Consistency-its measurement and control

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SUMMARY

-Why measurement of consistency.

Fibre consitency is one of the most important process variables to control when manufacturing pulp and paper. The consistency has to be measured to be able to implement proper process control

Going through the concepts for consistency measurement and control, the following will be discussed.

-The measurement of consistency

Different indirect methods for measurement are used depending on the level of the consistency.

-Eur-Control Consistency Transmitter Program,

With three different transmitters Eur-Control covers the whole consistency range from 0% - 16%

-Installation of a consistency transmitter

Having an accurate and reliable transmitter, the installation should be done observing some important points in order not to ruin the measurement.

-The process level of consistency

The level of the consistency in the process should be considered so that the best suited transmitter is chosen as well as to avoid high load on a single transmitter.

-The control valve and dilution water supply

To complete the control loop, a dilution water valve should be chosen and installed properly Carelessness gives bad performance as well as consistency disturbances

-The optimum dilution step

The size of the dilution step should be chosen to obtain the best control performance. This depends in the indiv.dual case on the installation of the transmitter, the design of the control loop as well as on the process itself.

With more than 50 years of experience of manufacture and supply of consistency trnamsitters, Eur-Control has the know-how and equipment to be able to offer a solution to consistency control problems.

WHY MEASUREMENT OF CONSISTENCY

In the manufacture of pulp and paper the result of many of the process steps very much depends on the concentration of fibres in the suspension fed into each single process equipment. The consistency measurement is thus fundamental to the process control. Some examples are given, fig. 1:

— When refining the stock the energy put into each single fibre by the refining tackle and the surrounding fibres depends on the number of fibres in refining zone. At steady flow through the refiner and constant load of the refiner motor, the specific refining energy (kWh/tons) will change according to changes in the concentration of the fibres. This gives a double effect. Firstly, on short term, quality variations are introduced and secondly the refining action will change. Unfortunately the necessitv for good consistency control (and also flow control) in the refining process is very often neglected or forgotten.

— Another example of influence of poor consistency control is the variation in basis weight of the produced paper. As the paper machine is fed from a constant level box system giving a constant flow, changes in the stock consistency will change the amount of fibres to the paper machine headbox. This will change the basis weight. The variations in basis weight

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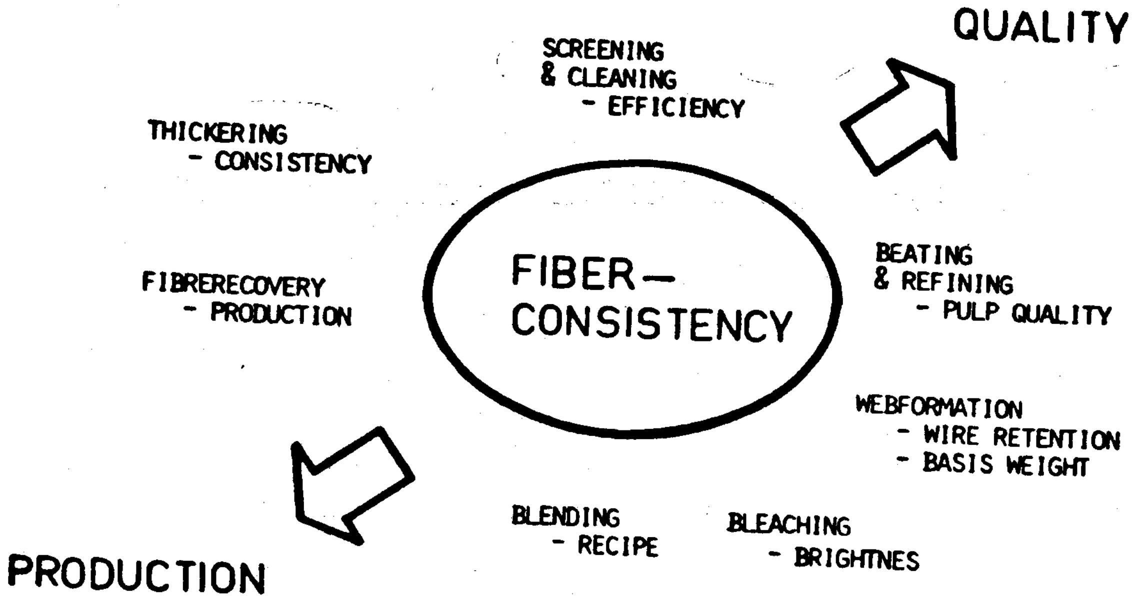

Fig. 1 Fibre consistency—an important process variable in pulp and paper processes

then influence the running of the machine and the quality of the paper. Many investigations for basis weight and moisture control systems have shown poor performance of the consistency control of the paper machine furnish.

— The result of bleaching of pulp depends on the dosage of bleaching chemicals. The dose is proportional to the flow of fibres into the bleaching tower. If the concentration of fibres varies the dosage does not correspond to the demand. A consistency control loop will decrease quality variations and simultaneously save bleaching chemicals.

— In the lower range of consistency below 1% of concentration one can stress the importance of good control of the consistency of the stock to the paper machine headbox. Even when a good control of the paper machine furnish is implemented, changes in the retention on the paper machine wire will cause basis weight changes.

— Screening of pulp is another process where consistency control is important as the best screening result is wanted at high throughput. The reject rate is very much depending on the inlet consistency as is the risk for clogging of the screen.

— A relatively new field is environmental control. Fibres over a certain level of concentration in effluents are no longer tolerated by the water authorities. Also with shortage of fibres becoming more pronounced outlets from processes must be better managed. In these cases the primary demand is a reliable measuring instrument for supplying information for better control.

These are just some examples of the demand for consistency measurement. The list is easily extended. It should be fully understood that no short-cuts exist to by-pass this measurement if one looks for good process control.

THE MEASUREMENT OF CONSISTENCY

Consistency is defined as the dry fibre content per litre of suspension, which is the concentration of fibres. No one has yet been able to supply a transmitter for industrial use that is directly operating according to the definition. It is only possible to follow the procedure for true concentration measurement in the laboratory. Therefore all existing consistency transmitters have to be calibrated as they are operating on some indirect method of measurement.

The principle of operation could be according to :

— measurement of shear forces on a float, fig. 2, wall or other surface wetted by the fibre suspension.

These are the very oldest consistency regulators, operating in an open box in a sample line. The sample line gives slow response and insufficient control.

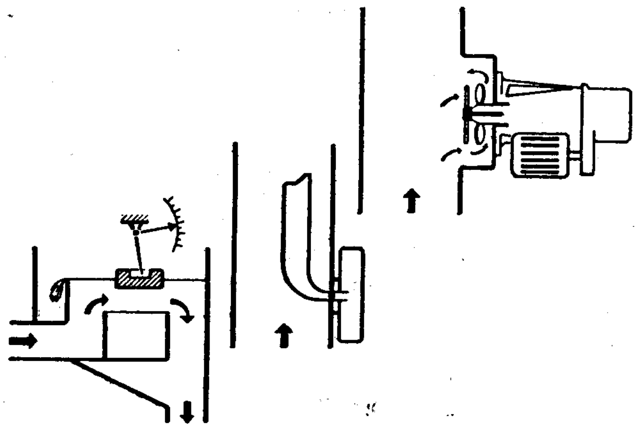

Fig. 2 Types of consistency transmitters

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— measurement of fibre network strength by use of a fix sensor or rotating sensor mounted in-line, fig. 2.

By this operating principle the main drawback with mounting off-line is avoided. The response is much faster. However, special care must be taken not to have a flow metering device. The fix sensor in the main stream is most flow sensitive and only usable in a norrow range of flow. The rotating sensor rotates or is arranged so that the velocity component from the process flow is minimized.

These two methods for industrial consistency measurement rely on the relationship between shear force or network strength and fibre concentration, fig. 3. In practice these will operate down to approximately 1% of consistency. Below this level the sensitivity will be low approaching zero. The measurements are also sensitive to the properties of the pulp as it consists of long or short fibres, chemical or mechanical pulp, degree of refining, temperature of water, filler content and pH-value. The influence from such secondary factors on the consistency measurement is for Eur-Control's in-line transmitter smaller than +—0.1% fibre consistency in the normal variation range.

Other principles are :

— measursment of the dampening of ultrasonic waves when passing through a fibre suspension, fig. 4.

Some instruments are in operation, but changes in the air content in the stock will disturb the measurement. The principle has found limited application.

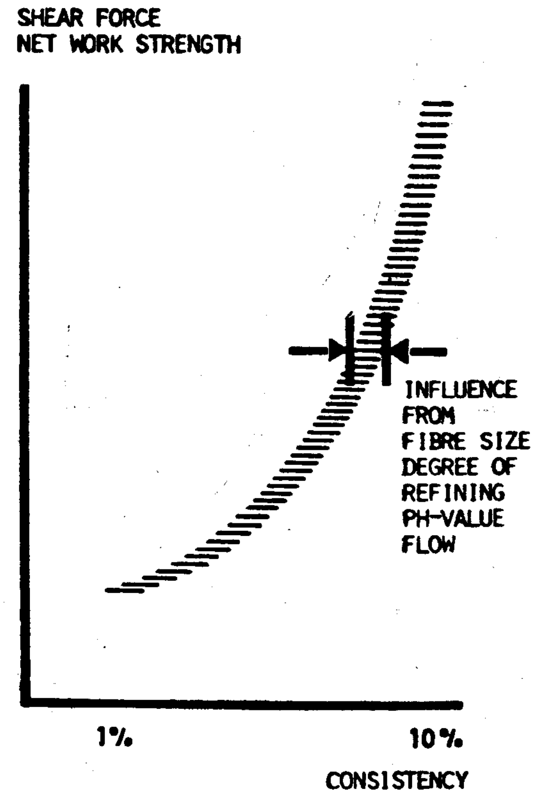

Fig. 3 Operating principle for consistency transmitters in a range 1-10% consistency.

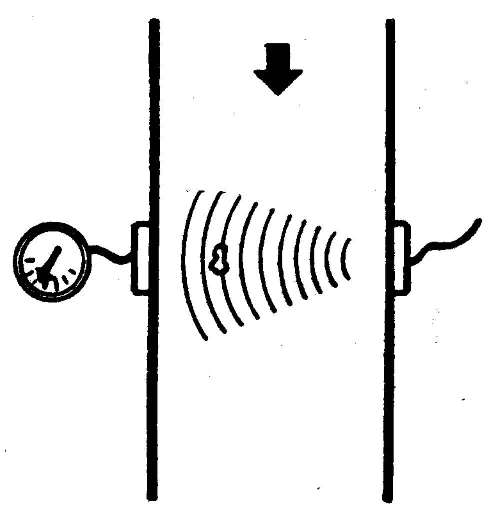

Fig. 4 Ultrasonics for consistency measurement

— measurement of transmitted light, fig. 5. For measurements in the lower range of consistency optical methods are used.

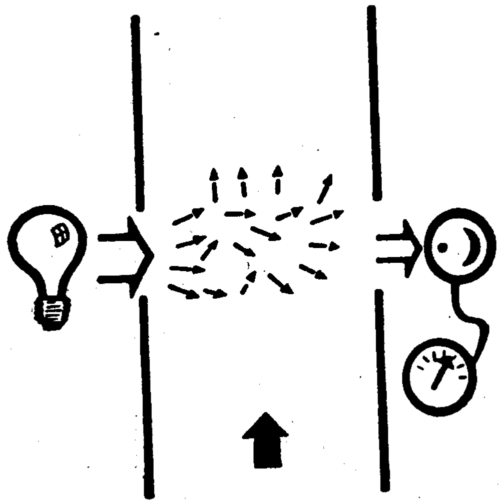

Fig. 5 Optical methods for the consistency range below 1%

The first instrument adopted by the pulp and paper industry was developed by the Norwegian Forest Research Institute and presented ten years ago. It operates according to the fact that a cellulose fibre is optically active and rotates polarized light. This type of instrument must be installed in a sample line as the suspension has to flow through a chamber made of glass.

EUR-CONTROL CONSISTENCY TRANSMITTER PROGRAM

Eur-Control covers the whole consistency range from 0%-16% with three transmitters, fig. 6.

— **MFK/MPK 2000, In-line Consistency Transmitter**, fig. 7.

operating from 0.8% to 16% of consistency. The operating principle is well known. A propeller continuously feeds a rotating sensor with fresh pulp, fig. 8. The propeller and the sensor are driven by a motor and rotate at the same speed. The fibres create a torque on the sensor as it cuts through the fibre network. The torque gives an angular lag between the propeller and sensor shafts as they are connected by a flexible rubber coupling. The lag is measured by a digital cogwheel system and converted to a voltage.

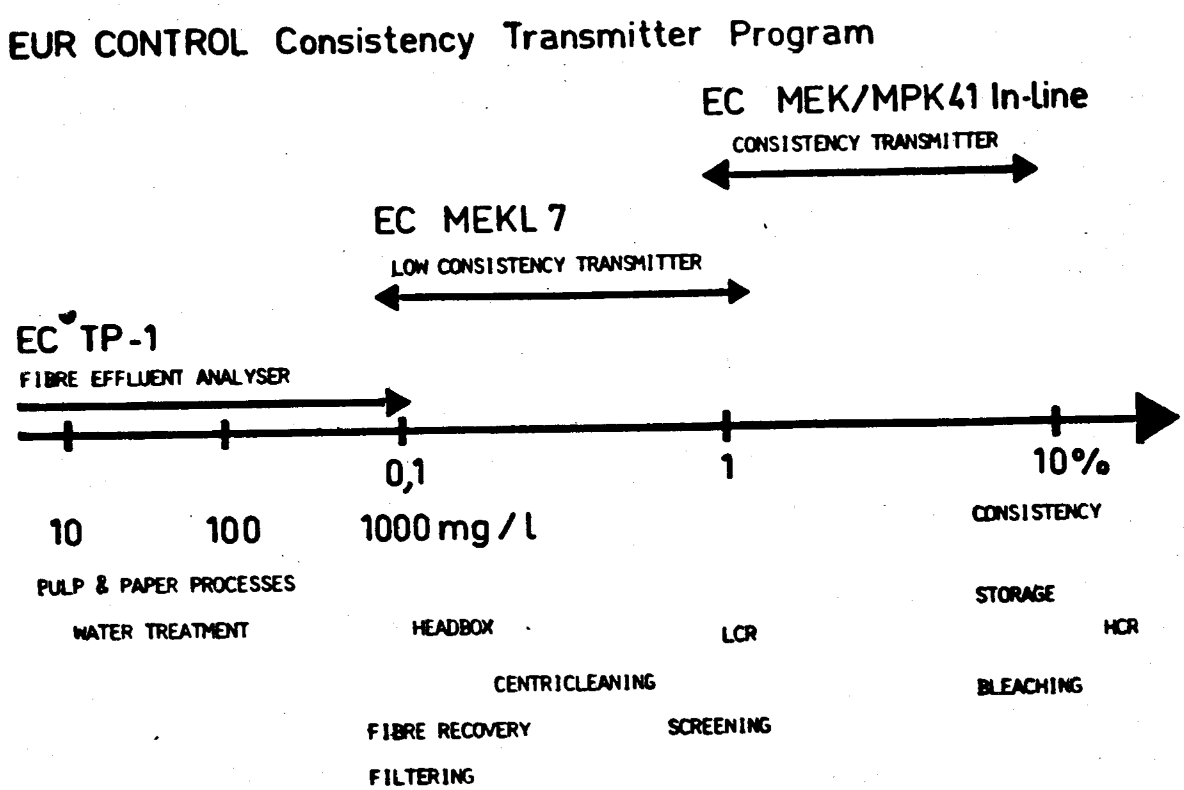

Fig. 6 Eur-Control Consistency Transmitter Program

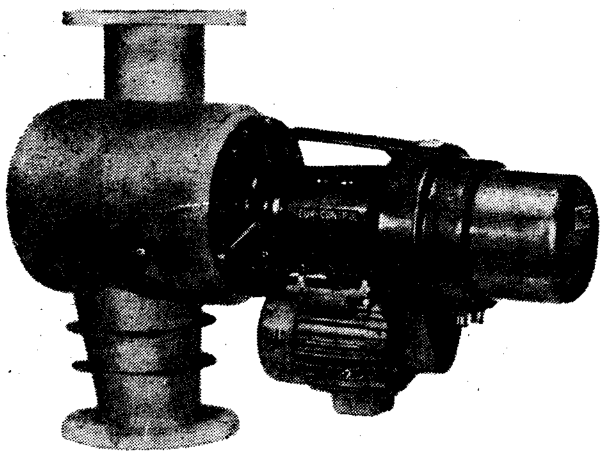

Fig. 7 In-line Consistency Transmitter Eur-Control MEK 2000

An amplifier produces an output current to two feedback coils, which by a magnetized force turn the sensor shaft back to zero position. Thus balancing the torque continuously, a feedback current directly proportional to the consistency of the stock is obtained. The transmitter is very sensitive. An output unit gives a standard 0/4-20mA output signal.

The pneumatic model operates on the same measuring principle. There is, however, a rotating pneumatic force balance system that counteracts the shear force torque. 3-15 psi is output signal standard.

In order to cover the consistency range from 0.85 to 16% for all kinds of pulp with high sensitivity a set of sensors is available, fig. 9.

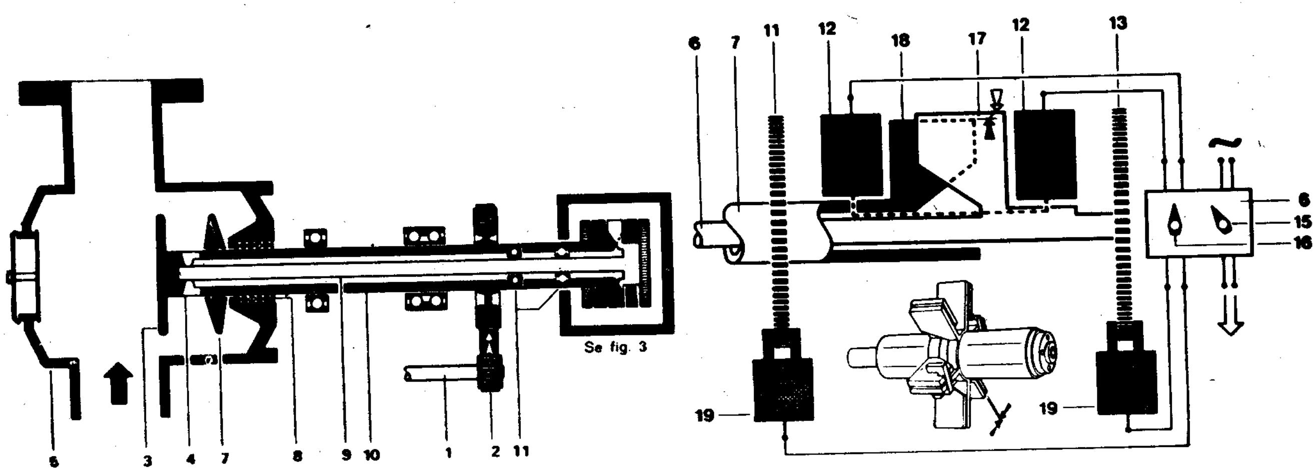

Fig. 8a Operating principle Eur-Control MEK 2000

1. Electric motor
2. Gear belt transmission
3. Sensor
4. Elastic seal for measuring shaft
5. Measuring vessel
6. Amplifier
7. Propeller
8. Stuffing box/mechanical seal
9. Measuring shaft
10. Drive shaft
11. Ball bearing
12. Feedback coils
13. Cog wheel on measuring shaft
14. Cog wheel on drive shaft
15. Potentiometer "span"
16. Potentiometer "zero"
17. Wing on measuring shaft
18. Wing on drive shaft
19. Optical sensors for angle difference between the cog wheels.

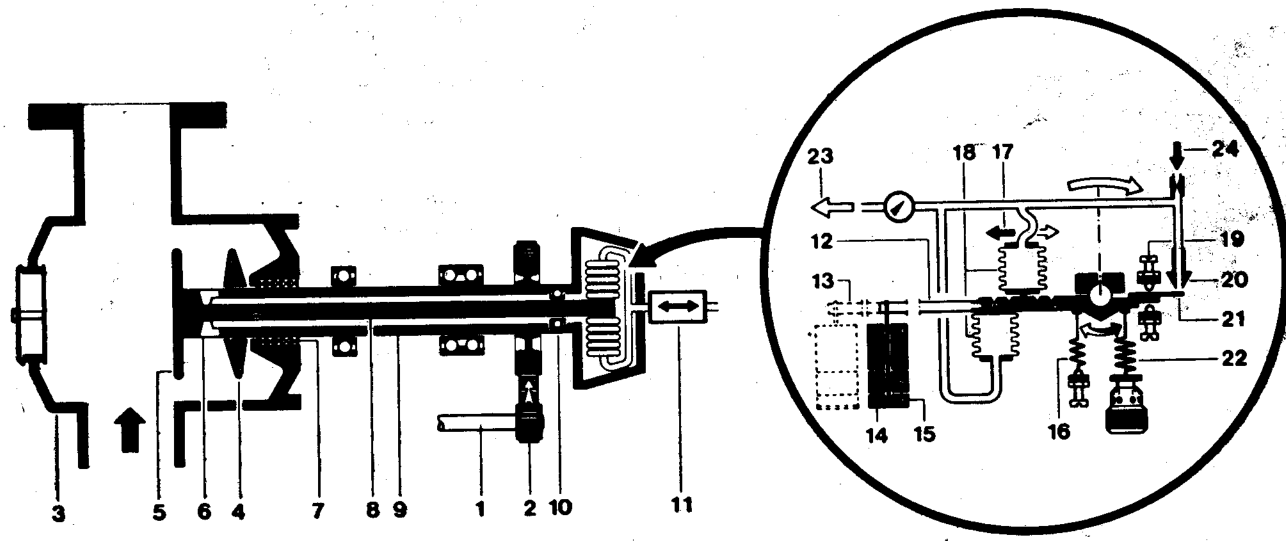

Fig. 8b MKP 2000 principle

1. Electric motor shaft
2. Belt gear
3. Measuring vessel
4. Propeller
5. Sensing element
6. Rubber torque coupling between drive and measuring shafts
7. Stuffing box/mechancical seal
8. Measuring shaft
9. Drive shaft
10. Radial ball bearing
11. Signal tranmission
12. 15. Set of weights for calibration check
16. Basic adjustment spring
17. Bellows adjustment
18. Feedback bellows
19. Mechanical stop
20. Air nozzle
21. Flapper
22. Zero adjustment spring
23. Output signal
24. Driving air

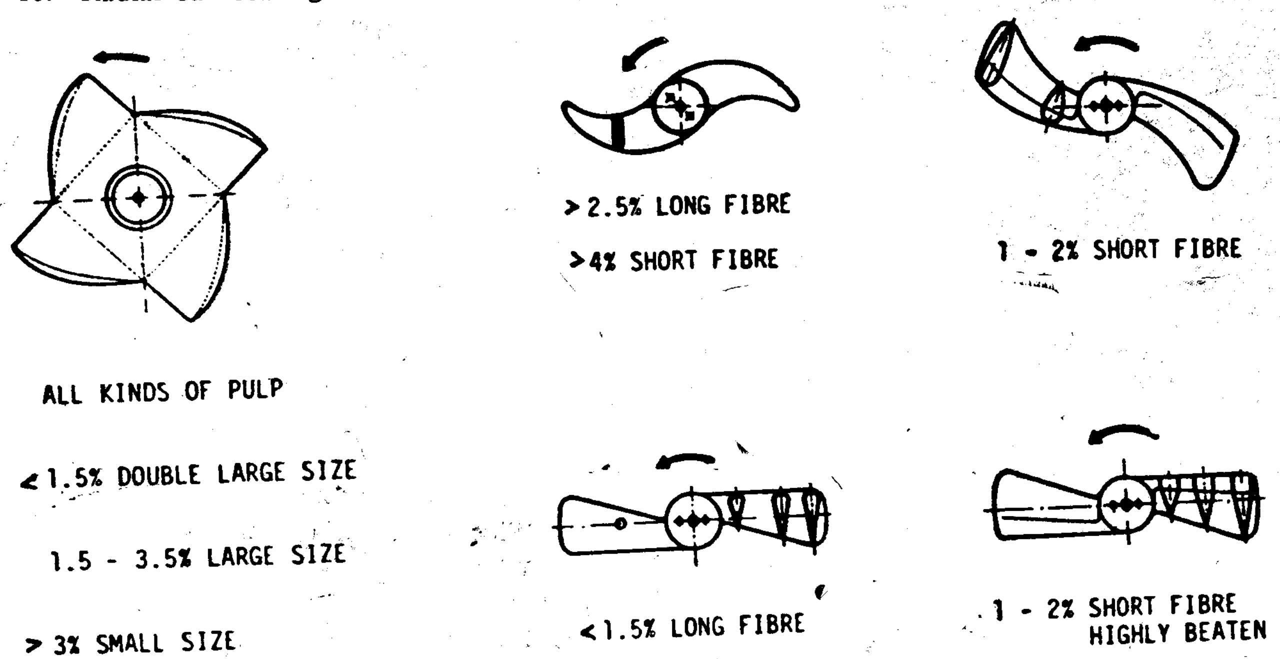

Fig. 9 Different sensors for optimum sensitivity

Typical data :

Operating range :	0.8-16% consistency
Measuring span :	Recommended min. 1% max. 5%
Measuring sensitivity :	A sensitivity of 0.01% or 0,005% consistency for MPK 2000 respectively MEK 2000 is obtained when process conditions are controlled.

The lower limit of the operating range for the shear force measuring principle depends on the kind of pulp but 0.8% has proved to be the lowest practical operating setpoint. For the medium low range going downwards from 1% of consistency, Eur-Control recommends :

MEKL 7, Low Consistency Transmitter, fig. 10

Developed by the Norwegian Forest Research Institute and manufactured by Eur-Control in Sweden, operates according to the depolarisation property of the cellulose fibre.

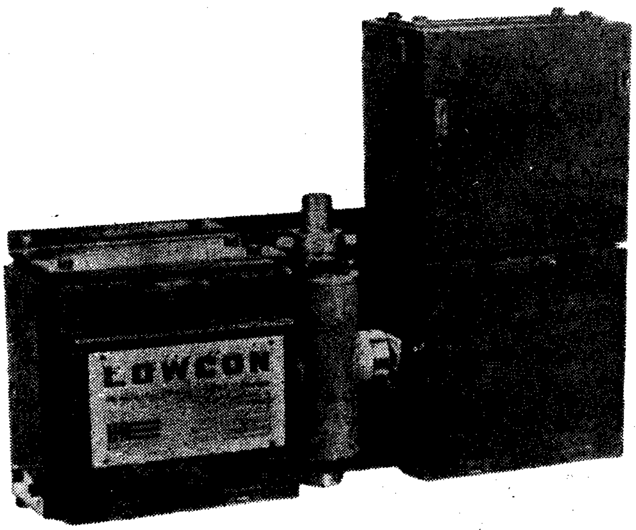

Fig. 10 Low consistency transmitter Eur-Control MEKL 7

A by-pass from the process line is fed through a measuring cell made of glass, fig. 11. Perpendicular to the flow in the cell a light beam generated by a halogen lamp passes a polarisation filter before entering into the cell. The transmitted light passes a second polarisation filter before it is focused on a photo detector. The two filters are turned at 90°, optical angle to each other. When water with no fibres passes the cell no light is transmitted through the second filter. When fibres are present the polarisation angle after the first cell is turned out of 90° and the light will

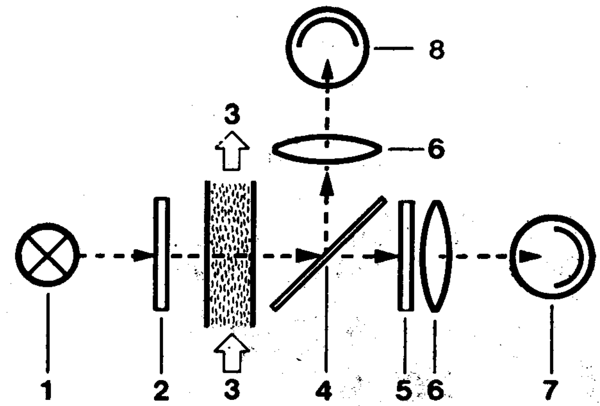

Fig. 11 Operating principle Eur-Control MEKL 7 "Lowcon"

1. Lamp
2. 1st polarisation
3. Measuring cell
4. Beam splitter
5. 2nd polarisation filter
6. Lens
7. Measuring photo cell
8. Reference photo cell

pass through the second filter. The intensity of transmission depends on the amount of fibres in the cell, which is equal to the concentration of the fibres. By splitting the beam before the second polarisation filter and mesuring the intensity of that beam a compensation for colour variations and different absorption is obtained. The ratio between the measured signal passing the two filters and the reference signal gives an output that is linear to the amount of fibres, i.e. consistency. An output unit delivers a standard output signal 0/4-20 mA or 0-10 V.

As a result of many years of experience with this type of measurement, Eur-Control is now supplying a low consistency transmitter with good reliability. Much effort has been put into the construction of the measuring cell to prohibit wear and clogging. Although this is an optical transmitter, influence from air in the pulp in very low. Installed units have proved, the influence to be neglectible. The transmitter is also almost insensitive to fibre dimensions and the degree of refining. No specific flow loop is needed as the measurement is not influenced by flow in a relatively broad range.

Typical data :

Operating range :	0.1-1% consistency
Smallest measuring span :	0.1% consistency
Measuring sensitivity :	Better than 1.5% of measured value, when operating on steady

secondary factors such as clay, fibre length distribution and temperature.

OPTICON

Eur-Control's vast experience with optical measuring systems and transmitters, e.g. for BDT measurement, flow measurement brightness measurement etc. led, late 1982, to the introduction of a new optical consistency transmitter–the OPTICON.

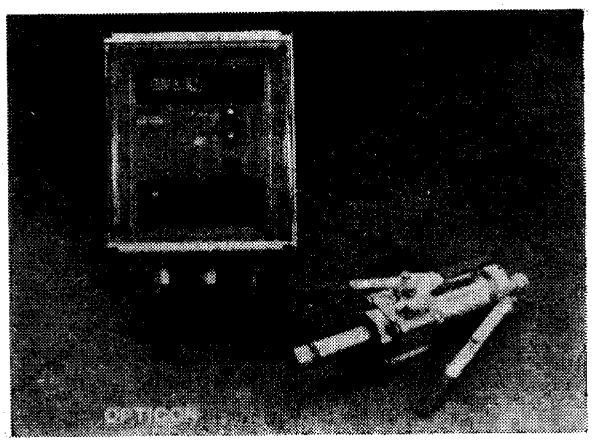

Fig. 12 Opticon

The OPTICON is an in-line transmitter, measuring the consistency of pulp in a moving stream. It is designed as a rugged utility instrument to complement other Eur-Control consistency transmitters, such as the rotating shear force transmitter M/K 2000 The OPTICON covers a consistency range from approximately 0.5 to 7%.

The instrument consists of the measuring probe and a separate electronics enclosure. The Probe can be inserted into the pulp stream through a ball valve assembly. With this arrangement the sensing probe can be taken out and installed without stopping the pump or any other disturbance in the process.

The tip of the probe contains a light source (LED) and two photo elements. The LED transmits a monochromatic pulsed infra-red light beam through a quartz window into the pulp flow. The extent that this beam is able to penetrate the mesh of the pulp fibres is related to the optical cross-section and density of the pulp fibres. Consistency is then measured by determining the ratio of the scattered light intensity at discretely defined locations.

The paths of the light beam from the source to that of the light reflected back to the detectors

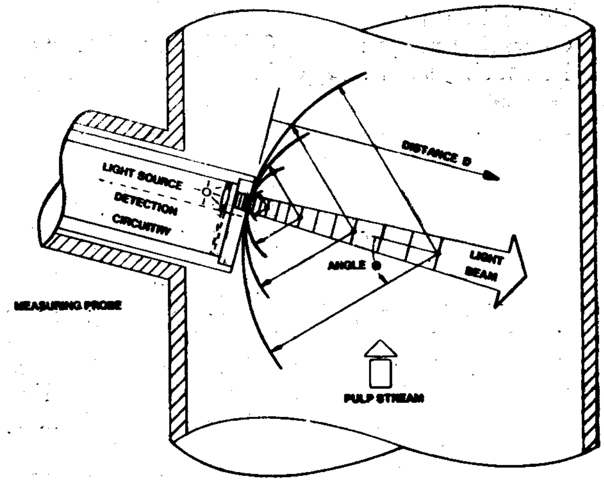

Fig. 13 Operating principle Eur-Control Opticon

are arranged, in such a way as to make the measurement insensitive to contamination build-up on the window.

If and when the quartz window gets contaminated, and alarm is triggered and indicated on the display of the electronics enclosure.

All optical devices that measure the scattering or reflection amplitude are sensitive to the optical cross-section of the fibres. The readings are thus somewhat more sensitive to different pulp grades compared to measurements based on shear forces.

Some of the salient features of this new optical consistency transmitter are:

- no moving parts or components–no maintenance costs
- insensitive to flow variations
- probe can be removed without shutting down the process line
- linear output signal 1–5% consistency.

INSTALLATION OF A CONSISTENCY TRANSMITTER

A sensitive and accurate consistency transmitter does not automatically guarantee a complete success. Incorrect installation of the transmitter can completely ruin the measurement.

1 Time lag from dilution water inlet to point of measurement

This was earlier a question of in-line versus off-line transmitters. Due to the fact that a long time lag will give a slow response for the control loop it is recommended to install an in-line transmitter, fig. 14. By this the lag from the dilution water inlet to the measurement will only be a few seconds. The lag is determined by flow and transportation length from water inlet to measurement. Having arranged a fast response makes it easier to damp the uncontrolled fast variations with smaller, but still well agitated chests or mixing volumes. Remembering that it is impossible to control variations faster than the time lag (including the response of the tranmsitter) it is recommended to install the transmitter very close to the dilution water inlet and have the consistency control followed by a chest for dumping the very fast consistency variations. Generally make the time lag short.

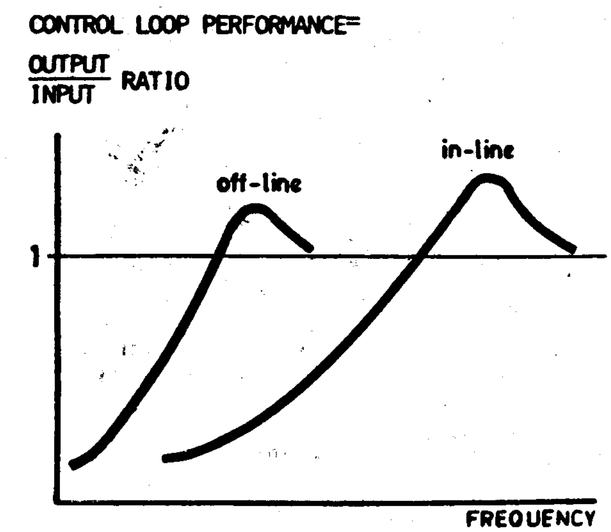

Fig. 14 Short time lag improves frequency response of the consistency control loop.

2 Stock flow conditions

Dilution water is commonly added before a pump to obtain a good mixing between the water and the stock. The transmitter is then installed after the pump. But at what distance ? Too close will give disturbances and too far away will give a slow control action. For Eur-Control's transmitter MPK/MEK 2000 it generally does not matter if the flow at the position of the transmitter is a plug flow or a turbulent flow as long as the propeller can supply the sensor with stock. This gives an operating range of 0.5–4 m/sec. for the velocity of the flow.

A stratification of the flow occurs very often at pump discharge. This means that a fraction of the flow moves faster causing an inhomogeneous consistency in the cross line section. Sometimes a jet is formed, pendling from one side to the other The same phenomena will also occur after a pipe bend or partly closed valve,

Different design of pump discharge demands shorter or longer straight line after the pump, fig. 15. Most severe disturbances would be caused by a pump with unsymmetrical discharge, giving the stock flow an angular direction to the process line, fig. 15c. The symmetrical conical discharge comes next. After a pipe bend or a control valve the same straight pipe length should be applied. If a shut-off valve is installed before the transmitter, this valv should be 100% open causing no flow obstructions.

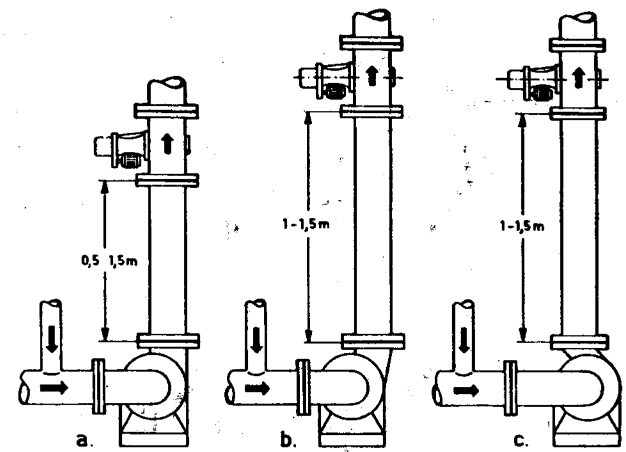

Fig. 15 Installation distance after pump discharge

3 Mixing of dilution water flow with stock flow.

A pump is often used to mix the dilution water with stock flow. However, the mixing effect by modern pumps is low as these are highly efficient with small losses from internal turbulence causing low mixing results. Insufficient mixing and water streams will cause flow stratification and momentary changes in consistency. Installation of Eur-Control inline-mixer[4] MIX 10, fig. 16, will improve mixing. It is designed for a capacity of mixing 360 t/day at a consistency level of 4%. With the in-line mixer it also becomes possible to completely move the dilution point away from the pump. Such an arrangement gives a new approach to many control problems. Eur-Control can here offer a complete Consistency Control Package with an in-line mixer, MIX 10, a dilution water valve, VBG 30, an in-line consistency transmitter, MEK/MPK 2000 and a sampling valve, VXKI. All equipment fitted to a 300 mm pipe, fig. 17.

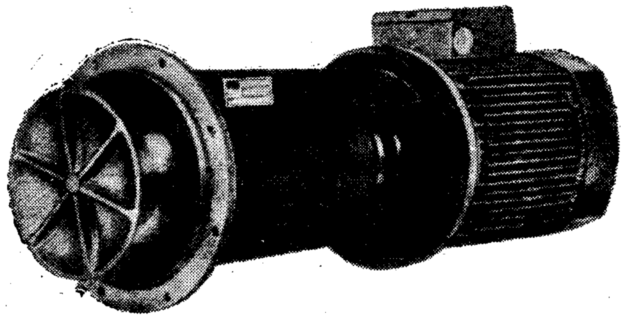

Fig. 16 In-line mixer Eur-Control MIX 11

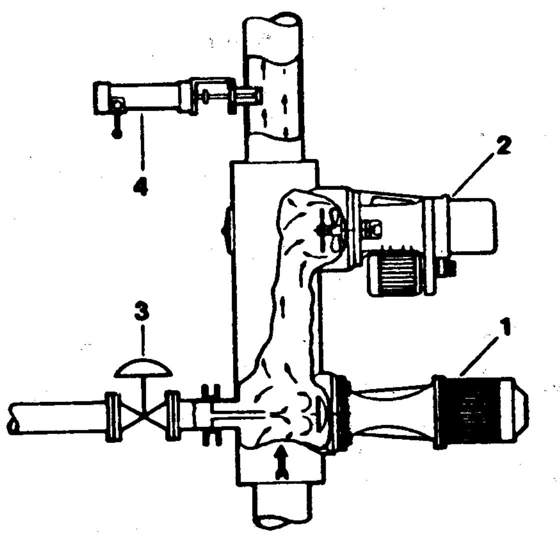

Fig. 17 Eur-Control Consistency Control Package

1. MIX 11 – in-line mixer
2. MEK/MPK 2000-in-line consistency transmitter
3. VBG 30 – ball sector valve
4. VXK2 – sampling valve

4 Well-agitated and homogeneous uncontrolled stock.

The uncontrolled stock is mostly coming from a chest, storage tower or pulper etc. To avoid upsets in the measurement and the control of consistency the stock should be agitated before it leaves the storage. When pulp is kept in a chest without agitation the fibres will separate from the water. This easily causes an outgoing stock with a consistency momentarily below the setpoint for the control. When that happens, control at the setpoint is impossible. If it is difficult to arrange for agitation in the storage an in-line mixer before the pump would be the solution to this problem.

5 When installing the transmitter in a horizontal line air pockets should be avoided. The air will leave the pocket when flow or line pressure change. Partly filled cross section of the line will cause disturbance in the measuring conditions.

THE LEVEL OF CONSISTENCY

Sometimes the consistency transmitter will not suit its intended application. The best trans- mitter should be chosen for the actual application giving optimum sensitivity to consistency. The number of transmitters depends on the dilution step and minimum there will always be two transmitters. The first one controlling the slow variations in consistency, emanating from different origin as raw materials change, changed condition for running of the process etc. This first control sometimes is a coarse control step and the dilution could be large. The second step will then control the faster variations caused by momentary upsets in the process.

The dilution step depends on the original consistency level e.g. having a pulper running at 9% and followed by a refiner running at 4% of consistency it is recommended first to control at a dilution step of approximately 40% giving a controlled level roughly at 5.2% of consistency. The next step will be taken to 4% of consistency with a dilution step of approximately 20%. Fig. 18 demonstrates this example.

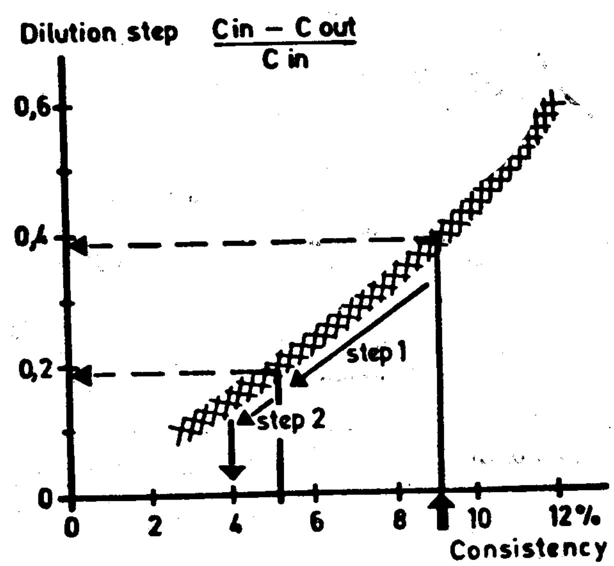

Fig. 18 Size of dilution step

By such stepping down from a high level the best sensitivity for the measurement will be obtained.

By considering these points the best conditions for the consistency control will be achieved.

THE CONTROL VALVE AND DILUTION WATER SUPPLY

Designing the control loop involves choice of proper dilution water valve (5). Consider :

—valve characteristics
—installed valve characteristics
—available pressure drop over the valve should not be lower than 0.5 bar
—dilution water flow range and production range

The Eur-Control VBG 30, fig. 19, is a ball sector valve, designed to fit into most consistency control loops even under very stressed process conditions.

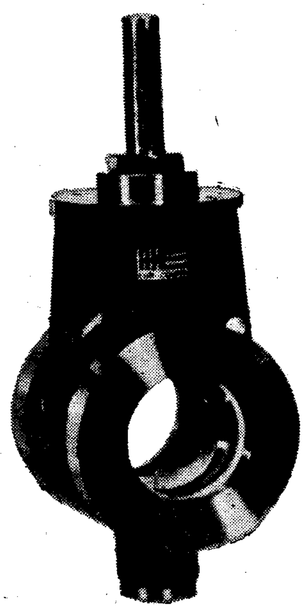

Fig. 19 Ball sector valve Eur-Control VBG 30

Very often the installed control valve is too large. This gives bad performance of the valve in the low flow region and sometimes even on-off control is the result. When oversizing depends on too optimistic a production rate it is better to change the valve rather than wait for the production increase.

Another very important factor is the capacity of the water supply. A pressure drop in the supply line caused by an external source will immediately upset the consistency. Water supply pressure should be kept steady. Many times a pressure control will prohibit unpredictable disturbances. Steady pressure seems quite obvious but this is often forgotten.

When the dilution water is added to the process line between a chest and a pump, fig. 20, it is generally recommended to :

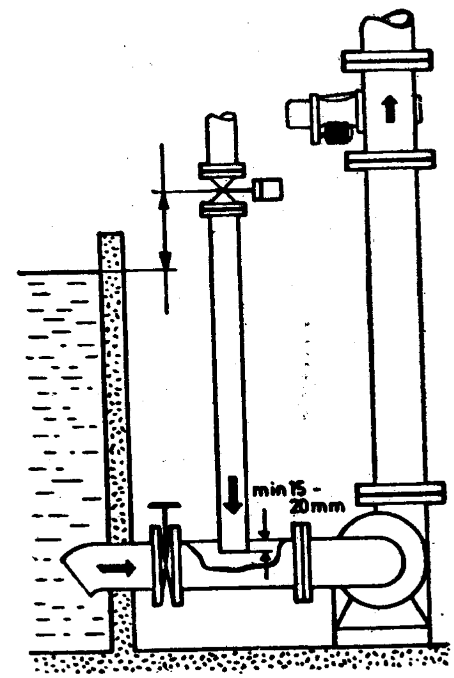

Fig. 20 Installation of control valve and water inject

— have the waterpipe penetrating minimum 15-20 mm into the main pipe. This will prevent air from entering the water pipe If air should collect underneath the valve body the flow control will be servely disturbed.
— install the valve at a higher positioner than the highest level in the chest. This will remove the risk for clogging of the control valve at a process shut-down or when water pressure is lost. If such an installation of the valve is difficult to realize it is recommended to arrange for flushing of the valve by water.

THE OPTIMUM DILUTION STEP

In consistency measurement and control there is often the question of the optimum dilution step. In the normal consistency control range of 3-4% a rule of thumb says : "never dilute more than 20%". Is this the optimum? At least it is a figure to start with.

The optimum dilution step is the point where the performance of the complete control loop is at maximum and giving minimum consistency variations remaining after the control, loop fig. 21.

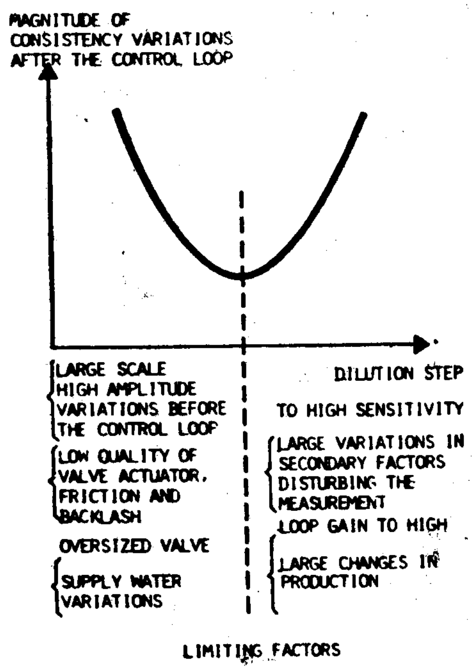

Fig. 21 The optimum dilution step

When controlling at optimum a small deviation from the setpoint will increase the magnitude of the variations in controlled stock. Consistency depending on disturbances in the uncontrolled stock. The distrubances could emanate from inhomogeneous stock, low performance of preceding consistency control loop, insufficient mixing of dilution water with stock etc. A low quality valve actuator with high friction and backlash will increase variations when the step is decreased. An oversized valve will also give the same result.

If the dilution step is increased from optimum the high measuring sensitivity will give two effects. a) Total loop gain will be too high—causing a cycling loop and b) influence from secondary factors such as degree of refining' recipe etc., will cause an increased offset. If the production range is large an increase in the step will lower the overall performance of the consistency control loop.

As all the factors above will depend on the individual installation the optimum step will be different for different cases. However, when designing the consistency control loop the rule—dilution step approximately 20%—and indication in fig. 18 could be applied. The dependence of many factors makes it difficult to give a figure that is optimal in every installation.

CONSISTENCY—ITS MEASUREMENT AND CONTROL

This is an expose over Eur-Control Consistency Transmitter Program as well as of the measurement and control of fibre consistency in pulp flows.

Generally the fundamental measuring principle has remained unchanged for half a century. Still indirect measurement of the weight of fibres, i.e. concentration of fibres in the process flow is dominating. As for all indirect measurement secondary factors will give disturbances. However development and continuous improvements of the transmitter's function has minimized the influence from disturbances. The result is accurate and reliable instruments. Accuracy and reliability are two fundamental properties in today's highly rationalized processes. However, installing a consistency transmitter does not entirely guarantee a solution to a consistency control problem. The measuring objective as well as the control objective has to be considered. control loops for other process variables matters regarding the performance of the overall process control. This means that when setting a target for a consistency controller this should be done in view of targets and results for other loops, controlling the process.