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DIRECCIÓN DE NUEVAS CREACIONES

2020
Bogotá, D.C.,

Abogado(a)/Señor(a)
J. IAN RAISBECK

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Patente de Invención	X			Patente de Modelo de Utilidad	
Vía Nacional					
Vía PCT (Fase Nacional)	X	Capítulo I	X	Capítulo II	
No. Solicitud Internacional	PCT/IB2012/054042				
Fecha de Presentación Internacional	08/08/2012				

Como resultado del Examen de Fondo realizado, con fundamento en el Artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se comunica:

1. Documentos estudiados

Descripción:	Rad. N° 14-058633-00000-0000	19/Marzo/2014
Reivindicaciones:	Rad. N° 14-058633-00005-0000	03/Marzo/2015
Dibujos:	Rad. N° 14-058633-00000-0000	19/Marzo/2014
Solicitud proceso PPH:	Rad. N° 14-058633-00003-0000	30/Septiembre/2014
Prioridad:	US 13/238,826	21/Septiembre/2011

2. Análisis de la Prioridad

Se acepta la reivindicación de Prioridad porque esta solicitud fue presentada dentro del plazo establecido (Art. 9 D 486) y su contenido técnico corresponde con el de la prioridad reivindicada.

3. Objeto de la invención

De acuerdo con lo establecido en el numeral 1.2.2.2 del Capítulo Primero del Título X de la Circular Única para efectos del examen de patentabilidad, se tendrá en cuenta la tasa pagada por el solicitante al momento de comenzar el examen para las reivindicaciones adicionales; esto es que cuando la solicitud contenga más de diez (10)

reivindicaciones y no se haya pagado la tasa complementaria, sólo se estudiarán las cubiertas por la tasa pagada. Por lo tanto se estudiarán las reivindicaciones 1 a 20.

Título de la solicitud: “Producto de papel tisú que comprende bambú y en donde la primera capa fibrosa se encuentra libre de fibras de bambú” (Pág. 3, radicado N° 14-058633-00005-0000).

El problema planteado en esta solicitud consiste en que las fibras de bambú tienen aspereza y partículas finas que son demasiadas para reemplazar las fibras de madera dura y una longitud de fibra promedio que es demasiado corta y paredes celulares que son demasiado gruesas para reemplazar las fibras de madera, esto genera una disminución en la suavidad de superficie y un incremento en la rigidez de las hojas de papel tisú.

Para resolver este problema técnico, la solicitud en estudio proporciona un elemento laminar secado por aire compuesto por fibras de bambú que tiene un volumen mejorado sin un incremento significativo en la rigidez o disminución en durabilidad.

El objeto de la presente solicitud se relaciona con la Clasificación Internacional de Patentes (CIP): D21H 17/02, 21/18, 27/42.

4. De la Solicitud de Patente

Reivindicaciones (Art 30 D 486, Art 22 PCT)

Las reivindicaciones 1 y 8 no son claras porque la expresión “*fibras de madera*” es general y no permite distinguir la invención del estado de la técnica. Se sugiere sustituirla por un término preciso o un rango concreto.

Las reivindicaciones 1 a 4 y 14 no son claras porque los términos “*al menos*”, “*por lo menos*”, “*menor a*”, “*menos que*” y “*menos de*” y son imprecisos y no permiten realizar una comparación adecuada con el estado de la técnica. Se sugiere cambiarlos por términos precisos o un rango concreto.

Las reivindicaciones 5, 7, 10 a 12 y 15 a 17 no son claras porque el índice de durabilidad, índice de rigidez y volumen son parámetros que no definen la invención y no deberían caracterizar el compuesto solamente por sus parámetros, si es posible definirlo de otra manera. Se sugiere definirlo por sus características esenciales estructurales.

Las reivindicaciones 1, 4 y 20 no son claras porque hacen referencia a un producto, pero presenta características técnicas de un proceso/método mediante el uso de la expresión como “*elemento laminar continuo secado por aire*”, lo cual no es permitido. Al respecto no debe olvidarse que las reivindicaciones de producto y de procedimiento son diferentes y, por ello, deben redactarse de manera independiente en el pliego reivindicatorio. Sobre las mismas, el Tribunal Andino de Justicia ha dicho lo siguiente:

“El objeto de la invención de producto está constituido por un cuerpo cierto destinado a llenar una necesidad industrial que el estado de la técnica aún no ha satisfecho. En cambio, el objeto de la invención de procedimiento se encuentra conformado por “una serie o sucesión de operaciones que inciden sobre una materia (sólida, líquida o gaseosa) que se encamina a la obtención de una cosa o un resultado”.¹

¹ Otero Lastres, José Manuel. Ob. Cit. Proceso 129alPa2007.

Descripción (Art 28 D 486)

Debido a que la invención se refiere a fibras obtenidas del bambú y este tipo de planta incluye a la guadua que es una especie que proviene de Colombia, se requiere al solicitante anexar el contrato de acceso a recursos genéticos o productos derivados de la guadua, expedido por el Ministerio de Ambiente, Vivienda y Desarrollo Territorial, o indicar el estado de trámite del mismo.

Se requiere al solicitante hacer las aclaraciones necesarias.

5. Determinación del Estado de la Técnica

El estado de la técnica se determinó con base en la fecha de presentación de la solicitud de prioridad invocada, es decir, 21 de septiembre de 2011.

Consultadas las fuentes de información con que se cuenta, se encontraron los siguientes documentos que anticipan el objeto de esta solicitud.

Ítem	Documento	Título	Fecha de Publicación
D1	WO 2008/003343	“Method of making an absorbent structure as a multilayer paper, especially a tissue”	10/Enero/2008
D2	WO 2007/004757	“Process for producing pulp utilizing Bamboo and pulp and paper using the same”	11/Enero/2007

El documento D1² divulga papel tisú capas secado por aire que proviene de una malla de fibras a ser cortada (Pág. 2, Párr. 2, Pág. 6, Párr. 2, Pág. 9, Párr. 5 a Párr. 10, Párr. 1).

El documento D2³ divulga pulpa de bambú que se emplea para papel tisú (Pág. 3, líneas 1 a 12, Pág. 8, líneas 7 a 9).

6. Examen de Patentabilidad (Art 14 D486)

Nivel inventivo (Art 18 D486)

La reivindicación 1 consiste en “*Un elemento laminar continuo de papel tisú...*” (Ver Pág. 6 del Rad. N° 14-058633-0005-0000).

Comparación de las características técnicas **esenciales**, con las del Estado de la Técnica:

Características esenciales	D1	D2
Un elemento laminar continuo de papel tisú estratificado secado por aire, caracterizado porque	Papel tisú capas secado por aire que proviene de una malla de fibras a ser cortada (Pág. 2, Párr. 2, Pág. 6, Párr. 2, Pág. 9, Párr. 5 a Párr. 10, Párr. 1).	Pulpa de bambú que se emplea para papel tisú, en donde se emplean el bambú como fuente de material alternativo a la madera (Pág. 3, líneas 1 a 12, Pág. 8, líneas 7 a 9).
El elemento laminar continuo comprende una primera capa fibrosa y una segunda capa fibrosa,	Se presentan dos capas fibrosas (Pág. 13, Párr. 5, Figs. 1 y 2).	No se menciona
La primera capa fibrosa comprende fibras de madera	Se tienen fibras de madera en cada una de las dos capas, una capa tiene madera dura y otra madera suave (Pág. 14, Párr. 1).	No se menciona

² <http://www.google.com/patents/WO2008003343A1?cl=en>

³ <http://www.google.co.ug/patents/WO2007004757A1?cl=fi>

Y la segunda capa comprende fibras de bambú	Las fibras empleadas en cada capa dependen de las características deseadas en las capas, en donde se tiene como una fuente de fibras el bambú (Pág. 7, Párr. 1).	No se menciona
En donde la primera capa fibrosa se encuentra libre de fibras de bambú	Se tiene fibras de madera de eucalipto en la capa suave del papel tisú (Pág. 11, Párr. 2 a Pág. 12, Párr. 2).	No se menciona
Y en donde las fibras de bambú comprenden por lo menos 10 por ciento del peso total del elemento laminar continuo secado por aire	No se menciona ^{4,5}	Para dar resistencia al papel se puede emplear entre un 10 a 25% de pulpa de bambú o para papel tisú se puede emplear solo fibras de bambú (Pág. 29, líneas 12 a 20).

Los documentos D1 y D2 se consideran el estado de la técnica más cercano a la invención definida en la reivindicación 1, pues divulgan papel tisú, su forma de obtención y los tipos de madera que lo pueden conformar.

La diferencia entre la invención, definida en la reivindicación 1, y el producto descrito en el documento D1 consiste en que en el documento D1 no se menciona que las fibras de bambú están en por lo menos un 10% dentro del elemento laminar.

La diferencia entre la invención, definida en la reivindicación 1, y el producto descrito en el documento D2 consiste en que en el documento D2 no se menciona que el elemento laminar presente dos capas fibrosas, una de ellas libre de bambú y la otra con bambú.

El efecto que logra el tener fibras de bambú en por lo menos un 10% en el elemento laminar es que permite obtener un volumen de hoja mayor y una mejor rigidez y durabilidad.

Por lo tanto, el problema técnico objetivo que pretende resolver esta invención se puede formular así “¿cómo modificar el producto descrito en el documento D1 para obtener un volumen de hoja mayor y una mejor rigidez y durabilidad?”.

Sin embargo, el empleo de fibras de bambú entre el 10 y el 25% para mejorar la resistencia del papel ya ha sido reportado por el documento D2, que se refiere a un método para la obtención de diferentes tipos de papel, entre ellos el tisú a partir de pulpa de bambú (Pág. 29, líneas 12 a 20).

En consecuencia, una persona normalmente versada en la materia incluiría las fibras del bambú entre el 10 y 25% del documento D2 en el producto de la anterioridad D1 para llegar así al objeto de la reivindicación 1, lo cual es considerado obvio y, por lo tanto, sin altura inventiva.

Adicionalmente, la reivindicación 1 y las reivindicaciones 2 a 4 se afectan con el conocimiento del técnico, “*el experto medio deberá poseer experiencia y contar con un saber general en la materia y con una serie de conocimientos en el campo específico de la invención*”⁴, el cual conoce que los porcentajes de bambú dentro del producto varían de acuerdo al tipo de papel a ser obtenido, es decir a las propiedades deseadas y por lo tanto para la persona versada en la materia es cuestión de realizar ensayos que varíen la concentración de los diferentes tipos de fibras para evaluar en cual relación de fibras se obtienen las propiedades deseadas, en donde para el papel tisú se tienen concentraciones de fibras de bambú del 90 y 100% (Pág. 14, Tabla 8)⁵.

⁴Proceso 43-IP-2002, publicado en la G.O.A.C. N° 870, de 9 de diciembre de 2002, caso: formulaciones de péptidos hidrosolubles de liberación retardada.

⁵Fiber and papermaking characteristics of bamboo. Technical bulletin No.1361. Agricultural Research Service. United States Department of Agriculture.1966.

Las reivindicaciones 5 a 7 son parámetros que no proporcionan nivel inventivo a las reivindicaciones de las cuales dependen.

La reivindicación 8 consiste en “*Un producto de papel tisú que comprende un primer elemento laminar...*” (Ver Pág. 7 del Rad. N° 14-058633-0005-0000).

Comparación de las características técnicas **esenciales**, con las del Estado de la Técnica:

Características esenciales	D1	D2
Un producto de papel tisú que comprende un primer elemento laminar continuo secado por aire, caracterizado porque	Papel tisú capas, secado por aire que proviene de una malla de fibras a ser cortada (Pág. 2, Párr. 2, Pág. 6, Párr. 2, Pág. 9, Párr. 5 a Párr. 10, Párr. 1)	Pulpa de bambú que se emplea para papel tisú (Pág. 3, líneas 1 a 12, Pág. 8, líneas 7 a 9).
Comprende una primera capa fibrosa y una segunda capa fibrosa,	Se presentan dos capas fibrosas (Pág. 13, Párr. 5, Figs. 1 y 2).	No se menciona
La primera capa fibrosa comprende fibras de madera	Se tienen fibras de madera en cada una de las dos capas, una capa tiene madera dura y otra madera suave (Pág. 14, Párr. 1).	No se menciona
Y la segunda capa comprende fibras de bambú	Las fibras empleadas dependen de las características deseadas en las capas (Pág. 7, Párr. 1).	No se menciona
En el que la primera capa fibrosa está libre de fibras de bambú	Se tiene fibras de madera de eucalipto en la capa suave del papel tisú (Pág. 11, Párr. 2 a Pág. 12, Párr. 2).	No se menciona
Y en que las fibras de bambú comprenden al menos 10 por ciento del peso total del elemento laminar continuo secado por aire,	No se menciona	Para dar resistencia al papel se puede emplear entre un 10 a 25% de pulpa de bambú o para papel tisú se puede emplear solo fibras de bambú (Pág. 29, líneas 12 a 20).
El producto de papel tisú tiene un peso base de 10 a 60 gramos por metro cuadrado	El papel tisú tiene un peso entre 8 a 30 g/m ² , pero si es multicapa hasta de 65 g/m ² (Pág. 1, Párr. 2).	No se menciona

Los documentos D1 y D2 se consideran el estado de la técnica más cercano a la invención definida en la reivindicación 8, pues divulgan papel tisú, su forma de obtención y los tipos de madera que lo pueden conformar.

La diferencia entre la invención, definida en la reivindicación 8, y el producto descrito en el documento D1 consiste en que en el documento D1 no se menciona que las fibras de bambú están en por lo menos un 10% dentro del elemento laminar.

La diferencia entre la invención, definida en la reivindicación 8, y el producto descrito en el documento D2 consiste en que en el documento D2 no se menciona que el elemento laminar presente dos capas fibrosas, una de ellas libre de bambú y la otra con bambú.

El efecto que logra el tener fibras de bambú en por lo menos un 10% en el elemento laminar es que permite obtener un volumen de hoja mayor y una mejor rigidez y durabilidad.

Por lo tanto, el problema técnico objetivo que pretende resolver esta invención se puede formular así “¿cómo modificar el producto descrito en el documento D1 para obtener un volumen de hoja mayor y una mejor rigidez y durabilidad.?”.

Sin embargo, el empleo de fibras de bambú entre el 10 y el 25% para mejorar la resistencia del papel ya ha sido reportado por el documento D2, que se refiere a un método para la obtención de diferentes tipos de papel, entre ellos el tisú a partir de pulpa de bambú (Pág. 29, líneas 12 a 20).

En consecuencia, una persona normalmente versada en la materia incluiría las fibras del bambú del documento D2 en el producto de la anterioridad D1 para llegar así al objeto de la reivindicación 1, lo cual es considerado obvio y, por lo tanto, sin altura inventiva.

Asimismo, el documento D1 divulga las características de las reivindicaciones dependientes, así:

Reivindicación 9: se tiene papel tisú multicapas (Pág. 1, Párr. 2).

Reivindicación 15: El papel tisú tiene un peso entre 8 a 30 g/m², pero si es multicapa hasta de 65 g/m² (Pág. 1, Párr. 2).

Reivindicación 17: El papel tisú tiene un peso entre 8 a 30 g/m², pero si es multicapa hasta de 65 g/m² (Pág. 1, Párr. 2).

Reivindicación 18: la longitud de las fibras son usualmente de menos de 1.8 mm (Pág. 11, Párr. 1).

Reivindicación 20: se puede tener papel crepado o no crepado (Pág. 6, Párr. 1)

Asimismo, el documento D2 divulga las características de las reivindicaciones dependientes, así:

Reivindicación 19: se tiene como fuente de bambú regiones como China o Myanmar, países que presentan determinadas especies nativas de bambú (Pág. 3, líneas 7 a 12).

Asimismo, las reivindicaciones 13, 14 y 17 se afectan con el conocimiento del técnico, *“el experto medio deberá poseer experiencia y contar con un saber general en la materia y con una serie de conocimientos en el campo específico de la invención”*⁴, el cual conoce que los porcentajes de bambú dentro del producto varían de acuerdo al tipo de papel a ser obtenido, es decir a las propiedades deseadas y por lo tanto para la persona versada en la materia es cuestión de realizar ensayos que varíen la concentración de los diferentes tipos de fibras para evaluar en cual relación de fibras se obtienen las propiedades deseadas, en donde para el papel tisú se tienen concentraciones de fibras de bambú del 90 y 100% (Pág. 14, Tabla 8)⁵.

Las reivindicaciones 10 a 12 y 16 son parámetros que no proporcionan nivel inventivo a las reivindicaciones de las cuales dependen.

7. Conclusión

Los requisitos de Patentabilidad de la presente Solicitud están afectados así:

Ítem	Documento	Reivindicaciones afectadas	Requisito que afecta
D1	WO 2008/003343	1 a 20	Nivel inventivo
D2	WO 2007/004757	1 a 20	Nivel inventivo

8. Respuesta a los argumentos del señor solicitante

Argumentos con respecto a la claridad del capítulo reivindicatorio

La solicitante indica que los términos al menos y por lo menos representan un límite

inferior cuando se trata de la cantidad de algún compuesto de interés y por lo tanto permiten definir de forma clara las reivindicaciones.

Al respecto esta Oficina reitera que dichos término son imprecisos por lo cual no permite distinguir la invención del estado de la técnica. Se sugiere sustituirlo por un término preciso o un rango concreto

Adicionalmente, la solicitante menciona que los resultados a alcanzar pueden estar presentes en las reivindicaciones según esta establecido en el Instructivo de exámenes de patentes de este Despacho.

Con relación a los resultados a alcanzar, esta Oficina aclara que si son permitidos pero estos no ofrecen novedad ni nivel inventivo a las reivindicaciones.

Argumentos con respecto a la excepción de la patentabilidad

La solicitante indica que la reivindicación 19 es patentable ya que la explotación y comercialización del bambú no presenta un impacto negativo contra la naturaleza en el territorio nacional.

Al respecto esta Oficina indica que cuando se emplean productos de origen biológico que son nativos de la Comunidad Andina se requiere el certificado de acceso a recurso biológico y por tal motivo a la presente solicitud en caso de obtener la patente tendría como exclusión las plantas del género *Guadua*.

En cumplimiento del artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se le indica que debe dar respuesta dentro del término de sesenta (60) días contados a partir del día siguiente de la fecha de notificación de la presente comunicación. En caso de no dar respuesta al presente requerimiento, o si a pesar de la respuesta subsistieran los impedimentos para la concesión, se denegará la patente.

Se invita al solicitante se sirva indicar, si así lo considera, su renuncia al término faltante de sesenta (60) días para dar respuesta a este requerimiento y presentarla por escrito.

Finalmente, se le recuerda al solicitante que si como respuesta a este requerimiento llegara a modificar el capítulo reivindicatorio y éste contenga más de diez (10) reivindicaciones, no pagará la tasa de modificación voluntaria pero sí la correspondiente al pago por reivindicación adicional.

Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Única No. 10 de 2001.



JOSÉ LUIS SALAZAR LÓPEZ
Director de Nuevas Creaciones (c)

El anterior requerimiento fue notificado por fijación en lista, de fecha 2015-04-21

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573

FIBER AND PAPERMAKING CHARACTERISTICS OF BAMBOO

Technical Bulletin No. 1361

**Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE**

Acknowledgment

The fiber and chemical studies described in this bulletin were performed by the Herty Foundation, Savannah, Ga., through research contracts with the U.S. Department of Agriculture under the provisions of the Research and Marketing Act of 1946. This bulletin reports the final results of these studies.

Contents

	<i>Page</i>
Summary -----	1
Introduction -----	2
Bamboo species studied -----	3
Gross physical characteristics -----	3
Determination of fiber dimensions -----	4
Maceration of specimen -----	4
Preparation of slides -----	5
Measurement of fiber -----	5
Evaluation of fiber measurements -----	5
Fiber dimension data -----	6
Chemical properties of bamboo -----	7
Preparation and evaluation of bamboo pulp-----	8
Exploratory techniques -----	8
Raitt two-stage and kraft single-stage cooking processes -----	8
Pilot plant processing -----	10
Papermaking -----	12
Bleaching -----	12
Refining -----	13
Machine operation -----	13
Physical Properties -----	13
Literature cited -----	16
Appendix -----	16
Preliminary experiments for macerating culms -----	16
Exploratory pulping studies -----	18

FIBER AND PAPERMAKING CHARACTERISTICS OF BAMBOO

By J. R. HAUN, formerly horticulturist, Crops Research Division; T. F. CLARK, chemical engineer, Northern Utilization and Development Division; and GEORGE A. WHITE, agronomist, Crops Research Division, Agricultural Research Service

SUMMARY

Chipped bamboo culms of *Phyllostachys meyeri* and *P. bambusoides* compare favorably in density to hardwood and softwood logs not debarked. Stacked whole culms are more bulky than logs because of the airspace in bamboo culms.

As a rule, bamboo fibers are about the same length as those of hardwoods but are shorter than those of most coniferous woods. Length-to-width ratios are higher than those of wood fibers. The fibers of the tropical bamboo, *Bambusa vulgaris*, are longer than those of other bamboo species. It was the only bamboo studied whose fiber approximated the length of southern pine fiber.

High length-to-width ratios indicate that bamboo fibers are flexible and strong rather than stiff and brittle. Slender, pliable fibers are better for most paper because they give softness and smoothness rather than hardness and coarseness to the product. These characteristics indicate that bamboo may have a possible use in the manufacture of high-quality material for facial tissue and for book, bond, and stationery

paper products. The various cooking procedures had no appreciable effect on bamboo average fiber length or fiber width.

Bamboo raw material and pulp were analyzed for ash, pentosan, and lignin content. A suitable method was developed for the determination of lignin because the methods used on wood were not entirely satisfactory for bamboo. The chemical composition of bamboo culms is not widely different from that of other material used in paper making. However, considerable chemical variation was evident among the species of bamboo. Pulping procedures affected the chemical composition of bamboo about the same way they affect other papermaking materials.

Of the several pulping methods used, the most promising were the kraft single-stage and the Raitt two-stage processes. For pulp of the same yield, the latter process gave better delignification, therefore better bleachability, with less removal of strength-giving pentosans than did the kraft process. The net consumption of chemicals was less in the

Raitt process than in the kraft process. For equivalent yield and brightness, the chlorine required to bleach pulp cooked by the Raitt process was less than that required to bleach pulp cooked by the kraft process. Bleachable bamboo pulp made by either method did not need refining before it was screened. Bamboo can be pulped readily with less power and chemicals than wood.

Considering the unbleached pulp yields, bleaching by use of standard procedures produced satisfactory brightness without undue loss of yield or strength. The bleaching of bamboo pulp consumes less chlorine as a rule than the bleaching of wood pulp.

Any of the bamboo species studied could be used for papermaking because there were only minor pulping differences among them. The choice of species to grow, therefore, depends largely on agronomic characteristics and availability of propagating material. Of the tropical bamboos, *Bambusa vulgaris* had somewhat superior papermaking characteristics.

Bamboo pulps are especially suited to papers that require softness and absorptivity. The qualities of bamboo pulp that favor its use for these types of papers are attributed in part to the slenderness and pliability of the fibers. Bamboo appears to be suitable for the following products:

a. Unbleached pulp for the manufacture of cable insulation and fruit wrapper; pattern, industrial saturating, and toweling papers; and very light dry-formed board.

b. Bleached pulp for the manufacture of absorbent molding, Bible, bread wrapper (waxed), and cigarette papers; cellulosic fiber media; sanitary papers requiring softness; and blends for high-quality writing and airmail stationery.

Other research on bamboo has shown the apparent suitability of *Phyllostachys bambusoides* for dissolving pulp (8)¹ and structural board (6). This species may also be suitable for making newsprint-type papers, but this possibility requires additional investigation (7).

INTRODUCTION

Bamboo has been grown in the United States on a limited basis for more than 50 years. It has been utilized mainly for ornamental purposes and to a limited extent for fishing poles. The Chinese have used it for centuries as a papermaking material, and in India it is one of the main raw materials used in the manufacture of paper.

Because of bamboo's potentiality as a new crop for the United States, fiber and chemical studies

were carried out by the Herty Foundation to determine the suitability of domestic bamboo for paper pulp. The first study by the Herty Foundation was started in 1953 to determine the comparative fiber dimensions and pulping characteristics of 21 species of bamboo. The second study, started in 1954, was designed to obtain additional comprehensive data on the pulping, bleaching, and paper-

¹ Italic numbers in parentheses refer to Literature Cited, p. 16.

variable, depending on the age of plant, and on soil, climate, and other factors. Consequently, culm sizes shown in table 1 are not necessarily representative for a particular species. The approximate maximum sizes of culms measured by McClure (5) for

three species of bamboo also studied by the Herty Foundation in 1954 were—

	Culm height, feet	Culm diameter, inches
<i>P. meyeri</i> -----	33	1 $\frac{7}{8}$
<i>P. nigra</i> 'Henon' -	50	3
<i>P. bambusoides</i> ---	75	5 $\frac{3}{4}$

TABLE 1.—Volume and density of bamboo culms and of softwood and hardwood logs¹

Species	Units			Piled volume of a cord occupied by culms or logs	Oven-dry weight	
	Kind	Number per cord	Average diameter		Bulk density	Density of solid portion
			Inches	Cubic feet	Pounds/cord	Pounds/cubic foot
<i>Phyllostachys meyeri</i> -----	Culms	3,988	0.97	100	1,772	² 40.9
<i>P. nigra</i> 'Henon'-----	Culms	2,223	1.30	83	1,143	34.0
<i>P. bambusoides</i> -----	Culms	880	2.02	79	1,200	² 34.8
Softwood (pine)-----	Logs	45-100	7-10	³ 83	⁴ 1,575-2,575	19-31
Hardwood-----	Logs	45-100	7-10	³ 83	⁴ 1,745-3,405	21-41

¹ Data for bamboo culms obtained from Stevens (13) and for logs, from Forest Products Laboratory Technical Note No. 191 (15).

² Value determined by displacement using chipped culms.

³ Based on an average volume of 65 percent wood and 35 percent bark and airspace in a freshly stacked pile. Solid volume content for a cord of bark-free logs is about 1.15 to 1.2 times that for logs with bark.

⁴ Basis green volume.

Bamboo culms have been assumed to require considerably more space than pine logs on a weight basis and thus would be impractical to handle and store. Data in table 1 indicate that whole culms may be more bulky than pine logs, but that chipped culms compare more favorably on a density basis.

Determination of Fiber Dimensions

Preliminary experiments were performed to determine an appropriate method for macerating culms that would minimize damage to the fibers. These experiments are described in the appendix.

Maceration of Specimen

Maceration procedure consisted of cooking internodal strips of about 2 mm. by 2 mm. by 25 mm. for 20 minutes at 15 p.s.i. steam pressure with a 10-percent NaOH solution (i.e., 100 grams per liter); soaking 3 days in distilled water with three changes of water; and then dispersing for 45 seconds in an Osterizer.² Later the Osterizer was replaced by a Hamilton-Beach Blender. A 15-second period with the blender running at low speed was found best for dispersal.

² Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty and does not signify that the product is approved to the exclusion of other comparable products.

Nieschlag et al. (9) determined bamboo fiber dimensions by modifying the maceration techniques of Spearin and Isenberg (11) and of Jarman and Pickering (4). This modification involved boiling samples for 1 hour in 1-percent NaOH; draining, washing with hot 5-percent acetic acid, and then digesting the material in an acidic (acetic acid) solution of sodium chlorite until cellular bundles were fairly well separated. Maceration was usually completed in 6 to 8 hours.

Preparation of Slides

Ten-gram samples of the macerated raw material were dispersed in distilled water in a 500-ml. Erlenmeyer flask. By progressive decantation and dilution with distilled water, the fiber dispersions were reduced to a consistency that weighed about 0.1 gram per liter. The actual fiber concentration was varied somewhat according to average fiber length.

Four test tubes 6 inches long and 0.75 of an inch in diameter were filled with the fiber suspension, taking care to shake the Erlenmeyer flask vigorously before filling each test tube. Next, three drops of a 1-percent solution of Congo Red, or of Methylene Blue, were added to the contents in each of the test tubes and let stand 1 hour. Methylene Blue was best for use on bleached fibers.

After standing 1 hour, each tube was shaken well and a little of the fiber suspension removed with a 5 mm.-diameter pipette. A drop of fiber suspension was placed on one end of each of two slides. Eight slides were prepared from fiber suspensions in the four test tubes. Careful manipulation

made it possible to deposit approximately 25 fibers on each slide. The slides were placed on a Temco hot plate adjusted to 50° C., and the water was evaporated slowly.

Measurement of Fiber

Slides with fiber suspensions were placed on the stage of an ACM Projektina that enlarged the image 10 times and projected it on a ground-glass screen. Fibers in the suspension were aligned parallel with the major axis of the slide by use of a microscope needle, taking care to straighten each fiber in order to facilitate measurement. The length of each fiber was then determined to the nearest 0.1 of a millimeter by use of the calibrated grid on the Projektina.

The slides were then transferred to the mechanical stage of a binocular microscope where fiber widths were measured by use of a 43-power objective lens, a 10-power ocular lens, and a micrometer scale. The resulting 430-power magnification made possible the measurement of fiber widths to the nearest 0.001 of a millimeter. A minimum of 200 measurements was made for each average dimension reported.

Evaluation of Fiber Measurements

Fiber measurements (for each average dimension reported) were evaluated by the following procedure:

1. The total range of fiber lengths was divided into intervals of 0.1 of a millimeter. The number of fibers in each length-interval was recorded, and the percentage of fibers a in the interval was calculated.
2. The mean length b of the fibers in each interval was calculated.

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After standing 1 hour, each tube was shaken well and a little of the fiber suspension removed with a 5 mm.-diameter pipette. A drop of fiber suspension was placed on one end of each of two slides. Eight slides were prepared from fiber suspensions in the four test tubes. Careful manipulation

made it possible to deposit approximately 25 fibers on each slide. The slides were placed on a Temco hot plate adjusted to 50° C., and the water was evaporated slowly.

Measurement of Fiber

Slides with fiber suspensions were placed on the stage of an ACM Projektina that enlarged the image 10 times and projected it on a ground-glass screen. Fibers in the suspension were aligned parallel with the major axis of the slide by use of a microscope needle, taking care to straighten each fiber in order to facilitate measurement. The length of each fiber was then determined to the nearest 0.1 of a millimeter by use of the calibrated grid on the Projektina.

The slides were then transferred to the mechanical stage of a binocular microscope where fiber widths were measured by use of a 43-power objective lens, a 10-power ocular lens, and a micrometer scale. The resulting 430-power magnification made possible the measurement of fiber widths to the nearest 0.001 of a millimeter. A minimum of 200 measurements was made for each average dimension reported.

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Fiber measurements (for each average dimension reported) were evaluated by the following procedure:

1. The total range of fiber lengths was divided into intervals of 0.1 of a millimeter. The number of fibers in each length-interval was recorded, and the percentage of fibers a in the interval was calculated.
2. The mean length b of the fibers in each interval was calculated.

The mean fiber length b' of the entire lot was determined by multiplying the interval average lengths by the interval percentages, adding the interval products, and dividing the sum by 100, as follows: Mean fiber length

$$b' = \frac{\sum (ab)}{100}$$

3. The mean fiber width c' was obtained by substituting the interval mean fiber width c in the preceding formula, thus: Mean fiber

$$\text{width } c' = \frac{\sum (ac)}{100}$$

4. The mean weighted fiber area was calculated from the sum of the products of the lengths $\times$ widths $\times$ percentages of frequency, as follows: Mean weight-

$$\text{ed fiber area} = \frac{\sum (abc)}{100}$$

5. Finally the frequency distribution of fibers by weight per length interval was calculated by dividing the interval fiber area (fre-

quency $a \times \text{length } b \times \text{width } c$) by the mean weighted fiber area $\left(\frac{\sum (abc)}{100}\right)$. Thus, the frequency distribution by weight

$$= \frac{abc}{\sum (abc)} \times 100.$$

Fiber Dimension Data

In most cases, measurements of fiber length and fiber width were made on raw material obtained from several places on each culm. Fiber lengths and widths of the lower one-third (base) and the upper two-thirds of the culms were averaged (table 2). The length-to-width ratios are means of ratios of the upper and lower portions of culms and, therefore, differ slightly from ratios that would be obtained by using average length and width means shown in table 2. Analyses of variance were performed and Duncan's Multiple Range test applied to each set of data.

TABLE 2.—Mean fiber dimensions of bamboo raw material

Species	Mean fiber length ¹	Mean fiber width ¹	Length-to-width ratio ¹
	<i>Mm.</i>	<i>Mm.</i>	
<i>Bambusa vulgaris</i>	2.28 a	0.0096 bcde	240 a
<i>Phyllostachys rubromarginata</i>	1.77 b	.0093 cde	190 b
<i>P. purpurata</i> 'Straightstem'.....	1.72 bc	.0096 bcde	176 bcd
<i>B. tuldoidea</i>	1.70 bc	.0097 bcde	176 bcd
<i>P. viridis</i>	1.69 bc	.0114 ab	146 cdef
<i>P. meyeri</i>	1.62 bc	.0092 cde	156 bcdef
<i>P. aurea</i>	1.61 bc	.0108 abcd	149 bcdef
<i>Guadua angustifolia</i>	1.60 bc	.0111 abc	148 cdef
<i>B. tulda</i>	1.56 bc	.0096 bcde	161 bcdef
<i>P. flexuosa</i>	1.54 bc	.0096 bcde	160 bcdef
<i>P. arcana</i>	1.52 bc	.0117 a	130 ef
<i>B. longispiculata</i>	1.48 bc	.0082 e	182 bc
<i>P. nidularia</i>	1.48 bc	.0090 de	166 bcde
<i>P. purpurata</i> 'Solidstem'.....	1.48 bc	.0091 de	162 bcdef
<i>P. nigra</i> 'Henon'.....	1.43 bc	.0089 de	145 cdef
<i>P. vivax</i>	1.38 bc	.0102 abcd	134 ef
<i>P. bambusoides</i>	1.37 bc	.0104 abcd	132 ef
<i>P. pubescens</i>	1.30 bc	.0093 cde	140 def
<i>P. aureosulcata</i>	1.26 bc	.0082 e	156 bcdef
<i>P. dulcis</i>	1.20 c	.0096 bcde	124 f

¹ For a given measurement, two means followed by the same letter or letters are not significantly different at the 5-percent level according to Duncan's Multiple Range test. The same degree of significance applies to ratios of length-to-width.

Chemical Properties of Bamboo

Bamboo for analysis was cut from whole culms by use of a power saw and identified as to position on the culm and number of nodes per section. Samples were then split lengthwise with an ax into pieces about $\frac{3}{4}$ of an inch wide and 6 inches long and then fiberized in the 015 Jackson & Church refiner mill.

The fiberized raw material was taken from the refiner mill and further reduced in size in an Abbe mill that had $\frac{1}{16}$ -inch perforations. It was then screened on a set of Synttron sieves to obtain material that passed through a 50-mesh sieve but was retained on a 100-mesh sieve.

Bamboo fiberized raw material was analyzed for ash, lignin, and pentosan by TAPPI³ standard methods, as follows:

a. Ash content, by use of TAPPI method T 15 m-48.

b. Lignin content, by use of TAPPI method T 13 m-45. The time of digestion in 72-percent H_2SO_4 was extended to 20 hours.

c. Pentosan content, by use of TAPPI method T 18 m-20. Krobner's table (2) was used for converting weights of furfural glucoside to pentosan.

The results of analyses of variance for duplicate determinations of ash, pentosan, and lignin in samples of bamboo raw material from the lower one-third of culms are given in table 3.

TABLE 3.—Composition of bamboo raw material from lower one-third of culms

Species	Ash ¹	Pentosan ¹	Lignin ¹
	Percent	Percent	Percent
<i>Bambusa tulda</i>	6.2 a	18.5 e	19.7 g
<i>Phyllostachys bambusoides</i>	2.1 b	22.3 a	32.2 b
<i>P. vivax</i>	1.8 bc	22.3 a	24.5 e
<i>P. purpurata</i> 'Solidstem'.....	1.8 bc	21.6 ab	26.9 d
<i>P. aureosulcata</i>	1.8 bc	20.6 bcd	21.2 fg
<i>B. tuldoidea</i>	1.4 cd	19.4 de	19.6 g
<i>P. flexuosa</i>	1.4 cd	20.1 cd	24.4 e
<i>P. meyeri</i>	1.2 de	21.0 abc	23.0 ef
<i>P. viridis</i>	1.0 de	18.4 e	21.6 fg
<i>P. rubromarginata</i>	1.0 de	22.2 a	36.8 a
<i>P. nigra</i> 'Henon'.....	1.0 de	18.2 e	29.3 c
Pine chips.....	.8 e	14.4 f	27.0 d

¹ For a given measurement, two means followed by the same letter or letters are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

In contrast to the procedure described in the foregoing paragraphs, a fairly simple and rapid method for the determination of lignin has been developed by the Agricultural Research Service's Northern Utilization Research and Development Division. This method, which is a modification of the procedure described by Aro-novsky et al. (1), involves 2 hours digestion in 80-percent sulfuric acid at 5° C., dilution to 3 per-

cent, and boiling for 1 hour. The residue is then recovered and weighed with correction for ash content determined by ignition of the dried residue.

³ Technical Association of the Pulp and Paper Industry. Also the name of the official publication of this Association. All publications of the Technical Association of the Pulp and Paper Industry may be obtained from the offices at 360 Lexington Avenue, New York, N. Y. 10017.

PREPARATION AND EVALUATION OF BAMBOO PULP

Exploratory Techniques

Studies were conducted with small amounts of raw material to determine the chemical-to-bamboo ratio required to neutralize organic acids and solubilize the cementing substance (lignin) enough to separate fibers for the determination of pulp yields. For this purpose, small digesters having a capacity of 900 ml. were made from 8-inch lengths of 3-inch pipe closed at one end by a welded plate and at the other end by a threaded cap having a thermometer well. The digesters were heated in an oil bath over a gas flame.

Bamboo for these digesters was prepared by cutting culms into sections with a power saw and splitting the sections into splinters. Both nodal and internodal sections were included. Splinter dimensions ranged from 1 to 10 mm. tangential, 1 to 6 mm. radial, and 74 to 202 mm. longitudinal. Mean dimensions were 5 by 3 by 150 mm., respectively. Splinters from each culm section were distributed equally among digesters.

The exploratory pulping studies and their results are described in the appendix.

Raitt Two-Stage and Kraft Single-Stage Cooking Processes

Comparative cooking studies using the Raitt and kraft processes were conducted with constant chemical-to-bamboo ratios on larger samples of material from various species of bamboo than described under "Explora-

tory Techniques." In these studies, the material was cooked in a 5-gallon or larger digester, and the results allowed an adequate evaluation of the pulp.

Bamboo for these two processes was prepared from basal sections (lower one-third) of culms by chipping in a Carthage 4-knife chipper. This machine made good chips, but it also made a lot of splinters. Splinters were separated by hand and chopped into suitable size with a hatchet.

Treatments given the bamboo chips and splinters follow.

1. Raitt two-stage cooking (10): Using 20 grams per liter active alkali (calculated as NaOH) at a liquor volume of 8 to 1, bamboo was cooked for 1 hour at 100° to 110° C., followed by cooking 1 hour at 150° C. Then using the same liquor volume containing 50 grams per liter active alkali (calculated as NaOH), the material was cooked 2 hours at 130° to 140° C.

2. Kraft single-stage cooking: Using 15-percent active Na_2O (calculated on moisture-free bamboo) and an 8 to 1 liquor volume, bamboo was cooked 2 hours at 160° to 170° C.

Fiber dimensions of the pulp prepared by the kraft process were determined according to the techniques described in the section "Determination of Fiber Dimensions." Results of these determinations are shown in table 4.

Kraft-cooked pulps were prepared for chemical analysis by oven drying followed by pulverizing in an Abbe mill. The content

of ash, lignin, and pentosans is shown in table 5. Methods used for the various constituent analyses were:

a. Ash content, TAPPI method T 211 m-44.

b. Lignin content, TAPPI meth-

od T 22 m-50. Digestion time was extended to 20 hours.

c. Pentosan content, TAPPI method T 19 m-20. Krobe's table (2) was used for converting weights of furfural glucoside to pentosan.

TABLE 4.—Fiber dimensions of bamboo pulp prepared from the basal sections of culms in 5-gallon digesters by the kraft process

Species pulped	Fiber dimensions ¹		
	Length	Width	Length-to-width ratio
	<i>Mm.</i>	<i>Mm.</i>	
<i>Bambusa vulgaris</i>	2.09 a	0.0109 ab	192 ab
<i>B. longispiculata</i>	1.80 ab	.0088 de	204 a
<i>B. tulda</i>	1.73 bc	.0108 ab	160 defgh
<i>Phyllostachys rubromarginata</i>	1.66 bc	.0091 cde	182 bc
<i>P. nigra</i> 'Henon'.....	1.65 bc	.0090 cde	184 bc
<i>B. tuldoidea</i>	1.64 bc	.0097 abcde	170 cdef
<i>P. flexuosa</i>	1.63 bc	.0094 bcde	174 bcd
<i>Guadua angustifolia</i>	1.62 bc	.0112 a	144 hi
<i>P. purpurata</i> 'Straightstem'.....	1.54 bcd	.0087 de	177 bcd
<i>P. meyeri</i>	1.50 bcd	.0098 abcde	153 efghi
<i>P. viridis</i>	1.48 bcd	.0104 abc	142 hi
<i>P. aurea</i>	1.44 cd	.0088 de	165 cdefg
<i>P. nidularia</i>	1.44 cd	.0085 e	169 cdef
<i>P. congesta</i>	1.43 cd	.0084 e	170 cdef
<i>P. vivax</i>	1.43 cd	.0101 abcd	140 i
<i>P. aureosulcata</i>	1.23 d	.0084 e	146 ghi

¹ For a given measurement, two means followed by the same letter or letters are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

TABLE 5.—Composition of bamboo pulp prepared from the basal sections of culms in 5-gallon digesters by the kraft process

[Results are duplicate determinations]

Species pulped	Ash ¹	Pentosan ¹	Lignin ¹
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
<i>Bambusa vulgaris</i>	2.35 a	20.1 b	7.6 d
<i>Phyllostachys congesta</i>	2.25 ab	26.6 a	9.7 c
<i>P. aurea</i>	1.85 ab	14.9 c	6.6 d
Pine chips.....	1.50 ab	9.0 d	21.3 a
<i>P. viridis</i>	1.25 ab	20.7 b	5.0 e
<i>P. bambusoides</i>	1.15 ab	20.5 b	17.3 b
<i>P. vivax</i>	0.90 b	19.8 b	18.0 b

¹ For a given measurement, two means followed by the same letter or letters are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

Representative data for some properties of the pulps produced by the Raitt two-stage and the kraft single-stage processes are shown in table 6. TAPPI method T 200 m-45 was used to evaluate the strength and other physical characteristics of the bambo

pulps. Refining by beating was performed in a 1½-pound Valley beater, and pulp was sampled at intervals to determine freeness and sheet making. A Rice-Barton Dynapulper was used in lieu of the British disintegrator for clearing the pulps before sheet

making. Based on a test from one cook, the dynapulper appeared to have no appreciable effect on the freeness of the stock. The beater bedplate clearance chamber did not have water inlets, but by exercising care, it was possible to keep the pockets free of accumulated fiber. Instead of the standard 5,500 grams on the bedplate lever arm, a total of 6,440 grams was used. Because the experimental results were subjected only to comparative interpreta-

tion, these departures were justified. Freeness was determined by use of TAPPI method T 227 m-50.

Handsheet forming was done by use of Noble and Wood equipment and procedure, except that sheets were dried on an electric hot plate instead of on a drum dryer. Six handsheets were made for each freeness determination. One of these sheets was preserved for reference; the other sheets were measured, tested, and the results averaged.

TABLE 6.—Some physical properties of bamboo pulps prepared by Raitt two-stage and kraft single-stage processes and refined to 400 ml. Canadian Standard (C.S.) freeness

Pulping method and species tested	Pulp yield	Beating time	Burst factor	Tear factor
	Percent	Minutes	G./sq. cm./g./sq. m.	G./g./sq. m.
Raitt two-stage:				
<i>Bambusa longispiculata</i>	41	62	22.0	132
<i>B. tuldoidea</i>	45	53	22.5	103
<i>B. vulgaris</i>	41	45	30.2	154
<i>Guadua angustifolia</i>	44	60	18.6	135
<i>Phyllostachys bambusoides</i>	44	40	20.3	85.4
<i>P. nigra</i> 'Henon'.....	46	41	17.3	92.7
<i>P. purpurata</i> 'Solidstem'.....	44	48	31.1	151
Kraft single-stage:				
<i>P. viridis</i>	49	47	22.2	110
<i>P. flexuosa</i>	50	28	31.1	93.3
<i>P. meyeri</i>	55	27	22.5	81.6
<i>P. nidularia</i>	54	48	22.5	77.4
<i>P. purpurata</i> 'Straightstem'.....	53	43	41.5	108
<i>P. rubromarginata</i>	54	48	35.4	110
<i>P. vivax</i>	53	39	31.1	79.8
Pine chips.....	57	55	43.6	106

After conditioning (TAPPI method T 402 m-49), the sheets were trimmed $7\frac{13}{16}$ inches square so that the weight in grams divided by the thickness in mils (1 mil = 0.001 of an inch) gave the "apparent density", i.e., grams per cubic centimeter of sheet volume. Each sheet was weighed to the nearest 0.05 of a gram and calipered in four places to the nearest 0.0005 of an inch. From these data the weight per ream of 500 sheets (24" by 36") and the apparent density were calculated.

Bursting strength of handsheets was determined with two pops on the Mullen tester (Model C), one from each side of the

sheet. The results were averaged and divided by the ream weight to obtain the burst factor.

Tearing strength of handsheets was determined with 6 pieces cut 2.5 inches square and torn according to TAPPI method T 414 m-49. The instrument reading was multiplied by 2.66 to obtain the grams of force that would be required to tear the 16 sheets stipulated in the method. This result was divided by the ream weight in pounds to give the tear factor.

Pilot Plant Processing

Bamboo chips were cooked in a 60-cubic-foot Blaw-Knox station-

TABLE 7.—Conditions used for the pulping of bamboo in pilot-plant studies

Type of cook and number; bamboo species pulped ¹	First-stage conditions				Second-stage conditions				Total alkalinity of both stages (active Na ₂ O on basis of moisture-free bamboo)	Pulp yield	Permanganate number	Chlorine bleach	Brightness Photo-volts	
	Active Na ₂ O		Time on temperature	Liquid-to-solids ratio	Active Na ₂ O		Time on temperature	Sulfidity of liquor						Liquid-to-solids ratio
	Concentration	On basis of moisture-free bamboo			Concentration	On basis of moisture-free bamboo								
R 1; <i>Phyllostachys viridis</i> -----	15.6	5.6	2.0	3.59	43.4	37.0	3.0	0	8.53	34	9	8.2	73	
R 2; <i>P. bambusoides</i> -----	15.6	6.5	1.0	4.16	51.9	34.5	0.5	0	6.66	41.0	19	13.9	84	
R 3; <i>P. bambusoides</i> -----	18.7	7.8	1.0	4.16	51.9	34.5	0.5	0	6.66	41.0	19	13.9	84	
R 4; <i>P. bambusoides</i> -----	18.7	7.8	1.0	4.16	51.9	34.5	0.5	0	6.66	41.0	19	13.9	84	
R 5; <i>P. bambusoides</i> -----	11.8	4.4	1.0	3.73	36.8	14.6	3.0	84	4.17	29.4	21	14.5	—	
R 6; <i>P. bambusoides</i> -----	13.2	4.2	1.0	3.18	37.7	13.8	3.0	34	3.30	18.4	21	9.0	—	
R 7; <i>P. bambusoides</i> -----	13.2	4.2	1.0	3.08	37.7	13.8	3.0	34	3.67	18.0	21	10.7	—	
R 8; <i>P. bambusoides</i> -----	14.6	4.5	2.0	3.08	40.8	12.8	2.0	34	3.14	17.3	44	—	—	
R 9; <i>P. vittata</i> -----	11.5	4.2	1.0	3.65	37.0	13.7	2.0	23	3.71	17.9	43	10.9	—	
R 10; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. nigra</i> 'Hemon'	13.6	6.8	2.0	5.00	37.6	14.2	3.0	19	3.73	21.0	23	7.0	—	
R 11; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. nigra</i>	13.6	4.0	2.0	2.94	33.8	14.8	2.0	11	4.38	18.8	46	9.9	75	
R 12; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. meyeri</i>	11.9	5.1	1.0	4.29	40.0	16.4	2.0	4	4.10	21.5	48	9.2	—	
R 13; 67 percent <i>P. meyeri</i> and 33 percent <i>P. vittata</i>	14.6	5.8	1.25	3.98	35.1	14.0	1.75	0	4.00	19.8	42	9.2	69	
R 14; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	14.6	5.8	1.25	3.98	35.1	14.0	1.75	0	4.00	19.8	41	9.2	69	
R 15; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	12.4	5.9	1.0	4.76	32.2	15.3	2.0	0	4.75	21.2	46	11.1	—	
R 16; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.1	5.8	1.0	3.84	36.3	14.0	2.0	0	3.86	19.3	49	13.3	64	
R 17; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.0	6.7	1.25	4.44	37.4	16.7	2.25	0	4.47	23.4	49	5.2	—	
R 18; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	14.7	7.0	1.25	4.76	36.7	17.6	2.25	0	4.80	24.6	42	10.0	77	
R 19; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	40.5	18.1	3.00	4.47	36.7	17.6	2.25	0	4.80	24.6	42	10.0	77	
R 20; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.3	7.0	1.25	4.58	34.1	15.7	2.25	0	4.60	22.7	42	6.0	—	
R 21; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	13.7	6.2	1.25	4.58	36.2	15.9	2.25	0	4.39	22.1	51	12.2	77	
R 22; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	42.0	19.2	3.0	4.57	38.9	15.1	2.25	0	—	19.2	40	9.6	69	
R 23; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	14.7	6.1	1.25	4.15	38.9	15.1	2.25	0	3.88	21.2	37	7.4	—	
R 24; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	14.7	6.0	1.25	4.08	38.2	15.1	2.25	25	3.89	21.1	43	4.6	72	
R 25; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.5	6.4	1.25	4.13	39.5	15.4	2.25	25	3.90	21.8	36	9.5	75	
R 26; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.0	6.3	1.25	4.20	38.9	15.1	2.25	25	3.83	21.4	43	11.7	66	
R 27; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.4	6.1	1.0	3.96	38.4	15.1	1.5	21	3.93	21.2	41	7.8	70	
R 28; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	15.4	6.1	1.0	3.96	38.4	15.1	2.0	21	3.93	21.2	43	7.3	66	
R 29; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	40.0	18.0	2.0	4.56	38.4	15.1	2.5	23	—	18.0	45	8.2	57	
R 30; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	40.0	18.0	2.0	4.56	38.4	15.1	2.5	23	—	18.0	45	8.2	57	
R 31; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	32.2	9.1	1.0	6.36	35.4	15.7	2.5	22	4.43	24.8	40	9.4	67	
R 32; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	32.2	18.1	2.0	5.52	—	—	—	29	—	18.1	43	77.1	66	
R 33; 70 percent <i>P. bambusoides</i> and 30 percent <i>P. vittata</i>	32.8	18.1	2.5	5.52	—	—	—	30	—	18.1	43	77.1	66	

¹ The types of cook R and K refer to the Raitt two-stage and the kraft single-stage treatments, respectively. Numerals that follow these letters are for experimental identification.

ary vertical digester to provide enough pulp for the subsequent production of paper on the pilot-plant fourdrinier. The pilot-plant digester was made of stainless steel and had a conventional design for either direct or indirect heating. Pulping liquor used in the cooking of bamboo was heated indirectly by means of a heat exchanger. Pulping liquor was withdrawn from the midsection of the digester, pumped through the heat exchanger, and reintroduced into the digester at the bottom near the blow valve and through

an inside distributing pipe near the top.

Bamboo was prepared for the pilot-plant digester in the same manner as is described in the section "Raitt Two-Stage and Kraft Single-Stage Cooking Processes." The conditions under which pulps were prepared for making into paper are shown in table 7. These pilot-plant studies showed that bamboo pulps require less chemical and less power for refining than pulps made from southern pine and southern hardwood.

PAPERMAKING

The experimental bamboo pulps made in the pilot-plant digester were used singly or in combination with conventional pulps to prepare furnishes for a variety of paper and pulp products. Conventional pulps used in the furnishes were commercial southern pine bleached kraft, commercial hardwood bleached soda, an oak groundwood, a flax pulp, and a rag pulp. Additives, fillers, dyes, pigments, and sizing agents (starch, clay, and alum rosin) were also included in the furnishes according to the characteristics needed in the final product.

Bleaching

Bleaching was accomplished by use of a three-stage procedure that involved chlorination, caustic extraction, and hypochlorite oxidation. A 75-pound Niagara-type tile-lined Valley beater was used to prepare slush stock of 3-percent consistency from the pulps described in table 7. Chlorination was performed in a 150-pound

Hooker rubber-lined chlorinator that had a diameter of 2 feet and a height of 14 feet and was equipped with a rubber-lined side tube 8 inches in diameter.

Circulation of pulp in the chlorinator and side tube was accomplished with a centrifugal pump having a 4-inch inlet (suction) and 3-inch vertical discharge. The pump was driven 1,750 r.p.m. by a direct-connected 10 hp. motor. The permanganate number (TAPPI method T 214 m-50) was used to calculate the amount of chlorine required.

Chlorine was injected from a cylinder mounted on a platform scale directly into the stream of slush pulp as it was pumped through the rubber-lined side tube. After 30 minutes, an NaOH solution was added at the top of the chlorinator to neutralize the acids that had formed and to adjust the pH to the range of 10 to 11. Circulation was continued another 5 minutes. The stock was then pumped out to a 300-pound hollander-type tile-lined Valley

beater equipped with an octagonal drum washer.

Caustic extraction was accomplished by adding NaOH to the pulp in the beater and then heating the pulp with direct steam. The amount of NaOH added was equal to 5 percent of the weight of oven-dry pulp. After heating for 1 hour at 50° C., the pulp was washed.

In the final stage, a calcium hypochlorite (HTH) solution was added, and the pH of the stock adjusted to a range of 9 to 10 by adding NaOH. The stock was circulated in the beater with hypochlorite for 1 hour, after which the pulp was washed. If a hand-sheet of the pulp lacked the required brightness, at least one more hypochlorite stage was carried out. Pulp was stabilized by the use of sulfurous acid formed in situ by injecting SO₂ from a cylinder of the liquefied gas. The final bleached pulp was pumped from the beater to a stock chest, run over the fourdrinier, and taken off as roll pulp or "wet laps" after the second press.

Brightness of the pulp was determined by a Photovolt instrument, which measured the reflectance in comparison with a standard white. Data on bleaching are shown in table 7.

Refining

In preparing the stock for the paper machine runs, a 300-pound hollander-type tile-lined Valley beater was used to break up laps

or other forms of pulp; to mix the ingredients or "furnish"; and to waterlog, or "hydrate", the fibers. Refining of pulp was accomplished with either a Valley pony jordan or a Hermann clafin.

The prepared stock was pumped into agitated stock chests, then through a Valley 6-plate diaphragm screen to remove shives and coarse dirt, and finally through a Bird Dirtec centrifugal cleaner to remove fine dirt before being pumped into the regulating feedbox of the paper machine.

Machine Operation

Sheet forming and drying were carried out by using a Pusey-Jones fourdrinier with 31-inch wire and 28-inch trim. This machine was complete with shake, three 6-inch flat boxes, a 12-inch-diameter brass couch roll, and a jacketed top roll; rubber bottom and granite top first press; rubber bottom and stonite top reversed second press; Mount Hope expander roll; nine 24-inch-diameter dryers; 7-roll calender; and a Pusey-Jones winder.

Physical Properties

Basis weight, caliper, burst factor, tear factor, breaking length, folding endurance (Massachusetts Institute of Technology), porosity, and smoothness of machine papers were determined in accordance with TAPPI Standard Methods. Composition of the various furnishes and properties of the products as shown in table 8.

TABLE 8.—*Composition and physical characteristics of papers made on pilot fourdrinier*

Type of paper made	Type of cook, number, and percentage of bamboo pulp; percentage of other pulp ¹	Additives					Basis weight
		Size	Alum	Clay	Starch	Dye	
		<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>		<i>G./sq. m.</i>
Bond-----	R 1, 83 percent; bleached kraft, 17 percent. ⁶	2	3	12	—	Paper blue and 1 percent TiO ₂ .	81.4
Bond-----	R 2, 80 percent; bleached kraft, 20 percent.	1	2	10	5	Paper blue-----	78.9
Bond-----	R 3, 80 percent; bleached kraft, 20 percent.	1	2	10	4	Paper blue-----	85.1
Saturating-----	R 4, 90 percent; bleached kraft, 10 percent.	—	—	—	—	—	166.8
Tissue-----	R 5, 90 percent; bleached kraft, 10 percent.	—	—	—	—	—	37.3
Wet strenght....	R 6, 100 percent-----	2-percent uformite and 3.5-percent alum; adjust pH to 4.0.					93.2
Book-----	R 7, 66 percent; soda, 34 percent. ⁷	1.5	3.0	25.0	—	—	72.7
Magazine-----	R 8, 56 percent; bleached kraft, 12 percent and soda, 32 percent.	1.5	2.0	26.0	—	3 percent TiO ₂ and Brilliant blue 2R.	86.7
Saturating-----	R 9 and R 10; no other pulp	—	—	—	—	—	92.6
Saturating-----	R 11 and R 12; no other pulp	—	—	—	—	—	214.3
Saturating-----	R 13 and R 14; no other pulp	—	—	—	—	—	155.2
Bond-----	R 16 and R 18; no other pulp	2	2	15	4	Paper blue-----	258.1
Book-----	R 15 and R 20, 50 percent; soda, 25 percent; and bleached kraft, 25 percent.	1.1	1.5	25.0	—	Paper blue-----	81.2
Book-----	R 15 and R 21; no other pulp	1.0	2.0	30.0	—	Paper blue-----	96.0
Bond-----	R 22, 50 percent; rag pulp, 50 percent.	2.0	2.0	15.0	4.0	—	66.2
Tissue-----	R 23, 100 percent-----	—	—	—	—	—	38.2
Food container board.	R 15, 100 percent-----	1.9	1.9	—	—	—	22.7
Bond-----	R 23 and R 24, 50 percent; flax pulp, 50 percent.	3	2	30	—	—	95.4
Bible-----	R 23 and R 24, 50 percent; flax pulp, 50 percent.	3	2	50	—	—	44.6
Corrugating medium.	K 27, 100 percent-----	2	1	—	—	—	12.4
Colored wrapper.	K 27, 69 percent and K 29, 31 percent.	2.5	3.1	—	—	Congo red-----	45.5
Magazine-----	K 30, 22 percent and R 26, 46 percent; oak groundwood, 16 percent and soda, 16 percent.	—	—	10	2	1 percent TiO ₂ ..	69.5
Stationery-----	R 25, 63 percent and R 28, 37 percent.	2	3	11	2	—	79.1

TABLE 8.—*Composition and physical characteristics of papers made on pilot fourdriner*

Caliper	Burst factor ²	Tear factor ³		Breaking strength		Massachusetts Institute of Technology double fold		Porosity		Smoothness section 8 ply	Brightness Photo-volts
		MD ⁴	CD ⁴	MD ⁴	CD ⁴	MD ⁴	CD ⁴	WS ⁵	FS ⁵		
<i>Mils</i>	<i>G./sq. cm./ g./sq. m.</i>	<i>G./g./ sq. m.</i>	<i>G./g./ sq. m.</i>	<i>M.</i>	<i>M.</i>						<i>Pct.</i>
5.2	8.5	45.5	54.0	2,050	980	1	1	6.2	6.0	91.2	68
4.9	8.1	44.4	58.3	2,700	1,180	1	1	34.3	34.3	65.2	70
4.5	28.1	60.0	77.6	5,870	2,820	15	11	211.0	211.4	70.8	68
11.2	25.3	12.0	12.6	5,680	3,160	189	160	10.5	11.0	—	—
2.5	22.6	43.0	51.0	5,000	1,970	1	1	30.8	34.2	77.6	70
6.2	20.4	78.3	83.7	4,580	2,360	50	47	2.7	2.7	46.4	—
4.5	12.6	48.1	57.8	2,940	1,100	1	1	9.3	9.3	116.4	76
5.6	13.8	50.8	58.8	3,690	1,850	4	2	36.4	36.4	117.2	68
7.1	16.0	76.7	78.8	4,250	1,580	3	1	7.7	7.8	24.0	—
13.5	18.7	82.1	84.4	4,670	2,950	35	11	11.2	11.2	37.6	—
9.8	21.3	79.2	83.7	5,280	2,750	13	9	1.6	21.6	25.8	—
4.9	11.2	24.8	27.9	1,700	720	1	5	154.9	155.0	104.8	74
4.4	19.9	72.6	72.6	3,690	1,720	5	3	24.5	27.7	168.4	70
4.0	19.0	47.9	47.9	4,510	2,150	10	8	410.7	410.8	286.8	—
3.6	27.6	10.4	11.3	6,340	2,620	69	58	80.3	80.2	86.4	—
2.0	16.6	41.0	42.0	3,840	1,920	1	1	92	92	184.4	—
14.3	18.0	86.2	92.4	4,570	2,730	66	49	11.5	11.5	54.0	—
4.9	16.2	67.0	75.5	4,610	1,960	7	5	155	155	104.8	74
2.3	11.0	47.1	47.1	3,440	1,050	1	1	68.0	68.1	143.2	—
11.3	17.0	62.6	66.6	4,440	2,410	10	8	3.3	3.2	47.2	Not bleached. Too red for reading.
3.1	15.5	77.1	81.5	4,700	1,620	1	1	2.9	2.9	74.0	
4.0	22.3	61.9	73.4	5,470	2,400	1	1	62.4	62.4	106.8	
3.9	23.1	63.2	69.6	5,300	2,280	15	9	65.8	65.8	90.0	73

¹ Letters R and K refer to the Raitt two-stage and the kraft single-stage treatment, respectively. The first numeral following these letters can be used to identify the species of bamboo in the cook and the conditions under which the pulp was made by referring to table 7. Where the percentage of bamboo pulp is not shown, the final composition of the pulp did not differ significantly from that shown in table 7.

² Burst factor—unit of measure is grams per square centimeter per grams per square meter.

³ Tear factor—unit of measure is grams per gram per square meter.

⁴ MD means machine direction; CD, across machine direction.

⁵ WS means wire side up; FS, felt side up.

⁶ Bleached kraft means this type of pulp made from southern pine and commercially available.

⁷ Soda means this type of bleached pulp made from hardwood and commercially available.

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APPENDIX

Preliminary Experiments
for Macerating Culms

The following methods were tried for preparing fiber macerates from bamboo culms:

1. Culms were cut into pieces $\frac{1}{8}$ by $\frac{1}{8}$ by 1 inch and macerated

mechanically in a 015 Jackson & Church refiner. This method caused excessive breakage of fibers.

2. Culm pieces of similar size were boiled at atmospheric pressure in a 10-percent NaOH solution (TAPPI method T 10 m-47).

This treatment, designed for pulp and paper manufacture, was too mild to macerate the culm material. It did not affect the outer layer of the pieces.

3. Strips of culms were cut 3 to 9 mm. tangentially, 1 to 6 mm. radially, and 135 to 165 mm. longitudinally (average dimensions were about 5 by 2.5 by 150 mm.). The strips were cooked under the following conditions in small digesters (3 inches in diameter by 8 inches in length) immersed in an oil bath:

a. In water at 150° to 165° C. for 3 hours. In this treatment, the strips were softened enough to pull apart with the fingers, but the resultant slivers were too raw for separation into individual fibers without damage to the fibers.

b. In a 0.78-percent Na_2CO_3 solution (approximately equivalent to 4.45-percent Na_2O) at 150° to 165° C. for 2 hours. This treatment did not soften the strips. The carbonate may have suppressed hydrolysis of carbohydrates (hemicelluloses) that would normally have occurred by unbuffered organic acids present or formed in the woody material. Hydrolysis could have caused fiber embrittlement and some fiber breakage. This would alter dimensions of fiber fragments but not of complete fibers. Some swelling might occur under alkaline conditions.

c. In a 1.4-percent NaOH solution (approximately equivalent to 1.0-percent Na_2O) at 150° to 165° C. for 1.5 hours. This treatment softened the strips more than when they were boiled in water alone for 3 hours, yet not enough to permit separation of the fibers without damage to them.

d. In 2.0- and 2.5-percent NaOH solutions at 150° to 165° C. for 1.5 hours. Strips cooked in this manner were softened more than they were when cooked in the 1.4-percent solution but still were not soft enough for damage-free separation of fibers.

4. About 5 grams of matchstick-size pieces of culm were boiled for 20 minutes in water to expel air; immersed in a hypochlorite solution (Chlorox 1:1) for 2 hours; washed in distilled water; immersed in a 3-percent Na_2SO_3 solution at 70° C. for 15 minutes; washed in distilled water; immersed in Chlorox again for 2 hours; washed; immersed in a 3-percent Na_2SO_3 solution at 70° C. for 15 minutes; washed in distilled water; placed in a 500-ml. Erlenmeyer flask with 125 ml. of distilled water, shaken vigorously, decanted, and diluted until there were only about 25 fibers in one drop. This treatment produced bleached fibers that would not stain readily, but they were too fragile for reliable measurement.

5. About 5 grams of matchstick-size pieces of culm were boiled in water 30 minutes to expel air; boiled 30 minutes in a 10-percent NaOH solution; washed; placed in a 500-ml. Erlenmeyer flask with 125 ml. of distilled water, shaken vigorously, decanted, and diluted until there were only about 25 fibers in one drop. This method gave incomplete separation of the outer wall (0.5 mm. thick), although the inner wall was fairly well macerated. The method was repeated extending the period of boiling in water to 4 hours, but there was no improvement in results.

6. About 5 grams of matchstick-size pieces of culm were boiled in water 30 minutes to expel air;

heated to 70° C. in a 4-percent HNO_3 solution for 1 hour; and washed in a 1-percent NaOH solution. No maceration occurred.

7. Strips of culm 2 by 2 by 25 mm. (approximately) were immersed in a mixture consisting of equal volumes of glacial acetic acid and 10-percent Na_2O_2 (substituted for H_2O_2) for 48 hours at 60° C. (3). This treatment gave incomplete fiber separation.

8. About 1 gram of small strips of culm were soaked 3 days at room temperature in a 1:1 mixture of a 4-percent nitric acid plus 5-percent chromic acid; then heated to 60° C. for 3 hours. This treatment produced little change in the culm strips.

9. About 5 grams of internodal strips 2 by 2 by 25 mm. (approximately) were covered with a 10-percent NaOH solution in a Mason jar and heated at 15 p.s.i. in a pressure cooker for 18 minutes, then allowed to cool slowly for 30 minutes. The NaOH solution was poured off, the strips were washed, and then dispersed in a Waring Blendor for about 3 minutes. This method gave a fairly complete maceration of strips without excessive fiber breakage.

10. Nodal strips were subjected to the same treatment as the internodal strips described in the foregoing method, but the boiling at 15 p.s.i. was extended to 30 minutes. This was followed by 2 days of soaking in distilled water (three water changes), and finally by dispersing in an Osterizer for 30 seconds. The nodal splinters proved more resistant than the internodal ones.

11. Strips were cut from a single node, covered with 10-percent NaOH , heated at 15 p.s.i. for 30 minutes, soaked in distilled water 5 days with three changes of

water, and then dispersed in the Osterizer for 30 seconds. This gave fairly good separation of the fibers. Variations of this method that were tried consisted of using pressures ranging from 5 to 15 p.s.i.; soaking for 3 to 4 days; dispersing in the Osterizer for up to 45 seconds.

Exploratory Pulping Studies

Cooking conditions and results of exploratory treatments were as follows:

1. Cooking in water only at temperatures of 160° to 170° C. for 1, 2, and 3 hours softened the bamboo slightly but did not pulp it. Yields (cooked bamboo) of the 2- and 3-hour cooks were 79 and 74 percent, respectively. The hydrolyzate was slightly acid.

2. Cooking with a 0.75-percent solution of Na_2CO_3 (equivalent to 2 percent of Na_2O on basis of moisture-free bamboo material) at a temperature of 150° to 165° C. for 1.5 hours did not soften the bamboo and resulted in a 98-percent yield of cooked bamboo.

3. Cooking with various concentrations of NaOH for 1.5 hours at temperatures of 150° to 160° C. failed to pulp the bamboo. Results are shown in table 9.

TABLE 9.—Results of cooking bamboo at 150° to 160° C. in stated concentrations of NaOH

Concentration of NaOH	Na_2O on basis of moisture-free bamboo	Yield of cooked bamboo	pH of hydrolyzate
	Percent	Percent	
1.36-----	3.6	92	5.6
1.90-----	5.3	90	6.5
2.40-----	6.6	90	7.8
2.50-----	6.8	85	9.0

4. Cooking in two stages.—The treatment was similar to that described by Raitt (10). First

stage: Bamboo was cooked at temperatures of 100° to 110° C. for 2.0 hours with 1.9-percent NaOH using the hydrolyzate from previous cooks fortified with additional NaOH until the final liquor contained 6.1 percent Na_2O (on the basis of moisture-free material). The final pH was 9.2. Second stage: Bamboo was cooked with kraft white liquor composed of 50 grams per liter of active

alkali as Na_2O (equivalent to 18.7 percent Na_2O on moisture-free material) at temperatures of 145° to 150° C. for 1.5 hours. The final pH was 11.9. These procedures produced a pulp yield of 49 percent, and the bamboo was well pulped. This two-stage cook was applied to several species of bamboo with similar results in which yields ranged from 40 to 50 percent.