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Chemically Enhanced Wet Pressing

Timothy Mishark
Western Michigan University

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By

Timothy Mishark

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Abstract

The problem of energy consumption is one of the largest confronting the paper industry today. One of the largest areas where this energy consumption occurs is the dryer section on the paper machine. If a legitimate way to reduce the load to the dryer section was developed, it would greatly benefit the paper industries financial situation. Some of the methods that have been used to reduce dryer load include; increasing the pressure in the press section, heating the press rolls in the press section, and applying chemicals to the felts which help inhibit rewetting. The latter item is what this project attempts to tackle. The chemicals that have been found to work in curtailing rewetting are for the most part, flammable. These include kerosene, which was found to work when washing felts, and a chemical similar to cyclohexane, developed by John Penniman. The main goal of this thesis is to find a nonflammable additive that reduces rewetting. In this experiment a drop press was used to simulate the actual press nip in a paper mill, and as is explained later, this was not a very successful portion of the experiment. The chemicals that were tested were kerosene, cyclohexane, pentane, toluene, and acetic acid. The chemicals were applied at a dosage of 0.1 g, 0.2 g, and 0.5 g per felt, and these were compared to the experiments with no chemicals added. When the experiment was performed it was found that acetic acid at 0.5 g application worked the best. In actuality the cyclohexane worked the best overall, and the acetic acid and kerosene were not as successful. The cyclohexane did tend to be less effective as the experiment wore on. Based on all of the criteria listed above the most successful chemical was the toluene.

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Introduction and Background

One of the major problems facing the industry today is runaway energy costs. This is no different for the paper industry. There are numerous areas where these energy costs can be traced to, and one of the major areas is in the drying of paper on the paper machine. The lack of ability to effectively use energy helps make the paper industry one of the most energy intensive in the world today. To rectify this situation, something needs to be done, especially since the amount of money generated from paper sales is not expected to increase significantly.

There have been numerous attempts to lessen the load to the dryer section. These include increasing the pressure in the press section, but this tends to produce sheet crushing and excessive wear on the felts. Heated press sections have also been attempted, yet this requires more energy and this is the problem which is trying to be remedied. Some work has also been done with water free forming, and using adhesives to replace the hydrogen bonds in the paper. Mass production using this technique are not even close to being realized.

One successful method in curtailing rewetting was the application of chemicals to the felts which help prevent rewetting. The chemicals which were used for this include kerosene and a chemical which is similar to cyclohexane. Kerosene was found to work by accident, and this is what led to further research in this subject. Kerosene is used to clean felts, and it was noticed that directly after this the dryer load was greatly reduced. Eventually it was determined that kerosene was the item causing this drop in dryer load. The cyclohexane type chemical is actually a patent which was developed by Penniman(1). These chemicals are both highly vaporous and flammable, thus they are not suitable in a great deal of paper industry situations.

Thus there is a need for a chemical which can severely inhibit rewetting and is not flammable. The amount of chemicals from which to choose is almost endless, thus a starting point is needed in choosing the chemicals to use for the experiment. This, of course, was given with kerosene. Thus the basis for the entire experiment was provided, and a starting point to select other chemicals was also provided. The next chemical which was selected was cyclohexane, which was selected due to its similarity to the patent by Penniman(1). Thus the basis we used for selecting the chemicals was that they should be long chain hydrocarbons, or organics. All of the chemicals used were some form of organic chemical. The organics that were selected, were so because of their vapor pressure and flash point temperature. The majority of the experimental background work was performed on the drop press, as explained in the experimental procedure section of the report.

Experimental Procedures

The experiment was basically broken down in to three sections. The first area was that of the drop press, the second was the chemical selection and the third was the actual experimental runs. The drop press is where the bulk of the time, energy and money was outlayed for this experiment. Chemical selection was fairly brief and should be extended for further experiments. The actual experiment was performed over a period of three days, and thus is not a highly difficult method to explain.

The work on the drop press actually began in the middle of October. It was decided, then that the drop press was adequate for the needs of this experiment. In the beginning of the next year, the drop press was moved to a location where it would not be interfered with by other students. At this time the height from which the weight needed to be dropped was also determined. However, at this time, the drop press was not functioning as well as it had earlier in the year.

Once the various options were evaluated it was decided it would be best to remove the catch mechanism from the press, and drop it and catch it by hand. This method was used for all experimental runs, which may have increased the amount of experimental error. Once the experiment was ready , the drop press was used to create a pressure pulse, which forced water from the wet paper.

The paper was placed on wet felts approximately 4 inches in diameter. The press was then dropped on wet, pre-weighed paper, and the paper and felt were then weighed again. This was done with measuring the height at which the press was dropped. The drop height was selected to produce an 8% increase in solids, which is typical of many commercial presses. This height was marked and used for the rest of the experiment. It should be noted that the paper was wetted by spraying a water bottle on the paper, usually three times. This achieved a fairly consistent beginning moisture from which to perform the experiment.

The chemicals used, and some of their properties, are shown in Table I located below. This table lists the characteristics of each chemical, at least the characteristics which were used in choosing the for the experiment. Once the chemicals had been chosen, the experiment was ready to be performed. The basic experimental procedure followed in this experiment is shown in Table II in the appendix.

Table I, Basic Properties of Chemicals Tested

Chemical	Formula	Vap. Press.	Soluble	Threshold	Flashpoint
Kerosene	C12 ---	18	no	200	17
Cyclohexane	C6H12	13	no	300	13
Acetic Acid	CH3CO2H	2.1	yes	10	43
Pentane	CH3CH2CH3	69	no	600	40
Toluene	C6H5CH3	3.8	no	100	4

The kerosene runs were performed first since this chemical has been shown to increase press solids on commercial machines. At first 1 gram of kerosene was sprayed on the felt and the press was dropped five times for five separate experiments. It was then determined that this was too high a level of a chemical application. The next step was to spray 0.1 grams of chemical on the felt, which was a much more realistic application. The chemical was applied to the felts only once and then used for all of the five runs. The chemical was applied by spraying it against the felt, which was the same way the water was applied to the paper.

The kerosene was then applied at 0.2 g, 0.3g, and 0.5 g. After all of these chemical applications were evaluated, it was determined that 0.1 g, 0.2 g, and 0.5 g were the best amounts of chemicals to apply to the felt. Thus these three amounts were used for each of the chemicals. The felts were not used for two different chemicals, thus no chemicals were mixed on the felt, and all of the felts came from the same material.

Results

This section focuses on the experimental results obtained using the drop press. The discussion is broken down into two major sections. The first section examines the amount of moisture which was removed, on average, from each application of the chemical. The second section focuses on the drop off in effectiveness as the number of runs increased. The runs are also compared to each other on the same graph, so the effect of different chemicals can be determined.

The first item shown is table 2 showing the overall results used in the next four figures. From this table, it can be seen that the greatest improvement in dewatering is with 0.5 grams of acetic acid. While the least effective chemical application was 0.2 grams of acetic acid. Figure 3 compares all the chemicals using 0.1 grams of active chemical. The remaining four figures contain the dry run removal percentage for comparison with the chemically aided runs. This chart shows that cyclohexane was the most effective chemical at this addition rate. This was followed by toluene, then kerosene, acetic acid, and the least effective which was pentane.

Figure 4 shows the % drop in moisture for 0.2 grams of chemical applied. This figure shows that kerosene was the most effective at 11.04% removal. This was followed by cyclohexane and toluene which both had removal rates of 10.86%. Next was pentane with a removal average of 10.34%, and then acetic acid which was the least effective at 9.24%.

Figure 5 shows the effectiveness of 0.5 grams of chemical. This figure indicates that acetic acid is far and away the most effective chemical with 13.7% of the water removed. This is a 5.64% difference from the dry runs. Cyclohexane is the second most effective with 11.78% removed. Toluene and pentane were next with 10.66% and 10.50% removed, respectively. Kerosene was the least effective at a 9.88% removal average.

Figure 6 simply shows the above results all placed on one graph. A couple of useful observations can be made from this figure. It can be seen that cyclohexane is the

Table 2, Experimental Raw Data			
Chemical	0.1 grams	0.2 grams	0.5 grams
Dry Run	8.24%	8.24%	8.24%
Kerosene	11.46%	11.04%	9.88%
Acetic Acid	9.78%	9.24%	13.70%
Cyclohexane	12.42%	10.86%	11.78%
Toluene	11.58%	10.86%	10.66%
Pentane	9.34%	10.34%	10.50%

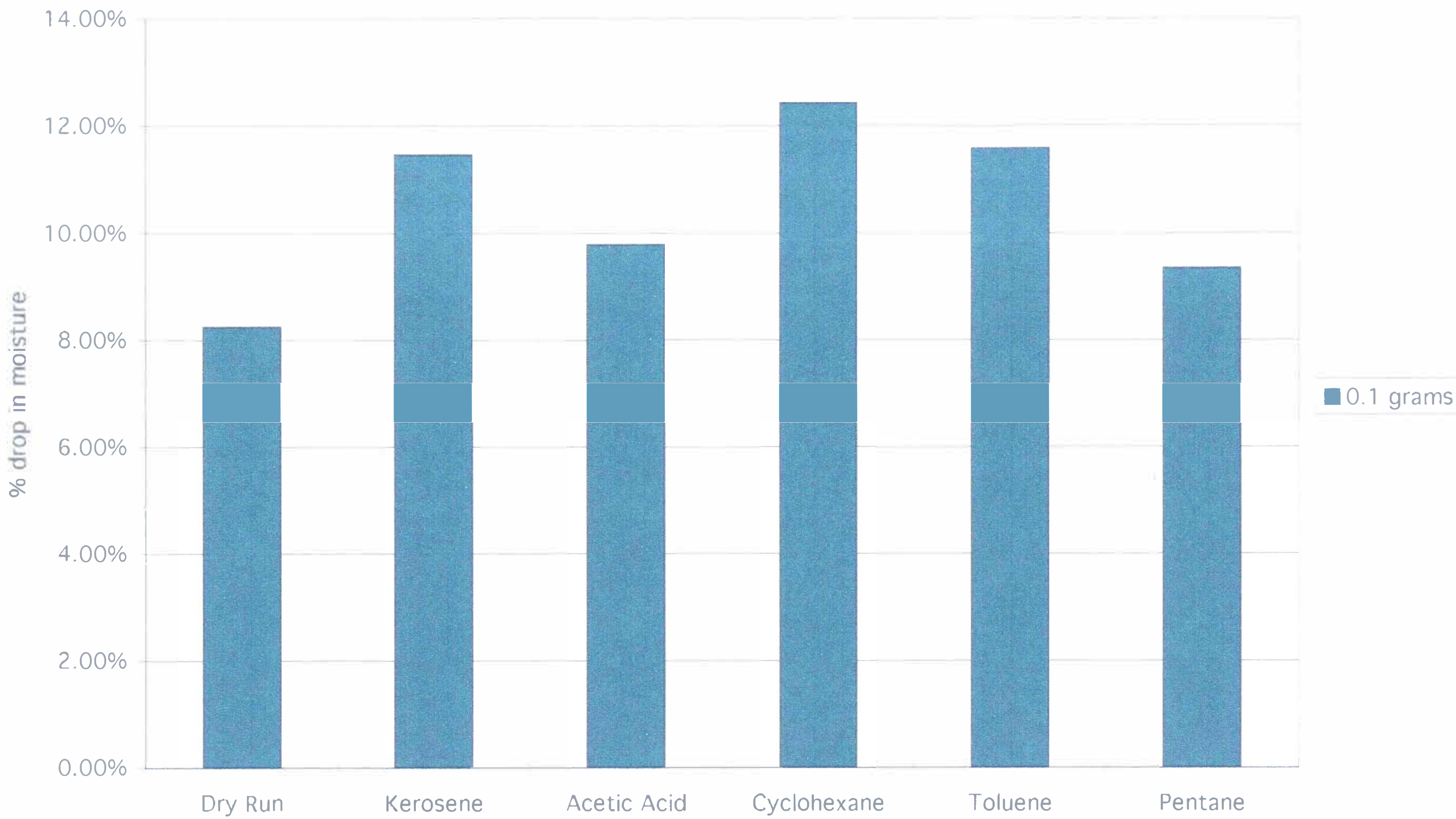

Figure 3, Chemical Runs for 0.1 gram

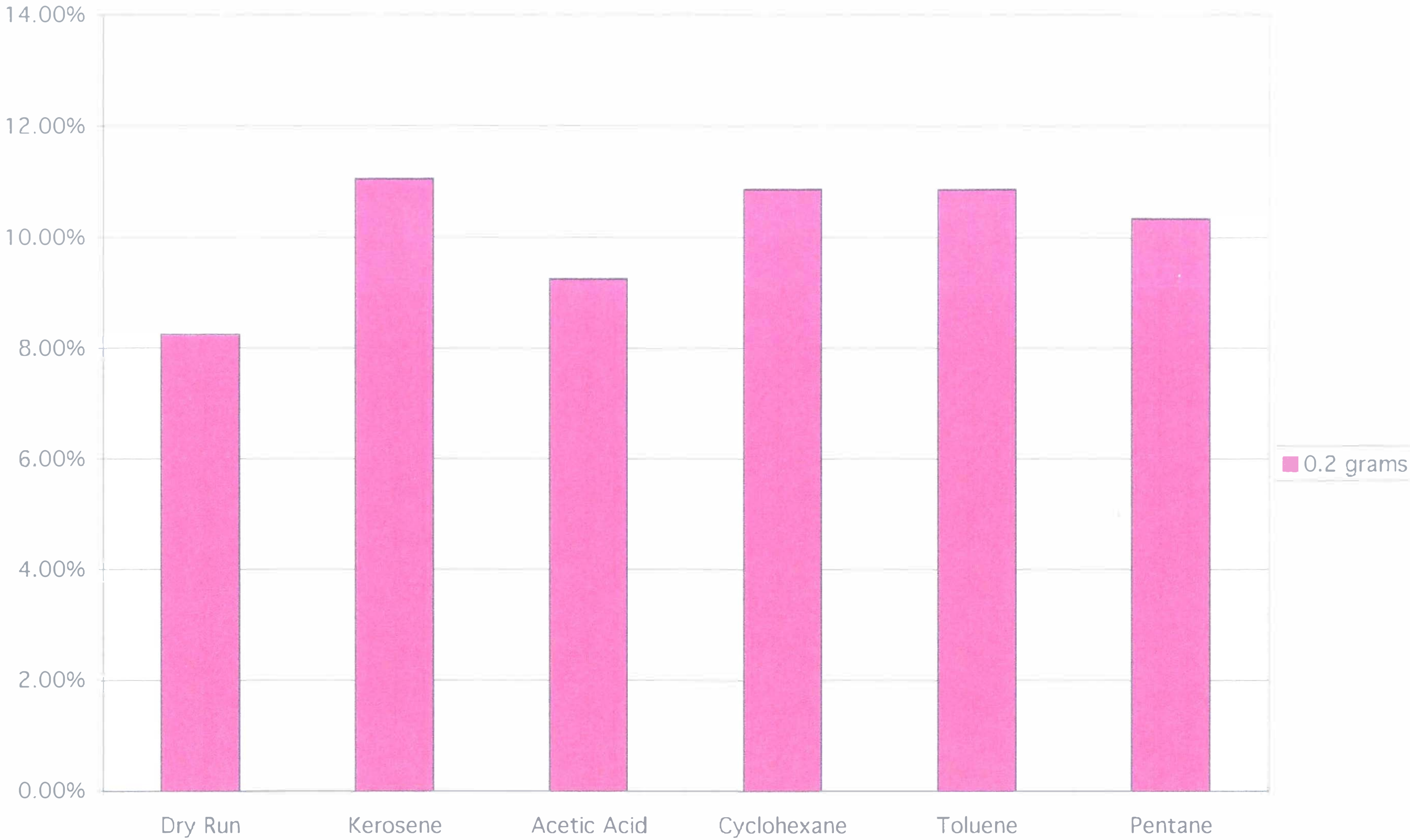

Figure 4, Chemical Use 0.2 grams

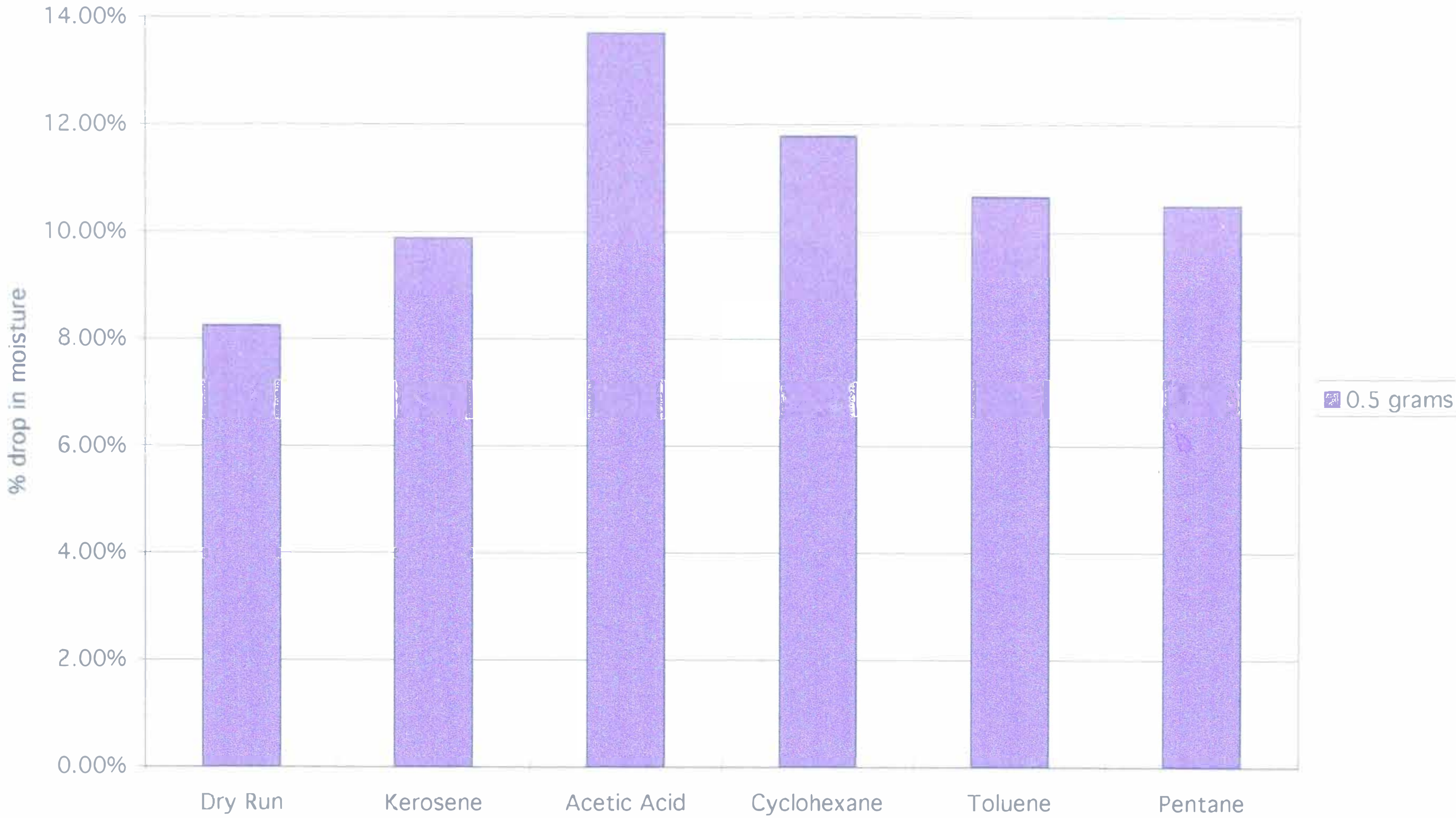

Figure 5, Chemical Use 0.5 grams

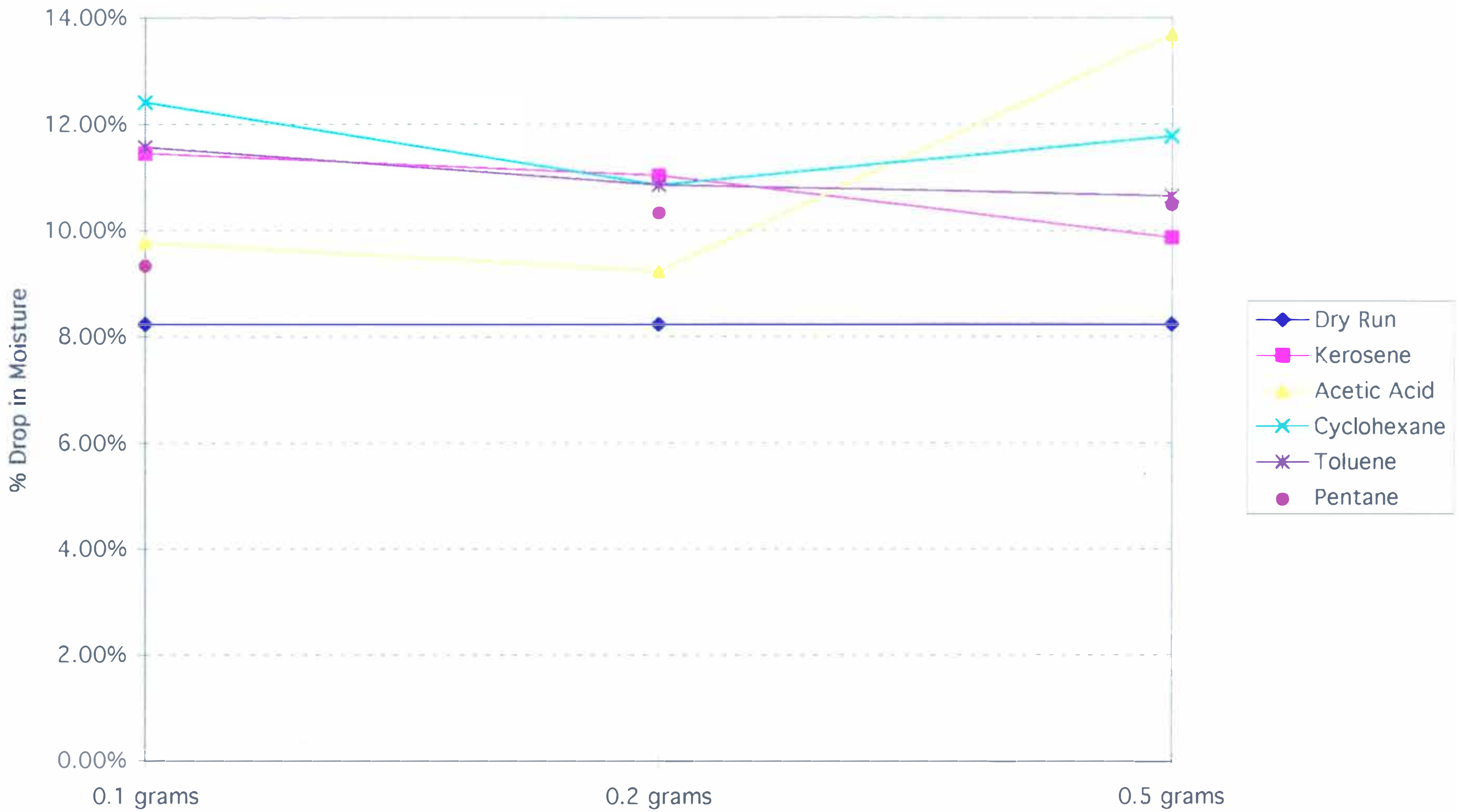

Figure 6, Total Comparison of Chemicals

most effective chemical on average for each of the applications. Toluene is the next most effective with kerosene following closely. Pentane and acetic acid can be seen to be the least effective, even though acetic acid has the highest removal percentage at one point.

The other grouping of data is the origin of the first, but it is not averaged. Table 3, located in the appendix shows how each run progressed over time. This was done to show how effective the chemical was after it was used once, twice, etc. Since the table just shows the raw data used for the figures, it will not be explained in detail.

The first group of figures compares the subsequent runs of the kerosene applications. It should be noted that all of these used trendlines to smooth out the variances from the normal. Figure 7 shows the runs of 0.1 gram of kerosene. This application provided a linear result with no drop-off. Figure 8 shows the runs of 0.2 grams of kerosene. This runs showed a fairly small drop-off when compared with some of the other chemicals, yet some fall off did occur. Due to significant variance, this chart is not as meaningful as some of the others. Figure 9 shows the effectiveness of 0.5 grams of kerosene. The amount of water removed actually increases on this chart, yet if the first two data points are removed, this would not be the case.

The next group of figures, figures 10 - 12, compare the subsequent runs of acetic acid applications. Figure 8 shows the effectiveness of 0.1 grams of acetic acid, and it should be noted that the scale is different on this figure. This figure shows that acetic acid has a significant drop off in its effectiveness, with more than a 2% fall off. Figure 11 shows the exact opposite effect of 0.1 grams. The 0.2 gram run actually showed an increase in the amount of moisture removed. This was not a significant increase however, overall it was approximately 1%. Figure 12 portrays the effectiveness of 0.5 grams of acetic acid. Once again the amount of moisture removed increased after each run. This time it was significant however, with more than a 3% rise noticed.

Figures 13 - 15 show the effectiveness of the cyclohexane applications. The first figure, figure 11, shows the slightly skewed drop off in moisture removed for 0.1 grams of cyclohexane. This figure is highly misleading due to the scale. Still a significant fall off occurs, with almost 2% being cut off of the original value. The second figure shows the effectiveness of 0.2 grams of cyclohexane, with well over a 2% drop off being realized. The final cyclohexane chart, chart 13, shows a flat trend or almost no drop off occurring.

Figures 16 - 18 show the effectiveness of toluene. Figure 16, the 0.1 gram of toluene application, shows a drop off of nearly 3%. The next figure in this group only shows a drop off of close to 1%, while the last figure, figure 18, shows an increasing trend. This unusual increase is only around a half of a percent.

The last group of charts show the effectiveness of the pentane. Figure 19 has a slight drop off, but it is too small to measure. It should be noted that this figure has a huge standard deviation also. Figure 20 shows the effectiveness of 0.2 grams of pentane, which has a drop off of close to 6%. The last figure, figure 19, also has an almost straight line with no drop off.

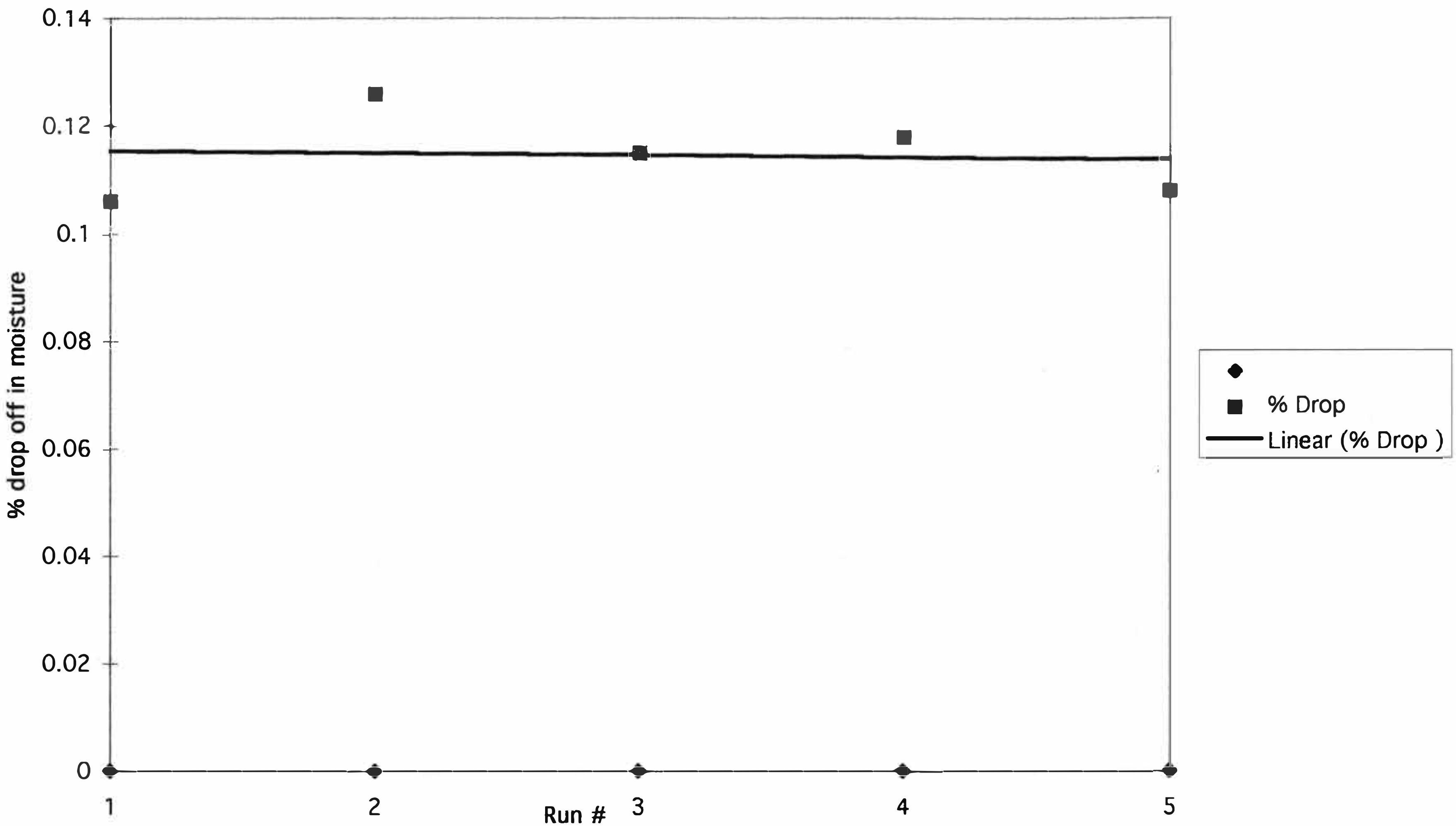

Figure 7, Effectiveness 0.1 grams of Kerosene

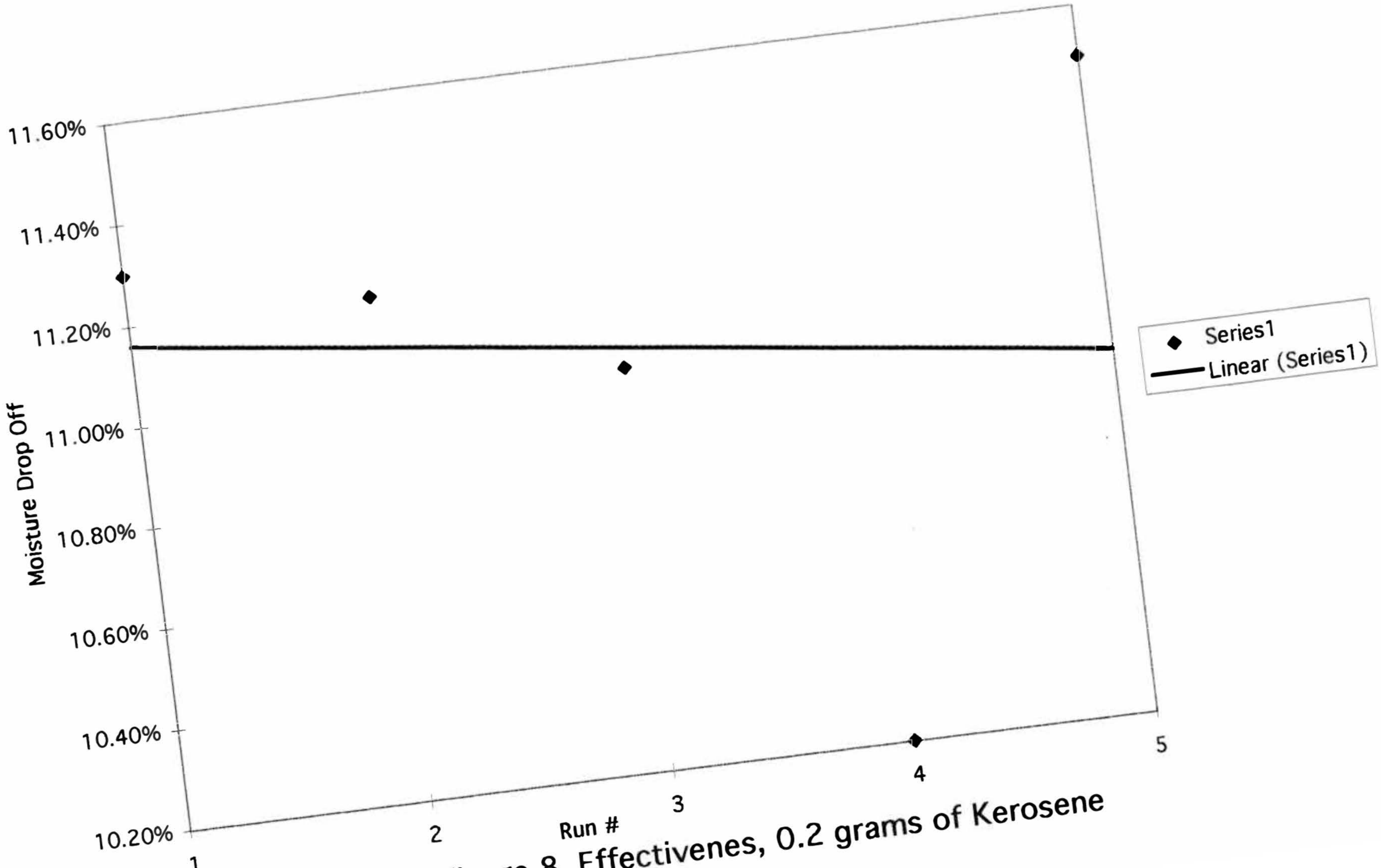

Figure 8, Effectivenes, 0.2 grams of Kerosene

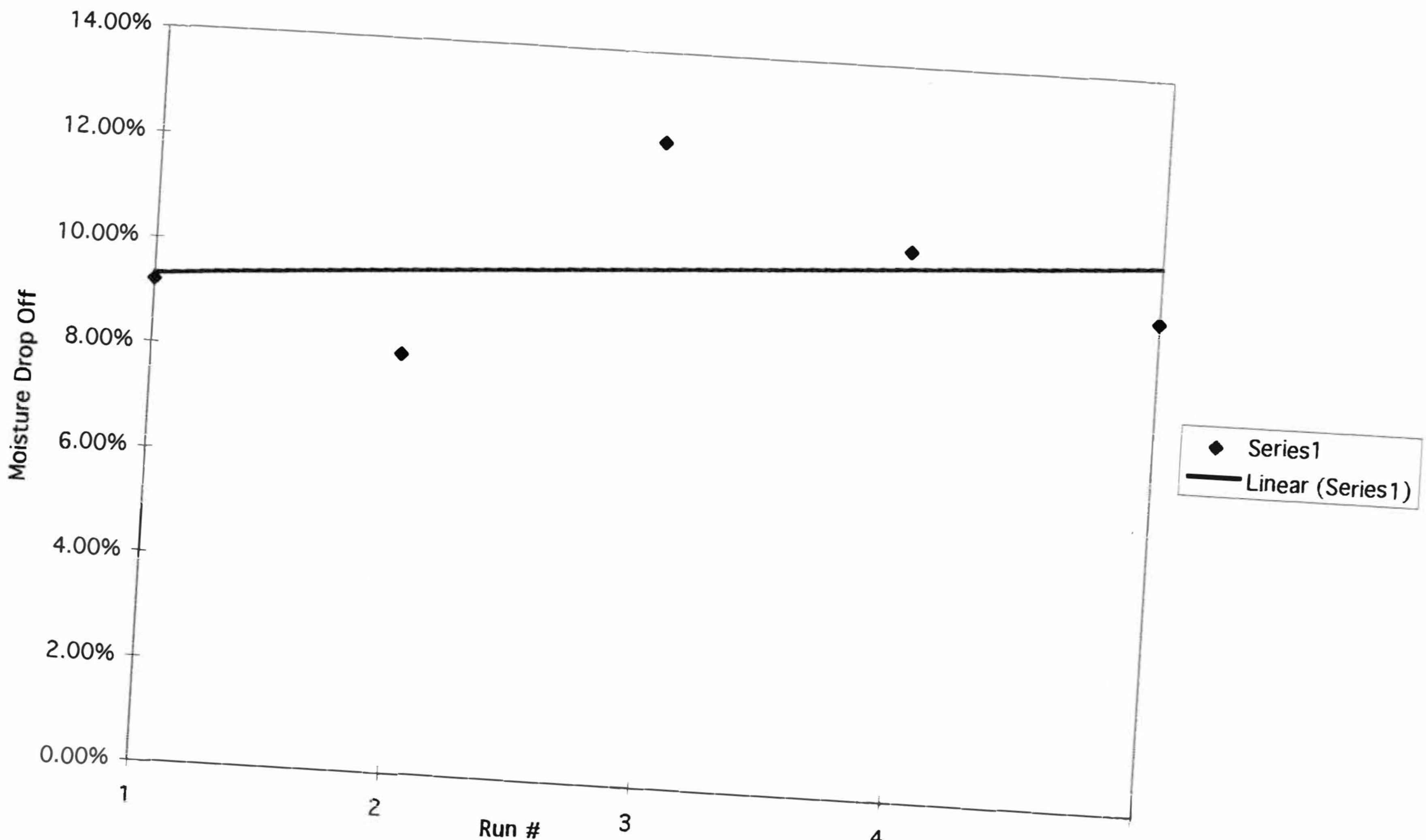

Figure 9, Effectiveness 0.5 grams of Kerosene

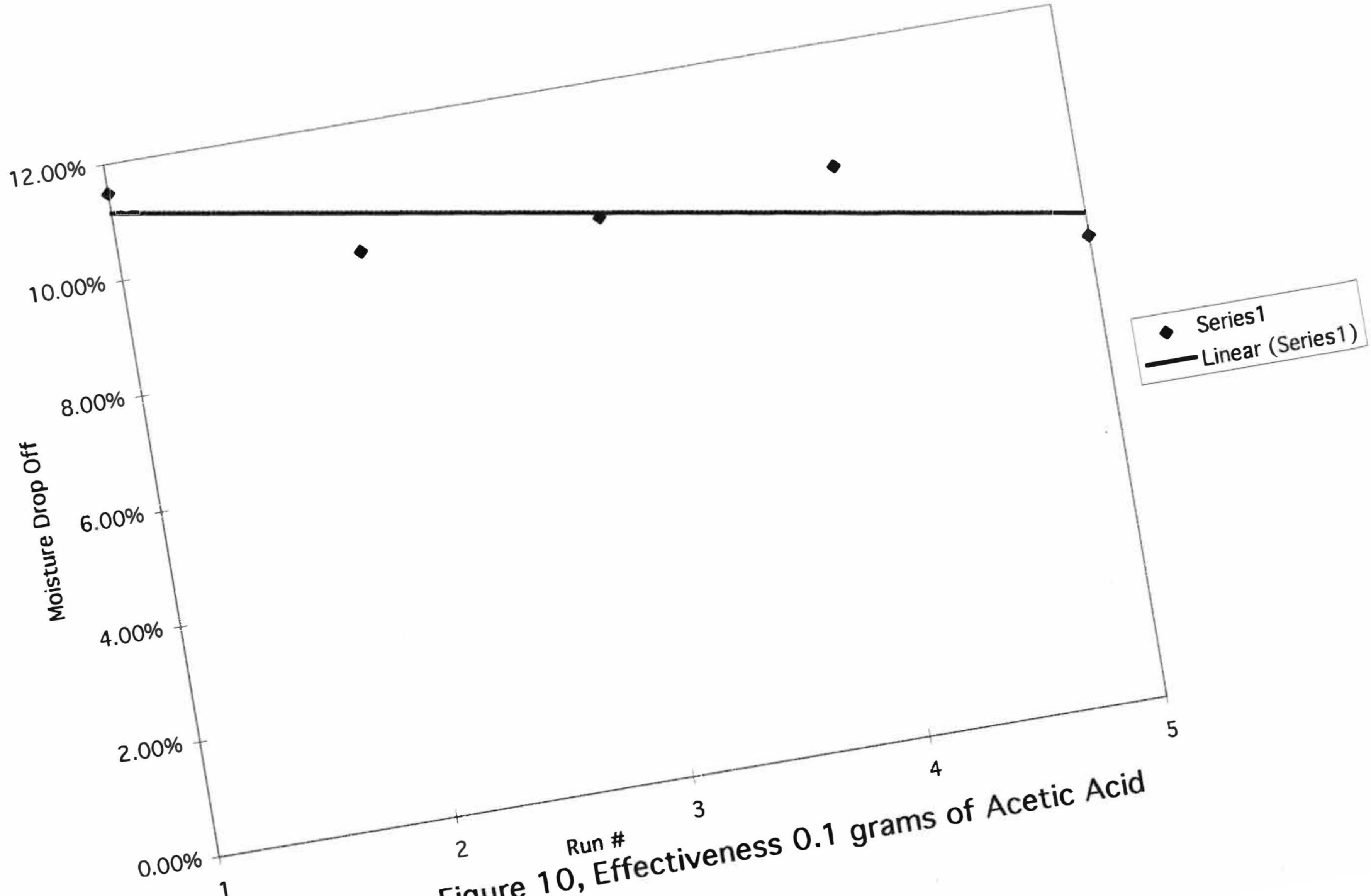

Figure 10, Effectiveness 0.1 grams of Acetic Acid

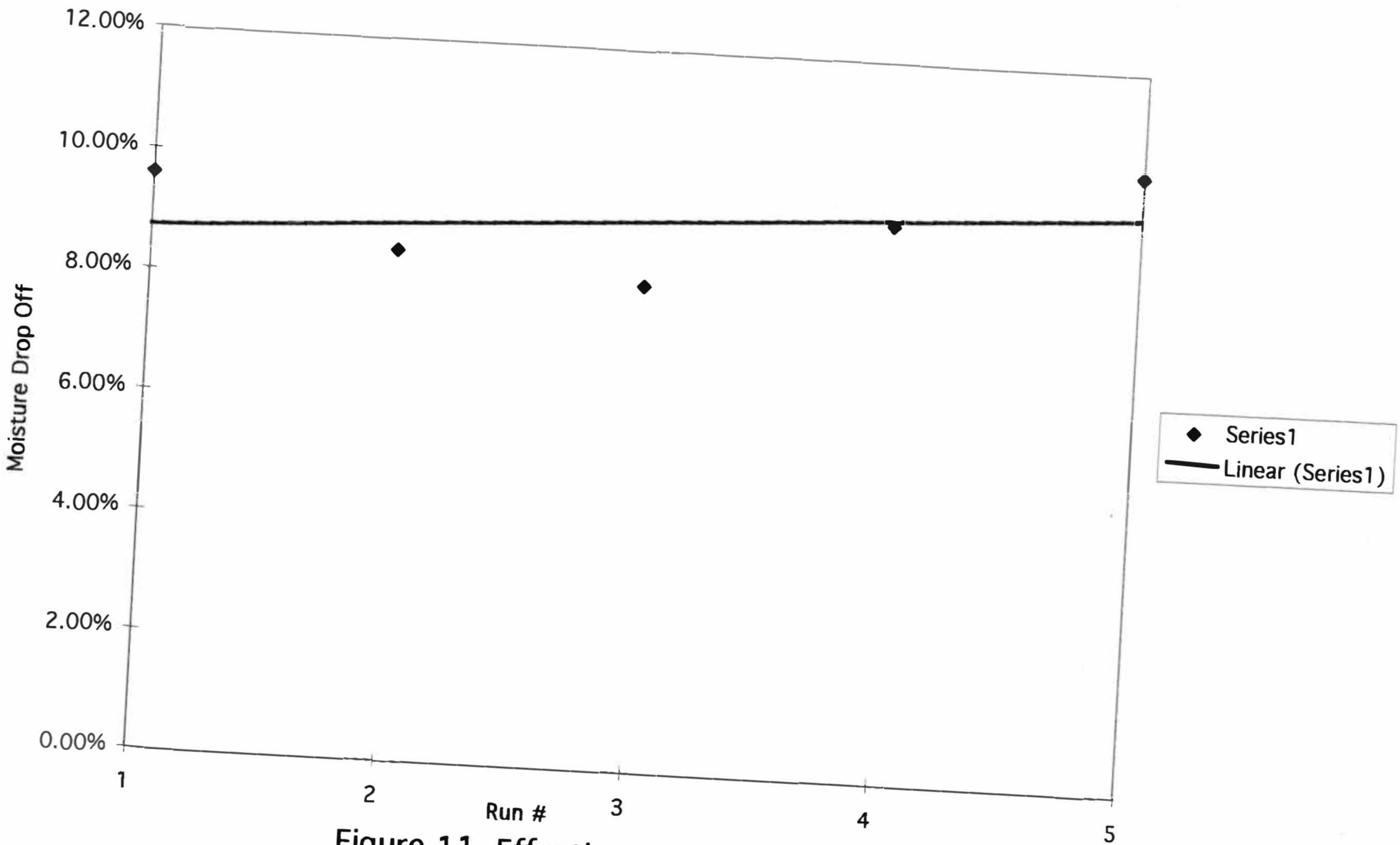

Figure 11, Effectiveness 0.2 grams of Acetic Acid

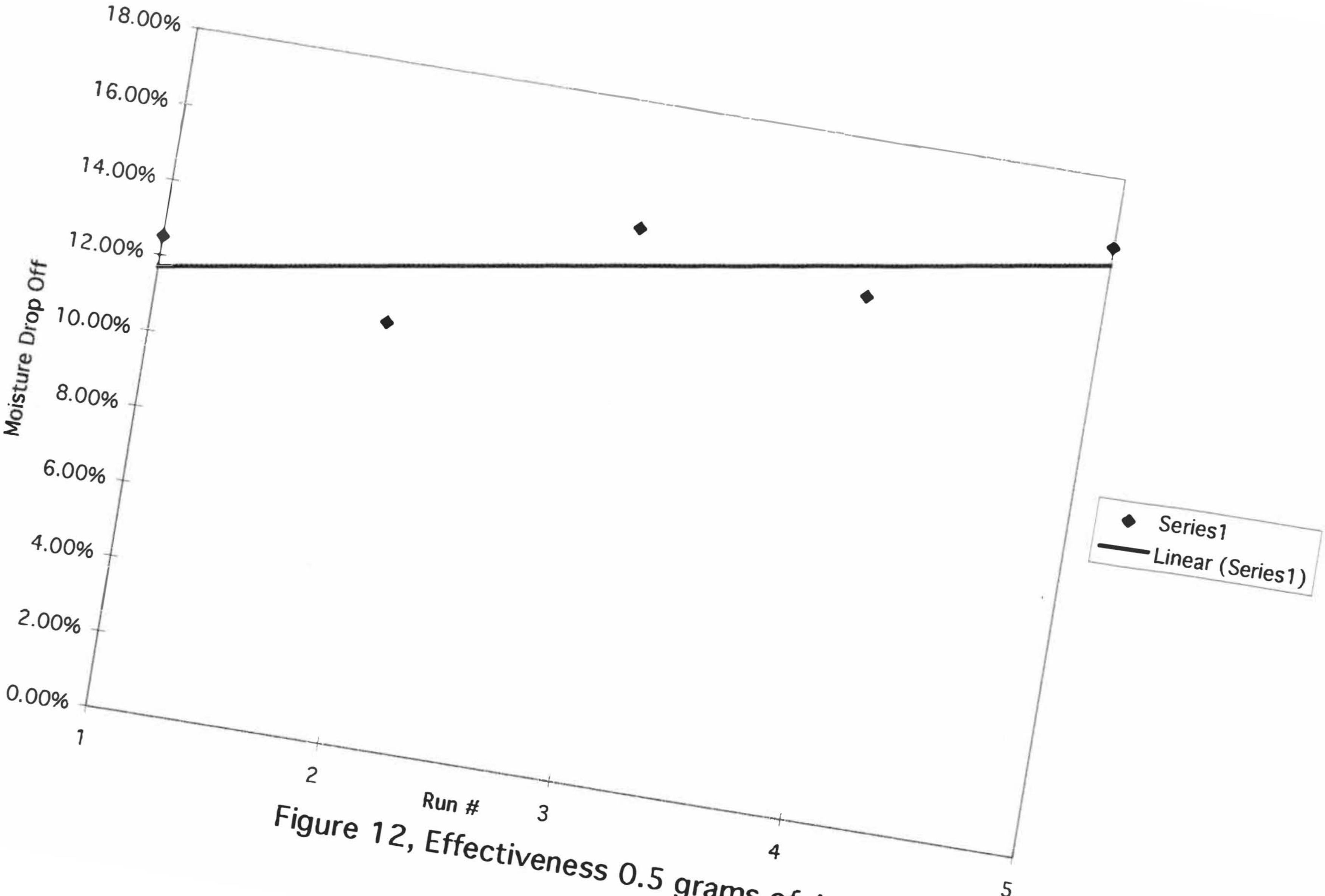

Figure 12, Effectiveness 0.5 grams of Acetic Acid

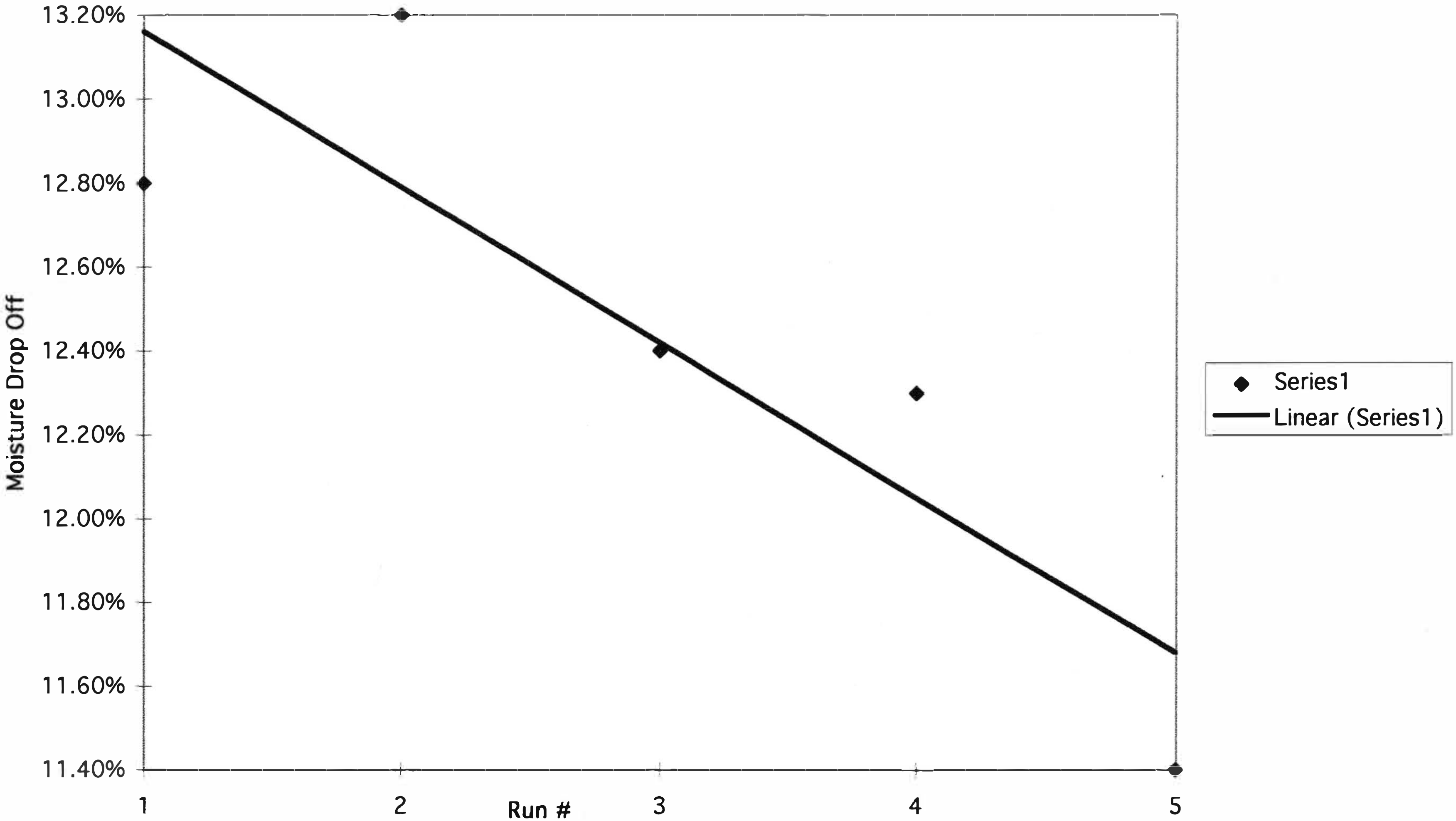

Figure 13, Effectiveness 0.1 grams of Cyclohexane

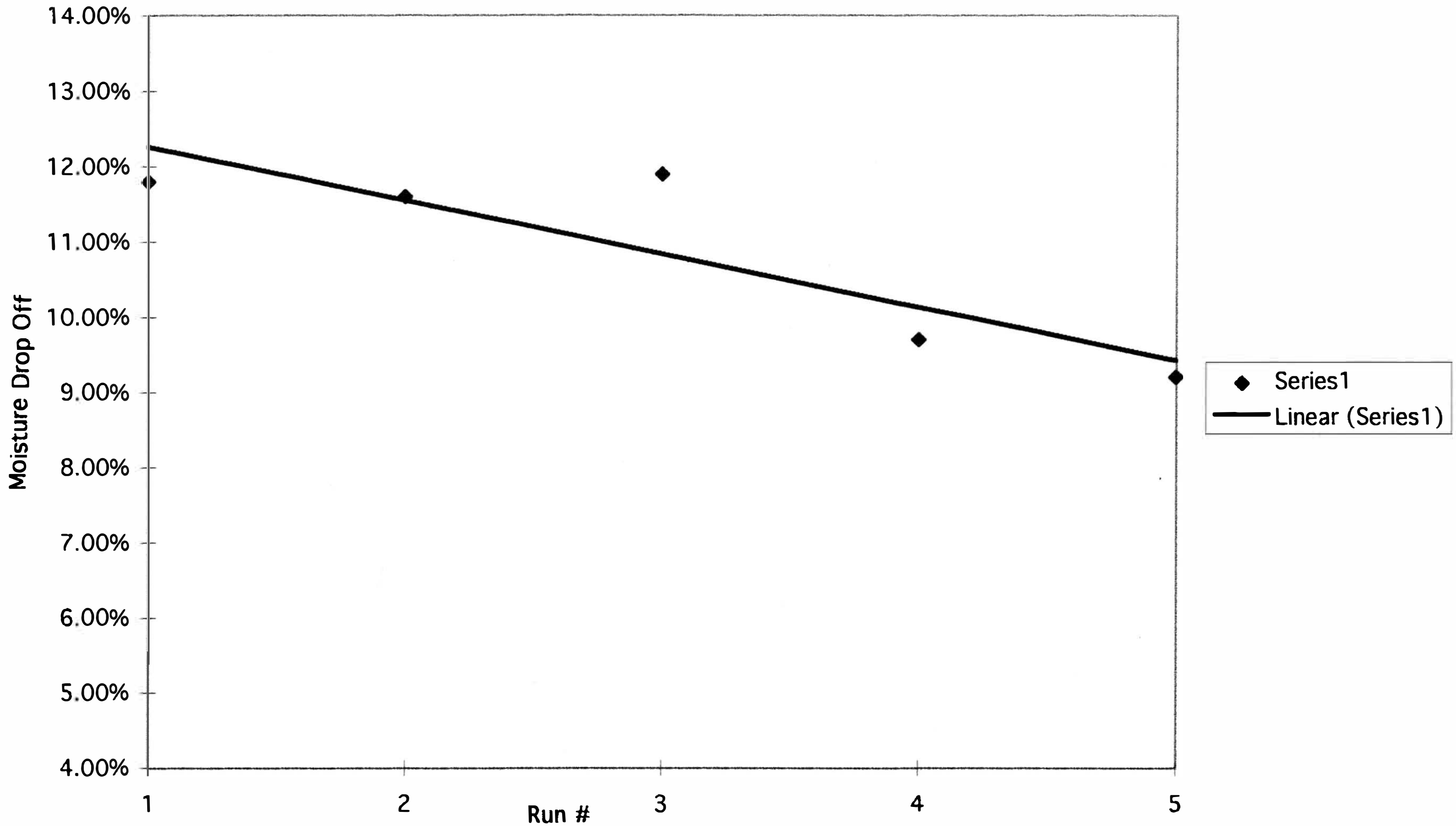

Figure 14, Effectiveness 0.2 grams Cyclohexane

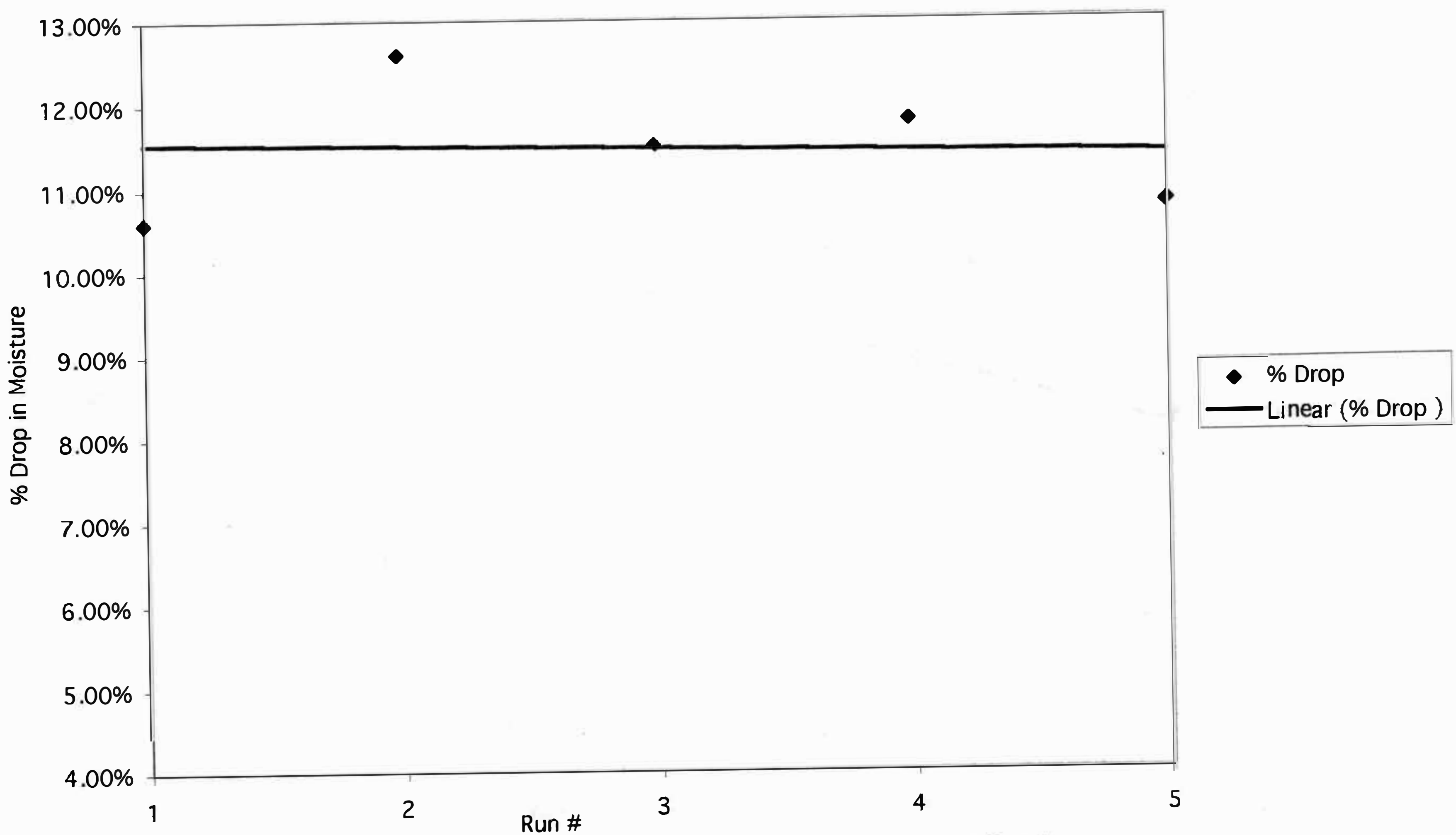

Figure 15, Effectiveness of 0.5 grams of Cyclohexane

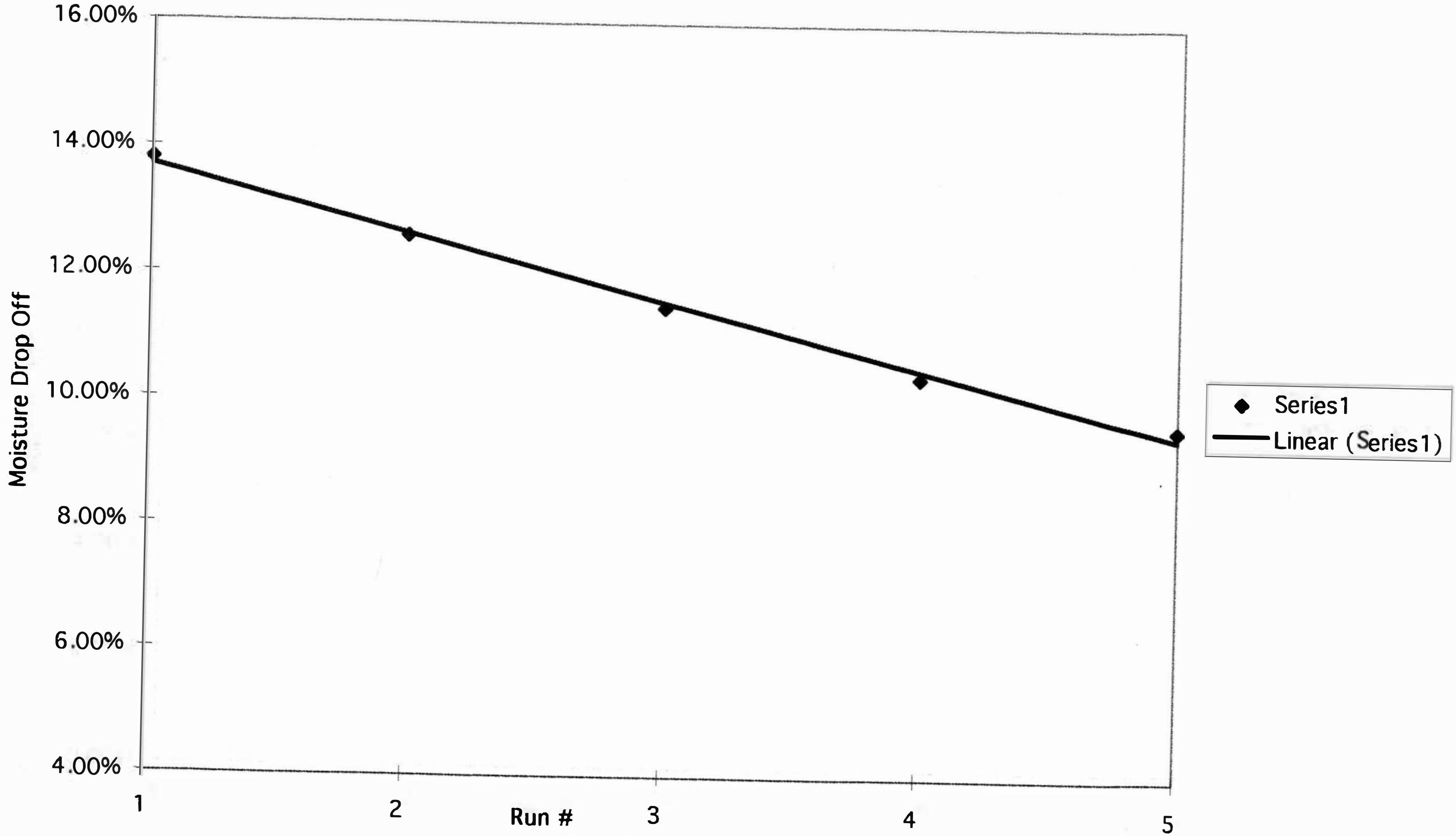

Figure 16, Effectiveness 0.1 grams of Toluene

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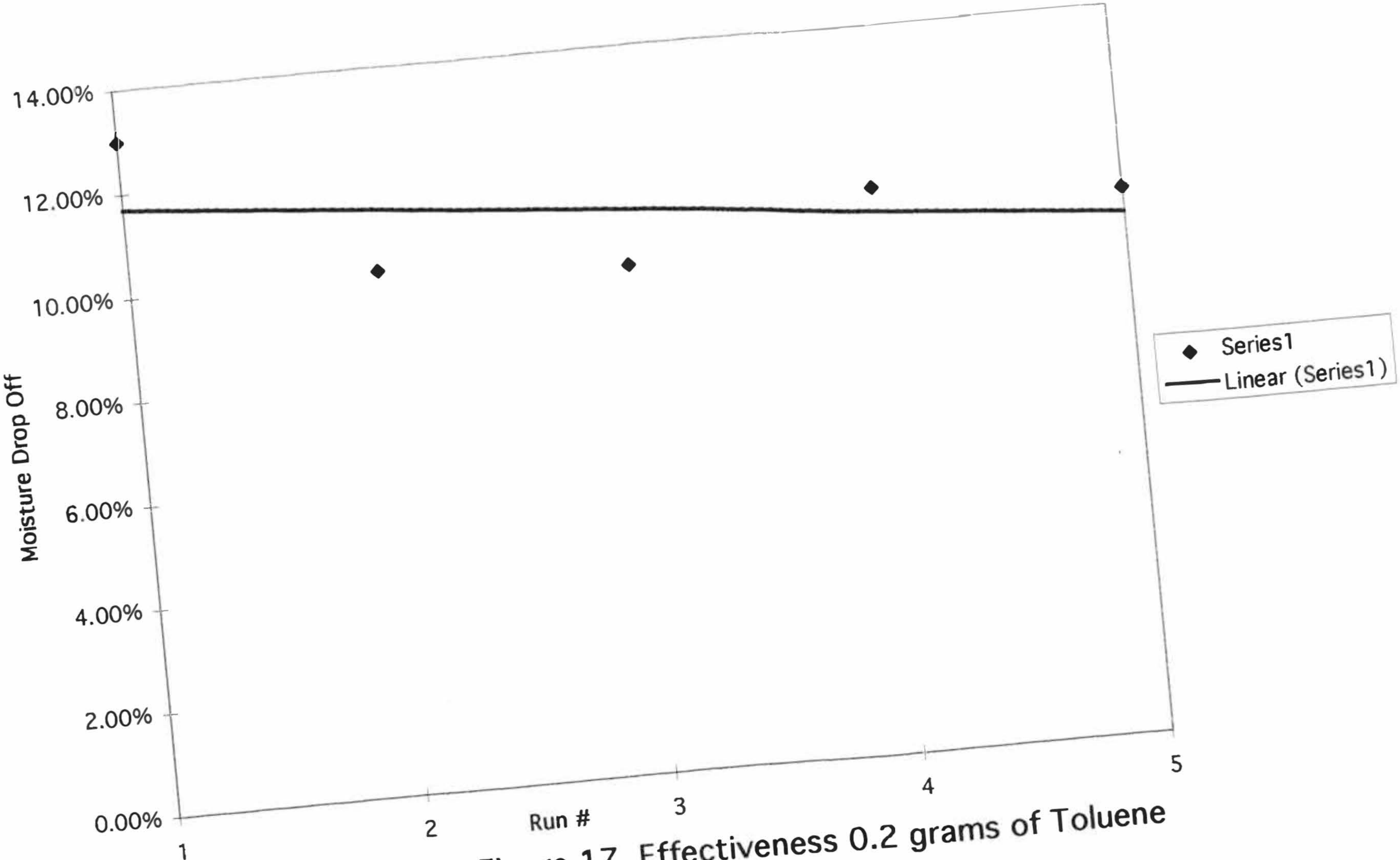

Figure 17, Effectiveness 0.2 grams of Toluene

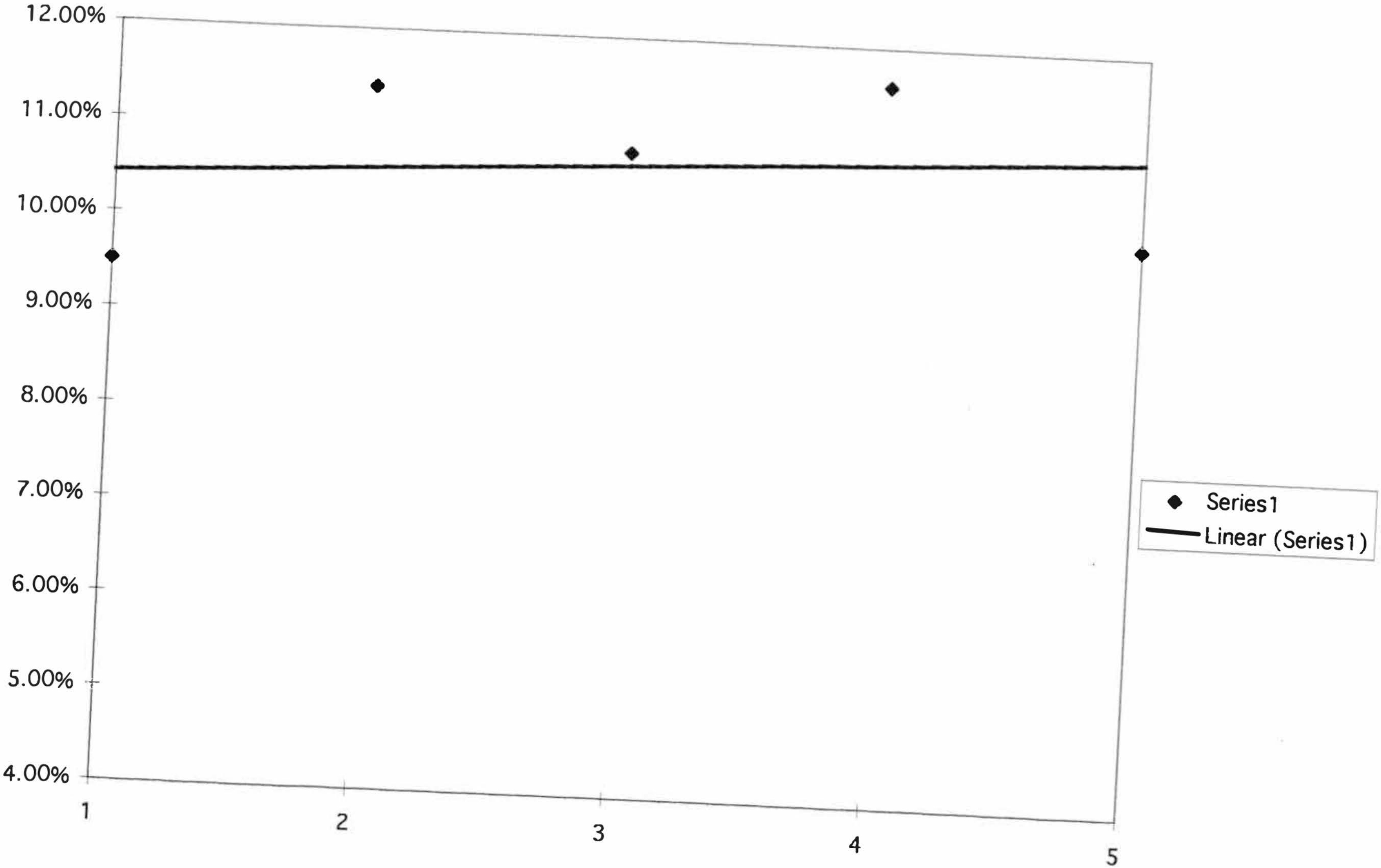

Figure 18, Effectivenes 0.5 grams of Toluene

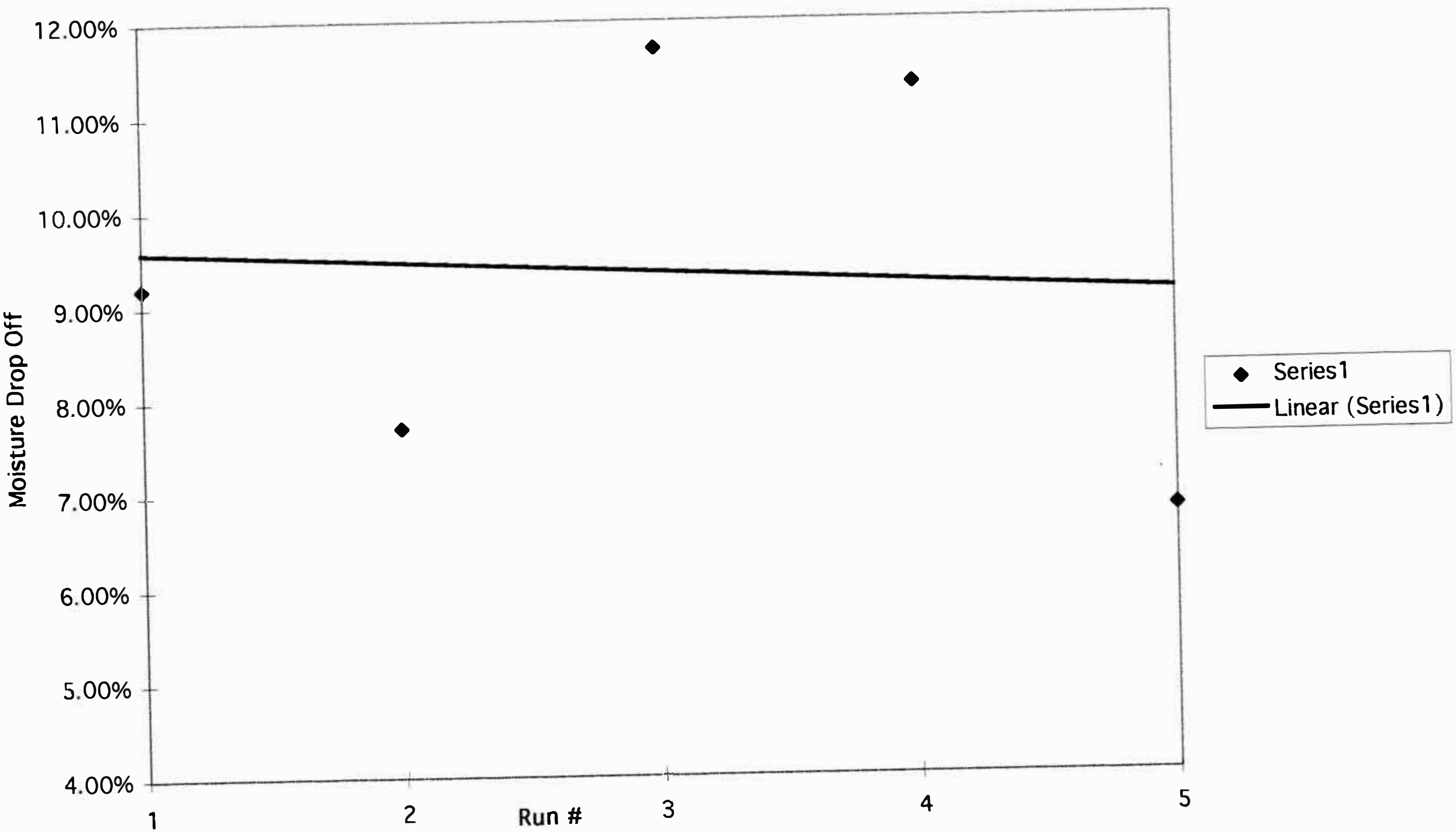

Figure 19, Effectivenss 0.1 grams of Pentane

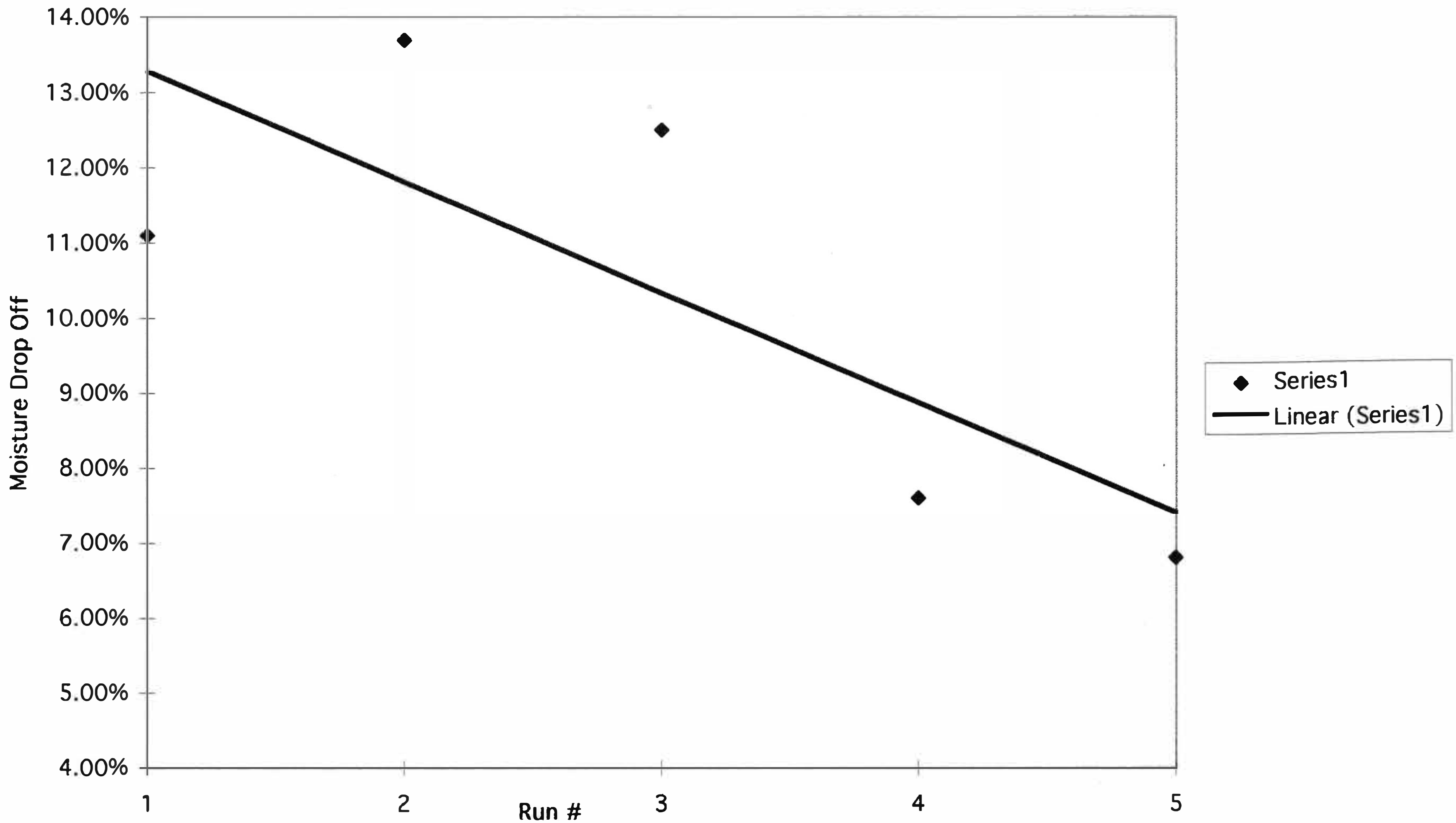

Figure 20, Effectiveness 0.2 grams of Pentane

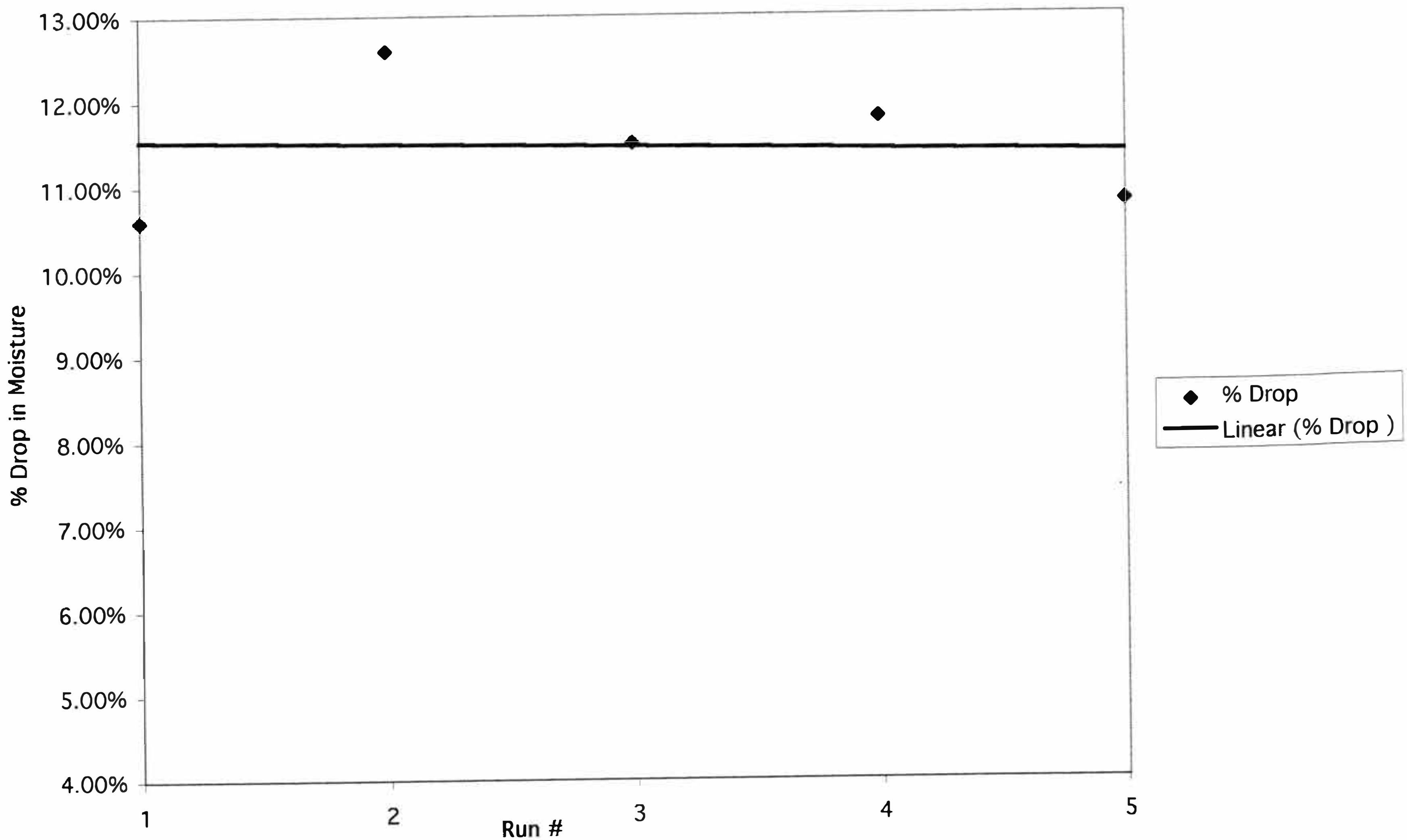

Figure 21, Effectiveness of 0.5 grams of Pentane successful of all applications tested. There is no explanation which can begin to state why this chemical worked. Further research needs to be performed with this chemical.

Cyclohexane was used because of the patent developed by Penniman. It was fairly obvious why a patent was given in his case, this was by far the most consistent and successful chemical used in the experiment. It was more effective when only 0.1 grams was applied, and once again no explanation is given for this. The cyclohexane decreased the rewetting in the sheet by an average of 4.18% when 0.1 grams was applied, and this is a significant difference.

The pentane followed a typical course by increasing in effectiveness as more chemical was added. However, the pentane evaporated too quickly to be considered as a legitimate chemical to use in this process. The toluene was almost as consistent and effective as the cyclohexane. The toluene also had a drop off in effectiveness as the amount of chemical increased, as did all of the effective chemicals. The toluene was the chemical used which might have some legitimate prospects for industry use.

Discussion of Results

This experiment produced some interesting and unexpected results . It also gave some results which almost had to be attributed to some form of experimental error. The drop press was obviously one of the reasons that some experimental error was received. The drop press was dropped by hand so this most likely produced slight experimental errors which may not have been noticed. The slight change in moisture contained in the felts also may have skewed some of he results. The fact that the chemical was sprayed on might have also affected the data, yet this is most likely how it would be applied in a mill so this will not be held accountable. The placement of the felt and paper was done manually, which may have caused it to be slightly off centered, which could produce some bad results. Some of the moisture may have dripped of the sheet of paper as it was transported to the press, which would have falsely added to the effectiveness of the chemical. With all of this being said, most of the results still should be useable.

The results of the dry runs, or really the wet runs with no chemical, should be fairly accurate. The dry runs were performed a total of twenty times to ensure for a legitimate number. The kerosene was the basis of the experiment and thus was the first chemical used. The kerosene was effective in lowering the amount of rewetting, but the effectiveness fell as the amount of applied chemical increased. This may be due to experimental error, some of the chemical entering the paper, or some unknown reason. Yet even poorest results produced a 1.64% increase in the moisture differential. While this may seem like a low number , it would translate into a larger reduction in the dryer load. The reason for the effectiveness of kerosene is not known and should be looked into during further research.

The next chemical used was the acetic acid. This was the one chemical which was used solely to see if a very low vapor pressure material would work. The acetic acid also produced positive results at application level. The 0.5 gram application was the most successful of all applications tested. There is no explanation which can begin to state why this chemical worked. Further research needs to be performed with this chemical.

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Recommendations

There are numerous directions which can be taken to further the research of this project. There are two main branches which need to be discussed which include further experiments which have already been performed and some completely new experimental methods. The main recommendation, for both experimental pathways, is to use a completely new drop press. The drop press which was used for this experiment is highly inadequate for specific results. This is due to no catch mechanism or release mechanism being used, both being accomplished manually. Also the pressure impulse was not able to be measured due to a faulty oscilloscope. These projects are currently being addressed by Dr. Cameron. He has already recieved the funds for these projects, thus eliminating one hurdle.

Some recommendations, concerning the experiment already performed, are to increase the number of times the press is dropped for each chemical application. When performing the experiment, the press was dropped 5 times for each chemical application. For the next person to study this phenomenon, the recommendation would be to drop the press at least 20 times to determine the longevity of the chemical in use. Also, they should try dropping the press from different heights, maybe two, to determine the effects of pressure on this phenomenon. This was not feasible for the experiment since no method was available to measure the pressure being exerted. The next person studying these effects should try applying the chemical to both sides of the felt to determine any difference. It should be noted that the chemical was applied to the backside of the felts in this experiment so no chemical was transfered to the paper.

The other major direction which should be taken, in further experiments, is to evaluate a bunch more chemicals. This experiment was based on using chemicals which were fairly long chain hydrocarbons. More hydrocarbons should be tested, with the criteria being low flammability and vapor pressure, along with availability of the chemical and environmental hazards. Some other chemicals should be tested which are not

Conclusions

The conclusions are summarized below

- The 0.5 gram application of acetic acidwas the single most effective chemical application used during the experiment.
- The 0.2 gram application of acetic acid was the least effective chemical used druing the experiment.
- On average the cyclohexane was the most effective chemical when all of the chemical applications are considered.
- Kerosene and toluene were also very effective chemicals when averaged out over the entire amount of chemical applications.
- Pentane and acetic acid were the least effective chemicals in preventing rewetting, on average.
- Kerosene was the most effective chemical in maintaining the drop off in moisture differential.
- Acetic acid's results were too skewed to make any legititmate or useful conclusions about.
- Cyclohexane had a fairly severe fall off in the amount of moisture removed after the first run.
- The majority of the results for pentane suggested a fairly constant amount of moisture removed, with only the 0.2 grams of chemical differing from this observation. The reason for this is not known.
- The results for toluene varied widely, with one increasing, the other decreasing and the other remaining fairly constant.

Aknowledgement

I would like thank Dr. Cameron who, as my advisor, peformed as much of the experiment as did I. Thanks also should be given to Mr. Matt Stoops and Mr. Bill Forester, who both helped with the drop press.

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Appendix

Table II, Experimental Procedure

Dry Runs

1. Test for Height
2. Get Consistent Results
3. Determine Height

Kerosene Runs

1. Run 1 gram on Felts
2. Each Run is Done 5 Times
3. Runs at .1, .2, .5 grams also

Other Chemical Runs

1. .1, .2, .5 gram apps.
2. Runs Done 5 Times
3. Get Consisten Results

Miscellaneous Experimental Procedures

Felts were sprayed once for each of the five runs

Paper was sprayed with water until at least 65 % moisture was achieved

Felts were cut to a 2 in. radius or 12.57 square inch area

Felt moisture varied from 45 % to 50 % for the entire experiment

Table 3, Raw Data		Breakdown			
Kerosene	0.1 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
% Drop	10.60%	12.60%	11.50%	11.80%	10.80%
Kerosene	0.2 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	11.30%	11.20%	11.00%	10.20%	11.50%
Kerosene	0.5 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	9.20%	8.00%	12.30%	10.50%	9.40%
Acetic Acid	0.1 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	11.50%	9.80%	9.70%	9.90%	8.00%
Acetic Acid	0.2 grams				
	Run 1	Run 2	Run3	Run 4	Run 5
	9.60%	8.50%	8.10%	9.30%	10.30%
Acetic Acid	0.5 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	12.50%	11.20%	14.70%	13.90%	16.20%
Cyclohexane	0.1 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	12.80%	13.20%	12.40%	12.30%	11.40%
Cyclohexane	0.2 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	11.80%	11.60%	11.90%	9.70%	9.20%
Cyclohexane	0.5 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	14.50%	13.60%	11.60%	10.50%	8.30%
Toluene	0.1 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	13.80%	12.60%	11.50%	10.40%	9.60%
Toluene	0.2 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	13.00%	10.10%	9.80%	10.90%	10.50%
Toluene	0.5 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	9.50%	11.40%	10.80%	11.60%	10.00%
Pentane	0.1 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	9.20%	7.70%	11.70%	11.30%	6.80%
Pentane	0.2 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	11.10%	13.70%	12.50%	7.60%	6.80%
Pentane	0.5 grams				
	Run 1	Run 2	Run 3	Run 4	Run 5
	14.50%	7.30%	10.80%	9.90%	10.00%