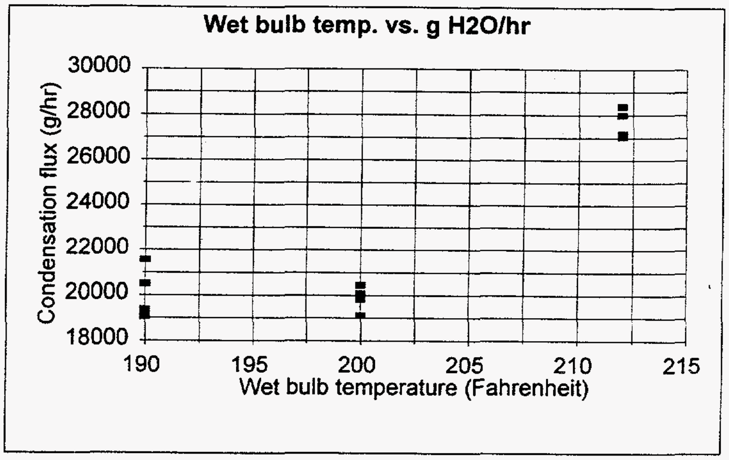
TASK 6. TECHNICAL REPORT OF RESULTS

No progress to date on this task. A Final Technical Report will be prepared during the next quarter.

Water Spray Results
May 17, 1996

Heat exchanger with deep grooved profile

test #	db	wb	h2o initial	h2o final	h2o total	g/hour
1	250	190	1431	10961	9530	19060
2	250	190	1351	11039	9688	19376
3	250	190	1398	11650	10252	20504
4	250	190	1507	12293	10786	21572
5	250	200	1459	6238	4779	19116
6	250	200	1437	6551	5114	20456
7	250	200	1449	6412	4963	19852
8	250	200	1533	6560	5027	20108
9	250	212	1459	8556	7097	28388
10	250	212	1409	8203	6794	27176
11	250	212	1417	8414	6997	27988
12	250	212	1432	8194	6762	27048



test #	db	wb	Heat transfer rate BTUs/hr * sq ft
1	250	190	7653.2
2	250	190	7780.1
3	250	190	8233.0
4	250	190	8661.9
5	250	200	7675.7
6	250	200	8213.8
7	250	200	7971.2
8	250	200	8074.0
9	250	212	11398.7
10	250	212	10912.1
11	250	212	11238.1
12	250	212	10860.7

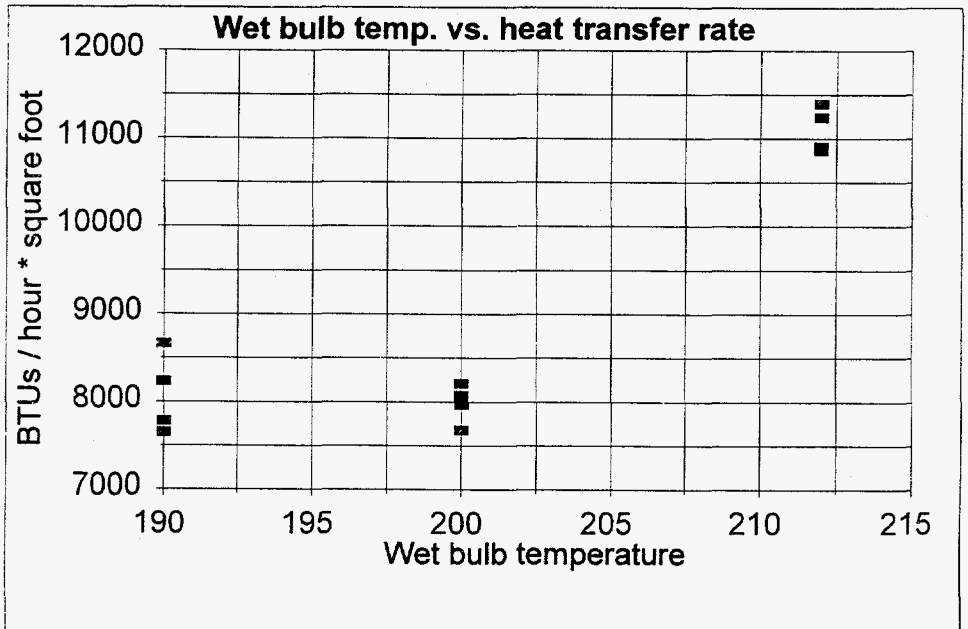
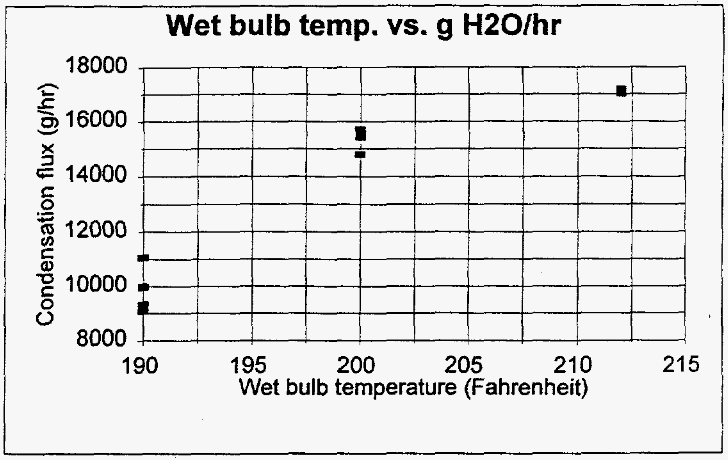


FIGURE 1. HEAT TRANSFER RATE AS A FUNCTION OF WET BULB TEMPERATURE FOR THE HEAT EXCHANGER WITH DEEP GROOVED PROFILE.

Heat exchanger with accordion profile

test #	db	wb	h2o initial	h2o final	h2o total	g/hour
1	250	190	1340	6013	4673	9346
2	250	190	1304	5849	4545	9090
3	250	190	1317	6310	4993	9986
4	250	190	1380	6913	5533	11066
5	250	200	1332	5031	3699	14796
6	250	200	1320	5226	3906	15624
7	250	200	1325	5182	3857	15428
8	250	200	1354	5281	3927	15708
9	250	212	1344	5601	4257	17028
10	250	212	1338	5632	4294	17176
11	250	212	1383	5679	4296	17184
12	250	212	1297	5470	4173	16692



test #	db	wb	Heat transfer rate BTUs/hr * sq ft
1	250	190	4239.6
2	250	190	4123.4
3	250	190	4529.9
4	250	190	5019.8
5	250	200	6711.8
6	250	200	7087.4
7	250	200	6998.5
8	250	200	7125.5
9	250	212	7724.3
10	250	212	7791.4
11	250	212	7795.0
12	250	212	7571.9

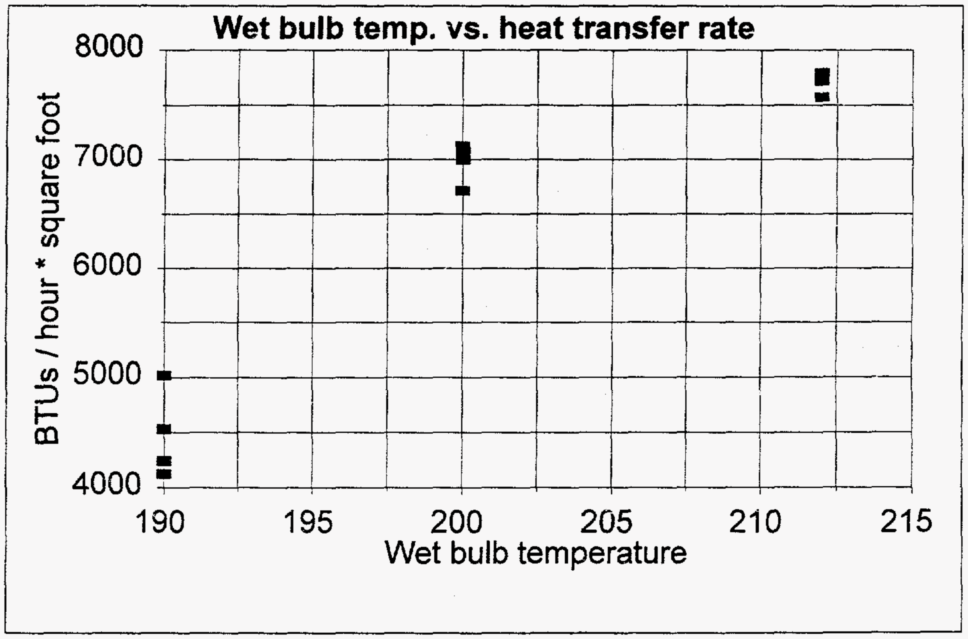
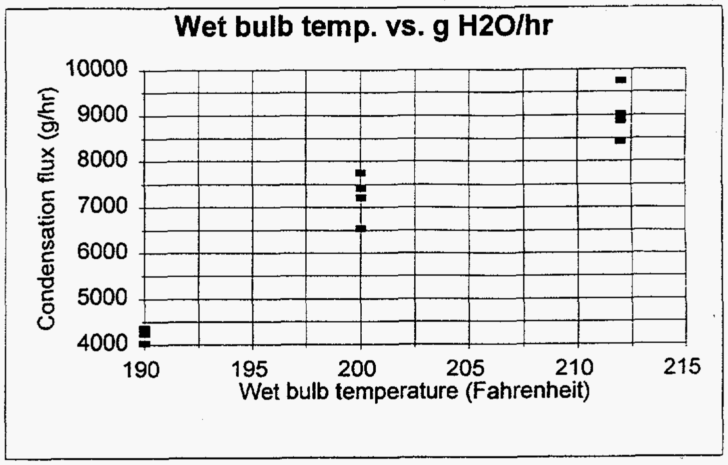


FIGURE 2. HEAT TRANSFER RATE AS A FUNCTION OF WET BULB TEMPERATURE FOR THE HEAT EXCHANGER WITH AN ACCORDION PROFILE.

Heat exchanger with flat profile

test #	db	wb	h2o initial	h2o final	h2o total	g/hour
1	250	190	1405	3586	2181	4362
2	250	190	1314	3333	2019	4038
3	250	190	1317	3444	2127	4254
4	250	190	1365	3534	2169	4338
5	250	200	1377	3316	1939	7756
6	250	200	1371	3225	1854	7416
7	250	200	1337	2972	1635	6540
8	250	200	1440	3244	1804	7216
9	250	212	1351	3570	2219	8876
10	250	212	1507	3614	2107	8428
11	250	212	1338	3593	2255	9020
12	250	212	1371	3809	2438	9752



test #	db	wb	Heat transfer rate BTUs/hr * sq ft
1	250	190	1751.5
2	250	190	1621.4
3	250	190	1708.1
4	250	190	1741.9
5	250	200	3114.3
6	250	200	2977.8
7	250	200	2626.0
8	250	200	2897.5
9	250	212	3564.0
10	250	212	3384.1
11	250	212	3621.8
12	250	212	3915.8

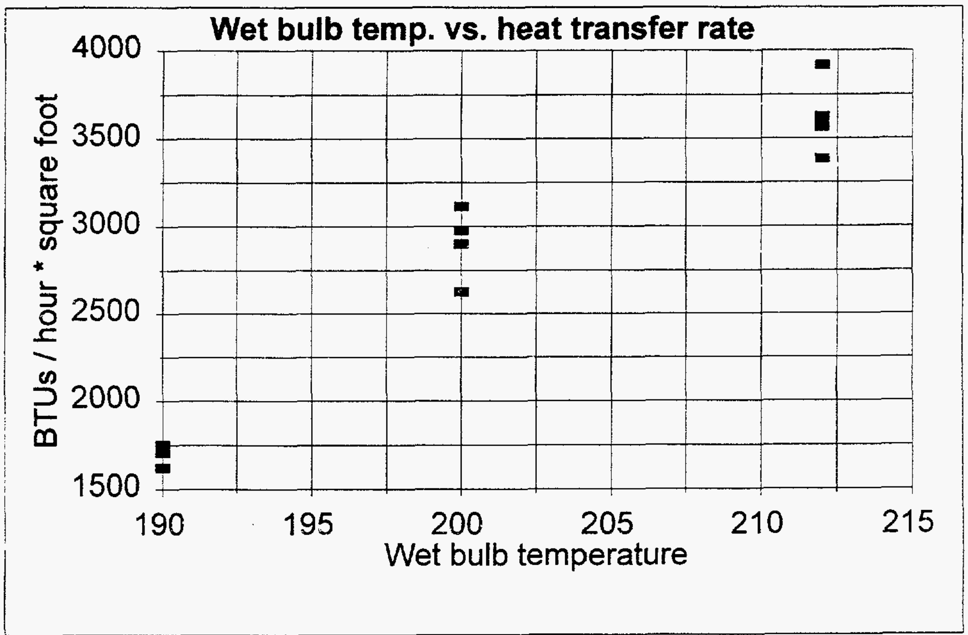


FIGURE 3. HEAT TRANSFER RATE AS A FUNCTION OF WET BULB TEMPERATURE FOR THE HEAT EXCHANGER WITH A FLAT PROFILE.