RELATIVE HUMIDITY MONITORING TO ASSESS COTTON SAMPLE CONDITIONING

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Abstract

The USDA, AMS, Cotton Division conducted a study in three classing facilities during the 1996 season to investigate the relationship of relative humidity in the air above and below cotton samples as they were conditioned on rapid conditioning units. The study results indicate that monitoring the conditioned air above and below the cotton samples is a useful tool for evaluating the rapid conditioning process. The study also revealed that potential exists for utilizing these measurements as an alternative means of assessing cotton sample conditioning.

Introduction

The Rapid Conditioning Unit (RCU) was introduced into USDA cotton classification facilities in 1993 as an improved means of conditioning cotton samples. The basic concept behind the RCU is to draw conditioned air down through cotton samples to enable them to reach the proper moisture content level for HVI testing (Alldredge, 1995). Prior to any HVI testing, the Cotton Division requires that cotton samples reach a moisture content level between 6.75 and 8.25 percent. To control the moisture content within the individual cotton samples, the Cotton Division controls the atmospheric conditions surrounding the samples. This is accomplished through the use of sophisticated Heating, Ventilation, and Air Conditioning (HVAC) systems at each facility (Earnest, 1994, 1995). The current standard for classing facilities is 70 degrees Fahrenheit +/- one degree and 65 percent relative humidity +/- two percent. The RCU is composed of a wire mesh conveyor equipped with a sheet metal plenum that is connected to the facility's mechanical system. While plastic trays filled with cotton samples move along the mesh conveyor for approximately ten minutes, conditioned air from the surrounding room is drawn down through the samples and into the plenum. The air is then returned through the mechanical system where it is reconditioned before being delivered back into the room as conditioned air. Moisture readings are taken regularly during shift operation to verify that cotton samples leaving the RCU are within the allowable moisture range. Samples not achieving this moisture level are returned back to the loading end of the RCU to be processed again. These moisture readings are currently taken with portable moisture measurement devices that measure the percent regain on a dry basis.

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A series of preliminary studies were conducted by Cotton Division personnel in the spring of 1996 to investigate the effect air flow through cotton samples has on conditioning time. Studies were also conducted to evaluate how varying air flow affects the rapid conditioning process. These studies evolved into the decision to conduct this relative humidity (RH) study to analyze how the air above and below the cotton samples reacts during the conditioning process.

Discussion of Study Procedure

The RH study was conducted in three classing facilities: Memphis, Tennessee; Lubbock, Texas; and Visalia, California. The purpose of the study was to monitor the relative humidity in the air above and below cotton samples as they were loaded onto the RCU and as they completed the rapid conditioning process. There were two goals in mind when the study began: 1) determine if monitoring the RH difference between the air above and below cotton samples is a viable method of assessing sample conditioning and 2) investigate if RH measurements associated with both incoming and outgoing samples provides any useful information about the rapid conditioning process.

In each office, one RCU was predetermined as the study device. Two pairs of sensory probes were used in the study. One pair of sensory probes was installed at each end of the RCU (See Figure 1). Within each pair, one was located slightly above the samples while the other was located directly below in the plenum beneath the trays. All of the probes were connected to a multiplexer and computer that continuously collected temperature and relative humidity readings throughout a study period. In most cases, a study period consisted of one shift of operation. A monitoring program was initiated such that readings were taken from each probe approximately every minute. This information was stored on the computer's hard drive for use during analysis.

Prior to the beginning of the study, each set of probes was calibrated at their respective offices. This process consisted of first using desiccant salts to calibrate the probes to their zero trim. Next, one of the probes was calibrated to the room RH using a sling psychrometer. This became the reference probe and the other probes were then calibrated to it.

Because it was very difficult to establish and maintain absolute agreement between test probes, a calibration check and offset determination was performed prior to each study run. This calibration check consisted of loading trays of preconditioned cotton samples known to be at equilibrium onto the RCU for approximately twenty minutes. At that time, RH measurements for each probe were logged onto data sheets. The difference between the top and bottom probes in each pair was then calculated and logged onto the sheet. If the difference between a pair of probes was within an acceptable range, that difference was logged in as the offset for the bottom probe (plenum probe). If the difference between probes was too substantial, the probes underwent an "ambient calibration check" consisting of placing the probe pair next to each other in an open ambient location. The probes were allowed to remain in this location for several minutes and their measurements checked. If the difference was acceptable, they were returned to their study locations and an initial calibration check was performed again. If the probe difference was still too substantial after the ambient check, a full calibration procedure was performed as in the beginning of the study. Once the offsets were calculated and logged, the calibration samples were removed from the RCU and the actual study run was started.

During each study run, any changes to the RCU operation were noted on the data sheets. These included changes in conveyor speeds, shift breaks, or equipment malfunctions. If the RCU conveyor was stopped for any reason during a study period, that time was considered "lag time" and the data was adjusted accordingly during analysis. Throughout each study run, moisture readings were taken as cotton samples were loaded onto the RCU as well as when samples completed the conditioning process. These readings were taken with a portable moisture monitor and recorded on a data sheet. The readings were then summarized for later use during data analysis.

Results and Discussion

This RH study produced valuable data regarding the air above and below cotton samples during rapid conditioning. It also revealed information about how relative humidity relates to sample conditioning in general. The results and conclusions for this paper are based on the study data analyzed thus far (approximately 80 percent of the projected total). Further collection and analysis of data for this study is ongoing as the classing season progresses. During the study, the following conditioning times were normal for each office: Lubbock - 8 to 10 minutes; Memphis - 9 to 12 minutes; Visalia - 7 to 8 minutes.

The major data analyzed for this paper was the RH difference between probes for the incoming versus outgoing samples, the standard deviations calculated for the probes and their differences, and the moisture contents measured during each study run. In virtually every study run, the RH difference for the outgoing probes was dramatically lower than that of the incoming probes. The averages for each study run and the overall office averages can be seen in Table 1. As the data indicates, the RH difference was much lower in the samples as they completed rapid conditioning. These comparisons can be seen graphically in Figures 2-5. The decrease in the RH difference was due to the incoming cotton's tendency to absorb moisture throughout rapid conditioning, especially early in the process. This was seen by the incoming bottom probe's consistently low humidity measurements, thus proving that the samples were absorbing much of the moisture introduced to them early in the RCU process. The samples continued to absorb moisture throughout rapid conditioning and as they approached the end of the RCU, the outgoing bottom probe's measurement was very close to the outgoing top probe.

The data also revealed that overall, the standard deviations corresponding to the probes' measurements and the calculated RH differences within each pair tended to decrease from the incoming to the outgoing samples (See Table 2). Exceptions to this occurred in isolated cases in the Visalia office in which the standard deviations rose slightly from incoming to outgoing samples. However, the data showed an overall decreasing tendency in Visalia as was the case in the other facilities. The standard deviations decreased in every study run conducted in Lubbock and Memphis. The standard deviation data indicates that the relative humidity differences for the outgoing samples tended to be less variable than those of the incoming samples. The standard deviation comparisons for each office can be seen graphically in Figures 6-9.

The data collected also showed that the average moisture contents of the incoming versus outgoing samples increased consistently during rapid conditioning (See Table 3). Figures 10-13 show that all of the average outgoing moisture contents measured for the study runs were well within the acceptable moisture range for HVI testing (6.75%-8.25%). The decrease in RH differences in the study runs directly corresponded to the increase in sample moisture content in almost every case. The exceptions to this were typically situations in which samples entered the RCU at a moisture level very close to or within the minimum acceptable level for HVI testing. In addition, the standard deviations of the RH differences were compared to the average moisture contents in each study run. With the exception of isolated cases in Visalia, the standard deviations also decreased consistently from the incoming to the outgoing samples. As in the case of the RH differences measured, the decreases in the standard deviations directly corresponded to increases in average moisture content in the samples. All of these comparisons can be seen in Figure 14.

Conclusions

The relative humidity study recently conducted in three cotton classing facilities produced valuable data regarding the relative humidity in air above and below cotton samples as they rapidly condition as well as the conditioning process as a whole. The data provided insight into a cotton sample's tendency to gain moisture and stabilize during the rapid conditioning process. The study also established relative humidity monitoring as a viable tool for assessing cotton sample conditioning. There proved to a be direct relationship between relative humidity in the spaces above and below cotton samples and those samples' conditioning performance. This corresponds to the observation that the cotton samples completing the rapid conditioning process during the study appeared to be less variable than those entering the process (See also Knowlton, 1995). This indicates that the RCU process is successfully conditioning the samples for HVI testing. Additional data for this study is currently being collected and will be added to existing data for future analysis.

This study clearly shows that relative humidity monitoring is an effective tool to use when analyzing sample conditioning and RCU performance. However, a question exists regarding the feasibility of using RH measurements as a substitute for checking moisture content by current methods. Although preliminary analysis shows that this concept is feasible, it requires the establishment of an acceptable RH range between humidity probes at the discharge end of the RCU. This range would correspond to the acceptable moisture content range of 6.75-8.25 percent currently required for HVI testing. Future studies will be conducted to further determine the role relative humidity monitoring can play in moisture measurement as well as overall RCU performance.

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Figures and Tables

Table 1. Relative humidity difference for test probes - incoming samples vs. outgoing samples

Office	Study Day No.	RH Difference Incoming Samples	RH Difference Outgoing Samples
Memphis	1	1.52	0.75
	2	1.07	0.48
	3	1.04	0.54
	4	1.40	0.21
	5	1.80	0.38
	6	1.38	0.49
	7	0.21	0.30
	8	1.51	0.11
	9	0.78	-0.02
	10	1.02	0.32
Average		1.17	0.36
Lubbock	1	2.97	0.78
	2	2.99	0.69
	3	1.63	0.12
	4	2.83	1.19
	5	1.62	0.57
	6	1.54	0.46
	7	3.63	1.47
	8	3.50	1.06
	9	3.43	1.43
Average		2.68	0.86
Visalia	1	3.95	0.59
	2	2.70	0.46
	3	4.04	0.90
	4	3.87	0.76
	5	2.66	0.86
	6	2.99	0.20
	7	2.43	-0.31
	8	1.95	0.51
	9	4.98	0.82
	10	4.24	1.13
Average		3.38	0.59

Table 2. Standard deviations for RH differences between test probes - incoming vs. outgoing samples

Office	Study Day No.	STDEV of RH Diff. Incoming Samples	STDEV of RH Diff. Outgoing Samples
Memphis	1	0.52	0.29
	2	0.34	0.20
	3	0.35	0.19
	4	0.60	0.28
	5	0.48	0.45
	6	0.59	0.39
	7	0.37	0.19
	8	0.89	0.23
	9	0.64	0.26
	10	0.47	0.27
Average		0.53	0.28
Lubbock	1	1.01	0.64
	2	0.87	0.49
	3	0.51	0.35
	4	0.76	0.44
	5	0.45	0.21
	6	0.44	0.39
	7	0.68	0.41
	8	0.65	0.43
	9	0.85	0.58
Average		0.69	0.44
Visalia	1	0.81	0.96
	2	0.65	0.96
	3	1.16	0.82
	4	0.92	0.96
	5	0.83	0.83
	6	0.93	0.37
	7	0.72	0.52
	8	0.62	0.53
	9	0.96	0.50
	10	1.08	0.50
Average		0.87	0.70

Table 3. Average moisture content - incoming vs. outgoing samples.

Office	Study Day No.	Incoming Moisture Content (percent)	Outgoing Moisture Content (percent)
Memphis	1	6.57	7.15
	2	6.59	7.30
	3	6.49	7.19
	4	6.87	7.70
	5	6.12	7.13
	6	6.19	7.10
	7	6.90	7.59
	8	6.74	7.34
	9	6.51	7.48
	10	6.17	7.16
Average		6.52	7.31
Lubbock	1	5.42	7.17
	2	5.88	7.60
	3	6.14	7.53
	4	6.24	7.51
	5	6.35	7.76
	6	6.48	7.68
	7	6.34	7.74
	8	6.38	7.77
	9	6.39	7.75
Average		6.18	7.61
Visalia	1	5.93	7.60
	2	6.34	7.44
	3	6.02	7.57
	4	6.05	7.53
	5	6.30	7.50
	6	5.79	7.57
	7	5.99	7.52
	8	6.06	7.54
	9	6.01	7.57
	10	5.87	7.69
Average		6.04	7.55

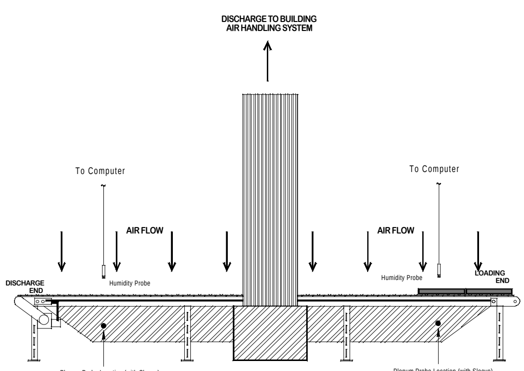

Figure 1. Side View of RCU including study set-up.

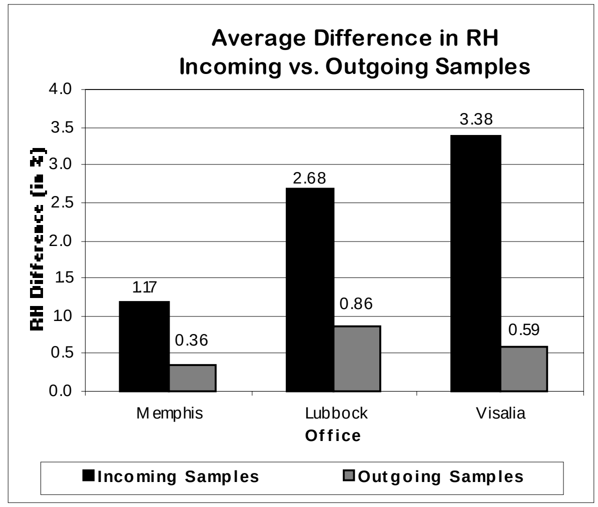

Figure 2. Average difference in RH readings for incoming vs. outgoing probes (all study data).

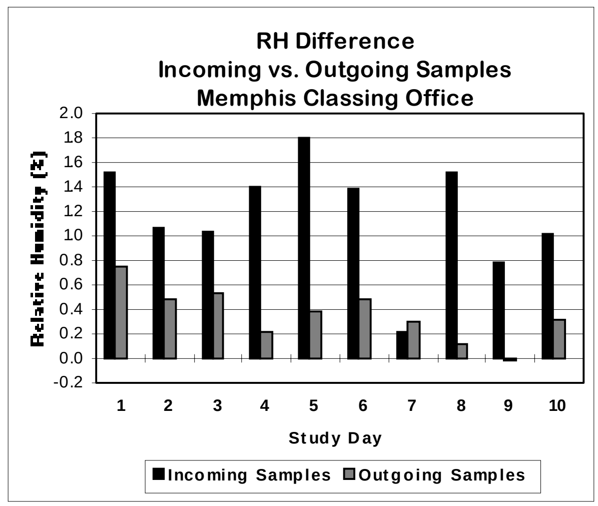

Figure 3. RH differences for incoming vs. outgoing probes shown by study day - Memphis, TN.

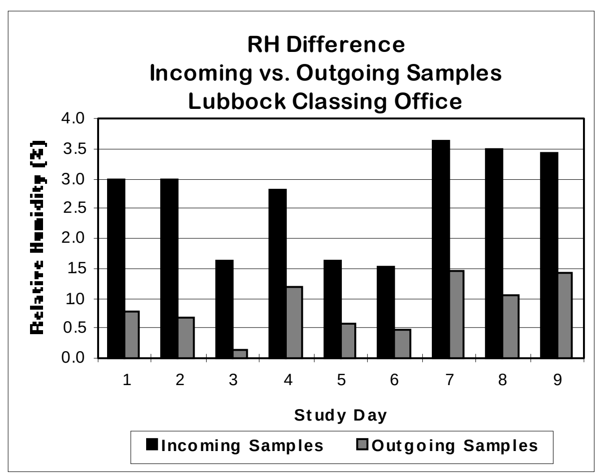

Figure 4. RH differences for incoming vs. outgoing probes shown by study day - Lubbock, TX.

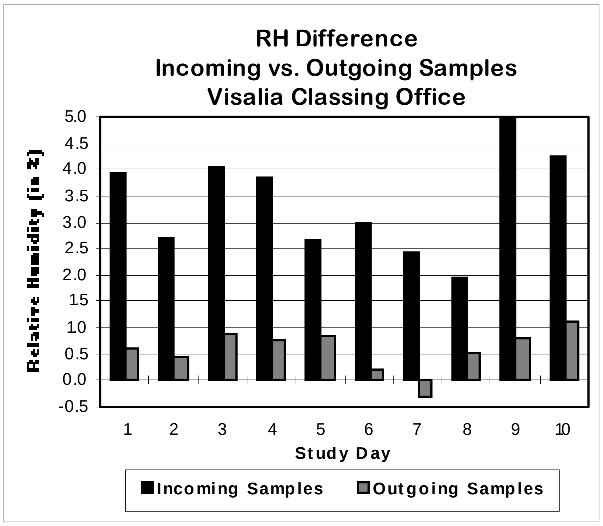

Figure 5. RH differences for incoming vs. outgoing probes shown by study day - Visalia, CA.

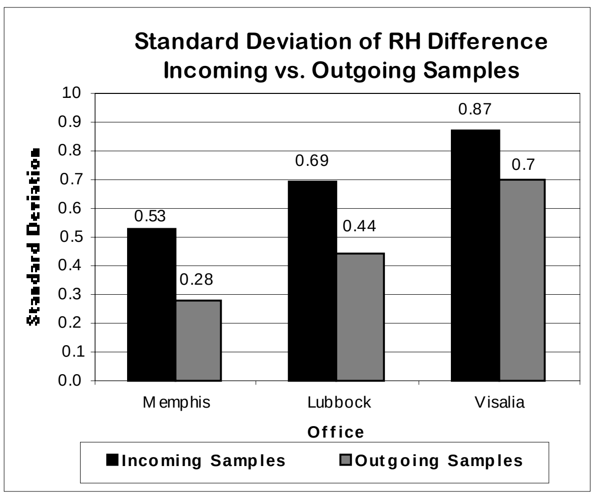

Figure 6. Standard deviation of RH differences for incoming vs. outgoing probes (all study data).

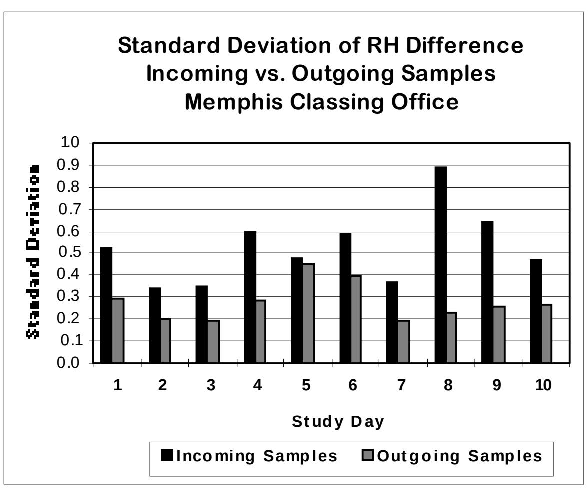

Figure 7. Standard deviation of RH differences for incoming vs. outgoing probes - Memphis, TN.

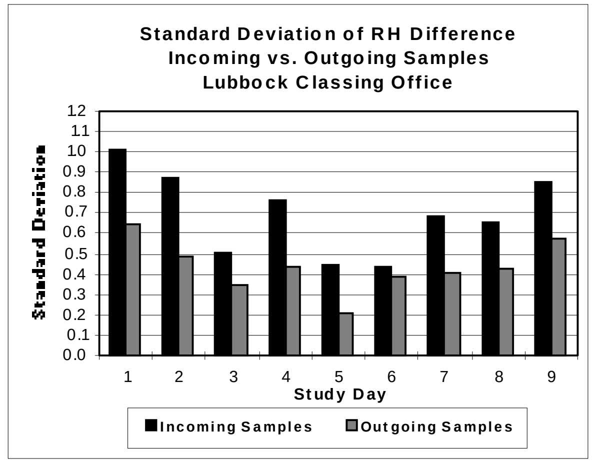

Figure 8. Standard deviation of RH differences for incoming vs. outgoing probes - Lubbock, TX.

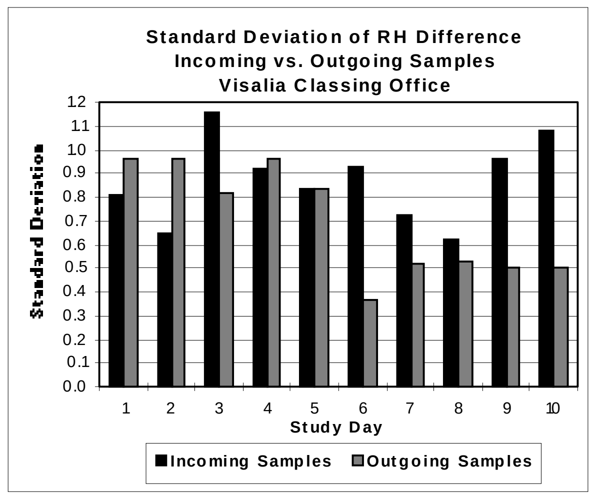

Figure 9. Standard deviation of RH differences for incoming vs. outgoing probes - Visalia, CA.

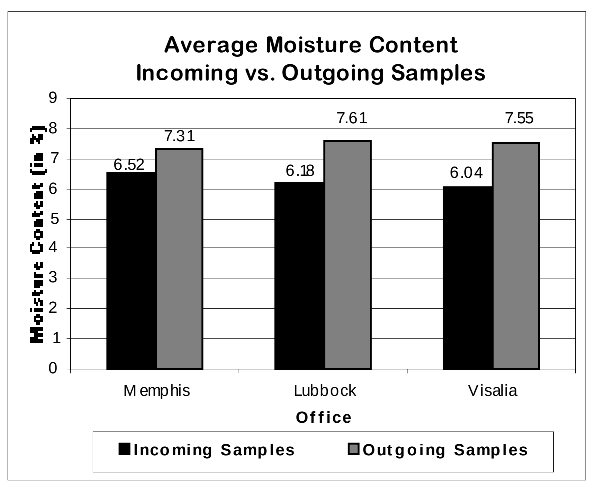

Figure 10. Average moisture contents for incoming vs. outgoing samples (all study data).

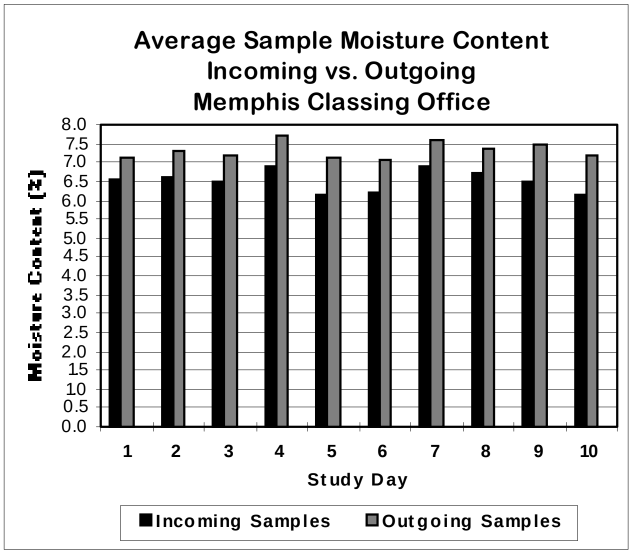

Figure 11. Average moisture contents for incoming vs. outgoing samples - Memphis, TN.

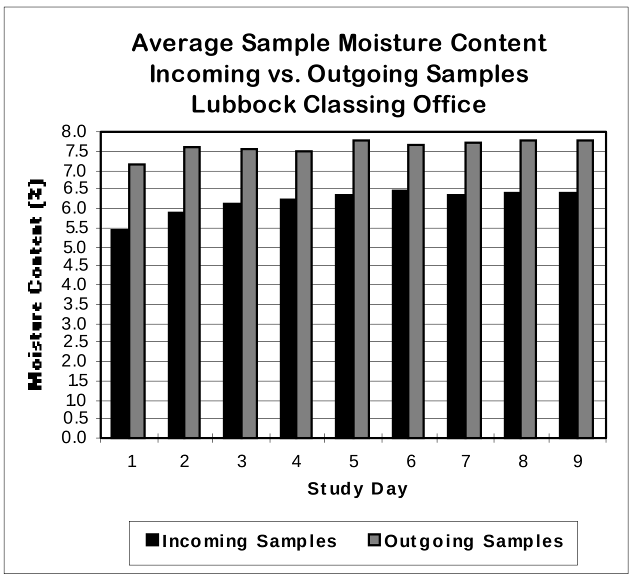

Figure 12. Average moisture contents for incoming vs. outgoing samples - Lubbock, TX.

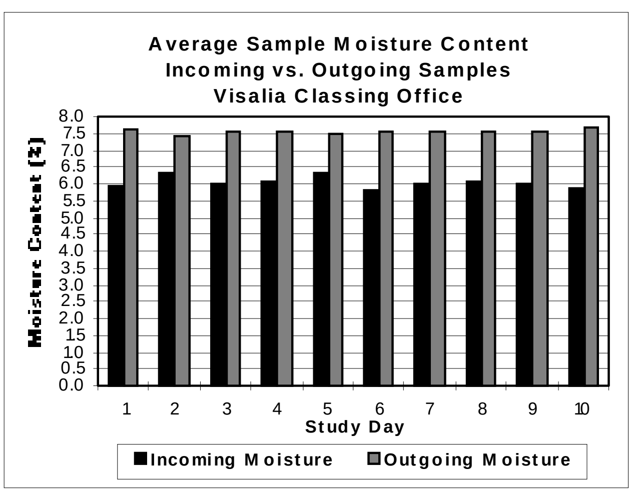

Figure 13. Average moisture contents for incoming vs. outgoing samples - Visalia, CA.

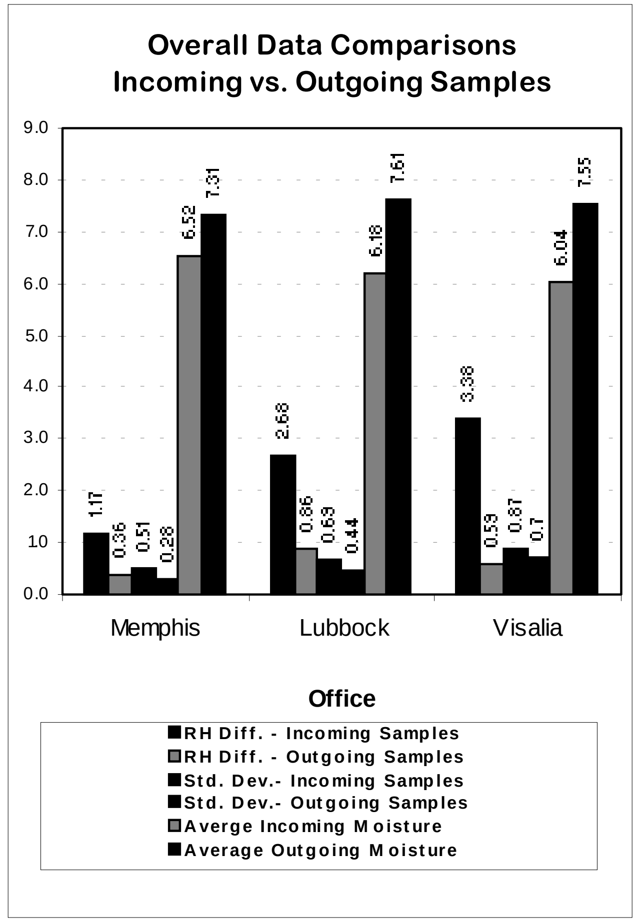

Figure 14. Overall Data Comparisons for Study Offices.