ON-LINE DENSITY CONTROL WITH THE IGT PRESS DENSITOMETER *

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The early printers in the first centuries after Gutenberg had, in fact, a very direct control of the printing procedure. Each printed sheet was first evaluated before the following one was printed. In this way, possible deviations in the printing procedure could be corrected immediately on the following sheet. Later on, mechanical driving of the printing presses lengthened this really very short regulating cycle. During the visual evaluation of one sheet, the press went on rotating, and therefore, a correcting intervention could only be made some ten sheets later.

In present times, the printer has at his disposal an accurate evaluation aid: the densitometer. Changes in the printing results are no longer estimated visually only, but also evaluated by means of figures. Therewith, theoratically a more accurate intervention of the printer became possible. However, nowadays the printing presses are so fast that easily over one hundred sheets are printed before a correction can be performed. Furthermore, such a correction is based on the evaluation and measured values of only one printed sheet. It is known that great density differences can occur between two consecutive printings. Thus, the possibility exists that a correction is made, which is based on one print rather different from the average prints at that moment. What the printer actually needs is a system which provides him continously with information about the current course of density. A system which, besides that, reduces the influence of exceptional deviations in the printing results by taking the average density values from several consecutive printed sheets. With such a quality control system, the printer could interfere immediately when the printing densities threaten to exceed the set tolerance limits. This system is now existing: the IGT press densitometer, an on-line quality control system.

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Description of the system

With the IGT press densitometer, the densities are measured on-line on the rotating press. The densities of each print are recorded during transportation from the last printing unit to the piler. Before the print has reached the delivery or sheeter, its densities have already been registered. The press densitometer consists of the following parts: (fig.1)

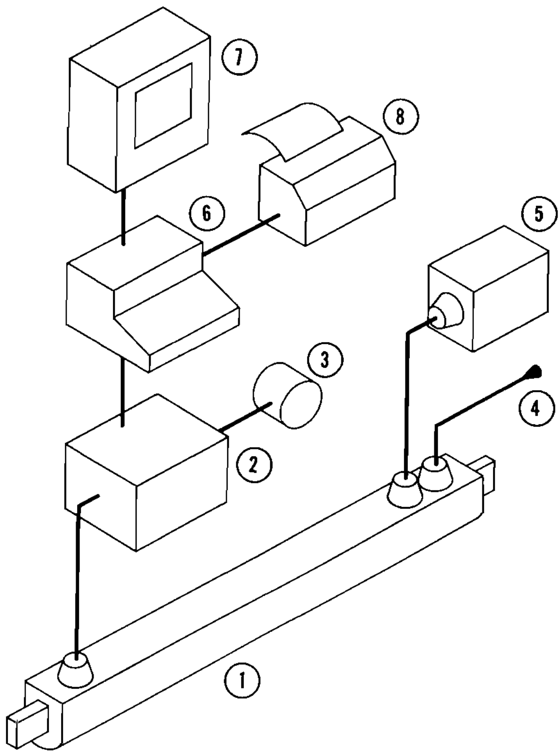

fig. 1

- a beam with the measuring heads...1
- a central light source............5
- an air compressor.................4
- a control unit....................2
- a micro-computer..................6
- a monitor.........................7
- a printer.........................8
- an operating console..............6
- an opto electronic puls generator.3

The beam with the measuring heads is mounted between the last printing unit and the delivery. The measuring beam is placed opposite the impressioncylinder of the last printing unit of a multi-colour sheet fed press.
The densities are measured on a special measuring strip, the surfaces of which correspond to the measuring heads in the beam. The measuring strip can be positioned at random on the print: at the beginning of the sheet, and the end of the sheet, or somewhere in between. Light from the central light source is projected through the measuring heads on the measuring strip; the reflected light falls on a photo-element in the measuring head. This photo-element emits an electrical signal to the control unit which, in its turn, transmits a signal to the micro-computer. The computer transforms the signal in a density and can process the measured densities in various ways. The results of these proceedings are displayed on a monitor. Some of the possibilities are: the average density of 10 to 20 sheets for yellow, cyan, magenta and black; deviations of the measured densities compared to the set standard densities; a trend figure showing whether the densities increase or decrease.
If desired, the data from the monitor can be transcribed on paper by the printer. Alterings in programming, standard values and instruction data can be dictated using the operating console.

Sensing

The measuring strip is composed of a number of solid tones and 70% halftones for the four printing colours. The minimal dimension of one measuring field is 6 mm in the printing direction. At various locations on the strip, a space is left open, where optional measuring elements can be added if desired. Measuring is done according to one of the known principles for reflection measurement: light is cast in a 45° angle on the surface to be measured, the reflected light is determined at 0°. Light is cast from two points opposite of each other on the surface to be measured. The two light beams have been chosed for, in order to reduce the influence of possible irregularities in the surface of the printing material. Besides, when sheets are printed, it may happen that the end of the sheet flutters a little during transportation. If this happens at the measuring moment, and in case the light comes from one side only, reflection of light would be influenced in an uncontrollable way. Also this phenomenon is partly compensated by light from two directions.

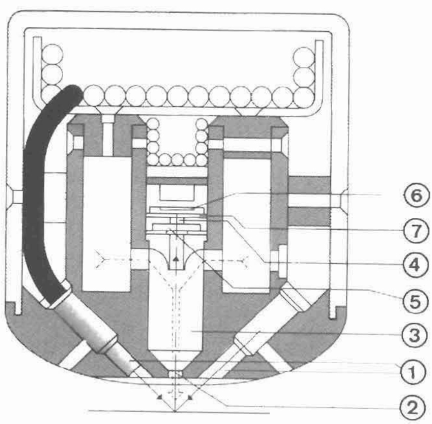

fig. 2

The diameter of the measuring opening is 2 mm (2), where as the measuring field (i.e. the area being measured) has a diameter of 3 mm. Diaphragms 2 and 4 determine the opening angle, which is kept as small as possible. In this way, a sharply limited measuring opening is obtained. The chamber wall (3) between both diaphragms is black, mat, and ribbed, so that scattered light is absorbed as much as possible. Infra-red light in the light beam is blocked to a large extent by an IR-filter (5) placed near to diaphragm (4). At the end of the light pathway, close before the photo-element(6), there is a complementary filter (7) in the measuring heads for yellow, cyan and magenta. They are the same filters as those also used in other densitometers, that is, Wratten 47b, 58 and 25. Therefore, no use is made of real narrow-band filters.

Photo-element

The photo cell is a silicium photo-element, with an increased sensitivity for blue light. On the other hand, such elements are also very sensitive to infra-red light, which is countered by placing an infra-red filter in the pathway of the light. The photo-element is current-driven: the electrical current is then proportional with the intensity of incoming light. In this case, the connection as current source offers advantages over the connection as voltage source. In this way, the element reacts faster (step response) and is less sensitive to temperature changes. Over an amplifying circuit, which will be discussed later, the current is converted into voltage, which is the outgoing signal of the measuring beam. This voltage is proportional with the intensity of the light reflected by the measured surface.

Central light source

All measuring heads receive light from one central light source. From this light source, light is transported to the measuring heads by glass fiber conductors. The light source is a halogen lamp: a multi-mirror lamp from General Electric. The quartz bulb is integrated with the multi-mirror reflector. One particular characteristic of this reflector is that it is partly transparent for infra-red light, and that it bundles the remaining light in the focus, where the beginning of the conducting bundle is located. The multi-mirror lamp has a very stable colour temperature of 3250 K. This colour temperature does not alter during the life time of the lamp, so that after replacement, the new lamp will have the same colour temperature as the old one. As heat filter, a further infra-red absorption filter is adapted before the lamp. The glass fiber conductors are manufactured by Schott. The diameter of one light conductor is 1 mm, whereas that of the fibers is 53 um. The spectral conductance is relatively constant. Dimming, or scattering of light, amounts approx. to 25% per meter. As the graphical representation shows, a relatively large scattering occurs already immediately upon penetration of the light, since glass fiber reflects a great part of the light, which, therefore, is not absorbed by the light conductor. The glass fiber cables are kept as short as possible on the surface to be measured.

Compressed air

Up to now, the function of the compressed air has not been brought to discussion. The compressed air has two functions. The first is to keep the distance between printed material and measuring opening constant. Especially on sheet presses, the printed material tends to flutter. Now, by blowing air through the measuring head perpendicularly onto the sheet, it is kept in place. The corners of the measuring head opening are rounded, in order to allow an unimpended streaming out of the air.

The second function of the compressed air is to keep the measuring heads clean. Paper particles flying about, ink and antistain powder might penetrate into the measuring head through the openings and pollute the extremities of the glass fibers and the optical light pathway. The compressed air streams through the dark room from the measuring head to the measuring opening as well as

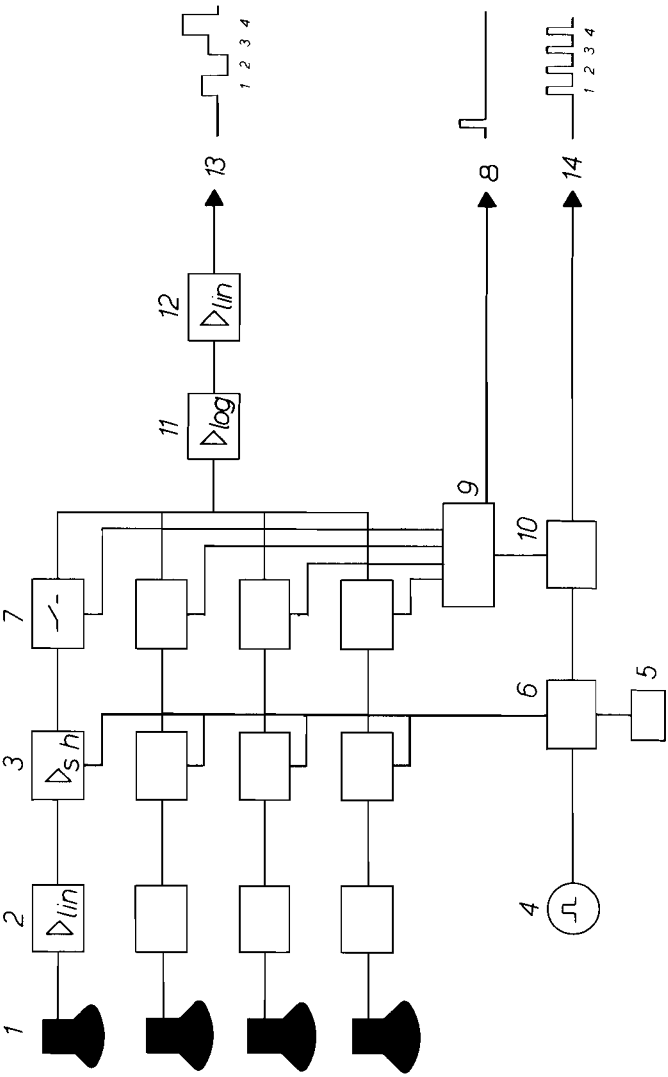

fig. 3

through a seperated air channel to the extremities of the light conductors. In the measuring head, the compressed air provides for an overpressure between 0.3 and 0.5 bar. The temperature of the compressed air is approx. 10°C higher than the surrounding temperature. Of course, the compressed air itself must be free from dirt. For this purpose, a tripartite set of filters is placed in the air conduct. First, a coarse filter removes eventual oil and water droplets sizing up to 3 um; then, a sub-micron filter gathers almost all dust particles exceeding 0.01 um and reduces the remaining oil percentage to 0.01 ppm; and finally, there is an active charcoal filter, which frees the air to 99.999% from all particles exceeding 0.01 um and reduces the remaining oil percentage to 0.005 ppm. Following this filtering procedure, the air is clean enough to be blown through the measuring heads.

Control

The schematic diagram of the control unit looks like shown here. In order not to complicate excessively the diagram, an operating unit for four measuring heads is shown. Through the measuring heads (1) light is projected continuously on the printed material, which reflects it again. Each photo-element in one head sends a small electrical current to a pre-amplifier (2).
Here, a transformation of current into voltage takes place. Subsequently, this signal is sent to the sample and hold amplifier (3) is to follow the signal until the command "hold" is given. Then, the amplifier holds the signal of that moment for a while. The hold command is given when the measuring strip is located exactly under the measuring heads. During the hold command, all the sample and hold outputs are connected through in a very rapid sequence to the logarithmic converter (11) by means of an analogue switch (7).
The logarithmic converter converts the intensity signals into density signals. These density signals are sent via the impedance converter (12) to the A/D converter of the computer (13). Now, how do the sample and hold amplifiers know that

the measuring strip is located exactly under the measuring head? To this purpose, an opto-electronic pulse generator (4) is mechanically connected with the axis of the impression cylinder in case of a sheet press (for almost every type of rotating press, this is different, so that this situation is left unconsidered here).
At each millimeter that the paper is moved, seen from a motionless point on the circumference of the impression cylinder, a pulse is generated. These pulses are counted electronically (6) and compared with the set value (5). At the moment that both figures are the same, the counter gives a signal, which warns the system that the measuring strip is located in the area now passing (coarse synchronization). The synchronization heads in the measuring beam become active and watch the passage of the synchronization surfaces, which are recorded in the measuring beam. As soon as these surfaces are underneath the synchronization heads, the latter give the hold command (fine synchronization).

Beside distance pulses, the pulse generator (4) also produces, through the multiplexer (9), a start pulse (8) which corresponds to the edge of the sheet. This is the starting signal for the counter on the one hand, and that for the computer on the other hand.

Via the multiplexer control (10), another signal, which indicates the sequence of the density signals (14), is sent to the computer. The sample and hold amplifiers measure in parallel (simultaneously), but their signals are sent in serial (one after the other) to the computer. Thus,the computer receives three signals from the control unit: a starting pulse, a digital pulse which indicates the sequence of the measuring heads, and an analogue density signal. Before it can be processed by the computer, the last signal still has to be converted into a digital signal by the A/D converter.
What happens now is the following: The start pulse warns the computer that a new series of density signals is arriving after a given number of pulses. Each time that the level of the digital

signal is high, the computer starts the A/D converter and reads the corresponding measured value. In this way, all the values of one strip are successively read.

Processing

Now, the signal from the A/D converter has to be converted by the computer into a density value. This density value can concord with the value indicated by the densitometer used by the industry. For this purpose, the press densitometer is calibrated on the densitometer of the industry before it is taken into operation. The relation between the signals of the press densitometer and the densities of the densitometer of the industry are stored in the computer memory. This relation is not linear. In addition, all measuring heads behave differently: for each measuring head, a separate curve has to be stored in the computer. Now, calibration occurs as follows: for each colour, a number of surfaces with increasing densities are measured with the manual densitometer. N.B.: This densitometer should not be equipped with polarization filters or narrow band filters. The surfaces are also measured with each measuring head of the press densitometer. In the computer memory, the densities for each measuring head, according to the manual densitometers, are stored with the corresponding signals of the measuring head.

Thus, a number of points are available to the computer, which indicate the relation between signals from the press densitometer and values from the manual densitometer. For the sake of simplification, it is assumed that the curved line between two consecutive points is linear. This line can be expressed by the equation: $y = ax + b$. The constants a and b are calculated and stored by the computer. Therefore, the curve is approximated by a series of straight lines. This approximation appears well usable in the practice and causes density deviations smaller than 0.025. For each measuring head, these data are stored in R(ead) O(nly) M(emories) of the computer, and, therefore, cannot simply be changed.

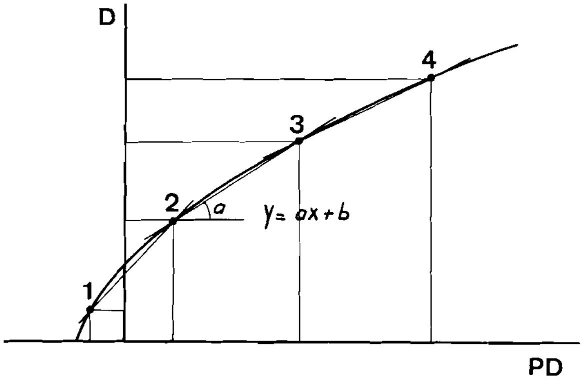

fig. 4

It is controlled regularly if the press densitometer still indicates the correct values. Pollution of the measuring heads or other causes could generate a deviation between the measured values and values according to the manual densitometer. Before or during a new commend, a calibration is done. Calibration is done on the white paper. Before the central light source, there is a filter wheel with four filters with increasing density. If the corresponding command is given, the white paper is measured automatically through all measuring heads with the four different filters, i.e. with four different intensities of light. In the case of a deviation, the computer calculates a correction factor, with which the density values of the relations stored in the ROMs are corrected.

Options

The presentation possibilities discussed till now are all part of the standard program of the press densitometer. However, as already said before, accessory devices can be added if desired; we will enumerate a few.
The tolerance control, for example, can be further extended with a status panel. On this panel, five LEDs affixed for each measuring head in the

system: seen from up to down a red one, an orange one, a green one, an orange and a red one. When the values of the corresponding measuring head remain within the first tolerance limits, the green led burns. Going back to the example of before: in that case, the green LED burns for the measuring heads for yellow when the full surface densities are between 0.91 and 0.97. If the full surface density for yellow reaches a value between the two tolerance limits, the lower orange lamp lights up when the value is too low (that is, between 0.91 and 0.88) and the upper orange one if the value is too high (between 0,97 and 1.00).
If the density decreases even under the tolerance limit of 0.88, the lower red lamp lights up; the density exceeds the tolerance limit of 1.00, the upper red lamp lights up. Thus, with this panel the printer sees at a glance if the material being printed is still within the set tolerance limits.
A second option of the press densitometer is registration of the impression. Each print is counted, and a differentiation is made between the sheets printed before the fiat density has been reached (the lost prints) and the prints with the correct density. Therewith, the exact netto-impression figures are available.
The third supplementary device we will mention is the telecommunication option. It is possible to transmit the measured values of the press densitometer on-line to other electronic processing systems, like a computer. This can be of importance, for example, for big printing companies with a central quality control department. The transmission of the printing data from the presses gives this department an immediate insight in the quality level reached.
It would lead us too far to discuss here all options on the press densitometer, and, to tell the truth, we do not even know all of them. During conversations with printers, new wishes are constantly expressed, which, in conclusion, can be realized on the press densitometer. It appears again and again that the press densitometer can be adjusted to the needs of the individual industries, and, therefore, that it can function in an optimal way under many different circumstances in an industry. That is one of the impor-

tant features of the on-line quality control system which carries the name of IGT press densitometer.

Display

The measured densities can be processed by the press densitometer and displayed on the monitor in various ways. The standard program of the press densitometer already offers a large number of possibilities. Besides, various other options make it possible to adjust each press densitometer to the needs of the individual industries.
The measuring heads are switched in clusters. In one cluster, there are maximal 16 measuring heads and one synchronization head. On the other hand, one press densitometer is constructed with a maximum of 8 clusters; therefore, it can have in total 128 measuring heads.
The construction in clusters makes it possible to divide the measuring strip into several smaller strips. If desired, the small strips can be located at different places on the printed sheet. They do not have to be situated in one line.
For each printed sheet, four clusters are used for the measurement. At the next printed sheet, it is the turn of the other clusters, when the press densitometer has more than four clusters. In rotation printing, two clusters are used for each print, because of the high printing speeds. For the next print, two other clusters follow, and so on. The choice of cluster sequence is completely free. Thus, for each print, the maximal number of measurements is 64 for sheet printing and 32 for rotation printing.
Generally, the system produces average values. Because of the high printing speeds, the display, on the monitor, of all individual values would lead to a continuous, illegible stream of changing figures. It can be chosen between the averages of 1 to 9000 measured values. These averages can be displayed in various ways.
For example, the average densities of one page (fig.5) including two clusters may be shown on the

monitor. In this case, four measuring heads for each colour are available per page. For each page and colour, the average density per measuring head is shown on the monitor. Apart from these average densities, also the trend can be displayed in this form. "Trend" is the average increase or decrease in density for each measuring head since the former measurement. In the same way, one can select display of the measure in which the actual density differs from the target or fiat density. These are also given for each colour and measuring head. In such a case, two tolerance limits are set. The first tolerance limit for yellow is for example 0.94 ± 0.03 D. Now, as soon as the average density reaches a value lower than 0.91 or higher than 0.97, this deviation is displayed on the monitor by flashing figures. The second tolerance limit is twice the first tolerance limit; i.e. in this example 0.88 and 1.00 D. If the average density for yellow comes underneath or over these values, a buzzer is heard.

A second presentation way is per colour over the complete breadth (fig.6) For example, four pages are placed over the width of the print, and each page is again covered by six measuring heads for each colour. Thus, four pages with six densities per colour each are displayed. In the same way, the trend or the average deviation between fiat value and measured density value can be called for. The system can also calculate and display K-values (7) This occurs as average K-values for each colour and page. Calculation of point enlargement is another possibility of the IGT press densitometer. For each colour and page, the system takes the average value of point enlargement according to Murray-Davies and displays these values on the monitor.(fig.8)

Finally, there is the printer. It can be programmed so that a print out of the densities of that moment is given every 5000 prints. Of course, it is interesting to have a total survey of the impression when a command is ready. Then, the average densities, the average density deviation, and the standard deviation can be printed for each page (2 clusters).

PAGE 1 : ___________________

	1	2	3	4
Y	---	---	---	---
M	---	---	---	---
C	---	---	---	---
B	---	---	---	---

fig. 5

MAGENTA: _______________

PAGE	1	2	3	4
1	---	---	---	---
2	---	---	---	---
3	---	---	---	---
4	---	---	---	---

fig. 6

PRINT CONTRAST

PAGE	Y	M	C	B
1	---	---	---	---
2	---	---	---	---
3	---	---	---	---
4	---	---	---	---

fig. 7

DOT GAIN

PAGE	Y	M	C	B
1	---	---	---	---
2	---	---	---	---
3	---	---	---	---
4	---	---	---	---

fig. 8