TIME SHARED COMPUTER SIMULATION OF A SIMPLIFIED SINGLE COLOR LITHOGRAPHIC PRESS

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ABSTRACT

A simulation of a simplified lithographic press is presented. Developed and tested with the help of experienced Pressmen of the graphic Arts Technical Foundation, Pittsburgh, Pennsylvania, the simulated press can be used to train novice operators, as a simulator for development of better controls for the real printing press, or as a first step towards a more comprehensive model.

I. INTRODUCTION

A general framework of Printing Press Analysis has been studied by A. Lävi and G. Jorgensen in several GATF projects (2) and a static model of the single color press has been developed. But, the complexity of the model which attemps to take into account every single aspect and characteristic of the press makes its practical implementation on a computer a very hazardous task at this stage.

In a lithographic printing press,the ink is applied to a cylindrical plate bearing a chemically defined image and transfered to a cylindrical blanket which prints directly on the paper. The press operator must adjust certain settings in order to get the desired quality.

> The majority of settings and controls on the press (and they are numerous) are seldom changed during a particular run. However, there are a few controls which the operator continually manipulates in order to maintain the product quality within the prescribed range. (3)

During a period of "press set-up" the operator adjusts some settings and possibly changes the viscosity of the ink in order to obtain a product of acceptable quality. Some adjustments can be made withous stopping the machine, others are more time consuming. In all cases, the effect of the change of a control is not immediate and in general, the operator prints several sheets before taking a sample to judge quality. After this set-up, the press is ready for production and only minor adjustments are needed during the operation, due to the effects of changes in temperature and humidity, drifts of some characteristics or settings and several other causes.

As a first step towards a more comprehensive model, we consider the model of a <u>Simplified Press</u>. The machine to be modeled has only a small number of controls and we are only interested in some characteristics of the printed sheet: a kind of "Ditto" machine. Using the knowledge of experienced pressmen, a model which mimics the behavior of a real press is built. The model is based more on the static reproduction of most input-output relations than on the reproduction of known physical, mechanical, or chemical interactions.

II. DESCRIPTION OF THE MODEL

Six inputs and nine characteristics of the printed sheet have been selected.

The following inputs are some of the main controls that the pressman uses during a normal run to control his press:

1.	Ink Feed Dial	:	Position of the ink feed dial as read on the press.
2.	Water Feed Dial	:	Position of the water feed dial.
3.	Speed of the Press	:	Number of printed sheets in an hour.
4.	Pressure Spacer	:	Thickness of the spacer which changes the pressure between the impression cylinder and the blanket. The

thicker is the spacer, the lighter is the pressure.

5. Pile Height : Maximum number of sheets that the delivery pile may reach without too much offsetting of wet ink of one sheet on the one below it.

6. Ink Tack : Resistance of an ink film to being split between two surfaces, as between rollers, plate and blanket and paper; stickiness.

To activate some of these controls may require stopping the press. For instance, it takes some time to change the ink, and the pressure spacers cannot be adjusted during the actual run.

The following nine outputs are related more or less directly to the quality of the print: (4)

1. Ink film thickness: "The thickness of the ink film on the press sheet". It is in general evaluated by measuring the optical reflection density of the ink film on the press sheet: the thicker the ink film, the better the print quality.

2. Resolution: "Highest number per inch of parallel, equal width white and ink line pairs that can be printed on the press sheet". It is desired to achieve a resolution as high as possible.

3. Pick: "Small pieces of the paper surface pulled out by the tack force of the ink during ink film splitting, causing white spots to appear in the ink film on the press sheet (usually constrained to zero)".

4. Ink offsetting and blocking: "Wet ink on the surface of the sheets transfering or sticking to the backs of following sheets in the delivery pile".

5. Wash Marks: "Areas of low ink density at the leading (toward gripper) edges of the image".

6. Ghost images: "Failure of the ink distribution system to completely replenish ink taken from the form rollers by one area of the plate before a "following area" (in the around-the cylinder direction) is ready to be inked, causing the ink film in the "following area" to be thinner in those areas corresponding to the first inked areas patterns on the form rollers".

7. Sheet Flatness: "The levelness and freedom from curl, embossing and wrinkles in the sheet following the impressions".

8. Plate dry-up: "Non-image areas of the plate lose their desentization due to lack of water, and begin to take ink (can be corrected by increasing water feed).

9. Snowflaky solids: "Minute white spots or holes in the ink film on the press sheet".

In evaluating printed sheet characteristics, only visual inspection is generally possible. It is, of course, possible to compute the density of such defects, but, practically after a visual inspection, the pressman makes a qualitative estimation: "It is 'very good', 'average', or 'bad'."

In the model, each of these nine outputs is first characterized by a continuous valued function of the control input. After scaling, this is transformed into a quality number which, compared to a normalized rank scale provides a quality estimate. The outputs can take seven levels of quality: Excellent, very good, good, average, poor, bad, rejected.

Any job characterized by only the first four items of this list is acceptable. When starting a job, the pressman establishes the quality scale of the job. There are three allowable levels: low, medium and high. Thus "average" is average for a low, medium or high quality job, as requested.

After a display of the outputs, the computer gives a "performance" which is the quality number associated, after scaling, with the output. The smaller is that number, the better is the print.

III. DESCRIPTION OF THE SIMULATION PROGRAM

The model consists of two components (Illustration 1)

- A subroutine (MODPRT) which contains a set of continuous input-output relations designed to mimic to actual behavior of the press.

- A set of mathematical transformations introducing some pertubations: changes in the parameters, addition of gaussian noise, modification of the paper characteristics for each job, and scaling and discretization of the continuous simulation output providing a discrete quality estimate.

ILLUSTRATION I

Modeling of a Single-Color Printing Press

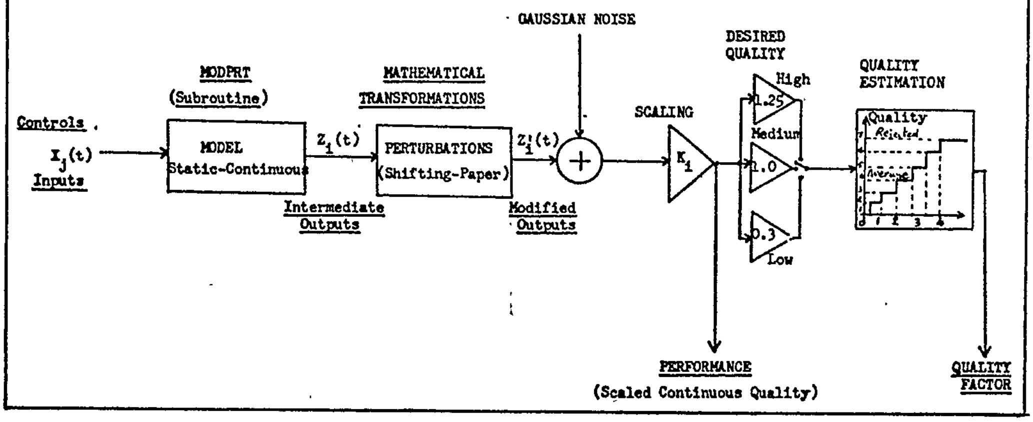


ILLUSTRATION 2

Influence on the Press Inputs on the Ink Film Thickness

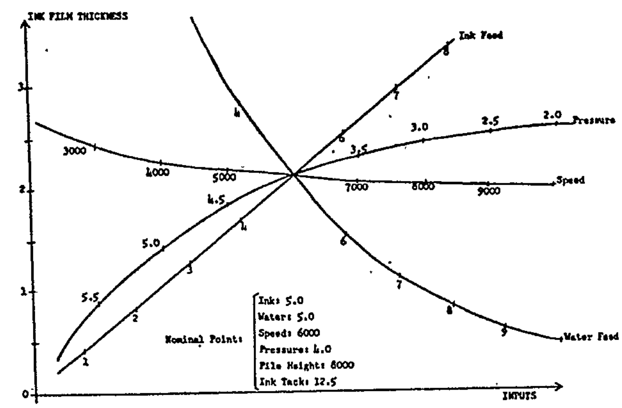
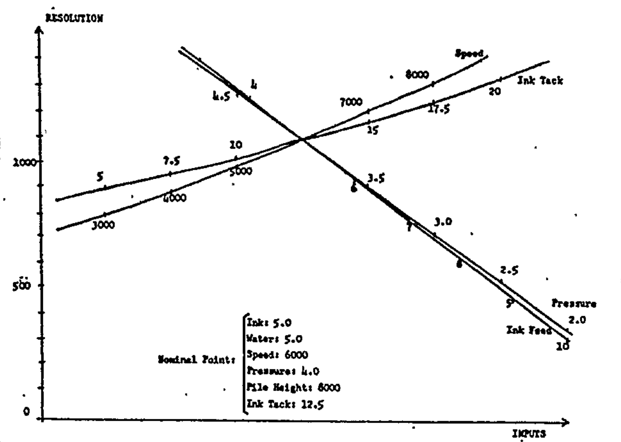


ILLUSTRATION 3

Influence on the Press Inputs on the Resolution



SUBROUTINE MODPRT

The Subroutine MODPRT contains a set of mathematical functions (outputs) of the press controls (inputs). The outputs carry some information about the quality, the physical dimension or the position of the actual outputs of the press and are used to determine quality.

The functions have been designed so as to resemble real-life relations but no actual testing has been carried out to check their quantitative accuracy. Rather their qualitative characteristics have been successfully checked by some experienced pressman comparing the behavior of the complete simulation model with what they would expect from a real printing press.

Each input and output has already been described and defined and we shall only explain here the physical meaning of their supposedly continuous relations and illustrate graphically the modelling of these relations in the case of a printing on an average uncoated paper.

The graphical illustrations (Illustration 2 to 10) have been drawn in an unconventional manner to visualize on a single graph the influence of the changes of any input on each output: each curve is obtained by perturbing a single input at a time, all the other inputs being kept fixed at a constant average value during that time: The crossing point of all the curves is then the nominal working point for that constant input setting.

The thickness of the film of ink on the paper (Illustration 2) increases quasi-linearly with the ink feed and increases also with the pressure of the blanket against the impression cylinder. It decreases with the water feed because the increased water prevents some of the transfer of ink from the form rollers to the plate and from the plate to the blanket in the printing area. It decreases also temporarily (several hundred sheets to as much as one thousand sheets) with press speed which brings in more water per impression, and has an influence on the inflow of ink.

The resolution increases with the tack of the ink - because of the rheological properties and the higher elasticity of tacky inks - and also with the speed. But it decreases with the ink film thickness, the ink feed and with the pressure which spreads the ink film (Illustration 3).

For our uncoated paper, the pick decreases with the water feed because more dampness and humidity prevents the surface of the paper from being damaged. It increases with the tack, the stickiness of the ink, and with the press speed, both factors increasing the mechanical constraints on the surface and the body of the paper during the ink film splitting. It has been assumed that with our stock of paper, the pick decreases with the ink feed but it should be noted that physically, that may be only true at very high ink feed rates (Illustration 4).

The ink offsetting-and-blocking (Illustration 5) increases heavily with the ink feed, the press speed and the delivery pile heights. While a heavy ink film requires some time to dry, the height of the pile and the press speed may increase the pressure between the back of a sheet and the print of the next sheet before it is dry enough. However, since water has an influence on the ink film thickness, more water decreases the danger of offsetting.

The wash marks, which are constrained to zero, are produced by a surplus of water, and increase with the water feed or with the speed of the press (Illustration 6).

The sheet flatness deteriorates with an increase in water feed or ink feed because the humidity of the paper increases its tendency to curl. Flatness becomes worse with an increase in ink tack and press speed, both of which create strains on the body of the paper (Illustration 7).

It is difficult to avoid the snowflaky solids completely, but if their number or density increases with the water feed and with the speed, it decreases with the ink feed and desappears almost completely for a high ink film thickness (Illustration 8).

ILLUSTRATION 4

Influence of the Press Inputs on the Pick

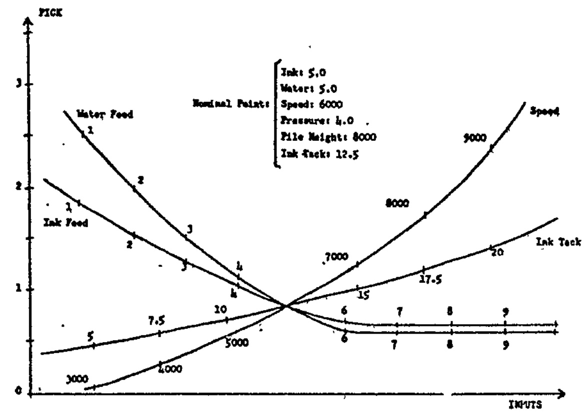


ILLUSTRATION 5

Influence of the Press Inputs on the Ink Offsetting and Blocking

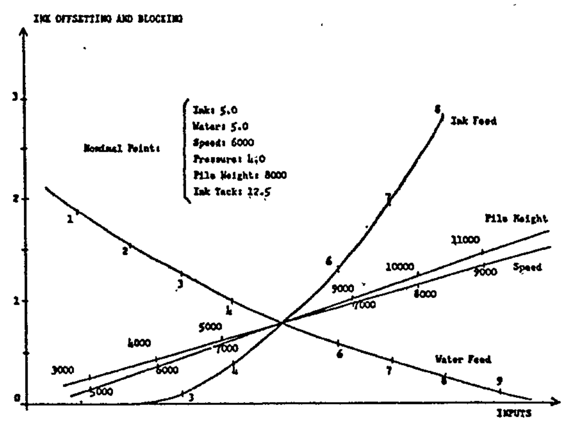


ILLUSTRATION 6

Influence of the Press Inputs on the Wash Marks

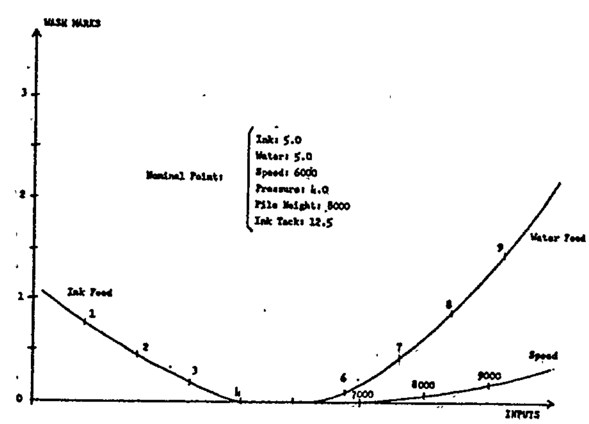


ILLUSTRATION 7

Influence of the Press Inputs on the Sheet Flatness

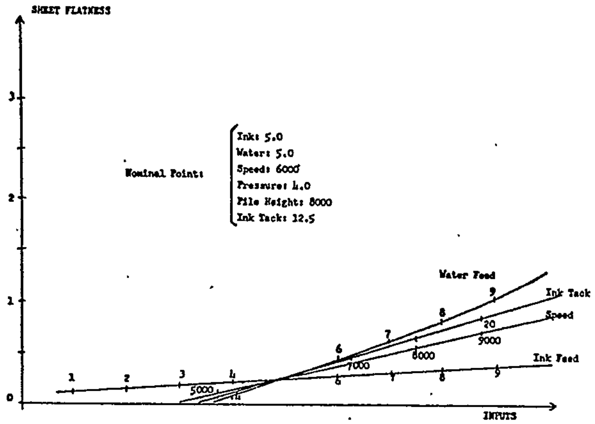


ILLUSTRATION 8

Influence of the Press Inputs on the Snowflaky Solids

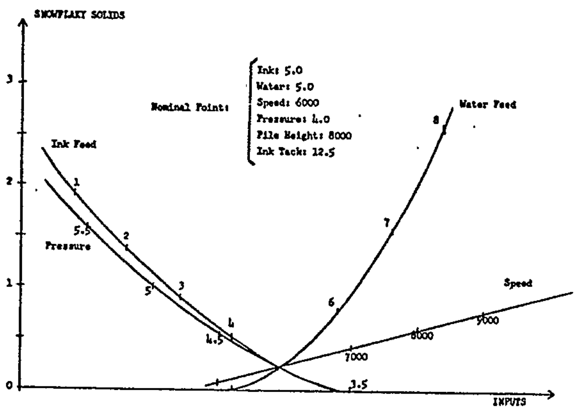
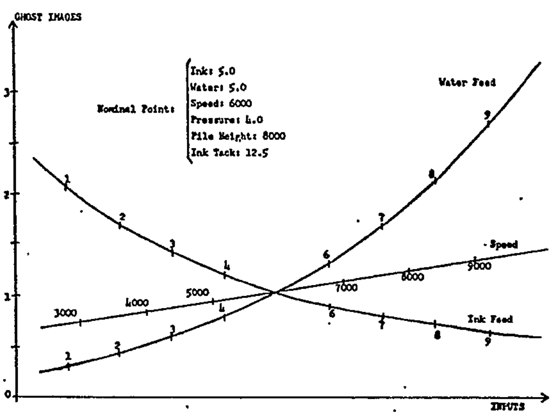


ILLUSTRATION 9

Influence of the Press Inputs on the Ghost Images



More common, and less noticeable to untrained eye, are the ghost images. They follow the same pattern as the snowflaky solids (Illustration 9).

The plate dry-up which increases with the ink feed can be reduced by increasing the press speed, and mainly by increasing the water feed (Illustration 10).

Each of these functions is approximated by straight lines and exponentials. The coefficients have been chosen to obtain curves with a shape acceptable to specialists and experienced pressmen.

MATHEMATICAL TRANSFORMATIONS

Subroutine MODPRT is a simplified static continuous model of a single color printing press printing on an average uncoated paper. The steady state of the press may shift under the influence of many factors: change in water feed pressure, heating of some parts or modification of the air temperature or humidity in the pressroom. It is not uncommon that during a four-hour run, the pressman has to reduce the water feed by nearly one half to keep the same printing quality.

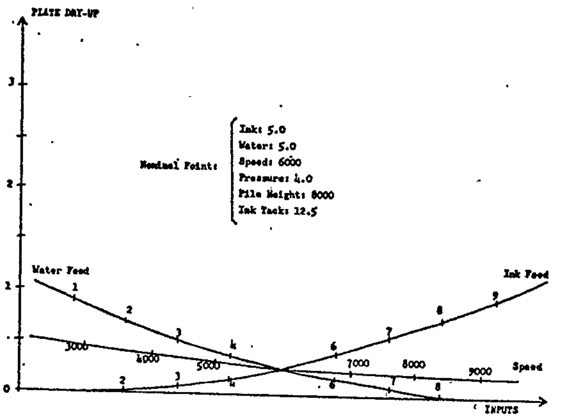
In the course of the same run, it is common to observe some periodic variations and some random changes in the characteristics of the paper coming from the same ream. The papers used for two consecutive jobs, though both uncoated in our case, may have drastically different characteristics in porosity, smoothness, acidity, moisture resistance, curling tendancy, and flatness, and the use of a new paper may require completely different control settings to maintain print quality.

The introduction of these time-dependant perturbations, dynamic properties of the press, variations in paper's characteristics and of this randomness is performed by a set of linear and non-linear transformations developed in the main program PRINTP. The set of modified outputs that results from these transformations represents the value of that output: Thickness of the film of ink, density of the snowflaky solids, degree of plate dryness.

In real life, the pressman pulls out a sample sheet, examines it and evaluates its quality before deciding whether to continue printing or to change some of the settings. Some of the characteristics are very important for the acceptance of the printed sheet, others can often be neglected. Thus the pressman gives more weight to some, less to others. To obtain a set of weighted stimuli, each modified output has to be properly scaled. These scaled stimuli can then be used to compute a quality factor associated with the corresponding characteristic.

ILLUSTRATION 10

Influence of the Press Inputs on the Plate Dry-up



There is a fair possibility that an equal interval scale for sensation or response marked out by an observer is not linear with respect to the corresponding stimulus which is represented here by scaled quantities. In the simplest case, when each stimulus can be considered to be independant from the other, such scales are found to follow logarithmic, power, or exponential curves. If we assume that the print quality rankings are not equidistant on the continuum in question, and also that what is AVERAGE can be selected by experience, there is a good possibility that the distance between adjacent intervals becomes smaller as we go towards their central tendancy (largest sensitivity towards the "average") and large towards the extremities.

If we take this approach, we can use a "normalized rank scale".

Seven quality factors have been selected, from EXCELLENT to REJECTED and this gives 100/7 = 14.3 percentiles for each quality factor. An AVERAGE quality factor has been chosen to correspond to a scaled stimulus of 2.5, and EXCELLENT AND REJECTED have the bounds 1.0 and 4.0, respectively.

The first experiments have shown that it is quite satisfactory. The simulation program PRINTP gives, associated with each quality factor, a quality number which is the "modified output", continuous unscaled value of the corresponding output, and its reading has been helpful to several pressman working on the Simulated Printing Press. The program also provides a performance, a number which is the worst scaled stimulus. The smaller is this stimulus, the better is the print quality.

IV. INPUT-OUTPUT AND MODEL UTILIZATION

The operator interacts with the model of the simulated press through a teletype. illustration 11 gives a summary of the controls and of the output characteristics available to the pressman. A typical run is shown on Illustration 11. When the computer is in control mode ("*"printed by the teletype), the operator can change any of the six input quantities by printing the corresponding code number and the change. When the computer is in reading mode ("–" printed by the teletype), the operator can request evaluation of the quality of any or of all the characteristics of the printed sheet prior taking new control decisions and deciding how many sheets will be printed prior to the next quality evaluation. Prior to any control input, the number of sheets printed and the time elapsed since starting the press set-up are given to the operator.

The present version of the program PRINTP contains three types of printing jobs which can each be performed at low quality (pamphlets), medium quality (ordinary printing) and high quality (art books). Termination of a job starts the next one.

As most of the pressmen who used the simulated printing press were not familiar with the operation of a computer terminal, all the input operations were performed by a qualified assistant: The pressmen sat beside the assistant, read the output displayed on the teletype and told the assistant which control actions were to be taken.

The model has been throughly tested and the similarity of its response with the response of a real press has been checked by the experienced pressmen involved in the study. It has been used as a tool for studying the decision-making process of pressmen engaged in an average lithographic printing task (1).

V. CONCLUSION

The result obtained with this model of a simplified printing press are promising. They provide an incentive for building a more complete simulator by increasing the number of controls available to the press operator and by improving the display of the characteristics of the printed sheets: use of a C.R.T. for output would permit a completely visual representation of the outcome of any course of action and provide an even better training tool for the printing industry.

The author wishes to thank Dr. A. Lavi of Carnegie-Mellon University for his help, and suggestions.

ILLUSTRATION 11

Example of a Simulated Press Run

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CALL PRINTP

    PRINTING      PRESS      MODELLING  .

AFTER * (CONTROL MODE),YOU PRINT A:B, WHERE A IS
THE # OF THE CONTROL,AND B IS ITS CHANGE, AND/OR RETURN,OR
F OR H TO TERMINATE OR FOR HELP,OR C TO CONTINUE.
   AFTER - (COMMAND  OR
READING MODE),YOU PRINT F (TERMINATE), H (HELP), C (CHANGE
OF OTHER CONTROLS), S (SHORT REPORT), D (DETAILED REPORT),
OR X X X ....,WHERE X IS THE ENTRY # OF THE OUTPUT
QUANTITY TO BE MEASURED...

  FIRST JOB  :  IT IS DESIRED TO PRINT  A
SERIES OF POSTERS,USING A SINGLE COLOR PRESS,
AND AN UNCOATED PAPER...

PRINT THE DESIRED QUALITY,1=LOW,2=MEDIUM,3=HIGH.
2

INITIAL INPUT SETTING

 1. INK FEED DIAL.                        8.00
 2. WATER FEED DIAL.                      2.00
 3. SPEED (# SHEETS/HOUR).                9000.
 4. PRESSURE SPACER(1/100 INCHES). 1.00
 5. HEIGHT OF PILE (# OF SHEETS).        6000.
 6. INK TACK (GRAMS*METERS).             17.50

1. INK FILM THICKNESS.     7.24  EXCELLNT
2. RESOLUTION      .     216.    REJECTED
3. PICK.                   3.99  REJECTED
4. INK OFFSETTING    .     3.90  REJECTED
5. WASH MARKS  .           0.00  EXCELLNT
6. SNOWFLAKY SOLIDS.       0.00  EXCELLNT
7. GHOST IMAGES.           0.54  VERYGOOD
8. SHEET FLATNESS.         0.76  REJECTED
9. PLATE DRY-UP.           1.03  ..BAD...
PERFORMANCE :  24.38

TIME:   0. MINUTES; # OF SHEETS:       0
*
6:-7.5
 6. =      10.00
1:-3.
 1. =       5.00    LESS    INK
2:1.
 2. =       3.00    MORE   WATER
4:-3.
 4. =       0.00    MORE    PRESSURE
4:4.
 4. =       4.00    LESS    PRESSURE
-
S
1. =  ..GOOD.. (   2.33)
2. =  VERYGOOD (1175.37)
3. =  REJECTED (   2.10)
4. =  REJECTED (   0.82)
5. =  EXCELLNT (   0.00)
6. =  ..BAD... (   0.49)
7. =  AVERAGE. (   1.12)
8. =  VERYGOOD (   0.16)
9. =  ..GOOD.. (   0.28)
PERFORMANCE :    9.41

TIME:   0. MINUTES; # OF SHEETS:       0
*
6:-1.
 6. =      9.00
2:1.
 2. =      4.00    MORE   WATER
5:-2000.
 5. =   4000.00

-
D

 1. INK FEED DIAL.                        5.00
 2. WATER FEED DIAL.                      4.00
 3. SPEED (# SHEETS/HOUR).                9000.
 4. PRESSURE SPACER(1/100 INCHES). 4.00
 5. HEIGHT OF PILE (# OF SHEETS).        4000.
 6. INK TACK (GRAMS*METERS).              9.00

1. INK FILM THICKNESS.     1.84  AVERAGE.
2. RESOLUTION      .     1110.   VERYGOOD
3. PICK.                   1.59  REJECTED
4. INK OFFSETTING    .     0.14  ..GOOD..
5. WASH MARKS  .           0.24  REJECTED
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ILLUSTRATION 11

(continued)

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6. SNOWFLAKY SOLIDS.       1.02  REJECTED
7. GHOST IMAGES.           1.39  AVERAGE.
8. SHEET FLATNESS.         0.21  VERYGOOD
9. PLATE DRY-UP.           0.20  VERYGOOD
PERFORMANCE :     7.38

TIME:  14. MINUTES; # OF SHEETS:     200
*
2:-1.
 2. =      3.00    LESS   WATER
3:-2000.
 3. =  7000.00

-
S
1. =  ..GOOD.. (   2.47)
2. =  ..GOOD.. (1012.65)
3. =  REJECTED (   1.16)
4. =  VERYGOOD (   0.02)
5. =  EXCELLNT (   0.00)
6. =  VERYGOOD (   0.15)
7. =  ..GOOD.. (   0.95)
8. =  EXCELLNT (   0.00)
9. =  ..GOOD.. (   0.33)
PERFORMANCE :    5.65
```

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2. Lavi, Abrahim and Jorgensen, George W. "Printing Press Process Analysis", Internal Graphic Arts Technical Foundation Research Report, Pittsburgh, Pa., 1968.

3. "Printing Press Process Analysis", p.35.

4. Definitions taken from "Printing Press Process Analysis", p. 61-82, by permission from Dr. A. Lavi.