H-Factor Concept For Scheduling Pulping Process And Its Correlationship with Delignification Rate.

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Beased on the time—temperature schedule and delignification knietic data on pulping of Eucalyptus grandis by Neutral Sulphite Semi Chemical (N S S C) process, H-factor was estimated and its applicability to the prediction of pulping charcateristics, measured in terms of chlorine number and pulp yield, was verified.

INTRODUCTION

Vroom† in 1957 proposed the 'H-factor' as a means of expressing cooking time and temperature in one single variable. H-factor represents the area under a curve in which relative reaction rates are plotted against time. It is thought, that such a measure can provide a ready guide for adjusting the cooking times for a variety of pulping temperatures (within a certain range of pulping temperature). If a single cycle is established, under otherwise constant pulping conditions all cycles having the same numerical value will produce pulps of equivalent yield and degree of delignification regardless of differences in the rate of temperature increase or in the level of maximum temperature. Any combination of cooking time and temperature giving the same H-factor results in similar pulps having almost the same pulping yield and degree of delignification.

† Vroom, K.E. the H-factor : a means of expressing cooking times and temperatures as a single variable Pulp and Paper Mag. Can. *58* (c), 228-31 (1957)

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The work rrported in this paper has been carried out with the following objectives.

1. To incorporate the effects of time-temperature into a single parameter (H-factor)
2. To study its applicability and usefulness as a guide for predicting compensatory adjustments of pulping schedules.
3. To study the applicability of H-factor to the prediction of pulping characteristics measured in terms of chlorine number and pulp yield.

Experimental

Pulping (NSSC) experiements were carried out on *Eucalyptus grandis* chips (2×1×.1 cm.) in oil batch heated stainless steel autoclave having 250 ml. capacity. For every cook 25 g. of air dry chips were taken and impregnated. Rapid heating and cooling of autoclave was performed. A fixed chemical charge of 15 per cent (12 per cent sodium sulphite + 3 per cent sodium carbonate), based on ovendry wood, was taken everytime. The liquor-to-wood ratio being kept at 4:1 everytime. Influencing parameters like cooking time of 0 to 5.5 hours, temperature in the range of 140° to 180°C were studied. For each cook equivalent cooking time was calculated. The softened chips were difibrized in Kollargang and beater. Pulp was analysed for chlorine number and yield. Results are tabulated in Table 1.

Results and Discussion

With the help of experimental data obtained, H-factors were calculated by first calculating the relative reaction (delignification) rates at various temperatures.

TABLE 1

Pulping Characteristics and H–Factor for Different Pulping Condition

Pulping tempera-ture, °C	Relative rate	Time of pulping minutes	Chlorine number g Cl_2/100 g O.D. Pulp	per cent yield	Pulp Lignin (% of O.D wood)	H–factor require-ment
140	51.34	32.8	28.55	82.25	20.45	28.06
		63.4	28.20	82.0	20.15	54.24
		122.2	27.90	81.2	19.70	104.55
		182.2	27.30	80.4	19.10	155,89
		242.2	27.00	79.9	18.80	207.23
		332.2	26.40	79.1	18.20	284.23
150	122.33	18.8	28.25	81.8	20.13	38 83
		33.8	28.20	81.0	19.88	68.91
		65.5	27.65	80.0	19.25	133.54
		123.3	27.00	79.0	18.56	251.38
		184.5	26.30	77.1	17.60	376.16
		244.7	25.60	76.2	16.95	498.89
160	280.02	19.5	28.30	79.6	19.60	91.00
		33.3	28.05	78.5	19.16	155.41
		63.3	26,80	76.5	17.85	295.41
		93.8	25.90	75.6	17.01	437.75
		123.8	25.25	74.8	16.40	557.76
		183.8	24.25	71.1	14.93	857.78
170	617.45	3.8	28.40	84.6	20.75	39.10
		18.8	27.75	79.75	19.25	193.47
		33.2	27.00	76.8	18.06	341.65
		35.0	27.00	76.3	17.91	360.18
		65.0	25.50	72.7	16.08	668 90
		93.2	23.95	70.7	14.70	9[illegible]9.10
		123.5	22.75	69.0	13.60	1270.91
180	1314.79	4.2	27.70	80.8	19.50	92.03
		13.6	27.05	76 3	17 95	298 02
		19.0	26.70	74.2	17.22	416.35
		33.6	25.40	70.5	15.59	736 28
		48.6	24.60	67.5	14.40	1064.98
		65.7	22.85	65.1	13.00	1440.13

The relative reaction rate can be calculated, as described below, by assuming the rate at 100°C to be unity.

Thus $\varrho = \left(\underset{e}{-}E/R\right)\left(\frac{I}{T}-\frac{I}{373}\right)$ ... ... (1)

Rate of delignification (r_1) is taken to be $= \frac{-dl}{dt} = KS^a\,L^b$ ... ... (2)

and as per Arrhenius law, reaction constant, $K = K_o \underset{e}{-E/Rt}$ (3)

Where ϱ = relative reaction rate.

E = Arrhenius activation energy, calories/mole

R = Gas constant = 1.987 cal/mole O_k

T = delignification reaction temperature, O_k.

K_o, a, b, = constants.

For *Eucalyptus grandis* value of E during NSSC pulping (within the conditions mentioned above under the heading experimental) was found out to be 30, 140 calories/mole.

Thus according to equation (1) relative reaction rate

$\varrho = \underset{e}{-}16,168\left(\frac{I}{T}-\frac{I}{373}\right)$ ... ... (4)

The results of relative reaction rates as a function of reaction temperature are given in Table 2. and presented in Figure 1.

From Figure 1 it is clear, that temperature dependence of delignification rate constant becomes

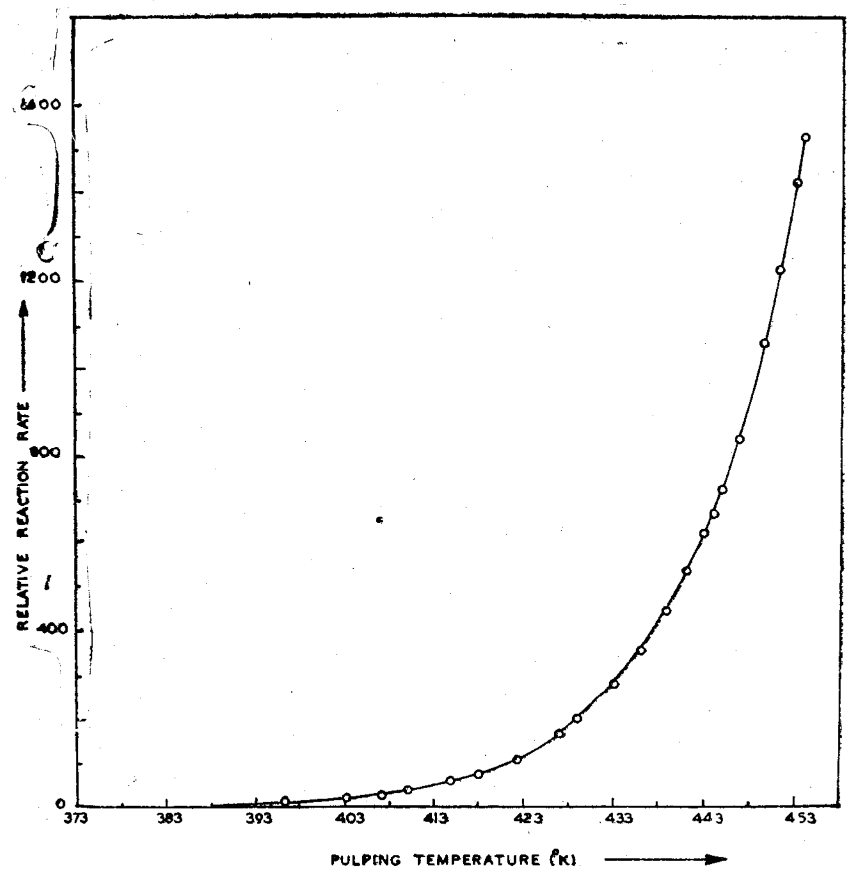

FIG I RELATIVE REACTION RATE Vs PULPING TEMPERATURE (°K)

FIG. 1

TABLE 2

Relative Reaction Rate Values For H-Factor in NSSC Pulping

Temperature, °K	Relative rate (ϱ)	Temperature °K	Relative rate (ϱ)	Temperature, °K	Relative rate (ϱ)
373	1.00	404	22.65	435	328 95
374	1.11	405	24.85	436	356.34
375	1.24	406	27 26	437	385.87
376	1.38	407	29.87	438	417.69
377	1.54	408	3 .73	439	451.97
378	1.71	409	35;85	440	488.90
379	1.90	410	39.24	441	528 65
380	2.11	4.11	42 49	442	571 43
381	2.35	412	46.96	443	617.45
382	2.61	413	51.34	444	666.95
383	2.89	414	56.10	445	720.17
384	3.20	415	61.28	446	777.37
385	3.55	416	66.91	447	838 82
386	3.93	417	73.02	448	904.82
387	4.35	418	79.66	449	975.69
388	4.82	419	86.87	450	1051.75
389	5.33	420	94.69	451	1133.37
390	5.89	421	103.17	452	1220.92
391	6.50	422	112.36	453	1314.80
392	7.18	423	122.33	454	1415.43
393	7.92	424	133.13	455	1523.27
394	8.73	425	144.82	456	1638.80
395	9.63	426	157.47	457	1762.53
396	10.61	427	171.16	458	1895.00
397	11.68	428	186.00	459	2036.78
398	12.86	429	201.99	460	2188.49
399	14.15	430	219.30	461	2350.76
400	15.56	431	238.01	462	2524.29
401	17.11	432	258.21	463	2709.77
402	18.79	433	380.02		
403	20.64	434	303.56		

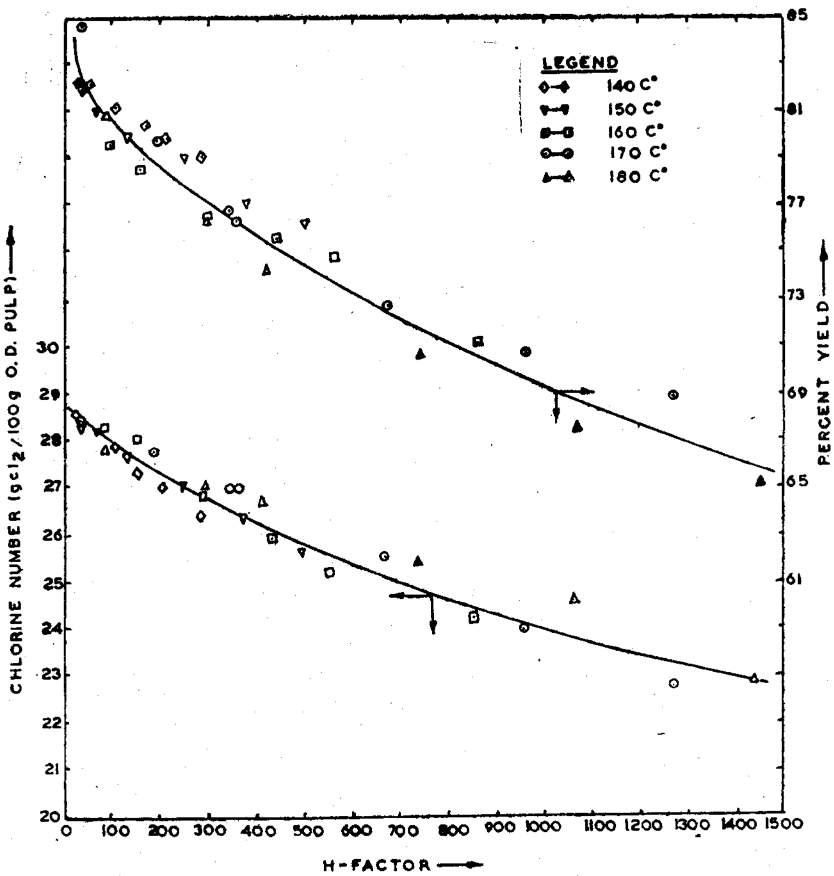

FIG 2— EFFECT OF H-FACTOR ON CHANGES OF CHLORINE NUMBER UNDER DIFFERENT PULPING TEMPEPATURES

FIG. 2

pronounced beyond 160°C. The relative reaction rate of delignification reaction is found to increase from 2 to 2.4 times per 10°C temperature-rise.

From the relative reaction rate, the value of H-factor, for each of the cooks, is calculated by using the relationship.

$$H = \frac{1}{60}\int^{t} \varrho \, dt$$

Where t=time of pulping minutes The results are tabulated in Table 1.

The applicability of H-factor for the prediction of pulping characteristics (expressed in terms of chlorine number and pulp yield) was ascertained by plotting the relationship of chlorine number and percent pulp yield against H-factor. The experimental results giving the relatiohship between delignification index and H-factor is presented in Figures 2 and 3.

From the figures, it is seen, that the prediction capability of the H-factor concept as a means of cooking degree index to NSSC pulp is verified within the yield level (65 to 85 per cent pulp yield).

Thus, with the devlopment of H—factor meter (Nicholls*), for the continuous recordeing of delignification level. throughout the cooking cycle, H—factor may be used to control and stop digestion at the most appropriate time

Conclusion:

Based on the verification of H-factor a guide for the prediction of pulping characteristics of NSSC pulp (in terms of Pulp yield, chlorine number, and pulp lignin content) it is reeommended to use H—factor as a simplified mathematical procedure for scheduling process for the raw material studied. To generalise the above findings some more work is needed on other species of wood.

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* Nieholls, M. R. : 'A Cooking rate integrator' A paper presented at the NZ National Electronics Corporation, Auckland (1968).

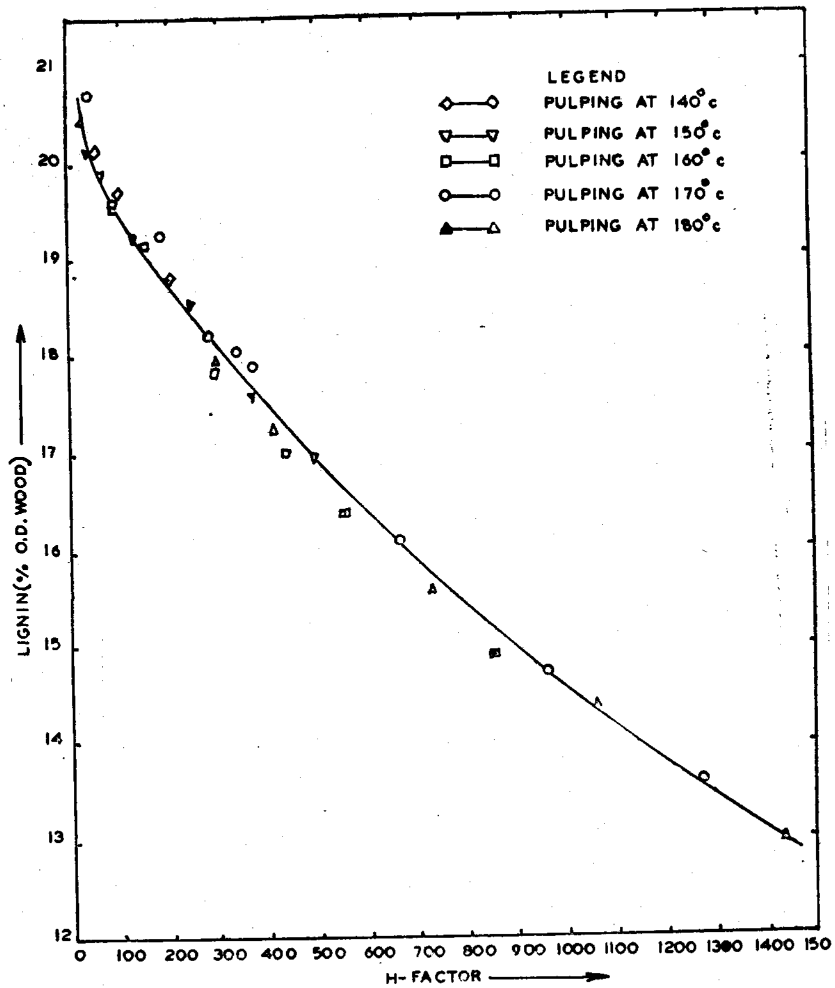

FIG 3 EFFECT OF H FACTOR ON THE YIELD OF PULP UNDER DIFFERENT PULPING TEMPERATURES

FIG. 3