

SOLVENT EVAPORATION FROM WEB OFFSET HEATSET INKS
DURING WEB OFFSET HEATSET PRINTING: AN
EXPERIMENTAL MODEL

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Abstract: A method has been developed to model the function of a web offset heatset press drying unit. The method developed was then used to determine the quantity and composition of retained solvents in web offset heatset prints. A modified DuPont model 951 thermogravimetric analyzer modeled the press oven function and also monitored the weight loss. Gas chromatographic (GC) analysis of the volatiles and extraction of the non-volatiles from the substrate followed by GC analysis identified these components. This technique is effective for modeling printing ink emissions on a web offset heatset press.

INTRODUCTION

It is generally accepted that in web offset heatset (WOHS) printing some of the solvent originally present in the web offset heatset ink is retained in the ink film on the web (paper) after the web has passed through the press's drying oven and over the chill rollers. Concerns over solvents being retained in the ink film on the paper have been voiced by the Environmental Protection Agency (EPA). The major concern is for the proper materials balance estimates of how much solvent is emitted in the web offset heatset printing process. A second concern is whether every web offset heatset printed object is a potential mobile pollution source. The EPA fears that the solvent retained on the web may eventually evaporate and be released into the atmosphere.

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Estimates of retained solvent concentrations vary. An EPA Guideline Series report published in 1981 entitled "Control of Volatile Organic Emissions from Full-Web Process-Color Heatset Web Offset Lithographic Printing" estimates that approximately 50% of the total solvent present in WOHS ink is retained on the web. The solvent, typically a high boiling hydrocarbon distillate fraction, usually comprises 30-40% of a WOHS ink. On the other hand, a study done by R.R. Gadomski, et. al. (1973) estimated that only 6-7% of the original solvent in the system is retained on the web. However, in the Gadomski study printed samples were collected and no indication was given of how long they were allowed to sit before being analyzed. If they were allowed to sit for a significant period of time, some of the solvent could have evaporated. Even though these solvents are high boiling hydrocarbon mixtures, the lower molecular weight components still have significant vapor pressures at room temperature, therefore, making solvent evaporation a concern.

The object of this study was to determine, under conditions approaching those observed on a web offset heatset printing press, the quantity and identity of solvents retained (i.e. those which do not evaporate) in a web offset heatset ink. Again, conditions are not exactly like those observed on a press because the heating and cooling rates are slightly slower than the rates on a press. Data indicating both the quantity and the composition of solvent evaporated from ink printed on two substrates was obtained. Both emulsified and unemulsified inks were examined. The two substrates used were paper and aluminum foil.

For the purposes of this study, the total solvent in an ink will refer to all of the volatiles present in an ink. Free solvent is being defined as the volatiles in an ink which are free to evaporate and does not include that solvent which appears to be bound or permanently trapped in the ink. This trapped solvent has a very low vapor pressure possibly due to Raoult's Law.

After heating samples of ink on paper and foil with the thermogravimetric analyzer (TGA), the volatiles, hydrocarbon solvents, were collected and the distribution of the evaporated ink solvent was examined. The distribution of the solvent emitted after heating the samples to 150° C and holding the samples at that temperature for approximately ten minutes was also examined. The ink remaining on the substrate was then extracted with pentane to remove any residual solvent. The extract was analyzed using a gas chromatograph. From the gas chromatograms, the solvent distribution and quantity of each component in every extract could be determined. Results indicated that for emulsified inks approximately 30% of the solvent originally present or 30% of the total ink weight (20% emulsified water, 10% ink) was lost during the first heating step. A large portion of the solvent remaining, particularly the more volatile components, is lost during the next heating step. The purpose of this heating step is identify any solvents which may evaporate at a later time. This heating step does not model reality, it is just a step to determine whether any potential volatiles remain in the ink. Some of the high molecular weight components remain on the substrate in the ink matrix, even after being held at high temperatures, and can be subsequently extracted with pentane. As expected, during the first heating step, most of the low molecular weight solvent species evaporate. During the second heating step, most of the mid-boiling range solvent components remaining evaporate. When the substrate with the ink residue is extracted, the high boiling components of the solvent are found. If the extracts are added together, all of the solvent present in the ink should be accounted for, and the distribution should be the same as the standard. This was indeed observed.

The above results were compared to results obtained from a printed sample collected from a press. The press sample was heated to 150° C and held there for approximately 15 minutes. The volatiles were collected during this time and examined using gas chromatography. The results were very similar to those obtained from the model system. The pentane extract from the paper with

the ink residue remaining on it, which was obtained after the long heating step, was also very similar to the model system extracts.

EXPERIMENTAL

The solvent used in the following studies was Magiesol 47 oil, which is a hydrocarbon distillate cut whose components have boiling points between 464° and 520° F. The solvent was obtained from Magie Bros. Oil Company. The ink used was a standard red WOHS ink which was produced internally.

The ink was emulsified with fountain solution using a VWR model 134-1 variable speed electric stirrer.

The solvent vapors were collected on charcoal air sampling tubes. The columns were obtained from SKC Inc.

Gas chromatograms of the hydrocarbon oils were obtained on a Hewlett Packard 5890 gas chromatograph with a 10% SP2100 column and a flame ionization detector. The gas chromatograph is interfaced to a Perkin Elmer model 7700 microcomputer which collects and processes the data.

Thermogravimetric analyses were done on either a DuPont model 951 thermogravimetric analyzer or a modified DuPont model 951 thermogravimetric analyzer. The TGA is interfaced to an IBM PS/2 model 60 microcomputer using DuPont Thermal Analyst 2000 software which collects and processes the data.

RESULTS AND DISCUSSION

The volatiles concentration in the ink was determined from both the ink formulation and by heating the sample on the TGA. The concentration of emulsified water was determined using either a Karl Fischer titration or by evaporating the volatiles on the TGA. Figures 1 and 2 show TGA plots of unemulsified and emulsified inks respectively. The two plots show weight loss as a function of time along with temperature as a

function of time. The samples were heated to 150° C and held at that temperature until all of the volatiles had evaporated. The values obtained corresponded well with the concentrations calculated from the ink formulation.

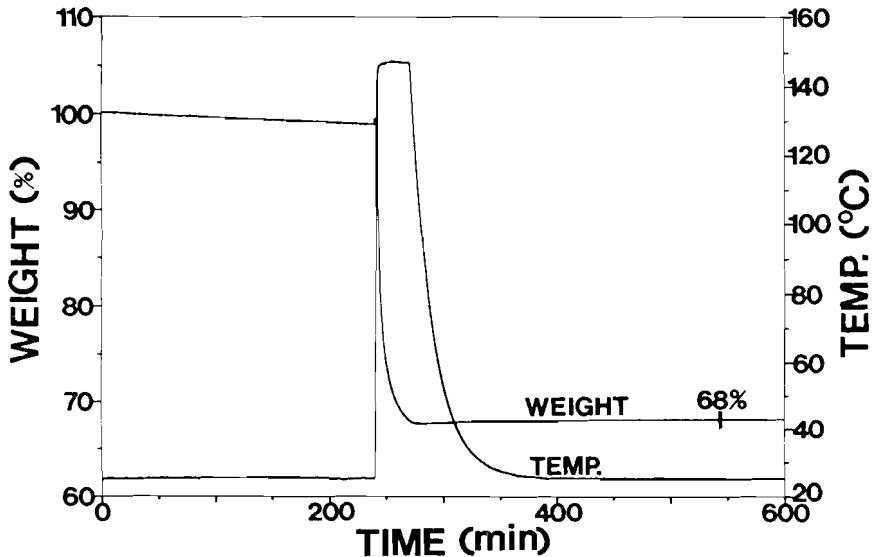


Figure 1. Weight Loss and Temperature as a Function of Time for a Web Offset Heatset Ink.

The TGA was modified to allow for better signal to noise and higher heating rates. On the DuPont instrument the TGA microbalance must be translated into and out of the furnace. When the microbalance is translated, weight variations of 0.3-0.4 mg are typically seen. This is 3-5 times larger than the weights which we are trying to measure. Sample sizes varied from 0.08 to 0.12 mg. The weight changes occurred if the balance vibrated when it was translated. This vibration causes at least two changes to occur which influence the apparent weight of the sample. One of the changes is a shift in the position of the counterweight resting on the counterweight arm. This causes an apparent weight jump. The second change is a shift in the position of the sample holder. Both changes cause the center of mass of

the balance arm to move thus causing an apparent positive or negative weight jump. Therefore, to eliminate the need to translate the microbalance, a different furnace was employed. A nichrome wire was used inside of the furnace tube to heat the sample. This not only eliminated the need to translate the furnace, but also allowed for higher heating rates in order to better model the press driers. Press driers heat the web to temperatures of 130-150° C in less than 1 second. The nichrome wire furnace is capable of heating samples to these temperatures in approximately 2-3 seconds.

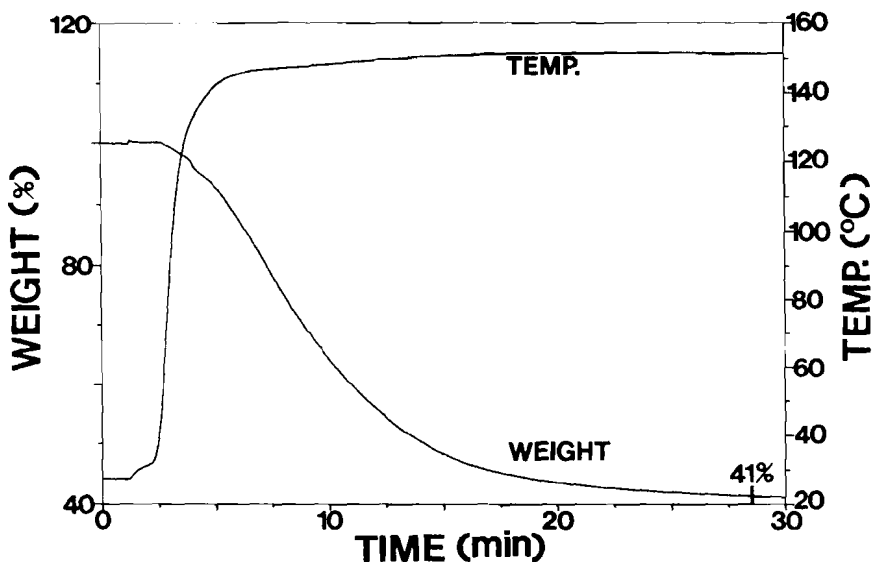


Figure 2. Weight Loss and Temperature as a Function of Time for an Emulsified Web Offset Heatset Ink.

The reproducibility using this technique is shown in figure 3. This figure demonstrates the weight change during heating and cooling using the above apparatus with the aluminum sample pan which holds the sample and is supported by a quartz beam. The large weight increase during heating is due to expansion of the quartz rod, which is part of the balance arm. As the rod cools, it contracts. From the figure, weights at identical temperatures are reproducible to within <0.005 mg.

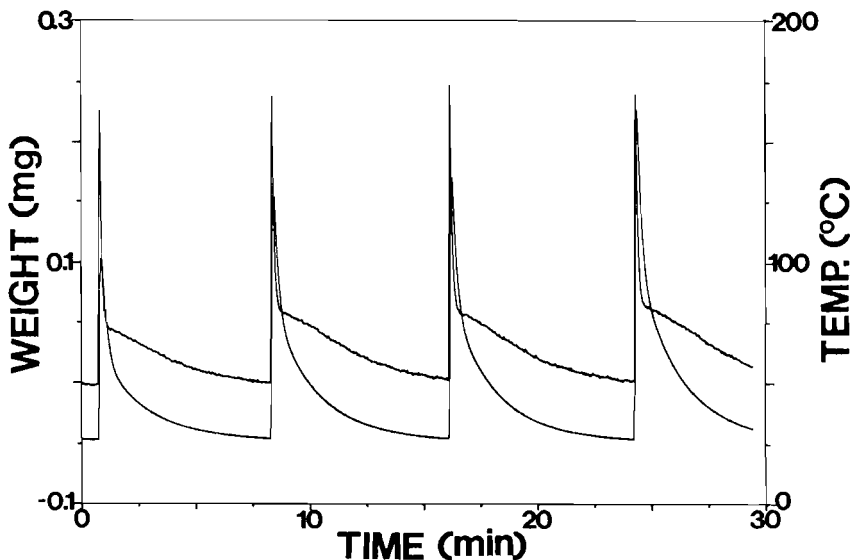


Figure 3. Weight Reproducibility for an Empty Sample Pan.

To demonstrate the effectiveness of this technique, figure 4 shows a TGA plot obtained with this instrument of a layer of hydrocarbon oil (boiling point 470° F) on aluminum foil. Weight percent is plotted versus time on one y-axis and temperature versus time on the other y-axis. The weight of the foil has been tared so that the total weight plotted is the weight of only the hydrocarbon oil on the substrate. After the initial heating cycle, 70-80% of the oil originally present on the foil is lost. Following the second heating and cooling cycle, the rest of the oil on the foil evaporates.

The next logical experiment is to print a layer of hydrocarbon oil on paper and examine the evaporation of the oil. However, before doing this, the behavior of the paper was examined. The results shown in figure 5 demonstrate a weight loss of approximately 3% followed by a reequilibration to 100%. This is merely evaporation of the water absorbed in the paper and then reabsorption of the lost water.

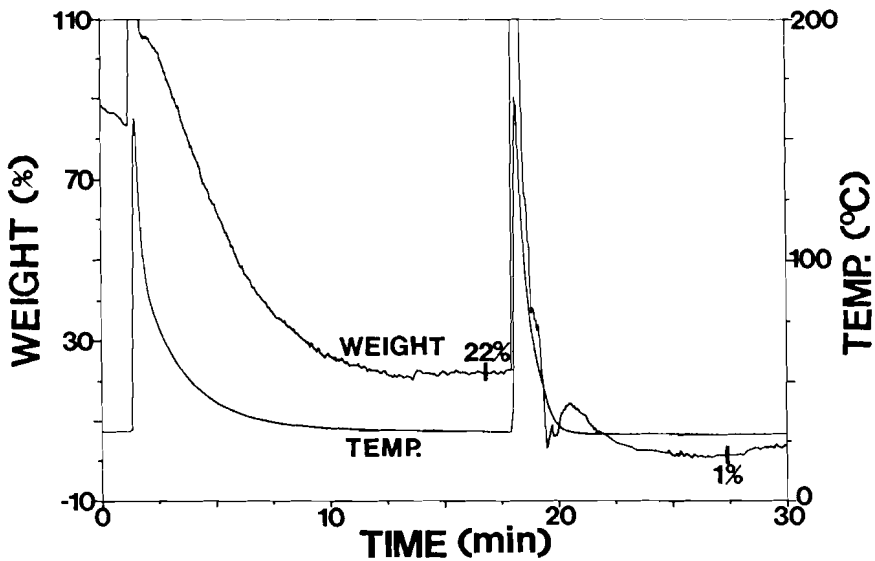


Figure 4. Weight Loss from Hydrocarbon Oil Printed on Foil.

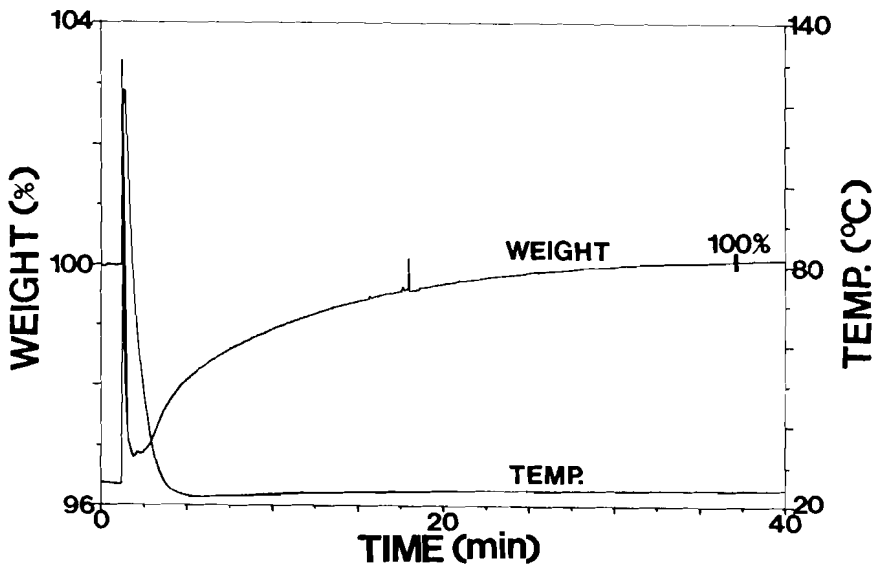


Figure 5. Weight Loss from Paper.

Figure 6 shows what occurred when paper coated with the hydrocarbon oil was heated quickly in the modified instrument. A weight loss of approximately 50% was observed. Given the evaporation rate observed for the hydrocarbon oil on aluminum foil, this was the expected weight loss for this sample, taking into consideration the final temperature that the sample reached. This figure indicates that the quantity of hydrocarbon oil which evaporates is identical within experimental error on both aluminum foil and paper.

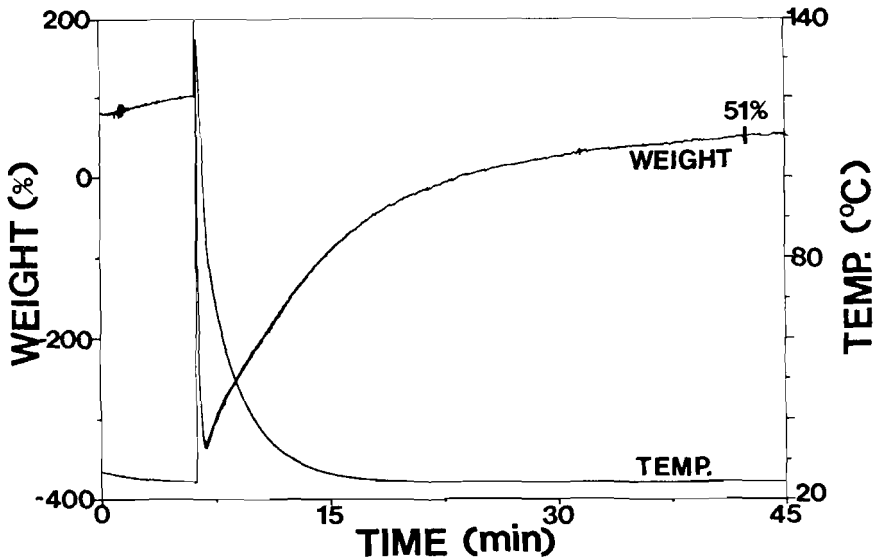


Figure 6. Weight Loss from Hydrocarbon Oil Printed on Paper.

The next experiment examined ink printed on aluminum foil. The results are shown in figure 7. Weight percent versus time, and temperature as a function of time are plotted again. The weight of the aluminum foil was tared. A weight loss of approximately 30% was observed. The ink is approximately 35% hydrocarbon oil, therefore, 5% of the hydrocarbon oil originally present is retained in the ink film. Results obtained with ink printed on a coated paper were identical.

The next step was to examine the behavior

under the same heating conditions of emulsified inks printed on the two substrates. The ink used above for the weight loss experiments was emulsified with fountain solution. The fountain solution is greater than 95% water. The ink and fountain solution were mixed for fifteen minutes using a VWR electric stirrer and the excess fountain solution was then decanted off. A conventional TGA experiment was done to determine the weight percent of fountain solution in the sample. A weight percent of approximately 40% was obtained. This TGA was shown in figure 2. A Karl Fischer titration performed on the ink verified the TGA results. The quantity of water which remained emulsified in the ink stayed constant over 2-3 days. After this period, the ink had to be reemulsified by stirring again with fountain solution because the ink and fountain solution separated.

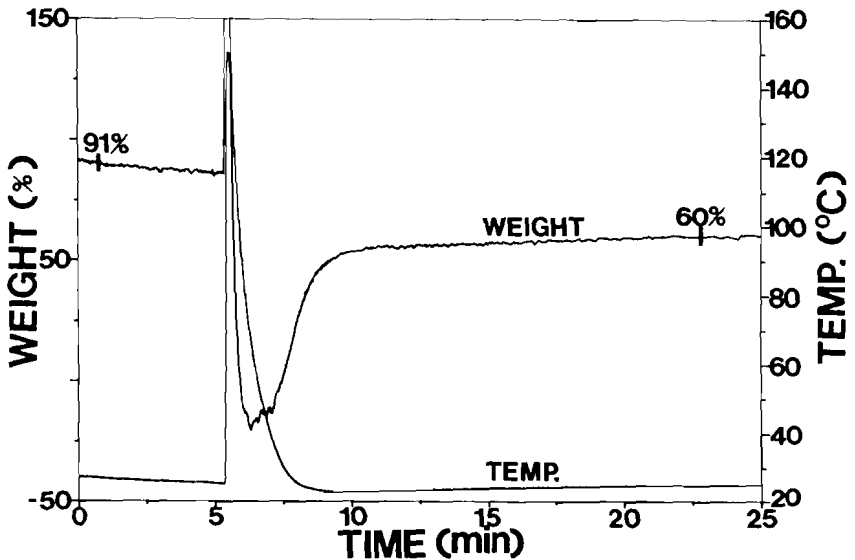


Figure 7. Weight Loss from Web Offset Heatset Ink Printed on Foil.

The next step was to print a film of the emulsified ink on aluminum foil. This was done with a Quick Peek roller. A TGA was performed on the sample using the modified instrument operating

at a fast heating rate ($2400^{\circ}\text{C}/\text{min}$). The results of this experiment are shown in figure 8. Again, both weight percent versus time and temperature as a function of time are plotted. The sudden change in the weight of the sample at approximately four minutes is due to vibrations in the quartz rod which supports the sample. The results show that a weight loss of approximately 30% is observed. Subsequent heating steps indicate no further weight loss, suggesting that the hydrocarbon oil components remaining are high molecular weight compounds with very low vapor pressures. The 30% weight loss corresponds to the retention of 20-25% of the solvent which was originally present. The rest of the weight loss is water. The method used to determine the ratio of water to retained solvent after heating will be discussed later in this report.

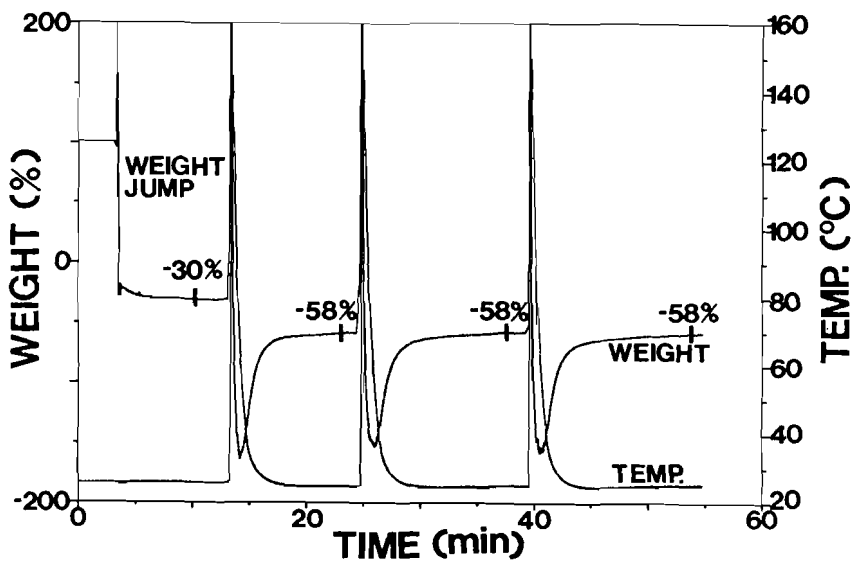


Figure 8. Weight Loss from Emulsified Web Offset Heatset Ink Printed On Foil.

The above experiment was repeated on the coated paper. The results are shown in figure 9, The data indicates an approximate 40% weight loss corresponding again to 20-25% retained solvents.

These results correspond well with the results obtained above for the emulsified ink printed on aluminum foil.

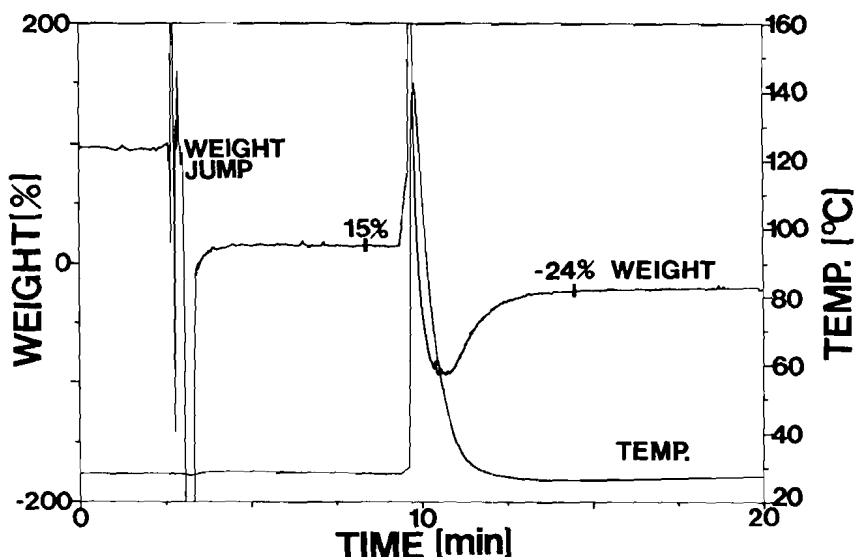


Figure 9. Weight Loss from Emulsified Web Offset Heatset Ink Printed on Paper.

To determine the amount of ink solvent remaining in a given quantity of emulsified ink (approximately 40% water emulsified into the ink) after the ink has lost approximately 30% of its weight, the following experiment was performed. First, the emulsified ink was heated to 150° C and held there until all of the volatiles had evaporated. The time required to reach a 30% loss in weight was then measured. Another sample was then placed on the instrument and the sample was held at 150° C for the length of time required to reach a 30% weight loss, which was determined above. The sample was then immediately cooled and, as expected, a weight loss of approximately 30% was observed. The sample remaining was then analyzed via a Karl Fischer titration, and the amount of water still present was determined. This information allowed us to calculate the quantity of hydrocarbon oil remaining in the ink.

It is desirable to know not only the quantity but also the identity of volatile materials which evaporate from a printed web on a web-offset heatset press. Hence, another series of experiments was performed on the TGA. The emitted volatiles were collected on charcoal air sampling tubes to be analyzed later by gas chromatography (GC). After heating samples of emulsified ink on paper and foil with the modified TGA at a high rate (2400° C/min), the volatiles were collected and the distribution of hydrocarbon oil components in the evaporated solvent was examined. Also examined was the distribution of the hydrocarbon oil emitted while heating the samples to 150° C and holding the samples at that temperature for approximately ten minutes. The paper or foil which had been printed and heated was then extracted with pentane to remove any residual hydrocarbon oil. The extract was examined on the gas chromatograph.

From the gas chromatograms, the hydrocarbon oil distribution and quantity of hydrocarbon oil in each extract could be determined. Results indicated that approximately 30% of the hydrocarbon oil originally present or 30% of the total ink weight (20% water, 10% oil) was lost during the first, fast heating. A large portion of the solvent remaining, particularly the more volatile components, is lost during the next long heating step. Some of the high molecular weight components remain on the substrate in the ink matrix, even after being held at high temperatures, and can be subsequently extracted with pentane. As expected, during the first heating step, most low molecular weight solvent species evaporate. Since the low-boiling species evaporated during the first heating step, most of the mid-boiling range hydrocarbon oil components evaporate during the second heating step. When the substrate with the ink residue is extracted, the high boiling components are found. If the hydrocarbon oil in all of the extracts was added together, all of the hydrocarbon oil present in the ink should be accounted for, and the distribution should be the same as the standard. This was indeed observed.

The above results were compared to data obtained from a printed sample collected from a web offset heatset press. The press sample was heated to 150° C and held there for approximately ten minutes on the TGA, like the samples printed with the Quick-Peek roller. The volatiles were collected during this time and examined using gas chromatography. The results were very similar to those obtained from the model system for the same heating step. The extract of the paper with ink residue remaining after heating had a chemical composition very similar to the model system extracts.

During the volatiles collection experiments the emulsified ink was printed on aluminum foil using the Quick-Peek roller as was previously reported. The sample was then heated rapidly to approximately 150° C and immediately cooled to room temperature. The sample was heated again to approximately 150° C rapidly and held at that temperature for 5-10 minutes. The weight loss results obtained are shown in figure 10. A weight loss during the first heating step of approximately 30% is observed as expected. This was similar to results reported earlier. This corresponds to approximately 25% of the solvent originally present being retained. During the second long heating step another weight loss was observed, which was unexpected given previous results. Volatiles collected and analyzed during this time indicated that the components were indeed the hydrocarbon oil components. Previous results indicated that no further weight loss after the initial heating would be observed. However, the experiment was different this time. Previously, the second and subsequent heating steps were always done quickly (i.e. the temperature was ramped to 150° C quickly and held there only momentarily). This was the first time that the sample was held at elevated temperatures for long times. Obviously, the hydrocarbon oil components remaining after the first heating step are high boiling, low vapor pressure fractions which evaporate slowly at temperatures in the 150° C range. As a result, a measurable weight loss is only observed if the sample is held at 150° C for long times. This may have important implications for

VOC testing methodologies.

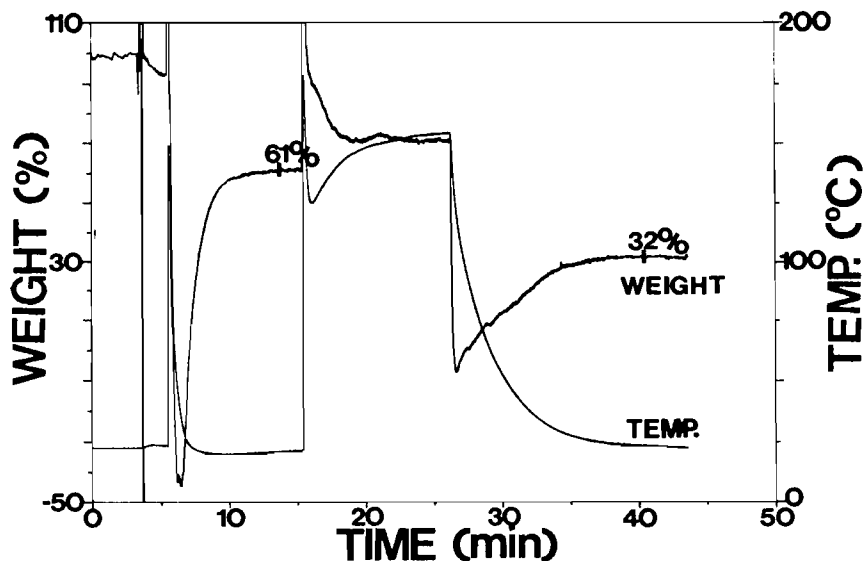


Figure 10. Weight Loss from Emulsified Web Offset Heatset Ink Printed on Foil.

Gas chromatograms of the pentane extracts collected from the two fractions are shown in figures 11 and 12 (fast, short heating step and long time heating step respectively). A copy of the gas chromatogram of the extracted foil with the ink residue remaining on it after the long heating step is shown in figure 13. A copy of the gas chromatogram of a 30 ppm hydrocarbon oil standard is shown in figure 14. It is obvious from the above chromatograms that the extract from the first, fast heating step contains a large percentage of low boiling range hydrocarbon oil components. The extract from the sample collected during the long heating step contains a large percentage of mid-boiling range hydrocarbon oil components. This is logical because most of the low boiling components evaporated during the first heating step. The extract from the piece of aluminum foil with ink residue indicated that some of the very highest boiling hydrocarbon oil components were still on the foil in the residue after

the last heating step. If the three chromatograms are added together and compared to the standard, a distribution very similar to the distribution of components in the standard is observed. The quantity of hydrocarbon oil present also agrees within experimental error with the quantity determined from the weight observed on the TGA. According to the TGA, a sample weight of approximately 0.87 mg was observed. According to the concentration of hydrocarbon oil collected and observed on the gas chromatographs, a sample weight of approximately 0.83 mg was present. These numbers agree to within 5% which is within experimental error.

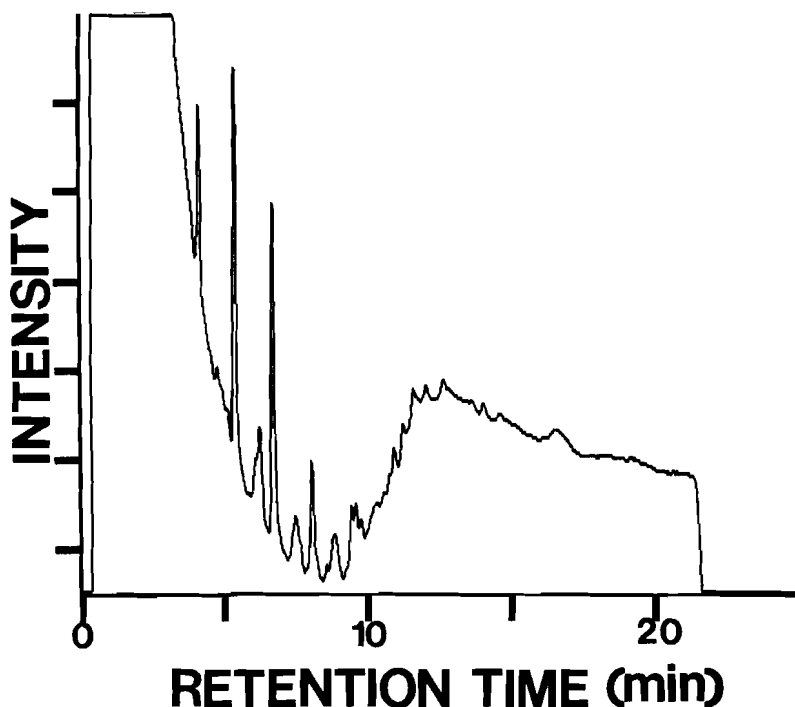


Figure 11. Gas Chromatogram of Extract of Vapors Collected after first Heating Step from Emulsified Ink Printed on Foil Sample.

In figure 13 there are four major peaks which will be examined. The peaks will be denoted as

peaks A, B, C, and D and have approximate retention times of 4.1, 5.4, 6.7, and 8.1 minutes, respectively. According to a report from Battelle Columbus Laboratories (1982) peaks A, B, C, and D correspond to regions where $n\text{-C}_{13}$, $n\text{-C}_{14}$, $n\text{-C}_{15}$, and $n\text{-C}_{16}$ compounds elute, respectively. It is obvious from figure 14, the hydrocarbon oil standard, that peak C is the highest and has the greatest area. As a result, calculations of ratios of peaks will be indexed to peak C. The ratios of the peak areas for the selected peaks (A, B, C, and D) to peak C for each chromatogram are shown in table 1. Also shown in table 1 are the ratios of the four peaks to peak C for chromatograms obtained by summing chromatograms determined experimentally from the extracts of the aluminum foil printed with emulsified ink and from the air sampling tube extracts.

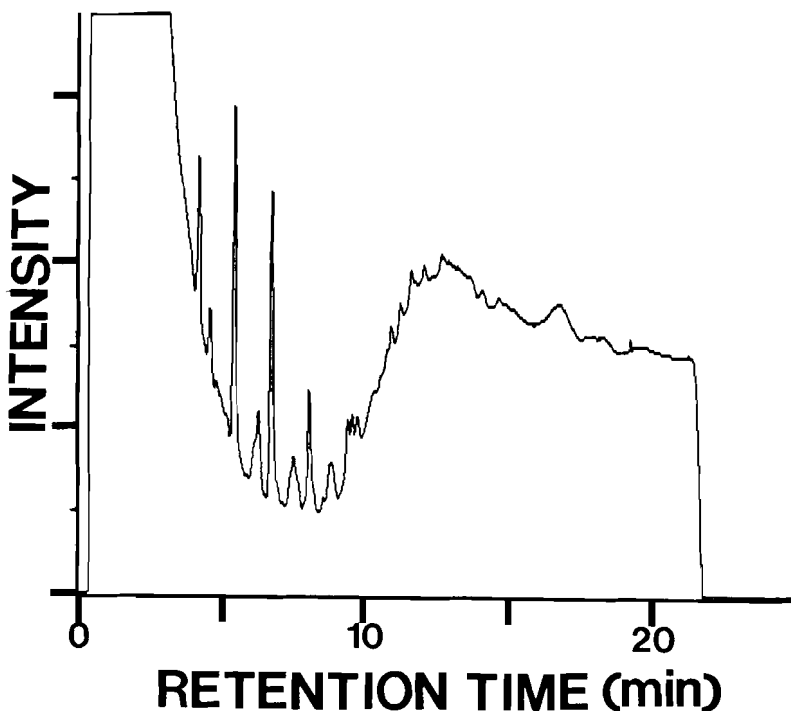


Figure 12. Gas Chromatogram of Extract of Vapors Collected after Second Heating Step of Ink on Foil.

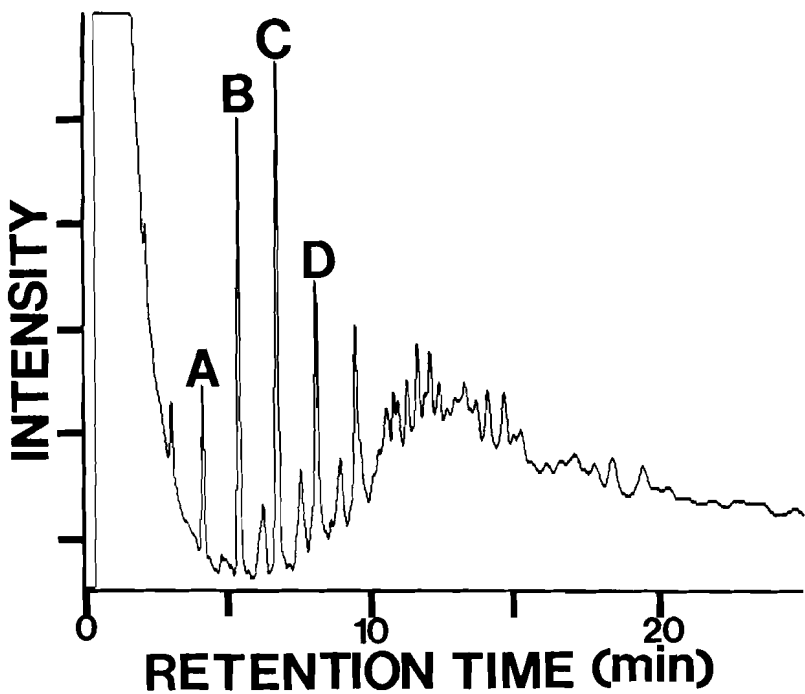


Figure 13. Gas Chromatogram of Extract of Ink Remaining on Foil after the Heating Steps.

SAMPLE	A	B	C	D
SHORT HEATING STEP	0.26	1.13	1.00	0.05
LONG HEATING STEP	0.51	0.96	1.00	0.31
RESIDUE ON FOIL	0.00	0.00	1.00	0.71
SUM OF 2 + 3	0.30	0.56	1.00	0.48
SUM OF 1 + 2 + 3	0.28	0.75	1.00	0.33
STANDARD OIL	0.30	0.84	1.00	0.36

Table 1. Ratios of Areas of Specified Peaks to Peak C for Emulsified Ink on Foil Samples and the Magie Oil Standard.

The results from the extract of the second, long heating step for the model samples are similar to the results obtained for the heating of the press sample. The extracts from the two substrates

are also similar. Therefore, the only conclusion could be that the instrumentation and method developed, models solvent evaporation on a web offset heatset press very accurately.

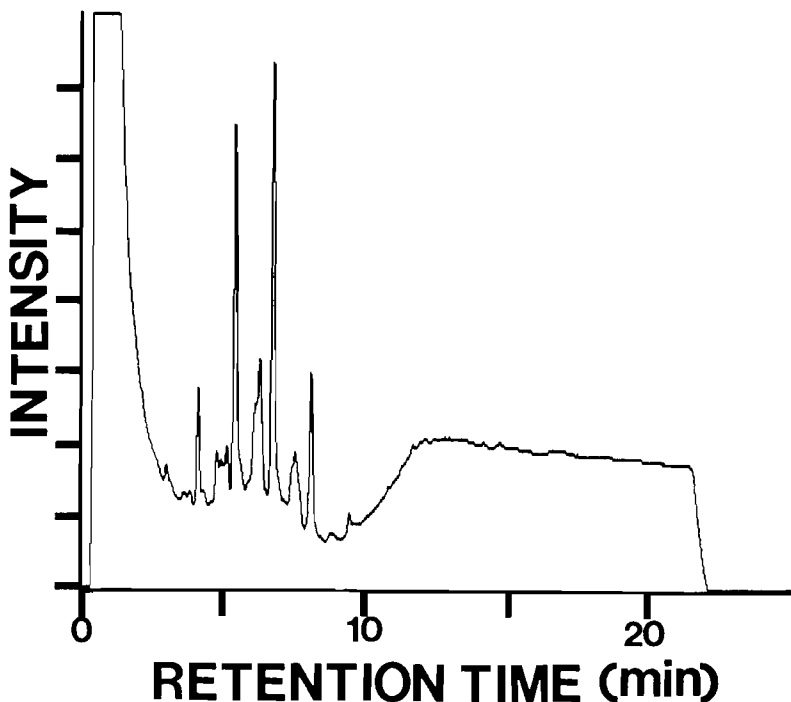


Figure 14. Gas Chromatogram of Hydrocarbon Oil Standard.

One further experiment was designed and run to examine weight loss after the initial fast, short heating step over long times. A piece of aluminum foil on which emulsified ink was printed was heated quickly to 150° C and then immediately cooled. The weight was then monitored over time at room temperature. The results, shown in figure 15, show that no further evaporation of hydrocarbon oil components is seen at room temperature over time.

The weight loss results of heating emulsified ink on paper for a short time, cooling the paper, and heating it again for a long time, as was done

with the aluminum foil, are the same within experimental error as those obtained on aluminum foil. This experiment, however, indicated that paper is not as desirable a substrate for this test as the aluminum foil, since it burns easily. Another disadvantage to using paper is the fact that it must first be preconditioned. The paper should be heated first to 150° C and held at that temperature for 0.5 hours. The purpose of this step is to remove any volatile material present in the paper which may interfere with the GC or weight loss results. After heating the paper, the user must then wait at least one hour for the paper moisture content to reequilibrate. Therefore, an experiment using aluminum foil as a substrate can be done in much less time than an experiment using paper as the substrate. Given that similar results are seen regardless of the substrate, there is no obvious advantage to using paper.

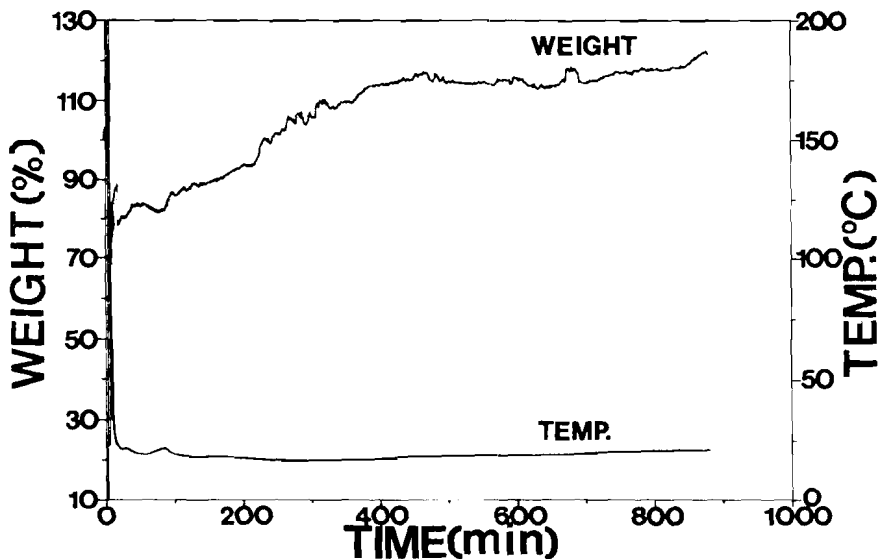


Figure 15. Weight Loss from Emulsified Ink Printed on Foil.

Gas chromatograms of the extracts obtained during the two heating cycles (short and long) for the ink on paper samples along with the chromatogram of the paper with residue extract are similar

to those obtained using aluminum foil. An extra peak, presumably from a paper or paper coating component, is seen at a retention time of approximately 4.9 minutes.

Figure 16 shows a TGA obtained on the modified Dupont instrument of a sample of paper printed on a web offset heatset press. The sample was heated to approximately 150° C and held there for 5-10 minutes. During this time the volatiles emitted were again collected on an air sampling tube and extracted with pentane. The gas chromatogram of the extract is shown in figure 17.

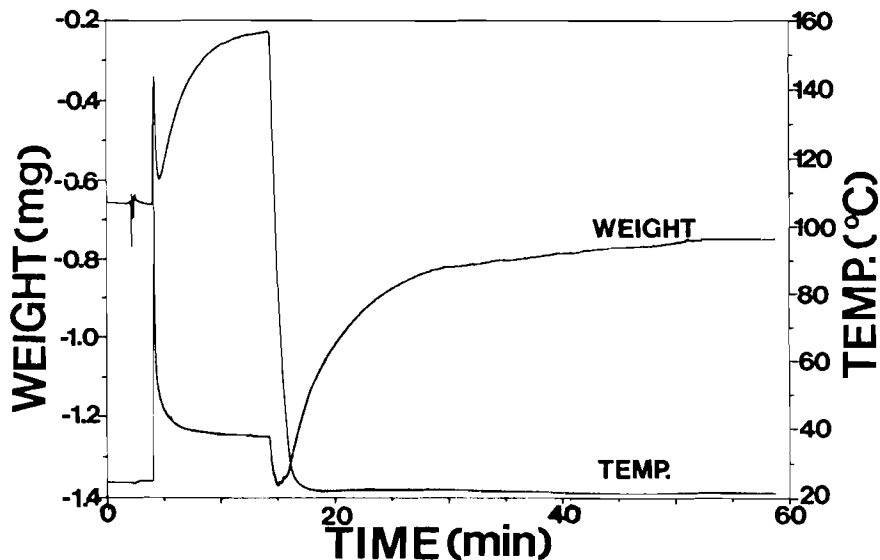


Figure 16. Weight Loss from Press Sample.

A comparison of the chromatogram shown in figure 17 with the chromatogram obtained from the extract of the volatiles collected during the slow heating step on the aluminum foil sample shows that the distribution of Magie oil components is very similar in both cases. The distribution of components in the extracted press paper after heating, shown in figure 18, is also very similar to the extracted aluminum foil with residue. The ratios of the peak areas for the selected hydrocarbon oil components in the press sample are

shown in table 2 along with the ratios for another summed chromatogram.

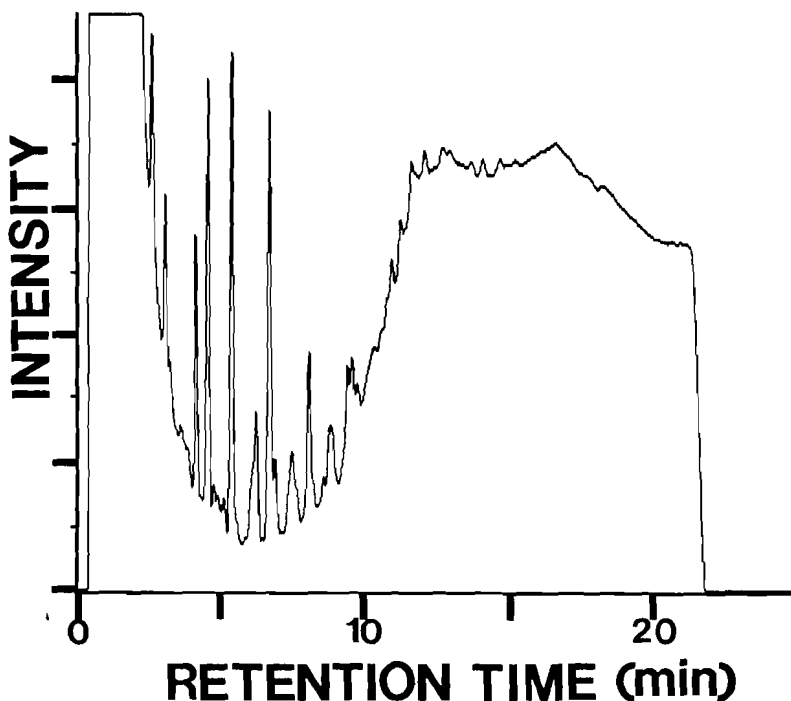


Figure 17. Gas Chromatogram of Extract of Vapors collected during Long Heating Step from the Sample Collected from a Press.

SAMPLE	A	B	C	D
LONG HEATING STEP	0.54	1.03	1.00	0.08
RESIDUE ON PAPER	0.01	0.42	1.00	0.71
SUM OF 1 + 2	0.14	0.57	1.00	0.55
STANDARD OIL	0.30	0.84	1.00	0.36

Table 2. Ratios of Areas of Specified GC Peaks to Peak C for Press Samples and the Magie Oil Standard.

To quickly summarize, web offset heatset ink emulsified with fountain solution was printed on both paper (70 lb. coated) and aluminum foil. The samples were then heated using the modified TGA to

150° C and immediately cooled. The volatiles emitted were collected on a charcoal air sampling tubes to be stripped and analyzed later by gas chromatography. The samples were again heated to approximately 150° C and held at that temperature for 5-10 minutes. The volatiles were again collected on a different air sampling tube. The substrate with the ink residue on it was then placed in pentane to be extracted and analyzed by gas chromatography. The results obtained are shown in table 1.

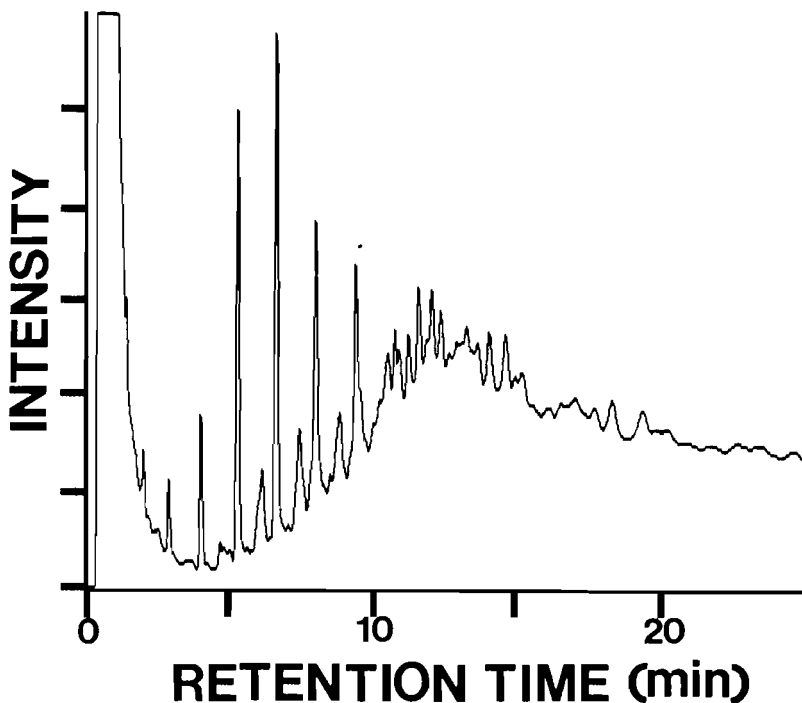


Figure 18. Gas Chromatogram of Extract of Ink Remaining on the Press Sample after Heating.

Prints collected from a press and refrigerated to limit solvent evaporation were then examined. The press samples, since they had already undergone the rapid heating and initial solvent loss on the press, were subjected only to the long time (5-10 minutes at 150° C) heating step. The

volatiles were collected during this heating step and analyzed using gas chromatography as had been done previously. The paper sample with the ink residue was also extracted and analyzed as was done with the model systems. The results obtained are shown in table 2.

This data indicates that the method developed models press conditions very accurately for the given ink and fountain solution used. There is no reason to believe that this will not be an accurate technique for modeling the performance of other inks and fountain solutions as well.

CONCLUSIONS

Given the increasing concern over solvent emissions, this study could be of fundamental importance to printers and ink makers in the United States. Presently we have a model which appears to simulate web press conditions accurately. Results obtained with emulsified inks indicate 20-25% retained solvents, which agrees with previously reported values for retained solvents on a web press. Results also indicate that these retained solvents are not permanently trapped on the paper at high temperatures, but may be trapped for very long periods of time at low temperatures and may not evaporate at all even over long time periods. This may be caused by either a lowering of the vapor pressure of the solvent as modeled by Raoult's law, or the molecular weight of the remaining solvent is high enough that it may be a solid, since the melting points of n-C₁₇ hydrocarbons are near room temperature.

The results obtained are tabulated in table 3. Results indicate that most of the solvent evaporates in unemulsified ink, but in emulsified ink 20-25% of the solvent originally present is retained.

The results obtained on the press samples agree very well with the results obtained using the model systems. Not only is the quantity of hydrocarbon oil retained on the substrates similar to the quantities reported in the literature and determined using the TGA, but the distribution of

the hydrocarbon oil in the samples heated on the TGA are similar to the distribution of hydrocarbon oil in samples collected from a web offset heatset press.

PRINTED OIL		
	Al FOIL	PAPER
HEAT. RATE (200° C/MIN)	0-5	0-5
HEAT. RATE (2400° C/MIN)	25	25

PRINTED INK		
	Al FOIL	PAPER
HEAT. RATE (200° C/MIN)	0-5	0-5
HEAT. RATE (2400° C/MIN)	0-5	0-5

PRINTED EMULSIFIED INK		
	Al FOIL	PAPER
HEAT. RATE (200° C/MIN)	0-5	0-5
HEAT. RATE (2400° C/MIN)	20-25	20-25

Table 3. Percentage of Total Solvent Weight Remaining on the Substrate After Heating to 150° C at the Indicated Rate.

When the samples were heated to 150° C and held there for an extended period of time after the first short heating, evaporation of most of the solvent remaining on the prints was seen.

Results obtained on both paper and aluminum foil are identical within experimental error. This is surprising given the porous nature of paper. However, a coated stock was used in these experiments.

The modified instrument that we have developed appears to work well, but it is desirable to further increase the heating and cooling rates and try to eliminate the possibility of jarring the sample holder.

This technique could potentially be very useful for determining ink volatility on a web-offset heatset press. This technique, although not routine, currently has the potential to be automated and thus made routine. This technique could be useful to not only the printing ink

industry but to any industry concerned with VOC's. This technique has several advantages over the other methods reported. Not only is it more accurate, but perhaps most importantly, it does not take a long time. An ink can be evaluated in one day and can be examined in a lab. The other techniques take weeks and require time on a web offset heatset press. These advantages make this technique very desirable. However, the instrument required is expensive so cost must be considered.

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