Some Experiments on the Utilization of Rice Straw in Papermaking

Kirit C. Mody
Western Michigan University

SOME EXPERIMENTS ON THE UTILIZATION OF RICE STRAW IN PAPERMAKING

SENIOR STUDENT THESIS
PRODUCED IN PARTIAL FULFILLMENT OF
REQUIREMENTS FOR THE DEGREE OF
BACHELOR OF SCIENCE IN PAPER TECHNOLOGY

by

KIRIT C. MODY

DEPARTMENT OF PAPER TECHNOLOGY
SCHOOL OF APPLIED ARTS AND SCIENCES
WESTERN MICHIGAN UNIVERSITY
KALAMAZOO, MICHIGAN

JUNE, 1961

SOME EXPERIMENTS ON
THE UTILIZATION OF RICE STRAW
IN PAPERMAKING

TABLE OF CONTENTS

SOME EXPERIMENTS ON THE UTILIZATION OF RICE STRAW IN PAPERMAKING

I. A BRIEF DESCRIPTION OF RICE STRAW

The botanical name for rice straw is Oryza sativa. Rice is a well-known cereal and is the staple food of hundreds of millions of people. According to R. J. Rochevica, cultivated rice, including all numerous varieties, originated from wild species, which are indigenous to Africa, India, and Indo-China (6).

Rice is grown in coastal plains, tidal deltas, and river basins in tropical, semitropical, and temperate regions, where fresh water is available to submerge the land. Principal rice producing countries are China, India, Pakistan, Japan, Thailand, Malay Federation, Indo-China, and Burma.

The total world rice crop for 1958 was estimated at 481,463.0 million pounds, compared with 425,211.8 million pounds in 1957 (11). According to statistics published by the U. S. Department of Agriculture (11) the production of rice was as follows in 1958:

Table I. World Production of Rice

Continent	Production Million Pounds
North America	6,683.2
South America	11,041.0
Europe	3,614.4
Africa	8,669.6
Asia	450,636.6
Australia	343.2
World Total	481,463.0

Total production of pulp from rice straw, wheat straw, rye straw and other types of straw amounted to one million tons per year, or three per cent of the world's production, according to F. A. O. publication issued in 1952 by the United Nations (12).

In the early nineteenth century, rice straw paper was used for newspaper. Because of technical and economical disadvantages, pulp producers did not give much attention to rice straw as raw material. But in these days of increasing demand for paper and paperboard, particularly in those areas of the world which are deficient in wood, rice straw can satisfy the demand (5). The yield of rice straw is one and one-fourth ton per ton of rice (12)

Before World War II, white paper of high quality was made in Java from 100 per cent rice straw. Two Javanese mills in operation today have together a capacity of forty tons per day (5).

The physical composition of rice straw is as follows: (5)

Table II. Physical Composition of Rice Straw

Culms	32.4 per cent
Leaf Sheaths	33.1 per cent
Leaf Blades	16.4 per cent
Rachis, Glumes, and Nodes	11.9 per cent
Residual Grains	0.7 per cent
Debris and Fines	5.5 per cent

II. ANATOMICAL PROPERTIES OF RICE STRAW

Small grains, straws, or culms are erect, elastic, generally tubular structures, separated at intervals by nodes, occurring as vascular bundles crowded together and interlaced to form a strong diaphragm between the internodes. The rachis, or top portion of the stem to which the seed is attached, is usually found with the straw. The leaf, starting at the node, forms a sheath part way up the straw stem and ends in a leaf blade. Straw grows from about two to six feet tall, depending upon variety, climate, and cultural conditions (1).

Aronowsky (1) compared the dimensions of straw fiber with fibers of other origin, as may be seen from Table III.

Table III. Dimensions of fibers

	Rice Straw	Wheat	Bamboo	Jack Pine Wood
Length in Micron:				
Maximum:	3,480	3,120	4,350	-----
Minimum:	650	650	1,450	-----
Average:	1,450	1,480	2,700	3,000
Diameter in Micron:				
Maximum:	14	24	27	-----
Minimum:	5	7	7	-----
Average:	8.5	13.3	14.0	40.0
Ratio of length to average diameter	170:1	111:1	192:1	75:1

Lathrop (9) in his study about pulp fibers from agricultural residues discussed their chemical composition and properties. He found that cereal straws, particularly rice straw, have a high ash content with respect to the physical property of dimension. The ratio of length to diameter of the rice fiber is about twice that of coniferous wood.

Lathrop compared the dimensions of rice straw fiber with bamboo and coniferous wood fiber, as shown in Table IV.

Table IV. Fiber Dimensions

Fiber	Rice	Bamboo	Coniferous Wood
Average Length, mu	1450	2700	2700-3600
Average Diameter, mu	8.5	14.0	32-43
Ratio: Length to Diameter	170:0	200:1	75-90:1
Relative Density	open	dense	dense
Relative Ease of Pulping	1	4	4

III. THE CHEMICAL COMPOSITION OF THE RICE STRAW

The chemical composition of rice straw is as follows: (1)

Table V. Chemical Composition of Rice Straw

	Rice Straw	Wheat Straw
Moisture*	8.1	8.3
Ash**	17.5	11.0
Lignin**	12.5	18.0
Pentosans**	24.0	28.0
Acetyl**	----	7.3
Solubility in		
Alcohol-Benzene**	4.6	3.5
Hot water**	13.9	15.5
One per cent Sodium Hydroxide**	50.0	47.8
Cross and Bevan cellulose		
Crude**	47.3	46.6
Pentosans in C & B cellulose***	27.9	29.5
Alpha cellulose in C & B cellulose***	67.5	66.2
Alpha cellulose, basis original straw**	32.1	30.5

* Values expressed in per cent of straw as received
** Values expressed in per cent of oven-dry straw
*** Values expressed in per cent of oven-dry C. & B. cellulose.

Nikitin (10) carried out chemical analysis of rice straw from North Korea, which gave the following results:

Table VI. Chemical Composition of Rice Straw from Korea

Component	Per cent
Cellulose (HNO_3-C_2H_5OH) *	51.4
Cellulose (HNO_3-C_2H_5OH) on ash free basis *	55.2
Pentosans (12% HCl method) *	20.5
Mannan and Galactan *	Traces
Lignin (72% H_2SO_4 method) *	23.0
Lignin on ash free basis *	9.0-10.0
Ash *	14.0
Polyuronides *	6.6
Readily hydrolyzable reducing sugars (Bartrand method) *	14.31
Alcohol -- Benzene extractive *	1.5
Composition of ash:	
SiO_2 **	78.8
Al_2O_3 **	1.9
CaO **	7.8
MgO **	1.8
SO_4 **	1.5
Na_2O + K_2O **	6.3

* Values expressed in per cent of O. D. straw
** Values expressed in per cent of dry ash

In comparison with wood, rice straw pulp production causes an increased number of problems; particularly the

higher ash content of rice straw causes some complications in pulp making and recovery of the chemicals used in the production processes.

IV. PULPING OF RICE STRAW BY VARIOUS PROCESSES

IV-A. Early Investigations on Mechano-Chemical Pulping

The technical literature contains limited information dealing with the pulping of rice straw, which type of pulp was produced as early as 1900 (5).

Aronowsky and Nelson (2) used wheat straw in their pulping rate studies. This investigation was carried out in a hydrapulper. The cooking chemicals were caustic soda, or caustic soda and sodium sulphide, or sodium carbonate and sodium sulphite at three levels of temperature, namely, 73°, 83°, and 93° C. The most rapid pulping rate occurred in the first five minutes. Delignification continued after this period but at a greatly retarded rate. About 55 per cent of the lignin, 30 per cent of the pentosans, and 85 per cent of the ash, based on the original dry straw, were removed in the first five minutes. At the end of one hour, amounts removed were 70 percent of the lignin, 35 per cent of the pentosans and 90 per cent of the ash.

The authors investigated also the effect of different pulping agents at comparable concentrations, namely, 12 per cent caustic soda, 8 per cent caustic soda plus 4 per cent sodium sulphide, and 12 per cent sodium sulphite plus 6 per cent sodium carbonate. The straw pulp decreased in yield very rapidly during the first five minutes of cooking. Caustic soda and mixtures of caustic soda and sodium sulphide gave practically the same degree of delignification of straw. Sodium sulphite was too mild to produce satisfactory pulp at the relatively low temperature used. Furthermore, the authors observed that increased cooking temperature and increased concentration of cooking chemicals accelerate the rate of delignification of straw.

The authors (2) concluded that efficiency of delignification in the mechano-chemical process is probably due to the increase in diffusion velocity of active chemicals and reaction products into and out of the fibrous plant material.

Aronowsky and Lathrop (3) prepared a series of cooks from wheat straw, using a Hydrapulper and a pressure digester for the sake of comparison. Cooking for one hour at 90 to 98° in a Hydrapulper gave strawboard pulp with yield and physical properties as good as the characteristics of a pulp obtained

by cooking at 140° C. and 40 Psi for five hours in a digester with the same amount of chemicals. Results of these experiments may be seen from Table VII: (3)

Table VII. Pulping Conditions; Hydrapulper versus Digester

Cook Number	662	663	678	683	687
Chopping:					
Type	D	—	W	D	W
Time, minutes	—	—	12	—	17
Cooking:					
Time, hours	5.0	5.0	1.0	1.0	0.5
Temp. °C.	140	140	95-98	91-98	90-98
Consistency %	14.1	14.1	3.0	8.0	5.0
Final liquor pH	8.8	8.9	11.4	11.1	11.4
Pulp yields:					
Crude -- B %	80.1	83.2	82.0	83.0	81.9
Crude -- C %	—	81.1	—	84.1	80.7
Washed -- B %	75.3	79.9	75.8	78.0	5.0
Washed -- C %	—	75.9	—	79.1	5.0
Fines -- B %	4.8	5.3	6.0	77.6	4.3
Fines -- C %	—	5.2	—	77.8	2.9
Power -- H.P./ton pulp/day					
Chopping	—	—	7.0	—	14.9
Pulping	—	—	30.2	39.3	27.0
Total	—	—	37.2	39.3	41.9

Legend:

D: Dry chopping
W: Wet chopping
B: Defibered and washed in Noble and Wood beater
C: Defibered in Bauer pulper and washed in Noble and Wood beater

Further investigations showed that higher yields of kraft straw pulps were produced by a one-half hour treatment in a Hydrapulper than by a two hour treatment in a pressure vessel at 100 Psi and 170° C. The physical properties of the Hydrapulper product were claimed to be fully as good as those obtained by the pressure cook; as to chemical composition, higher pentosans, and lower ash content characterized the Hydrapulper product. Finally, it was established that re-using the kraft black liquor from the Hydrapulper had little effect on the yield and properties of the resultant pulp, thus making possible significant savings in cost of chemicals and steam.

IV-B. Recent Investigation in Pulping of Rice Straw

Chittenden and Morton (4), in their pulping studies of rice straw by the kraft process in a digester, stated that severe cooking conditions produce relatively slow pulp with a high drainage time. On the other hand, under milder cooking conditions, the pulp was stronger and relatively free, thus being suitable for wrapping paper and similar grades.

The authors carried out bleaching trials, using either three stages, chlorination, alkaline extraction, and hypo-

chlorite treatment or single stage hypochlorite treatment. The total chlorine consumption in three stage bleaching was 4.3 per cent based on oven-dry unbleached pulp, and the yield was 27 per cent based on dry straw. The single stage bleaching was carried out, with 4 per cent available chlorine based on hypochlorite; the yield was 30 per cent in terms of dry straw.

Furthermore, the authors evaluated the pulps by the beater method. The results are shown in Table VIII.

Table VIII. Sulphate Cooks on Rice Straw. Cooking Data (4).

Cook Number	K34	K35	K38	K39	K40
Effective alkali as NaOH on oven-dry raw material %	24	20	15	10	20
Sulphidity %	20	20	25	20	25
Ratio of liquor to oven-dry raw material	7:1	6:1	6:1	6:1	6:1
Maximum temperature, C°	150	150	150	150	150
Time to reach maximum temperature, hour	1	1	1	1	1
Time at maximum temperature, hour	1	1	1	1	1
Consumption of effective alkali on oven-dry raw material	17.9	15.9	9.5	----	16.1
Yield of unbleached pulp:					
Screen pulp %	20.7	27.1	38.1	----	33.5
Screening %	0.2	0.3	0.8	----	0.6
Total %	20.9	27.4	38.9	50.2	34.1

Pulp produced from rice straw by the K39 cooking conditions, when bleached by a single stage bleaching procedure, has properties very similar to commercially available bleached wheat straw pulp. The K39 pulp was suitable for the manufacture of many grades of papers such as writing, printing, and light wrapping papers.

Fahmy, Yehia, and Fadl (7) in their investigation used Egyptian rice straw. The pulp was produced by pressure cook, mechano-chemical and alkaline chlorine processes at different temperatures and pressure. The experimental conditions may be seen from Table IX, and the results may be found in Tables Xa and Xb.

Table X. Digestion Data (7)

Process		Temperature C°	Time, hour	Liquor ratio
1	Mechano-chemical	---	1.00	1:10
3	Pressure cook	120	1.25	1:10
4	Pressure cook	120	4.00	1:10
5	Pressure cook	150	0.30	1:10
6	Pressure cook	170	2.00	1:10
7	Soaking without agitation	---	1.00	1:20

It was observed that pulp no. 5, prepared at 150° C. with 30 minutes cooking time, contained less ash than pulp no. 3 cooked at 120°C. for 1.25 hours. Pulp from the alkaline chlorine process had the lowest strength. It was observed in experiments 1 through 6 that low ash content could be correlated with relatively high degree of polymerization of the holocellulose.

Table Xa. Pulping Data and Strength Characteristics of Different Processes (7)

Experiment No.	1	3	4	5	6	7
Cooking temp., C.	Mech-Chem	120	120	150	170	Alkaline
Cooking time, hour	1.0	1.25	4.0	0.30	2.0	Chlorine
Yield, grams o.d.	48.5	45.5	45.2	44.3	42.8	----
Alpha cellulose	73.3	75.1	75.4	75.7	83.7	
Furfural	17.51	17.43	17.31	16.68	14.41	
Degree of polymerization	756	758	742	840	628	
Ash	0.76	0.73	1.80	1.28	11.10	
Lignin	2.1	2.3	1.9	1.2	1.1	
Brightness %	75	75	74	74	72	75
Beating time to 50° in sec.	120	180	60	150	60	5
Breaking length, km	5.81	5.78	4.79	5.54	4.25	4.32
Elongation %	4.0	3.8	3.5	3.4	4.0	2.8
Folding endurance	645	755	327	780	200	160
Burst factor	26.2	26.3	20.3	22.8	20.0	20.0
Tearing resistance	122	113	102	109	89	98

Table Xb. Pulping Data and Strength Characteristics of Different Processes (7). Unbleached

Experiment No.	1	2	3	4	5	6
Cooking temp., C.	Mech-Chem	Ohne Rühr	120	120	150	170
Cooking time, hour	1.0	1.0	1.25	4.0	0.30	2.0
Yield, grams o.d.	49.5	51.0	47.8	47.3	46.5	45.6
Presence of coarse material (shives)	++	+++	++	+	+	0
Alpha cellulose	71.5	----	72.6	72.9	73.0	81.2
Furfural	17.72	----	17.63	17.53	16.84	14.66
Degree of polymerization	882	----	860	850	857	785
Ash	3.05	3.01	4.91	4.10	5.12	13.3
Lignin	3.8	4.2	3.9	3.5	1.8	1.5
Methanol-benzene extractive	0.93	----	1.45	1.51	1.52	1.32
Natural chlorine demand (chlorine no.)	2.50	----	1.90	1.75	1.60	1.25
Breaking length, km.	6.18	7.65	6.47	6.58	6.52	5.60
Elongation %	3.96	4.40	4.05	3.70	3.95	4.08
Folding endurance	513	671	577	850	893	383
Burst factor	23.2	37.1	31.3	33.0	33.8	23.3
Tearing resistance	121	109	114	119	115	141

The above data indicates that short cooking cycles at high and low temperatures resulted in higher freeness values, lower ash content and better strength characteristics than the prolonged cooking cycles.

Earnest, Fauad and Clark (5) in their investigation used rice straw from Louisiana, Arkansas, and Egypt. They employed mechano-chemical and pressure pulping techniques. The mechano-chemical process was carried out for one hour at 90° C., using 14, 16, and 18 per cent chemicals for the soda process and 14 per cent chemicals for the kraft process. The pressure cook process was carried out for two hours at 170° C, using 12 and 14 per cent chemicals for the soda cook and 15 per cent chemicals for the kraft process.

The mechano-chemical process using caustic soda for pulping was most effective in developing pulp strength. It was more effective than mechano-chemical process using kraft liquor and was more effective than the pressure techniques used. Pressure cooked pulps required less chemical for bleaching than pulps obtained from the mechano-chemical processes. Low ash content (0,50 per cent) of the rice straw pulp could be obtained by the mechano-chemical technique with caustic soda,whereas ash content values as high as 12.0 were found when straw was digested under pressure cook.

It was also found that centrifugal cleaning of the pulp was an effective means for improving the quality of rice straw pulp. This procedure resulted in ease of bleaching and improved strength characteristics of rice straw pulp.

Hoepner (8) investigated the pulping of rice straw by the soda process using different concentrations of caustic soda at 120° and 170° C. for two hours. The yield decreased considerably with increase in temperature and caustic soda. He studied and discussed the effect of cleaning , cooking temperature, and cooking time on physical properties and yield.

Table XIa. Pulping Data and Strength Property of Rice Straw Pulp at 125° C. (8)

NaOH %				
Added	8.4	10.8	14.5	19.3
Used	5.7	7.7	10.0	14.8
J. N. permanganate no.	85.0	68.0	61	56
D. P.	955	1010	1080	1100
Yield %	70.9	67.1	67.0	64.7
Ash %	19.0	17.8	16.7	9.4
Strength properties (masc. values)				
Tensile strength, km.	5.2	5.6	7.0	8.0
Folding endurance	130	270	400	500
Bursting area, sq. m.	24	26	30	37
Tearing strength, gm. cm./cm.	96	95	100	101
Yield.bleach				
Pulp basis %	85.0	88.5	92.1	91.8
Straw basis %	60.0	59.3	63.4	60.0

Table XIb. Pulping Data and Strength Properties of Rice Straw Pulp at 170° C. (8)

NaOH %				
Added	8.4	10.8	14.5	19.3
Used	8.1	10.2	12.0	16.5
J. N. permanganate no.	96	68	54	52
D. P.	985	1015	1035	1095
Yield %	23.1	22.7	19.1	12.5
Ash %	64.1	62.0	60.6	58.8
Strength propertiex (max. values)*				
Tensile strength, km.	5.3	5.1	5.4	6.9
Folding endurance	85	110	190	350
Bursting area, sq. m.	25	24	28	34
Tearing strength, gm. cm./cm.	96	82	105	107
Yield %				
Pulp basis %	87.7	91.0	92.0	92.0
Straw basis %	56.1	56.5	58.8	54.1

A. E. Williams (14) in his report mentioned that pulp from rice and wheat straw was produced in the following manner:

Pieces of straw, cut into one inch lengths, were mixed with lime to soften the plant tissue and to assist in releasing the cellulose; this mixture was then transferred into digesters. The author reported that the Indian Forest Research Institute carried out experiments with 10, 12, and 15 per cent lime in a temperature range between 142 and 162° C., to find the most suitable concentration of alkali and working

temperature. It was reported that the yield from wheat straw was higher when 12 and 15 per cent lime was applied. In addition the straw, treated with 10 per cent lime, was found to be undercooked. The yield with 12 and 15 per cent chemicals at 142° and 153° C. was higher than the yield obtained at 162° C.

The Institute made many attempts to convert rice husk to useful pulp, but efforts have not been very promising so far. Rice husk cooked with 15 per cent lime for six hours was not even softened. In other experiments, husk was soaked in water for 25 days and then digested with 26 per cent caustic soda at 162° C. for six hours; this brought about some softening of the husk. Further processing produced 35.1 per cent yield of material in the form of powder, which possessed limited usefulness.

Research work carried out at the Institute showed that strength properties of both wheat and rice straw increased by beating the pulp. It was concluded, considering strength properties and yield, that the digestion of rice straw with 12 per cent lime at 142° C. for four hours gave the best results.

The report of the United States Technical Co-operation Mission to India (13) described the Van Hwa plant of Taipei; Taiwan, as to chemical composition the rice straw used in that mill, when compared with wood, contained approximately an equal amount of holo cellulose. However, the rice straw contained more hemicellulose and less alpha cellulose than wood.

The pulp from rice straw was prepared by a three step process: 1. Steam purging, 2. Liquor impregnation, and 3. Pressure cooking. The pulping condition may be seen from Table XII.

Table XII. Pulping Conditions Used in the Van Hwa Plant (13)

Cooking temperature	170° C.
Cooking pressure	90 P.S.I.
Cooking cycle	6 hours
Charge and steaming	30 min.
Hot liquor impregnation	1 hour 30 min.
Heating from 140 to 170° C.	20 min.
Cooking at 170° C.	3 hours.
Steam relieving	20 min.
Dumping	20 min.
Sodium hydroxide used *	9 per cent
Chlorine used **	6 per cent
Sulpher Dioxide used **	1 per cent
Pulp yield from digester ***	48 per cent
Pulp yield from bleaching ***	42 per cent

* Based on a. d. rice straw.
** Based on a. d. pulp
*** Based on o. d. straw

Bleaching was carried out in two steps: (1) bleaching by means of sodium hypochlorite, soaking at room temperature for at least 12 hours to reduce the nodes and shives in the straw, (2)* treatment with sulphurous acid, to reduce the iron in the straw pulp. The brightness reported was 75 per cent.

Screening was carried out in two stages, a procedure which gave cleaner straw pulp than one stage screening.

The strength quality of rice straw pulp actually approached the strength of soft wood sulphite pulp in all characteristics except tearing resistance. The fiber length of straw pulp was fairly short and the drainage time relatively high. Thus high quality paper could be produced when the bleached rice straw pulp was blended with some chemical wood pulps or rag pulp.

L. Bogulslawski and J. Marchlewska-Szrajerowa (20) in their report described the rice straw pulp mill in Sznolnok which uses the kraft and neutral sulphite process.

V. PROBLEMS CAUSED BY USE OF RICE STRAW PULP IN PAPERMAKING

Vemos, Mero. and Langyel (15) found in their experiments that rice straw may cause difficulties due to its high ash

content. Suitable cooking conditions could be found to eliminate the complication caused by high ash content. The authors observed difficulties on the paper machine, especially due to slow drainage in dewatering and due to picking on press rolls.

The authors carried out laboratory and mill experiments and they claimed that one could produce good quality paper from rice as well as wheat straw if the following conditions were maintained: a relatively free stock, as little water on the wire as possible for the sake of proper dewatering, a wire of proper length provided with ample number of suction boxes, good transfer from wire to presses, and perhaps the application of vacuum transfer.

Kober, Langyel, Tibor and Morvey (17) stated that the difficulties encountered on the paper machine when one uses straw pulp are mainly caused by sticking of wet pulp at the first press. These difficulties can be explained by the difference in wet tearing resistance between wood pulp and straw pulp. At an equal degree of beating, the drainage rate for wood pulp is different from that of straw pulp. The performance of straw pulp on the paper machine is influenced favorably by short cooking cycles and by use of adequate quantity of chemicals in cooking. The strength charac-

teristics are favorably influenced by thorough washing of the straw pulp and by multi-stage bleaching procedures. The strength characteristics are unfavorably influenced by prolonged storage. Similar observations were reported by P. Gati and G. Vamos (18).

VI. RECOVERY OF CHEMICALS AND STEAM FROM RICE STRAW PULP BLACK LIQUOR

When the rice straw pulp is produced by the soda or kraft process, one should recover chemicals, since, otherwise, cost will be very high. In addition, the recovery of the fuel value contained in the black liquor is of main importance in production of pulp from rice straw. In recovery of chemicals the high content of silica in rice straw is an obstacle. The silica reacts with alkali and produces silicates, which in turn cause encrustation in evaporators and furnaces. Due to these difficulties caused by high silica content, one has to find some process to eliminate silica from black liquor before evaporation (16).

Kober, Mero and Langyel (17) discussed the recovery of chemicals from waste liquor. The methods of reclamation of chemicals from black liquor, from sulphate and soda pulping

alike were complicated due to high silica content of rice straw amounting to 8 to 12 per cent. This high silica content resulted in 16 to 22 gms./liter of silica in black liquor.

The authors stated that the best known methods for removal of silica compounds before evaporation of the waste liquor were the CEPI process and the Gruen process (19). The second method which used CaO and eliminated the silica compounds by means of carbon dioxide was quite promising in laboratory experiments, because it removed silica effectively and produced a precipitate, which was relatively easy to filter.

The authors continued that the recovery of lime used for causticizing is not practical at present and will be possible only as soon as the problem will have been solved of how to remove the silica content from black liquor.

LITERATURE CITED

1. Aronowsky, S. I., "Annual Crop Fibers," Pulp and Paper Manufacture, Vol. 2.

2. Aronowsky, S. I., and Nelson, G. H., "Mechano Chemical Process-Rate of Deliquification," Tappi, Vol. 34, No 5: 216-222 (May 1951).

3. Aronowsky, S. I., and Lathrop, E. C., "A New Mechano Chemical Process," Tappi, Vol. 32, No. 4: 145-149 (April 1949).

4. Chittend, A. E., and Morton, D., "Report on Rice Straw from British Guiana for Papermaking." Colonial Plant and Animal Prods. (Gt. Brit.) 6, No. 1:53-62 (1956): B. I. P. C. 27:1289; C. A. 51:14263.

5. Earnest, A. J., Fauad, Y., and Clark, T. F., "Rice Straw for Bleached Papers." Tappi, Vol. 43, No. 1:49-53.

6. Encyclopedia Brittanica, "Rice" Vol. 19 (1955)

7. Fahmy, Yehia and Fadl, Mohammed, "A Comparison of the Suitability of Different Rice Straw Pulping Process." Das Papier 13, No. ½: 15-17 (January 1959) [In German, English, and French Summaries]. A. B. I. P. C. 29:1343.

8. Hoepner, Theodor., "Rice Straw and Rye Straw for Pulp and Paper." Tappi. Vol. 43, No. 5: 214A-218A (May 1960)

9. Lathrop, E. C., "The Characteristic of Pulp Fibers from Agriculture Residue." Tappi, Vol. 35, No. 11:60A-68-A (November 1952)

10. Nikitin, V. M. and Din, Kim Kha., "The Composition of North Korean Rice Straw." Bumazh from 33, No. 5:15-16 (May 1958). A. B. I. P. C. 26:862; C. A. 52:19120.

11. U. S. Department of Agriculture, "Agriculture Statistics 1959." U. S. Govt. Printing Office 1960, Washington, D. C.

12. "Raw Materials for More Paper" Food and Agriculture Organization of the United Nations., Rome, Italy (December 1952).

13. United States Technical Cooperation Mission to India, "Rice Straw Paper Manufacture." Indian Pulp and Paper, Vol. 12, No. 1:73-74, (July 1957), B. I. P. C. 28:833.

14. Williams, A. E., "Progress in Indian Strawboard Manufacture." Papermaking Vol. 75, No. 4:14-16; B. I. P. C. 27:999.

15. George Vamos, Tiber Mero, and Paul Lengyel, "Rising Utilization of Straw Pulp in the Paper Industry." Tappi, Vol. 40, No. 7:180-A-188A (July 1957).

16. Casey, J. P., "Pulp and Paper Chemistry and Chemical Technology." Vol. 1:398-400.

17. Kober, Lidia; Langyel, Pal, Tibor, Mero, and Mervey, Sandor. "Some Problems of Straw Pulp Manufacture." Papiripar 2, No. 4:121-132 (1958), A. B. I. P. C. 29:1025

18. Gati, Peter, and Vamos, George, "Some Problems of Straw Manufacture in Hungary." Zellstoff U. Papier &, No. 5:142-9 (May 1958), A. B. I. P. C. 29:83.

19. Gruen Bengt H. E., U. S. Pat. 2,628,155 (Feb. 1, 1949) B. I. P. C. 23:516; C. A. 47:8368.

20. Bogullawski, L, and Marchelewska-Szrajerowa, J., "Rice Straw as a Papermaking Raw Material in Hungary." Przeglad Papierniczy 12, No 11:321-325 (1956); B. I. P. C. 27:1289; C. A. 51, No. 10:7713.

Experimental Design

Objective of the Project:

The purpose of this investigation was to ascertain whether suitable cold soda pulp could be prepared from rice straw.

Experimental Procedure Planned for this Study:

It was planned to carry out cold soda pulping of this straw, using 4 to 6 inch size pieces. The pulping variable studied was the effect of the period of soaking of straw for one-half hour, one hour and two hours. The concentration of the caustic liquor to be used was 60 gms/liter. This was done at room temperature and atmospheric pressure.

At the end of the soaking period the residual alkali in the liquor was estimated.

The yield of refined and screen pulp was determined. The zero-span was determined for fiber strength. The freeness of the pulp was recorded.

In addition it was planned to carry out single stage bleaching with hypochlorite, hydrogen peroxide and zink hydrosulphite.

Experimental Work

Raw Materials, Method and Equipment Used

I. Straw:

The rice straw was obtained from Louisiana State, U.S.A. The straw was cut into pieces of 4 to 6 inches

in length by paper cutter and stored.

II. Preparation of Cold Soda Pulps

Three pulping experiments were made.

Pulping Procedure:

In all experiments the variable studied was the effect of time on soaking straw in alkali. The other variables pressure, temperature, concentration and liquor-to-straw ratio were kept constant.

For each experiment an equivalent amount of 200 gms A.D. straw was weighed out and 1500 ml of 6 per cent sodium hydroxide was added separately.

pH of Liquor:

The pH of liquor was determined at the start and end of the steeping period by means of a Beckman pH meter equipped with glass electrode.

Residual Alkali:

After the soaking period the excess of liquor was separated by filtration and 10 ml of this liquor was titrated against hydrochloric acid and the amount of residual alkali was calculated.

Total Solids:

To determine the total solids in black liquor 10 ml of black liquor were used and evaporated on a

sand bath. The total solids present were calculated on oven dry.

Refining:

After the black liquor was removed the straw was refined repeatedly in a Bauer refiner using for first pass drecker plate and for second and third pass through medium plate at load of 3.5 amperes on meter with water running through the refiner.

Yield:

After screening through 0.01 inch cut screen, the yield of the screened pulp and rejects were determined.

III. Bleaching:

For each bleaching experiment the amount of pulp used was 15 gm O.D. The bleach requirements and the consistency were different for different experiments. The pH before and after bleaching were noted. The temperature was kept constant at 50° C for 60 minutes. The yield and brightness were determined.

Bleaching by Hydrogen Peroxide:

The amount of pulp used was 15.0 gms O.D. at consistency of 3 per cent. The chemical used was 3 gm of H_2O_2 per 100 gm of O.D. pulp. Temperature and time were maintained constant at 50° C and 60 minutes at pH 10.0.

Bleaching by Hypochlorite:

The consistency of the pulp was 1 per cent. 10 gms of available chlorine were used per 100 gm O.D. pulp at pH 10.0.

Bleaching by Zink Hydrosulphite:

The consistency of pulp was 3 per cent. Chemical used was 4 gms per 100 gms O.D. pulp at pH 5.0.

IV. Evaluation of pulps for Fiber Strength Properties:

For zero-span of pulp the hand sheets were prepared.

Forming of Handsheets:

Handsheets were prepared in accordance with TAPPI standard procedure T205M-58 and these were conditioned in a constant temperature and humidity room as specified by TAPPI standard practice.

Testing of Handsheets:

The handsheets were tested for basis weight, brightness by I.P.C., and zero-span, according to TAPPI standard procedure.

Presentation of Results

Experimental conditions, alkali consumption, yield, freeness are shown in Table I. The bleaching experiments data is given in Table II. The fiber strength, zero-span

of unbleached and bleached pulps are shown in Table III. The brightness of unbleached and bleached pulp is shown in Table IV.

The values for rejects, accepts and zero-span plotted against time are shown in Figures I, II and III.

Discussion of Results:

I. Pulping Results:

a) Alkali Consumption:

The alkali consumption decreases with decrease in time of penetration. In all three experiments alkali used were 102.7 gm. In experiment I due to long penetration time more alkali was consumed than in experiment III.

b) Screen Rejects:

The amount of screen rejects was high when relatively penetration time was small. This was resulted due to inadequate penetration.

c) Yield:

The yield is maximum in experiment III, I and then II. The acceptable fibers are maximum in experiment III may be accounted for relative difficulty in screening.

II. Bleaching Characteristics:

In bleaching the hypochlorite is most suitable for rice straw pulp as it gives rise in brightness by 14

points approximately. Treatment by zink hydrosulphite reduced the brightness, while hydrogen peroxide increases brightness by 4 points approximately. While loss in both hypochlorite and hydrogen peroxide is equivalent. Lower the consistency more gain in brightness point, which is observed in hypochlorite bleaching.

In experiments II and III after bleaching the zero-span increases are due to the removal of lignin.

III. Strength Characteristics:

The zero-span of fiber is relatively higher when penetration time is longer. It can be accounted for removal of more lignin. The strength decreases in experiment I after bleaching but increases in experiment II and III. At lower penetration time, pulps obtained had low strength properties. This is apparently due to insufficient removal of lignin.

Conclusions

a) Rice straw is suitable for the manufacture of cold caustic soda pulp.

b) To obtain better quality of pulp, the straw should be washed and cleaned before penetration, to remove node, dirt and grit.

c) The 6 per cent sodium hydroxide for rice straw produced the best strength properties and fairly good yield.

d) Instead of single stage bleaching if three stage

bleaching is carried out, then better quality pulp can be expected.

e) In no case is zink hydrosulphite suitable for rice straw. The hypochlorite is most suitable.

Acknowledgment

The assistance of Dr. R. A. Diehm, Dr. A. H. Nadelman and the faculty of the Department of Paper Technology is greatfully acknowledged.

Kirit C. Mody

Table I: Pulping Conditions and Results

Experiment	I	II	III
Straw used O.D. gms	202.0	196.0	196.0
Time of Penetration in hours	2	1	1/2
Accepted fibre	78.0	72.5	80.0
Rejected fibre	6.0	7.4	28.7
Yield %	39.3	36.4	40.8
Alkali used in gms	102.7	102.7	102.7
Alkali consumed in gms	46.21	43.43	36.95
Total solids	83.44	69.12	60.38
pH of alkali	10.3	10.3	10.3
pH of B. Liquor	10.3	10.3	10.2
Freeness in C.S.	450	317	390

Table II. Data of Bleaching

Type of Bleaching	Pulp No.	Chemical Concentration in gms	Time in minutes	Temp. in C°	pH	Consistance %	Loss in gms
Hypo-Chlorite	I	10 gm available Cl_2/100 gm O.D.	60.0	50°	10.0	1.0	1.77
	II	"	60.0	50°	10.0	1.0	4.50
	III	"	60.0	50°	10.0	1.0	5.43
Hydrogen Peroxide	I	3 gm/100gm O.D.	60.0	50°	10.0	3.0	1.50
	II	"	60.0	50°	10.0	3.0	4.12
	III	"	60.0	50°	10.0	3.0	5.25
Zink Hydro-sulphite	I	4 gm/100gm O.D.	60.0	50°	5.0	3.0	----
	II	"	60.0	50°	5.0	3.0	3.8
	III	"	60.0	50°	5.0	3.0	4.8

Table III: The Zero-span of Bleached and Unbleached Pulps

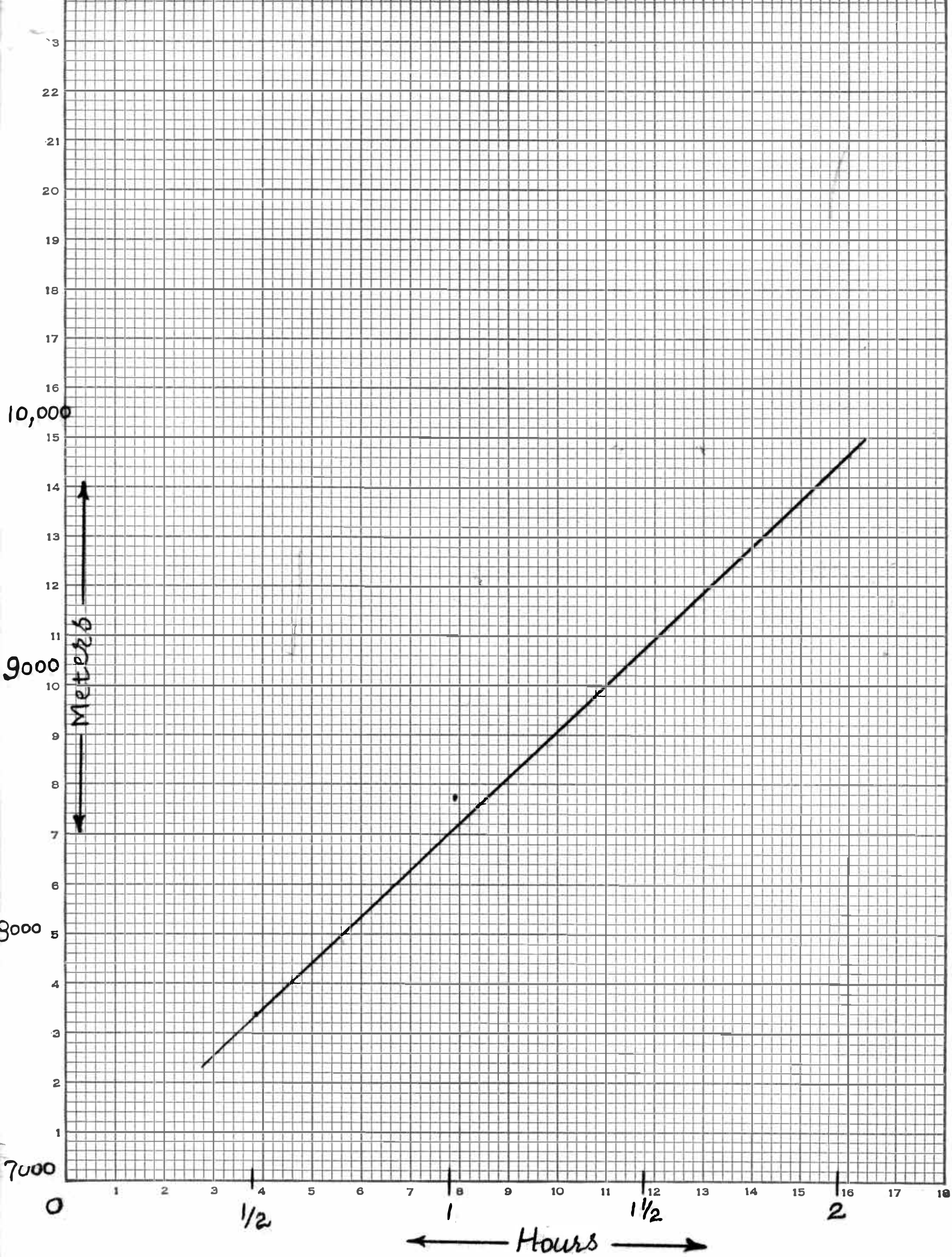
Type of Bleaching	Pulp No.	Zero-span in meters Before Bleaching	After Bleaching	Diff. in zero-span
Hypochlorite	I	9971	9563	- 408
	II	8543	9652	+ 1109
	III	7604	9547	+ 1943
Hydrogen Peroxide	I	9971	8588	- 1383
	II	8543	9257	+ 714
	III	7604	10,281	+ 2677
Zink Hydrosulphite	I	9971	----	----
	II	8543	9128	+ 585
	III	7604	8385	+ 781

Table IV: The Brightness of Bleached and Unbleached Pulps

Type of Bleaching	Pulp No.	Brightness Before Bleaching	Brightness After Bleaching	Difference
Hypochlorite	I	22.4	39.1	+ 16.7
	II	19.1	34.5	+ 15.4
	III	21.2	34.1	+ 12.9
Hydrogen Peroxide	I	22.4	25.9	+ 3.5
	II	19.1	27.5	+ 8.4
	III	21.2	24.9	+ 3.7
Zink Hydrosulphite	I	22.4	----	----
	II	19.1	18.4	- 0.7
	III	21.2	18.5	- 2.7

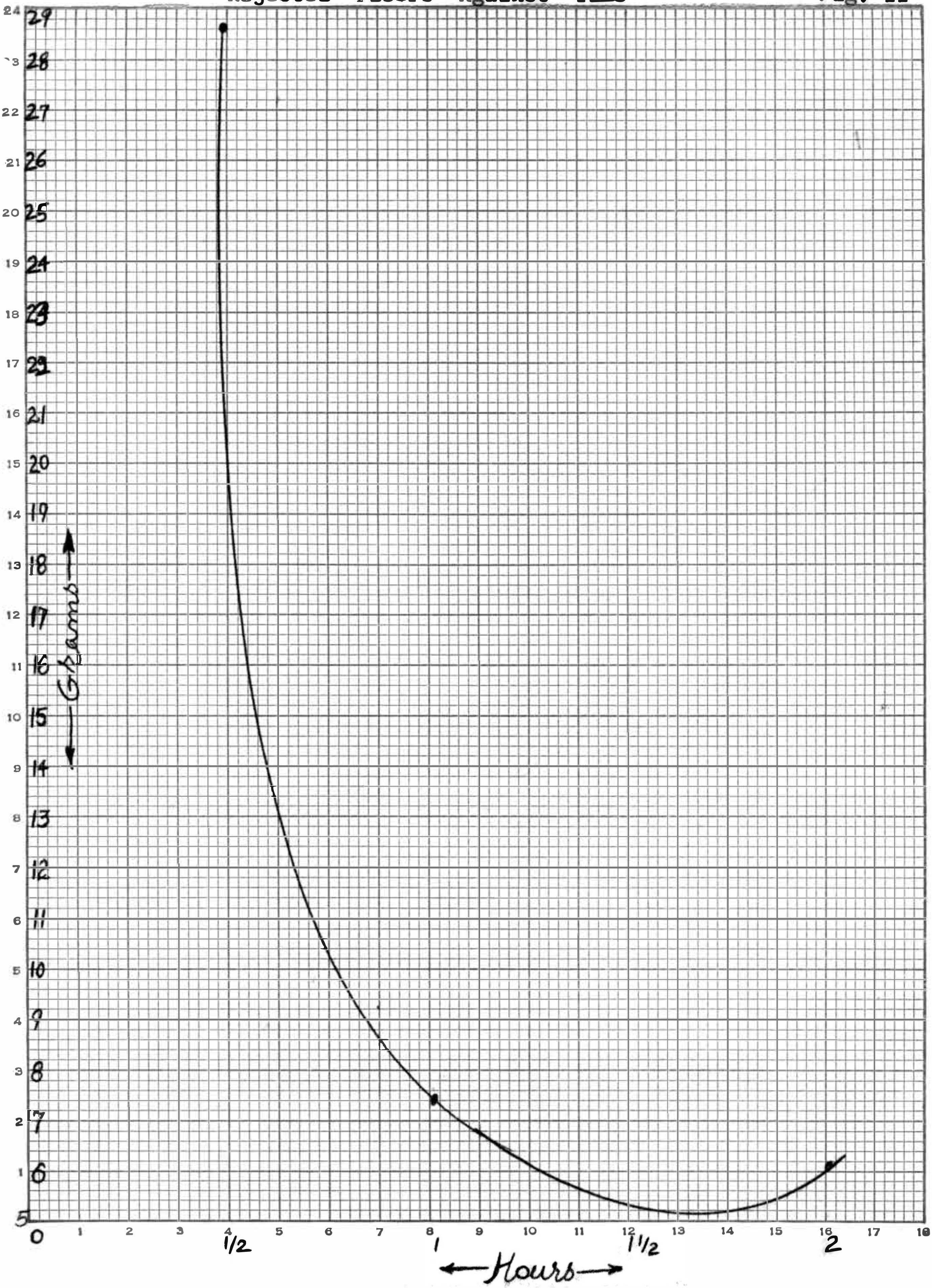
Zero-Span in Meters against Time

Fig. I



Rejected Fibers Against Time

Fig. II



Accepted Fibers Against Time

Fig III