4-11-1996

Deinking in a Closed Loop and the Effects of Solids on Paper Properties

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by

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A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Engineering Degree

Western Michigan University
Kalamazoo, Michigan

April 11, 1996

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ABSTRACT:

Deinking is of critical importance to the reuse of secondary fiber in the paper industry. As with all papermaking processes there is a definite concern on the final quality of the product and the waste that is generated. Waste problems are a growing concern and with tighter discharge limits there is a growing concern of how to deal with these problems. One solution to this problem is the idea of a closed cycle deinking process which reutilizes the wastewater stream for pulping and recovering of usable fiber which is otherwise lost to the system. As with everything there are problems that can occur when implementing a system such as this. The focus of this project is to determine if there is solids build up within the deinking and paper making loop and if there indeed is show these effects on the final paper by testing the whitewater and comparing those tests to the physical properties of the paper. From the results of the whitewater tests there does seem to be a build up of suspended material within the system, but contrary to the initial belief the amount of dissolved material in the system actually decreased. Trends were also observed when comparing TSS and TDS to tensile and tear indexes. It seemed that both were effected by dissolved material and tensile was effected by suspended material both deal with bonding potential. It was also seen and will be explained in more detail that the optical properties of paper were not effected namely opacity and brightness but, scattering coefficient was slightly effected by the increase in suspended solids. The following parts of this report will go through the actual data and trends and will also go through the background and experimentation that was completed.

TABLE OF CONTENTS:

INTRODUCTION:

In recent times recycling has become and to some extent always has been a major source of secondary fiber in the paper industry. Today by either government or consumer demand the use of secondary fiber has increased and the quality of the products produced has also needed to be increased. A major part in the recycling of secondary fiber is the deinking process. Deinking is a fundamentally laundering operation. Once the ink has been removed from the fiber by chemical or mechanical means, there are three basic approaches to removing the ink from the aqueous pulp slurry: washing, froth flotation, and other mechanical devices. However, due to more stringent regulations on discharges of waste and the growing landfill problems, alternative processes must now be considered to reutilize some of the waste stream in the deinking process. Reutilization of the waste through a new process called a "closed loop" would allow for the recovery of usable fiber which is otherwise lost to the waste treatment facility. The focus of this project was to see how a system such as that affects the overall quality of the final product.

BACKGROUND DISCUSSION:

In looking through the literature nothing substantial was found on the subject of closed cycle deinking. However, a study done by NCASI turned up to show the feasibility of implementing such a system and the overall cost (1). The study did not have any data on the effects of such a system once it was in operation, but the article did state that there were definite areas of study that needed to be taken care of in order to effectively implement this kind of system in order to have the least amount of problems. The areas of concern were mostly on the effect of the closed system on the equipment and runnability of the paper machine. However, the focus of this project was to determine the effects of solids build-up within the system and to determine the effects of these solids on the outcome of the final product. The NCASI study also reported that there had not been any pilot or bench type studies on these effects.

The remaining literature gave a good background in the various types of deinking processes and how chemicals are used to remove the ink from the fiber (2,3,4,5,7). Along with the concerns of product quality and the effective wear on the machinery, there were other positive notes on how a system such as this would benefit the waste handling, and the environment. The main benefits would be a reduced water requirement, any toxic chemicals coming in with the pulp would be totally contained and be easier to handle, and the waste discharges would be greatly reduced to the wastewater treatment plant and to the landfill.

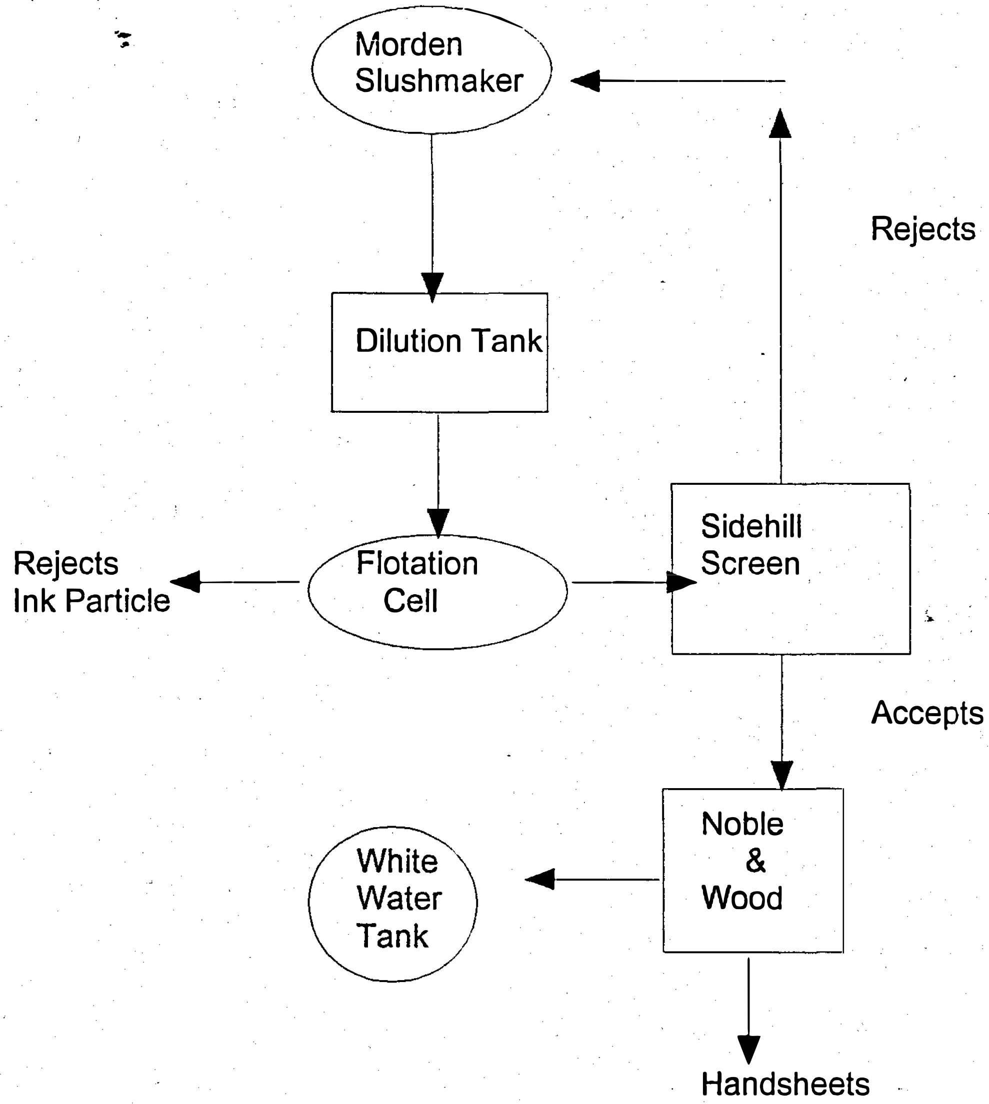
CLOSED LOOP DEINKING: FOCUS

The main focus of this project was to see how the reutilization of water and rejects effects the physical and optical properties of paper (i.e. tensile, tear, brightness, opacity, and scattering coefficient). This would also incorporate the comparison of these physical properties to the results of whitewater tests which were run on the white water during the sheet making process. These tests included total suspended and dissolved solids which were then used to show the effects of the solids on the above paper properties.

EXPERIMENTAL PROCEDURES:

The deinking process was of basic design which included a flotation stage and a washing stage done on the laboratory sidehill screen. Old newspapers were obtained from the Kalamazoo Gazette that contained 66% thermomechanical pulp and 33% of recycle stock of which 70% was old newspaper and 30% was of magazine stock. The process consisted of five runs each of which started out being pulped in a laboratory Morden slushmaker at 4% consistency for 10 minutes. The pulped stock was transferred to a dilution tank and diluted down to 0.75% consistency. After being thoroughly mixed a surfactant from Shell Corporation (Lionsurf) was added at a fixed addition level of 10 milliliters per batch. The stock was then deinked in the laboratory flotation cell and pumped to a sidehill screen to be washed. The washed accepts from the screen were then used to make handsheets and the rejects and water were used as the pulping water for the next run. The accepted stock was used to make 60 grams/meter squared handsheets at a sheet weight of 2.5 grams. Five sheets were made from each run and after each batch a whitewater sample was taken to run total suspended and dissolved solids. The handsheets were then conditioned and then tested for tensile, tear, brightness, opacity, and scattering coefficient. (A simple flow diagram of the stock flows appears on the first page of the appendix)

Process Design



RESULTS PRESENTATION:

The results from the handsheet and whitewater testing are shown in Tables I-V with formulas of the various calculations at the end. In table I the consistencies for the five runs were at or near 1.0% consistency. Table II shows the average readings for the handsheets for basis weight (55.7-61.88 g/m2), brightness (42-46%), opacity (93-98%), and scattering coefficient (42-48%). Table III shows the results of the whitewater tests showing total suspended solids (TSS) ranging from 12.5 to 36 mg/L and total dissolved solids (TDS) ranging from 78 to 88.5 mg/L. Tables IV and V show the results and calculation of tear and tensile index.

Table I: Consistency Calculations

Run #	Filter pad wt. (g)	Pulp weight (g)	Pad weight (g)	Consistency %
1	1.71	529.51	6.57	0.918
	1.61	267.04	4.36	1.030
2	1.64	219.29	3.85	1.008
	1.65	186.18	3.7	1.101
3	1.68	202.67	3.51	0.903
	1.62	240.7	3.77	0.893
4	1.62	173.61	3.17	0.893
	1.66	247.95	3.86	0.887
5	1.67	232.27	3.57	0.818
	1.56	254.86	3.67	0.828

% Consistency = X - Y/Z *100
X=Pad weight
Y=Filter weight
Z=Pulp weight

Table II: Handsheet Data

Run #	Basis Weight	Brightness	Opacity	Scattering Coefficient
1	59.66	46.226	93.48	42.19
2	68.42	42.646	97.04	42.75
3	57.44	45.094	93.51	43.1
4	55.7	45.46	98.26	45.31
5	61.88	43.546	97.71	48.46

Table III: Whitewater Testing Results Sample Volume 100 mL

Run#	Tin#	Filter+sample wt.	Dry weight(g)	TSS (mg/L)	Average
1	1	1.3657	1.367	13	12.5
	2	1.3781	1.3793	12	
2	3	1.37	1.372	20	19.5
	4	1.3722	1.3741	19	
3	5	1.3683	1.3709	26	27
	6	1.37	1.3728	28	
4	7	1.3644	1.3673	29	29
	8	1.3675	1.3704	29	
5	9	1.3746	1.3783	37	36
	10	1.3645	1.368	35	

Run#	Tin#	Pan weight(g)	Dry Weight(g)	TDS (mg/L)	Average
1	11	1.2544	1.2632	88	88.5
	12	1.2606	1.2695	89	
2	13	1.2566	1.2649	83	83.5
	14	1.2644	1.2728	84	
3	15	1.263	1.2713	83	83
	16	1.2597	1.268	83	
4	17	1.2802	1.2884	82	78
	18	1.2661	1.2735	74	
5	19	1.2642	1.2725	83	84.5
	20	1.2547	1.2633	86	

Table IV: Tensile Data

Run #	Sheet #	Tensile Value	Average	kgf	Tensile Index
1	1	2.505	2.592	1.18	12.882
		2.679			
	2	1.756	1.9395	0.88	9.639
		2.123			
	3	2.572	2.721	1.23	13.523
		2.87			
	4	2.706	2.6765	1.21	13.302
		2.647			
	5	1.774	1.816	0.82	9.025
		1.858			
Average Tensile Index for Run# 1 =			**11.67**	**Nm^2/g**	
2	1	2.526	3.165	1.44	13.716
		3.804			
	2	3.286	3.859	1.75	16.724
		4.432			
	3	3.391	3.268	1.48	14.162
		3.144			
	4	3.246	3.304	1.50	14.318
		3.361			
	5	2.47	2.606	1.18	11.293
		2.741			
Average Tensile Index for Run# 2 =			**14.04**	**Nm^2/g**	
3	1	2.999	3.066	1.39	15.827
		3.133			
	2	2.91	2.513	1.14	12.972
		2.115			
	3	2.722	2.509	1.14	12.952
		2.295			
	4	2.572	2.534	1.15	13.081
		2.495			
	5	2.564	2.519	1.14	13.003
		2.475			
Average Tensile Index for Run#3 =			**13.57**	**Nm^2/g**	
4	1	2.652	2.745	1.24	14.612
		2.838			
	2	2.746	2.448	1.11	13.031
		2.15			
	3	1.812	2.125	0.96	11.312
		2.438			
	4	2.566	2.329	1.06	12.398
		2.091			
	5	2.489	2.428	1.10	12.925
		2.367			
Average Tensile Index for Run#4 =			**12.86**	**Nm^2/g**	

Table V: Tensile and Tear Data

Run #	sheet #	Tensile value	Average	Tensile kgf	Tensile Index(Nm^2/g)
5	1	2.835	2.878	1.305	13.790
		2.921			
	2	2.765	2.856	1.295	14.194
		2.947			
	3	2.915	2.855	1.295	14.189
		2.794			
	4	2.84	2.988	1.355	14.850
		3.136			
	5	2.413	2.514	1.140	12.494
		2.615			

Average Tensile Index for Run # 5 = 13.90 Nm^2/g

Tear Data

Run #	Tear value	Tear Force mN	Tear Index (mNm^2/g)
1	10	392.4	6.577
	8	313.92	5.262
	8	313.92	5.262
	10	392.4	6.577
	11	431.64	7.235
	8	313.92	5.262
Average Tear Index for Run#1=			**6.029** m'Nm^2/g
2	12	376.704	6.314
	12	376.704	6.314
	14	439.488	7.367
	15	470.88	7.893
	14	439.488	7.367
	15	470.88	7.893
Average Tear Index for Run#2=			**7.191** mNm^2/g
3	11	345.312	5.788
	12	376.704	6.314
	12	376.704	6.314
	12	376.704	6.314
	12	376.704	6.314
	11	345.312	5.788
	11	345.312	5.788
	12	376.704	6.314
Average Tear Index for Run # 3 =			**6.117** m'Nm^2/g
4	12	376.704	6.314
	12	376.704	6.314
	11	345.312	5.788
	11	345.312	5.788
	11	345.312	5.788
	11	345.312	5.788
	11	345.312	5.788
Average Tear Index for Run # 4 =			**5.938** m'Nm^2/g
5	17	533.664	8.945
	14	439.488	7.367
	14	439.488	7.367
	13	408.096	6.840
	13	408.096	6.840
	13	408.096	6.840
Average Tear Index for Run # 5 =			**7.367** mNm^2/g

Formula Sheet for Data Calculations:

Tensile Index:

$$T.I. = \frac{(\text{value x lbs})}{(2.205\ \text{lbs/kg})} \times \frac{(653.8\ \text{g/kg})}{\text{Basis Weight g/m}^2}$$

Tear Force:

$$T.F. = \frac{(\text{Tear value} * 16 * 9.81)}{\text{No. of sheets torn}}$$

Tear Index:

$$T.I. = \frac{\text{Tear Force}}{\text{Basis Weight}}$$

Total Suspended Solids:

$$TSS = \frac{(\text{Weight of filter and sample}) - (\text{Weight of dry sample}) * 1000\text{mg/g}}{\text{Sample Volume (100 mL)}}$$

Total Dissolved Solids:

$$TDS = \frac{(\text{Pan Weight and Sample}) - (\text{Pan Weight after Drying}) * 1000\text{mg/g}}{\text{Sample Volume (25 mL)}}$$

DISCUSSION OF RESULTS:

The results of the various handsheet and whitewater tests will be discussed here as to how they do or do not correlate with each other. The first graph in the appendix is the graphical interpretation of the whitewater solids content that includes TSS and TDS. These results were graphed by run to see if they start to build up within the system as the water is recirculated. As is seen in the graph suspended material does indeed increase which is as expected due to the recirculation of the whitewater. However, it is also shown that the amount of dissolved material decreases as time goes on. It was thought initially that the trend of dissolved material would follow the same curve as the TSS but as seen this is not the case. There is only one possible explanation for this, it decreases because of the handsheet process itself in which water leaves with the sheet after the headbox is drained and is lost to the system by either pressing or with the drying stage. This explanation does not in fact account for that much of a decrease in TDS since the quantity of water leaving with the sheet is small as compared to the entire whitewater system. However, this is the only explanation available since there are only two possible exits for water to leave the system with the flotation froth and at the headbox with the sheet.

The next graph in the series shows the effect of TSS on strength properties namely tear and tensile index. This graph shows that tear and tensile follow the same type of curve which should not be the case since tensile is effected by the number of bonds and bonding area and tear is more effected by fiber length. Tensile Index does show a slight increase after the later runs which can be attributed to the amount of fines increasing within the system which lend to better bonding and higher strength. Tear however does not show any increase but it should be suspect to change as suspended material starts to really build up and a higher percentage of fines gets trapped in the sheet which will ultimately lower the tear index.

The third graph is similar to the second except the strength properties are subject of the effect of total dissolved solids. It is seen that the curves are again similar which should not be the case but the trend is easily explained. As seen both tensile and tear both increase slightly as the runs progress and at the later runs they both start to fall off. This can be attributed to the deposit of dissolved material on the fibers themselves creating a layer between the fibers that does not give as good a bond as would a direct fiber to fiber bond.

The forth graph depicts how tensile strength changes after each batch and shows the effect of solids at each batch. It shows that in the first batches the solids have more of an effect early and towards the later batches the effects are less due to the fact that the solids build up is not as dramatic later as they are earlier. That initially, there are no solids to speak of and when the first pulp is added to the system the solids fraction is very high. However, when subsequent additions are made the effect is less and less and according to the graph tend to start to equal out as time goes on. To say that the amount of solids added nearly equals the amount taken out of the system with the sheet.

Graph number five shows the relationship of TSS on Opacity and Scattering Coefficient. It shows that suspended material does not effect opacity over the five runs. However, it can be foreseen that as the solids really start to build up and the number of fines increase the more dense the sheet will become and the higher the opacity will be. Also, it should be noted the opacity is affected by the basis weight of the sheet, the caliper of the sheet, and the spot where the reading of opacity was taken which in the future may come into play. As for scattering coefficient initially it is not effected but in the later runs there is a definite increase which can be attributed to the build up of fines in the system which causes more surfaces for light scattering thereby increasing the scattering coefficient.

The final graph deals with the effect of TSS on the brightness of the sheet. As seen from the chart brightness was not effected over the five runs. However, it can be inferred that as solids really start to build up within the system brightness will be affected somewhat.

CONCLUSIONS:

The use of a totally closed loop deinking system is relatively new in the paper industry and its affects are just now being understood. There are many other concerns that must be dealt with in order to implement a system that addresses these issues. Through researching the data that was just presented it was found that the amount of suspended material within a system like this does indeed build up over time. The amount of dissolved material from the data presented shows a decrease which can only be attributed as a loss through the transport of water with the sheet. This is not a satisfactory explanation for that amount of material to be lost but it is the only one that can be made. Along with the build up of solids there is a definite impact on the strength of the sheet. As seen tensile strength does increase with TSS and can be attributed to fines accumulation within the system. Tear can be inferred to decrease as fines increase within the sheet. As for TDS and strength you have to take a look at the bonds between fibers. It can be concluded that as dissolved material deposits on the sheet and the fibers the bonding is weakened and the sheet is not as strong as it would be if just fiber to fiber bonds existed. It was also seen that the effects of solids is greatest early on and that later the solids effects are less due to the removal of solids with the sheet. Brightness and opacity went relatively unchanged but it can be expected that as solids start to really build up and suspended and dissolved material deposit on the sheet there would be an affect. And finally, scattering coefficient did increase and was directly affected by the increase in suspended material caused by the deposition of fines in the sheet causing more surfaces for light scattering and may cause drainage problems on the paper machine thereby affecting machine speeds.

RECOMMENDATIONS:

If time did not dictate everything that is done in this world there was allot of things that could have been accomplished to supplement the data that was just presented. One of the thing that could have been done was to conduct more runs which would have generated more data points and given better trends in which to base more sound conclusions. Another area of study would be how changing the surfactant level after each run would affect the solids content and the properties of the sheet. Comparing different furnishes to each other would be very interesting to see how they would react to the same type of conditions. The best area of study would be changing the length of the pulping time this would definitely change the solids content in the loop and there might be an opportunity to see better the effects of solids on the sheet properties.

LITERATURE CITED:

1. NCASI Special Report, "A preliminary engineering study and cost implications of converting deinking mills to closed cycle operation." No. 94-03, march 1994.

2. Ferguson, L.D., "Deinking Chemistry I and II," TAPPI, 7:75 and 8:49, 1992.

3. Shrinath, A., J. T. Szewczak and I. Jerry Bowen, "A Review of Ink Removal Techniques in Current Deinking Technology," TAPPI, 7:85, 1991.

4. Ferguson, L.D., TAPPI Notes, Deinking Seminar, 1992.

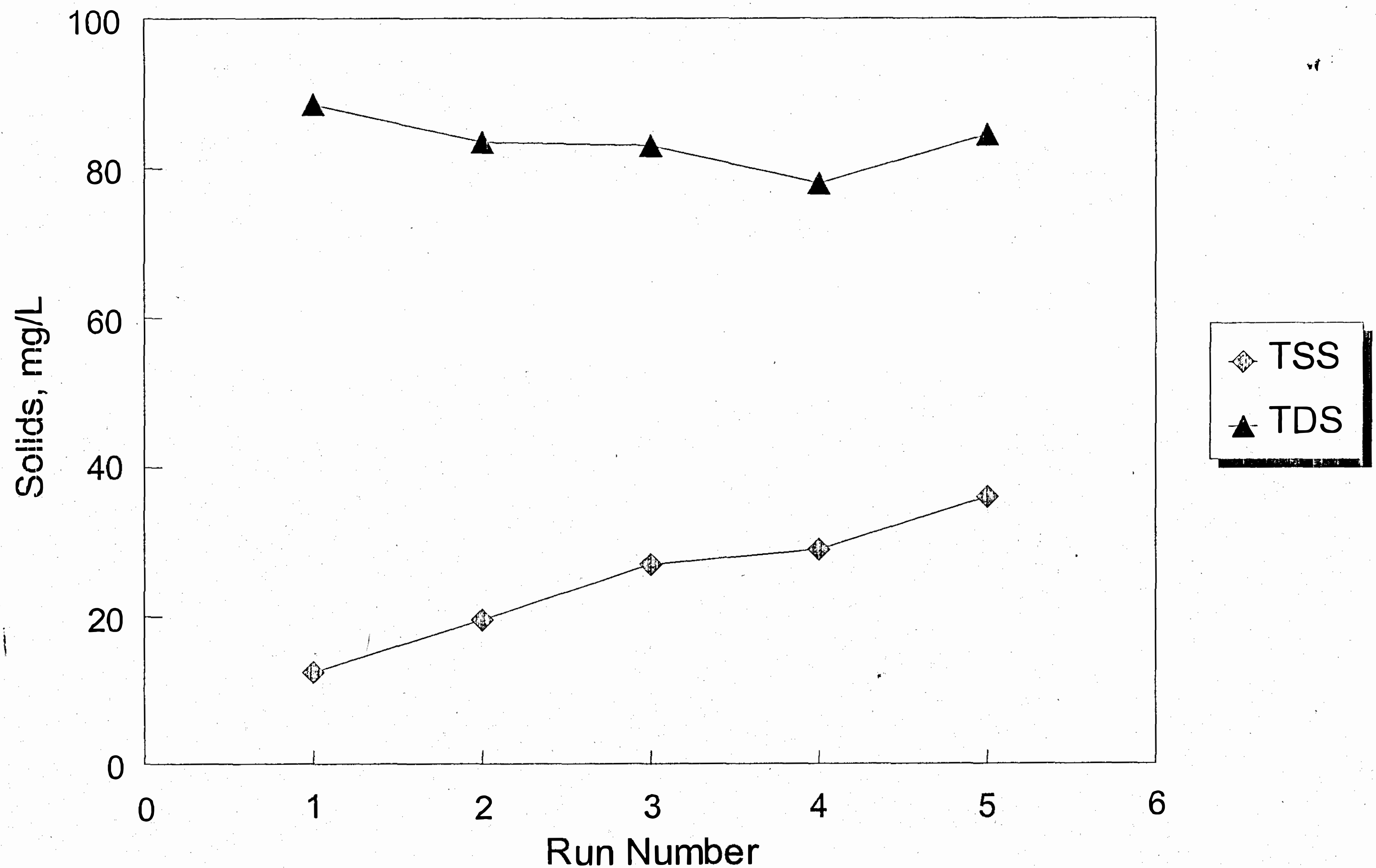
5. Streebin, Leale, George Reid, Paul Law, etc., "Water Reuse in a Paper Reprocessing Plant," TAPPI, 5:105, 1976.

6. Geller, L. and L. Gottsching, "Closing Water Systems Completely in Federal Republic of Germany," TAPPI, 9:97, 1982.

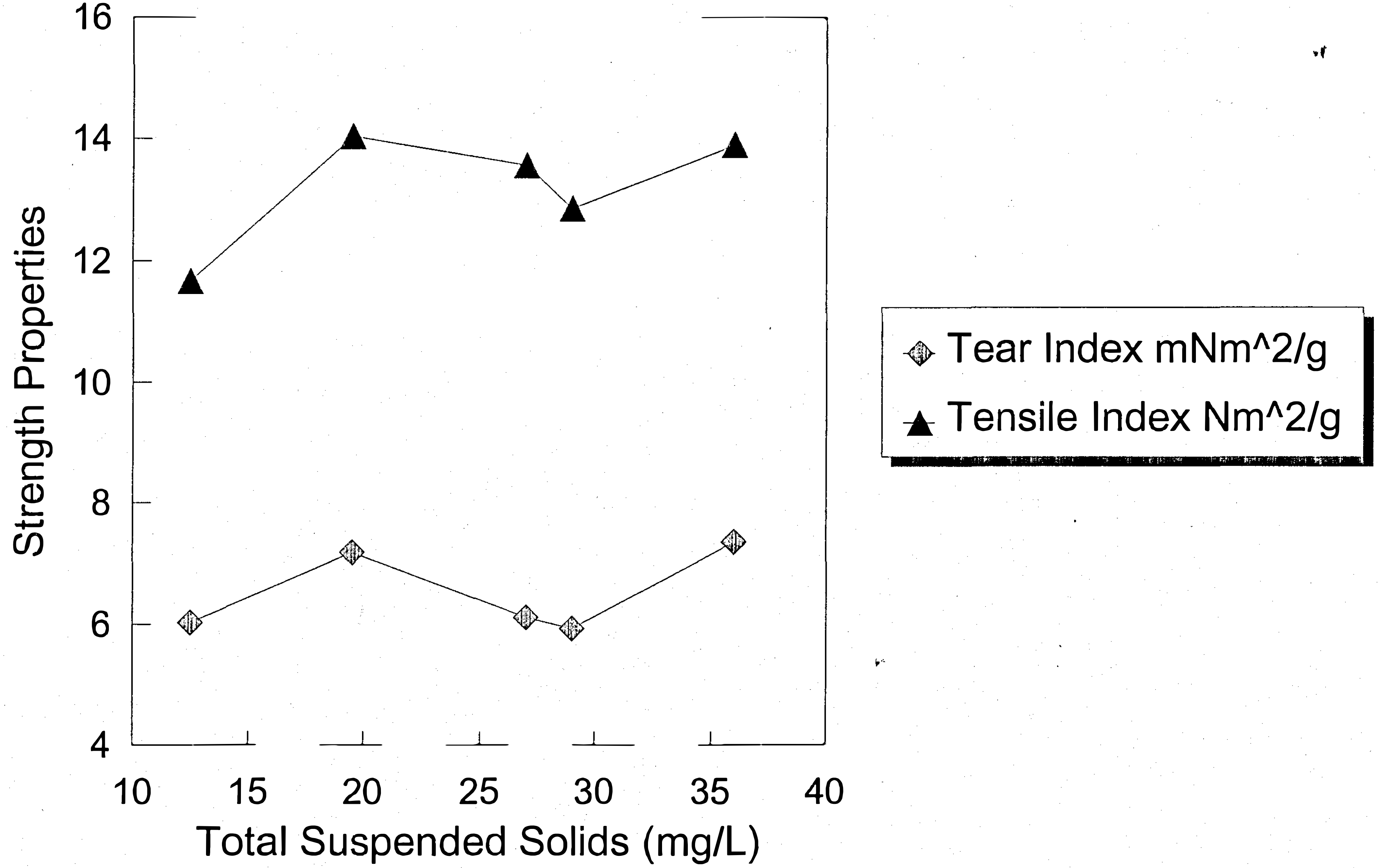
7. Secondary Fiber Recycling, chapters 6 and 15, TAPPI, 1993.

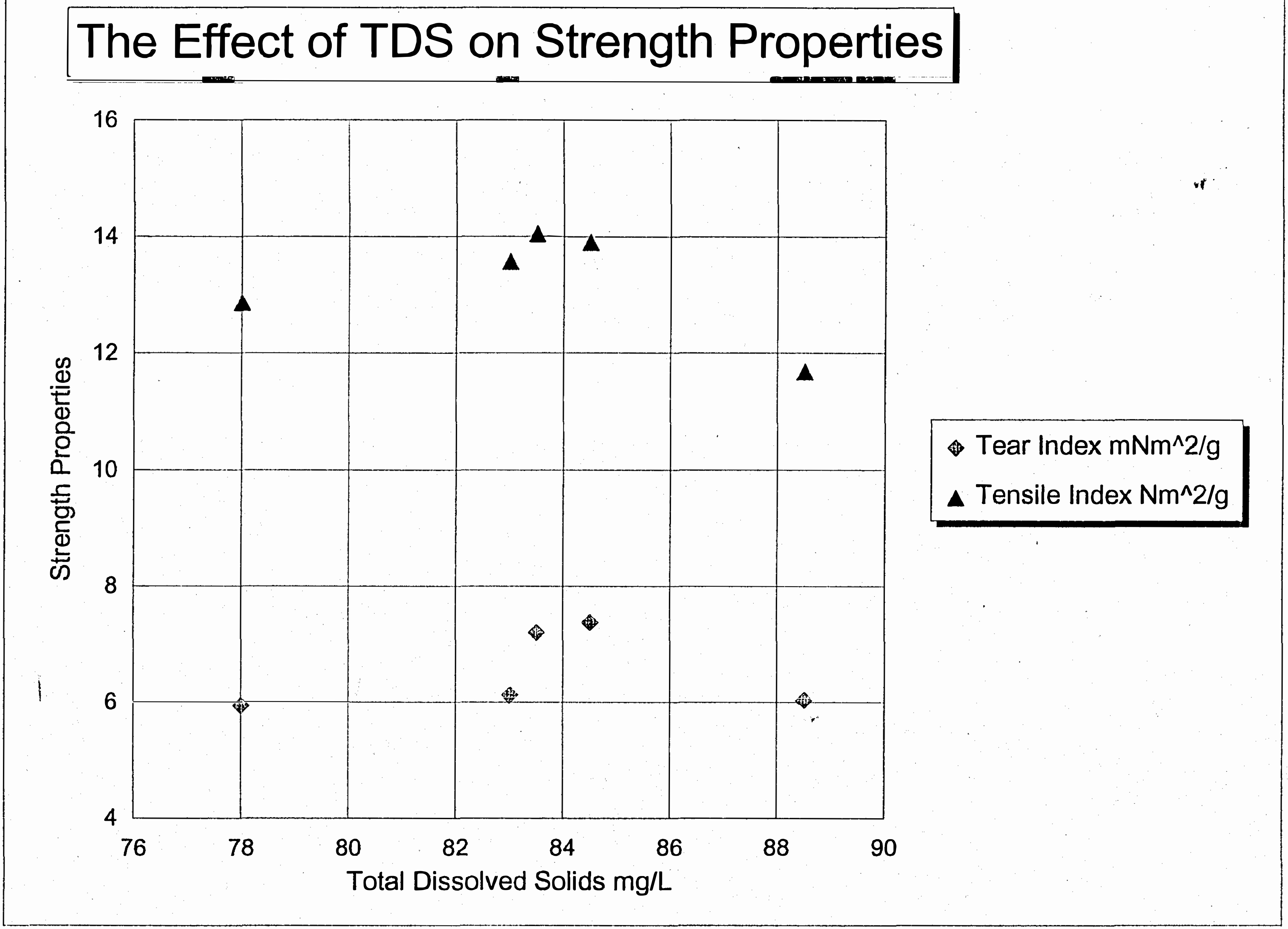
APPENDIX:

Total Suspended and Dissolved Solids

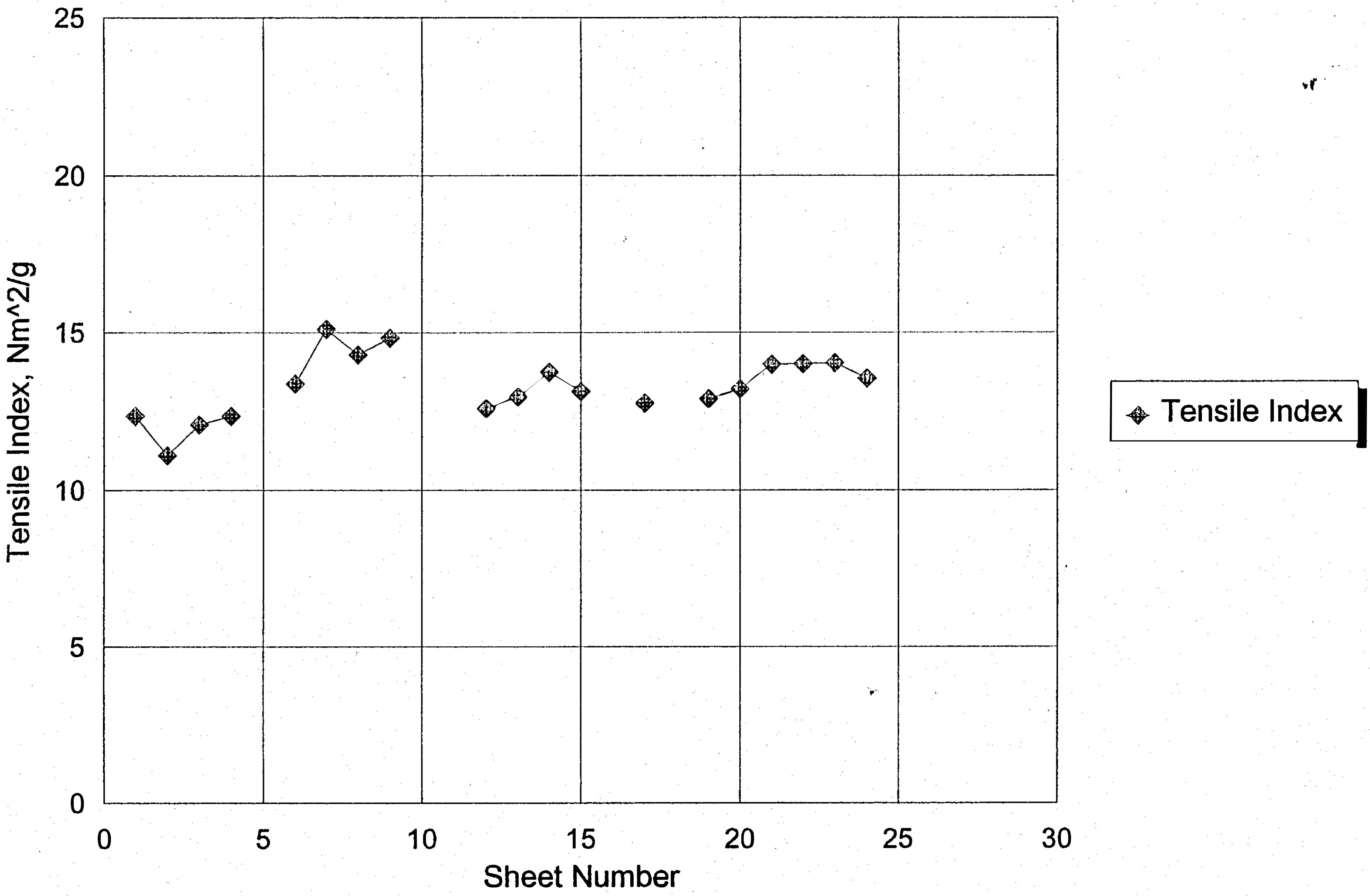


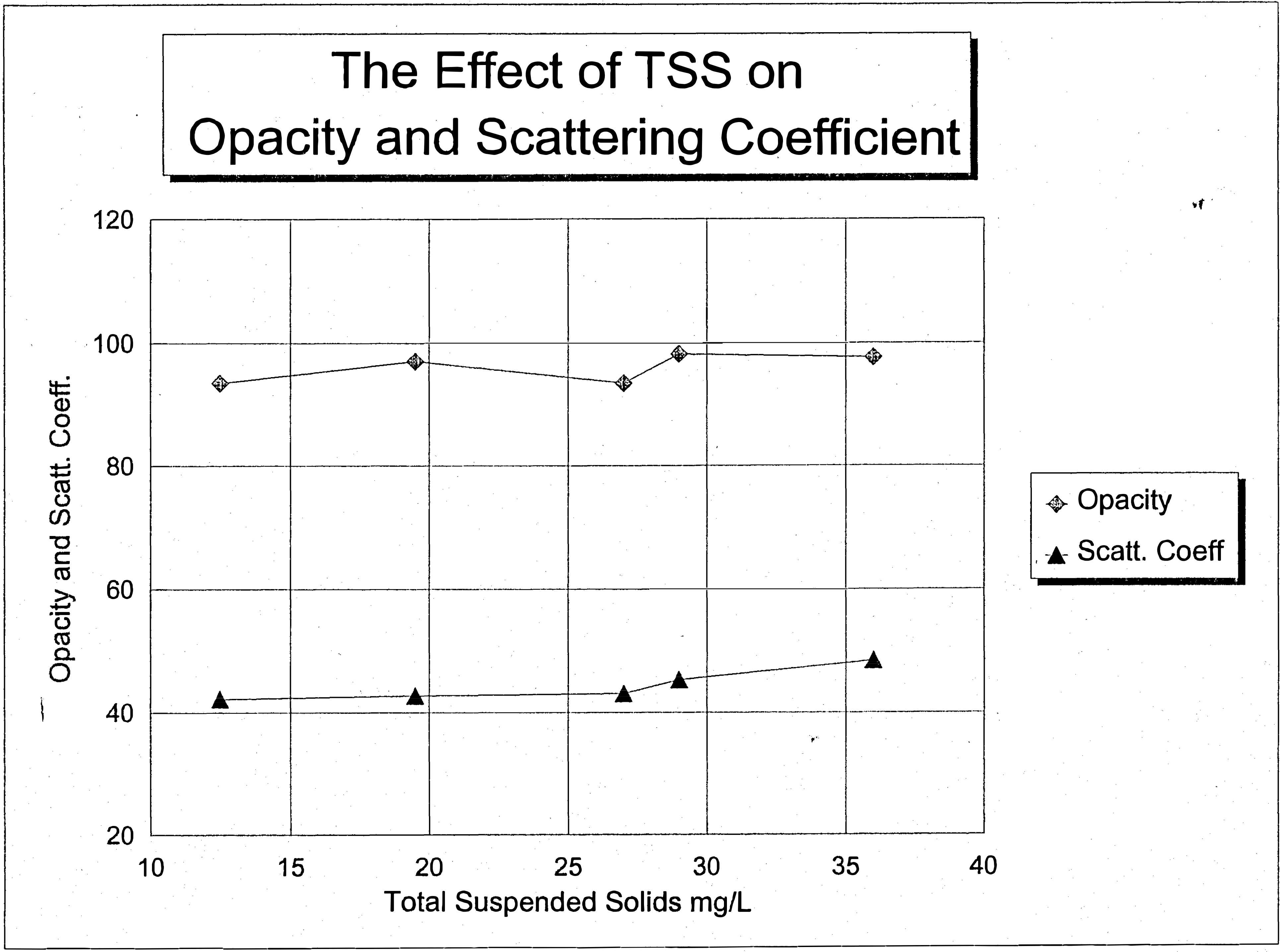
The Effect of TSS on Strength Properties




The Effect of TDS on Strength Properties
Strength Properties
16
14
12
10
8
6
4
76
78
80
82
84
86
88
90
Total Dissolved Solids mg/L
Tear Index mNm^2/g
Tensile Index Nm^2/g

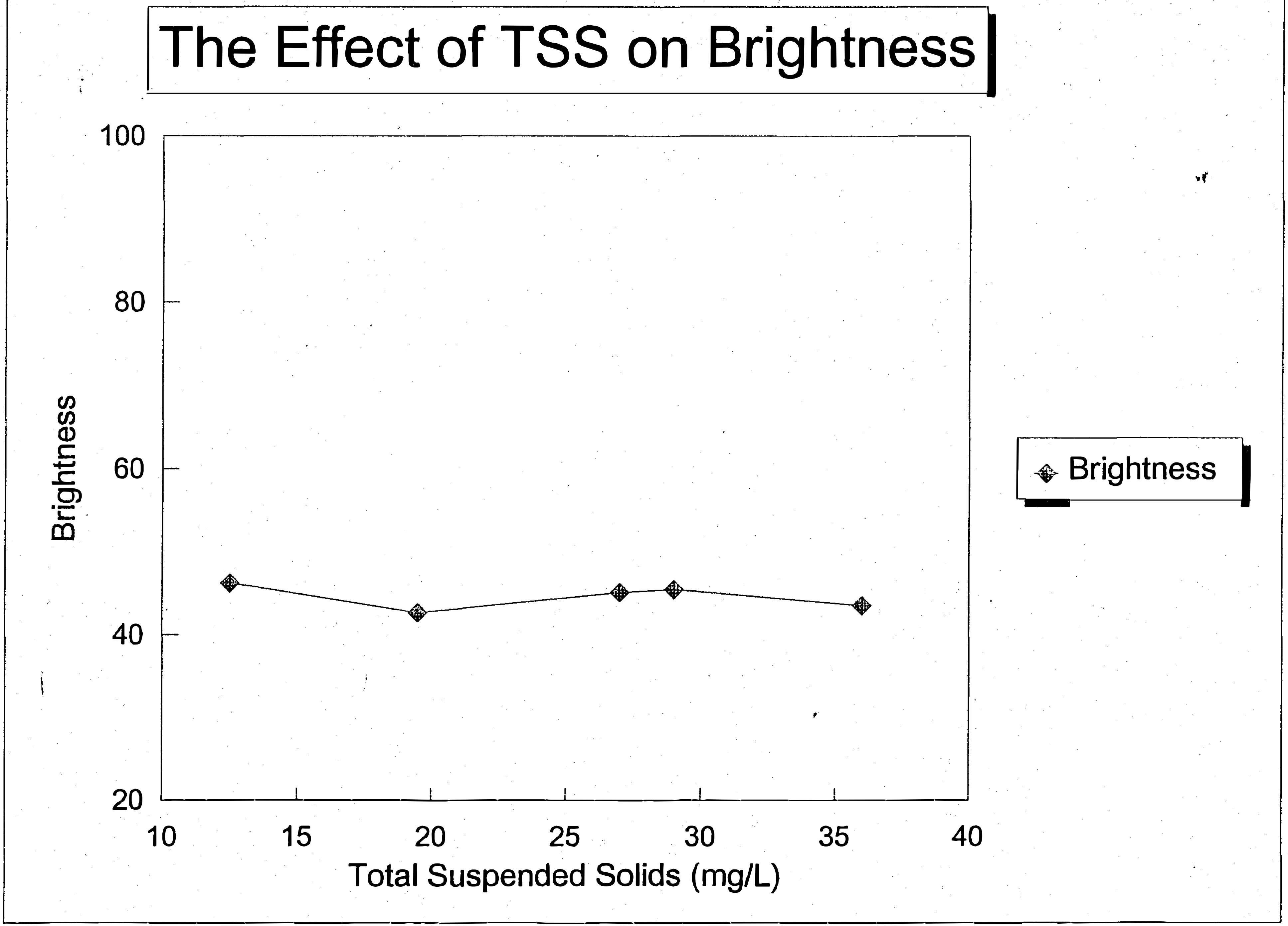
Sheet Batches and How Tensile Increases per Batch





The Effect of TSS on
Opacity and Scattering Coefficient
120
100
80
60
40
20
10
15
20
25
30
35
40
Total Suspended Solids mg/L
Opacity and Scatt. Coeff.
Opacity
Scatt. Coeff

25.


The Effect of TSS on Brightness
100
80
60
40
20
Brightness
10
15
20
25
30
35
40
Total Suspended Solids (mg/L)
Brightness

26.