# High Density—Hot Refining

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In recent years, efforts in the field of chemical pulp research have been concentrated mostly on chemical cooking, e.g., kraft, sulphite, neutral sulphite, polysulfide, etc. Searching for the possibility of improving yields through selective lignin removal and carhydrate retention, tailor made pulps have resulted, e. g., through the use of chlorine dioxide and caustic extraction cook and sodium chlorate catalyzed with molybdenum. Fiber mechanical separation after cooking has always been the complementing device for a high yield chemical pulp.

The W. R. Grace pulp and paper research group reaffirmed the need for a more homogeneous cook of their bagasse pulp, since bagasse fiber is a natural fiber blend material, with low lignin and high hemicellulose content and certainly opposite to the mechanical composition of softwood fiber.

The question of how much delignification should be conducted in order to attain a good, high yield, chemical pulp has been raised very often. It is especially true of agriculture residues' fibers for which lignin values are relatively low.

Research has been conducted on bagasse pulping, combining chemicals and defibration. Combination of chemicals, concentration, pressure, temperature and time showed that bagasse fiber was easily pulped to a low permanganate number, although some remaining shives were shown in the pulp after refining. Studies were conducted to find out the reasons for the heterogeneity of the pulp. Shives were strong and resistant to any mechanical defibrating device.

## BAGASSE DELIGNIFICATION REACTIONS

Generally speaking, the bagasse pulps were well-delignified, and the lignin removal was shown to be preferentially from the cell-wall up to the point of 50% total lignin removed. The lignin in the middle lamella was less attacked. Under stronger delignification conditions, the same reaction was shown followed by a rapid rate of removal of lignin from the middle lamella.

In the PEADCO Process (Process Evaluation and Development Corporation, a subsidiary of W. R. Grace & Co.) delignification is conducted under vapor-phase conditions. The pores of the fibers are filled with steam during the delignification; consistency at the end of the reaction becomes as high as 35% and cooking temperature i.e. 347° F under 125 psig pressure.

Lignin remaining in the fiber cell-wall and middle lamella (bundles of fiber) when the pulp is blown out of the digester is cooled off by the air that gets into the fiber during the natural flash-off of steam. Air is pulled into the fiber pores by the vacuum produced when the setam pressure is reduced to zero. As a result of this, the lignin becomes hard and brittle. Defibration of such fiber and fiber bundles becomes inefficient.

Experimental work has shown that when bagasse fiber bundles are defibered at the blow-line (before the blow-tank) at temperatures above 290° F and at a consistency over 20%, air introduction is prevented and the lignin does not harden. Fiber pores are filled by the water condensed during the defibration stage

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prior to the blow-tank. Fiber bundles are easily and efficiently separated. A very homogeneous pulp is obtained, shives are minimum, if any, and pulp strengths and freeness are higher than normal.

The explanation of this phenomenon is that bagasse lignin is thermoplastic; its point of solidification is under 136° C. This means that when lignin is still in the fiber middle-lamella and the temperature is over 136° C. fibers can be detached from bundles by a mechanical device without affecting the length of the papermaking fiber. When the temperature is below 136° C, the lignin becomes solid and breakable. Any mechanical defibration will yield an heterogeneous pulp, having a great amount of non-defibered bundles of fiber and a high percentage of broken fibers reported as fines. The lengths of individual fibers are affected.

**EXPERIMENTAL WORK**

At the bagasse pulp mill in Paramonga, an experimental program was established for applying in the mill the work developed at laboratory scale. The digester line of the pulp mill called the "Experimental Line", which is equipped with a continuous American Defibrator digester (single tube) and two blowlines for discharge, was utilized under normal operating conditions, the digester disharged into a blow tank, and pulp consistency was controlled at 4%. Pulp was then defibered by a Claflin conical refiner in a single pass; material was washed by three-stage washing (3 washers).

The first part of the trials were performed using a Sprout-Waldron 20″ twin-flow refiner that was connected to the blow-line of the continuous digester. Prior to the blow tank, the temperature was shown to be over 136°C at the point selected. Some modifications were required in the Sprout-Waldron unit for better performance in this use. The pulp passed through the Sprout-Waldron showed a lower percentage of bundles. However, to keep the unit working steady with the operation of the pulp mill was difficult due to the fluctuation of the volume per minute passed through the refiner. Research work was conducted to find a more steady flow to the blow pipe and through the refiner. When the pulp was over 30% consistency and the pressure was 90 psig, the floating disc of the Sprout Waldron was not maintained at the center and mechanical problems were found. Black liquor was injected at the blow-line at a maximum rate of 7 gallons per minute; the blow valve orifice was reduced until the flow was found to be even without increasing the retention of the pulp.

Pulp from the trials was evaluated, alternating the refiners before (at the blow-line) and after the blow tank. It was noticed that the percentage of fines in the pulp was substantially reduced when refining was conducted at the blow-line of the digester in comparison with the percentage of fines with refining after the blow tank, as is shown in **Table I.**

In exchanging ideas with the Sprout Waldron technical group, they suggested and furnished an hydraulic set for holding the floating disc. The unit worked better, and we should hold the refiner working at the blow-line for several hours. The floating disc did not hold satisfactorily, and mechanical problems as well as heterogeneity of the refining were found. Changes were made connecting the inlet of the pulp to only one of the inlets of the refiner and using the other inlet as the outlet. The original outlet was closed. Efficiency of the refiner was improved, but capacity dropped to a point at which we could not operate with the full amount of pulp coming from the digester. It was decided to increase the inlets and outlets of the Sprout Waldron refiner to a maximum bore of 4 inch. from the original 2½ inch. The unit was operated again. Although the capacity was acceptable, the floating disc did not hold sharply, and heterogeneous defibered pulp was produced.

The defibration trials at the digester blow-line were so encouraging that a Claflin unit was installed. This unit was reinforced for the working pressure conditions. The Claflin was connected on May 26, 1968, and from that time the Claflin has been very successful from the mechanical point of view. Modications

**TABLE I**

| Sampling Place | Freeness S.R. cc. | Fiber Classification | | | | |
|---|---|---|---|---|---|---|
| | | +14 | +28 | +48 | +100 | —100 |
| Digester discharge | 870 | 28.4 | 12.0 | 18.6 | 22.0 | 19.0 |
| Refiner before blow-tank | 820 | 8.6 | 12.6 | 20.2 | 32.2 | 26.4 |
| Refiner after blow-tank | 800 | 12.8 | 6.2 | 7.4 | 30.4 | 43.2 |

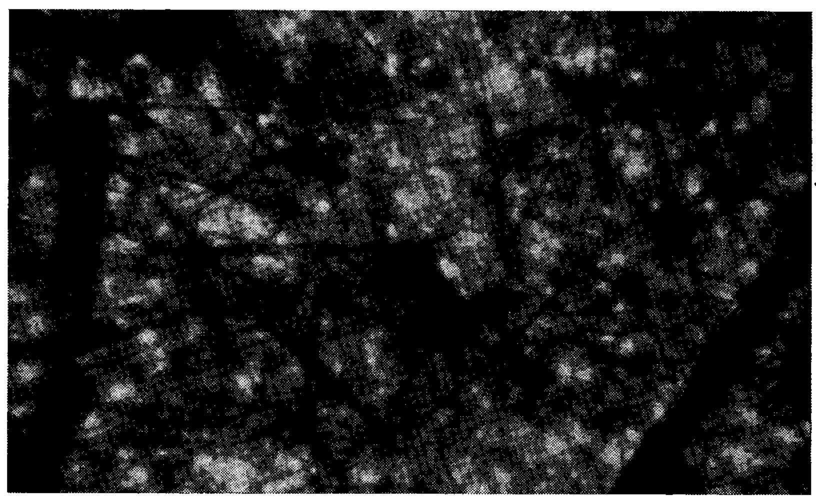
of the tackle and the shell were necessary (dams) in order to give the desired retention and brushing action to the pulp. **The attached pictures** show the difference between hot-high density refining and normal refining.

Freeness drop for hot-high density conditions is minimum. Normally, freeness decreases from 870 to 820 cc. S.R. Examining the performance of the Claflin working at high consistency and high tempterature before the blow tank, it was observed that pulp retained on mesh 150 at the washers was decidedly improved from normal operation (refining after blow tank) of 43.2% to 26.4%. This is a very important improvement that has been shown daily and has a significant meaning not only from the point of view of pulp quality but also yield of the pulp and its performance on the paper machine. The Claflin refiner is working smoothly. Although we know that the energy transferred from the bars to the fiber is lower (55%) than the energy transferred through a disc refiner (70%), the Claflin is handling itself very well at high consistency (30%) and temperature (136° C).

## RESULTS AND DISCUSSIONS

When conducted under high pressure, temperature and consistency by means of well-con-

**(Before Regning (44 x).**



**After Refining (44 x).**

**TABLE II Fiber Classification vs. Different $KMnO_4$ Numbers**
**Normal Pulps July — 1969**

| TRIAL * | No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| $KMnO_4$ | No. | 20.2 | 20.4 | 25.4 | 27.0 | 28.0 | 28.0 | 30.5 | 33.1 |
| Fiber Classification | | | | | | | | | |
| Mesh + 14 | % | 8.6 | 7.8 | 17.0 | 17.6 | 14.8 | 14.6 | 21.2 | 23.2 |
| Mesh + 28 | % | 21.2 | 20.6 | 13.4 | 14.0 | 13.0 | 11.0 | 22.0 | 18.6 |
| Mesh + 48 | % | 20.0 | 19.6 | 15.2 | 18.4 | 15.8 | 15.6 | 19.4 | 16.2 |
| Mesh + 100 | % | **22.7** | **22.4** | **24.6** | **24.6** | **24.2** | **25.2** | **14.6** | **17.8** |
| Usable Fiber | % | 72.5 | 70.4 | 70.2 | 74.6 | 67.8 | 66.4 | 77.2 | 75.8 |
| Mesh — 100 | % | 27.5 | 29.6 | 29.8 | 25.4 | 32.2 | 33.6 | 22.8 | 24.2 |

* Samples taken in the last washer

trolled mechanical refiners, the defibration of bagasse pulp yields pulps free of shives and fiber bundles.

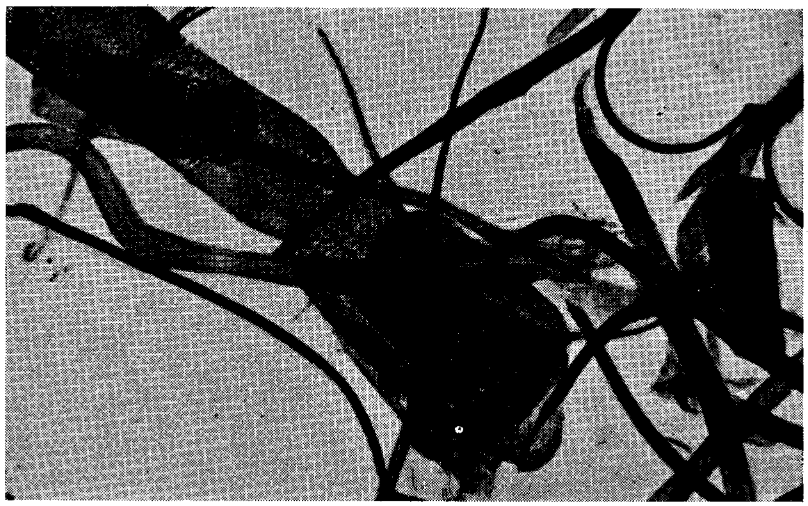
The main part of the study was carried out with vapor-phase cooking, and all data reported here refer to this method. The solids and heat balances give a theoretical water/solids cooking ratio of 1.67 and a water/fiber ratio of 1.90. Theoretical fiber consistency at the refiner stage located before the blow tank) is 24.39. However, flash phenomenon was present, since actual consistency at the refiner was reported to be over 30%.

The results obtained prove that for the temperature and consistency tested, the defibration was conducted efficiently and no pulp bundles were present.

The fiber classifications of the normal pulps are summarized in **Table II.** For comparison, corresponding data for pulp cooked at different $KMnO_4$ numbers are also reported.

In **Table III,** fiber classifications of pulp cooked with and without hot-high density refining are compared. The high reduction of the portion retained on the 14 mesh screen should be noted since this indicates the shives and bundles present. Additionally, the freeness is almost not affected by the defibrating action of this kind of refining.

In **Table IV,** the physical characteristics of the pulp obtained with hot-high density refining are summarized. For comparison, corresponding data for normal production pulp are also reported.



**Before Refining (100 x).**

**Before Refining (100 x).**

**(After Refining (100 x).**

**TABLE III KMnO$_4$ Number Vs. Fiber Classification with and without Hot-High Density Refining JULY — 1969**

| TRIAL | No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Before Refining** | | | | | | | | | |
| KMnO$_4$ | No. | 20.4 | 18.9 | 19.0 | 20.8 | 19.6 | 27.2 | 28.7 | 32.2 |
| Freeness S.R. | cc. | 880 | 880 | 860 | 870 | 860 | 880 | 880 | 860 |
| **Fiber Classification** | | | | | | | | | |
| + 14 mesh | % | 5.8 | 5.2 | 5.0 | 18.8 | 4.8 | 23.2 | 20.0 | 27.4 |
| + 28 mesh | % | 12.4 | 10.4 | 16.8 | 16.6 | 13.2 | 17.4 | 17.0 | 11.0 |
| + 48 mesh | % | 23.6 | 22.8 | 21.2 | 19.0 | 21.2 | 16.2 | 18.2 | 16.2 |
| +100 mesh | % | **27.2** | **29.0** | **26.4** | **25.6** | **28.2** | **18.8** | **22.0** | **24.2** |
| Usable Fiber | % | 69.0 | 67.4 | 69.4 | 80.0 | 67.4 | 75.6 | 77.2 | 78.8 |
| —100 mesh | % | 31.0 | 32.6 | 30.6 | 20.0 | 32.6 | 24.4 | 22.8 | 21.2 |
| **After Refining** | | | | | | | | | |
| KMnO$_4$ | No. | 20.1 | 18.4 | 18.7 | 19.9 | 19.4 | 27.0 | 28.7 | 31.9 |
| Freeness S.R. | cc. | 860 | 865 | 845 | 860 | 830 | 860 | 860 | 850 |
| **Fiber Classification** | | | | | | | | | |
| + 14 mesh | % | 2.2 | 4.8 | 0.6 | 5.2 | 2.6 | 17.6 | 14.6 | 20.0 |
| + 28 mesh | % | 13.0 | 14.0 | 13.0 | 14.4 | 11.6 | 14.0 | 11.0 | 11.0 |
| + 48 mesh | % | 26.4 | 24.6 | 20.0 | 19.0 | 22.8 | 18.4 | 15.6 | 15.8 |
| +100 mesh | % | **32.2** | **24.4** | **26.4** | **26.6** | **31.2** | **24.6** | **25.2** | **24.8** |
| Usable Fiber | % | 73.8 | 67.8 | 60.0 | 65.2 | 68.2 | 74.6 | 66.4 | 71.6 |
| —100 mesh | % | 26.2 | 32.2 | 40.0 | 34.8 | 31.8 | 25.4 | 33.6 | 28.4 |

**TABLE IV Physical Properties Vs. KMnO$_4$ Number Pulp Before and after Hot-High Density Refining**

| | | KMnO$_4$ No. | Freeness cc. | B. Weight g/m$^2$ | Tear Factor | Tensile Mts. | Mullen Factor | Folding No. | Digester Line | Type of Fiber |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | Before refining | 22.5 | 850 | 63.6 | 73.4 | 2,704 | 12.2 | 5 | 10 | fiber washed |
| | After refining | 19.8 | 810 | 64.6 | 79.1 | 2,828 | 14.6 | 13 | | in the |
| (2) | Before refining | 24.4 | 830 | 64.6 | 88.6 | 2,964 | 13.1 | 10 | 10 | experimental |
| | After refining | 22.0 | 790 | 65.1 | 84.3 | 2,972 | 19.6 | 18 | | depither |
| (3) | Before refining | 23.0 | 820 | 65.1 | 88.1 | 2,810 | 12.5 | 14 | 7 | normal |
| | After refining | 21.9 | 790 | 62.1 | 85.9 | 3,187 | 16.3 | 8 | | |
| (4) | Before refining | 25.0 | 830 | 64.6 | 88.6 | 2,904 | 13.4 | 16 | 7 | fiber |
| | After refining | 23.1 | 800 | 63.6 | 87.2 | 3,224 | 20.1 | 20 | | |

**Above Pulps Refined at Freeness S.R. 600 cc.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1a) | Before refining | 22.0 | 590 | 59.6 | 52.2 | 5,338 | 30.0 | 26 | 10 | fiber washed |
| | After refining | 19.5 | 590 | 61.6 | 57.8 | 5,605 | 36.5 | 48 | | in the |
| 2a) | Before refining | 24.1 | 600 | 64.1 | 67.2 | 5,980 | 39.3 | 32 | 10 | experimental |
| | After refining | 21.3 | 600 | 60.1 | 55.9 | 6,510 | 34.8 | 36 | | depither |
| 3a) | Before refining | 22.4 | 600 | 63.1 | 56.3 | 5,264 | 30.1 | 91 | 7 | normal |
| | After refining | 21.4 | 600 | 64.6 | 62.0 | 6,027 | 32.8 | 72 | | |
| 4a) | Before refining | 24.3 | 600 | 64.6 | 65.0 | 5,386 | 35.7 | 80 | 7 | fiber |
| | After refining | 22 9 | 600 | 63.1 | 56.4 | 6,287 | 33.7 | 88 | | |

**CONCLUSIONS**

1. This study has demonstrated that a continuous digester equipped with an in-line refiner located before the blow tank at the pressurized zone can be advantageously adapted for producing an homogeneous shive-free pulp.

2. High consistency (25-30%) and a temperature of 136° C are critical and necessary for a good defibrating action.

3. The continuous digester and the pressure refiner are standard machinery for the industry and are used in a wide capacity range. Consequently, the digester can be designed for high production capacities. This is an interesting feature of the system, since most continuous digestors for bagasse pulping have comparatively limited capacities.

4. This study and development has demonstrated further that hot-high density refining at the digester's blow-line can be applied not only for bleachable shive-free pulp but also for high yield semichemical pulp.

5. The digester system with hot-high density refining can be used only for vapor-phase cooking. Preliminary results indicate that liquid-phase cooking gives a lower consistency and a more non-uniform pulp quality than with the vapor-phase method.

6. Bagasse pulps produced in the new digester system are uniform, shive-free and have good strength properties. The pulps are well suited for bleached pulp production or for the manufacture of multiwall and corrugating medium from a high yield semichemical furnish.