Preferred citation: C.R. Silversides. The forest to the pulpmill and how the system is controlled. In **Papermaking Systems and their Control**, *Trans. of the IVth Fund. Res. Symp. Oxford, 1969*, (F. Bolam, ed.), pp 173–182, FRC, Manchester, 2018. DOI: 10.15376/frc.1969.1.173.

THE FOREST TO THE PULPMILL AND HOW THE SYSTEM IS CONTROLLED

C. R. SILVERSIDES, Department of Fisheries and Forestry, Ottawa

Synopsis Operations involved in the delivery of pulpwood from the standing tree to the consuming pulpmill are considered as a subsystem of the whole papermaking system. Pulpwood may be produced by any one of four different systems, namely, shortwood, tree length, full tree and remote chipping. Control in woodlands operations is management control and is primarily a function of administration. The principle is identical to that in process control. Control is not accounting in the conventional sense, but is involved with improved planning and the conservation of resources.

Co-ordination between the production of pulpwood and the requirements of the consuming mill is essential to ensure continuity of mill operation, at the same time ensuring minimum pulpwood inventories. The pulp and paper industry, for the most part, carries its inventory in raw material rather than in the finished product. Optimum co-ordination of pulpwood deliveries is rendered difficult owing to seasonal variation in mill consumption along with seasonal constraints on pulpwood deliveries attributable principally to climatic conditions. Proper control at this point in operations can result in great savings in pulpwood inventories. With pulpwood constituting 40–50 per cent of the cost of the final product and with the absolute cost of pulpwood at an all-time high value, control of pulpwood production and delivery is critical at this time.

Introduction

WITHIN the context of the programme of this symposium, the series of operations that are involved in the delivery of pulpwood from the standing tree to reception at the pulpmill are considered as a subsystem of the whole papermaking system. What ends up as a page in a newspaper or a box of tissue or a carton starts out as a tree.

As described by Koten, a timber harvesting and delivery system is a complex production system composed of the usual resources of men, machines,

Under the chairmanship of Dr S. A. Rydholm methods and money that includes an input and an output.[1] The input to such a system is the output of a biological system, which is subject to variations in location, size, density and quality. This output is the tree of a species suitable for pulpwood. Further complexity is introduced in the harvesting operation by the present necessity of moving the harvesting machines to the input, hence encountering the various physical conditions imposed by soil, topography and climate associated with the site. Personnel associated with a harvesting system will also operate under the constraints imposed by variations in the site conditions.

There is considerable variety in the form in which pulpwood is produced and the steps involved in each variation are considered to form a separate and distinct system.

A differentiation should perhaps be made at this point between a logging method and a logging system. This can best be shown by example. The tree length method involves the production of tree lengths from stump to roadside by any means at hand. It existed in the days of cross-cut saws and of horses. The tree length system as used in this context is considered to be totally mechanised from the felling of the trees to the skidding and handling of the tree lengths at the roadside where pulpwood bolts are produced 'untouched by human hands'. Systems analysis is concerned with the problems of compatibility that result when many parts are assembled together to form a whole and with the emergent properties of the system, that is, with the properties of the system that the individual parts, taken separately, do not possess.

Timber harvesting

AT THE present level of mechanisation in forest operations, few pure systems exist as such, but systems analysis and the total cost concept are widely accepted and are spreading rapidly and are aiding greatly in the acceptance of total mechanisation.

There are at the present time, at various stages of worldwide development, four different major systems of timber harvesting for pulpwood. Again, within each system, there is great variety in the components that make up the system. These timber harvesting systems are short wood, tree length, full tree and remote chipping. The titles of these systems are highly descriptive.

In the shortwood system, pulpwood in bolt form is produced in the forest stand and is piled or bunched in the vicinity of the stump from which the tree has been severed. At present, it is a highly labour intensive operation with distinct limitations on man-day productivity. As labour rates increase, because of the high labour content, the cost of wood produced by this method increases directly. The volume of pulpwood produced by this method has declined markedly in recent years in the major pulpwood producing regions and this trend will continue until suitable machines are developed to produce shortwood mechanically with greatly increased man-day productivity and reduced cost. In the shortwood method at present, only a fraction of the working day is spent in actual cutting—that is, felling, limbing, topping and cutting the tree into bolts of required length. The remainder of the time is spent in clearing trails or roads, clearing pile sites, moving bolts of wood to the piling site and piling. The latter operations add little or nothing to the physical production of the pulpwood and, if they are eliminated, man-day productivity can be increased.

In the tree length method, trees are felled, limbed and topped within the forest stand in the vicinity of the stump from which the tree has been severed, then skidded to the roadside or landing for conversion into pulpwood bolts or to be loaded and transported in tree length form. There is no attempt in this method manually to move, assemble or pile wood in the forest. Man-day productivity is considerably greater than with the manual shortwood method, because a greater level of mechanisation has been reached.

In the full tree system, the trees are felled and with no further work expended on them, they are dragged out to roadside or landing for conversion there or for transportation to a central processing plant. The concept of full tree logging is not new, but the transformation of this method into a system depends upon the development of suitable equipment. A number of such machines exist today in prototype and preproduction models and the system is receiving wide acceptance.

In the remote chipping system, remote simply implies at a distance from a central pulpmill woodroom. Trees are converted into chips either within the stand in the vicinity of the tree stump or at the roadside or landing. At the present level of technological development, this system shows least promise in terms of man-day productivity and cost. Limitations at present are its power requirements and relatively low productivity resulting from a need in most instances to have suitable tree debarking before chipping. Tree size is probably the controlling factor in the success of this system.

The flow charts of Table 1 show clearly the physical distribution of the operations to be performed in the various systems. The shortwood system has the maximum number of operations carried out in the forest, the full tree system has the minimum number of operations, whereas tree length and remote chipping systems are intermediate in character.

The number of tree harvesting or processing machines making up each system will vary, depending upon the functions each perform. It is obvious that the fewer machines and men involved, the higher the man-day productivity is likely to be, although this is not true in every instance.

TABLE 1—FLOW CHARTS FOR VARIOUS LOGGING SYSTEMS

SHORTWOOD		TREE LENGTH	FULL TREE	REMOTE CHIPPING
Manual Felling Machine Forwarding	Machine Felling Machine Forwarding	Machine Felling and Machine Skidding	Machine Felling and Skidding and Machine Processing	Machine Felling and Machine Skidding and Chipping
○ - Fell ○ - Delimb and Top ○ - Cut to Length □ - Scale ▽ - Storage ○ - Load o - Transport ○ - Load on Truck	○ - Fell ○ - Delimb and Top ○ - Cut to Length □ - Scale ▽ - Storage ○ - Load o - Transport ○ - Load on Truck	○ - Delimb and Top ○ - Fell ○ - Pile ▽ - Storage o - Transport ○ - Unload ○ - Cut to Length □ - Scale ○ - Load on Truck	○ - Fell and Load o - Transport ○ - Unload ○ - Delimb and Top ○ - Cut to Length □ - Scale ▽ - Storage ○ - Load on Truck	○ - Delimb and Top ○ - Fell ○ - Pile ▽ - Storage o - Transport ○ - Unload □ - Scale. ▽ - Storage ○ - Chip and Load in Van

Transportation

THE systems of transportation of pulpwood to consuming mills vary widely in different regions. The system chosen in any specific instance will be influenced by topographic, climatic, legalistic and other factors. Pulpwood is transported on water by floating, barging or as boat cargo. It is transported on land by truck, tractor trailer and railway. Other means of transport such as aerial tramways, pipelines, helicopters and balloons have been explored with very little application to date. The transportation phase of timber harvesting is strongly influenced by size and shape of the product to which trees are reduced. Wood chips cannot be floated on lakes or rivers, long bolts and tree lengths do not permit such high density loads as will short bolts. Barked pulpwood will permit denser larger payloads than rough wood. Such factors may have a controlling influence on the choice of a transportation system.

Control of operations

THE growing, harvesting and delivery of pulpwood involves many operations distinct in time and place. Control of these operations is essential, but often difficult. Control of a production process within a pulp or paper mill is defined as the ability to bring the process to any given state and maintain it there.[(2)] The purpose of such control may vary. It may be improved throughout, improved quality, reduced cost, fullest utilisation of existing plant facilities or any combination of these. In a general sense, this is the purpose of control in woodlands operations, but the application is different and often more difficult.

Control in woodlands operations is management control and is primarily a function of administration. Although management control cannot be effected as rapidly as process control, the principle is identical to that in process control. In management control, the data collection system gathers data, determines which are within specified limits and which require correction and acts to regulate the latter. This is analogous to process control.[3]

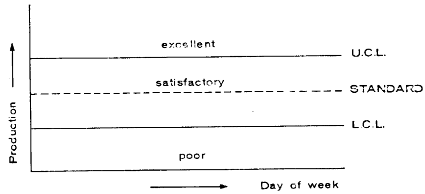

Fig. 1—Production control chart[4]

Control in logging is essentially the common sense application of reliable cost and production data to day-by-day logging problems. At lower organisational levels and/or the subforeman level, the spheres of decision making or the number of optional courses open are relatively limited. They became more complicated at higher levels, but this is due more to the greater number of options than to the complexity of each. At the top management level, controls may be exercised through the manipulation of funds; at the operating management level, control may be concerned with deciding how work is to be produced and how existing facilities may best be used; at the foreman level where cutting area, equipment and forest labour are all assigned, control may be very largely a matter of volume.[5]

A control department represents a clearing house. The information flowing from it is no more reliable than that flowing in and it must be assumed that the checks and counterchecks necessary to evaluate the quality of the data have been thoroughly established within the reporting and recording systems.

As long ago as 1928, a few paper companies in eastern Canada introduced a rigorous system of control in their woodlands operations. The industrial engineering approach to operations flourishes best in industries with a highly developed scientific outlook and the forest industry 40 years ago was generally far removed from this attitude and control at that time was usually carried out by rule of thumb. The system of control as originally developed has passed through many forms since its inception, but the principle of control as established at that time has not changed. Control was defined then as 'the presentation to management of timely information as to the progress, status, and regulation of operations'.[6] This definition is as valid now as when written, but managers today must make decisions much more rapidly than in the past. New techniques for supplying such information have been developed to permit rigid analysis and evaluation.

It must be established at the outset that control is not accounting, at least in the conventional sense. Accounting is basically the recording and distribution of past expenditures for product costing, for inventory control and for the preparation of year and financial statements. It is highly regulated by 'generally accepted principles' and is usually quite inflexible.

Systems approach

CONTROL, including cost control, deals with a much broader area than accounting and is involved with improved operations, future planning and the conservation of resources. The inputs are the resources available such as hours of labour, acres of timber, size of trees in stand and horsepower of machinery, all of which must be combined to produce a given product or volume of output. Production data is essential. It may show the relationship between the inputs and outputs in purely physical terms, in contrast to cost and price data which show economic relationships only.[7]

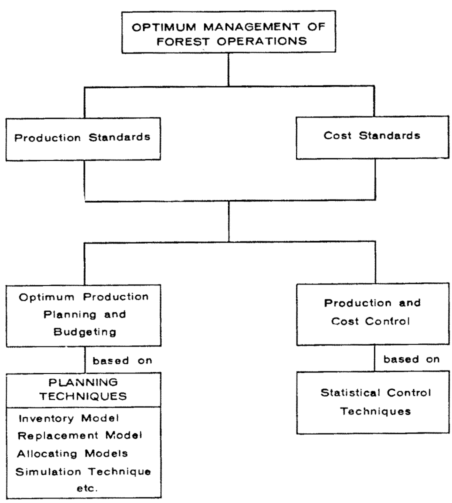

Fig. 2—Steps involved in the optimisation of a logging system

Physical inputs tend to be more stable over a longer period of time than cost and price data. For example, the output for a given skidding tractor may vary with new and larger models, but the cost of a tractor's output will vary more frequently with changes in operator's wages, fuel costs, etc.

Lussier has outlined the steps involved in the optimisation of a logging system.[8] Production and cost standards for the basis of sound managerial decisions must be developed. The setting up of standards in logging is not an easy problem and a lot of time must be spent in designing the procedure to get the information and analyse it properly. Standards are established for various operations, equipment and work methods, in relation to different sets of work conditions. When production and cost standards are known for sets of working conditions, it will be possible to find the combination of production elements that will yield the minimum cost per unit of product (Fig. 2).

There are several underlying principles that apply to control in the subsystem in question and these might be reviewed briefly[9]—

Principle of uniformity—All reports and data used for purposes of control must be in terms corresponding to the operations that the reporter can influence. For any given operation, a person's authority and responsibility must correspond.

Principle of comparison—All reports and data used for purposes of control must be in terms of standards of performance. There should be a target to aim at and any deviations from the target should be explainable (Fig. 3).

Principle of utility—All reports and data used for purposes of control must be produced in a time period that permits their use by management. This might be compared with or be analogous to real time in a computer that is carrying out a control function in a process.

Principle of exception—All reports and data used for purposes of control should emphasise deviations from the norm as it is there, deviations which require consideration and action. As described earlier this is analogous to process control.

Inventory

THUS far, control of wood production and procurement has been described. The co-ordination of such production or procurement with the requirements of the consuming mill has not been discussed and this is a critical interface. There are two major elements in such co-ordination, to ensure continuity of mill operation and to ensure minimum pulpwood inventories. The co-ordination required to deliver the right quantity of wood of the right quality at the right time is very considerable.

Unlike many other industries, the pulp industry carries most of its inventory in the form of raw material or pulpwood. Pulp and paper, except fine papers, are generally made to order and it is not customary to build up large stocks of pulps and papers to inventory against possible future orders. For this reason, relatively large inventories of pulpwood are carried at the consuming mill and possibly at other locations.

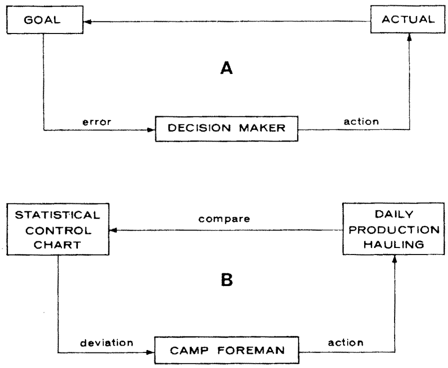

Fig. 3
A. Flow chart of self-controlling communication system
B. Control loop for pulpwood hauling operation (L. J. Lussier)

Properly to control the pulpwood inventory, it is necessary to (1) hold minimum safe inventories at all points of delivery that will be sufficient to ensure continuity of production at the mill, (2) hold the pulpwood inventory at the stage that involves least cost and (3) know when excessive or too small inventories develop.

The pulpwood inventory programme cannot be considered separately from woods production or from the end product demand patterns of mill output.[10]

When wood is cut and piled in the forest, it may be considered as undelivered inventory. It is destined for delivery by any one of a number of different methods, but is considered as undelivered until it shows up in one of the subsequent stages of delivery. When delivered to the next point, it ceases to be undelivered wood and becomes a more costly form of inventory. Regardless of whether pulpwood is moved by water or land, it ultimately arrives at a mill, where it is received and stored in large piles. From the blockpile, the pulpwood is taken into the mill and consumed in the pulping process (Fig. 4).

If there was no trend in mill consumption and no seasonal variations in pulpwood production or procurement caused by climatic or other physical factors, then the time path of mill consumption would be a straight line and this would hold also for the flow of pulpwood from standing tree to mill consumption. Without any instabilities, there would be no need for variation, but there are physical constraints on any wood flow process, usually caused by seasonal or climatic conditions. Because seasonal constraints tend to be relatively simple, they can be superimposed on a seasonally adjusted model.

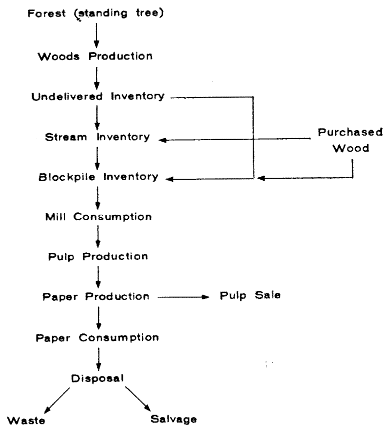

Fig. 4—Flow process of pulp and paper products from raw material to end use and disposal

Average seasonal variations month by month for past periods can be measured. They can be divided out of the actual data to leave as a residue the main non-seasonal movements inherent in the data, which are cyclical in nature. When the dominant seasonal variations are removed, the remaining non-seasonal movement are relatively smooth cycles. Actually, there are two seasonal variations—that in mill consumption is related to end product needs; that in wood production influenced by physical constraints or climate.

It has been observed that mild cycles in mill consumption are reflected in magnified form in woods production, indicating an overcompensation with alternate overproduction and underproduction. If mill production can be properly forecast, the wild fluctuations in production and procurement of pulpwood could be controlled more closely.

With proper inventory and delivery controls, it should be possible to permit the holding of minimum safe inventories at each stage, which will be sufficient to ensure continuing operation at the next stage. It should be possible to reduce the most costly inventory (blockpile) perhaps at the expense of earlier and less costly inventory (undelivered). Observations in the eastern Canadian pulpwood logging industry in 1966 indicated inventories as four and one half months in the undelivered stage, two and one half months in the stream (water storage and delivery stage) and three months in the blockpile stage for a total of ten months wood inventory. One study[10] indicates that these inventories could be reduced to three and one half months in the undelivered stage, two months in the stream and one and one half months in the blockpile, which would reduce the total inventories by 40 per cent.

Conclusion

TODAY, pulpwood constitutes 40–50 per cent of the cost of manufacturing most pulps and some papers. The absolute cost of pulpwood is at an all-time high value. There is a real danger of loss of competitive position with substitutes, both in finished product as well as in the raw furnish. For this reason, control of pulpwood production, in procurement, delivery and inventory is more critical at this time than ever before.

References

1. Koten, D. E., 'Engineered harvesting systems—problems and promises' (Society of American Foresters, Winter 1969 meeting of New York Section, Liberty, N.Y.)
2. *Introduction to control systems* (General information manual International Business Machines, 1961)
3. Den Uyl, D., 'Forest decision making in an integrated firm': *J. Forestry*, 1968, **66** (10), 796–798
4. Lussier, L. J., *Planning and Control of Logging Operations* (Laval University, Quebec, 1961)
5. Harkness, W. D., 'Control in logging' (Seminar on mechanised logging, Lulea, Sweden, 1963)
6. Soderston, H. R., *Control in logging* (Abitibi Paper Co. Ltd., 1928, unpublished report)
7. Bruce, R. W. and Adams, T. C., 'Logging cost analysis in management planning': *Forest Prods. Res. J.*, 1962, **12** (11), 519–522
8. Lussier, L. J., *Use of operations research in determining optimum logging layouts* (Canadian Pulp & Paper Association, 1960, Woodlands Section Index No. 1947)
9. Urwick, L., *The Elements of Administration* (Sir Isaac Pitman & Son Ltd., London, 1947)
10. Beckett, W. A. and Associates, *A model for pulpwood inventory control* (Canadian Pulp & Paper Association, 1966, Woodlands Section Council)

Discussion

The Chairman I think Mr Annergren's paper is the first really coherent presentation of the complete control aspects of the chemical pulp mill and will serve as a basis for the systems engineers in their future work.

Mr B. Kvaavik You mentioned that one of the inputs to the control system was the brightness. How do you measure this?

Mr G. E. Annergren The brightness referred to in the paper is measured after sampling on handsheets in an Elrepho brightness meter in our mills. Visual inspection is used for more frequent analyses.

Mr E. A. Leaver I am rather surprised to hear that sampling techniques were used for brightness measurement. An automatic brightness recorder was developed by a paper company some time ago. Over 50 of them have been manufactured under an exclusive license. Although such instruments do not represent perfection in the measurement of this variable, it could provide more representative, immediate and usable information than hand sampling will.

Mr Annergren We are aware of this rather interesting technique, but hesitant about it, because the environment is not very favourable for the instrument on our washers. Measurements in the wet stage are also less accurate, especially when the washer is operating inefficiently. Continuous measurements are also of little use in the final stages, if you have chosen a bleaching sequence with good control characteristics. After the first stage though, a continuous measurement would be very interesting. The colour there is very unstable, however, which makes it necessary to base the control on lignin measurements.

The Chairman This elusiveness of colour has something to do with the chemical configuration of lignin. After chlorination, it forms a chlorinated *o*-quinoidal system that is quite unstable.

Mr Kvaavik How do you measure the moisture content?

Mr Annergren There are various methods. A laboratory method using manual sampling, drying and weighing gives good accuracy, provided the sample is big enough. Weighing a digester full of wood before charging with liquor is often used for estimation of the moisture content, since the variations in moisture content dominate the variations in the amount of dry wood. Later, we developed a continuous measuring device.

Mr G. Bohlin Indeed, we have tried to use an instrument with a neutron source and a gamma source for this purpose. Our experience showed that the instrument is accurate enough for control of the liquor-to-wood ratio, but inadequate for the alkali-to-wood ratio. The accuracy is 0·5–1 per cent in moisture content. There are other methods such as microwave technique to measure moisture content, but it is impossible to use them when the chip temperature is below 0°C, which is the case for us several months each year. The radioactive method is unaffected by temperature.

Dr D. W. Clayton Before we go on, please clarify a point about the standard deviations in Table 3? These are given as 4 per cent and 2 per cent for the wood charge and for the charge of white liquor, respectively, but for the liquor-to-wood ratio the standard deviation is given as 0·2. What would this be when expressed as a percentage?

Mr Annergren The standard deviation of the liquor-to-wood ratio is not given as a percentage. It is 0·2 m^3/ton oven-dry wood. The table refers only to normal batch cooking, for which the procedure is to charge the wood by volume, measure the moisture content separately in a suitable way, measure the white liquor according to the specification on the alkali charge and calculate the black liquor as a make-up to the total amount of liquor required.

Dr I. B. Sanborn For the continuous measurement of chip moisture content, the most reliable means that I know of today is by using a device that works very well on unfrozen chips. It works on a dielectric principle, I believe.

Dr A. Kohl We have quite a number of moisture meters installed for wood chips. The normal installation is that the flow of chips is weighed on a conveyor belt and the moisture is measured afterwards either in the main stream or in a by-pass. Because the chips are of various size, a correcting compensation for the density has to be introduced.

Another possibility is the use of a vibration chute, whereby uniform packing is achieved and the density compensation can therefore be omitted. The read-out of the instrument is in percentage water and for this, together with the measurement the air-dry weight on the conveyor, the oven-dry weight of the chips can be calculated.

This equipment is operated on continuous and batch digesters. Sometimes, the chips pass through a hot steam stage, in which case, the moisture should be measured before and after this operation.

Mr H. B. Carter Have you had any experience of using methods of measuring moisture content and weight on chips of different species of wood? We, for example, have had to use balsam fir and black spruce: can you comment on these species?

Mr Bohlin We have studied this question and found that the neutron signal is greatly affected by the different wood species; the gamma signal is more independent. It is necessary therefore to have a calibration curve for each species.

Dr D. Rusten (written contribution) The moisture content of wood is one of the main factors responsible for the variations in the pulping result and particularly so if the charge of chemicals added is proportional to the weight of wood measured by a chip weighing system. The principle of weighing a certain volume of chips packed in a standardised way—for instance, a batch digester after chip filling—works reasonably well, so long as one utilises one type of wood from a limited area.

If a mixture of wood species of different density is cooked, the problem becomes more difficult. Microwave techniques and measurement of dielectric properties have been used successfully, but they present problems in cold winters when the wood taken in may be frozen. One principle of measurement already mentioned in the discussion utilises a combination of neutron and gamma radiation. The former is sensitive to the hydrogen in the sample, the latter is used to measure the total density. This principle has been tried in a few mills, but has met with such problems as—

1. The two types of radiation are active over different volumes and this varies with the moisture content.
2. The instruments have not been rugged enough for mill use, thus causing frequent breakdown.
3. Hardwood and softwood in varying mixtures may be difficult to measure, but mixtures of softwoods such as larch, spruces and pine have been shown to give satisfactory results, at least when the wood is fast grown and so containing little pitch. As extractives contain another percentage of hydrogen than does the dry wood itself, this may create problems.

It is fair to say that there is yet more to be done to give a fully satisfactory measurement for moisture content of chips in order to be able to control the cooking process properly.

Dr J. N. Chubb I would like to ask some questions about the biological cycle as a whole. What do you have to do after felling the trees to prepare the ground for replanting? Do you have to replace any of the materials? What sort of cycle time do you have in the entire process and are there uniform yields on repeated cycling?

Mr C. R. Silversides Very briefly, the forests around the world vary considerably. In the great coniferous forests of our pulp and paper industry, the time cycles vary from possibly 75 to 125 years. Formerly, we looked for natural regeneration almost entirely. The criteria of the good forester was that he was able to obtain natural regeneration. Today, however, it is almost universally the practice to plant or to seed and the purpose for this is that, in seeking natural regeneration, there is a time lag of 5–10 years.

Our forest lands have become too valuable to permit of this delay and the practice now is to plant immediately or within two years following cutting. When planting, such trees have a head start of 1–4 years over natural regeneration. In America's southern states, they have a life cycle rotation of perhaps 25 years; in Australia and New Zealand, they can obtain pulpwood size trees at 7–10 years. So there is a tremendous range in our coniferous forests, depending on the geography.

The general practice of our forest industries is to regenerate and support the forest as a source of raw material to the greatest possible extent, but this varies widely among countries. In Canada, 90 per cent of our forests are owned in the name of the Crown and are leased to the industry; in other regions of the world, they are owned 100 per cent by the industry. A very marked development has taken place in the post-war period. Tree harvesting used to be considered analogous to an agricultural harvesting operation; today, certainly in North America, it is considered to be an operation producing an industrial raw material. Our logging operations are therefore becoming highly mechanised and highly controlled and capital intensive in contrast to the previous labour intensive operations.

The Chairman This emphasises the sort of time lags that the forester has to deal with.

Mr J. A. S. Newman Are the variances in Table 3 those applying at the start or at the end of the study? If it was the former, what did you hope to achieve?

Mr Annergren The figures refer to the conditions described in Fig. 2, which is somewhat hypothetical, since it presents somewhat adjusted average figures from several Swedish pulp mills. They are therefore not altogether valid for our mills, but are fairly close to what can happen there without improved control. The table gives a lead on how to proceed. By installing a device for *H* factor calculations, we have in one case been able to decrease the variation to about half of the indicated variation. The problem in this, however, seems to be the temperature signal, which is not always representative for the cook. An improved chip-filling technique and more homogeneous chip quality will further improve the result.

Prof. L. W. Zabel Mr Annergren mentioned the use of the *H* factor*, but this is a rather simplified rate equation. Have you found this sufficiently precise for your use or do you think that something more comprehensive such as Carroll's work would be better?

Mr Annergren In the computation, you can take into account only what you measure. The *H* factor covers the variations we can control. If the temperature signal is good, we have found the *H* factor very precise for our purposes.

Mr D. Attwood In Mr Annergren's Table 3 (which I am sure will become quite famous), the variance of liquor-to-wood ratio is only unity; but, if you remove this completely as a source of variation, it would hardly affect the total variance of $6{\cdot}3^2$ (that is, 38·54). This implies that liquor-to-wood ratio control is irrelevant, which seems surprising.

Mr Annergren It is true that a narrow liquor to wood ratio control is irrelevant to the control of the lignin content of the pulp in batch cooking. There are, however, other reasons for controlling it.

Mr B. Nilsson I accept Mr Annergren's comments about redevelopment for computer control. We would much rather complete it with the equipment at the other end of the system, but half a loaf is better than none. When someone has the other equipment, we will certainly be glad to use it.

Mr Silversides said that, with the centralised tree processing equipment, there was no particular problem with slash. I believe the control problem there to be real.

* The *H* factor (a numerical expression) was developed by K. E. Vroom, Pulp & Paper Research Institute of Canada in 1956–57 for treating kraft pulping times and temperatures as a single variable (see *Pulp & Paper Mag. Can.*, 1957, **58** (3), 228–231)

Mr Silversides I think you might consider the slash more of an inconvenience than a problem. You may be familiar with the fact that the Logging Research Associates (the developers of this particular full tree system) employed the Ontario Research Foundation to make a detailed study of any possible use or application of twigs, branches and bark, hopefully, so that the companies concerned might develop useful by-products. They were completely unsuccessful in this respect. There is a considerable debate going on at the present time in the forest about the implications of the removal of the organic material involved in the branches, twigs and the bark from the site, because of its potential as a fertiliser. Studies are under way both by the Department of Fisheries and Forestry and by the Pulp and Paper Research Institute of Canada in an attempt to resolve this.

There is a further point. When you remove a full tree, you remove the source of the seed. This is counteracted to a degree by the fact that, when you remove all potential slash and debris from the cut over the area (as we do in the full tree method), you simplify greatly the artificial regeneration of tree planning, because you have removed a good deal of the obstructions normally found on the cut over area.

Mr P. H. Engelstad I am anxious to know about the actual improvements achieved by these instruments for measuring moisture content and chip weight. Has Dr Kohl any evidence of what the improvement was in terms of reduced variance or standard deviation in the kappa number of the final pulp before and after the installations were made? Could he also give a rough estimate of the cost of the installations?

Dr Kohl The installation of moisture meters on wood chips has two tasks—

1. To change over the purchase procedure of the wood from the volumetric to the oven-dry weight method.
2. To control the digesting process.

Foresters are so far reluctant to go ahead on the first application, but the application of the equipment in the pulping process itself has been carried out by many mills quite successfully. This has been not only to control the flow of the incoming material on an air/oven-dry basis, but also to control the subsequent chemical process. The cost for such an application would be between £3 000 and £8 000.