GRAVURE CYLINDER
3D DIGITAL MANUFACTURING
Feasibility Study

El-Gal Engineering LTD

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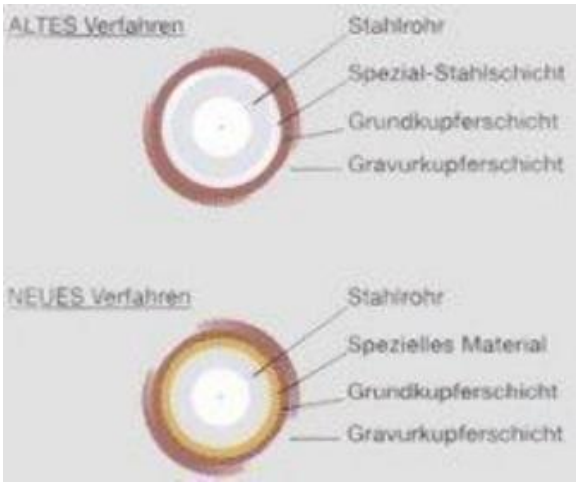
Gravure Cylinder. Construction

- Construction
  - Stain steel body
  - Copper (or Silver, or Nickel) under layer 2-5micron
  - Copper work layer 80-120 micron
  - Chrome work-protective layer 2-4 micron



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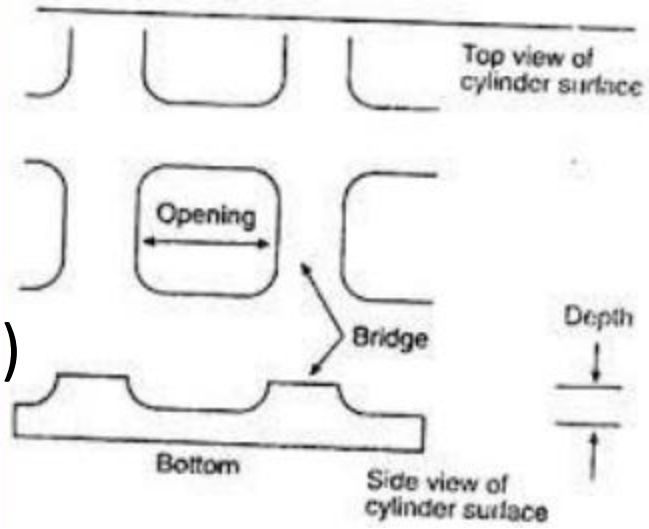
Gravure Cylinder. Construction

- Printing elements
  - Depth 4-60 micron
  - Shape – rectangular –
  - Profile – trapeze (chemical) or pyramided (mechanical engraving)
  - Basic line /sell size relation from 1:3-1:5 up to 1:10
  - Screen
    - Unified LPI 150-175 with different angles Y&M=45*, C30*, Bk15*
    - Unified angle 45* with different LPI C&M= 175, Y= 150, Bk=200



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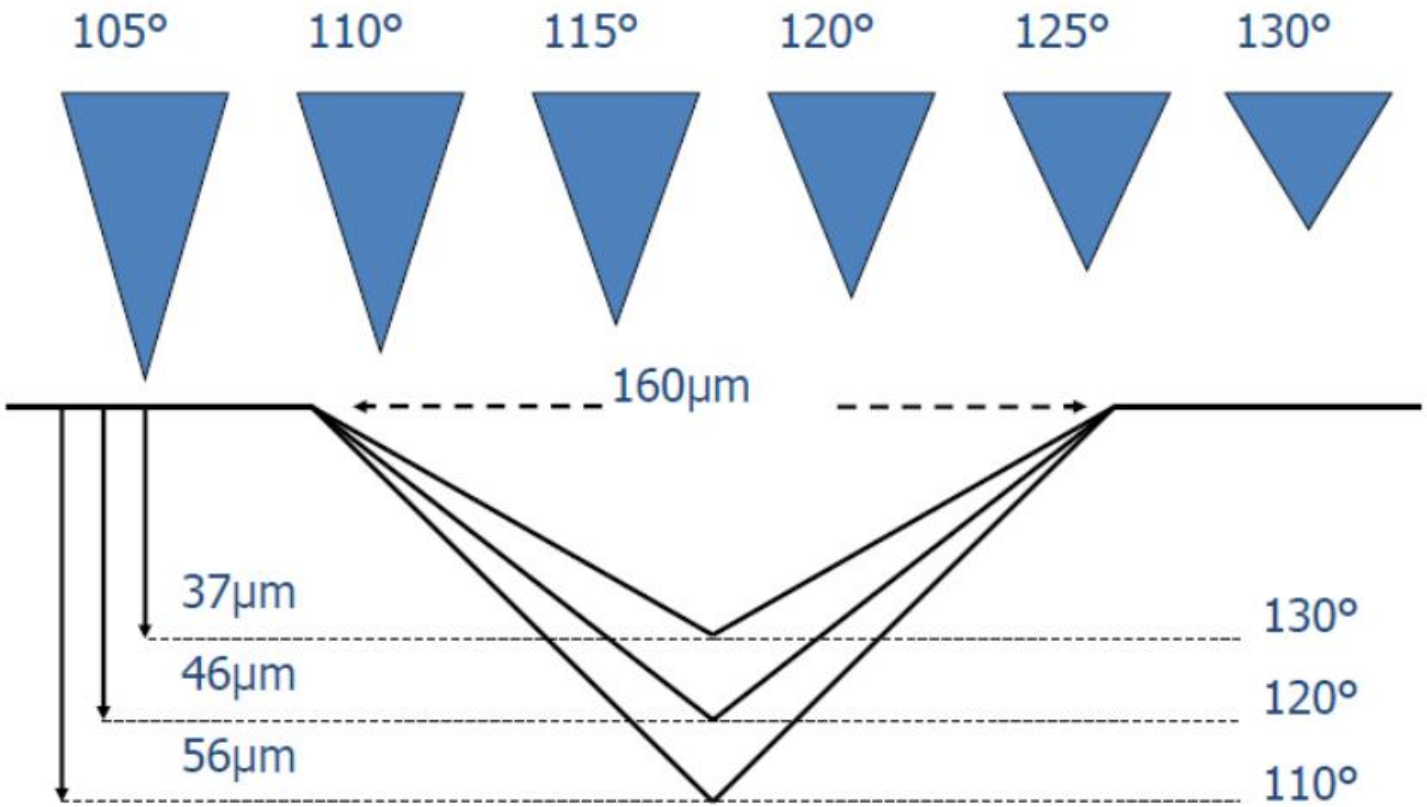
Gravure Cylinder. Cell Depth

The steeper the stylus angle, the greater the depth.

(Illustration based on same size cell opening.)



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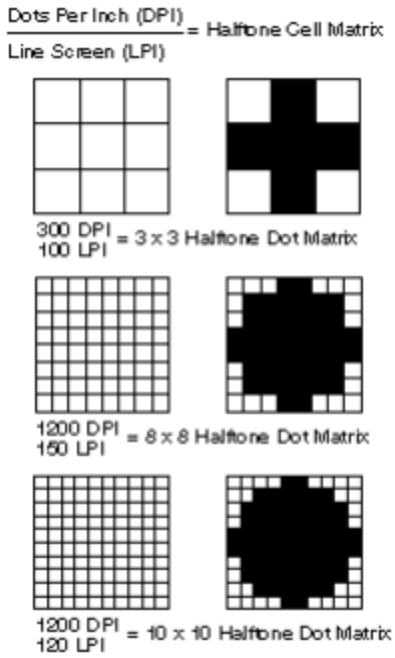
Gravure Cylinder. Cell Shape

- Printing resolution
  - LPI 175=68LCM
  - Pitch 145 micron
- Dot cell creation resolution
  - DPI resolution

DPI	Dot/mm	Pitch, micron	Usage
175	6.89	145.0	Gravure printing
360	14.17	70.6	Technical inkjet
720	28.35	35.3	Middle range inkjet
1200	47.24	21.2	High quality inkjet
1440	56.69	17.6	High quality inkjet
2400	94.49	10.6	Laser writing
3000	118.11	8.5	Laser writing



Halftone Cell Matrix

Halftone required level - at least 64-100 therefore needed

- matrix 8x8 => min matrix spot size 145/8=18 micron

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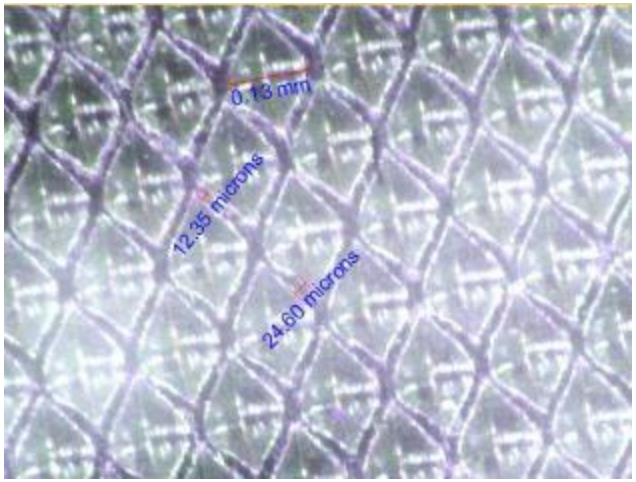
Gravure Cylinder. Properties

- Printing pressure 4.5MPa
- Hardiness
  - Steel 5-8.5
  - Copper 2.5-3
  - Chrome 9
- Impact resistance
- Surface scratch & abrasion resistance from
  - Blade from Steel contact pressure 70-120g/cm
  - Printed Substrates: Paper, Cardboard, BOPP, PET
- Temperature resistance 60-70*C
- Adhesion to printing inks are based on toluene or water
- Chemistry resistance to next solvents
  - Toluene, Basis 5% NaOH, Acid 5%HCl, Water, Ethyl acetate, Butyl acetate, Isopropanol, Petrol



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Gravure Cylinder. Existed Manufacturing

- Workflow
  - Old image mechanical peal off (for used cylinder) – 0.25-0.5 hours
  - Chemical process – copper layer build up 2 hours
  - Mechanical engraving – 0.3 sq. m /hour
  - Polishing – 0.3-0.5 hours
  - Chemical process – Chrome layer build up 0.5-0.75 hours
  - Proofing 0.0.25-0.5 hour (Not included)

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Gravure Cylinder. Existed Manufacturing

- Total net productivity for
  - 0.5 sq. m – 5 hours
  - 1.0 sq. m – 6 hours
- Print run length
  - Copper 50-70 K
  - Zink 70-100 K
  - Chrome – 1M

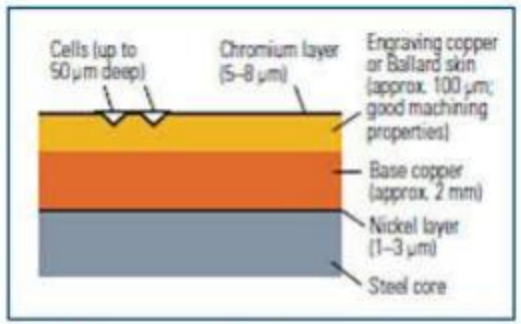

Fig. 1.3-12 Structure of a gravure cylinder

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3D Method. Media Requirements

- Liquid initial UV& thermo sensitive plastic composition
- Suitable for inkjet or stereo lithography
- UV curable
- High adhesion to Copper or Chrome surface
- Finished layer should be
  - thick -100 micron
  - Hard - not less then 80 Shore D
  - Smooth - roughness less then 1micron
  - Impact resist (IZOD method not less than 29 J/m, TBD)
- Final product should have
  - Good adhesion to the printing inks
  - High resistance to ethanol, benzene, toluene and water
  - Scratch resistance to the steel blade& printing substrates
  - Thermo dimension stability

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3D Method. Workflow

- Data input & preparation
- Cylinder mounting
- Surface treatment (for original cylinder)
  - Chrome& Copper old image mechanical removal (peel up) up to copper surface
  - Or direct chemical treatment of Chrome or Copper surface
- Surface treatment (for 3D manufacturer cylinder)
  - 3D plastic old image mechanical removal (peel up) up to copper surface
  - direct chemical treatment of Chrome or Copper surface
- Basic layer build up with UV curing
- Image layer build up simultaneous with preliminary image UV curing
- Surface and deep layer finishing by thermo curing
- Ready Cylinder dissemble
- Digital & physical proof from cylinder

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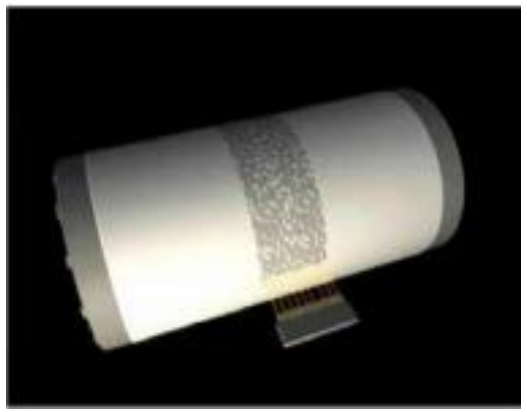
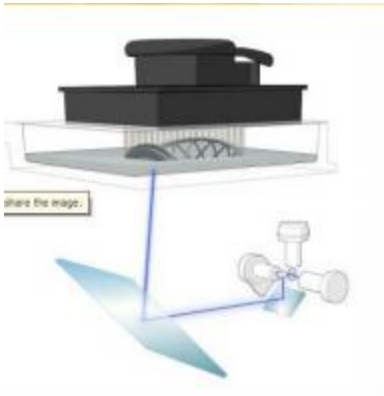
3D Method. Stereo lithography

- Stereo lithography
  - Media
    - Methacrylate oligomer &monomers
    - Photo initiators
    - Additives
    - Price
  - Workflow
    - Liquid Media supply
    - Laser expose & imaging by curing
    - Finishing (IR) 16-30$/kg
  - Construction base
    - Direct expose or
    - Optical scanning
    - Resolution 3000LPI
    - Pitch 5-7 micron
  - Spec key data (similar system for other target)
    - 8-28 sq. m/hour
    - 30-50 g/hour
  - System BOM equals 3-300K depending on the purpose & spec





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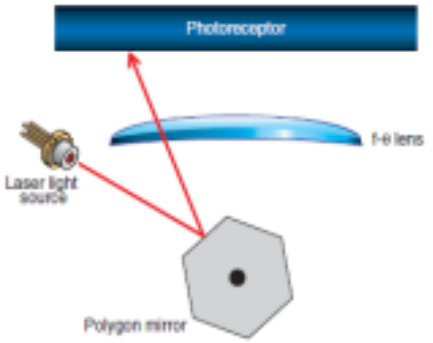
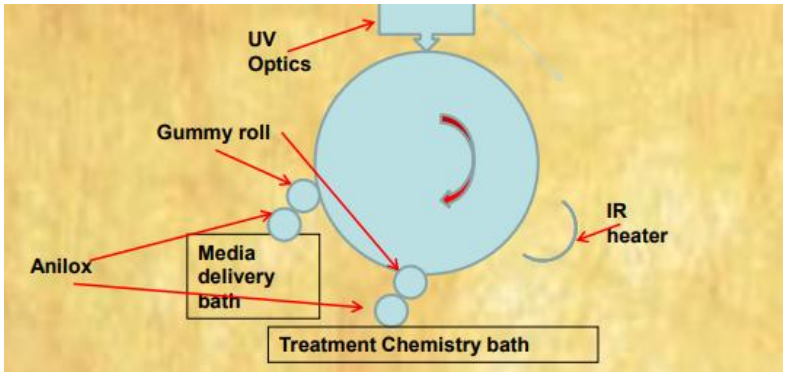
Stereo lithography Pro & Contra

- Advantages
  - High resolutions
  - Less expensive media
  - Possible less expensive construction



- Disadvantages
  - Absence of full length laser array required at least 4 (four) optical system and stitch image problem solution



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Stereo lithography& Inkjet: Pro & Contra

Inkjet properties	Steo lithography properties
• Min drop diameter – 20 micron	• Standard Laser beam diameter are 5-10 micron

• Layer thickness
  • 7 micron every layer, at least 14 (fourteen) layers or
  • 6 micron every layer, at least 17 (sixteen) layers
	• Layer thickness
	  • 5-10 micron layer,
	  • 20-10 (ten) layers

• min wall width for
  • 6pL drop is 22.5 micron
  • 3pL drop is 18 micron
	• Min wall width will be 10-15 micron

• Possibility for one or two step (more productive) process
  • Basic plating
  • Imaging
	• One step process
	  • Basic plating and imaging

• Tried and proven technology for large model formats	• less well-known and proven technology for large model formats

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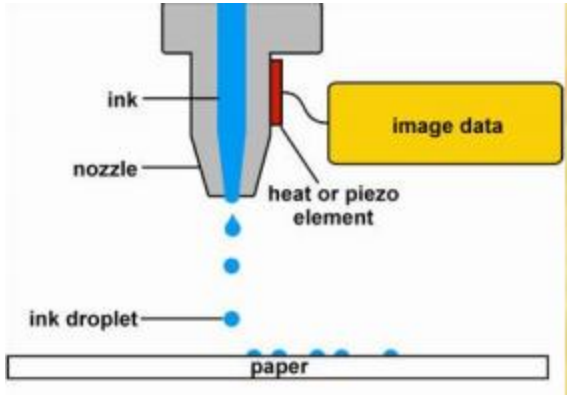
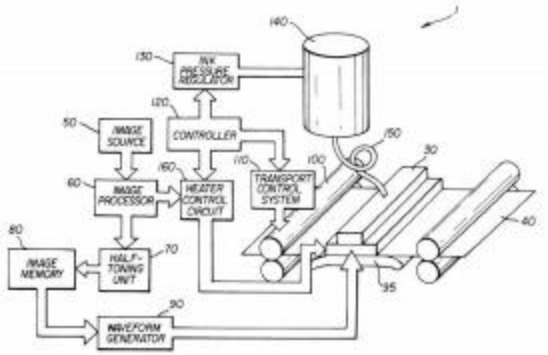
3D Method. Inkjet

- Media
  - Methacrylate oligomer &monomers
  - Photo initiators
  - Additives
  - Price 100-150$/kg
- Workflow
  - Inkjet imaging
  - UV curing
  - Finishing (IR and mechanical)
- Construction base
  - Print head motionless bridge
  - Resolution 1200-1440DPI
  - Drop min diameter 23 micron
- Spec key data (approved)
  - 100 sq. m/hour
  - Up to 1000 g/hour
- System BOM equals 250-300K





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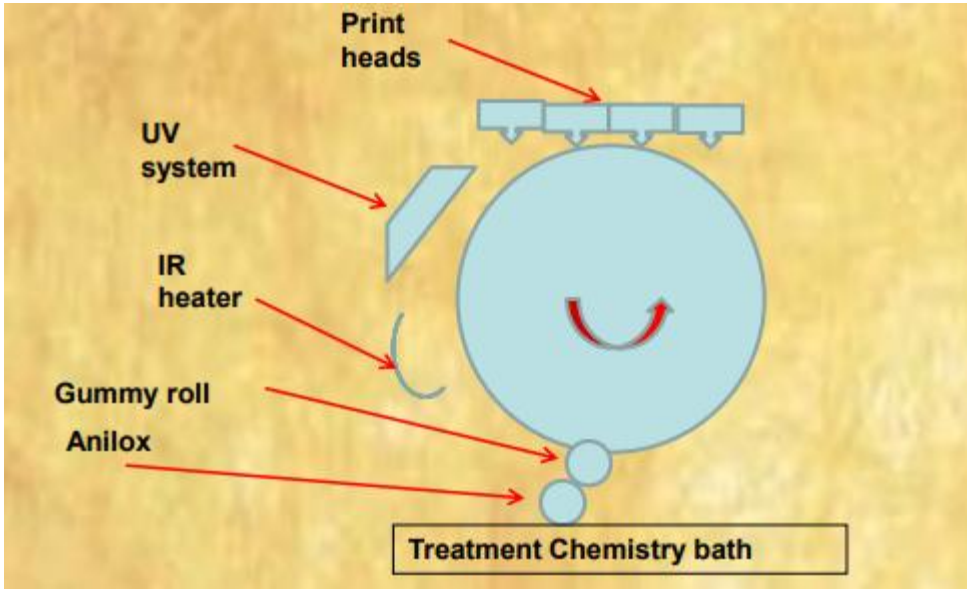
Inkjet system Construction

- Need two or four print head lines for full coverage or
- One-two print head lines for back-forward 50 micron moving
- Resolution 1440 or 1200
- Max/min layer thickness 14 - 6micron for 48-3 pL drops



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First priority. Media Composition

- Possible solutions
  - Radical UV cure
  - Cationic UV cure
  - Hybrid UV systems (cationic and free radical curing performed at the same time)
  - Dual cure system (solvent based; additional thermal curing performed after UV curing)
- Chosen direction – Cationic dual cure system with the next advantages
  - Outstanding adhesion to metals
  - Complete curing
  - Low viscosity
  - Excellent toughness
  - Low shrinkage and good dimensional stability
  - No air inhibition and high curing rates under air
  - High chemical and solvent resistance

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First priority. Media Properties

- Starting composition
  - Basic resin – 45%
  - Cross linking agent-41%
  - Viscosity determinant -7%
  - Surfactant - 2.0%
  - Photo-initiator package 4.5%
  - Hardness additives 0.5%
- Basic properties for the process conditions
  - Process temperature 40-50*C
  - Jet ability
  - Viscosity (10-30 cPuaz)
  - Surface tension (25-32 g/cm)
  - UV sensitivity to 395-405 nm radiation

- Patentable with the next original claims
  - Specific UV wave length sensitivity
  - Additional to regular UV thermo curing properties
  - Additives for surface hardness improvement

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First priority. Inkjet System Specification

Item	Detail	Unit	Value	Comments
Image resolution		DPI	Not less than 1200	1440 standard
layer thickness		Micron	6-7	
Min element size		Micron	18-23	
Media coverage		g/hour	120-240	
tank volume		L	2-4	
Input data format			PDF, EPS, Tiff, BMP	
Imaging Width	Min/max	Mm	600-1300	
Cylinder width	min/max	Mm	600-1300	
Cylinder diameter		Mm	200-400	
Process speed		Cm/sec	5-10	3-6KHz jetting
Productivity	Target	Sq. m/hour	0.5-6.0	
Electrical power	General	KW	35	
	UV	KW	15-20	
	IR	KW	5-7.5	

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First priority. BOM

Item	Definition	Supplier	Price /Cost	Comment
Classy	Ready system			
Treatment system	Chemistry resist, 2-3 steps	Self made	10-15K$	
Ink system		Self made	10-15K$	
Print head	XAAR1001 or KJ4B-Z	XAAR (76 heads) or KYOSERA (12-24heads)	1.5x72=108K$ (12-24)x3 =36-72 K$	Connect to order quantity
Print head bridge		Self made	35-50K$	
UV system	120-180w/cm or 15.6-23.4KW	NORDSON or SHENZEN LAMPIC or PHOSION	Up to 45K$	
IR system	60-80w/cm or 7.8-10.4 KW	HERAEUS or DELTA	Up to 15K$	
Electronics				
Data flow support	Computer, SW electronic board	Self made & outsourcing		
Total				

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Ink Consumption

Item	Unit	Cylinder width 60 cm	Cylinder width 110 cm	Cylinder width 130 cm	Cylinder width 160 cm	Comments
Cylinder diameter	cm	28.67 cm	31.8 cm	36.7cm	40.76cm	
Target layer thickness		100 micron =0.1 mm	100 micron =0.1 mm	100 micron =0.1 mm	100 micron =0.1 mm	
Printed area calculation	Sq. cm	3.14x28.67 x60	3.14x31.8x1 10	3.14x36.7x1 30	3.14x40.76x 160	PA=3.14xDx W
Printing area result	Sq. cm	5400	10983	14980	20478	
Target volume	cub cm	5850x 0.01 =58.5	10983x0.01 =109.83	14980x 0.01 =114.98	20478x 0.01 =204.78	
Ink mass about	g	65	125	165	225	Ink mass 1.1g/ cub cm

- The ink consumption for one cylinder creation (net) equals 65-225g
- It may take into account the empty cell from one hand and the maintenance requirements from other

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Layer Thickness &Diameter Calculation

- Printing resolutions should be 1440 -1200 dpi
  - 1440/25.4=56.7 dot per mm
  - Pitch 1000/56.7= 17.63 micron
- Drop volume is 3-6 pL
  - V=(1/6)x(3.14xDiam^3)
  - 6 pL drop 6x10^(-12)=(1/6)x(3.14xDiam^3) Diam= 22.5 micron
  - 3pL drop 3x10^(-12)=(1/6)x(3.14xDiam^3)
    Diam= 18 micron
- Thickness of the single drop in full printed layer
  - LT=V/Pitch^2
  - 6pL drop

  LT= 6x10^(-12)/((22.5x10^(-4)^2

  Layer thickness max 11.8 micron – 7.5 micron practical value
  - 3pL

  LT= 3x10^(-12)/((22.5x10^(-4)^2)

  Layer thickness max 8.7 micron – 6micron practical value

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Net Printing Productivity Calculation

- All calculation were made for printing resolutions 1440dpi & single layer thickness 6 micron

Item	Cylinder width 60 cm	Cylinder width 110 cm	Cylinder width 130 cm	Cylinder width 160 cm	Comments
Cylinder diam.	28.67 cm	31.8 cm	36.7cm	40.76cm	
Circumference	90 cm	100cm	115cm	128cm	=3.14x D
Time of one rotation	18sec	20sec	22sec	25sec	According 3KHz jetting
Rotation number	306 sec	340 sec	374 sec	425 sec	17 layers for 100micron
XAAR-6pL net time	306x4= 1224 sec	340x4= 1360 sec	374x4= 1496 sec	425x4= 1700 sec	360 dpi-18 heads moving bridge
XAAR-6pL	306x2= 612 sec	340x2= 680 sec	374x2= 748 sec	425x2= 850 sec	720 dpi – 36 heads moving bridge
XAAR-6pL	306 sec	340 sec	374 sec	425 sec	1440dpi -72heads
KYOCERA-3pL	306 sec	340 sec	374 sec	425 sec	12-24 heads

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Preliminary Conclusion

- According to the calculation for 100 micron layer &1440 DPI
  - Net printing time may take 5-20 minute for 0.5 sq. m cylinder
    - The full process time will be bigger by additional operation
    - Pill up of the old image
    - Surface pretreatment
    - Post curing
    - Polishing
  - The work flow should content the data operation and cylinder mounting and dismounting
- The estimation of those operation time may be estimated as the additional 30-40 min.
- It means that the full process time will be no more than 1 hours per 0.5-1.0 sq. m
- Those values are much faster than electromechanical processes and in the one order with Laser engraving
- The real accuracy and productivity will calculated after the preliminary technology tests and the risks estimation

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Risks & Items for Development

- Risks - Open Items for the followed development
  - Media properties
    - jet ability
    - UV sensitivity
    - IR effectiveness
    - strength, durability
    - gravure ink interaction
  - Process accuracy
    - Head choice
    - Screening accuracy
    - On-line pretreatment
    - Mechanical finishing neediness
  - Process productivity frame
    - Treatment 10-15 min
    - Imaging 1-2 hours for 0.5-1.0 sq. m
    - IR Finishing 5-10 min

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List of Sources

- List of
  - Basic Sources
    - http://www.era.eu.org
    - http://www.bobst.com/usen/products/rotogravure-printing/gravurepresses/overview/machine/rotomec-4003hs/#.Uh2-gRs_ujY
    - http://digitalcommons.utep.edu/dissertations/AAI3433546
    - http://www.uvcuring.com/uvguide/chap3_2/chapter3_2.htm
  - Possible competitor (gravure cylinder & engraving system manufacturers) information
    - http://www.bolz-gmbh.de
    - http://www.daetwyler.com/graphics/index.php?page=582
    - http://www.hell-gravure-systems.com

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Thank You

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