On-Line Brightness Sensor and Chemical Analyzer For Bleaching Automation

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ABSTRACT

The text has dealt with the instruments used in modern bleaching control. All problems facing bleach measurement technology have not yet been solved, but still the present situation can be regarded as satisfactory. The consistency and flow measurements required for actual production measurement are still lacking, and they will continue to give work for the developers and manufacturers of process instrumentation. Also measurements after the stages and their use for improved control is an interesting field which requires much attention in the future. Last but not least, every innovation in process technology will introduce new problems for bleaching control and present new challenges for instrumentation manufacturers.

INTRODUCTION

The purpose of pulp bleaching is to cause controlled changes in the optical properties of pulp without weakening its other properties (e.g. strength, runnability) and at the same time keep the yield as high as possible. Efficient control of the bleaching process to the desired result requires continuous information of the process status. Better process control in turn helps to achieve better and more stable product quality and lower production costs, facilitates the production of special products, etc.

As mechanical and chemical pulp are bleached according to different principles, also the optimum operation conditions differ considerably. Additionally the stages of chemical pulp bleaching differ from each other significantly. However some basis measurements are always needed no matter which bleaching method or stage is in question. These meesurements (including temperature, pH, consistency, stock flow, and chemical flow) form the basis for the adjustments that are used to keep the process conditions on the optimum level. Also some specific measurements are needed to monitor and control the brightness development and final brightness in bleaching. The modern sensor technology has been able to introduce new applications for better process control in locations where measurement data has so far been insufficient.

2. MEASUREMENTS

2.1. Brightness measurement

The brightness measurement of stock is based on the measurement of light reflectance. The subjective impression of brightness depends both on the colour of the measured object and on light scattering.

The goal of continuous measurement is to replace manual methods as process control tools and to aid in process control automation. The measurement must be reliable and quick to be of use as the principal measurement of the control.

CORMEC brightness measurement is based on the analysis of stock reflectance spectrums in four wave length ranges. Brightness is measured from stock line so that high intensity light is transmitted through an optical fiber cable to the stock. The reflected light is then led by the measurement cable back to the main unit which calculates brightness using four measurement wavelengths (Fig. 1).

2.2. Residual measurement

Chemical costs form the main part of the total bleaching costs (30-40%). Optimization of chemical consumption is therefore necessary when aiming at

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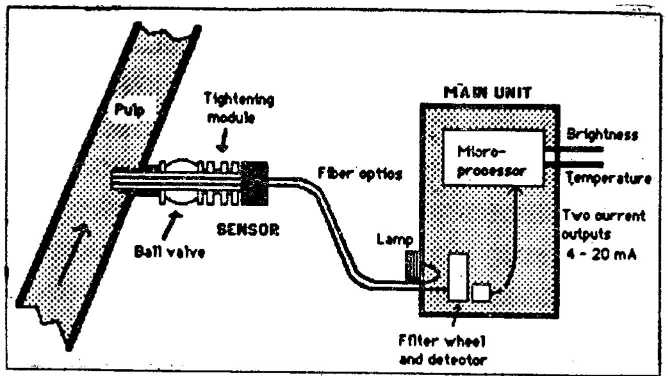

Fig. 1. CORMEC sensor main parts

competitive production, and continuous monitoring of chemical-consuming reactions is vital for this purpose.

POLAROX residual sensor measures continuously the concentration of oxidizing and reducing chemicals in the stock flow. The device measures an eleectrode current generated by electrochemical reactions which is directly proportional to the concentration of the chemical to be measured. Fig. 2 and 3 illustrate the operation principle and construction of POLAROX.

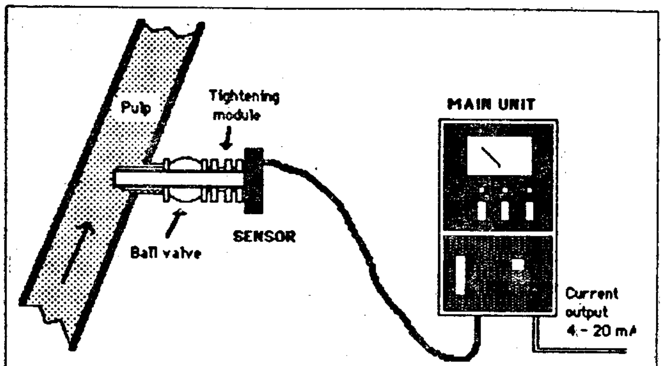

Fig. 2. POLAROX sensor main parts

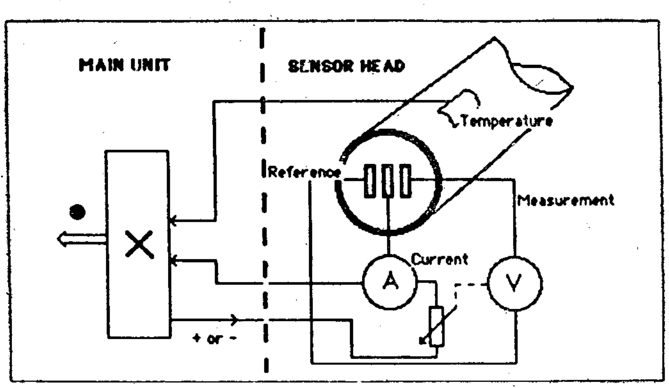

Fig. 3. POLAROX sensor measurement electrodes

Forexample the chlorine reaction can be Illustrated with the following formula :

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

The chlorine is reduced into Cl- ions at the measurement electrode which acts as cathode. The Cl_2 molecules receive electrons from the surface of the measurement electrode and are ionized. This generates a diffusion current which is then measured and converted into a standard current signal proportional to chemical concentration.

2 3. Standard bleaching measurements

Successfully completed bleaching requires that the basic conditions at every stage are kept at the optimum level. This target in turn means that measurements for production, chemical flow, temperatures and pH exist and that they are used to carry out the necessary control at each stage.

— Chemical flow is usually measured with magnetic flow meters.

— Temperature can be measured with a Pt-100 temperature sensor installed in the CORMEC or POLAROX measurement sensors.

— Production measurement is based on measurements of flow and consistency from which the actual production is calculated. Production can be measured before the bleaching sequence, but present-day technology cannot guarantee reliable production measurement between the stages.

— pH measurement is the central bleaching measurement, as pH has an impact both on reaction speed and brightness development It is extremely important to measure and adjust pH at the optimum level during every stage. Particularly significant it is at the D-stage, and this matter shall be more closely disussed in connection with the D-stage applications.

pH measurement sensors can be installed in the process line. However, this installation method may complicate equipment maintenance, and the most reliable way to measure pH is to take a filtrate sample from process and measure pH from the filtrate.

SAMPLEX is an automatic sampler which is able to take a continuous fiber-free sample in consistencies up to 15%. The operation principle of the device is presented in Fig 4. The process pressure forces liquid through a filter at the sensor head whiles fibers remain on the ffilter. The acquired filtrate sample is than led along the sample pipe inside the sensor to be analyzed. The filter is cleaned automatically with backflushing.

SAMPLEX can be used either an independent sampler or it may be integrated in the POLAROX sensor.

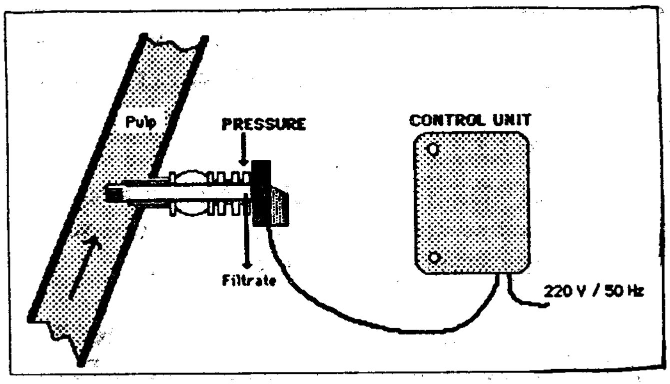

Fig. 4. SAMPLEX filtrate sample

3. MEASUREMENT APPLICATIONS IN A CIDEDED FILTER BLEACH PLANT

Kajaani Electronics Ltd. has for several years applied the instrument range CORMEC/POLAROX/SAMPLEX in the monitoring and control of different bleaching stages. Because the applications vary from stage to stage, the following text will discuss each stage in turn.

3.1. Chlorination stage

Successful Chlorination requires that the reactions between chlorine and lignin happen optimally despite quality variations in the incoming pulp. K-number variations cause variation also in reaction speed, and additionally consistency variations, washer losses and varying temperature can charge both reaction speed and chemical demand. Stock flow changes are thus not the only factor causing varying. Typical problems of the chlorine stage are over and under-chlorination which both destroy stock.

Consequently chemical dosage control cannot be based on a constant chemical percentage fixed on stock flow, but the control must be able to compensate accurately chemical demand changes due to changes in process conditions.

The chlorination control solution developed by Kajaani Electronics is based on the combined use of the CORMAC and POLAROX sensors. When static mixing is used the sensors are installed appr. 40 sec-1.5 min after chemical injection. In case MC-technology is applied, the sensor installation point can be situated 20-30 seconds after chemical injection.

The principle of chlorination control is illustrated in Fig. 5. The KAJAANI 4 microprocessor receives brightness residual, temperature, production, and chemical flow signals and calculates from these values the necessary dosages percentage and compensated brightness. The dosage percentage acts as measurement value for the dosage control (FRC). The compensated brighness in turn serves as measurement value for the brightness adjustment (ORC).

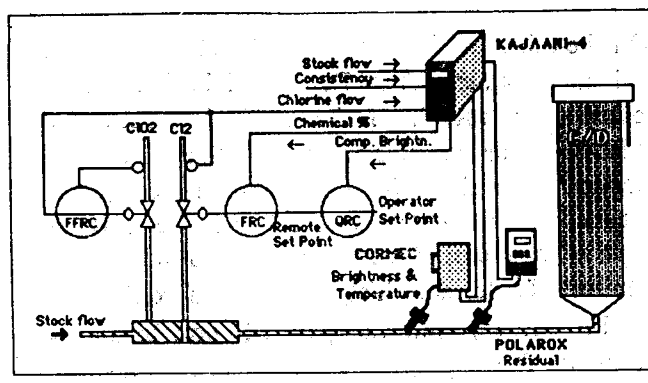

Fig. 5. Chlorination stage control principle

The chlorine feed is controlled with cascade feedback control where the brightness control loop gives set value for dosage adjustment and this in turn controls the actuator. Brightness control loop corrects the dosage control so that target brightness is achieved despite momentary changes in chemical demand caused by procees disturbances.

In the following brightness development and residual are observed separately after the moment that chlorine reaches pulp.

In chlorination stage the CORMEC sensor, installed shortly after chemical injection, measures the K-number variation in pulp entering the stage. If the control is based on optical measurement only, the pulp will be over- or underchlorinated because the K-number of the pulp varies. Fig. 6 illustrate the situation : if the sensor has a constant target level for all incoming K-numbers, the pulp will be underchlorinated when the incoming K-number is lower, and vice versa. Also the effects of stock flow and temperature variations on reaction time and speed must be compensated.

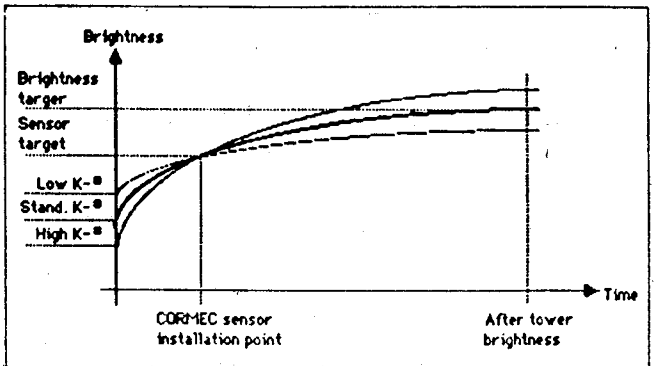

Fig. 6. Brightness devolopment for different incoming K-numbers

On the other hand, if the control is based only on residual measurement (Fig. 7), it will behave exactly the other way round. If the residual target of the POLAROX sensor remains constant with all incoming K-numbers, increasing K-number and shortening reaction time produce increased residual in the measurement point and consequently the control will reduce the amount of chlorine. Yet, in reality more chlorine would be needed, and the pulp will now be underchlorinated. The opposite is true when K-numder decreases and reaction time is longer.

The effects of stock flow and temperature on reaction time and speed must again be compensated, but the compensation happens in the opposite direction.

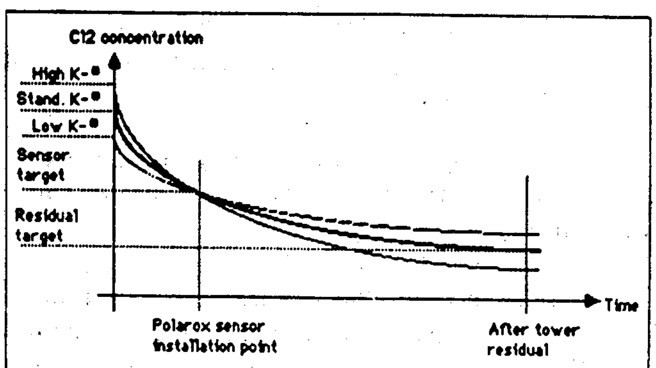

Fig. 7. Residual for different K-numbers

All this lets us conclude that chlorination control requires both brightness and residual measurement if the full advantage of modern measurement technology is to be taken in the process control.

One important point is that this electro-chemical POLAROX measurement depends on the mixing of chemicals in the C/D stage. If the mixing is poor, it will not be possible to reach a good result, neither can operation be improved with instruments because an average distance between two fibrers in a 3% consistency is about 0 4 mm and in 12% consistency about 0.1 mm. The diffusion speed of the chlorine and chlorine dioxide molecules in these conditions according to some studies is only some millimetres per hour.

3 2. Dioxide stage

In the dioxide stage the brightness development must continue to its target value despite process variables which may complicate the development.

Even though chlorination stage control were efficient, insufficient alkaline stage control or difficult process conditions at the early bleaching stage may still cause variations in the incoming K-number in D-stage, If the stage is controlled manually on the basis of laboratory measurements, the information is received too late for control purposes. Additionally variationsn in the chlorine dioxide feed is regulated correspondingly.

pH has a significant effect on brightness development in D-stage. Fig. 8 illustrates the dependence of brightness on pH. The optimum pH range for brightness development is around 4, but there may be other factors influencing the selection of the operating pH (e.g. shives in stock demand a lower pH value).

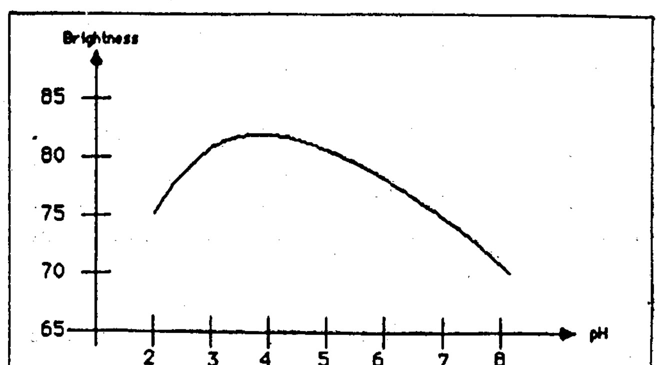

Fig. 8. Brightness and final pH at D-stage

If the stock flow changes but the shower water before the D-stage is not adjusted correspondingly, varying amounts of chlorinated lignins and alkaline will be carried over into the D-stage. These influence brightness development either by consuming the bleach chemical or by changing the pH. The use of filterarte water may also cause problems if the residual chemicals in the water compensate the desired changes at the application point. For instance, if filtrate containing ClO_2 is used at the alkaline stage washer. will decrease the pH and limit the efficiency of lignin removal which in turn reflects as a higher chemical demand in the next bleaching stage.

All these variables and the long retention time required make manual D-stage control extremely difficult, and usually the process is then run with over-dosages in order to guarantee sufficient brightness after tower. However, chlorine dioxide is an expensive chemical and too high dosages should naturally be avoided. Additionally high residuals after tower must be neutralized with SO_2 water in order to prevent colour reversion afterwards.

Also the D-stage control solution of Kajaani Electronics is based on the use of two sensors. CORMEC measures incoming pulp brightness either before chemical dosage or immediately after it so that the start value of brightness development is known. Fig. 9 presents brightness development after chemical injection. The figure shows that the effect of the dosage on brightness development cannot be predicted at the beginning of the reaction and consequently incoming pulp brightness can be measured also after the dosage.

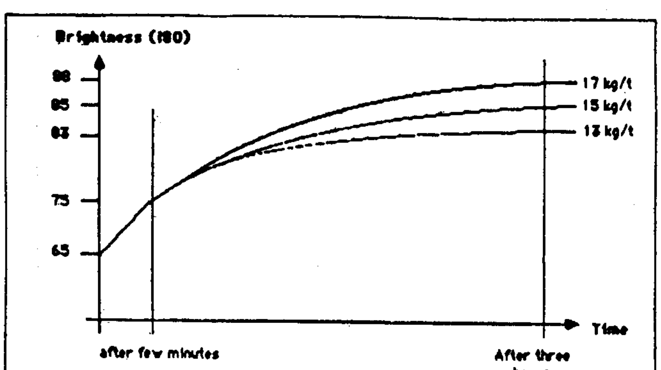

Fig. 9. Brightness development in D-stage for three different chemical dosages

POLAROX measures dioxide residual with a short retention time. It is thus able to detect changes in the chemical demand which may also be caused by disturbances in the process. The measured values (including pH) are used for calculation of compensated brightness. Compensated brightness acts as measurement value for the brightness control loop and its output serves as set value for the dioxide flow control loop.

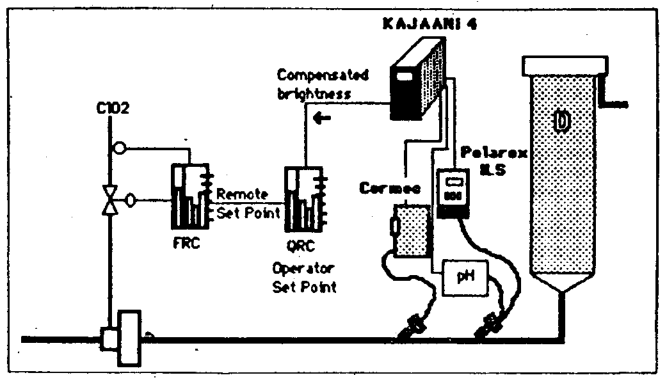

Fig. 10. D-stage control principle

This two-sensor method has proved to be the most efficient control method also for dioxide stage control.

3.3. Residual neutralization

The chlorine dioxide residual after D-stage causes colour reversion in pulp and corrosion problems in the process machinery after the stage unless the residual is neutralized Neutralization is usually done with SO_2 water which is fed into the pulp before the final washer. Continuous measurement is necessary to ensure effective feed control and to prevent overdosage.

POLAROX sensor can be calibrated to measure both the ClO_2 and SO_2 residual. The control principle is illustrated in Fig. 11.

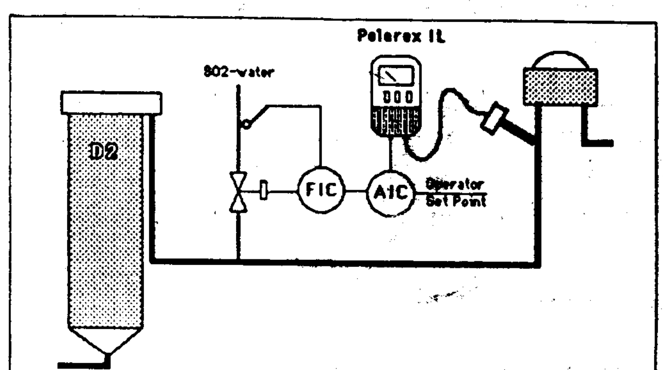

Fig 11. Neutralization of chlorine dioxide residual with SO_2

POLAROX is installed 15 sec-1 min after the SO_2 water feed point. Operator gives set value for residual and the output of the residual control loop (AIC) directs the SO_2 flow controller (FIC) so that the residual target (ClO_2 or SO_2) is achieved.

Fig. 12 presents the POLAROX electrode current at the neutralization point. When the device is calibrated so the part of the output current range is at the ClO_2 side and part in the SO_2 side, the measurement signal can be used to carry out the described control.

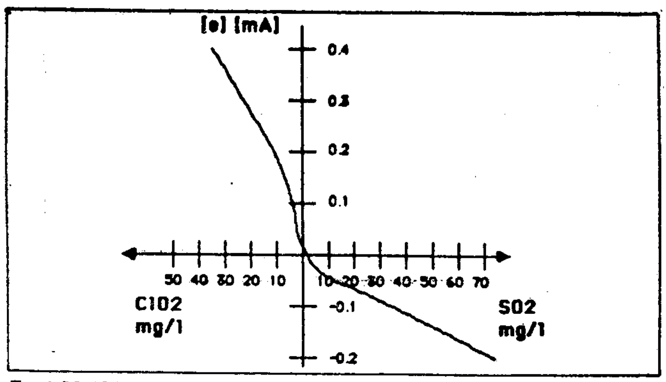

Fig. 12. POLAROX electrode current at the neutralization point

4. MEASUREMENT APPLICATIONS FOR BLEACHING OF MECHANICAL PULP (GW, TMP)

The increasing use of mechanical pulp in papermaking sets higher demands for the brightness of pulp and for the stability of final brightness. It also requires better chemical consumption optimization.

In chemical pulp bleaching the purpose is to remove the contained lignin as thoroughly as possible, whereas in mechanical pulp bleaching the aim is to make the coloured compounds of the pulp (mainly lignin) colourless without solubilizing amounts of fibrous matter. Consequently the yield of bleaching is high, appr. 97-99%.

Mechanical pulp bleaching can be divided in two different types, oxidizing and reducing, according to the bleaching chemical used. Today the chemicals include peroxide (oxidizing) and hydrosulfite (reducing).

Also in mechanical pulp bleaching certain standard measurements are needed :

—Chemical flow is measured with magnetic flow measurement.

—Temperature is an important factor and must be measured. For this purpose a Pt-100 temperature sensor installed in the CORMEC sensor can be used.

—PH is a central factor in the bleach reaction, as a wrong pH range causes either chemical decomposition or significantly slows the reaction. If reaction pH is not within the optimum range, the best possible final brightness cannot be achieved.

—Stock flow measurement is problematic, as a reliable measurement does not yet exist. Also reliable and accurate consistency measurement is lacking. This is particularly due to the strongly varying consistencies used in mechanical pulp bleaching. A typical consistency in hydrosulfite bleaching is 3-4%, but MC-technology has made the use of much higher consistencies possible (appr. 10%). High consistency technology has facilitated the spreading of peroxide bleaching. but consistency measurement in consistencies of 20-35% is still difficult.

The Mechanical pulp bleaching control by Kajaani Electronics is based on CORMEC brightness measurement which is installed a certain time after chemical injection (hydrosulfite bleaching appr. 1 minute, peroxide bleaching 7-8 minutes). CORMEC detects brightness variations in the incoming pulp as well as brightness level changes caused by the bleaching chemical. However, if the other process variables change, control cannot be based on brightness data alone and therefore the CORMEC signal is supported by temperature, stock flow, chemical dosage and pH measurements The control principle is illustrated in Fig. 13.

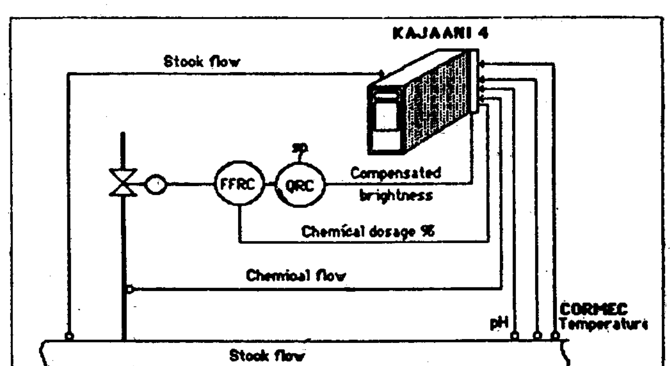

Fig. 13. Control principle of mechanical pulp bleaching

The acquired measurement data are fed into a Kajaani 4 microprocessor which calculates the necessary chemical dosage and compensated brightness. The output of the compensated brightness conlroller (QRC) acts as set value for the FFRC-chemical dosage controller, and the output of the FFRC in turn controls the actuator.

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