WHICH PRINTING MARKET SECTIONS MIGHT BE THREATENED BY NEW PRINTING TECHNOLOGIES ?

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1. Main Market Sections and their main Technologies

Printing Technologies		Market Sections
	heliogravure	newspapers
	flexo	
	letterpress	magazines
	litho offset	
		periodicals
web		
		commercial advertisement
	litho offset	catalogs
sheetfed	letterpress	
		books
	silk screen	
		packaging
		forms
small offset		
	litho offset	patents
instant printing		
		newsletters
		manuals
		circulations
Corporate Electronic Publishing		proceedings
		scripts
Desktop Publishing		
	IP, NIP	hand outs
Computer Printing		
		manuscripts
Typewriter Printing		
		single issues

I.) Conventional Printing Technologies
consist of five repeatable steps:

Original	Process	Replica
manuscript	photosetting	film
original	scanning	film
film	mounting	film
film	exposure	plate
printing machine with durable plates	printing	print on any paper with high density and high resolution and in color

They are threatened by...

II.) New Printing Technologies
(supposed to be cheaper and faster)

manuscript	typing	memory (e.g. disk, tape)
original	digitizing	memory
memory	computing	memory
computer + printer electronic printing form	toner / ink jet / thermo } printing	copy on special paper with good density and low resolution

The main advantages and disadvantages of both types of printing technologies are obvious. Fig.1 shows the simulation of both kinds of printing technologies.

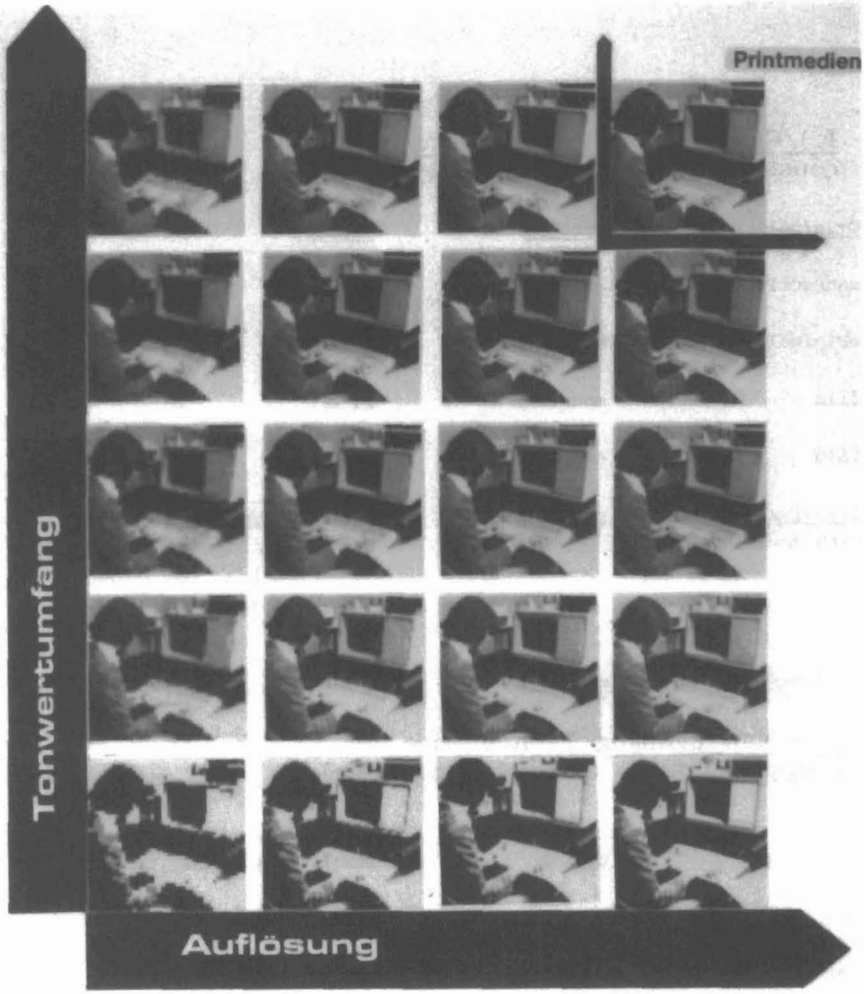


Fig.1 Courtesy of VTT

Images with different resolutions (horizontal) and different gray scale levels (vertical). Higher technologies are able to show lower ones, not vice versa.

THREAT

From the technological point of view, can a coarse measure for threatening be found?

Experience shows that threat is inversely porportional to run length and information content

$$\text{threat} \sim \frac{1}{R_l \times I_c}$$

R_l = run length
I_c = information content

The higher the run length of a job and the higher the information content, the lower the possibility of market sections to be captured by low printing technologies

or, in other words, a Technology Indicator T_I can be defined.

Technology Indicator $T_I \sim R_l \times I_c$
(Run lenghth x Information content)

$$T_I = f \cdot (R_l \times I_c)$$

f = factor or function for not yet known parameters and to trim the dimensions, usually = 1

If T_I is higher than i.e. $10^7 \ldots 10^8$, then conventional printing technologies are asked for

and

if T_I is lower than 10^7, then new printing technologies might be more economical.

Nominal R_l = sheets in number of letter $\hat{=}$ A4 size is a common base
I_c = bit per square inch

Information Content

The Information Scientists defined Information Content as follows:

> A numerical measure of the information generated in selecting a specific symbol (or message) equal to the negative of the logarithm of the probability of the symbol (or message) selected. Also known as negentropy.

$$H = \sum_{i=1}^{N} p_i \, \mathrm{ld} \, \frac{1}{p_i}$$

N = number of possible information in a repertoire
p = probability or frequency of appearance
ld = logarithm dualis

We assume for printed image a probability of Gaussian distribution. Then the information content simplifies to

$$H_{max} = N \cdot ld\ Z$$

N = number of pixels of an image

Z = number of distinguishable events,
i.e. Z = 2 if a pixel is either black or white, otherwise the number of grey steps.

Fig.2 gives a practical example. (Courtesy /1/)

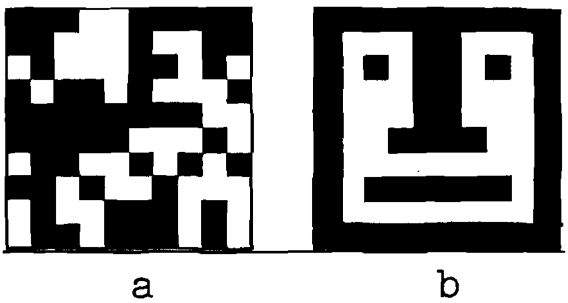


Fig. 2 Images of same maximal information content

Both pictures a and b consist of the same information content. They both consist of 10 x 10 = 100 pixels or 100 bits.

The maximal $I_c = 100 \cdot ld\ 2 = 100$ bit $= ld\ 2^{100}$ because $2^{100} = 10^{30}$ different binary pictures are possible. Two of them are shown here.

If the information content of a print is the same as of the original then the quotient q of both equals to one. In other words, the quotient q is a good measure for print quality. /2/

The information content should not be mixed up with let's say the intellectual information content. An example for two different intellectual information contents of even one single information content shows Fig.3 (Courtesy /1/ F.Bartlett)

Fig. 3
2 different intellectual information contents

Either you recognize a young lady with a feather and a necklace or an old toothless woman with a headscarf, but not both at the same time.

To calculate the information content of prints of new and conventional printing technologies seems to be rather easy.

The number of pixel N per inch are almost the same in new and conventional printing technologies, namely:

120 dpi $\hat{=}$	50 lines/cm	news paper
150 dpi $\hat{=}$	60 lines/cm	commercial printing
200 dpi $\hat{=}$	80 lines/cm	
300 dpi $\hat{\approx}$	120 lines/cm	

The big difference, which some people sometimes forget to mention is the number of Z. Z = 2 for new printing technologies, because one pixel has only 2 possibilities, either black or white.

The interesting question is what value has Z for conventional technologies, i.e. how many gray steps do we have? Some /3/ mean $64 = 2^6$ are enough, others mean $256 = 2^8$ are common.

Considering 200 dpi i.e. 80 l/cm screen and one sqi

for 64 gray levels $I_c = 200 \cdot 200 \cdot \mathrm{ld}\, 2^6$ per sqi

$= 240$ k bit/sqi $\hat{\approx}$ 37 k bit/cm^2

and for 256 gray levels $I_c = 200 \cdot 200 \cdot \mathrm{ld}\, 2^8$ per sqi

$I_c = 320$ k bit/sqi $\hat{\approx}$ 50 k bit/cm^2

in new technologies $I_c = 200 \cdot 200 \cdot \mathrm{ld}\, 2$

with 2 "gray" levels $I_c = 40$ k bit/sqi $\hat{\approx}$ 6 k bit/cm^2

compared with 8...80 k bit/cm^2 for computer disks.

Another way to calculate the amount of Z is the following. Conventional scanners digitize a conventional dot by joining let's assume 12.5µm pixels together to a dot. A square inch of printed paper may consist again of 200x200 dots. Each square dot has a length of 1/200 inch ≈127µm. A full dot square therefore consists of roughly 10x10 = 100 pixels i.e. 100 gray steps are possible.

Fig. 4 shows how many gray steps are possible with a given light beam diameter (horizontal) for different screen rules (vertical)

beam diameter (µm)		170	127	85	44	22	10	7
corresponds to resolution (L/cm)		60	80	118	227	455	1024	1400
" " " (dpi)		150	200	300	577	1155	2600	3555
for a screen rule of								
dpi	L/cm							
50	20	9	16	34	128	517	2621	4900
100	40	2	4	8	32	129	655	1225
150	60	1	1	3	14	57	291	544
resolution	limit of eye							
200	80	-	-	2	8	32	163	306
300	118	-	-	1	3	14	95	140
		Laserprinter New Technology			Scanner + Typesetter Conventional Technology			

Fig.4 Number of possible gray scale levels depending on screen rule and beam diameter

$$\text{Number of possible gray steps} = \frac{\text{Scannerresolution (L/cm)}}{\text{Screenrule (L/cm)}}$$

All those printed matters which need more than 10...30 gray levels are not threatened by new technologies.

How many gray levels do we really need?

Hradetzky /4/ mentioned in his thesis that density variations of

$$\Delta D = \pm\ 0.02 \text{ (in black and white!)}$$

can be just recognized. If we print a solid density of 1.5 then $\Delta D = 0.02$ corresponds to 75 different recognizable gray levels. If we print 1.8 then 90 gray levels are recognizable, for black and white work.

For fourcolor work we may need much more gray levels. Some research is going on in different places of the world.

Therefore we may conclude, that top printed work, which needs at least 60 gray steps can not at all be threatened by new printing technologies, especially good color work.

So far the technological point of view, the information content, which depends on the achievable degree of gray levels.

What about run length, the economical point of view? Where has the borderline to be found between conventional and new technologies? Let's dare a trial.

The following comparison of costs is calculated under the following preconditions:

1) Image to be reproduced is available as

complete paste up	or as	image on monitor
printing foil		
offset print		toner print
with high density many gray levels on any paper		with good density few gray levels on special plain paper

2) Printing foil image is produced with a hired copier. Quality is therefore comparable with toner printer. The cost per produced foil is DM 0,25.

3) costs for paper, operator, energy, housing } are excluded because of being comparable

4) costs for maintenance
consumables (ink, toner, rubber blanket, drum, etc.)
capital costs
are included because of being different.

5) Machine respective system will be depreciated in 8 resp. 5 years although a machine lasts much longer than a system. It actually means that resale prices differ considerably. With other words the following calculated break even point favours the toner printing system.

Costs of Copies and Break-Even Point for Run Length

The costs per single page printed in a duplicator under the above mentioned conditions can be calculated by

$$cc = \frac{pc}{10} + \frac{P(p + 1/d) + M}{2{,}4 \cdot JD \cdot SJ} + \frac{100\,F}{SJ}$$

The costs per single page printed in a toner printer can be determined by

$$cc = \frac{pc}{10} + \frac{P(p + 1/d) + M}{2{,}4 \cdot CD}$$

where

cc = cost per copy in cents
pc = generalized printing costs per thousand in Dollar
F = cost of printing foil (or plate) in Dollar
SJ = average number of sheets per job
JD = number of jobs daily
P = price of machine in Dollar
d = linear depreciation in years
p = interest
M = cost of maintenance p.a.

Instead of SJ and JD the amount of daily copies (CD) can be put in, respectively the twentieth of the volume of a month.

It seems to be rather difficult to compare costs of both technologies. A duplicator needs a foil (F) or plate and runs a number of sheets per job (SJ) and so many jobs per day (JD). A toner equipment delivers a certain amount of copies (CD) per day. But equipment prices (P), capital costs by interest (p) and depreciation (d) can easily be compared for toner printers, copiers or litho offset duplicators.

Consumables, except paper are introduced by the term pc. It is a generalized average value for printing 1000 copies. Examples of costs are shown in Fig.5 - 7 In order to determine a threat by costs a break-even point can be calculated between a duplicator with foil costs (F) and on the other side a toner system. Underneath this break-even point, because of a too short run length, the conventional printing technologies might be threatened by new ones.

The break-even point can be determined by the following formula:

$$BEP = \frac{10}{p} \left(100\, F - \frac{1}{JD} \cdot \frac{\Delta MF}{2,4}\right)$$

where

$$\Delta MF = MF_2 - MF_1$$

and

$$MF = P(p + 1/d) + M$$

$$\Delta p = pc_2 - pc_1$$

An example is given by Fig. 8 and 9.

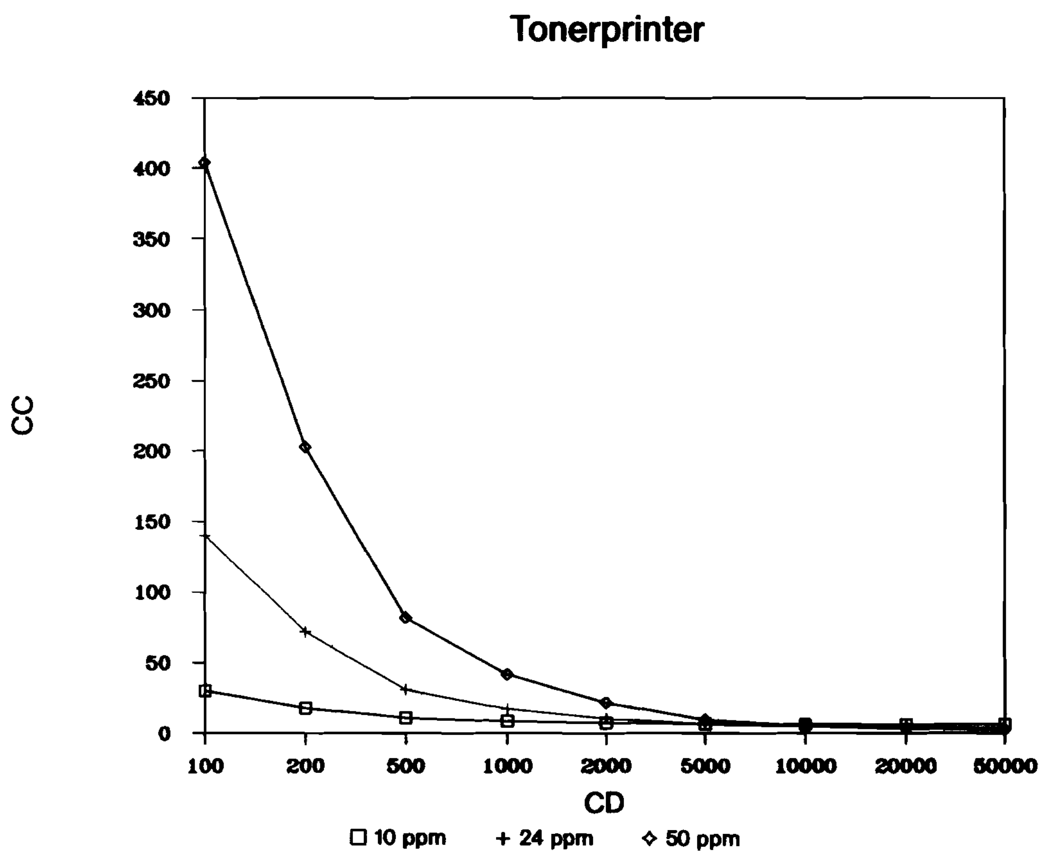

Tonerprinter
450
400
350
300
250
200
150
100
50
0
CC
100
200
500
1000
2000
5000
10000
20000
50000
CD
□ 10 ppm
+ 24 ppm
◇ 50 ppm

Figure 5

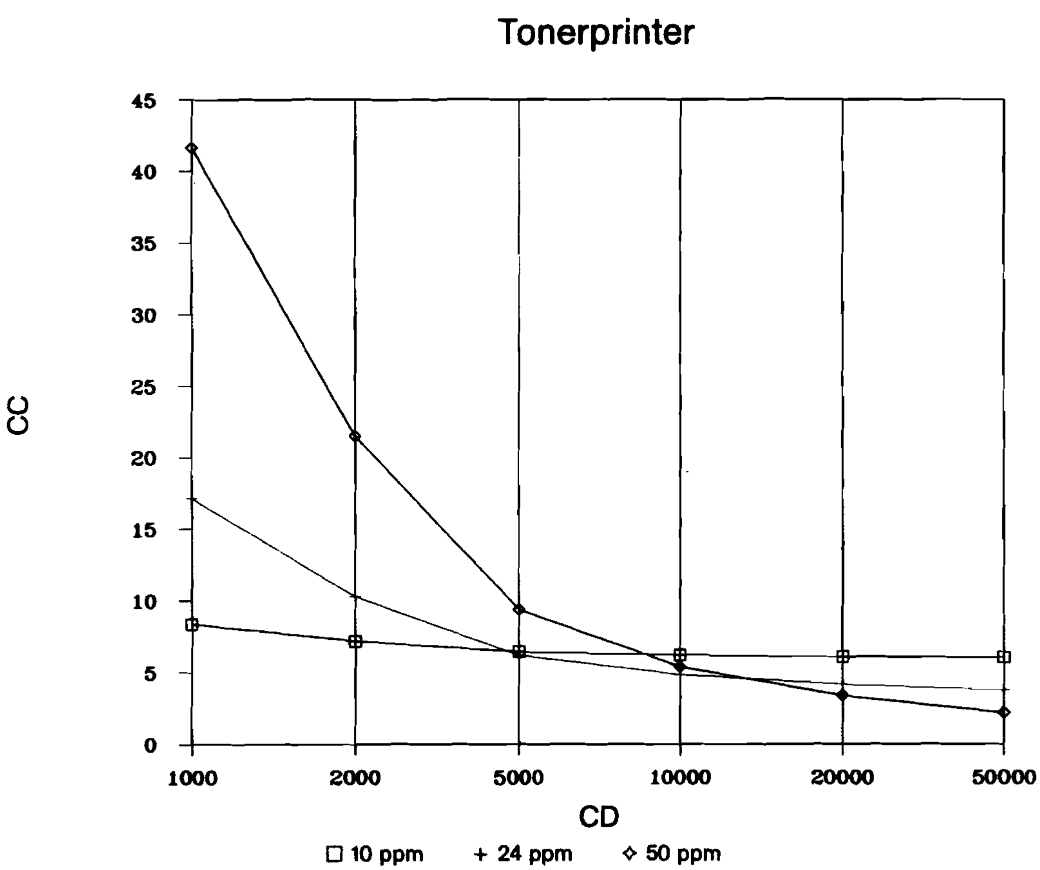

Tonerprinter
45
40
35
30
25
20
15
10
5
0
CC
1000
2000
5000
10000
20000
50000
CD
□ 10 ppm
+ 24 ppm
◇ 50 ppm

Figure 6

Blattkosten in DPf für Duplicator

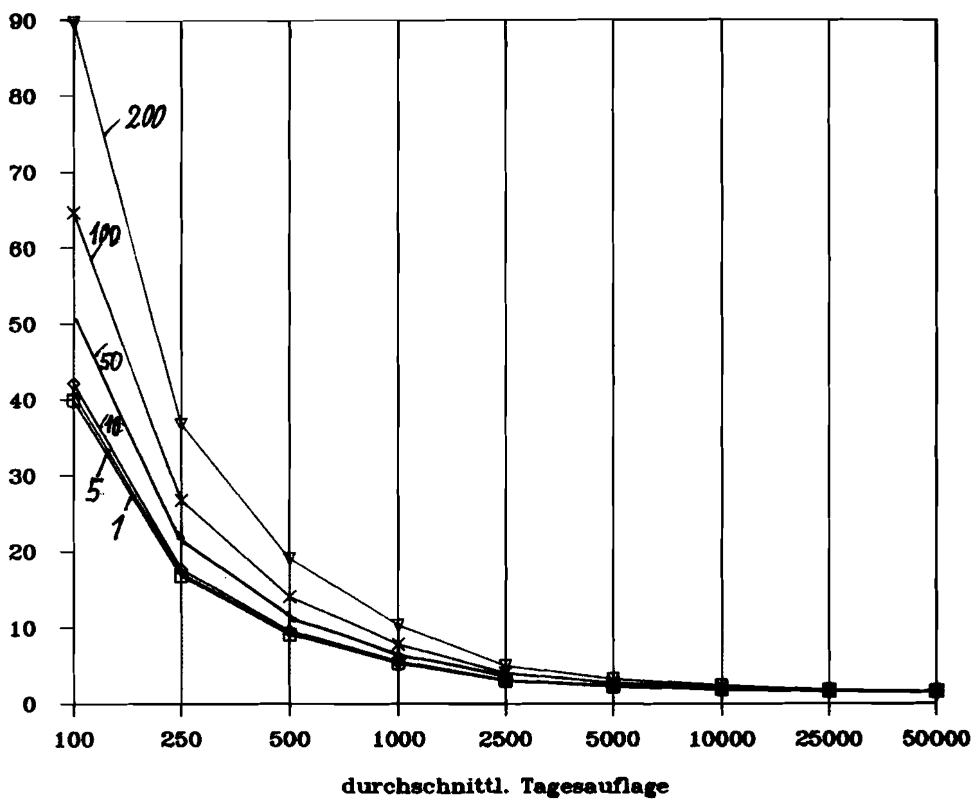


Figure 7

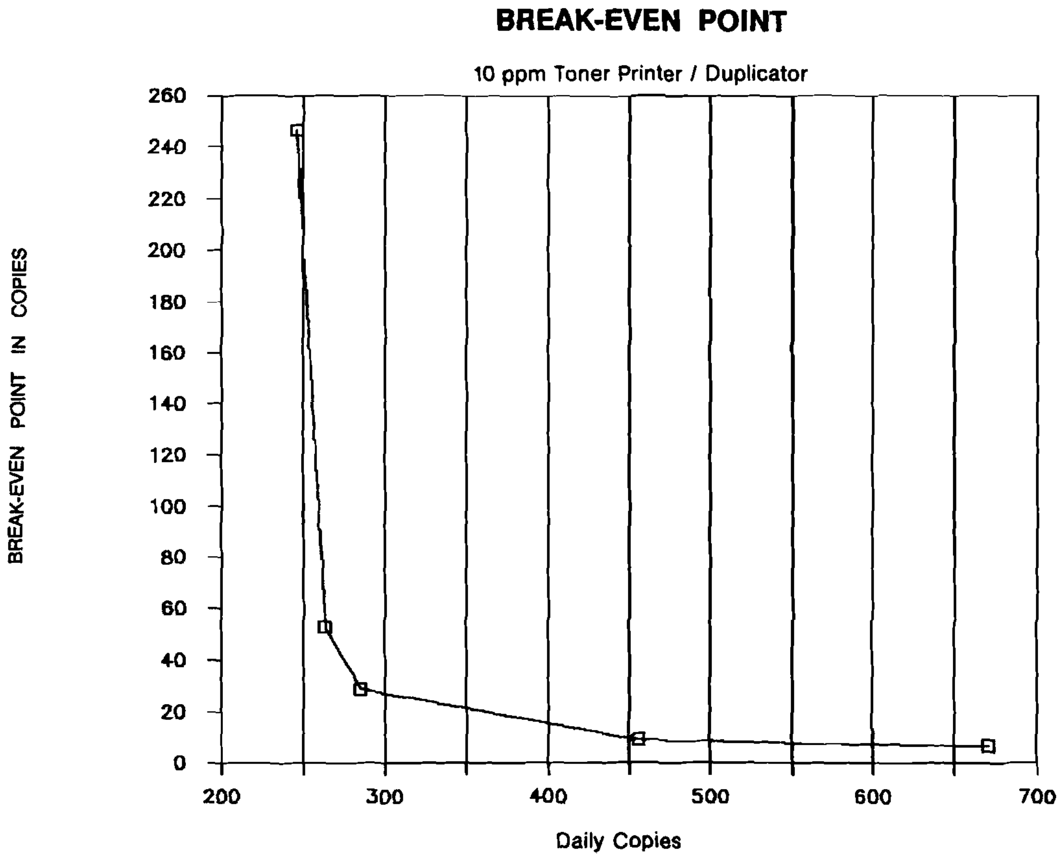

BREAK-EVEN POINT
10 ppm Toner Printer / Duplicator
BREAK-EVEN POINT IN COPIES
260
240
220
200
180
160
140
120
100
80
60
40
20
0
200
300
400
500
600
700
Daily Copies

Figure 8

BREAK-EVEN POINT

24 ppm Toner Printer / Duplicator

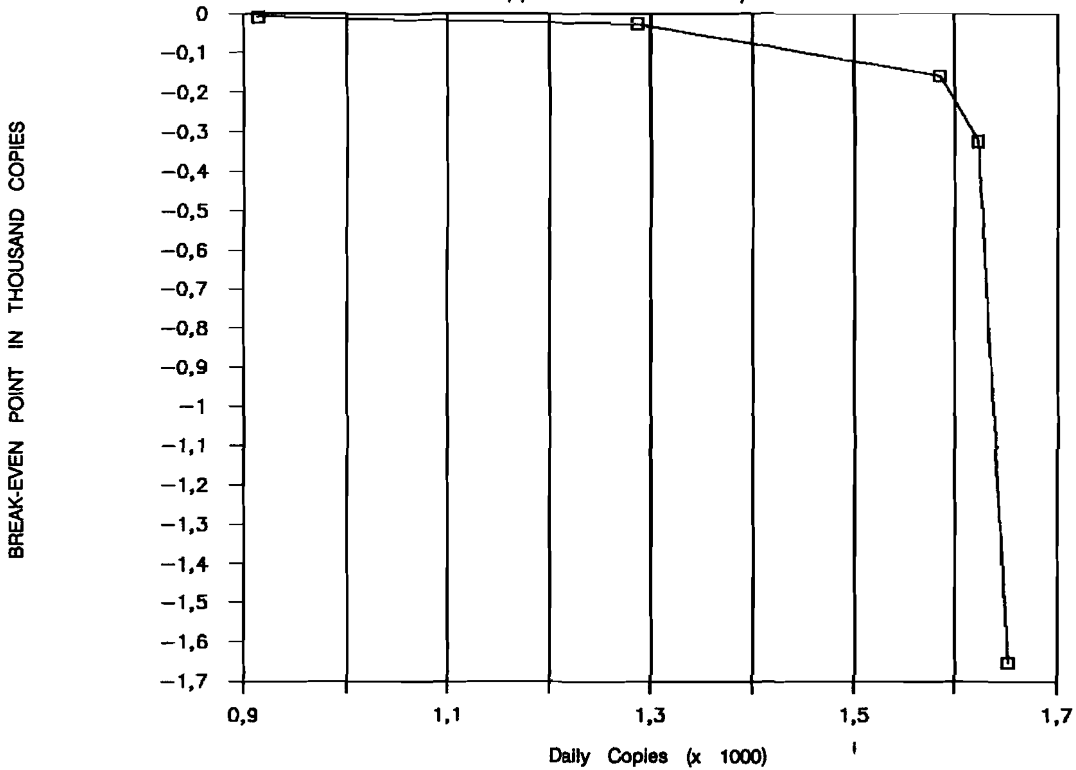
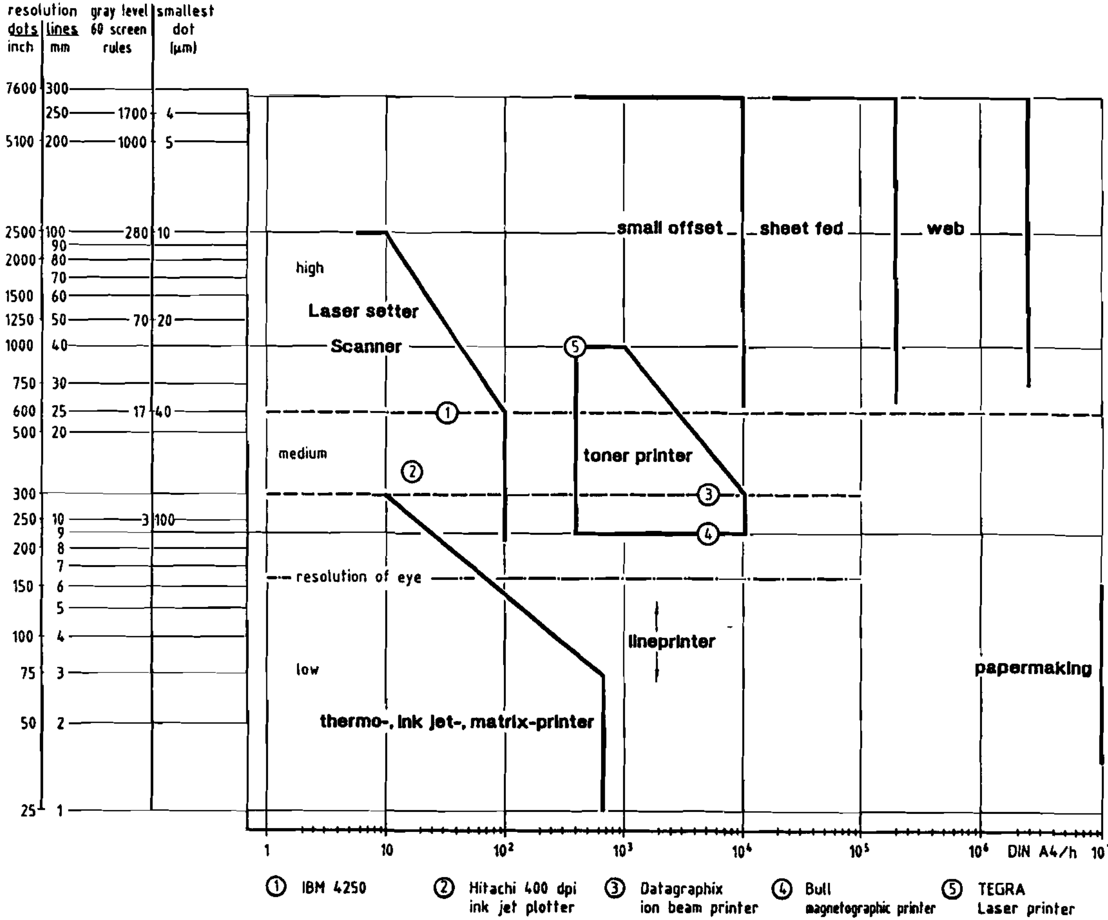


Figure 9



resolution
dots/inch
lines/mm
gray level 60 screen rules
smallest dot (µm)
7600
300
250
1700
4
5100
200
1000
5
2500
100
280
10
90
2000
80
70
1500
60
1250
50
70
20
1000
40
750
30
600
25
17
40
500
20
300
250
10
3
100
9
200
8
7
150
6
5
100
4
75
3
50
2
25
1
small offset
sheet fed
web
high
Laser setter
Scanner
medium
toner printer
resolution of eye
lineprinter
low
papermaking
thermo-, ink jet-, matrix-printer
1
10
10²
10³
10⁴
10⁵
10⁶
DIN A4/h
10⁷
① IBM 4250
② Hitachi 400 dpi ink jet plotter
③ Datagraphix ion beam printer
④ Bull magnetographic printer
⑤ TEGRA Laser printer

Figure 10

References

/1/ Karl Steinbuch, Kommunikationstechnik, Springer-Verlag 1977

/2/ Wolf & Scheuter, Beitrag zur Systemtheorie der Druckverfahren, Institutsbericht 2/70, Institut für Druckmaschinen und Druckverfahren der Technischen Hochschule Darmstadt, F.R.Germany

/3/ Schneider, J. (FOGRA-Institut), Informationsdichte in Produkten, Referat auf dem VFG/GLV IARIGAI-Symposium "Unkonventionelle Druckverfahren", Wien, 26.-28.11.1986

/4/ Hradetzky, Objektive Qualitätsbeurteilung von Druckprodukten und Möglichkeiten zur analytischen Behandlung von Reproduktions- und Druckprozessen mit Hilfe der Informationstheorie. Dissertation 1977 Technische Hochschule Darmstadt

Figures