Print Technology Analysis

Laser versus direct thermal Rx document printing for high volume pharmaceutical (HVP) fulfillment centers

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List of Figures

2-1: Direct thermal printing
4-1: Pre-printed advertising

A2-1: Printhead wear versus dot line overcoat hardness
A3-1: Laser Printer maintenance kit
A5-1: Maverick Multi-pack system

List of Tables

ES-1: Total effective HVP Rx fulfillment center printer operating cost
ES-2: Daily production delay probability index
2-1: Laser printer published cost performance comparisons
2-2: Rated retail operating cost per page
2-3: Total hardware cost per page – maintenance kits plus printer replacement
2-4: Effective toner yield at 20% coverage
2-5: Total consumables cost per page
2-6: Effective printer price performance summary
2-7: Output speed per five page print job
2-8: Effective print speed example

3-1: Prescription filling center workflow example
3-2: Typical labor cost
3-3: Daily impact of packing and printing delays on productivity and cost
3-4: Automated high volume Rx fulfillment facility benchmarks

Appendix Tables

A1: Labor rate
A2: Daily Rx productivity benchmarks
A3: Service & handling (S&H) cost and down time
A4: S&H totals
A5: Total consumables cost per page – same as Table 2-5
A6: Effective print speed based on benchmark
A7: Effective operating cost/page – same as Table ES-1

Table of Contents

Section 1 - Executive summary

Section 2 – Printer cost/performance
- 2.1. Data communications and first print out delays
- 2.2. Printer Maintenance
- 2.3. Cut sheet feed versus continuous roll feed printing
- 2.4. Cut sheet finishing options
- 2.5. Bar code readability
- 2.6. Document security & automated error detection

Section 3 – Rx fulfillment workflow performance
- 3.1. Manual Rx fulfillment
- 3.2. Paper configuration options
- 3.3. Automated Rx document printing

Section 4 – Summarized findings and recommendations

Appendix:
- A1. Data tables
- A2. Thermal printhead and platen life
- A3. Laser printer functionality and maintenance
- A4. Bar code printing
  - A4.1 Resolution versus addressability
- A5. Automated Rx fulfillment
- A6. About the author

Section 1 – Executive summary

This report benchmarks the usage of laser printers versus thermal printers in high volume pharmacy (HVP) Rx fulfillment centers. Its intended audience is pharmacy fulfillment center directors and IT managers interested in evaluating document printing technologies The two printers selected for this comparison are the Kyocera 95309DN laser printer and the PDC Thermal Rx printer. The Kyocera printer was selected based on its price/performance competitiveness compared with other suitable laser printers (Table 2-1). This report compares the two printers and printing technologies in the context of HVP document and labeling requirements. Therefore all comparisons are based on HVP Rx fulfillment application volumes.

All printer manufacturers specify speeds and feeds. However, most printers rarely achieve continuous operation at maximum speeds and feeds over prolonged periods of operation in demanding environments. When this is achieved, it is usually due to some level of application and data flow optimization tailored to that environment. Note that media and media supply optimization are also key ingredients in specialized production printing applications.

In comparing supplies cost, maintenance kit (MK) cost and published print speed, the laser printer has the edge. However, in production printing applications it is continuous throughput that counts. To evaluate continuous throughput in a production environment, many other factors must be considered. Issues such as first print out delays, data communication delays, paper loading time, jam frequencies and printer MTBF negatively impact the overall daily print speed or printer productivity, referred to in this report as "Effective Print Speed". When measuring productivity based on effective print speed, the thermal printer outperforms the sheet fed laser printer. The only remedy for the laser printer's lower effective print speed is the addition of more printers to maintain the daily throughput requirements of high volume pharmaceutical fulfillment centers. When you factor in the need for multiple laser printers per unit thermal printer, together with the first print and paper handling issues with laser printers, the thermal printer delivers a lower "effective cost per page". For these reasons the thermal printer offers compelling productivity benefits for moderate to high volume Rx fulfillment center requirements. Table 1 exemplifies the effective cost per page of both printers, based on a 30,000 script per day HVP issuance facility that averages five (5) pages per script.

Effective Operating Cost Per Page (cpp)					
Printer Type	Consumables cost/page (cpp)	Hardware cpp	S&H Cost/Page	Printer cpp/day	Effective Cost/Page
Thermal printer	$0.02240	$0.00242	$0.00003	$0.00242	$0.02728
Laser printer	$0.02480	$0.00217	$0.00101	$0.01085	$0.03883

Table ES-1: Total effective HVP Rx fulfillment center printer operating cost

A major consideration in the evaluation performed by this report is the contrast between the cut sheet fed paper configuration utilized by laser printers and the continuous roll feed or box fed fan fold paper supply utilized by thermal printers. Continuous feed printers need less frequent media re-loads and are considerably less susceptible to paper jams. Further, the "single consumable" nature of direct thermal printing, whereby the ink is contained within the surface coating of the paper, eliminates the possibility that the printer can run out of ink before it runs out of paper. The fact that direct thermal printers eliminate the need for a separate ink supply dramatically reduces the mechanical complexity of thermal printers as compared to all other digital printing methodologies. Mechanical simplicity relates directly to increased reliability. This fact, together with the quality and readability consistency delivered by thermal printers accounts for their continued dominance of the on-demand bar code printing market as well as other mission-critical applications such as POS printing and data recording.

Table ES-2 below estimates the maximum relative probability of daily production delays using each print technique.

Occurrences per Day	Daily likelihood probability Index	
	Thermal Printer	Laser Printer
Multiple paper loads/day	1	5
Paper jams per day	1	4
Toner Replacement/Day	N/A	3
Average Probability Factor	**1**	**4**

Table ES-2: Daily production delay probability index
Scale: 1 = 20%; 2=40%; 3=60%; 4=80%; 5=100%

In terms of raw consumables costs laser printers have the advantage. One component is a $0.01 per sheet difference in paper cost, Table 2-2. Note that this edge would be eroded if the laser sheets were pre-perforated for half page or quarter page folds, as is commonplace with thermal paper. Another prime factor in the consumables comparison is that laser toner cartridge yield is based on 5% coverage per page. By definition, thermal paper price per page yields 100% coverage, if needed. To rationalize this difference based on the target usage a 20% yield reduction was factored into the toner price per page used in Table ES-1. Section 2 further details the consumables cost build-up comparison.

Thermal printers, in fact the entire thermal printing industry supply chain, has been built up around providing optimal printing and media solutions for specialized applications. Application optimized, continuous feed thermal printers can deliver needed productivity advancements in the HVP Rx fulfillment document printing and labeling marketplace.

Section 2 – Printer cost/performance analysis

The scope of this report is to provide an analysis of the use of sheet fed laser printers versus continuous roll feed direct thermal printers for use in high volume Rx fulfillment centers. As a starting point for this report, a survey of production volume desktop laser printers was conducted to identify a suitable laser printer alternative to the PDC Thermal Rx printer. The Kyocera 9530 DN was selected based on overall price/performance comparison with other comparable laser printers utilized in this application. Table 2-1 compares the Kyocera 9530 DN with two other printers used in this application environment.

Category	Printer Make & Model		
	Kyocera FS 3830 N	Kyocera F9530 DN	Lexmark T654 DN
Price	$300.00	$4,850.00	$1,837.00
Speed in pages per minute)ppm)	33	51	53
First Print Out Delay (seconds)	11.5	3.5	7.5
Paper supply per draw (# of sheets)	100	500	550
Pages per maintenance kit (ppmk)	300,000	500,000	300,000
Max duty cycle – pages/month (ppm)	120,000	300,000	275,000
Maintenance kit cost	$556.00	$749.00	$493.00
Pages per toner cartridge	10,000	40,000	25,000
Toner cartridge price	$90.00	$132.00	$413.00
Toner cost per page (cpp)	$0.00900	$0.00330	$0.01652
Size(H x D x W)	13.6" X 15.4" X 11.8"	23.6" X 25.4" X 24.2"	17.2' X 24.6" X 20.1"

Table 2-1: Laser printer published cost/performance comparisons

With respect to operating cost comparisons, this report compares a selected offer-the-shelf laser printer with a more specialized thermal printer that has been purpose built for HVP Rx fulfillment center document printing. That said, Tables 2-2 through 2-8 below compare the two printers. Table 2-2, summarizes the rated retail consumables cost per page for both printers including paper, toner and the maintenance kit (MK).

Operating Cost per page (cpp)				
Printer Type	**Paper**	**toner**	**MK**	**Consumables cpp**
Thermal printer	$0.02000	$0.00000	$0.00240	$0.02240
Laser printer	$0.01000	$0.00330	$0.00150	$0.01480

Table 2-2: Rated retail operating cost/page

Based on the rated consumables cost shown in Table 2-2 the laser printer yields a $0.0076 per page cost advantage over the thermal printer. Since daily print volumes at HVP fulfillment centers necessitate running laser printers at or near their maximum duty cycles, the laser printers themselves need more frequent replacement. Table 2-3 calculates printer replacement (MTBF) cost per page (cpp) based on estimated printer replacement frequency, and adds it to the periodic MK cost per page. This yields a total hardware cost per page for the HVP environment. Presuming both printers receive periodic maintenance at rated intervals, each thermal printer will outlast multiple laser printers running at their maximum monthly duty cycle.

	Maximum Duty cycle		MTBF		MTBF cost/page (cpp)		Hardware cpp
Type	**Monthly**	**daily**	**Months**	**Pages**	**Printer cost**	**Cost/page**	**MTBF+MK**
Thermal	3,000,000	100,000	48	144,000,000	$4,795.00	$0.00003	$0.00242
Laser	300,000	10,000	24	7,200,000	$4,850.00	0.00067	$0.00217

Table 2-3: Total hardware cost/page, including maintenance kits (MK) plus total printer replacement (MTBF)

Note: Table 2-2 contains MK cost per page

Rated toner yield in laser printers is based on 5% page coverage whereas thermal paper provides for 100 % coverage. Table 2-4 reduces toner yield by 20% to insure a realistic ink supply comparison in HVP document printing applications.

Toner cost	yield	Coverage	Factor	Effective yield	Effective cpp
$133	40,000	5%	20%	10,000	$0.0133

Table 2-4: Effective toner yield (cpp) at 20% coverage

Please also note that Kyocera printers are different than others in that two key components in the toner transfer process - the photoconductor (drum) and the developer section - are in the printer, not the cartridge. This eliminates the added cost of drums and developer rollers every time you buy cartridges, as is the case with Lexmark and HP printers. This is one of the primary reasons the Kyocera printer was selected as the best laser printer fit for this comparative study. Consequently HVP centers that utilize HP or Lexmark laser printers experience much greater consumables cost than that reported herein. Table 2-1 reveals that toner cost per page is five times greater with the Lexmark T654 DN. This further disadvantages laser printers as compared with thermal printers for HVP Rx fulfillment center document printing.

Table 2-5 totals the consumables cost per page for each printer in an HVP environment, by including the following three components:

1. total hardware cost per page (Hardware cpp) of Table 2-3.
2. rated consumables cost per page of Table 2-2, modified by the toner yield adjustment of Table 2-4.
3. media service and handling (S&H) cost per page, as derived in Appendix A-1 based on a 30,000 script per day, five page per script benchmark requirement.

	Equipment		Consumables			Total
Printer	MTBF	S&H	Paper	Toner	PM kit	
PDC-TimeMed H8308	$0.00242	$0.00003	0.02000	0.00000	0.00240	$0.02485
Kyocera 9530 DN	$0.00217	$0.00101	0.01000	0.01330	0.00150	$0.02798

Table 2-5: Total consumables cost/page

Printer	Price	Cost/page	Print Speed (ppm)		Paper Supply
			Rated	Effective	
PDC-TimeMed 8303	$4795.00	$0.025	44	34	Continuous roll feed Continuous bulk stack z-fold
Kyocera 9530 DN	$4850.00	$0.028	51	20	1200 A size sheets Large tray option – 3000 sheets

Table 2-6: Effective printer price/performance summary

Table 2-6 summarizes the key price/performance metrics for both printers. More frequent media loads, paper jam occurrences and greater first print and job data delays significantly reduce the effective print speed of the laser printer as compared with the thermal printer. Consumables and printer cost aside, this means two or more laser printers are needed per thermal printer, based on typical production volumes in HVP fulfillment centers. Appendix A1 contains the data derivation tables that support the summary data presented in Tables 2-1 through 2-8.

2.1 Data communications and first print out delays

With respect to speed, laser printers typically have a first page out delay per print job relating to the image formation and fixing time within the printer. The Kyocera 9530DN, at 3.5 seconds, has one of the lowest first-page-out delays among comparable laser printers as shown in Table 2-1. Tables 2-7 and 2-8 demonstrate the effect of first print out delay on output speed per job. The smaller the job in terms of page count, the lower the effective job output speed.

Printer Type	Print speed	Warm-up time	First print delay	Time/5 page job	Output speed
	ppm	seconds			ppm
Thermal Printer	8.00	0	0	37.50	8.00
Laser printer	9.35	60.0	3.5	35.59	8.43

Table 2-7: Output speed per five page print job

Adding to first page out delay is the data latency time between data transmission and printing. Laser printers are page printers. Thus, their entire data flow architecture is centered on page and job printing. Depending on the printer architecture, operating system environment and, in particular, print driver design, some amount of initial delay between data transmission and the start of printing is not uncommon with laser printers. Page by page spooling versus job spooling is one of several architecture choices that affects data delays. In office environments such delays go unnoticed, but in production environments, where print speeds and paper handling are synced with manual or automated packaging operations, such delays can limit production and raise costs. Table 2-8 exemplifies the degree to which the combination of first-page-out delay and data latency delay can reduce the effective print speed (actual document throughput speed) of an otherwise fast printer.

Printer type	Print speed	Print time/page	Delay/5-page job	Effective print speed
	ppm	seconds		ppm
Thermal Printer	8.00	7.5	2	6.32
Laser printer	9.35	6.4	10	4.00

Table 2-8: Effective print speed example

Effective print speed reveals the degree to which delays per print job can limit daily throughput using off-the-shelf laser printers. Thermal printers are typically purpose-built continuous feed printers. As such the dataflow architecture and print drivers are typically designed to spool data continuously through the printer, at or faster than the inherent dot line or page printing speed of the thermal printer, thus ensuring minimal datacomm delay.

Their technical complexity notwithstanding, laser printers could also be purpose built or configured to optimize data flow in continuous batch flow environments. However the need to fully develop a latent image on a drum that transfers it to paper, is, by definition a discrete, cut sheet printing methodology. Further, the low cost of laser printers results directly from their optimization around the high volume office automation market for which standard page and sheet sizes prevail. It is simply not practical or cost effective in most instances to build special purpose laser printers.

2.2 Printer maintenance

With respect to preventative maintenance, periodic replacement of the maintenance kit (MK) is essential to continued operation of a laser printer. In thermal printers, printhead or platen replacement is rarely essential to continued printer operation. Rather, such replacement is typically done in the interest of maintaining the highest level of print quality. The preventative maintenance kit (PM) cost specified in Table 2-2 is based on replacing the printhead and platen in the thermal printer every three million linear inches. This is conservative rating as opposed to the best-case rating typically utilized for laser printers. Appendix A2 discusses options by which thermal printhead and platen life can be extended.

The present level of laser printer reliability is a tribute to their decades of refinement around office document printing. Much of this reliability stems from planned replacement of key wear items, either as part of the toner cartridge, part of the maintenance kit or both. For more detail on the functionality contained in laser printer toner cartridges and/or maintenance kits, consult Appendix A3.

Thermal printers can offer inherently more reliability due their comparative mechanical simplicity, lack of a separate ink supply and continuous paper feed system (Figure 2-1). Cut sheet fed laser printers are more complex and susceptible to occasional paper jams. Down time for any reason is a cost factor in production environments.

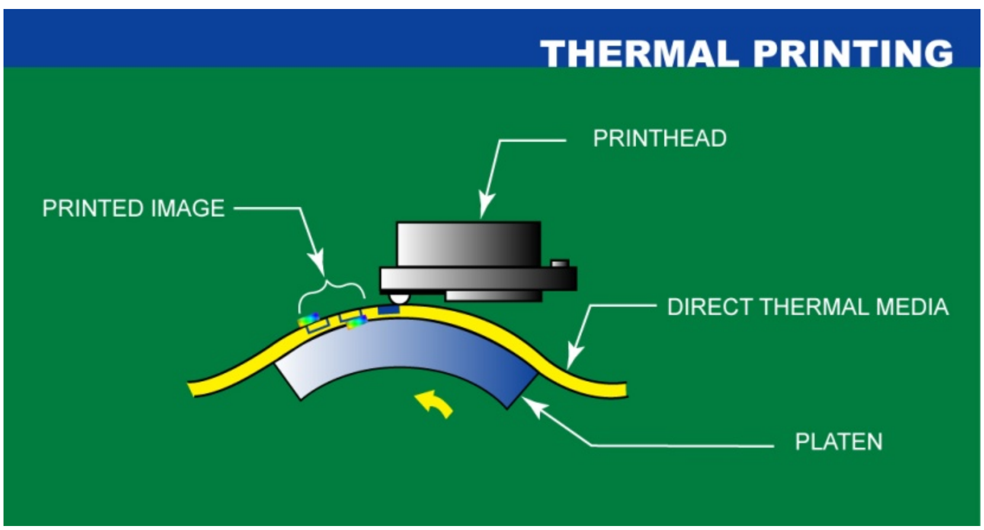

Figure 2-1: Direct Thermal Printing

2.3 Cut sheet page feed versus continuous roll feed printing

Speeds and feeds notwithstanding, the use of cut sheet printers versus continuous roll feed printers poses significantly different workflow considerations. The use of laser printers in real time workflow applications typically requires special purpose sheets forms or labels, designed specifically for a given application. Small format office labels, for example, are typically sized and die-cut to fit within a standard 8.5” x 11” (A-size) backing page which functions as the release liner. For batch printing of multiple-up labels at one time, this poses no problem as the variable data flow from label to label is handled by the software, the print driver, or both. In applications such as patient or event admissions or retail over-the-counter pharmaceutical sales, only one or two labels at a time may be needed.

Making effective use of multi-part forms in these instances typically requires that an A-size cut sheet of labels be loaded repeatedly into the printer until all labels per sheet are utilized. Since integer relationships between the number of labels per cut sheet and real time issuance requirements are unlikely, this usage problem is further complicated. For this reason, dedicated workflows using cut sheet laser printers typically demand special purpose forms. Such forms are typically designed to travel with an item or asset in a sales or manufacturing quality assurance application, or with a person in an admission or entitlement processing application. To be cost effective, "process traveler" forms often combine die-cut, peel off labels for real time dispensing with tear-away transaction receipts together with process or usage instructions that require perforation or folding. Since such forms must account for all variables within a given process, they are often only partially utilized by a given single instance of the process. Given their high converting, pre-printing and procurement cost, many procedures become slaved to specialized procedure forms once such forms are in widespread use and distribution for a given application.

In summary, the choice of cut sheet, page size forms printing versus continuous feed thermal paper fundamentally impacts real time process and transaction procedures. Ultimately, the nature of a given process, together with the IT/middleware infrastructure, will determine transaction or process document configuration choices. In hospital admissions and patient tracking applications for example, the choice between multiple-up A/A4 forms versus dedicated, one-document-at-a-time thermal printed forms depends often on the volume of patients handled, the types of printers on hand, and the installed base of middleware and enterprise-wide patient tracking software.

For optimal efficiency in highly distributed, real time workflows, dedicated direct thermal printers that provide one-up waste free label or document printing offer compelling advantages:

- elimination of most, if not all, of the need for costly multi-part forms
- one-up, waste-free dispensing for over-the counter transactions
- single consumable simplicity and efficiency (the ink is in the paper itself)
- ultimate, instant start, mission critical reliability
- secure process: fixed form and personalization data printed at point-of-issuance
- compatibility with automatic label applicators and packaging equipment

Virtually all POS receipts, continuous charts and graphs and package shipping labels are produced using direct thermal technology. For harsh manufacturing, distribution and Rx fulfillment environments, no other print technology offers the combination of instant start reliability, bar code readability and consumables simplicity offered by direct thermal printing. Examples include hand held, hip mounted or gas pump resident receipt printers, airborne or ruggedized military and industrial printers, real time physiological chart recording and event monitoring and package delivery shipping label printing.

2.4 Cut sheet finishing options

Production quality cut sheet laser printers, such as the Kyocera 9530DN selected for this benchmark analysis, offer a wide range of finishing options:

- duplex printing
- extra large capacity paper trays
- multi-trays to accommodate different supplies
- finishers that punch, staple and bind pages into finished documents and books

Note that these finishing options are aimed at document production and publishing, and not in-line production workflows requiring special purpose printing. Thus they are far better suited to manual rather than automated process and packaging procedures for which continuous feed printing in more inherently adaptable to automation equipment.

2.5 Bar code reliability

Two inherent factors ideally suit thermal printing technology to bar code printing:

- thermal printheads have rectangular printhead dot element geometries
- thermal printing requires direct media contact

Given proper attention to printhead dot temperature management by thermal printer designers and manufacturers, rectangular thermal printhead dot elements, which are in direct paper contact during printing, can reproduce bar code geometries and straight edge acuity with amazing fidelity and print contrast ratios. By virtue of the direct contact nature of thermal printing, concern over the edge acuity imperfections and random ink or toner scatter typically associated with ink jet or laser printers is eliminated. Appendix A4 contains a more detailed comparative assessment of the benefits of thermal bar code printing.

2.6 Document security and automated error reduction

The use of 400, 600 and 1200 dpi printhead resolution enables variable data microprinting. Consider that commercial press microprinting is typically done at 1200 dpi. Appendix A4.1 discusses the differences between resolution and addressability in the context of bar code printing. Given the spatial print fidelity of thermal printing, it is possible to perform useful variable data microprinting at 400 and 600 dpi. Given the high degree of worldwide drug counterfeiting, variable data microprinting can deliver effective overt, covert and even forensic countermeasures, if deployed within a carefully layered, document security architecture.

Incorporation of covert (non eye-visible) ultra violet and infra-red inks and masks can be added to thermal media along with a wide variety of taggants, threads and tracers to build in varying degrees of layered document security. Covert inks can be used to print human eye invisible, machine-readable 1D and 2D bar codes. Eye visible replication of such bar codes on the same label or document can be used to decoy their covert existence without sacrifice of critical eye readable real estate. While many of these features can be added to laser paper, standard printer models cannot be modified to mix covert variable data printing with standard eye readable printing.

The use of covert and overt bar codes also enables their usage for error prevention and validation in automated pharmaceutical packaging and retail drug dispensing applications. Whether a deterrent to fraud or an effective method of error prevention, the combined use of covert inks with high-resolution variable data bar codes and security images are comparatively easily to cost justify. As with most security and automation initiatives, a critical element in their strategic deployment is the availability of covert readers throughout the distribution and supply chain, along with the necessary IT infrastructure. For closed loop applications in high volume Rx fulfillment centers this is more easily managed. In highly distributed environments, every transaction within the supply chain must be equipped and connected for such practices to be effective.

Section 3 – Rx fulfillment workflow performance considerations

In production packaging the degree to which document printing compliments and dovetails with workflow is critical to productivity. The proper documents must be attached to the right Rx package before it can be shipped. Rx errors are costly and can also be dangerous. Cost efficiency and error prevention in high volume pharmacy (HVP) environments such as Central Mail Order Pharmacies (CMOPs), Central Fill facilities, and Mail Order Pharmacies (MOPs) are critical success factors.

Evaluation of suitable print technologies for this target environment quickly centers on whether a given facility utilizes manual or automated Rx packing. As discussed in Section 2, the choice between cut sheet laser printers and continuous feed thermal printers is somewhat less critical in manual packing environments. This is because people collate and insert or attach Rx documents to their respective prescription packages. Notwithstanding this fact, several benefits accrue to using thermal printers in both environments as follows.

3.1 Manual Rx fulfillment

In manual Rx fulfillment operations, print speed must complement or equal the reciprocal of the time required to manual pick, collate and attach or insert the proper document with the proper package to achieve optimal productivity.

Order Page Data & Descriptions	Average Value	Pages/Type
Number of PPO pages per Rx order	5.1	
Page types	Reorder page	1
	Invoice	1
	PPO pages	2
	Address change form	1
Number of Order Form Pages per order	2	
Number of Invoice pages per order	1	
Number of PPI pages per order	1	
Workflow Data & Descriptions		
Number of Prescriptions (Rx) per order	2.1	
Number of orders per packer per hour	100	
Number of pages per hour per packer	510	

Table 3-1: Prescription filling center workflow example

Table 3-2 utilizes the order statistics of Table 3-1 to produce a typical labor cost scenario for a fairly large manual packing line. Presuming the packers are paid hourly rather than piecemeal, the shift productivity shown in Table 3-2 relates directly to the hourly page printing rate.

24 pack filling lines	
Number of packers	24
Pages printed per hour	12,240
Average number of hours/shift	7
Pages printed per shift	88,128
Hourly Labor Rate	$12.00
Overhead Factor (Taxes & benefits	$2.50
Burdened hourly labor rate	$30.00
Daily labor cost/packer	$216.00
Daily labor cost	$5,184.00

Table 3-2: Typical labor cost

Table 3-3 highlights the impact of handling delays at a 30,000 Rx fill per day manual HVP operation, in terms of the number of printers and packing lines needed to offset the delay and the resulting daily cost. Case 1 illustrates the optimum scenario in which the packing time does not exceed the print speed and maximum printer throughput is maintained throughout the shift. Case 2 illustrates the productivity impact of pack time taking one (1) minute longer than the print time per Rx, presuming 5 pages per Rx order. Case 3 illustrates the same impact caused by losing the one (1) minute per job due to reductions in print speed rather than delays in pack time. Case 3 differs from Case 2 inasmuch as additional printers and packing lines are added to compensate for the slowdown.

In practice, 100% productivity is rarely achieved consistently with any process. Thus printing and packing speed variances can be much greater than those exemplified in Figure 3-3. Prudence suggests, therefore, that it is important in actual practice to build in greater print speed margins if the goal is to insure that Rx pack productivity is not gated by printer performance.

	Examples	Order	Shift statistics			Print speed		Printing & packing lines		
Case	Volume	# pages	Rx pack time	Pages/day	pph	ppm	pph	# printers	# pack lines	Daily cost
1	30,000	5	8.63	153,000	21,250	44	2640	8	8	$1,739
2	21,671	5	9.63	110,522	15,350	32	1907	8	8	$1,739
3	30,000	5	8.63	153,000	21,250	32	1907	11	11	$2,407

Table 3-3: Daily impact of packing or printing delays on productivity and cost

3.2 Paper configuration options

By definition cut sheet fed laser printers fit into manual packing operations. Custom micro-perforated cut sheet stacks can be ordered to facilitate quick folding for easy quarter of half page envelope and package insertion or attachment. Another alternative is the utilization of paper folders and bursters typically utilized for mailing insertions.

Continuous feed thermal paper offers benefits in both manual and automated packing operations. Three configurations best-fit manual packing:

1. printers equipped with rotary or guillotine cutters that can cut on demand from continuous feed rolls based on job or document size requirements.
2. pre-perforated rolls of thermal paper facilitate easy separation from the supply roll without the use of cutters, as well as quarter page or half page folding.
3. a bulk (e.g., ten ream) box of pre perforated z-fold paper can be positioned to feed through the printer.

For optimal use of configuration options 2 and 3, the use of top-of-form, pre-printed sense marks enable the printer to find and position the first line of print for each page.

In addition to the specialized converting benefits previously described, the use of a continuous feed paper supply also eliminates the potential for cut sheet paper jams that occur from time to time with laser printers.

3.3 Automated HVP document printing

Table 3-4 illustrates the wide range of production possibilities that could be encountered by a high volume, automated HVP fulfillment center. While it is unlikely that volumes and Rx page counts would combine to produce the high volume benchmark shown in Table 3-4, it nonetheless defines the effect of significant volume increases relative to printing.

Daily volume benchmarks	Low	High
Daily Rx Volume	100,000	130,000
Pages/Rx	3	30
Pages/day	300,000	3,900,000
Pages/hour (pph)	41,667	541,667
Pages/min (ppm)	694	9,028
# of printers	16	205

Table 3-4: Automated, high Volume Rx fulfillment facility benchmarks
(Rx pack times are faster than print times)

Table 3-4 presumes pack times are faster than print times, typically a safe assumption in automated packaging environments. This means printer speed and productivity is the gating factor in maximizing daily throughput.

Section 4 - Summary and recommendations

The expected growth rate for the pharmaceutical label industry suggests increasing future volumes for HVP fulfillment centers. Demographic forces such as an aging population and longer lifespan, combined with fast paced advances in medical science virtually assure steady growth for the pharmaceutical industry itself.

Competition in pharmaceutical labeling is primarily dependent on solutions that reduce cost and increase productivity. This trend suggests steady future growth in the use and adoption of automated packing and delivery systems such as those described in Appendix A5. Purpose built automation systems demand purpose built printing and labeling solutions. This is where thermal printing shines. It is reasonable to conclude that laser printer cost/performance will continue to improve as it has done steadily for more than twenty years.

So, what are the prime criteria in selecting future printing solutions for the HVP Rx fulfillment market?

It is the degree to which future cost/performance benefits that may accrue to laser printers based on the mass market for office automation can compete with more dedicated, purpose-built thermal printers. Cut sheet feed versus continuous roll and/or fan fold box feed constitutes one of the more fundamental print technology differences considered here. If the primary goal is integration with automation equipment, the nature of the automation equipment process and its inherent compatibility with either paper configuration will drive this decision. If the primary goal is delivery of printing and labeling solutions that optimize productivity by consistently delivering the highest effective print speed, thermal printing has a great deal to offer.

Thermal printers are typically purpose built to achieve the operating cost and productivity goals of specialized applications. Thermal media is custom configured and converted to meet specialized, high productivity document and labeling needs. An extensive and mature supply chain of coaters, laminators and converters supports this need. The achievability and environmental resistance of direct thermal papers has improved dramatically over the years. Direct thermal top-coats are now highly application optimized. For example, labels for pharmaceutical and clinical usage are resistant to hand creams such as Purell, as well as other substances that likely exist in the usage environment.. Thermal media can be configured with covert inks and security markers to build layered document security solutions and error prevention mechanisms. Contrary to some claims otherwise, thermal papers are also routinely back-side or front side pre-printed by converters to convey advertising, production promotions or loyalty coupons.

Figure 4-1: Pre-printed advertising example

In summary, based on the massive office automation market it is designed to serve, laser printing typically offers the lowest equipment price and supplies cost and highly competitive preventative maintenance costs. Alternatively, purpose built thermal printers offer closely competitive supplies and preventative maintenance costs combined with inherently better continuous flow printing reliability, repeatability and bar code readability.

With respect to preventative maintenance, it's worth repeating that periodic replacement of the PM kit is essential to continued operation of a laser printer. In thermal printers, printhead or platen replacement is rarely essential to continued printer operation. Rather, such replacements are typically done in the interest of maintaining the highest level of print quality.

As the demands of HVP label and document printing continue to evolve, use of thermal printing enables continued purpose built product optimization and specialization. By definition of their main purpose, the use of laser printers for specialized applications is based on leveraging the price/performance capabilities developed for the office automation market. For applications where off-the-shelf laser printers are a drop in fit, it will be hard to beat. For more specialized application optimization, thermal printing is likely to be the best fit.

Appendix

A1 Data derivation

Tables A1 and A2 provide the benchmark labor and production rates that form the baseline for comparisons in this study. Using these baselines, Table A3 estimates probable daily printer down time due to three factors:

1. paper loading
2. jam clearance
3. ink replacement

Results are summarized in Table A4

Hourly Rate	O/H Factor	Burdened Rate	Rate/Minute
$12.00	$2.50	$30.00	$0.50

Table A1: Labor rate

Scripts per day	Pages/script	Pag4es per day	Daily Shift (Hours)
30,000	5.1	153,000	7

Table A2: Daily Rx production benchmark

Paper loading	Pages/supply	Pages/day	Paper Loads Per Day	Minutes Per Reload	Daily cost per Reload	Reload Cost/Page	Down Time
Thermal printer	16,670	153,000	9	1	$4.59	$0.00003	9
Laser printer	600	153,000	255	1	$127.50	$0.00083	255
Jam Clearance	**Jams per paper load**	**Paper Loads/Day**	**Jams/day**	**Pages/jam**	**Minutes/jam**	**Jam Cost Per Page**	**Down Time**
Thermal printer	0.50%	9	0.05	3,334,000.00	1	$0.00000	0
Laser printer	5.00%	255	12.75	12,000.00	2	$0.00008	26
Toner Refill	**Toner cost**	**Pages/toner cartridge**	**Minutes/ Reload**	**Reloads/Day**	**Daily Cost/Reload**	**Cost/Page/ Reload**	**Down Time**
Thermal Printer	N/A	N/A	N/A	N/A	N/A	$0.00000	N/A
Laser printer	$0.0015	40000	2	4	$3.83	$0.00010	8

Table A3: Service and Handling (S&H) cost and down time calculations

S&H Totals	Down Time cpp	Down Time
Thermal Printer	$0.00003	9
Laser Printer	$0.00101	288

Table A4: S&H Totals

The data contained in Table A4 enables us to compute the total estimated consumables costs (Tables A5 and 2-5) for the benchmark application considered in this report.

	Equipment		Consumables			Total
Printer	**MTBF**	**S&H**	**Paper**	**Toner**	**PM kit**	
Thermal printer	$0.00242	$0.00003	0.02000	0.00000	0.00240	$0.02485
Laser printer	$0.00217	$0.00101	0.01000	0.01330	0.00150	$0.02798

Table A5: Total consumables cost/page – contained in report body as Table 2.5

Table A6 utilizes the down time estimates in table A3 to compute the effective page printing rates per day for each printer. This data leads to the number of printers needed to reach the daily page printing benchmark of 153,000 pages. This leads to a total cost per page per day for each printer type.

Category	Thermal Printer	Laser Printer
$&H Down Time	9	288
Effective Speed	34	20
Pages lost/day	314	5,763
Pages/day/printer	14,688	8,640
Effective pages/day/printer	14,374	2,877
Printers/day/benchmark	1	5
Cost/page/day	**$0.00242**	**$0.01085**

Table A6: Effective print speed based on benchmark

Finally, Tables A7 below and ES-1 summarize the total effective cost per day attributable to each technology in order to hit the 30,000, five page scripts per day productivity benchmark.

Effective Operating Cost Per Page (cpp)					
Printer Type	**Consumables cost/page (cpp)**	**Hardware cpp**	**S&H Cost/Page**	**Printer CPP/day**	**Effective Cost/Page**
Thermal printer	$0.02240	$0.00242	$0.00003	$0.00242	$0.02728
Laser printer	$0.02480	$0.00217	$0.00101	$0.01085	$0.03883

Table A7: Effective operating cost/page – contained in report body as Table ES-1

A2 Thermal printhead and platen life

The use of harder and/or thicker thermal printhead overcoats can extend the usable life of the printhead thereby reducing the preventative maintenance (PM) frequency and lowering the PM cost/page. The use of premium grade thermal papers can also extend usable printhead life. Adopting the use of both premium grade papers and more durable printhead overcoats will deliver the best possible extension of prinrhead life. The economic test here is whether the incremental cost of harder printhead dot line overcoats and/or use of premium grade papers can be justified by the corresponding incremental increase in printhead life.

Figure A2-1 exemplifies the effect of harder thermal printhead dot line overcoats. This graph, from the Kyocera thermal printhead web site, illustrates the relative reduction in abrasive wear as a function of print volume, due to the user of harder glass overcoats. As previously discussed, thermal printing is a direct contact technology. Abrasive wear results from the pressure of direct dot line contact during printing. Manufacturers specify the abrasive wear life of thermal printheads in kilometers (km) of paper printed, based on a specified level of paper smoothness. Once the glass overcoat is fully eroded to the point where dot elements are exposed to air and contaminates they fail. Thus, the harder the overcoat and/or the smoother the paper, the greater the useful life of the printhead in terms of paper kilometers or pages printed.

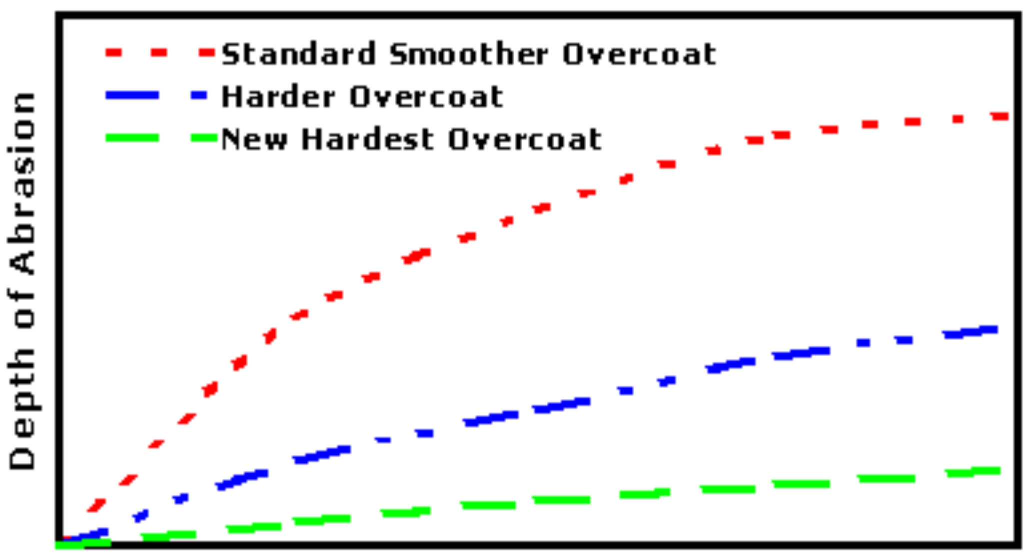

Figure A2-1: Kyocera thermal printhead overcoat wear versus print volume (km)

A3 Laser printer functionality and maintenance

Figure A5-1 below illustrates a typical maintenance kit. Typically, laser printer maintenance kit contains paper pickup rollers, paper feed/separation rollers, a transfer roller, and the fuser assembly.

Figure A3-1: Lexmark T654 DM maintenance kit

A brief description of the key functional parts of laser printers that need periodic replacement as a part of the toner cartridge or maintenance kit is as follows.

Drum

The drum is a photosensitive barrel typically made of aluminum. It attracts electrically charged toner as it turns and is sensitive to damage. In many cases the drum is routinely replaced as part of the toner cartridge. In some instances it is part of the maintenance kit

Paper Pickup or feed/separation roller:

Used to pickup and feed the paper and subject to mechanical wear and oxidation. The rubber compound used to manufacture these critical to paper pick and feed performance and need to be replaced based on usage frequency.

Transfer Roller:

The transfer roller is a black/gray sponge-like roller that runs the width of the paper path. It is positioned just below the toner cartridge. During the printing process, this roller is electrically charged and as the paper passes between this roller and the drum in the toner cartridge, the toner from the drum is transferred to the paper. It is subject to mechanical wear and degradation of its ability to hold a uniform charge. It also accumulates paper dust and can be contaminated with finger oils if touched. Therefore it needs frequent replacement based on usage frequency

Fuser Assembly:

This assembly uses heat and pressure to "fuse" or melt the toner into the fibers of the paper. Because of the heat and pressure this assembly is subject to mechanical wear. The heating element is also subject to electrical failure. The plastic gears also degrade over time and continuous exposure to the high temperatures and eventually fail.

A4 Bar code printing

It should be noted that the latest laser and ink jet printers combine high print resolutions with sophisticated spatial ink scatter control to significantly reduce this problem. That said, rectangular thermal printhead dot elements in direct contact with thermal media can accurately and repeatedly reproduce high fidelity bar codes with consistently excellent contrast ratios. This capability, combined with the inherent reliability and productivity of thermal printers, is the reason thermal printing remains the dominant on-demand bar code printing technology after more than three decades of on-demand bar code printing.

On-demand pharmaceutical label and document printing is increasingly reliant on the use of higher spatial density linear bar codes and newer two-dimensional bar code formats such as Datamatrix. The use of small format pharmaceutical labels and forms increases the value of document real estate. This trend demands usage of bar code geometries that deliver higher spatial data densities and plays directly to the aforementioned strengths of thermal printing. The traditional 200 and 300 dpi resolution printheads found in most thermal bar code printers can accommodate these geometries. For ultimate precision and resolution, use of 200 and 300 dpi thermal printheads can be replaced by 400, 600 and even 1200 dpi thermal printheads in new purpose built printers.

A4.1 Resolution versus addressability

To put thermal printhead resolution in the proper context, the distinction between addressability and resolution is worthy of mention. Note that laser and ink printers typically advertise 600 and 1200 dpi resolution. Resolution implies the ability to print a dot or line whose spatial size or width is the reciprocal of the stated resolution. Addressability refers to the spatial positioning of that dot or line within a document. Ink jet and laser printers typically deploy higher resolution printheads than that required for document addressability to enable the use of multiple dot firings that carefully tailor character and line detail. While this benefit also accrues to thermal printers, it is of much less importance in achieving good edge acuity. For this reason, thermal printers offer comparatively high print quality with lower printhead resolutions. A one dot per pixel print relationship is viable and repeatable with thermal printers. This is not always the case with laser and ink jet printers.

A5 Automated Rx fulfillment

Continuous feed printers are usually required for use with in line packaging equipment. In this case the added converting cost of perforating and top of form sense mark printing can be avoided by feeding the continuous roll feed output of a thermal printer into in-line folders, cutters and bursters that prepare the associated document for insertion or attachment to the Rx order.

Commercially available automated packaging systems are capable of delivering 500 to 800 Rx orders per hour. Equipment suppliers typically offer a modular approach to maximize their system adaptability to specific workflows:

- Multi-level envelope and coupon insertion
- Multi-point tote and product validation
- Literature 1/2 & 1/4 fold print and insert systems
- Safety cap insertion
- In-line weigh and manifesting
- Automatic postal sortation

Consider the five-page per Rx order benchmark utilized in this report. Running five-page orders on an automated packaging system at 500 Rx orders per hour requires 2500 pages printed per hour, or 42 pages per minute. Since this falls within the rated print speed of the thermal printer, it suggests that one PDC direct thermal printer could meet this level of throughput if interfaced directly to such a system.

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Figure A5-1: Automatic packing system

A6 About the author

An industry expert in electronic printing and document security, Harold Schofield was President, CEO and founder of Atlantek Incorporated, prior to selling the company to Zebra Technologies. Atlantek pioneered the transition from photographic to digital photo ID card printing, becoming the leading supplier of photo ID card printers and card media solutions for driver licenses. Other Atlantek products included digital photo printers sold to Eastman Kodak, ruggedized plotters sold into oil and gas industry, military, utility and newspaper proofing applications, specialized OEM bar code printers and digital media test equipment. Atlantek's ASTM approved thermal sensitometry testers remain the standard of the thermal paper industry. Atlantek was noted for many product innovations on behalf of major multi-national corporations including Hewlett-Packard, Dupont, Datacard, Polaroid, ICI, Avery Paxar and Eastman Kodak. Atlantek served on AAMVA's (American Association of Motor Vehicle Administrators) Industry Advisory Board for many years and was a leading contributor to AAMVA's published Recommended Best Practice Guidelines for driver licenses.

Formerly Design Engineering Manager at Gulton Industries, Mr. Schofield pioneered many early product and technology advances in thermal printing. He holds a BSEE degree from University of Massachusetts at Dartmouth and was involved for several years in the development of air traffic control systems technology at MIT Lincoln Laboratory. Mr. Schofield assisted the US Secret Service in creating the Document Security Alliance of which Atlantek was a founding member. Mr. Schofield is a frequent speaker at industry conferences and author of many articles and white papers on digital printing and document security. Mr. Schofield retired as VP and General Manager of Zebra-Atlantek, founding Schofield Imaging Associates (SIA) to pursue independent consulting and new business development interests. Mr. Schofield may be reached at SIA via email at hschofield@cox.net or by phone 401-783-7316.