**Preferred citation:** E.L. Graminski. Characterisation of pulps manufactured from waste paper. In **Fibre-Water Interactions in Paper-Making**, *Trans. of the VIth Fund. Res. Symp. Oxford, 1977*, (Fundamental Research Committee, ed.), pp 921–931, FRC, Manchester, 2018. DOI: 10.15376/frc.1977.1.921.

# CHARACTERISATION OF PULPS MANUFACTURED FROM WASTE PAPER

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THE conclusions of many studies on material policy emphasise the need for materials conservation and more efficient utilisation of materials. Recycling of municipal waste is an alternative to solid waste disposal and a means for conserving our natural resources. Although the benefits from recycling are many, there are technological and economic barriers to large scale recycling in the private sector. Unless these uncertainties are removed, increased recycling will occur only when no other alternatives exist.

Solid waste is almost always contaminated with undesirable products and is usually of unknown composition. Successful recycling depends upon a consistent composition of solid waste, or, lacking this, a rapid and accurate assay of the solid waste material. A major technological need, common to all materials recycling, is the ability to characterise the waste material itself or the raw material produced from waste.

In analysing the utilisation of various waste paper grades recycled, it is obvious that the least contaminated, best characterised waste paper has the greatest utility in paper recycling.[1] Practically all mill waste is recycled, while only a relatively small percentage of mixed waste is utilised. Unfortunately, however, mixed waste is the most abundant grade of waste paper available. If paper recycling is to increase significantly, greater utilisation of this grade of waste paper must occur.

Usually paper stock dealers are uncertain of the long range demand for mixed waste paper and thus results in a great reluctance to handle this grade of paper stock. Processors are uncertain of the ability of suppliers to provide an acceptable mixed waste over an extended period of time. Furthermore, it is always questionable whether the equipment to process mixed waste papers is sufficiently reliable to produce a product which will meet the customers' specifications.

*Under the chairmanship of M. I. MacLaurin*

Some of the uncertainties could be removed by developing analytical and physical test methods which would enable either the waste paper or the pulp produced from the waste paper to be characterised. The great variability that is so common with mixed papers could then be easily coped with by processors and there would be a greater probability of producing products capable of meeting customers' specifications. Appropriate test methods can thus provide a greater incentive for recycling by reducing many of the economic and technological uncertainties.

Two of the greatest concerns of paper recyclers are the cleanliness of the recycled pulp and the mechanical properties of the pulp fibres. Clean pulps are necessary for good performance on paper machines and for appearance properties of the paper. The mechanical properties of pulp fibres have a strong influence over the physical properties of the paper, and, if the fibres are seriously degraded, the resulting paper will not meet the customer's strength specifications. Failure to meet one or both specifications can result in the loss of a substantial amount of money to the paper manufacturer.

Dirt in pulp and paper can be assessed satisfactorily by microscopic measurement. In addition, the morphological characteristics of pulp fibres such as fibre length distribution, fibre coarseness, curl and the length-to-width ratio (which are important to the mechanical properties of paper) can be conveniently measured by microscopy. Nevertheless, microscopic measurements are hardly ever used in quality control of paper manufacture because the measurement process is too lengthy and tedious. If it were possible to

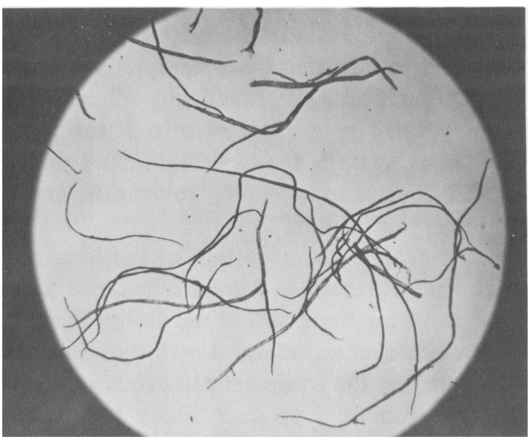

***Fig. 1***—Photomicrograph of a southern softwood pulp showing individual fibres

decrease the time needed for microscopic measurements by orders of magnitude, without compromising accuracy, microscopic measurements would most certainly be used for quality control in paper manufacturing.

Work is in progress at the National Bureau of Standards to increase the speed of microscopic measurement by the use of image analysis. Image analysis is simply a technique for making rapid and accurate measurements and analysis of images by means of a computer. It essentially augments the eye in extracting accurate and quantitative information from images. A semi-automatic technique has been developed for determining the fibre length distribution and curl of pulp fibres. This work has been described in a recent publication(2) (*Proceedings of the IEEE Computer Society Conference on Pattern Recognition and Image Processing*, June 6–8, 1977) and a portion of that paper will be excerpted.

### *Fibre measurement algorithms*

#### A. *Semi-automatic data acquisition*

FOR purposes of defining an image analysis algorithm and exhibiting the results of such an analysis, we adopt here the procedure of using semiautomatic methods for data acquisition. We will discuss subsequently the methods for acquiring these data with image scanners. The data to be analysed consists of a set of photomicrographs, such as that shown in Fig. 1, in which a separable, but nevertheless partially overlapping, set of fibres appears. Manual measurements on these fibres can be made by using graphic stylus techniques. We have written programs which use a graphic stylus to trace the fibres in Fig. 1 and to provide to the computer co-ordinate information concerning the location of points traced along each of the fibres.

With a 10·2 cm by 12·7 cm print photomicrograph and a graphic tablet having a resolution of 0·25 mm, we can manually trace each of the fibres by successively placing the graphic stylus on points arbitrarily chosen along the length of the fibre and automatically register the $x$ and $y$ co-ordinates of such points. With the programs we use, it is possible to tell the computer which points constitute the beginning and end of each fibre. This manually solves an important image analysis problem of separating individual fibres which overlap. In Fig. 2 we show a display produced by the computer, exhibiting, for each internal point measured along each fibre, the location of that particular point. Only those fibres lying wholly within the microscope field have been traced.

This method of manually tracing fibre photomicrographs inherently contains certain errors. There is the error associated with imprecise placement of

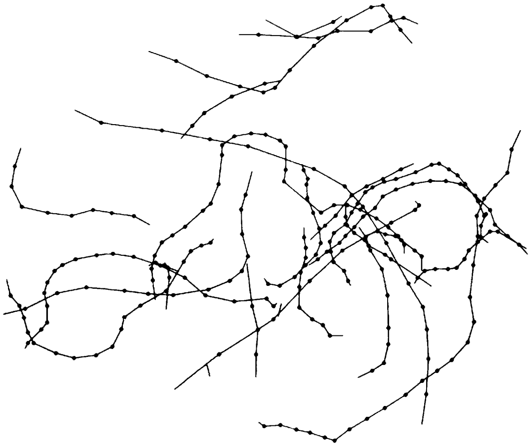

***Fig. 2***—Tracing of photomicrograph in which manual tracing points are marked

the graphic stylus on the image. There is also an error associated with the nonsystematic choice of measurement points along the length of the fibre. For the data that were analysed in this experiment, points were chosen according to a nonrepeatable criterion in which more points were plotted in regions where fibres bend and fewer in straight sections of such fibres as can be seen in Fig. 2.

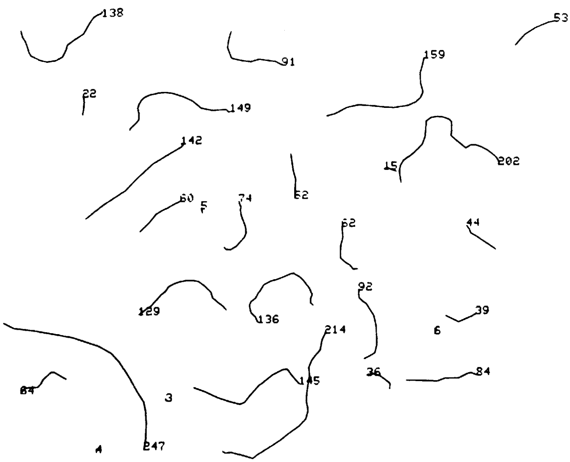


***Fig. 3***—Image of Fig. 2 in which individual fibres have been separated by the computer with lengths (in units of 0·01 mm) calculated for each fibre

Notice that with this semi-automatic method of acquiring the image data, it is possible, by straight-forward methods, to separate fibres which are otherwise overlapping. Thus the original image of Fig. 2 can be transformed and rescaled into the image of Fig. 3 in which individual fibres have been translated so as to eliminate overlap and to make it possible to perform measurements on isolated fibres.

B. *Fibre length calculation*

ONCE a sequence of points along the length of a fibre have been located, a number of possible measurements can be made. The most useful and also simplest is the measurement of fibre length. Using the points similar to those indicated in Fig. 2, a sequence of straight line vectors joining those points can serve as an approximation for the original fibre. The length of the fibre then is approximated by the sum of the lengths of the straight line vectors joining those points in sequence along the fibre. For those fibres shown in Fig. 2, the length of the original fibre, given in units of 0·01 mm, is shown in Fig. 3. Thus, one of the fibres in Fig. 3 is as long as 2·47 mm and one of them as short as 0·04 mm. These are true projected lengths obtained by calibrating the photographic process with a microscope reticle.

Using this method we measured fibre lengths for three different pulps. The first was a southern softwood pulp for which 425 fibres were measured from a sequence of different photomicrographs. The second was a northern softwood pulp for which 620 fibres were measured. The last was a hardwood pulp for

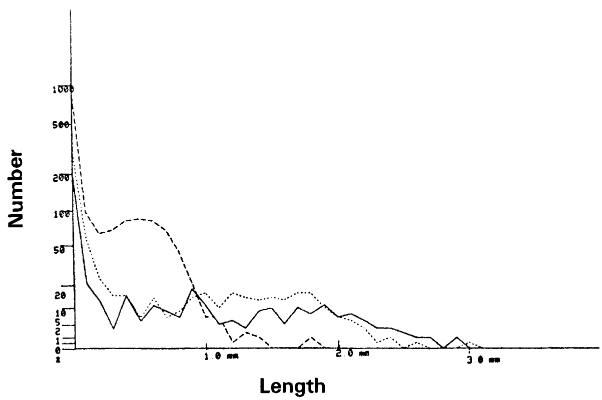


***Fig. 4***—Histogram of fibre lengths for three pulps in length classes of 0·1 mm. Tracings were made for 425 southern softwood fibres (solid line), 620 northern softwood fibres (dotted) and 1540 hardwood fibres (dashed)

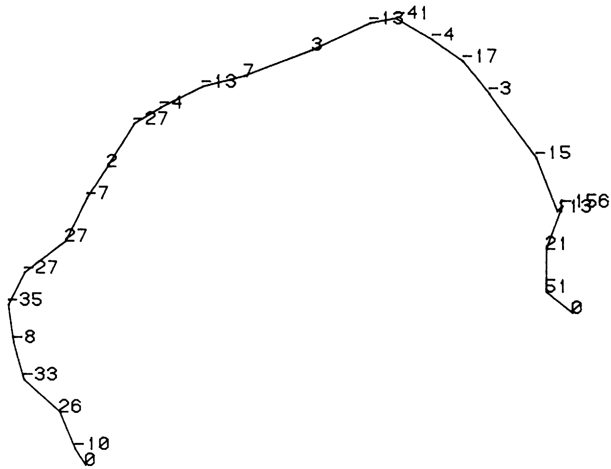


***Fig. 5***—Single fibre (from centre of Fig. 3) with angle of bend displayed at each plotted point

which 1 540 fibres were measured. In all 2 585 fibres were measured. A histogram showing the distribution of fibre lengths for these three pulps is given in Fig. 4 in which the class lengths are 0·1 mm. The longest fibre is slightly more than 3 mm in length. Significantly different length distributions characterise the different types of pulps. Thus, as one might expect, the hardwood pulp shows a preponderence of short fibres with the softwood pulps having broader distributions and longer fibres.

With these semiautomatic data being used to approximate the shape of the fibres, there are small systematic biases leading to underestimates in the fibre lengths. One underestimate comes from the fact that the straight line cords joining points along fibres are shorter than the arc length along the fibres. That error is reduced by taking points closer together. As can be seen in the example of Fig. 2, points were taken closer where there was bending in the fibres. One would expect, with a fully automatic method, to use points considerably closer together than is practical with the semiautomatic method used here. The other systematic bias is caused by the use of fibre images projected on a plane. The effect of this error is reduced by proper microscope slide preparation.

### C. *Curl measurement*

By using these same fibre tracing data, it is possible to make a measurement of a morphological property of the fibres that is a candidate for capturing

***Fig. 6***—Image of Fig. 2 with just those points marked where angle of bend exceeds 45°

the notion of 'curl' as it is currently understood in paper physics. To understand the algorithm for curl measurement, consider the image of Fig. 5 in which a single fibre, taken from Fig. 2, is displayed enlarged. Here the tracing points are not indicated. Rather, at each internal point along the fibre, a number is shown which indicates the angle at that point between the two straight line vectors incident upon that point. Thus, as we proceed around the fibre, the angles between the straight line segments constituting that fibre, as it is traced are successively 10°, −26°, 33°, 8° and so on. These angles indicate the bend of the fibre at each of the points manually traced.

These angle measurements have been obtained for all of the 2 585 fibres which were traced. This produces a very large set of data and raises the question of how best these data may be understood to capture the notion of curl. One interesting possibility is indicated in Fig. 6. Here we show the same image of Fig. 2 with only a small subset of the tracing points being marked. Those points are marked for which the corresponding angle measurement exceeds, in this case, 45°. We thus see a set of fibres which are marked at those points which bend with an angle greater than some prescribed amount, 45°, in the case of Fig. 6.

One might now systematically use this method to quantify the notion of curl. Suppose we consider that fibres are divided into segments, each segment being located between two adjacent marked points or between a marked point and the end of the fibre. Thus, in Fig. 6, some of the segments for the 45° angle

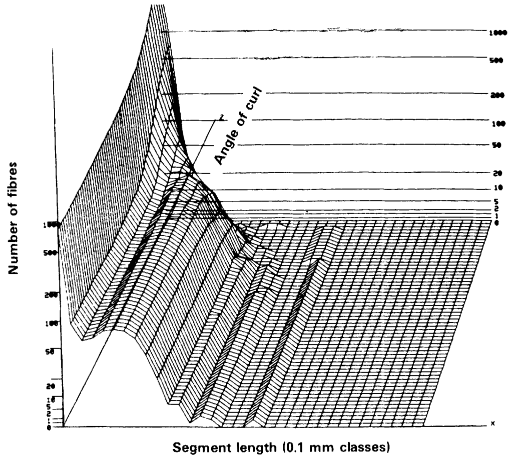


***Fig. 7***—Histogram of number (Y) of fibre segments in length intervals (X): 0 mm (0·1 mm), 3·4 mm, as curl angle (Z) is varied 180°, fibres traced from hardwood pulp

constitute the whole fibre, whereas other segments are proper subparts of a whole fibre. Some fibres are 'broken' into several segments in Fig. 6. We can systematically present a whole set of data corresponding to the fibres from a

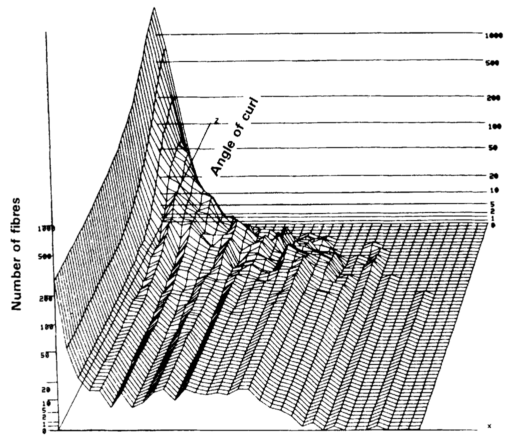


***Fig. 8***—Histogram of number (Y) of fibre segments in length intervals (X): 0 mm (0·1 mm), 3·4 mm, as curl angle (Z) is varied 180° (3°), 0°. Measurements from 620 full fibres traced from northern softwood pulp

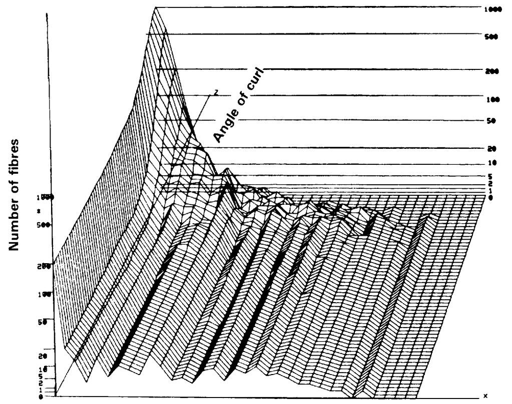


***Fig. 9***—Histogram of number (Y) of fibre segments in length intervals (X): 0 mm (0·1 mm), 3·4 mm, as curl angle is varied 180° (3°), 0°. Measurements from 425 full fibres traced from southern softwood pulp

particular pulp by a method whose results are shown in Figs. 7, 8 and 9. To understand these three dimensional surfaces, consider what would happen if we were to take the distribution of fibre segment lengths rather than whole fibre lengths as we did in Fig. 4.

For each different angle and resultant segmentation as in Fig. 6, we get a different histogram. Thus, the histogram of fibre segment lengths, corresponding to an angle of bend sharper than 180°, is of course the ordinary fibre length histogram since no bend in a fibre can be greater than 180°. Thus, in each of Figs. 7, 8 and 9, the plane closest to the observer corresponding to an angle of 180° is merely the classical fibre length histogram, just as it appears in Fig. 4. Now, however, we see in addition how the histogram of fibre segment lengths changes as we change the angle of bend. In each of these three figures, as one moves one's point of view away from the front plane, the shape of the distribution of fibre segments changes significantly.

Interestingly enough, the change from the classical fibre length distribution to others, through the use of curl information, is slower for the hardwood pulp than it is for the two softwood pulps. There are many different ways to interpret these surfaces exhibiting the histogram of fibre segment lengths as a function of curl angle. Corresponding to each of these interpretations there is a different candidate measurement which captures a notion corresponding to curl. We do not presume here to choose among these various measures, but rather to suggest that a choice among them may yield a candidate which can serve as a useful algorithm to quantify that notion of curl which can predict paper properties.

The work described in the above excerpt is an attempt to establish that measurement methods based on algorithms can be applied to obtain measurements of fibre morphology which are useful in predicting paper properties. The method is only semi-automatic, however, work is in progress on developing tracking algorithms which will enable these measurements to be fully automatic. This work will be the subject of a future report. In addition, plans have been made to develop algorithms for the automatic measurement of other important morphological properties of pulp fibres. When all of the measurement algorithms are completed, it should be possible to make the necessary fibre morphological measurements in real time and enable secondary pulps to be characterised on a routine basis.

Work has been recently reported on the measurement of dirt in pulp and paper by image analysis[3]. Considerable work will have to be done before this measurement technique is standardised, but it is encouraging that an important, but difficult, measurement on pulp and paper is being automated by image analysis. One of the requisites for standardising dirt measurement by image analysis is a standard material for dirt to enable calibration of the instrument. Without a dirt standard there is likely to be disagreement between laboratories on dirt measurement.

Once secondary pulps are able to be characterised routinely, many of the technological uncertainties associated with paper recycling will be removed. As the need for new pulp sources increases due to expansion of paper manufacture, new pulp mills could be designed to utilise waste paper rather than virgin timber for its raw material. Apart from the technological advances required to remove some of the uncertainties in paper recycling, co-operation between governments and the private sector is required for success in collection of waste paper and acceptance of recycled paper products. There will be a need for the paper manufacturing and converting industries to remove contaminants originating in those industries to simplify paper recycling. Perhaps the greatest stimulus for increased paper recycling would be to direct the same creativity and ingenuity towards the problems of recycling as has been directed towards the problems of papermaking using virgin fibres.

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# Discussion

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*Mr M. I. MacLaurin* Esoteric theories about hydrogen bonding, for example, are very much our bread and butter at this symposium. We are doing fundamental research. But we must also be concerned with the real world—often the money for our research comes from people who are concerned with mills and with machinery—and make sure our endeavours are directed towards a fairly practical end, even though we may use the methods of fundamental research methods to get there.

*Dr R. Oye* I would like to ask a question to Dr Eastwood. I was very impressed with PIRA's work which he described on recycling. The state of paper technology seems to be quite similar in the East. In our case the recovery of paper and board is 38–40 per cent; and 0·68 ton, on average, of waste paper is re-utilised to produce 1 ton of paper board. For every 1 ton of newsprint produced, 0·1 ton of recycled fibre is added to the furnish. As Prof. Marton pointed out this morning, there is not too much difficulty in the case of mechanical pulps except for de-inking and screening. However, if we want to increase the cycling ratio from 40–50 per cent, it is necessary to use much more waste paper for making printing or other papers. Have you any ideas how to develop the use of waste paper in printing or other specified papers?

*Dr F. G. Eastwood* Good quality waste can certainly be incorporated into a pulp furnish for printing papers and I am sure this is being done at the present time. There are two important problems with using this waste which are not caused by strength property defects. Firstly, very small quantities of a contrary, such as latex in the waste paper, can cause difficulties in the final printing process on the press and such contraries can be very difficult to sort out from the waste paper. Secondly, the quantity of waste paper of the quality required for such printing paper is in short supply in the UK. As to your question of developing the merits of recycled fibres on specific papers, we have considered the problem from a different viewpoint; although I thoroughly agree with the importance of your approach. The upgrading work at PIRA

*Under the chairmanship of M. I. MacLaurin* has been on improving the strength properties of pilot machine recycled semi-bleached kraft, a material of known prehistory, and also on mixed waste, (see paper by Eastwood & Clarke in a recent edition of Paper Technology and Industry), and on news and pamphlets and other material in abundant supply. Only recently have we started to think about how we might introduce our upgrading work to particular grades of paper made in the mill rather than as received from the waste paper merchant.

*Mr B. W. Attwood* As one who has been involved with secondary fibre over many, many years, I find it most refreshing that at last there is a chance for a fundamental approach to be made. If it is only to stop people repeating experiments carried out many years ago over and over again. I have some criticisms, but I hope these will be constructive. We must understand that it is an extremely complex problem. Suppose you had waste which was entirely from a tissue machine and you recycled it. What sort of material would you get? At the other end of the spectrum, say you had waste which came from a glassine machine and you tried to recycle, what would you get? On top of all this you have the contamination problem. Also a point which I entirely agree with: what really is a handsheet? What are we comparing handsheets with? We still do not know very much about the process and there is a case for taking sheets right the way through a paper machine and having a look at the developments that take place down the machine.

*Mr A. T. Luey* Dr Graminski, will your technique indicate contaminants that are present from a level of something like 25 parts per million? If you do have stickies present in that quantity, and they tend to agglomerate and you have a rejection.

*Graminski* The difficulty would be to develop the technique for measurement. I have specifically asked the recycling industry what their problem was with regard to making high grade papers. One of the questions was about dirt in paper which was very small and which can be very detrimental. The reply was 'I'm not interested in measuring it, I want to know how to get it out'. But, if you do have a method for getting it out, I think you want to be sure that you do have it out; and here is where the technique would be helpful. I think in the future we may be able to measure several properties of interest, two of which are coarseness and wet fibre flexibility.

*Mr V. B. Balodis* Dr Graminski, how do you ensure that the curl of the fibres on the photomicrograph corresponds to the curl of the fibres in the suspension?

*Graminski* There were fibres taken from a dilute suspension placed on a microscope slide and covered with a cover glass so that the fibres were kept flat. I presume, if you can measure a sufficient number of fibres, then I think you have a pretty good idea of the statistical distribution of the curl of those fibres. In automatic mode it will only take a fraction of a second to carry out such an analysis.

*Dr A. de Ruvo* In answer to Prof. Marton's earlier comments, you said that there is an influence due to the pulping process—and of course you are right. The largest losses in strength of course we get when using chemical pulps. We have noticed that, in general, for sulphate pulps, there is a decrease in the recovered properties as you decrease the yield. This is a little depressing as this is the strongest pulp we have. However, if you break the cook at about 65 per cent yield and then proceed with the chlorine bleaching, then this trend is counteracted. This work was reported at the Ellenville Conference in 1975. The explanation for this should be found in the structural differences between the selective delignification and the composite removal of components—hemicellulose and lignin—that you get in the ordinary kraft cook. So, if you selectively remove the lignin, that will improve the ability of the fibre wall to reswell.

*MacLaurin* I was just wondering how many of you here were concerned in the technology or science of recycling and waste paper—I see about four-fifths of the audience,

Dr Caulfield, would you like to comment on the effect of heat cycling on cross-linking?

*Dr D. F. Caulfield* Our work on cross-linking runs contrary to the concept of recycling of fibres. The work is intended for specific purposes where structural factors are more important than recycling.

*MacLaurin* So you do not think it has relevance to what we were talking about?

*Caulfield* It is relevant in the respect that cross-linking will prevent recycling. Unless you can develop a special cross-linked bond that can be hydrolised by some method; that will not hydrolise the rest of the cellulose chain.

*Dr J. D. Peel* I would like to ask those people who have worked in the field of the importance of fines in recycling. Undoubtedly this is one of the most important features of recycling. The increase in fines on repeated recycling seems to be very large. Why? The energy you put into reslushing is nothing like as much as you put into refining, yet on Prof. Szwarcsztajn's figures the amount went up from 5–25 per cent on repeated recycling.

*Prof. E. Szwarcsztajn* On recycling the fibres change by hornification and then they are generating more and more fines during repeated cycling. It is a cumulative process for each recycle.

*Mr P. Howarth* We might be up against a question of definition here. What are fines? If you define fines as what passes through a 200 mesh screen, then in our experiments we do not find this increase in fines. How do you define fines Prof. Szwarcsztajn?

*Prof. Szwarcsztajn* We separate fines in a Swedish Crill separator. The maximum length of these fines is 0·2 mm.

*Dr H. Corte* I would support Dr Peel. No matter how you define fines the fact remains that the drainage resistance increases. That is what matters. You cannot run the machine as fast as you can with virgin fibres. So this is a matter of real mill practice, not just one of definition.

*Mr Howarth* The point has often been made before that we put too much energy into the preparation of waste paper furnish before running it on the machine. That is part of the trouble. We make the recycled pulp too wet.

***Prof. G. Duffy (Prepared Contribution)***

In 1975 I had the privilege of working with Dr de Ruvo's group at the Swedish Forest Product Research Institute in Stockholm and at that time we developed a method of separating fibres at 3–4 per cent concentration into long, medium and fines fractions. The fractionator is a high speed atomisation device and it works just as well at 1 per cent stock concentration as it does at 4 per cent. We can separate the bark, sand, shives and other fine material. It atomises the suspension using a specially designed atomising unit rotating at 20 000 r.p.m. and we get coarse, fine and medium-fine fractions. Obviously from that we could take the long fibred material, beat those long fibres only and recombine them with other fractions to form a better furnish. This may have some value in the future.

TABLE 1—WASTE PULP FROM SEDIMENTATION TANKS

| *Feed* | | *Rejects* | *Total Accepts* | *Accepts 1* | *Accepts 2* |
|---|---|---|---|---|---|
| Fibre | 615 | 62 (10·1%) | 553 (89·9%) | 382 | 171 |
| Shives | 305 | 187 (61·3%) | 118 (38·7%) | 60 | 58 |
| Bark | 39 | 29 (74·3%) | 10 (25·7%) | 2 | 8 |
| Ash | 41 | 11 (27·8%) | 30 (73·2%) | 20 | 10 |
| TOTAL | | 289 (28·9%) | 711 (71·1%) | | |
| Cellulose | 920 | 249 (27%) | 671 (73%) | 442 (48%) | 229 (25%) |
| Bark particle (mm) | | 0·65 | | 0·032 | 0·079 |

Also we have used waste sedimentation pulps as shown in Table 1. This is a waste pulp from the sedimentation tanks. You can see from the Feed composition that we had six hundred-odd parts of fibre, three hundred parts of shives and a small quantity of bark and ash. In another case we had over one hundred parts of sand. You can see from the Accepts column that the chamber has several parts for collection (we collected Accepts from positions one and two only) and we recovered five hundred and fifty parts as long fibre, which is nearly 90 per cent. The shives recovery was about one hundred and eighteen parts (about 39 per cent of the shives), but these were very small particles as you can see from the comparative bark analysis at the bottom of the table. The Reject bark size was at 0·65 mm whereas the Accepts bark size is of the order of 0·032 mm so the shives were of that order of size for comparison. Only the fine shives and fine bark were retained in the Accepts. Keep in mind that 90 per cent of the fibres were recovered from the waste from sedimentation tanks which was collected over several days from the different tanks and added together.

TABLE 2—WASTE PULP WITH SAND

| *Feed* | | *Rejects*‡ | *Accepts* Total | *Accepts* Position 1 | *Accepts* Position 2 | *Accepts* Position 3 |
|---|---|---|---|---|---|---|
| Fibre | 363 | 31 (8·5%) | 332 | 42 | 159 | 131 |
| Shives | 506 | 283 (55·9%)† | 223* | 2 | 39 | 182 |
| Alum | 21 | 7 | 14 | | | |
| Sand | 110 | 105 (95·5%) | 5 | | | |

* Fine shives (increase in coarseness from positions 1 to 3).
† Coarse shives (90%).
‡ 36% Cellulose (11% fibre), 95% Sand in Rejects.

*Discussion*

With the sand case as in Table 2, one hundred and five parts were in the Rejects and only five parts out of the one hundred and ten parts of sand were in the Accepts.

Referring now to Table 3; this is an interesting experiment. We had some waste corrugating board and the liners were peeled manually from the corrugating medium. These were slushed separately and handsheets were formed. Then the waste box material was slurried, dispersed without beating and passed through the fractionator. You can compare, say, the handsheet properties of the liner on the right hand side of the table. Although there is some disparity due to the fact that we did not quite select the correct positions in the collection unit, you can see that there is a fairly good comparison between the properties of the sheets formed from the pulp of the manually separated liner with those of the sheets from the fractionated pulp recovered from the total reslushed boxes. Now, if you compare the corrugating medium you can see again some similarity in the sheet properties. We have gained perhaps in the properties of the corrugating medium over the comparable properties of the liner, but this was the first attempt and it is possible to obtain pulps from the fractionator that agree more closely with the individual liner and corrugating medium.

TABLE 3—FRACTIONATION OF A WASTE CORRUGATED BOARD

| | *Corrugating medium* | | *Liner* | |
|---|---|---|---|---|
| | *Manually Separated* | *Fractionated* | *Manually Separated* | *Fractionated* |
| Basis weight (gsm) | 114 | 131 | 183 | 182 |
| Density ($kgm^{-3}$) | 583 | 544 | 583 | 552 |
| Tensile index ($Nmg^{-1}$) | 34·6 | 40·7 | 43·5 | 36·3 |
| Burst index (k Pa $m^2g^{-1}$) | 1·79 | 2·30 | 2·69 | 2·11 |
| Stretch (%) | 2·1 | 2·2 | 2·0 | 1·8 |
| Elastic modules ($Nmm^{-2}$) | 2820 | 2870 | 3250 | 2840 |
| Tensile energy absorption index ($Jkg^{-1}$) | 502 | 509 | 609 | 470 |
| CMT (N) | 130 | 140 | 184 | 159 |

The atomising unit can therefore be used to screen, clean and fractionate pulps at high stock concentration.

*Mr MacLaurin* Let me try to sum up what the rest of us thought. Firstly, people working on fibre properties should not confine their attention to virgin fibres. Secondly, there must be some way that fundamental research can help the engineers and technologists to design more cost effective processes.

Thirdly, we need better methods of measurement to characterise the stock. A further problem area is how to remove fine contaminants. How do we get rid of them? Up to 400 kWh/tonne for obtaining a clean product from waste is too high. The future energy policies will demand that we reduce this. We also have to find ways of making strong paper from waste without causing drainage problems. First drying is the most important thing, and for countries who buy in their pulp, is their 'first drying' really their second drying? So, perhaps it would be worthwhile investigating whether it would be more cost effective to pay slightly more for pulp at a higher moisture content. Pulp mills are near the forest, so how about small market pulp mills for recycled fibres near the town? That is not just a technological and engineering problem; there are scientific considerations to be taken into account as well.

It is quite clear that we have tried to do too much in the time, but we would be glad to hear any constructive criticisms you may have. I would like to thank all our panelists and discussion contributors for what they have done today. I would also like to thank our two microphone girls, Julie and Sandra, not only for today but for the whole week.