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# ON-SITE WASTE INK RECYCLING

Technology Evaluation Report

by

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## FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, Superfund-related activities, and pollution prevention. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Passage of the Pollution Prevention Act of 1990 marked a strong change in the U.S. policies concerning the generation of hazardous and nonhazardous wastes. This bill implements the national objective of pollution prevention by establishing a source reduction program at the EPA and by assisting States in providing information and technical assistance regarding source reduction. In support of the emphasis on pollution prevention, the "Waste Reduction Innovative Technology Evaluation (WRITE) Program" has been designed to identify, evaluate, and/or demonstrate new ideas and technologies that lead to waste reduction. The WRITE Program emphasizes source reduction and on-site recycling. These methods reduce or eliminate transportation, handling, treatment, and disposal of hazardous materials in the environment. The technology evaluation project discussed in this report emphasizes the study and development of methods to reduce waste.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

## ABSTRACT

This evaluation addresses the product quality, waste reduction, and economic issues involved in recycling a printing ink in a facility such as *The Hartford Courant* newspaper in Hartford, Connecticut. The specific recycling unit evaluated is based on the technology of distillation and filtration. Ink recycling was found to have good potential as a means of waste reduction and long-term cost saving. Product quality was evaluated by conducting selected performance tests and comparisons of the printed material by qualified professionals of the spent, recycled, and virgin inks. A good product quality of the recycled ink was also achieved by this unit. The recycled ink fared well in laboratory performance tests such as viscosity, grind, residue, tack, tinting strength, water content, and water pickup. Ink and solvent that would have gone to waste were recovered and reused. The resulting cost saving gave a payback period of about ten years.

This report was submitted in partial fulfillment of Contract Number 68-CO-0003, Work Assignment 0-06, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from September 10, 1990 to August 30, 1992, and work was completed as of August 30, 1992.

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## SECTION 1
## PROJECT DESCRIPTION

This study, performed under the U.S. Environmental Protection Agency's (EPA) Waste Reduction and Innovative Technology Evaluation (WRITE) Program, was a cooperative effort among EPA's Risk Reduction Engineering Laboratory (RREL), Connecticut Hazardous Waste Management Service (CHWMS), and *The Hartford Courant*. The objective of the WRITE Program is to evaluate, in a typical workplace environment, examples of prototype or innovative commercial technologies that have potential for reducing waste. In general, for each technology to be evaluated, three issues should be addressed.

First, it must be determined whether the technology is effective. Since waste reduction technologies usually involve recycling or reusing materials, or using substitute materials or techniques, it is important to verify that the quality of the recycled product is satisfactory for the intended purpose. Second, it must be demonstrated that using the technology has a measurable positive effect on reducing waste. Third, the economics of the new technology must be quantified and compared with the economics of the existing technology. It should be clear, however, that improved economics is not the only criterion for the use of the new technology. There may be justifications other than saving money that would encourage adoption of new operating approaches. Nonetheless, information about the economic implications of any such potential change is important.

This evaluation addresses the issues involved in using a particular commercially available technology offered by a particular manufacturer for recycling waste printing ink. The recycling unit used in this study is a mobile unit offered by Separation Technologies Inc. Other recycling units and technologies (with varying capabilities) applicable to the same wastestream (waste ink) are also commercially available.

### PROJECT OBJECTIVES

The goal of this study was to evaluate a technology that could be used to recycle waste printing ink for reuse in lithographic (newspaper) printing operations. This study had the following critical objectives:

- Evaluate the effectiveness of the recycling unit in generating an ink of acceptable quality
- Evaluate the waste reduction potential of this technology
- Evaluate the cost of recycling versus the cost of former practice (disposal).

## DESCRIPTION OF THE SITE

The ink recycling technology was tested at *The Hartford Courant*, a newspaper located in Hartford, Connecticut. The *Courant*, which employs about 1,500 people, has a daily circulation of 225,000 and a Sunday circulation of 320,000. Approximately 200 gallons of waste ink are collected per week. Most of the waste ink is black ink with a small amount of colored ink. Previously, the ink was sent to Solvents Recovery Services and blended with other solvents to create a supplemental fuel. Since October of 1990, waste ink has been recycled on-site and reused for printing.

## DESCRIPTION OF THE TECHNOLOGY

A detailed description of various types of printing processes and printing inks is provided in Appendices A and B. The *Courant* uses the web-fed lithographic printing process. During printing, excess ink contaminated with the blanket wash solvent, fountain solution (mostly water), and paper dust is collected in trays underneath the presses. The black and colored waste inks are collected together and processed through the recycling unit into a reusable black ink product. The colored waste ink also ends up as black ink through this process.

The recycling process is shown in Figure 1. The major components of the recycling unit at the *Courant* were purchased on a skid from Separations Technologies Inc. Other equipment was added as required. Trays containing waste ink from the press room are emptied on a 1/4-inch wire mesh to remove nuts, bolts, and other gross contaminants. The waste ink then goes to a large waste ink storage tank. When enough ink is available in this tank, a batch is processed. Processing primarily involves vacuum distillation, filtration, and blending.

Waste ink from the storage tank is transferred to the distillation still and distilled at 140°C under vacuum. Solvent and water from the waste ink are vaporized, condensed (by a chiller), and collected in a separator tank where water and solvent separate out into two phases

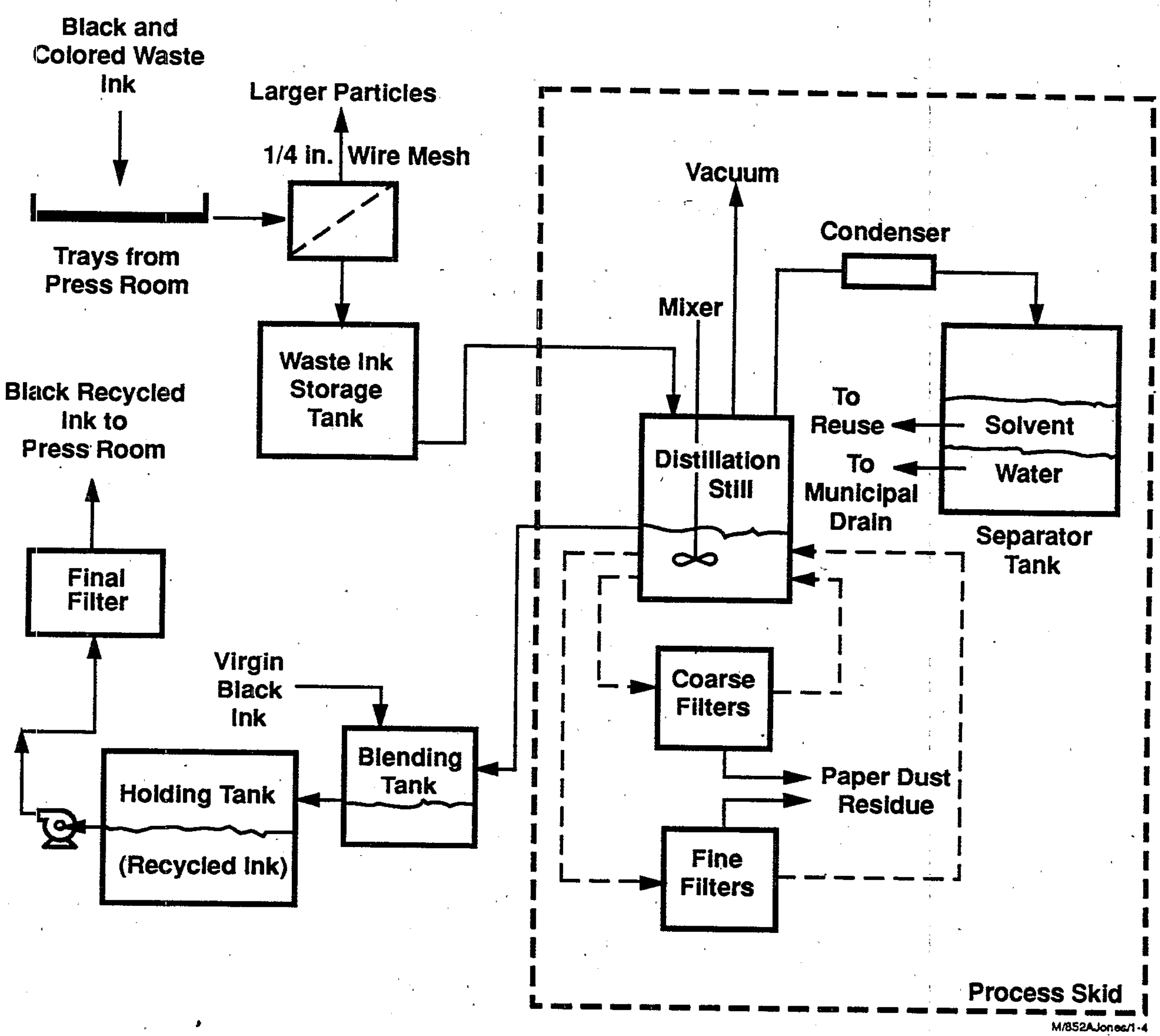


Figure 1. Waste Ink Recycling Process.

under gravity. The water is drained off and discharged to the municipal sewer (under permit), and the solvent is reused in the presses. The ink in the distillation still is sent through 100 and 325 mesh filters to remove paper dust, and then transferred to a blending tank. At this point, a grind test and a drawdown test are performed and the amount of virgin black ink required (typically three to four times the amount of the processed ink) for blending is determined. The virgin ink is added to improve the color, consistency, and other functional properties of the processed ink to an acceptable range. The processed ink, after the virgin black ink is blended into it, is now referred to as the final "recycled" ink.

After blending, the recycled ink is transferred to a clean holding tank. On demand, valves in the ink supply lines switch the supply from virgin to recycled on certain presses. The recycled ink is then drawn by a pump through a final 40-micron filter to the presses.

## SUMMARY OF APPROACH

A Quality Assurance Project Plan (QAPP), prepared at the beginning of this study (Battelle 1991), describes the detailed approach and scientific rationale used to evaluate the recycling unit. The evaluation covered product quality testing, waste reduction estimation, and economic analysis.

### Product Quality Evaluation

A product quality evaluation must show that the quality of recycled ink is acceptable compared with virgin ink (new off-the-shelf ink). This was accomplished by running the same series of standard analytical and performance tests on the recycled (blended) and virgin inks and comparing results. Whenever possible, a sample of waste ink was also analyzed, and the results were compared with those for the recycled ink to estimate the improvement in quality. Two batches of waste ink were processed and sampled to ensure repeatability.

### Waste Reduction Evaluation

The waste reduction evaluation was based on the amount of waste ink generated annually by the *Courant* that is prevented from entering the environment as a result of recycling. Recycling sidestreams were measured, namely, (a) the wastewater distillate that collects in the separator and (b) the residue on the filters. At the time of this evaluation, the wastewater was being stored for eventual discharge to the municipal sewer line, following permission from the local publicly owned treatment works (POTW). The filter residue is hauled away for incineration as a supplemental fuel at an off-site contractor location. During this evaluation, the wastewater distillate generated was collected and analyzed for parameters that are typically required by POTWs.

## Economic Evaluation

The economic analysis included a comparison of operating costs for the new technology (recycling) with the costs for the former practice (disposal). A return on investment (ROI) and payback period for the purchase of the recycling process equipment were also calculated.

## SECTION 2

## PRODUCT QUALITY EVALUATION

As described in Appendix B, inks used for the offset lithographic printing process are classified as oil or paste inks. Inks are composed of coloring matter (dyes or pigments) and a vehicle or carrier (usually a mineral oil). Pigments, which can be organic or inorganic compounds, are finely dispersed in the vehicle. During the printing process, the excess (waste) ink is collected underneath the presses, along with excess fountain solution (water) and the blanket wash solution (typically an aliphatic-aromatic blend solvent). Paper dust and fibers generated by the newsprint also enter the waste ink. The recycling process should remove these impurities and restore the properties of the ink.

Two batches of waste ink were processed through the recycling unit and samples of the waste and recycled (blended) ink were collected for analysis. Samples of the virgin (new) ink used at the *Courant* were also collected and analyzed. A comparison of the analytical results of the waste and recycled inks indicates the improvement achieved by recycling. A comparison of the analyses of recycled and virgin inks indicates how closely the recycled product approximates the virgin product.

### ON-SITE TESTING

Table 1 describes the on-site testing conducted during this evaluation. Exact volumes entering and leaving the various stages of the recycling system could not be measured. The best estimates based on level indicators on the various tanks in the process are provided in Table 1. The average volumes reported by the *Courant* during past operation are also mentioned and can be used as representative of the system.

TABLE 1. ON-SITE TESTING DESCRIPTION

| Batch No. | Waste Ink Volume[a] (gallons) | Solvent Distillate (gallons) | Wastewater Distillate[a] (gallons) | Filter Residue (gallons) | Processed Ink[a] (gallons) |
|---|---|---|---|---|---|
| 1 | <200 | negligible | <80 | 1 | <150 |
| 2 | <200 | negligible | <60 | 1 | <150 |
| Average[b] | 200 | <10 | <70 | 1 | 120 |

[a] Before blending. Volumes estimated from level indicators on each tank.

[b] Average from past operations.

Both batches (Batch 1 and 2) processed during this evaluation had a processing time of about 48 to 50 hours. However, actual operator involvement was only 1 to 2 hours because most of the recycling process is automated. Enough waste ink (75% black and 25% colored) had been previously collected in the waste ink storage tank to run two batches for this evaluation. A sample of the waste ink from the holding tank was collected with a bailer (a long tube open at both ends). This ensured that the sample was representative of all levels in the tank. Considerable inhomogeneity was noticed in the tank especially with respect to water, which was immiscible and appeared to be accumulating in pockets at various points in the ink.

Each batch was transferred to the distillation still and processed at 140°F under vacuum. Water was distilled off and collected in the separator tank. Usually a layer of solvent also distills off and forms a separate layer on top of the water in the separator tank. However, in the two test batches run, very little solvent was noticed in the distillate. *Courant* staff mentioned that solvent volumes vary with each batch depending upon printing press operational variations. The water was drained off from the separator tank and stored for municipal sewer disposal. At the time of the evaluation, the *Courant* had applied for and received verbal approval from the local POTW for discharge of this wastewater. The water was being stored pending formal approval. The solvent generated in the distillate is reused as blanket wash in the presses.

After cooling to room temperature, the residual ink in the still was recirculated several times through coarse (100 mesh) and fine (325 mesh) filters to remove paper fibers and other particulates. After filtration, the ink was transferred to the blending tank. An intermediate sample of the ink, at this stage, was subjected to a grind test (see following text) and a drawdown test by *Courant* staff. These tests indicated how much virgin ink was to be blended into the processed ink to get an acceptable quality. The drawdown test was especially useful in comparing the processed ink with virgin ink. In this test, about half a teaspoonful each of processed and virgin inks were poured side-by-side on a piece of white paper. With an ink knife, the two inks were smeared in a single stroke (drawdown) across the length of the paper. The two smears were then compared visually. The virgin ink smear looked perfectly black and hid the whiteness of the paper. The processed ink smear looked lighter and bled a bit of red along the edges of the smear (probably from red pigment in the original waste ink). For both test batches, *Courant* staff determined that 3:1, virgin:processed inks, was an acceptable ratio. According to *Courant* staff, this ratio can vary between 3:1 and 5:1. A test mix was prepared at this ratio in a beaker and again subjected to the grind and drawdown tests. Considerable improvement was noticed after blending in both grind and drawdown tests. Thus, a proportional amount of virgin ink was added to the blending tank and mixed with the processed ink. The resulting recycled ink was transferred to the recycled ink holding tank for reuse. Samples of this recycled (blended) ink were collected for analysis. The printability of recycled ink from Batch 1 was tested by switching from virgin to recycled ink midway though a press run for the Sunday paper. Thus, the same image was printed several times, first with virgin ink, and then with recycled ink. The two sets of newspapers were shown to eleven people (not associated with the Courant) familiar on a day-to-day basis with printing and imaging to compare the print quality.

## ANALYTICAL RESULTS

The waste, recycled (blended), and virgin ink samples collected during the on-site testing were analyzed in the laboratory for various characteristics. The results are shown in Table 2 and described below.

### Viscosity

Inks are generally non-Newtonian fluids. The rheology of ink is an important factor in controlling roller-to-plate transfer, fidelity of printing, drying speed, holdout, and trapping properties obtained on the substrate (paper). Rheology is also a good indicator of color strength (pigmentation). Viscosity, the resistance to flow, is the property generally used to describe rheology. Viscosity does not completely describe the rheology of inks, but is useful in controlling the ink quality during production and for specification acceptance between supplier and purchaser.

TABLE 2. RESULTS OF PRODUCT QUALITY ANALYSES

| Batch No. | Sample Type | Viscosity (Poise) | Grind (mil) 4/10[b] | Residue (%) | Tack (gram-meter) | Tinting Strength (%)[c] | Water Content (%) | Water Pickup (%) |
|---|---|---|---|---|---|---|---|---|
| | | Analytical Tests[a] | | | | | | |
| 1,2 | Waste Ink | NA | NA | NA | 3.4 | 69 | 23.6 | NA |
| 1 | Recycled Ink[d] | 19 | 0.4/0.3 | 0.0817 | 4.4 | 96 | 0.102 | 86 |
| 2 | Recycled Ink[d] | 21 | 0.6/0.3 | 0.0735 | 3.9 | 92 | 0.049 | 80 |
| -- | Virgin Ink | 20 | 0.3/0.0 | 0.0019 | 4.0 | 100 | 0.057 | 50 |
| -- | Industry Standard | -- | 0.4/0.2 | 0.01 | 3.7-4.3 | 93 | -- | -- |

[a] NA = Not analyzed. Tests could not be performed because of the large amount of water in the sample.

[b] 4/10 refers to 4 or 10 scratches at reported endpoints.

[c] Strength of recycled ink was compared to the virgin ink and given as a percentage of the virgin ink strength.

[d] Processed ink blended with virgin ink in the ratio 1:3.

Ink viscosity was measured by ASTM D 4040-89 (Table 2). The viscosity of the spent ink sample could not be measured because a considerable amount of immiscible water was present throughout the ink mass, forming a separate phase. The viscosity of both recycled samples was close to that of the virgin ink (within $\pm$ 1 Poise) and in the normal range for newspaper inks, indicating that this parameter had been restored during recycling.

## Grind

This test (ASTM D 1316-87) uses an NPIRI Standard Grindometer to evaluate the fineness of grind of printing inks, that is, the prevalence of oversize particles (contaminants) in the ink dispersion. This NPIRI gauge runs 1 mil deep to flush. The ink is drawn down over this gauge, and the depths at which 4 and 10 scratches in the ink film (caused by particles) appear are recorded (as 4-scratch and 10-scratch endpoints). The test measures the size of the largest particles in the finished dispersion and not the average particle size or concentration of sizes. Oversize particles in the ink may damage a printing plate and disrupt the appearance of ink films. Industry-suggested guidelines recommend that there should not be 4 scratches above 0.4 mil or 10 scratches above 0.2 mil.

The spent ink could not be analyzed because its high water content caused it to run and form a separate phase. The virgin ink sample was within the industry guidelines mentioned above. The recycled ink came close, but exceeded both endpoints by 0.1 mil in Batch 1 and by 0.2 (4-scratch) and 0.1 mil (10-scratch) in Batch 2. This indicates that some fine particulates were retained in the recycled ink.

## Residue

The grind test indicates the size of the largest particles present in the ink. The residue test, also called the wash-out test, measures the weight percentage of the solid particles (impurities) larger than 325 mesh in the ink. In this test, 100 g of ink was mixed for 30 minutes with 50 mL of naphtha. This mixture was poured through a 325-mesh standard sieve, and the residue on the sieve was weighed. The percent by weight of this residue is reported in Table 2.

This test could not be performed on the spent ink sample because the naphtha formed a gel with the contaminant water. The virgin ink showed very little residue (0.0019%). The residue in the recycled samples was an order of magnitude higher (0.0817% and 0.0735%). Industry recommends a level of around 0.01% for newspaper inks. The higher residue content in the recycled samples indicates that spent ink contains particles smaller than 325-mesh, or paper fibers with a diameter less than 325-mesh, that escape the fine filters on the recycling unit. Blending virgin ink at ratios greater than 3:1 (used for the test batches) would be one way of reducing the residue percentage in the recycled ink, although the current residue levels do not appear to have caused a significant difference in print quality (see subsection titled Printability of the Recycled Ink).

## Tack

Tack is a rheological parameter representative of internal cohesion of the fluid. Tack of the ink controls its high-speed transfer properties. It is a function of the force required to split a thin fluid film of ink between two rapidly separating surfaces, such as between the plate cylinder and the offset cylinder or between the offset cylinder and the newsprint. Tack (ASTM D 4361-89) was measured as the frictional torque on a three-roller distribution system (B101 Electronic Inkometer) in units of gram-meters (g-m). Tack was measured at speeds specific to the *Courant* (1200 rpm at 1 min for web-fed inks).

Industry recommends a range between 3.7 to 4.3 g-m for tack for this type of ink. The virgin sample and the recycled sample from Batch 2 were within this range (Table 2). The recycled sample from Batch 1 was slightly above this range. Press operators at the *Courant* did not think that this slight deviation was of any significant concern. The waste ink sample was well below acceptable range, indicating that recycling had considerably improved this parameter.

## Relative Tinting Strength

The waste ink at the *Courant* contains, in addition to black ink, some amounts of colored ink. During recycling, the processed ink is blended with black virgin ink to restore its color and strength. Color and strength are therefore important parameters of the recycled ink. Tinting strength of the ink was measured by a method similar to ASTM Methods D 387, D 2745, and D 4838.

In this test (commonly called the bleach test), a standard white tinting base or bleach (white pigment dispersed in a suitable vehicle) is added side-by-side to the virgin and recycled inks. The amounts of bleach required to get equivalent color strength in the recycled samples and the virgin sample is the relative tinting strength.

Table 2 shows that if the virgin ink at the *Courant* is used as the reference (100% relative strength), the recycled ink in Batches 1 and 2 were within 4 and 8% respectively of the virgin ink. The waste ink had a relative strength of only 69% (31% deviation from virgin), indicating that considerable improvement in tinting strength was achieved by recycling. Industry recommends that relative tinting strength be within $\pm$ 7% of the standard. If virgin (new) ink is considered as the standard, Batch 1 was within the acceptable range and Batch 2 was slightly out of range. This could have been corrected by blending virgin ink into Batch 2 at a ratio greater than the 3:1 used for this batch, although current tinting strength values appeared to provide an acceptable print quality (see subsection titled Printability of the Recycled Ink).

## Water Content

Water gets into the waste ink because of the fountain solution used in lithographic printing. This water alters the consistency and functional properties of the ink and has to be removed during recycling. Water content of the ink samples was measured by ASTM D 1744-83 and results are reported in Table 2. Water content was reduced by recycling from 23.6% in the waste ink to levels comparable with those in virgin ink, indicating that most of the water was removed during the distillation step.

## Water Pickup and Bleeding

The lithographic printing process requires that some fountain solution (mostly water) be emulsified in the ink. This emulsifying capability of the ink was measured by the water pickup test (ASTM D 4942-89). A measured amount of fountain solution (the same one used at the *Courant*) is thoroughly mixed with the ink. Any unemulsified or free water is returned (decanted out of the ink). The percent of water (fountain solution) picked up by the ink relative to its own weight is recorded in Table 2. As part of this test, the color, pH, and conductivity of the return (free) water was also measured. This test was not performed on the waste ink because it already had a large quantity of water.

The water pickup of recycled inks from Batches 1 and 2 was 86 and 80% respectively, compared with 50% for the virgin ink. The water pickup of most inks is between 40 to 80% of the weight of the ink. Newspaper inks are sometimes formulated to pick up far more fountain solution depending on the type of press.

Inks that bleed into the fountain solution could cause tinting in the non-image areas of the newspaper. The virgin and recycled inks did not change the fountain solution to black, but the recycled as well as virgin samples did change the returned (unemulsified) fountain solution from clear to pink. The pH of the fountain solution as used was 6.5 before the test and changed by 0.1 pH units or less after the test (as measured in the unemulsified or returned fountain solution). A drift of less than 0.5 pH is recommended, and the virgin as well as recycled samples were well within this range.

## PRINTABILITY OF THE RECYCLED INK

The above analytical tests indicate the quality of the recycled (blended) ink in terms of laboratory measured parameters. The visual effect and behavior of the recycled ink, once it is printed on a newspaper, was evaluated by (a) taking densitometer readings on black image areas of newspaper pages printed with virgin and recycled inks and (b) requesting 11 experienced viewers to record their preference for newspaper pages printed with recycled or virgin inks.

### Densitometer Test

Three complete copies of the June 30, 1991 edition of the *Hartford Courant* were printed using virgin ink, and three copies using recycled ink. All printing was done on the same press. The switch from virgin to recycled ink was done within minutes to minimize other sources of variation. From these six newspapers, an outer page (a "wrapper" page) and an inner page (a "core" page) were selected, in order to gauge the effects of the two sides of the newsprint on the ink evaluation. The same two pages were selected from each newspaper; thus all selected wrapper pages contained identical printing, as did all selected core pages.

Densitometer readings were obtained on each selected page from three areas of solid ink shading. The densitometer measures the concentration of black dots per unit area of the page, thus indicating the uniformity and color strength of the ink layer on the newsprint. The three areas selected for densitometer analysis on a given page were the same for each wrapper page and for each core page. Table 3 contains the densitometer readings obtained from each area of the tested pages. Higher densitometer readings indicated a higher ink density.

The statistical objective of the densitometer analysis was to determine primary sources of variability present in the densitometer readings, and to determine whether the readings were

TABLE 3. RESULTS OF DENSITOMETER READINGS ON THE NEWSPAPERS

| | | Densitometer Readings (units) | | |
|---|---|---|---|---|
| Paper Type[a] | Location on Page[b] | Paper Printed with Virgin Ink | Paper Printed with Recycled Ink[c] | % Difference[d] (Recycled to Virgin) |
| Wrapper - Newspaper 1 | 1 | 0.95 | 1.10 | 14.6 |
| | 2 | 0.99 | 1.00 | 1.0 |
| | 3 | 0.98 | 1.09 | 10.6 |
| Wrapper - Newspaper 2 | 1 | 0.91 | 1.08 | 17.1 |
| | 2 | 0.95 | 1.03 | 8.1 |
| | 3 | 1.00 | 1.11 | 10.4 |
| Wrapper - Newspaper 3 | 1 | 0.94 | 1.07 | 12.9 |
| | 2 | 0.97 | 1.02 | 5.0 |
| | 3 | 0.91 | 1.04 | 13.3 |
| Core - Newspaper 1 | 1 | 1.05 | 0.99 | -5.9 |
| | 2 | 1.00 | 1.01 | 1.0 |
| | 3 | 1.02 | 0.92 | -10.3 |
| Core - Newspaper 2 | 1 | 1.08 | 1.06 | -1.9 |
| | 2 | 1.02 | 1.01 | -1.0 |
| | 3 | 1.01 | 1.02 | -1.0 |
| Core - Newspaper 3 | 1 | 1.05 | 1.01 | -3.9 |
| | 2 | 1.01 | 0.97 | -4.0 |
| | 3 | 0.97 | 0.98 | 1.0 |

a Wrapper refers to the exterior pages of a newspaper section while core refers to the interior pages. Three complete editions were printed with virgin ink, and three with recycled ink.

b The same three locations were tested on each wrapper page and each core page.

c Processed ink blended with virgin ink in the ratio 1:3.

d A positive % difference indicates that the tested areas were denser for recycled ink according to the densitometer, and vice versa.

statistically higher or lower for one ink than another. To meet this objective, an analysis of variance procedure was applied to the densitometer readings. Based on the experimental design used in the densitometer analysis, the effects of each of the following factors on the densitometer reading were able to be estimated:

- Ink used (recycled or virgin)
- Type of page (wrapper or core)
- Location on the page (three distinct locations).

The results of the statistical analysis on densitometer readings inferred that the readings tended to differ between the side of the page and the ink used. Table 4 contains the means and standard deviations of the readings for each page side and ink. A more detailed discussion of the differences in densitometer readings is included in Appendix C.

TABLE 4. MEANS AND STANDARD DEVIATIONS FOR DENSITOMETER READINGS ACCORDING TO INK TYPE AND SIDE OF PAGE

| | Means (and Standard Deviations) | | |
|---|---|---|---|
| Ink Type | Wrapper Page | Core Page | All Pages |
| Virgin | 0.9556 (0.0324) | 1.0233 (0.0324) | 0.9894 (0.0470) |
| Recycled[a] | 1.0600 (0.0387) | 0.9967 (0.0387) | 1.0283 (0.0497) |
| All Inks | 1.0078 (0.0639) | 1.0100 (0.0373) | -- |

[a] Processed ink blended with virgin ink in the ratio 1:3.

In summary, the densitometer readings (concentrations of black dots) were significantly higher for recycled ink on the wrapper side (level of significance was 99.99%). On the core side, the densitometer readings were marginally higher for virgin ink (level of significance was 93.46%). Generally the differences were small and the denseness quality of the recycled and virgin inks can be said to be comparable.

## Viewer Evaluation

A subjective comparison of the two inks was performed by having eleven viewers rate their preferences between recycled ink and virgin ink as printed on newsprint. The viewers were experts in the printing and printed material field. The visual examination was conducted within five days after printing because the print needs to be stable over this period, especially for the Sunday edition. The criteria which the viewers used to rate their preferences were the following:

- glossiness
- smoothness
- opacity
- rub resistance
- blackness
- absorption/bleed-through
- sharpness

Two pairs of pages were given to the viewers for subjective rating. One pair consisted of two wrapper pages and one pair contained two core pages. Within each pair, one page was printed using recycled ink and one with virgin ink. The two pages, both containing identical printing, were labelled "page A" and "page B" to prevent the viewer from knowing the type of ink used in the printing. These pages were selected for evaluation according to the type of imaging printed, ensuring that both pages had at least some black patches, some half-tones, and some lettering of different fonts and sizes. For each pair of pages, the viewers were asked to determine whether they preferred page A or page B according to each criteria above. A non-preference response was also permitted. A copy of the rating instrument used by the viewers is found in Figure 2.

In the subjective evaluation, it was of interest to determine the proportion of preferences for virgin ink versus recycled ink, and not vice versa. Thus all non-preference responses were combined with those responses indicating a preference for recycled ink. Table 5 contains a summary of the numbers of viewers preferring virgin ink, according to each of the above criteria.

The results in Table 5 show that few, if any, viewers preferred virgin ink over recycled ink when rating the wrapper page by the above criteria. The most viewers rating virgin ink over

Figure 2

## COMPARISON BETWEEN NEWSPAPERS PRINTED WITH VIRGIN AND RECYCLED INKS

We are trying to compare the quality of a newspaper printed with virgin (newly manufactured) ink to that of a newspaper printed with recycled ink. Recycled ink is ink reclaimed by processing the waste ink collected underneath lithographic printing presses.

Please use your best personal judgement to compare the two pages of the newspaper marked "A" with the corresponding two pages of the newspaper marked "B" for the following qualities and mark your preference in the following columns. If you cannot see any noticeable difference in the print quality of the two newspapers please mark the column "no noticeable difference".

### For page H-10

| | "A" looks better than "B" | "B" looks better than "A" | No noticeable difference |
|---|---|---|---|
| Gloss | ________ | ________ | ________ |
| Smoothness | ________ | ________ | ________ |
| Opacity | ________ | ________ | ________ |
| Rub resistance | ________ | ________ | ________ |
| Quality of blackness | ________ | ________ | ________ |
| Absorption/bleed thru' | ________ | ________ | ________ |
| Sharpness | ________ | ________ | ________ |

### For page J-4

| | "A" looks better than "B" | "B" looks better than "A" | No significant difference |
|---|---|---|---|
| Gloss | ________ | ________ | ________ |
| Smoothness | ________ | ________ | ________ |
| Opacity | ________ | ________ | ________ |
| Rub resistance | ________ | ________ | ________ |
| Quality of blackness | ________ | ________ | ________ |
| Absorption/bleed thru' | ________ | ________ | ________ |
| Sharpness | ________ | ________ | ________ |

Thank you for your cooperation.

TABLE 5. RESULTS OF VISUAL JUDGING FOR PRODUCT QUALITY

| | Wrapper Page (outer) | | | Core Page (inner) | | |
|---|---|---|---|---|---|---|
| Parameter | # Viewers Preferring Virgin Ink | # Viewers With No Preference or Preferring Recycled Ink[a] | Upper 95% Confidence Bound on the Proportion Preferring Virgin Ink | # Viewers Preferring Virgin Ink | # Viewers With No Preference or Preferring Recycled Ink[a] | Upper 95% Confidence Bound on the Proportion Preferring Virgin Ink |
| Glossiness | 0 | 11 | 0.238 | 2 | 9 | 0.470 |
| Smoothness | 0 | 11 | 0.238 | 4 | 7 | 0.650 |
| Opacity | 0 | 11 | 0.238 | 4 | 7 | 0.650 |
| Rub Resistance | 3 | 8 | 0.564 | 1 | 10 | 0.364 |
| Blackness | 0 | 11 | 0.238 | 4 | 7 | 0.650 |
| Absorption/ Bleed-Through | 2 | 9 | 0.470 | 1 | 10 | 0.364 |
| Sharpness | 1 | 10 | 0.364 | 3 | 8 | 0.564 |

[a] Processed ink blended with virgin ink in the ratio 1:3.

recycled ink did so according to rub resistance, and only three of the eleven viewers did so. No viewers preferred virgin ink to recycled ink on the wrapper page according to glossiness, smoothness, opacity, or blackness.

When rating the core page, at least one viewer rated virgin ink over recycled ink in each of the criteria. However, no more than four viewers preferred virgin ink for any one of the criteria for the core page.

To determine the extent of variability in the proportion of viewers preferring virgin ink, a series of upper 95% confidence bounds on the true proportion were calculated for each of the seven criteria. These confidence bounds were calculated as follows, and are discussed further in Hollander & Wolfe (1973):

$$\text{upper conf. bound} = 1 - \frac{11-x}{(11-x) + (x+1)^{*}F(2(x+1),2(11-x))},$$

where x is the number of viewers preferring virgin to recycled ink, and F(A,B) is the 95th percentile of the F distribution with A numerator degrees of freedom and B denominator degrees of freedom. The calculated bounds are included in Table 5 for the wrapper and core pages. Note that when two or less of the eleven viewers preferred virgin ink, the upper 95% confidence bound on the proportion is less than 0.5. This states that the proportion of viewers preferring virgin ink is significantly less than 0.5. In summary, there was no significant difference in print quality between the virgin and recycled inks in the opinion of experienced viewers.

## PRODUCT QUALITY ASSESSMENT

The product quality of the recycled ink was very good. In most of the laboratory tests described above, the recycled ink matched the properties of the virgin ink. In some cases, the recycled ink properties were slightly outside industry recommended ranges, although it should be noted that these ranges are recommended by industry for newly manufactured inks. No standards exist specifically for recycled inks, and it is left to the users to determine acceptable ranges for the ink. Recycled ink quality has been found to be acceptable at *The Hartford Courant*, where recycled ink is regularly used for printing both the daily and Sunday newspapers, without any drop in quality. Regular readers of the *Courant* have not noticed any difference in print quality. The panel of experienced viewers that evaluated the newspaper printed with virgin and recycled inks did not notice any significant difference in quality either.

Improvements that can be made in the recycling system, as it now exists, should be in the area of fine particulates removal. This could be addressed by increasing the blending ratio of virgin:processed inks from 3:1 (in this evaluation) to 4:1, which would further reduce the concentration of the fine particulates in the ink. In fact, the *Courant* could automatically blend virgin ink into the processed ink at ratios of 5:1 or higher given that the amount of processed ink is such a small percentage of the total amount of ink required for production.

Another improvement could be to increase the efficiency of filtration. The fact that the residue test showed some residue on the 325-mesh sieve in the laboratory indicates that the 325-mesh filters on the recycling units may not be fully efficient. One difficulty could be that paper fibers may have a lengthwise dimension greater than 325 mesh, but a fiber diameter of less than 325 mesh. Depending on its orientation, this fiber could either pass through or be retained on the filter. Several more passes through the recycling unit filters may be required before such fibers are removed. However, the slightly elevated levels of fine particulates in the recycled ink, compared to virgin ink, did not noticeably influence the performance or printability of the recycled ink.

## SECTION 3
## WASTE REDUCTION POTENTIAL

The waste reduction potential was measured in terms of (a) volume reduction and (b) pollutant reduction. Volume reduction addresses the gross wastestream and affects environmental resources (e.g., landfill space) expended during disposal (e.g., waste ink), whereas pollutant reduction addresses the specific hazards of individual pollutants (e.g., heavy metals) in the gross wastestream.

### WASTE VOLUME REDUCTION

The waste-volume-reduction potential of this technology involves the amount of waste ink prevented from being disposed into the environment (by landfilling, waste incineration or as supplemental fuel). Table 6 lists the various wastestreams and waste volumes generated by disposal and by recycling. The *Courant* generates approximately 175 gal/week or 9,100 gal/yr waste ink. Every 200 gal of waste ink contains, on average, about 80 gal of water and solvent (mostly water), and the rest (120 gal) is ink. Previously, this waste ink was being disposed by a waste hauler by incineration as supplemental fuel.

TABLE 6. WASTE REDUCTION POTENTIAL

| Wastestream Generated | Amount Per Year |
|---|---|
| <u>Current Practice</u> | |
| 1. Waste Ink | 9,100 gal |
| <u>With Recycling</u> | |
| 1. Wastewater | 3,049 gal |
| 2. Residue (paper dust) | 46 gal |

By recycling, the ink is recovered. The recycling wastestreams consist of water (wastewater) from the separator and the paper-dust paste residue from the filters. Any solvent that distills off is reused in the printing process. At the time of this evaluation, the wastewater was being stored for discharging down the municipal sewer. The *Courant* is considering installing an activated carbon filter for polishing off the organics in the wastewater, so that the water can be used again. The paper-dust residue (about 1 gal/200 gal of waste ink processed) is disposed of by off-site contractor incineration as supplemental fuel.

## POLLUTANT REDUCTION

Individual pollutants present in the wastestreams are discussed in this section. As described in Appendix B, the waste ink contains a number of components that potentially could render it hazardous. The waste ink at the *Courant* has been tested and is not considered a hazardous waste per RCRA, and can be disposed of according to state regulations for oily wastes. However, solvent washes for other inks that contain lead or chromium in their formulation are listed as hazardous waste (EPA Waste Number K086) under RCRA. In addition, other waste inks could contain constituents that render them flammable or toxic. Many toxicity problems are caused by the pigments used. Lead, chromium, barium, and organic compounds are common toxics in pigments. Solvents in the waste ink are usually aliphatic-aromatic blends. These solvents may contain hazardous organic constituents. By recycling, virtually all of these potential pollutants in the waste ink are reused and thus prevented from entering the environment.

The recycling process generates paper-dust residue, which is basically a paste-like substance containing paper fibers covered with a thick mass of ink. The hazards associated with this residue are the same as discussed above for the ink, the advantage being that, for every 200 gal of waste ink, less than 1 gal of residue is generated.

The recycling process also generates wastewater as a wastestream, which the *Courant* plans to discharge to the municipal sewer, after approval from the POTW is obtained. This wastewater was analyzed for potential hazards during this evaluation. Two samples of the wastewater, both from Batch 1, were collected. Two samples were collected because the separator tank had to be emptied halfway through the distillation of Batch 1 to make room for more distillate. The two samples represent the initial distillate and the later distillate. Results for the chemical analysis are reported in Tables 7 and 8. A blank consisting of tap water collected at the

TABLE 7. RESULTS OF ORGANIC ANALYSIS OF WASTEWATER

| Batch No. | Sample Type | Oil & Grease (mg/L) | Total Hydrocarbons (mg/L) | Aromatic Organics (mg/L): Benzene | Chlorobenzene | 1,4 Dichlorobenzene | 1,3 Dichlorobenzene | 1,2 Dichlorobenzene | Ethylbenzene | Toluene | Xylene |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 (initial) | Wastewater | 67.9 | 43.9 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | 0.0177 | 0.425 |
| 1 (later) | Wastewater | 31.5 | 56.9 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | 0.373 |
| -- | Blank | 1.06 | <0.5 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 | <0.0025 |

TABLE 8. RESULTS OF METALS ANALYSIS OF WASTEWATER (μG/L)

| Batch No. | Sample Type | Lead | Cadmium | Chromium | Zinc | Nickel | Copper |
|---|---|---|---|---|---|---|---|
| 1 (initial) | Wastewater | 89.2 | <4.1 | <4.4 | 831 | 6.9 | 14,600 |
| 1 (later) | Wastewater | 17.3 | <4.1 | <4.4 | 42.3 | <3.4 | 662 |
| -- | Blank | 14.6 | <4.1 | <4.4 | 14.4 | 69.0 | 95.1 |

*Courant* was also analyzed to check for any extraneous contamination (from the tap water or during sampling and analysis). The blank did not contain any significant levels of the analytes.

The organic analysis of the wastewater showed elevated levels of oil, grease, total hydrocarbons, toluene, and xylene. The metals analysis of the wastewater showed elevated levels of lead, zinc, and copper. These pollutants in the wastewater are components of the ink (vehicle and pigment) or the blanket wash solvent that get carried over into the distillate. Because of these pollutants, the wastewater cannot be discharged directly to natural waters but has to be treated. At the time of the evaluation, the *Courant* had obtained verbal approval from the POTW for discharging this wastewater to the local wastewater treatment plant where these pollutants will be removed. The *Courant* is expected to generate approximately, 67 gal of wastewater per 200 gal of waste ink, or 3,049 gal/yr.

Because toxicity of influents is a growing concern among POTWs, acute aquatic toxicity tests were conducted on the wastewater. A distilled water control sample was also run alongside each test sample. Before the test, the wastewater was gently aerated (as required by the standard method) to increase dissolved oxygen from 4.7 mg/L to 9.0 mg/L, and pH was adjusted from 4.7 to 8.4 with hydroxide. Acute toxicity was measured on two aquatic organisms C. dubia (daphnids) and P. promelas (fathead minnows) according to EPA method 600/4-85/013. In the screening test using 100% wastewater (as received), all organisms of both species died within the first day after they were introduced into the wastewater (Table 9). Therefore a definitive test (Table 10) was conducted with various dilutions of the wastewater to determine the $LC_{50}$ (lethal concentration at which at least half the organisms die). The definitive test was conducted in duplicate for each dilution on the minnows.

TABLE 9. ACUTE TOXICITY ANALYSIS OF WASTEWATER--SCREEN TEST

| | Number of Live Organisms | | | |
|---|---|---|---|---|
| | C. dubia[a] | | P. promelas[b] | |
| Day | 100% Wastewater | Control | 100% Wastewater | Control |
| 1 | 0 | 5 | 0 | 10 |
| 2 | NA | 5 | NA | 10 |
| 3 | NA | 5 | NA | 10 |
| 4 | NA | 5 | NA | 10 |

[a] Five C. dubia (daphnids) were introduced into each tank on Day 0.

[b] Ten P. promelas (fathead minnows) were introduced into each tank on Day 0.

NA: Not applicable.

TABLE 10. ACUTE TOXICITY ANALYSIS--DEFINITIVE TEST

| Water Concentration (%) | C. dubia[a] Day Number | | P. promelas[b] Day Number | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 3 | 4 |
| Control | 5 | 5 | 10/10 | 10/10 | 10/10 | 10/10 |
| 6 | 0 | NA | 10/8 | 7/7 | 5/5 | 4/3 |
| 12 | 0 | NA | 2/0 | 0/NA | NA | NA |
| 25 | 0 | NA | 0/0 | NA | NA | NA |
| 50 | 0 | NA | 0/0 | NA | NA | NA |
| 100 | 0 | NA | 0/0 | NA | NA | NA |

[a] Five C. dubia (daphnids) were introduced into each tank on Day 0.

[b] Ten P. promelas (fathead minnows) were introduced into each tank on Day 0. Test was conducted in duplicate for each dilution.

NA: Not applicable.

The static acute toxicity test on the daphnids indicated that the $LC_{50}$ for both 24-hr and 48-hr tests was below 6%, the lowest concentration tested. The definitive test on the minnows indicated that the 24-hr, 48-hr, 72-hr, and 96-hr $LC_{50}$s were 8.5%, 7.0%, 6.0%, and <6%, respectively. The results show that the wastewater from the recycling process is highly toxic and would need to be diluted at least 10 to 20 times to make it non-toxic. The swiftness with which the aquatic organisms died appears to indicate that toxicity is caused primarily by organic constituents in the wastewater (when inorganic constituents such as heavy metals cause toxicity, the organisms tend to die more slowly). Organic analysis of the wastewater (Table 7) showed elevated levels of oil, grease, total hydrocarbons, toluene, and xylene.

This result indicates that the part of the solvent that co-distills out into the separator tank may not be forming a separate phase easily. This would mean that (a) wastewater is evacuated from the separator tank without allowing enough time for the solvent to separate out into a separate phase on top of the water or (b) that the solvent has some solubility in water or may be forming a micro-emulsion. In the first case, the *Courant* could allow the water to settle for an extended period of time before draining the separator tank. In the second case, some other means such as activated carbon filtration of the wastewater could be used, although the *Courant* is not currently required to do so. It should be noted that the amount of wastewater generated through the recycling process is so small (less than 80 gal/week) that it is not expected to cause problems at the POTW, where it would get diluted several times by other influents and the treatment process would remove the organics. However, to avoid letting the water go to waste, it would be desirable to run it through an activated carbon filter and reuse it. The *Courant* is considering such an addition.

## WASTE REDUCTION ASSESSMENT

There is considerable potential for waste reduction by recycling waste ink. Valuable resources such as ink and solvent, are recovered from the waste ink and reused. In the case of the *Courant*, the amount of waste disposed has been reduced from 9,100 gal/yr of waste ink to 46 gal/yr of paper-dust and 3,049 gal/yr of wastewater. The wastewater is a lower hazard compared to the waste ink. The volume of the wastewater stream can also be reduced considerably by installing an activated carbon filter and reusing the water.

SECTION 4

# ECONOMIC EVALUATION

## MAJOR OPERATING COSTS

The major operating costs associated with the disposal option and the recycling option are given in Table 11. With disposal, the main cost is the fee charged by the waste hauler to take the waste ink away for incineration. The *Courant* was paying $200/55-gal drum for disposal, plus the cost of the empty drum itself ($30/drum).

With recycling, the major operating costs are for utilities (energy), labor, and disposal of wastewater and paper-dust residue. Utility costs were estimated to be $105/batch (see Appendix D for details). Utility costs were based on the energy requirements of the distillation still (steam heat generated by a gas-fire boiler), distillation still agitator, ink pump, water pump, vacuum pump, blend tank pump, blend tank mixer, day tank pump, and chiller (compressor, fan motor, and coolant pump).

At *The Hartford Courant* no additional labor (other than that already employed for disposal operations) was needed to operate the recycling equipment. Although no extra labor was needed at the *Courant*, one hour of operator time per batch (including time for intermediate quality tests on the ink) was considered for the economic analysis. The paper-dust residue on the filters is hauled away for incineration at a cost of $250/55-gal drum. The wastewater from the separator would be discharged to the POTW at a sewer charge of $0.10/1,000 gal.

## VALUE OF RECYCLED PRODUCT

Recycling waste ink at *The Hartford Courant* has resulted in savings (or revenue) from reduced virgin ink and solvent purchases. According to the *Courant*, for every 200 gal of waste ink generated, 120 gal of ink and 12 gal of solvent are reclaimed. The *Courant* generates 9,100 gal of waste ink per year, therefore, 5,460 gal of ink and 546 gal of solvent are reclaimed.

TABLE 11. MAJOR OPERATING COSTS

| Item | Quantity/Yr. | Unit Cost ($) | Total Cost ($/Yr) |
|---|---|---|---|
| Former Practice | | | |
| Disposal: | | | |
| Waste Ink | 9,100 gal | 200/55 gal drum | 33,100 |
| Drums | 165 | 30 | 4,950 |
| | | | Total 38,050 |
| Current Practice | | | |
| Disposal: | | | |
| Water disposal | 3,049 gal | 0.10/1,000 gal | negligible |
| Residue disposal | 46 gal | 250/55 gal | 250 |
| Drums | 1 | 30 | 30 |
| Recycling: | | | |
| Electricity | 59 batches | 75.62/batch | 4,462 |
| Gas | 59 batches | 29.70/batch | 1,752 |
| Labor | 59 hrs | 10.00/hr | 590 |
| | | | Total 7,084 |

The *Courant* currently pays \$3.32/gal for virgin ink and \$2.95/gal for new solvent. The resulting savings are equal to \$18,127/year of ink value and \$1,611/year of solvent value, or a total of \$19,738/year.

## PAYBACK - - PRELIMINARY ESTIMATE

A simple payback period calculation can be performed with just the major operating costs in Table 11.

$$\text{Payback period (in years)} = \frac{\text{(Purchase Cost)}}{\text{(Annual Reduction in Operating Cost)} + \text{(Annual Value of Recycled Product)}}$$

The purchased cost of the unit is \$318,000 including installation. The reduction in major operating costs can be obtained from Table 11 as \$30,966/year. The value of the recovered ink and solvent is \$19,738/year. A simple payback calculation results in a payback period of 7 years. This simple payback calculation is presented as a rough estimate of how long it would take to recover the investment. It does not include inflationary costs, tax rates, maintenance, etc. A more through payback calculation is presented in the following text.

## ECONOMIC ANALYSIS

The return on investment and payback period for recycling were based on the worksheets provided in the Waste Minimization Opportunity Assessment Manual (U.S. EPA, 1988).

### Capital Costs

Table 12 provides the capital cost inputs used in the worksheet.

- Equipment costs are \$318,000, which includes installation, and modifications to the room where the equipment is stored.
- Installation costs are included above.
- Plant engineering costs are included above.
- Contingency costs are assumed to be \$500.
- Working capital is negligible.

TABLE 12. CAPITAL COSTS FOR THE ECONOMICS WORKSHEET

| | | | |
|---|---|---|---|
| **INPUT** | | **OUTPUT** | |
| | | **CAPITAL REQUIREMENT** | |
| **Capital Cost** | | | |
| | | Construction Year | 1 |
| Capital Cost | | | |
| Equipment | $318,000 | Capital Expenditures | |
| Materials (incl.) | $0 | Equipment | $318,000 |
| Installation (incl.) | $0 | Materials | $0 |
| Plant Engineering | $0 | Installation | $0 |
| | | | |
| Contractor/Engineering | $0 | Plant Engineering | $0 |
| Permitting Costs | $1,000 | Contractor/Engineering | $0 |
| Contingency | $500 | Permitting Costs | $1,000 |
| Working Capital | $0 | Contingency | $500 |
| Start–up Costs | $1,200 | Start–up Costs | $1,200 |
| | | Depreciable Capital | $320,700 |
| % Equity | 100% | Working Capital | $0 |
| % Debt | 0% | Subtotal | $320,700 |
| Interest Rate on Debt, % | 0.00% | Interest on Debt | $0 |
| Debt Repayment, years | 0 | Total Capital Requirement | $320,700 |
| | | | |
| Depreciation period | 7 | Equity Investment | $320,700 |
| Income Tax Rate, % | 43.00% | Debt Principal | $0 |
| | | Interest on Debt | $0 |
| Escalation Rates, % | 5.0% | Total Financing | $320,700 |
| | | | |
| Cost of Capital | 15.00% | | |

- Start-up costs are based on 40 hours of operator time.

- 100% equity is assumed, that is, *The Hartford Courant* self-financed the unit. If a loan were taken, the percent debt and interest rate would have been entered here.

- The tax rate is based on *The Hartford Courant's* rate of 43%.

- Escalation (inflation) rate is assumed to be 5%.

<u>Operating Cost/Revenue</u>

Table 13 provides the operating cost/revenue inputs used.

- No raw materials are needed for this process.

- Utility costs are based on the energy and gas costs in Table 11

- 1 hour per batch of additional labor was needed for recycling (as compared to disposal).

- Operating supply costs are based on the miscellaneous solvents and rags.

- Maintenance costs are based on a percentage of capital costs.

- Overhead costs are based on supervision costs (10% of O&M labor costs), plant overhead (25% of O&M labor and supervision), and labor burden (28% of O&M labor and supervision).

- Revenue is based on the value of the recycled ink and solvent as discussed in Section 4.2.

<u>Results of Economic Analysis</u>

Tables 14 and 15 indicate the results of the economic analysis. A return on investment is obtained in the tenth year of recycling. A firm that has a cost of capital of 9% or less would find this investment economical.

## ECONOMIC ASSESSMENT

The recycling equipment is a large investment, even for a medium- to large-size newspaper such as the *Courant*. At a payback period of ten years or more, this system could be

TABLE 13. ANNUAL OPERATING COST/REVENUE INPUTS TO THE ECONOMICS WORKSHEET

| Operating Cost/Revenue | | | | |
|---|---|---|---|---|
| | | | | |
| Marketable By–products | | | Operating Labor | |
| Recycled Ink | $18,127 | | Operator hrs/batch | 1 |
| Recycled Solvent | $1,611 | | Batches/year | 59 |
| Total $/yr. | $19,738 | | Wage rate, $/hr. | $10.00 |
| | | | | |
| Utilities | | | Operating Supplies | 10 |
| Gas | $1,752 | | Total $/yr. | $10 |
| Electric | $4,462 | | | |
| Total $/yr. | $6,214 | | | |
| | | | Maintenance Costs | |
| Raw Materials | | | (% of Capital Costs) | |
| Total, $/yr. | $0 | | Labor | 0.50% |
| | | | Materials | 0.50% |
| Waste Disposal Savings | | | | |
| Offsite Fees, $ | $32,850 | | Supervision | |
| Storage Drums $ | $4,920 | | (% of O&M Labor) | 10.0% |
| Total Disposal Savings | $37,770 | | | |
| | | | Overhead Costs | |
| | | | (% of O&M Labor + Super.) | |
| | | | Plant Overhead | 25.0% |
| | | | Home Office | 0.0% |
| | | | Labor Burden | 28.0% |

TABLE 14. INCREASED ANNUAL REVENUES AND OPERATING SAVINGS FROM RECYCLING

| | | | | |
|---|---|---|---|---|
| **REVENUE AND COST FACTORS** | | | | |
| | | | | |
| Operating Year Number | | | 1 | 2 |
| Escalation Factor | | 1.000 | 1.050 | 1.103 |
| | | | | |
| **INCREASED REVENUES** | | | | |
| Increased Production | | | $0 | $0 |
| Marketable By--products | | | $20,725 | $21,761 |
| Annual Revenue | | | $20,725 | $21,761 |
| | | | | |
| **OPERATING SAVINGS (Numbers in parentheses indicate net expense)** | | | | |
| | | | | |
| Raw Materials | | | $0 | $0 |
| Disposal Costs | | | $39,659 | $41,641 |
| Maintenance Labor | | | ($1,670) | ($1,753) |
| Maintenance Supplies | | | ($1,670) | ($1,753) |
| Operating Labor | | | ($620) | ($650) |
| Operating Supplies | | | ($11) | ($11) |
| Utilities | | | ($6,525) | ($6,851) |
| Supervision | | | ($229) | ($240) |
| Labor Burden | | | ($705) | ($740) |
| Plant Overhead | | | ($629) | ($661) |
| Home Office Overhead | | | $0 | $0 |
| Total Operating Savings | | | $27,601 | $28,981 |

TABLE 15. RETURN ON INVESTMENT (ROI)

| RETURN ON INVESTMENT | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Construction Year | 1 | | | | | |
| Operating Year | | 1 | 2 | 3 | 4 | 5 |
| | | | | | | |
| Book Value | $320,700 | $229,071 | $163,622 | $116,873 | $71,059 | $25,245 |
| Depreciation (by straight–line) | | $45,814 | $45,814 | $45,814 | $45,814 | $45,814 |
| Depreciation (by double DB) | | $91,629 | $65,449 | $46,749 | $33,392 | $20,303 |
| Depreciation | | $91,629 | $65,449 | $46,749 | $45,814 | $45,814 |
| | | | | | | |
| **Cash Flows** | | | | | | |
| | | | | | | |
| Construction Year | 1 | | | | | |
| Operating Year | | 1 | 2 | 3 | 4 | 5 |
| | | | | | | |
| Revenues | | $20,725 | $21,761 | $22,849 | $23,992 | $25,191 |
| + Operating Savings | | $27,601 | $28,981 | $30,431 | $31,952 | $33,550 |
| Net Revenues | | $48,326 | $50,743 | $53,280 | $55,944 | $58,741 |
| – Depreciation | | $91,629 | $65,449 | $46,749 | $45,814 | $45,814 |
| Taxable Income | | ($43,302) | ($14,706) | $6,530 | $10,129 | $12,927 |
| – Income Tax | | ($18,620) | ($6,324) | $2,808 | $4,356 | $5,558 |
| Profit after Tax | | ($24,682) | ($8,383) | $3,722 | $5,774 | $7,368 |
| + Depreciation | | $91,629 | $65,449 | $46,749 | $45,814 | $45,814 |
| After–Tax Cash Flow | | $66,946 | $57,066 | $50,472 | $51,588 | $53,182 |
| | | | | | | |
| Cash Flow for ROI | ($320,700) | $66,946 | $57,066 | $50,472 | $51,588 | $53,182 |
| Net Present Value | ($320,700) | ($262,486) | ($219,335) | ($186,150) | ($156,654) | ($130,213) |
| **Return on Investment** | | –79.12% | –46.11% | –26.16% | –13.18% | –4.61% |

(Continued)

TABLE 15. (Continued)

| **RETURN ON INVESTMENT** | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Construction Year | | | | | |
| Operating Year | 6 | 7 | 8 | 9 | 10 |
| | | | | | |
| Book Value | $0 | $0 | $0 | $0 | $0 |
| Depreciation (by straight-line) | $45,814 | $0 | $0 | $0 | $0 |
| Depreciation (by double DB) | $7,213 | $0 | $0 | $0 | $0 |
| Depreciation | $25,245 | $0 | $0 | $0 | $0 |
| | | | | | |
| **Cash Flows** | | | | | |
| | | | | | |
| Construction Year | | | | | |
| Operating Year | 6 | 7 | 8 | 9 | 10 |
| | | | | | |
| Revenues | $26,451 | $27,773 | $29,162 | $30,620 | $32,151 |
| + Operating Savings | $35,227 | $36,989 | $38,838 | $40,780 | $42,819 |
| Net Revenues | $61,678 | $64,762 | $68,000 | $71,400 | $74,970 |
| − Depreciation | $25,245 | $0 | $0 | $0 | $0 |
| Taxable Income | $36,433 | $64,762 | $68,000 | $71,400 | $74,970 |
| − Income Tax | $15,666 | $27,848 | $29,240 | $30,702 | $32,237 |
| Profit after Tax | $20,767 | $36,914 | $38,760 | $40,698 | $42,733 |
| + Depreciation | $25,245 | $0 | $0 | $0 | $0 |
| After-Tax Cash Flow | $46,012 | $36,914 | $38,760 | $40,698 | $42,733 |
| | | | | | |
| Cash Flow for ROI | $46,012 | $36,914 | $38,760 | $40,698 | $42,733 |
| Net Present Value | ($110,321) | ($96,443) | ($83,773) | ($72,204) | ($61,641) |
| **Return on Investment** | 0.43% | 3.41% | 5.79% | 7.69% | 9.21% |

very expensive for smaller printers. However, smaller modules with similar capabilities are commercially available and could be considered by smaller newspapers. Also, as the cost of disposal continues to grow (as indicated by current trends) and issues of long-term liability assume greater importance, the economic attractiveness of this system can be expected to increase.

## SECTION 5
## QUALITY ASSURANCE

A Quality Assurance Project Plan (QAPjP) was prepared and approved by the EPA before testing began (Battelle 1991). This QAPjP contains a detailed design for conducting this study. The experimental design, field testing procedures, and laboratory analytical procedures are covered. The QA objectives outlined in this QAPjP are discussed below.

### ON-SITE TESTING

On-site testing was conducted as planned in the QAPjP, which the following variations. Two samples of the wastewater from the separator were collected and analyzed instead of the one sample planned because the capacity of the separator tank is smaller than the amount of water that comes out as distillate. During processing, the tank was filled while more distillate was being generated. The contents of the separator tank were emptied to make room for fresh distillate. Because the fresh distillate may be of a different composition than the first distillate, the original contents of the tank as well as the fresh distillate were sampled for chemical analysis.

### LABORATORY ANALYSIS

All analyses were performed as planned, except that a duplicate analysis for oil and grease in the wastewater samples could not be performed because the laboratory was unable to conserve enough sample volume for a second analysis. Also some tests, i.e., viscosity, grind, residue, and water pickup, could not be performed on the waste ink samples because the large amount of water present in the samples tended to split off into a separate phase.

Grind test results were reported as the mean of readings from four paths. Tack results were reported as the average of two determinations. All aquatic toxicity tests were conducted with at least one replicate for each dilution.

Table 16 lists the precision data for the chemical analysis of the wastewater. All precision data were in the acceptable range (± 25% precision). Table 17 lists the accuracy data for the chemical analysis. All matrix spike recoveries were in the acceptable range (75% to 125% recovery).

## LIMITATIONS AND QUALIFICATIONS

Based on the above QA data, the results of the on-site and laboratory testing can be considered as a valid basis for drawing conclusions about product quality and waste reduction. Data for economic analysis were obtained primarily from records kept by the *Courant*. Any assumptions made are specified so that the readers can adjust them to their own case.

TABLE 16. PRECISION DATA FOR METALS ANALYSIS

| Parameter | Sample No. | Regular Sample | Duplicate | Precision[a] (%) |
|---|---|---|---|---|
| Cadmium | HC2WW | <4.1 | <4.1 | NC |
| Chromium | HC2WW | <4.4 | <4.4 | NC |
| Copper | HC2WW | 661.8 | 700.5 | 5.7 |
| Lead | HC2WW | 17.3 | 15.1 | 13.6 |
| Nickel | HC2WW | <3.4 | <3.4 | NC |
| Zinc | HC2WW | 42.3 | 39.7 | 6.3 |

[a] NC = Not Calculable.

TABLE 17. ACCURACY DATA FOR WASTEWATER ANALYSES

| Parameter | Sample No. | Regular Sample (mg/L) | Matrix Spike Level (mg/L) | Matrix Spike Measured (mg/L) | Accuracy % Recovered |
|---|---|---|---|---|---|
| Oil & Grease | HC-2-WW | 31.5 | 25 | 59.4 | 112 |
| Total Hydrocarbons | HC-2-WW | 56.9 | 50 | 111.9 | 110 |
| Benzene | HC-1-BL | <2.5 | 50 | 41.57 | 83 |
| Toluene | HC-1-BL | <2.5 | 50 | 39.32 | 79 |
| Chlorobenzene | HC-1-BL | <2.5 | 50 | 38.82 | 78 |
| | | | | | |
| Cadmium | HC-2-WW | <4.1 | 500 | 446.5 | 89 |
| Chromium | HC-2-WW | <4.4 | 500 | 424.7 | 85 |
| Copper | HC-2-WW | 661.8 | 500 | 1,069 | 81 |
| Lead | HC-2-WW | 17.3 | 500 | 420.5 | 81 |
| Nickel | HC-2-WW | <3.4 | 500 | 425.3 | 85 |
| Zinc | HC-2-WW | 42.3 | 500 | 458.2 | 83 |

## SECTION 6
## CONCLUSIONS AND DISCUSSION

The ink recycling system installed at *The Hartford Courant* newspaper succeeded in restoring the waste ink to a satisfactory quality. The recycled ink (processed waste ink blended with virgin ink) fared well in laboratory performance tests, including viscosity, grind, residue, tack, tinting strength, water content, and water pickup. In most of the tests, there was no noticeable difference between the performance of the recycled and virgin inks. When the same newspaper pages were printed first with virgin ink and then with recycled ink, viewers experienced with printed materials could not tell the difference with respect to glossiness, smoothness, opacity, rub resistance, tone, absorption/bleed-through, and sharpness. Densitometer measurements taken on the black image areas on the newspapers showed that both recycled and virgin inks produced the same uniform layer on the newsprint.

The ink going to waste can be virtually eliminated by recycling. Over 99% of the ink in the waste can be recovered. A small fraction sticks to the paper-dust residue on the filters and has to be disposed. The blanket wash solvent in the waste can be recovered and reused. The wastewater (generated from the fountain solution component of the waste) contains some levels of contaminants that make it toxic. However, the small volume of this wastewater (254 gal/month) should not be a problem for a POTW. Nevertheless, it may be desirable from a resource recovery standpoint, to treat this water on-site by an activated carbon filter and reuse it.

Economic incentive for recycling is the value of the ink and solvent recovered, as well as reduced disposal costs and potentially reduced liabilities through direct control over potentially hazardous waste. The payback period for the recycling system at the *Courant* was 10 years.

According to preliminary data published by the American Newspaper Publishers Association (ANPA 1991), there are 49 daily newspapers with circulation above 250,000, 96 dailies with circulation between 100,000 to 250,000, and 1,466 dailies with circulation below 100,000. The *Courant* has a daily circulation of 225,000 and can be considered as a medium-sized newspaper. A much smaller recycling system than the one installed at the *Courant* would be required for smaller newspapers. The technology (distillation and filtration) used at the *Courant* is fairly straightforward, and smaller scale units can be assembled. Several smaller vacuum distillation batch stills are commercially available at much lower cost. Some smaller newspapers have designed their own reclamation systems, essentially filtration units (Rosenberg 1988). Another option for smaller newspapers is to utilize the services of a mobile truck-mounted recycling system that goes from site to site and recycles waste ink for a charge. One such mobile unit is being operated by a vendor in California. The advantage of this system is that the generator does not have to invest in capital equipment. Potential savings by recycling exist even for generators that produce a single drum (or less) of waste ink per month.

Two types of recycling systems are commercially available. One is the distillation type at the *Courant*. The other is the filtration type. Depending on the operation of the presses, the blanket wash solvent and fountain solution can be segregated from the rest of the waste ink. In that case, the only contaminant in the waste ink is the paper dust, which can be removed by filtration making distillation unnecessary. Some printers have been able to recycle waste ink just by blending it with virgin ink and reusing it (Cross 1989). Besides newspapers, other printers (e.g., advertising companies) may be able to use similar technologies.

## SECTION 7
## REFERENCES

American Newspaper Publishers Association (ANPA). Facts About Newspapers. Washington, D.C. April 1991.

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# APPENDIX A

## DESCRIPTION OF PRINTING PROCESSES

Printing processes can be classified into four main categories: relief (letterpress and flexographic), gravure (intaglio), stencil or porous (screen) and planography (lithography). Relief printing involves image carriers in which the printing image is raised above the carrier. Ink is applied only to this raised surface and then transferred to the paper or other medium. The gravure carrier is the reverse of the relief, in that the printing image is recessed, usually to different depths. Ink is applied to the whole carrier and then removed from the top surface, before being transferred to the paper. Stencil printing uses porous carriers (silk or steel screens) and the ink flows through the carrier to the paper. The image is determined by controlling the porosity of different areas of the carrier. The process which we are most concerned with for this project is planography, which is described in more detail in the following paragraphs.

In planography the carrier is generally a flat surface which is divided into areas that attract oil (hydrophobic), and areas that repel oil (hydrophilic). The ink adheres to those surfaces that are hydrophobic. A slightly acidic water-based fountain solution, which adheres to the hydrophilic surfaces, is applied before inking.

The planographic printing process can be divided into four separate methods: stone lithography, direct lithography, offset lithography, and collotype. Of these, offset lithography is the most widely used, and is shown in Figure A-1. The printed image on the metal plate cylinder is transferred (offset) to an offset cylinder that transfers the image to the paper. The offset cylinder is a rubber-covered blanket cylinder which is better able to conform to the irregularities in the paper surface than the metal cylinder. The use of the offset cylinder also results in a thinner ink film applied to the paper and therefore the speed of drying is increased. Trays are placed beneath the cylinders to collect excess ink, fountain solution, solvent, and paper dust. The contents of these trays constitute the waste ink.

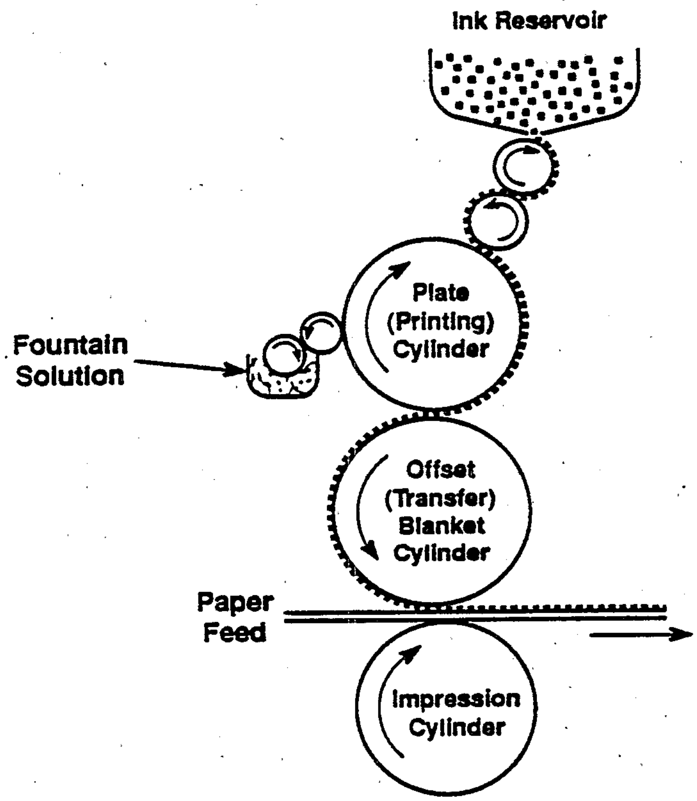


Figure A. Offset Planographic (Lithographic) Printing



M/652JonesA

## APPENDIX B
## DESCRIPTION OF PRINTING INKS

Inks vary according to the printing process, the consistency required, the kind of paper, the kind of drying, and other printing qualities required. Often, printing inks are classified as oil or paste inks and solvent or liquid inks. Lithographic and letterpress processes use oil or paste inks and flexographic and rotogravure processes use solvent or liquid inks. The focus will be on those inks used in the newspaper industry for offset lithographic printing (described in A.1).

In the lithographic process the ink comes in contact with a water-based fountain solution. The ink should not mix with, or become emulsified in this solution. This is prevented by using a water-insoluble ink with high viscosity. In offset printing the ink is transferred to the paper by way of an intermediate cylinder, therefore the ink is thinned out. For this reason, the concentration of the coloring matter needs to be increased to maintain a dark print.

Ink is composed of a coloring matter and a vehicle. The coloring matter in most commercial inks is a dry pigment dispersed in the vehicle. Besides being responsible for the color of the ink, the pigment also affects properties of viscosity, drying, useful life of printed material, and chemical resistance. In the lithographic process, the pigment must not be able to bleed in the water solution.

Pigments are grouped as organic and inorganic. Organic pigments can be in the form of toners, that are insoluble in pure form or in the form of lakes, which require a metal or inorganic base for precipitation. Organic pigments can be divided into six categories: 1) Azo insoluble which are insoluble in water (toluidine, para-chlorinated nitroanalines, naphthol reds, Hansa, benzidine and dinitroanaline orange). 2) Acid-azo which contain acid groups (lithol, tartrazine, red lake C, Persian orange). 3) Anthraquinone (alizarine, madder lake, indathrene, vat colors). 4) Indigoid (Indigo blue and maroons). 5) Phthalocyanine (phthalocyanine green and blue) 6) Basic ( PMA, PTA-PMA and PTA toners and lakes, rhodamine, malachite green, methyl violet, Victoria blue). (Kent, 1983)

Inorganic pigments include the following: all white, some colors, black, extenders, and metallic pigments. The pigment compounds include zinc oxides, barytes, iron oxides, lead and zinc chromates, red lead, chromium oxides, and nickel titanate. Though there is a variety of compounds used in pigments, the most common in the newspaper industry is carbon black, an organic pigment. Carbon black yields the blackest color of the pigments, and has the highest tinting strength and opacity.

The pigment is combined with a vehicle, which usually acts to bind the pigment to the paper. The vehicle contributes properties of glossiness, wear resistance, and drying qualities such as type and speed of drying. Linseed oil in an aliphatic hydrocarbon solvent, is a common vehicle used in lithographic printing. A solvent is used to reduce the viscosity of the ink and then evaporate off after application. In determining the vehicle for lithographic printing the type of press used must be considered. There are sheet-fed and web-fed presses. Web-offset presses operate at higher linear printing speeds and therefore a lower ink tack or "stickiness" should be used.

The resulting waste ink from the printing process will not only contain the ink but also the fountain solution, solvents and other additives. These must be considered in the recycling process. The fountain solution is a slightly acidic water-based solution. Solvents are either hydrocarbon solvents, alcohols, or glycols. Other ingredients may include driers, waxes, anti-oxidants, lubricants, gellants, defoamers and other additives.

# APPENDIX C
## DENSITOMETER TEST DISCUSSION

When considering data from both inks simultaneously, the difference in average densitometer readings between wrapper and core pages was not significantly different from zero (observed difference was -0.0022). However, when observing this difference for the two inks individually, highly significant differences were noted. The difference in average readings between wrapper and core for virgin ink was -0.0677, which was significantly different from zero at the 0.0001 significance level. This stated that the readings averaged significantly higher on the core page than on the wrapper page when virgin ink was used. In contrast, the difference in average readings between wrapper and core for recycled ink was 0.0633. This difference was also significantly different from zero at the 0.0001 significance level, but in the opposite direction from what was observed with the virgin ink. Thus the readings averaged significantly higher on the wrapper page than on the core page when recycled ink was used. These conclusions indicate that the type of ink must be considered when comparing densitometer readings for the two page types.

A similar difference in conclusions was observed between printed pages when comparing densitometer readings between the two inks. The difference in average readings between virgin ink and recycled ink was -0.1044 for the wrapper page, which was significantly different from zero at the 0.0001 significance level. This result stated that readings for virgin ink averaged significantly lower then for recycled ink on the wrapper page. In contrast, the difference in averages was 0.0267 for core page readings, stating that virgin ink averaged higher than recycled ink on the core page. This difference was significantly different from zero only at the 0.0654 significance level. The distinct results between wrapper and core page implies that overall conclusions on densitometer readings between the two inks cannot be made without considering the type of printed page.

The effect on densitometer readings of location on the page was also included in the analysis of various procedure. However, this effect was not statistically significant.

Thus, in summary, densitometer readings were significantly higher for recycled ink than for virgin ink on the wrapper page. The readings averaged slightly higher for virgin ink than for recycled ink on the core page, but this difference was only marginally significant.

Likewise, the readings were significantly different between the wrapper and the core page, but the difference depended on the ink used. Significantly higher readings were noted on the wrapper page when using recycled ink, while significantly higher readings were noted on the core page when using virgin ink. These findings indicate that statistical conclusions on differences in densitometer readings between inks cannot be made without considering whether the printed page is wrapper or core.

APPENDIX D

The Hartford Courant
Ink Recycling System Operating Cost Estimate

| item | volts | phase | amps | hours per batch | kwh per batch |
|---|---|---|---|---|---|
| skid mixer | 460 | 3 | 1.8 | 50 | 60.9 |
| ink pump | 460 | 3 | 1.6 | 2 | 2.2 |
| water pump | 208 | 3 | 1.8 | 1 | 0.6 |
| vacuum pump | 460 | 3 | 2.8 | 50 | 94.8 |
| blend tank pump | 460 | 3 | 6.5 | 50 | 220.1 |
| blend tank mixer | 460 | 3 | 4.5 | 25 | 76.2 |
| day tank pump | 460 | 3 | 6.8 | 50 | 230.3 |
| chiller | | | | | |
| compressor | 460 | 3 | 6.2 | 37.5 | 157.5 |
| fan motor | 230 | 1 | 2.9 | 50 | 28.3 |
| coolant pump | 460 | 3 | 2.2 | 50 | 74.5 |
| | | | | total | 945.3 |

electrical cost per batch at $0.08 per kwh = $75.62

gas cost per batch 45 ccf per batch
at $0.66 per ccf = $29.70

utility cost per batch $105.32

P. J. Reynolds 8/16/91