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MONITORING TO CONTROL EFFLUENTS

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Abstract—The paper discusses general aspects on "monitoring to control effluents" and tries to out-line how environmental monitoring and control in industry should be regarded as part of a total control system. Some of the problems involved are pointed out. The importance of rapid, internal actions when process disturbances occur is stressed, and the characterization of effluents is considered a critical problem together with sensor developments. The connection between production control and environmental care is briefly discussed. Finally, two projects on environmental measurement systems are mentioned. The first of these has been carried out and the second is in its planning stages on an internordic basis.

INTRODUCTION

The scope implied by the title of this paper is indeed wide. The organizing committee desired that the paper should discuss recent developments regarding monitoring to control effluents, and those to be expected within a predictable future. Further, the paper should have the character of a survey.

I would like initially to remark that the opinions I express in this paper are my own. I do think, however, that the paper should fairly well indicate the lines along which the Swedish Forest Products Industry is discussing these matters today.

The major part of this conference has been devoted to pollution abatement through improved process technology. This is no doubt the most effective means of reducing the emission to air and water. However, the application of improved measurement and control techniques can make a major contribution to ease the load on the environment. So it is indeed pertinent to have a special session on the monitoring to control effluents.

You represent many different countries from different parts of the world, and with considerable differences in local conditions. You also represent different types of industries—chemical industries, metal industries, pulp and paper industries, food industries etc. There are certainly problems in common, but each industry also has its special problems. So I have decided to give some general views on "monitoring to control effluents" with the hope that the subsequent discussion papers will illustrate some of the points and supply details.

The paper will discuss the role of environmental monitoring in industry and try to indicate how it ought to be part of an integrated control system. I will try to point at some of the difficulties that exist within this area. It is very easy to say that we should measure and control effluents—it is much harder to carry that through, especially where costs have to stay within reasonable bounds.

The data used in this paper originate from the Swedish Forest Products Industry, which is a major polluter in Sweden. Figure 1, which is probably familiar to you, indicates this situation. Much has been done (as is evident from the graph) regarding pollution abatement within this industry. A special session at the conference has discussed aspects of this. Another excuse for sticking to my own industry is that I believe that the Swedish Forest Products Industry represents fairly advanced thinking as regards environmental monitoring and control. As will be described at the end of the paper we are also planning a big project together with Finland and Norway, which will carry our knowledge even further.

The words "monitoring" and "control", which are the key words in the title of the paper, identify the two major aspects of my subject, namely

(i) measurements for the purpose of internal control actions, e.g. when disturbances occur, with the purpose of reducing effluents through rapid feed-back of information.

(ii) measurements to record the amount of effluents leaving an industrial plant, mainly for reporting to authorities.

I shall thus regard measurement of recipient conditions as largely outside the scope of this paper.

There is no doubt in my mind that internal measurements and control actions (i), is the most interesting aspect. This is the only way environmental measurements can contribute actively to both ease the load on the environment and at the same time increase the efficiency of production. The connection between in-plant control and emission control that this discussion implies may by some be regarded with suspicion. "Authorities should keep themselves outside the fence". This is a valid principle, but I suspect industry itself has to show that the authorities can remain outside with confidence.

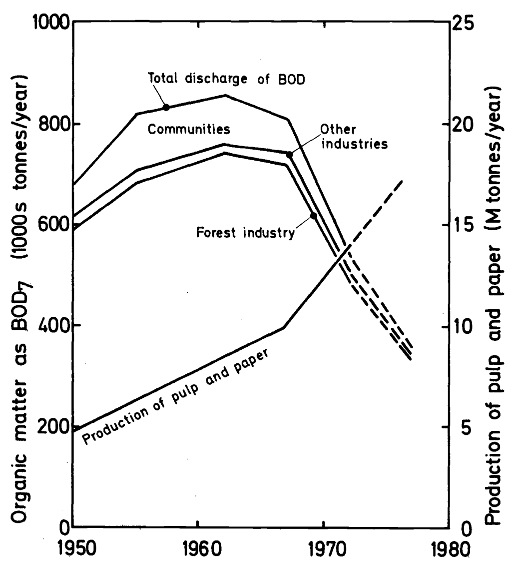

Fig. 1. The emission in Sweden of organic matter from different sources, measured as BOD_7 as a function of time. The large contribution from the forest industry is evident. Also included is the development of the production capacity of pulp and paper in Sweden. (Source: The SSVL environmental care project, Technical Summary, 1974).

Another point I would like to make is that environmental care and environmental control should not be regarded as something special and apart from the production system. Environmental control can and should in my opinion be considered as an integral part of the overall control system for the industrial plant.

So, monitoring to control effluents should be a lot more than just measuring at the point of emission and reporting data to authorities.

"NORMAL" AND "TEMPORARY" DISCHARGES OF POLLUTANTS

An industrial plant is represented by a normal condition when processes are operating in the intended fashion. In this situation the emissions to the recipient will stay at a fairly stable level. This represents the normal discharges. In all process industries there will, however, be disturbances. They may be due to manual mistakes, equipment failure, stops for maintenance etc. Under these conditions there is always a risk of accidental or temporary discharges. Hopefully these will be coped with before they reach the recipient.

The temporary discharges are highly unwanted. They can give rise to uneven running conditions in both the production and effluent treatment facilities and there is a risk that valuable chemicals are lost. In the forest products industry we could for example have an overflow of water containing wood fibres. These fibres have lost most of their value even if they are recovered from a sedimentation lagoon.

In the past, the normal process losses were often much larger than they are today and relatively little attention was perhaps paid to the temporary discharges. Today the total emissions have been cut considerably as is evident from Fig. 1. These improvements have been achieved mostly by cutting the normal process losses, e.g. by system closure and effluent treatment facilities. This means that the temporary discharges have increased in relative importance and they will continue to do so.

Let us look at some rough numbers. In 1972, in the Swedish Pulp and Paper Industry as a whole, between 30–50% of emitted chemicals and fibres were due to temporary discharges. Another important finding at that time was that the temporary discharges often had very short durations. A significant fraction of them, perhaps 50%, had durations less than one hour. When it comes to the design of a monitoring system, these are very important factors to consider.

This point is perhaps almost dramatically demonstrated in Fig. 2. The figure displays the variation in fibre content in the collected effluent from a sulphate pulp mill before external treatment. We can distinguish what could be called a normal level of emission, and also a lot of temporary discharges. I believe that for a pulp mill this is a fairly typical picture. One finds that in this particular case 70% of the fibre content is due to temporary discharges. The recording also indicates the need for rapid information, if one wants to do something to retain these fibres in the process. Many of the peaks are undoubtedly small and they are so rapid that it is of course not possible to do anything about them. In the case of the larger peaks, however, we found that their cause could be traced and actions initiated to cut them down. Here valuable virgin fibres could otherwise have been lost.

THE OBJECT AND THE PROBLEMS

Let us now consider the three types of environmental measurements that can be of interest to us:

(i) in-plant measurements
(ii) measurement of effluents
(iii) measurement of recipient conditions.

These measurements can form the basis (1) for actions inside the plant, and (2) for reports to authorities. What is then needed to fulfill these two tasks and what are the problems? In discussing these questions I take the liberty to leave-out recipient measurements.

In order to perform the effluent control we need:

1. A description of the effluents; that is what substances they contain.

2. A relevant way of characterizing these effluents; that is what parameters should be used for measurement.

3. Knowledge of the information desired by authorities.

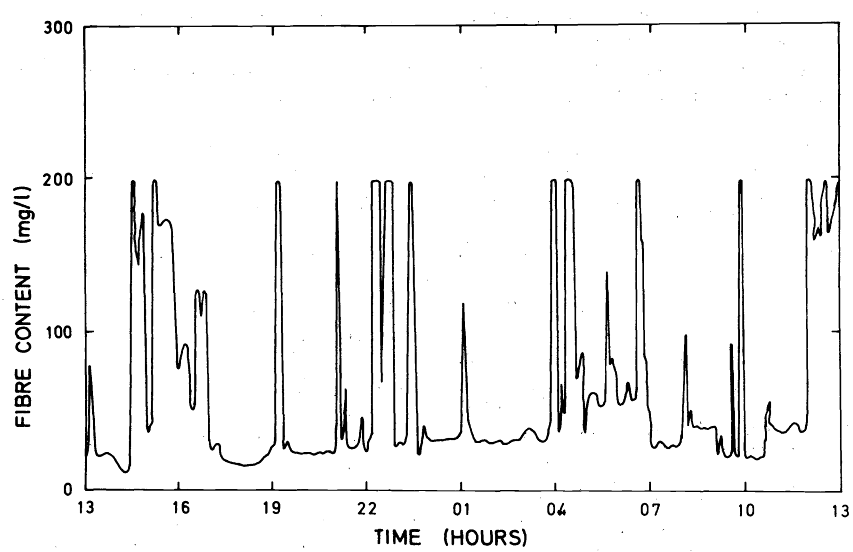

Fig. 2. Recording during a 24 hr period of the variation in the content of wood fibres in the collected effluent from a sulphate pulp mill. The result has been obtained at the inlet of a pre-sedimentation lagoon. The measurements have been made with a so called FIBERLOG instrument. The output signal has been limited at 200 mg/l.

4. Knowledge of measurement and of analytical techniques.

Inside the plant we need:

1. A description of internal streams.
2. Process knowledge.
3. Knowledge of measurement techniques.
4. Simple decision rules ("operators-guide").
5. Process control knowledge.
6. Production control knowledge (described later).

When these needs are fulfilled we know where to apply sensors and what to measure in the laboratory, we know the requirement on accuracy and sampling frequency, and what information should be extracted internally and externally. Thus an environmental measurement and information system is thereby defined.

Which are then the major problems? The development of sensors and analytical techniques is the major one. But the characterization of the effluents is also a great problem which I will discuss further. An essential problem is to keep the cost of the environmental measurements at a reasonable level. At present the manpower needed is often very large. A fourth problem is that of educating plant personnel.

Figure 3 schematically indicates the three types of environmental measurements:

(1) First we have the internal measurements, primarily close to the machinery. They essentially serve to give alarm so that rapid actions can be taken at distrubancies. One can very often use simple measurement techniques—for example measurement of level, temperature, conductivity. Some of the actions could be automatic.

(2) Secondly, measurements have to be made at points where effluents reach the recipient. Usually this is after some sort of external treatment facility and the delay time can be long.

(3) Measurements in the recipient should describe the status of the recipient—like dissolved oxygen content, pH. In most cases this is a matter of long term changes.

We don't have to perform measurements at all possible points in this scheme. This could be a frightening thought for those who have to pay for the investment. One has to evaluate in each case what is really needed and the most appropriate way of obtaining sufficient information. Measurements that create data that are not being used, are a waste of money and of human efforts.

We should look upon environmental measurements as part of an integrated system for the control of an industrial plant. This is also schematically indicated in Fig. 3. One can distinguish different levels in the decistion making process. These levels reflect the different time constants involved and they also reflect the cost-magnitude of the actions to be taken.

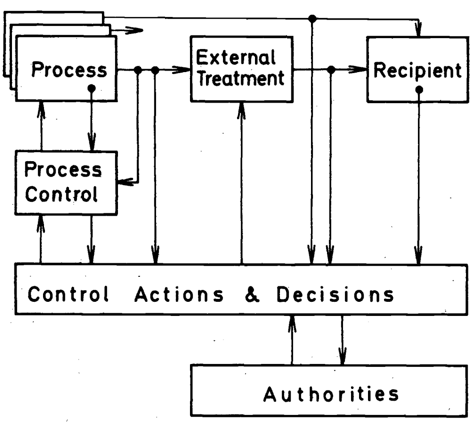

Fig. 3. Schematic picture indicating the different types of environmental measurements and their integration into a total concept.

When a process disturbance occurs, a "first aid" is needed. Here, flows can be automatically swiched over to tanks and treated separately, or the personnel rapidly initiates actions on the basis of very simple rules of the yes-or-no-type. This might not be sufficient and the operator has to interact with his process on the basis of process-knowledge. To his help he might have a computer-based process control system. In some cases this control system might be designed to initiate directly the proper changes itself. It is not unlikely, however, that the process control system is not designed to cope automatically with the type of situations that we discuss here.

It may occur that a disturbance persists for a longer time or that the running conditions of a process have to be changed significantly. If so, the interactions with neighbouring processes may have to be considered, so that production volume and product quality can be maintained. This is made easier with a production control system, something I will return to later.

Finally we may have feed-backs from authorities to plant-management. On may have noted that the conditions in the recipient have gradually improved or got worse which has longterm implications. Investments could be necessary.

If we look upon environmental measurement and control activities in the way I have outlined here, they do not differ from any other decision-making process concerning the industrial plant. I believe this is an advantage.

CHARACTERIZATION OF EFFLUENTS

We shall now further discuss general requirements on environmental measurements. After brief remarks concerning internal measurements and measurements in the recipient, we shall focus on what I believe is a critical problem, namely the principles after which effluents should be characterized.

For the internal measurements the requirements are easy to formulate. Any arrangement can be used that serves the purpose to indicate exceptional conditions. This is because we can utilize process knowledge. For example, increased conductivity can often in a unique way be associated with the increase in the amount of a specific chemical compound since there are no other compounds that can possibly contribute. A consequence of this approach is that measurements should be performed close to the processes before mixing with other streams. These monitors should preferably work continuously. What I have now described is a standard approach and quite self-evident. Still, it is along these lines that most progress will be made.

The measurements in the recipient represent a more difficult problem. It is obvious that one wants to describe recipient conditions in terms that are relevant to the biological life, and sometimes to recreational aspects. We have to accept that it is a complex problem to characterize recipient conditions. We shall probably not be able to express this in a detailed way by using a few parameters. I have been given the impression that there is a great deal of basic knowledge missing here despite extensive research. If we disregard the possibility of using living organisms as indicators of recipient conditions then we have to single out a limited number of parameters which together hopefully give a satisfactory description.

I shall now discuss the characterization of the emissions into the recipient, the effluents. One can, as I see it, adopt two entirely different policies. And one can also find others. The first approach is that one tries to characterize the emission directly in terms of its potential danger to the recipient. Determination of biological oxygen demand is the most well-known example of this philosophy. Another approach could be to characterize the emission in terms of reasonably well defined substances—for example emitted tons of wood fibres per month. From the points of view of developing instruments and analytical techniques, the choice of policy here is of course crucial since it will lead to quite different solutions.

With the second approach (which is not used at present) a translation has eventually to be made between the emission of a certain quantity of a substance and its environmental effects. In principle, industry should be able to leave this to the authorities. I am afraid, however, that authorities will seldom have the manpower to cope with this problem. An advantage with this approach would be, that the measurement system is not so dependent on a switch in the opinion as to what is environmentally dangerous.

Let me discuss in more detail only the first approach which is the most commonly used as I understand it, namely the one that tries to describe the effluent in terms of its effect on the recipient. I will take the situation within the pulp and paper industry as example. Whether there are similar problems in other industries I do not know.

In terms of water pollution a pulp and paper mill produces dissolved organic matter like carbohydrates and lignins. The latter are very resistant against decomposition and they are coloured brown. There is also colloid matter and solid particles of sizes from small fibre fragments in the micron range to entire wood fibres. There might also be filler materials, like china clay, from the papermaking process.

The approach one has taken (cf. Fig. 4) to characterize these emissions has been to say that they consume oxygen, they may affect the penetration of light, and they can settle on the bottom of the recipient. To quantify this we have got standardized laboratory methods to measure biological oxygen demand BOD, suspended solids, and colour. Without discussing these laboratory methods in detail, I will point out some of the weaknesses in the present situation.

First, in the suspended solids content there may well be components that also contribute to the oxygen demand. There are components that by scattering of light may affect the optical properties of the recipient and also fibres, which in fact do not remain suspended, but settle rather fast. So one wonders just what relevant information the suspended solids measurement gives.

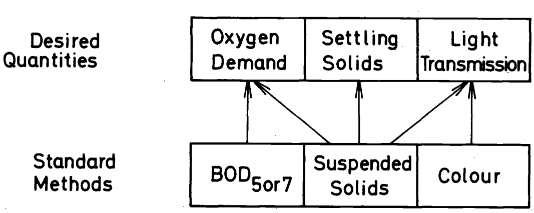

Fig. 4. Connection between desired quantities and standard methods for the characterization of effluents from pulp and paper mills.

Similarly it is not quite clear to one what relevant information the measurement of color gives. The colour parameter does not take light scattering into account. Perhaps it is used as an indirect measure of the brown-coloured lignins.

Regarding BOD, the 5- or 7-day analysis is only of histroical value. Another disturbing factor is that both the BOD-test and the suspended solids determination suffer from great uncertainties. This is outside my own field but I have been told that a good analyst can product almost any BOD value that one might like to have. I hope it is not quite true. I am afraid suspended solid values can also be varied within a fairly wide range. This situation is discouraging to all parties.

I think I have given sufficient arguments to show that the present situation is not at all satisfactory. The parameters we use are not mutually independent. There is therefore a need for studying alternative approaches that may lead to methods that are reproducible and possible to automate, perhaps even to perform with continuous instruments.

This is a major problem as regards progresss in environmental monitoring in the pulp and paper industry.

As a result of the slow and uncertain BOD-test one has instead tried to measure some other parameter, for example COD (chemical oxygen demand), or TOC (total organic carbon). It has been common to try to correlate these measurements with BOD values. Sometimes correlations are good, sometimes very poor. It is questionable whether one should try to find such correlations. Should we not instead accept that TOC, COD or some other similar analyses can give just as relevant a description of environmental effects as does BOD? There may in fact be situations where BOD is even a misleading parameter. As said before, it may be that this discussion is most relevant to the pulp and paper industry.

So far this paper has discussed the importance of process disturbancies. I have discussed measurement and control problems in a general sense, and I have tried to point at some of the problems involved. Of those we have discussed the characterization of effluents in more detail.

In the rest of the paper I shall try to point at the connection between production control and environmental care. Finally, I shall mention two projects on envinromental measurement systems in Sweden, the latter of which is in its planning stages.

PRODUCTION CONTROL AND ENVIRONMENTAL CARE

In a process industry there are often different departments with storage capacities in and between these departments. Such a configuration is depicted in Fig. 5, showing the layout of an integrated pulp and paper mill in Sweden. This is a complex system, and disturbancies can rather easily propagate through the system.

With production control we mean the establishment of good operating conditions in the plant as a whole, particularly when disturbancies occur. With good operating conditions we usually mean high production volume, but there are of course other aspects to consider. In general production control is a matter of proper coordination of the activities in the plant and a good use of the storage capacities. I will now try to indicate the interaction between production control and environmental care. As we have pointed out before, disturbancies and temporary discharges are often linked together. Further, production control needs information on the status in the

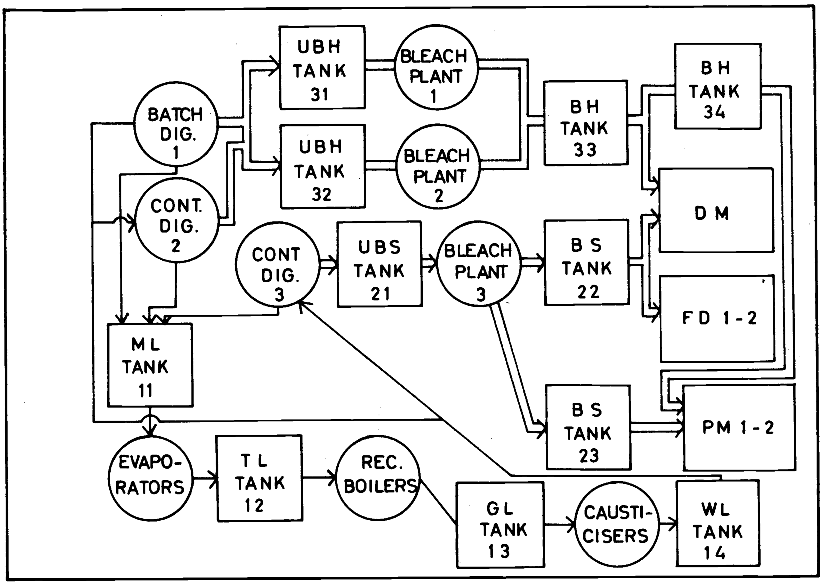

Fig. 5. Lay-out of an integrated pulp and paper mill, indicating the complexity of the system. Different departments are linked together by storage capacities.

plant and environmental measurements are part of that information.

The environmental implications of production control are:

(i) Since the storage capacities are entered as restrictions in a production control system, there should in principle under planned conditions be no possiblities for over-running storage tanks. In the Swedish pulp and paper industry this has been found to be the major cause of temporary discharges despite the fact that these storage tanks have level indicators.

(ii) The most important consequence of a production control system is that disturbancies can be taken care of with least possible consequences to the production volume. It is also possible in advance to evaluate the consequences of changes in the production system.

(iii) By using strategies that well utilize the storage capacities, the number of events when storage tanks are full, and thus represent a potential risk of overflow, can be reduced also when distrubances occur. It might also be worthwhile to investigate the benefit from increased storage capacities.

I believe that in larger process industries, like the pulp and paper industry, we will gradually see computer-based production control systems appear, although we do not yet know their final design. It is no doubt that environmental aspects will be tied into such systems.

EXPERIENCES FROM AN ENVIRONMENTAL MEASUREMENT SYSTEM

Within the "SSVL environmental care project" in Sweden a subproject was carried out at the Frövifors sulphate pulp mill in inland Sweden. The object was to build and gain experiences from a full scale computer-based measurement system. The main tasks of the system were to supply an indirect measure of the emissions from the mill, to give alarm signals in critical situations, to supervise sensors and to present information in an accessible way to mill management and operators.

The monitoring is carried out at four different levels. Each separate process is checked and each department is supervised as a single unit. The separate process effluents and the final effluent to the recipient are watched in the same way. The aim of the system is to give an alarm as soon as possible so that approriate action can be taken with a minimum of delay. These alarms are graded by the computer according to a previously chosen set of priorities. Some of the alarms must be acknowledged by the mill personnel.

Each morning the computer presents a report giving details of stoppage times for major equipment and mean values and standard deviations of the measurements from the various sensing devices. The report also includes laboratory data and finally a list of alarms during the previous twenty-four hour period. Communication with the computer takes place via two terminals, one in the control room and one in the laboratory. The system includes 50 digital and 40 analogue sensors, most of them of conventional type.

Those responsible for this system conclude after two years of experience that the dominating problem has been that of the sensors. Problems with corrosive and moist atmosphere, corrosive liquids, vibrations, transient over-voltages, inductive currents, foam and deposits were experienced. Although improvements were gradually obtained, it is concluded that much effort is still needed to apply this type of instrumentation to the environment of a pulp and paper mill. The amount of maintenance is relatively high. This illustrates that the development of better instrumentation is a critical problem in the monitoring of effluents.

The most positive experience with the system is the possibility to check up the function of sensors, the data handling of the primary data and the possibility of getting a complete picture of the process.

The Frövifors system is the first system in the Swedish pulp and paper industry where an environmental measurement system has been built around a dedicated computer. The experiences gained have formed a valuable platform for further development work.

A PLANNED PROJECT FOR ENVIRONMENTAL MEASUREMENTS

Much of what I have said serves to give a background for a brief description of a large project that we are presently planning within the pulp and paper industries in Finland, Norway and Sweden.

It was felt that the problems within this area were indeed large and they tended to increase in magnitude, particularly the cost for the environmental control increased rapidly. A big effort was therefore needed if a significant progress was to be made. Preferably the project should be carried out on a internordic basis.

As is shown in Fig. 6 the planned project will tackle the problem in a broad sense, incorporating all the aspects that we have touched upon.

The project is planned to have a budget around 10 M Swedish Crowns and will run over a 3 yr period. The central forest products research institutes in the three countries and the Swedish Water and Air Pollution Research Laboratory will take part, together with pulp and paper mills. In the steering committee of the project authorities will also be represented.

The project has two focal points. One is to solve the problems around the measurement of emissions. The other is to work out the principles of internal measurements and their feed-back to the process, particularly at distrubancies.

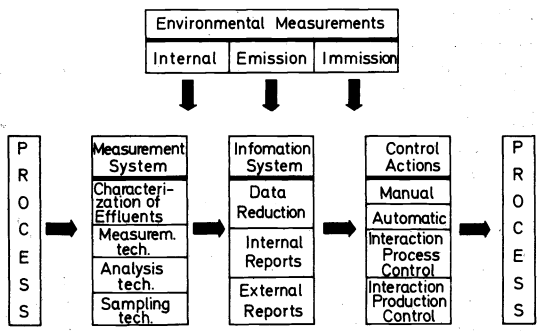

Fig. 6. Brief out-line of the content of a planned project for an environmental measurement system with participation from Finland, Norway and Sweden.

A large fraction of the budget will be allocated to the development and testing of physical instrumentation, analytical instrumentation and sampling techniques. An essential part of the project is to establish the costs involved in the environmental measurements.

An important aspect of this project is that it will result in a thorough documentation which those responsible for environmental measurement and control in the mills can use in their daily work. At present such information is scarce.

FINAL REMARKS

Environmental instrumentation has to work in a very tough atmosphere, and a very high availability will be demanded. This is further underlined by the fact that this instrumentation does not yet have the same priority in the plant as instrumentation more closely related to the production. It represents a cost with no easily measurable benefits.

To the operator the environmental factors represent a further complication in an already difficult job. This is the reason why we see alarm systems plugged up with wooden sticks or cotton waste. Education is the only solution to this. We must never give the operator the impression that he is supervised, otherwise a negative reaction is inevitable.

The development of environmental measurement systems can not proceed without the participation of authorities. I have come to the conclusion that this problem area is so complex and there is so much basic knowledge missing that it can hardly be solved if industry and authorities do not cooperate constructively. If it comes to the point where both parties start to suspect each others intentions, then, we are in for troubles. Unfortunately, due to the inherent nature of the problem such situations can easily arise. However, in Sweden it seems that the necessary atmosphere of confidence for such discussions exists.

A last remark would be that we should not believe that we have solved the problem by installing an environmental measurement system with proper alarm functions. There must always be some one who is responsible for taking action and he probably needs training to make good use of his tools.