Integrated Oil Recycling System for the HP Indigo Liquid Electrophotographic Printing Press

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Abstract:

Liquid Electrophotographic (LEP) printing systems utilize color pigments, binders and other additives suspended in a non-polar liquid as the printing ink. The print process requires periodic addition of "Imaging Oil" that is a blend of the non-polar liquid combined with specific additives that enhance printing performance. The non-polar liquid is a long-chain hydrocarbon and must be contained appropriately. Accordingly, the HP Indigo print system design includes a vapor recovery system that captures the vaporized liquid inherent in the image formation process minimizing fugitive emissions. Past HP Indigo printing press designs collect this by-product of printing in waste containers that are ultimately discarded appropriately. The collected oily waste and replacement liquid materials impacts cost of printing, waste disposal expenses, and user convenience. This paper discusses the implementation of an integrated oil recycling system that separates water from the captured liquid, introduces specific additives, and reintroduces the internally reconstituted "Imaging Oil" into the print process for reuse.

Introduction:

The HP Indigo Liquid Electrophotographic Printing Presses use a relatively low pressure, non-polar hydrocarbon as the liquid carrier for the ink particles that form the photographic quality, printed image. Subsequent removal of this liquid from the press interior environment results in the accumulation of used oil that past HP Indigo products have collected as oily waste byproducts requiring appropriate disposal. The objective of the integrated oil recycling system design is to systematically reclaim and purify the recovered oil, replace specific, required additives and return the reconstituted oil to the press for reuse. The system significantly reduces both oil consumption of the printing process and oily waste. Figure 1 illustrates the recycling system assembly which includes a series of liquid containing chambers (translucent in the diagram), level indicators and a mixing pump whose functions will be described in more detail.

Theory of Operation:

During printing, each color separation of the image is transferred to a transfer blanket similar to offset printing. The portion of liquid carrier which transfers to the blanket along with the ink particles is evaporated by heating the blanket surface to approximately 100°C and is subsequently removed by high speed airflow. This airflow carries the oil vapor through a water cooled condenser and collection chamber.

The oil and water laden air condensed by the water cooled heat exchanger collects in a drip tray below the condenser. The condensate gravity feeds through a tube into the oil/water separation chamber of the oil recycling system assembly illustrated above.

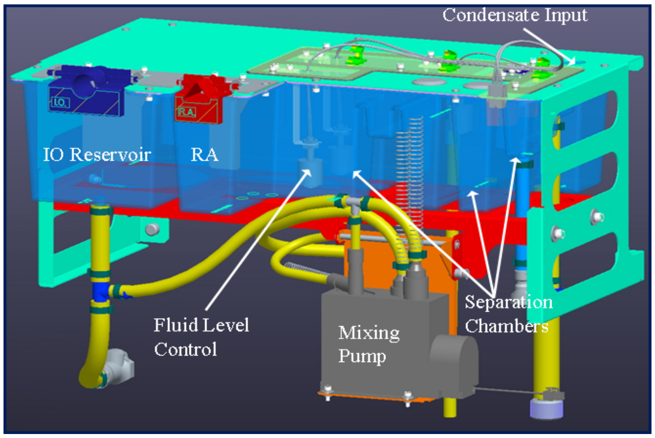

Figure 1 *– Oil Recycling System Assembly*

Separation of the oil from water and particulate contaminates is strictly passive and relies on the differences in mass density and immiscibility of the liquids and solids. The schematic diagram in figure 2 illustrates the fundamental gravimetric properties utilized to provide the necessary purification of the reclaimed oil that is to be recycled in the printing process.

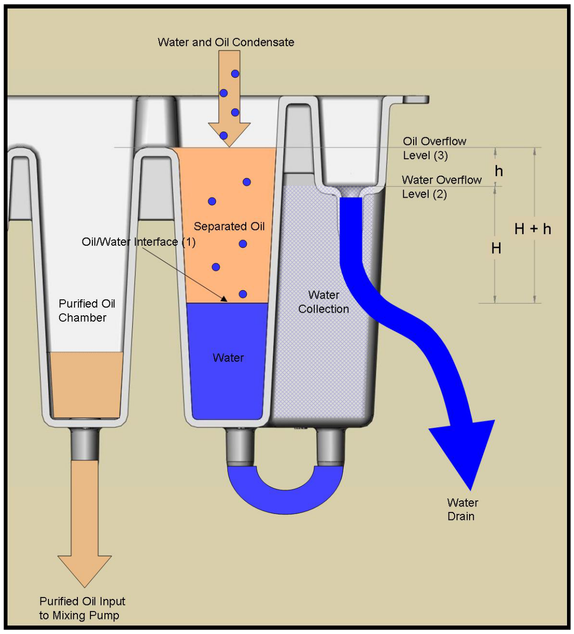

Figure 2 *– Schematic illustrating theoretical basis for the Oil/Water Separator with key relative dimensions*

Water, having higher mass density than oil, flows to the bottom of the separator chamber. The oil/water interface height (1) relative to the water overflow height (2) and the oil overflow height (3) in the separator chamber, schematically illustrated in figure 2, is related by the following mathematical expression:

$$\mathbf{(h + H) * Density_{OIL} = H * Density_{WATER}}$$

For the oil used in the HP Indigo Presses, $h \cong H/3$. Accordingly, the oil overflow channel is designed to be approximately 4/3 times the distance H to allow sufficient “head” to force the water to overflow into its collection container.

Description of Oil Recycling System:

The oil recycling assembly includes a system of chambers that passively separate the condensed material into water and oil as described. Additional chambers are provided to store the special concentrated Oil Recycling Agent and the reconstituted imaging oil, as well as to enable removal of water from the system as it is accumulated. Overflow chambers and drains are contained in additional chambers.

Figure 3 is a schematic of the oil recycling system with key features identified for reference. The following chambers are identified:

(1) Separator – collects oil/water condensate

(2) Separated Oil – purified oil that overflows from the separator chamber

(3) Water – purified water moves from base of separator to this chamber which then overflows from a predetermined height [identified by (2), figure 2]

(4) Recycling Additive – storage for additives that are blended with recycled oil

(5) Mixing pump – positive displacement pump that combine the Recycling Additive with the recycled oil

(6) Overflow chamber – excess material flows into this chamber as waste

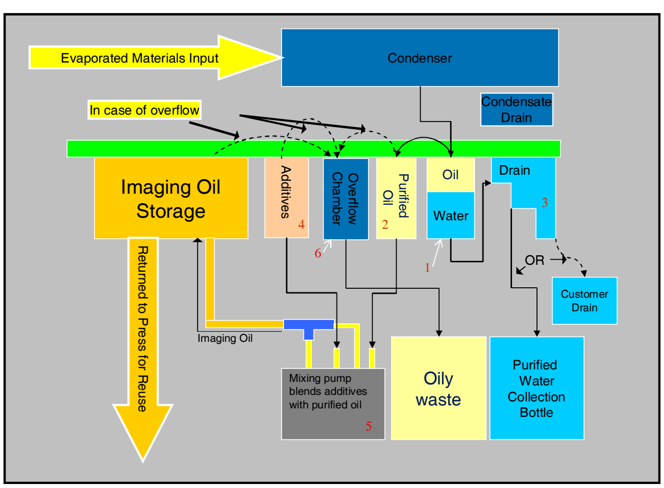

***Figure 3** – Schematic of Oil Recycling System*

The condensed oil, water and a minute quantity of solid contaminates drain from the Press condenser catch-tray into the separator chamber. The oil accumulates in the separator chamber above the water layer. Once sufficient volume accumulates, the high purity oil layer overflows into an adjacent chamber through a small, centrally located opening. The base of the separation chamber is connected to an adjacent chamber by a hose attachment fastened to its bottom. This hose allows the distilled water to move into an adjacent water collection chamber with a hose attachment at its base as well. This water collection chamber has an overflow wall that limits the water to a constant level. Once water accumulates to this predetermined level, the water overflows into another chamber that allows drainage to a collection container.

The minute quantity of solid contaminates that flow into the oil recycling system accumulate at the oil surface, oil/water interface or the bottom of the containers. Ridges surround each outlet preventing solids that fall to the container bottoms from flowing to the mixing pump or the water container. The solids accumulating at the oil/water interface or oil surface remain harmlessly at that interface for millions of impressions.

Fluid levels in the oil collection chamber are monitored and once a predetermined level is attained, a precise, positive displacement pump with two input ports is activated to pump and simultaneous mix the recycling additive and the purified oil.

To optimize accumulation of recycling additive in the inks and oils within the process, the additive concentrations were measured as a function of the printed page coverage. From this information a semi-empirical model was developed that characterized accumulation for a range of printing requirements. This enabled an optimal formulation of the special recycling agent to maintain the additive benefits yet prevent unwanted accumulation.

System Design Performance Summary:

The HP Indigo printing press oil usage and disposal requirement as a function of A4 page coverage was experimentally quantified. Figure 4 presents a summary of the empirical results for HP’s past Digital Press products contrasted with the HP5500, HP7000, and future products that contain the integrated oil recycling system (IORS).

In Figure 4, the blue line indicates the performance of the Press containing the integrated oil recycling system whereas the red line represents the past products. The solid lines indicate the oil added to the Press as required maintaining ink levels. The dashed lines indicate excess oil that is discarded as oily waste.

For many commercial print jobs, pages that contain 15% to 20% of ink coverage per impression or color is typical for many customers. For the common 4-color printed page, this coverage corresponds to 60% to 80% of the page covered with ink. Focusing on this print coverage range, note that products containing the IORS have little need for oil to be added during printing. In contrast, past products did require a significant need for added oil as shown. With recycling implemented, the quantity of excess oil that must be discarded is reduced by a factor>4.

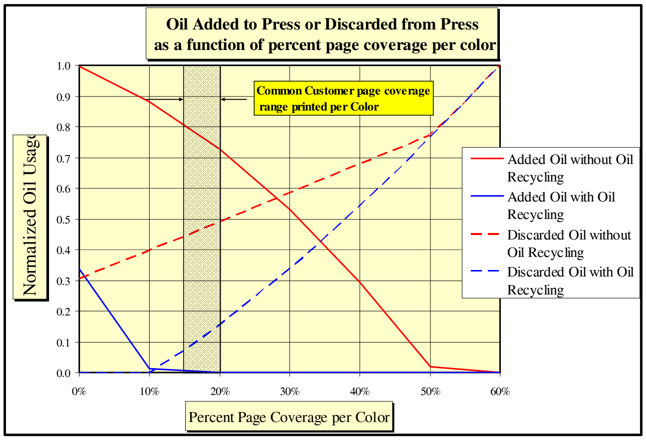

***Figure 4** – Oil Added and Waste per A4 Page*

Complimenting the characterization testing, extensive print tests and chemical analyses were completed over a period of months (~2.5 million impressions) to demonstrate the consistency of internally reconstituted "Imaging Oil" formulation and ensuring the resulting oil/water separation purity consistently met the specifications. The chemical analyses confirmed that the recovered, separated solvent was >99.5% pure. This is well within the purity requirements for the manufacturing of "Imaging Oil." The collected, distilled water was analyzed and confirmed to be chemically equivalent in purity as commercially available distilled water and, consequently, could be safely disposed into a municipal water drain without incurring disposal costs for our customers.

Conclusions:

The Integrated Oil Recycling System is a major improvement in liquid carrier containment for the HP Indigo printing process. The IORS is currently included in HP5500 and HP7000 Digital Printing Presses. In addition, the oil recycling function will be incorporated in all future HP Indigo Press designs. HP remains strongly committed to continue active research into new and better ways to minimize the environmental impact of all our printing technologies.

Author Biography:

John A. Thompson is a Master Engineer at Hewlett Packard Company. He has worked in the field of Electrophotography for 35 years including HP and IBM in both dry powder and liquid electrophotographic copying and printing systems. He also worked as a Mechanical Design Engineer for Texas Instruments and McDonnell Aircraft. He earned his B.S.M.E. from the University of Arkansas with graduate work in Engineering Mechanics and Electrical Engineering at the University of Texas Austin and the University of Kentucky, respectively.