Effect of Temperature and Pulp Consistency on Power Consumption and Physical Strength Properties During Beating of Decker Pulp in Laboratory Valley Beater

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SUMMARY

Laboratory experiments were conducted to study the beating characteristics of Decker pulp beaten in a Laboratory valley beater. It is observed that 35°C temperature and 1.5% consistency is the optimum condition for maximum development of physieal strength properties as well as for low power consumption. Higher pulp consistency and temperature has pronounced effect in reduction of physical strength properties, while lower pulp consistency is uneconomical. Power consumption during beating increases with increase in temperature at the same consistency. Power consumption reduces with increase in pulp consistency.

INTRODUCTION

In the present energy crisis all over the world it is of utmost importance to reduce energy consumption in every possible way by adopting modern technology or by improving old pattern of technology viz. designing and modification of the equipment used and process modification. Paper industry is one of the industries in India which has high power consumption. The energy is chiefly consumed in chipping, pulping, bleaching, refining or beating and finally for paper making.

During beating or refining power is consumed to fracture and partially remove primary wall of fiber, decrease the fiber length, cutting the fibers and the formation of fibrils which help in increasing fiber flexibility and thereby improve sheet formation. Power consumption also depends on other factors such as the design of refiner or beater, nature of raw material, consistency and temperature of the stock.

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In the present investigation Decker pulp was beaten in a laboratory valley beater at different temperatures and different consistencies to optimise the beating conditions.

EXPERIMENTAL

Bamboo and mixture of of hardwoods (Bamboo 70-75% + Hardwoods 25-30%) are the raw materials used in our mill for making writing, printing and other grades of paper by using kraft process. Decker pulp was used for the present investigation for carrying out beating studies in the laboratory valley beater. The pulp was beaten at 25, 35 and 45°C. Beating characteristics were also studied at 1.0%, 1.5% and 2% consistencies. An arrangement was made to get the desired stock pulp temperature with heating element without obstructing flow of the pulp in the beater. Power consumption during the course of beating were recorded at different time intervals (Table 1, 2 & 3). Pulp samples were drawn at different freeness °SR and standard sheets were prepared and tested for physical strength properties employing Tappi standards. Physical strength properties of the beaten Decker pulp at 25°C and consistencies 1.0%, 1.5% and 2%

are recorded in Tables 4, 5, & 6. Similarly physical strength properties of beaten pulp at 35°C and 45°C were also determined at consistencies mentioned above and are recorded in Tables 7, 8, 9, 10, 11 & 12 respectively.

RESULTS AND DISCUSSIONS

Decker pulp beaten at 25°C, different °SR freeness and consistencies 1.0%, 1.5% and 2.0% shows that with increase in pulp consistencies power consumption

TABLE—1 POWER CONSUMPTION IN KWH/TONNE OF DECKER PULP BEATEN IN VALLEY BEATER AT 25°C AND VARIOUS CONSISTENCIES.

S. No.	Decker Pulp beaten at freeness °SR	Power Consumption in KWH/Tonne of Decker Pulp. Consistency of Decker Pulp.		
		1.0%	1.5%	2.0%
1.	25	411.02	318.0	254.0
2.	35	693.60	542.0	383.75
3.	45	899.10	729.0	479.80
4.	55	1027.55	853.0	536 60

TABLE—2 POWER CONSUMPTION IN KWH/TONNE OF DECKER PULP BEATEN IN VALLEY BEATER AT 35°C AND VARIOUS CONSISTENCIES

S. No.	Decker Pulp beaten at freeness °SR	Power Consumption in KWH/Tonne of Decker Pulp Conistency of Decker Pulp		
		1.0%	1.5%	2.0%
1.	25	705 3	376 4	310 0
2.	35	932.5	583.2	508.0
3.	45	1073 3	752.8	618.8
4.	55	1271.6	876.0	729.04

TABLE—3 POWER CONSUMPTION IN KWH/TONNE OF DECKER PULP BEATEN IN VALLEY BEATER AT 45°C AND VARIOUS CONSISTENCIES.

S. No.	Decker pulp beaten at freeness °SR	Power consumption in KWH/Tonne of Decker Pulp Consistency of Decker Pulp		
		1.0%	1.5%	2.0%
1.	25	791.772	414.820	373.000
2.	35	961.322	621.660	576.000
3.	45	1130.868	781 800	678 100
4.	55	1300.410	904.240	755.000

TABLE—4 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 25°C AND PULP CONSISTENCY 1.0%.

S. No.	Particulars	Freeness of Beaten Pulp °SR.			
		25	35	45	55
1.	Beating time (minutes)	16	27	35	40
2.	Caliper (micron)	96 4	94.77	88.4	83.0
3.	Bulk cc/g	1 52	1.50	1.38	1.36
4.	Breaking length (meter)	3307	4520	5555	5601
5.	Burst factor	22 04	34.80	35 60	36 62
6.	Tear factor	50.39	69.37	66.66	64.13
7.	Double fold	30	124	134	170

TABLE—5 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 25°C AND PULP CONSISTENCY 1.5%

S. No.	Particulars	Freeness of Beaten Pulp °SR			
		25	35	45	55
1.	Beating time (minutes)	17	29	39	46
2	Caliper (micron)	95.9	93.4	84.4	80 6
3.	Bulk (cc/g)	1 52	1 50	1 36	1.26
4.	Breaking length (meter)	3792	5350	5623	6094
5.	Burst factor	23.67	219 61	37 09	39 37
6.	Tear factor	71.43	89.23	87.09	65 62
7.	Double fold	42	130	205	235

TABLE—6 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP, BEATEN IN LABORATORY VALLEY BEATER AT 25°C AND PULP CONSISTENCY 2.0%

S. No.	Particulars	Freeness of Beaten Pulp °SR			
		25	35	45	55
1.	Beating time (minutes)	18	27	34	38
2.	Caliper (micron	98.8	91.4	88.4	81.60
3.	Bulk (cc/g)	1.58	1.53	1 50	1 41
4.	Breaking length (meter)	3514.37	4023.7	4515.5	4939.2
5.	Burst factor	19.1	24 60	28.9	33.7
6.	Tear factor	84.45	91.50	85.09	82.96
7.	Double fold	51	170	215	235

TABLE—7 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 35°C AND PULP CONSISTENCY 1.0%

S. No.	Particulars	Freeness of Beaten Pulp °SR				
		15	25	35	45	55
1.	Beating time (minutes)	—	25	33	38	45
2.	Caliper (micron)	130.4	109.4	94.4	91.4	88.4
3.	Bulk (cc/g)	2.09	1.65	1.54	1.45	1.39
4.	Breaking length (meter)	1395.6	3562.3	3937.6	4720.0	5052.0
5.	Burst factor	1.93	21.37	28.54	30.56	33.57
6.	Tear factor	45.09	67.18	65.62	57.92	53.67
7.	Double fold	2	38	100	135	190

TABLE—8 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 35°C AND PULP CONSISTENCY 1.5%

S. No.	Parliculars	Freeness of Beaten Pulp °SR				
		15	25	35	45	55
1.	Beating time (minutes)	—	20	31	40	46.5
2.	Caliper (micron)	131.9	98.4	93.4	82 4	78.4
3.	Bulk (cc/g)	2.17	1.59	1.51	1.42	1.29
4.	Breaking length (meter)	1594.5	4720.0	5119.91	6384.20	6780.69
5.	Burst factor	5.43	25.70	31.22	39.44	41.27
6.	Tear factor	46.09	77.73	71.14	68.89	52.78
7.	Double fold	2	60	90	125	145

TABLE 9 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 35°C AND PULP CONSISTENCY 2.0%.

S. No.	Particulars	Freeness of Beaten Pulp °SR				
		15	25	35	45	55
1.	Beating time (minutes)	—	24	36	44	42
2.	Caliper (microns)	116 4	94.40	88 40	89 4	87.4
3.	Bulk (cc/g)	1.96	1.60	1.41	1.30	1.20
4.	Breaking length (meter)	1500	4140	4505	5085	5335
5.	Burst factor	5.07	23.83	32.20	36.09	37.82
6.	Tear factor	60.86	71.49	63.59	60.99	54.72
7.	Double fold	2	24	156	176	225.

TABLE No. - 10 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 45°C AND PULP CONSISTENCY 1.0%

S. No.	Particulars	Freeness of Beaten Pulp °SR				
		15	25	35	45	55
1.	Beating time (minutes)	—	28	34	39	46
2.	Caliper (micron)	105	98	100	86	84
3.	Bulk (cc./g)	1.72	1.50	1.47	1.35	1.32
4.	Breaking length (meter)	1300	3300	3890	4250	4450
5.	Brust Factor	2.4	29.0	30.5	31.9	33.5
6.	Tear factor	78.	96.9	91.0	85.3	80.7
7.	Double fold	2	200	250	275	320

TABLE—11 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 45°C AND PULP CONSISTENCY 1.5%

S. No.	Particulars	Freeness of Beaten Pulp °SR				
		15	25	35	45	55
1.	Beating time (minutes)	—	22.0	33.0	41.5	48.0
2.	Caliper (micron)	110	86	87	83	80
3.	Bulk (cc./g)	1.80	1.47	1.40	1.38	1.33
4.	Breaking length (meter)	1450	4309	4609	5070	5555
5.	Burst factor	9.8	28.9	30.7	36.8	38.8
6.	Tear factor	90.3	100.0	93.7	87.5	83.3
7.	Double fold	2	90	200	210	250

TABLE—12 PHYSICAL STRENGTH PROPERTIES OF DECKER PULP BEATEN IN LABORATORY VALLEY BEATER AT 45°C AND PULP CONSISTENCY 2%

S. No.	Particular	Freeness of Beaten Pulp °SR				
		15	25	35	45	55
1.	Beating time (minutes)	—	26	41	48	54
2.	Caliper (micron)	105.0	90 0	83.98	85.26	74.30
3.	Bulk (cc/g.)	1.73	1.49	1.37	1.34	1.24
4.	Breaking length (meter)	1400.0	350.00	3915.0	4491.20	4784.5
5.	Burst factor	9.85	25.7	30.1	34.8	36.05
6.	Tear factor	95.4	101.0	97.8	94.4	90.0
7.	Double fold	2	25	160	245.	310

decreases (Fig. 1). The main effect of consistency is its influence on the specific beating energy; the higher the consistency the lower will be the beating energy required. Pages[1] suggested that due to fiber interaction the compressive stress is greater at higher consistencies and causes an appreciable shortening of intact fibers. Decker pulp was also beaten at 35°C, different °SR freeness,

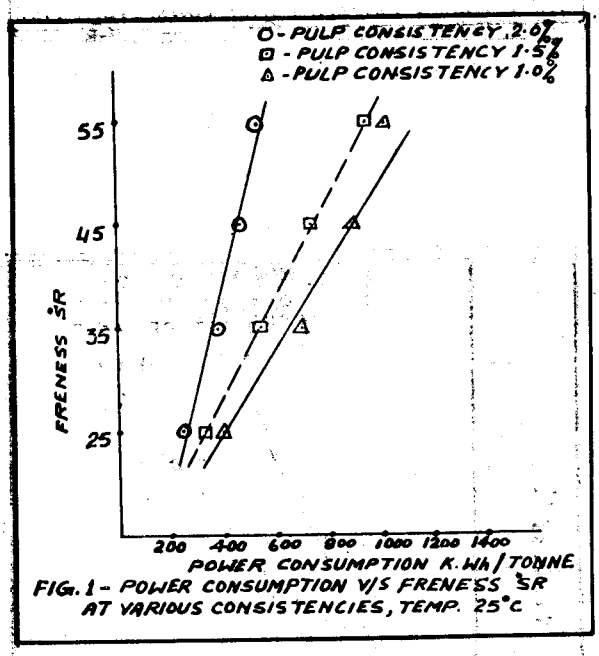

FIG. 1 - POWER CONSUMPTION V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 25°C

consistencies 1.0%, 1.5% and 2% (Fig. 2). It is observed that power consumption is more at higher temperature beating if same consistency is being maintained. In another set of experiments Decker pulp was beaten at 45°C, different freeness °SR and consistencies 1.0%, 1.5% and 2.0% (Fig. 3). The effect of temperatures at consistencies 1.0%, 1.5% and 2.0% versus power consumption has been shown in fig. 4, 5 & 6 respectively. It is evident from these figures that power consumption at particular consistency increases at elevated temperature. The

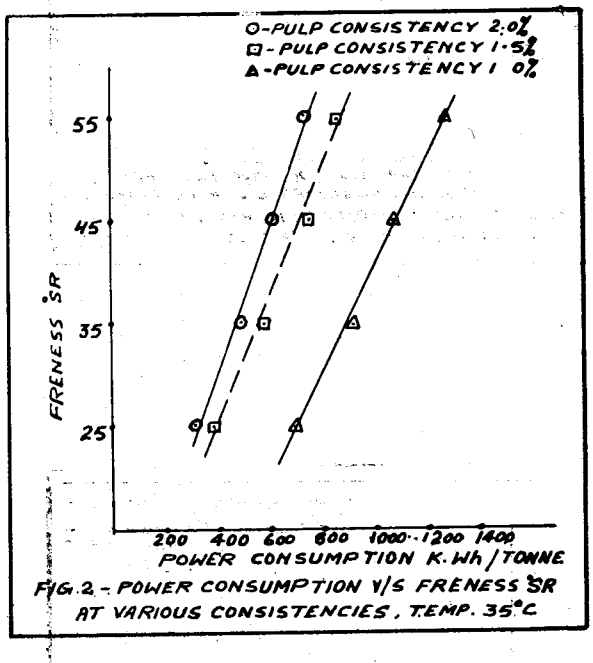

FIG. 2 - POWER CONSUMPTION V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 35°C

favourable effect of low temperature on beating rate is probably linked with swelling of cellulose at lower temperature. Swelling is increased at lower temperature[2,3] and encourage fibrillation. Beaten pulp sheets prepared at 1.0%, 1.5% and 2.0% consistencies, different freeness °SR and beating temperature 25°C were tested for physical strength properties. It was observed that breaking length and burst factor were maximum at 1.5% consistency and were lower at 2% consistency. Tear factor was maximum at lower freeness °SR which decreased as the freeness of the pulp increased.

This is because tearing strength is determined almost entirely by fibre length[4]. Breaking length, burst factor and tear factor at different consistencies against freeness °SR are plotted in Figs. 7, 8 & 9. Similar trends of the curves were observed regarding

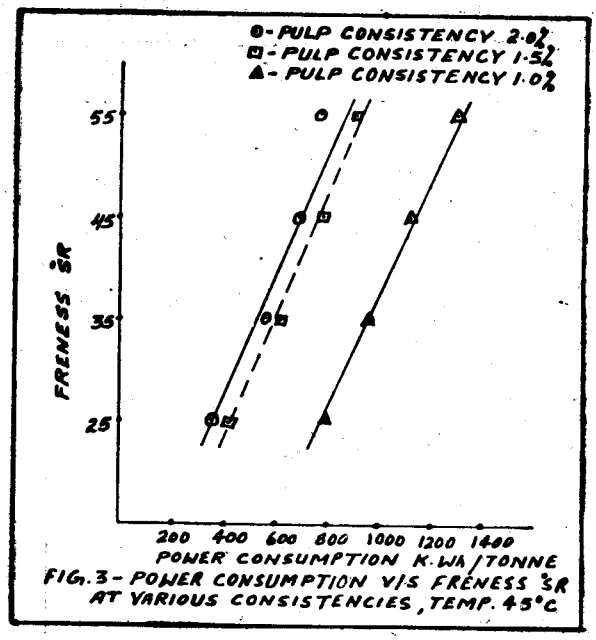

FIG. 3 - POWER CONSUMPTION V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 45°C

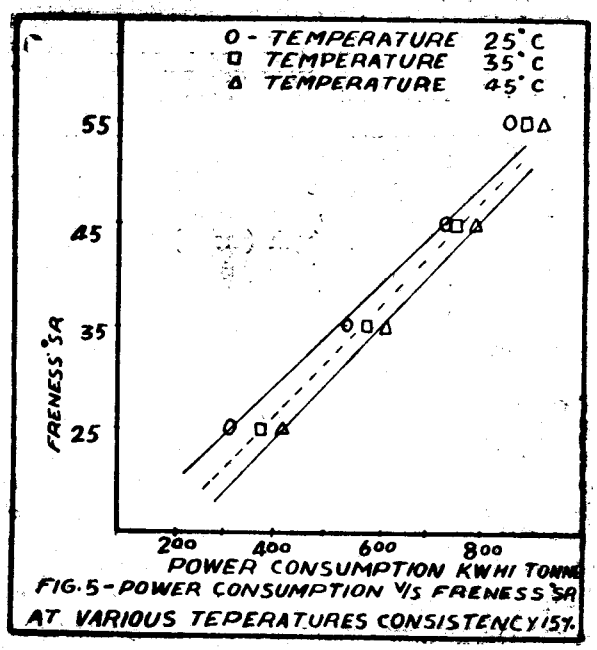

FIG. 5 - POWER CONSUMPTION V/S FRENESS °SR AT VARIOUS TEPERATURES CONSISTENCY 1%.

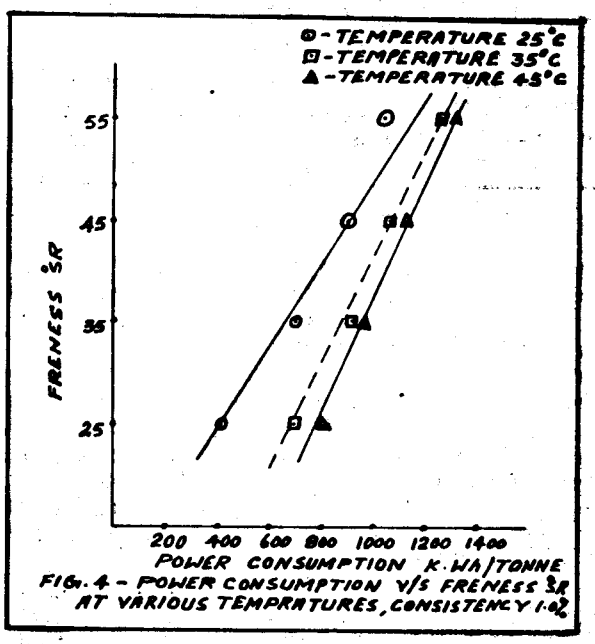

FIG. 4 - POWER CONSUMPTION V/S FRENESS °SR AT VARIOUS TEMPRATURES, CONSISTENCY 1.0%

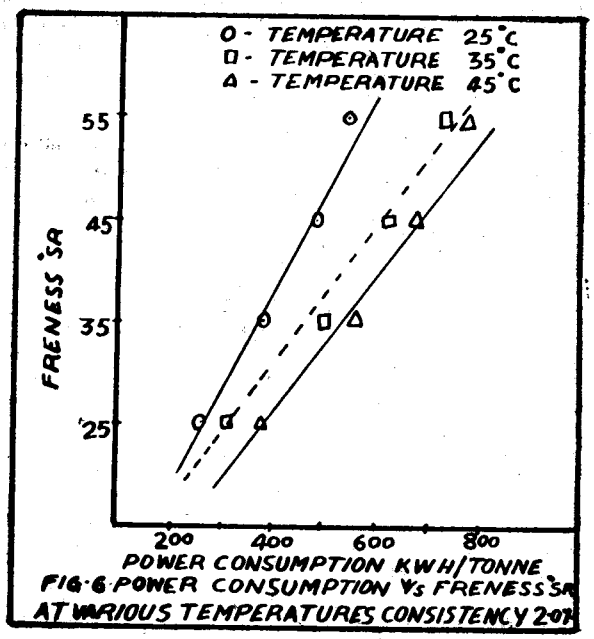

FIG. 6 POWER CONSUMPTION V/S FRENESS °SR AT VARIOUS TEMPERATURES CONSISTENCY 2.0%

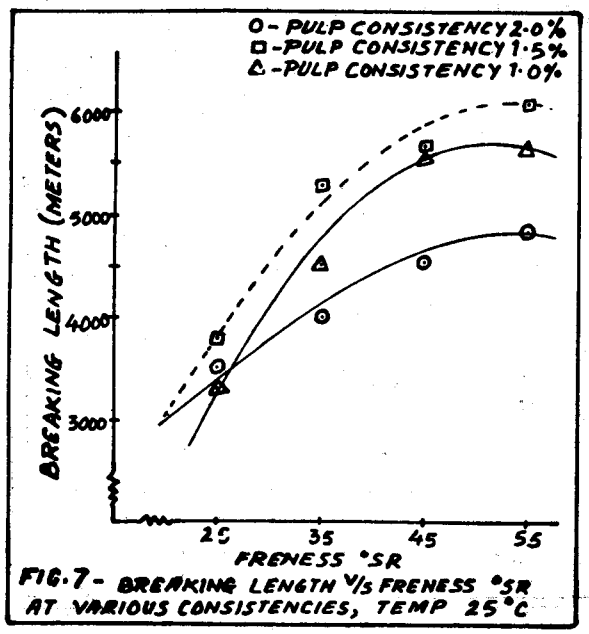

FIG. 7 - BREAKING LENGTH V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 25°C

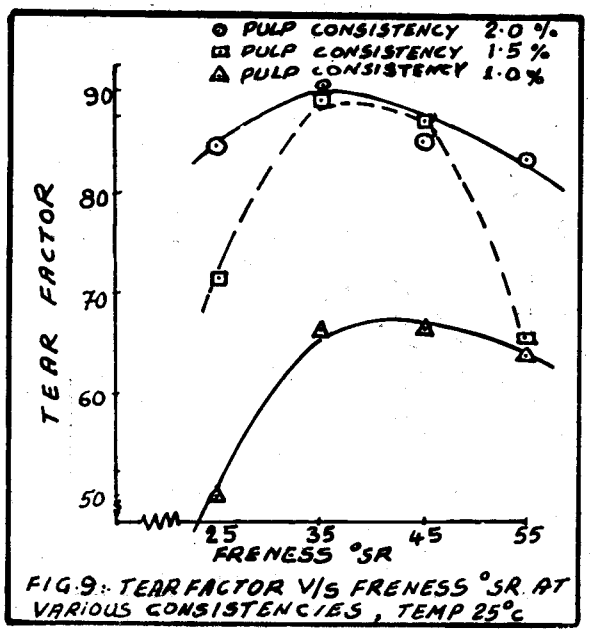

FIG. 9 - TEAR FACTOR V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 25°C

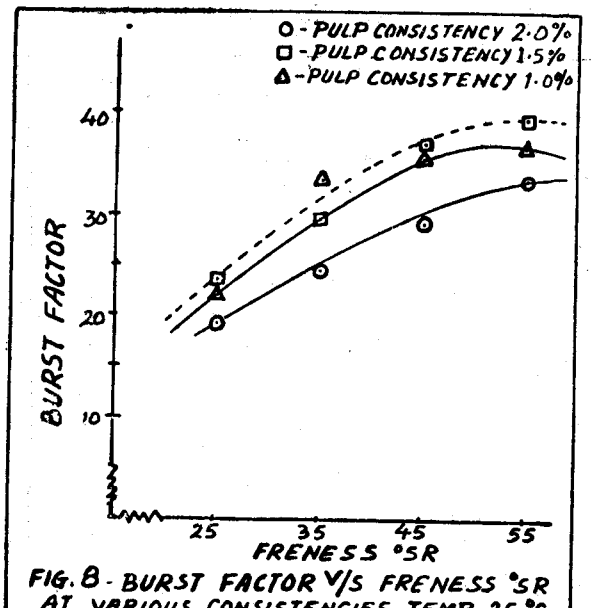

FIG. 8 - BURST FACTOR V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 25°C

physieal strength properties of the beaten pulp at 1.0%, 1.5% and 2.0% consistencies, different °SR and temperatures 35°C and 45°C. Breaking length, Burst factor and tear factor at different consistencies have been plotted against different freeness °SR (Fig. 10, 11, 12, pulp beaten at 35°C and fig. 13, 14 & 15, pulp beaten at 45°C). At elevated temperature and high consistency fibre shortening is minimum[5] which reduces fiber flexibility and therefore allows less fiber-to-fiber contact when pressed into sheets. The physical strength properties of the sheets are lower at elevated temperature and higher consistency. From the graphical data (Fig. 7 to 15) it is evident that physical strength properties of the sheets were maximum at 35°C when the pulp consistency was kept at 1.5%. Beating at elevated temperature results in flocculation of fibrils which in turn decrease the physical strength properties[6].

Graphs have been plotted between breaking length/bulk against freeness °SR at different consistencies and at particular temperature (fig. 16, 17 & 18). It is evident from the figures that whatever are the temperatures and consistencies the relationship is linear and the slope of the line is constant. It also confirms that the composition of the Decker pulp used throughout the beating experiments was same.

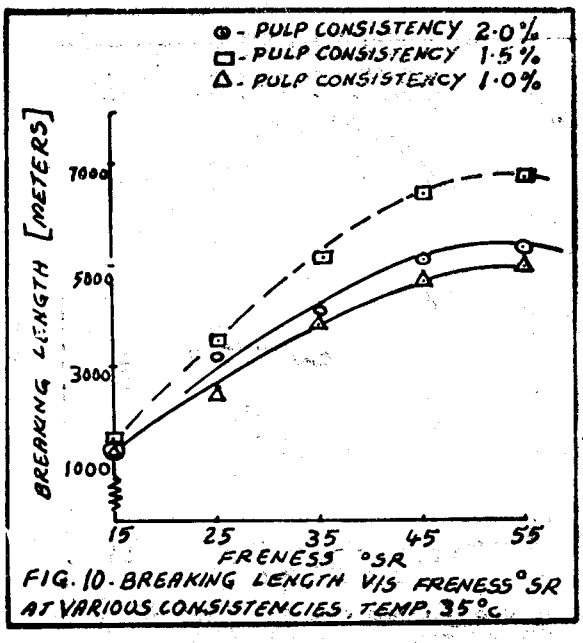

FIG. 10 - BREAKING LENGTH V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 35°C

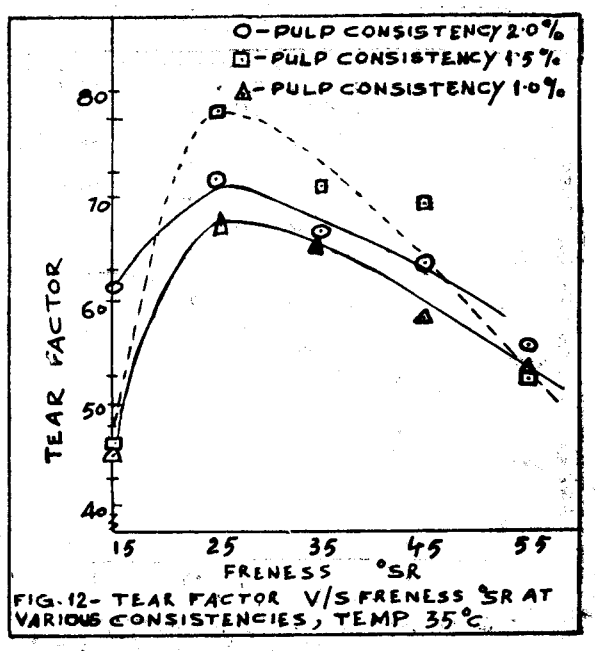

FIG. 12 - TEAR FACTOR V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 35°C

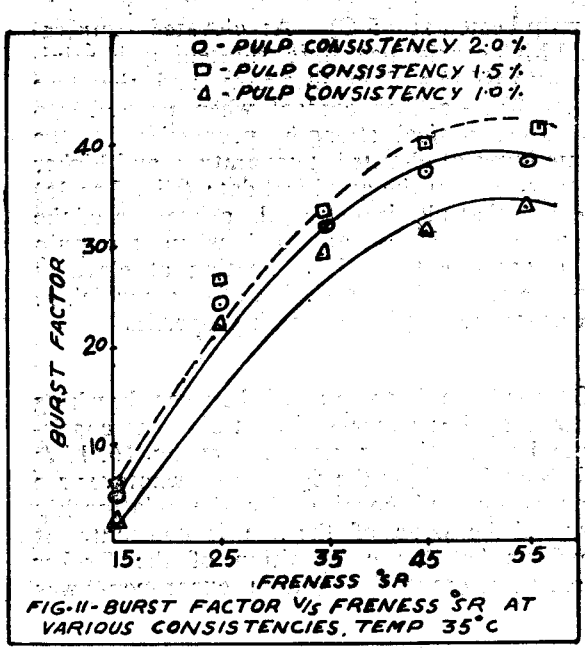

FIG. 11 - BURST FACTOR V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 35°C

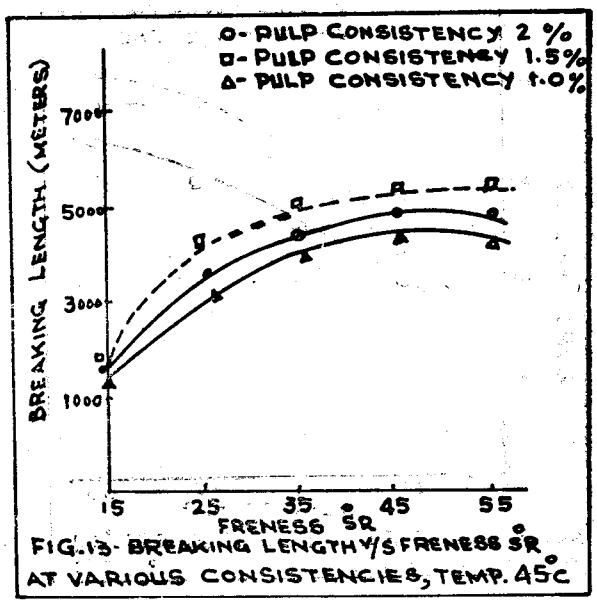

FIG. 13 - BREAKING LENGTH V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 45°C

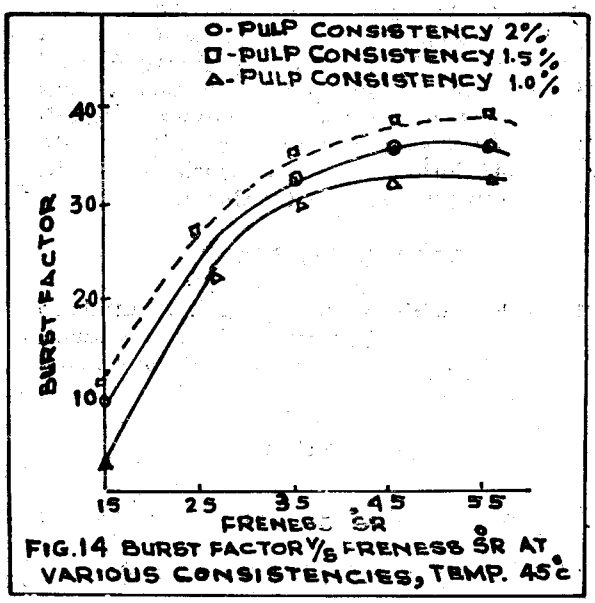

FIG.14 BURST FACTOR V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP. 45°C

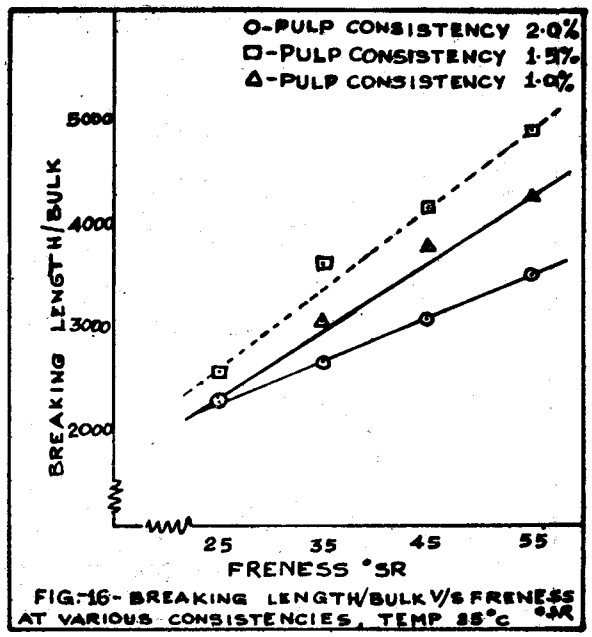

FIG.-16- BREAKING LENGTH/BULK V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 35°C

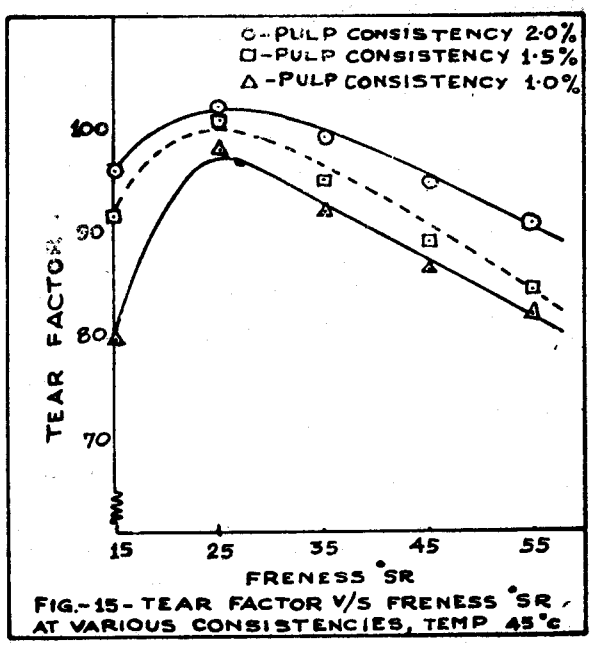

FIG.-15- TEAR FACTOR V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 45°C

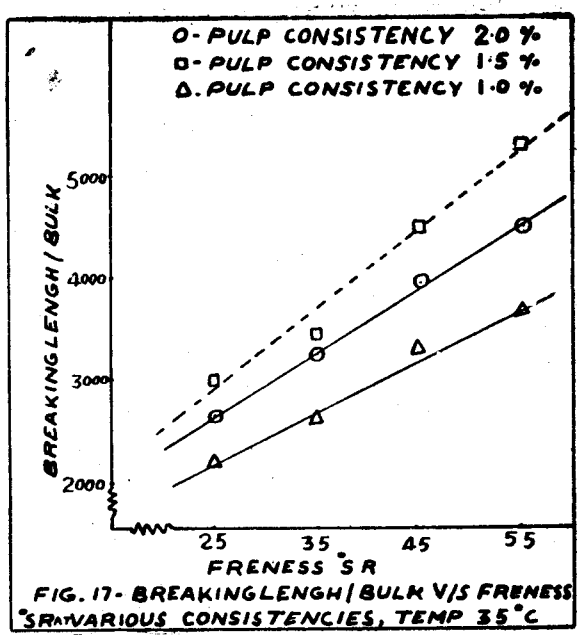

FIG. 17- BREAKINGLENGH/BULK V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 35°C

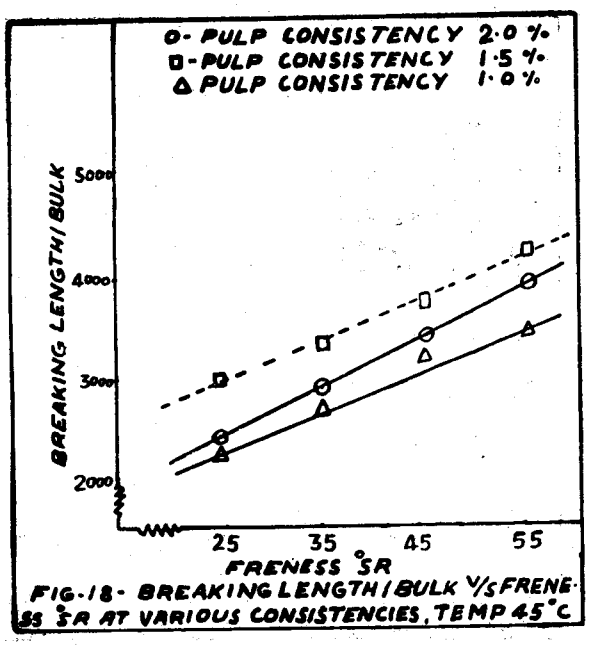

FIG.-18- BREAKING LENGTH/BULK V/S FRENESS °SR AT VARIOUS CONSISTENCIES, TEMP 45°C

CONCLUSION

It is concluded from the present investigation that power consumption increase with inceasc in temperature when the consistency of the pulps were kept same in the valley beater while power onsumption reduces with increase in pulp consistency.

The pulp beating consistency 1.5% at 35°C was found optimum for higher physical strength properties of the sheets. Lower consistency is uneconomical and higher pulp consistency has pronounced effect in lowering of physical strength properties. At higher temperature pulp beating results in flocculation of fibrils which lowers the physical strength properties of the sheets.

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