paper technology

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New film issue

No 4

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Journal of the Technical Section
British Paper and Board Makers' Association

INCORPORATING TECHNICAL BULLETIN AND PROCEEDINGS OF THE TECHNICAL SECTION *

August 1960 Vol. 1 No. 4

CONTENTS

* IMPORTANT NOTICE ON PAGES **367** & **368** *

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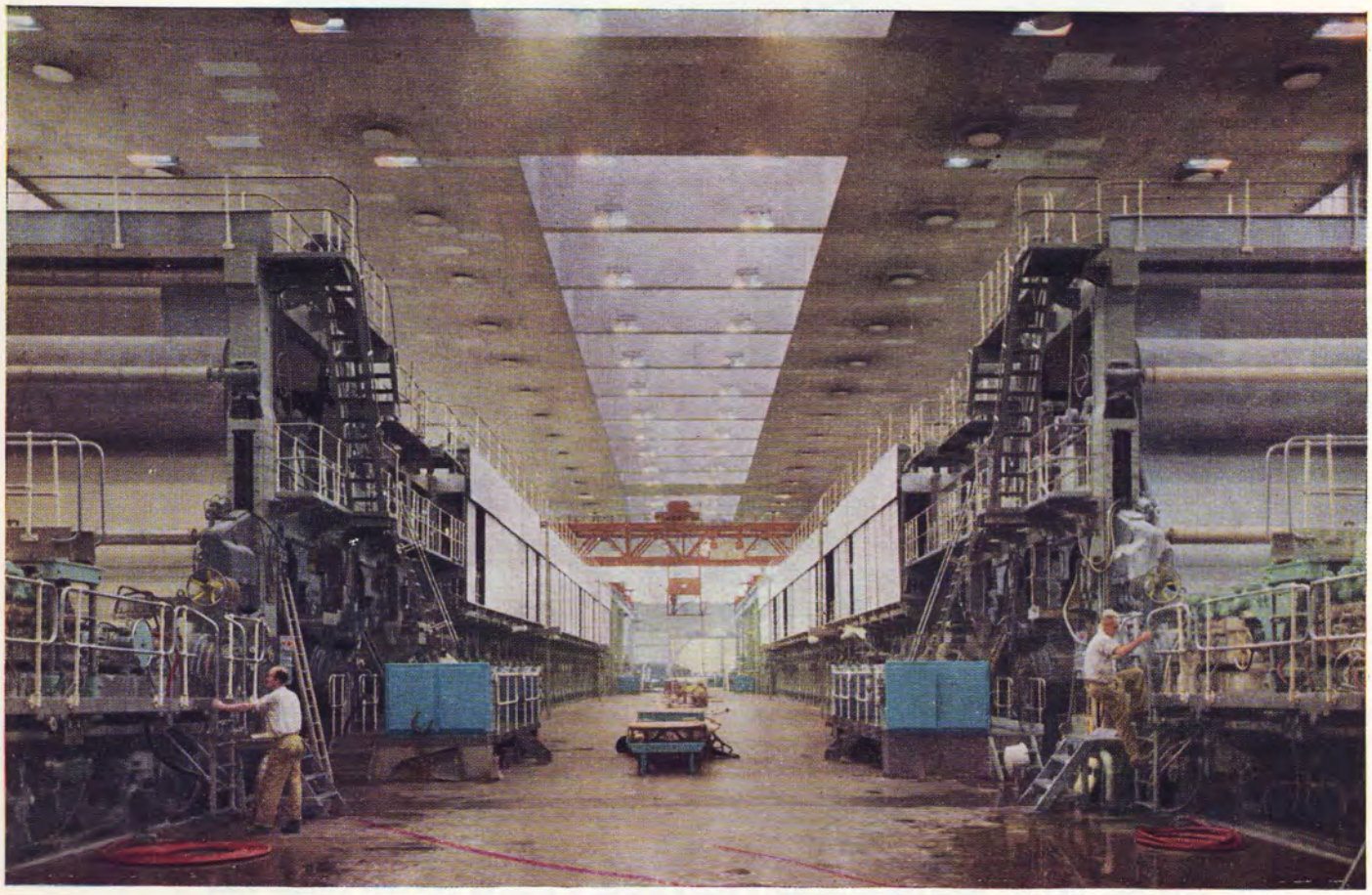

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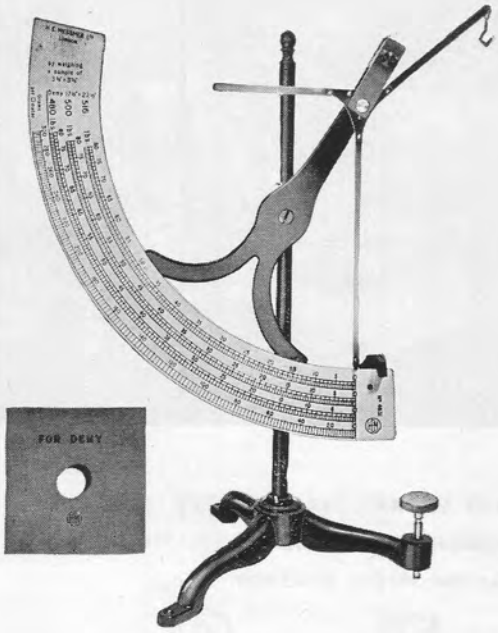

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Technical Section membership

DURING May and June 1960, the changes in membership were as shown—

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K. D. T. Armstrong—*Junior*
P. Charlton—*Full*
R. T. Clutterbrook—*Junior*
L. E. Dawes—*Associate*
L. W. Dewhurst—*Junior*
J. R. Edgar—*Junior*
R. L. Farrell—*Associate*
A. R. Fishwick—*Junior*
F. B. Hardcastle—*Associate*
H. E. Higginson—*Associate*
P. Hill—*Full*
E. D. H. Hutchinson—*Associate*
E. J. Jarvis—*Full*
E. Jowett—*Full*
K. W. H. Loy—*Associate*
C. F. Mannering—*Full*
C. Mepham—*Full*
M. J. P. Mills—*Junior*
J. Neild—*Associate*
E. Pelzer—*Associate*
A. F. Peterson—*Associate*
D. Seal—*Full*
A. J. Sutherland—*Associate*
S. G. Tucknott—*Full*
A. Vickers—*Full*
E. Walton—*Full*
A. W. T. Woodward—*Associate*

Northern Division
D. Clark—*Full*
J. R. Edgar—*Junior*
W. Kearley—*Full*
D. W. Moffatt—*Associate*

Scottish Division—
R. Bain—*Full*
J. Barclay—*Full*
J. H. Henderson—*Full*
A. A. Izatt—*Full*
J. R. Park—*Full*

Western Division—
D. C. Harris—*Full*

Overseas Associate—
R. Hefti
Olin Mathieson Corporation
O. F. Olsen

Resignations and withdrawals

London Division—
O. C. W. Johnsen—*Associate**
L. G. S. Hebbs—*Associate**
C. F. White—*Junior*

* Deceased

Scottish Division—
A. Beaton—*Full*
Lt. Col. R. Chadwick—*Full*
G. A. Parkin—*Full*

Overseas Associate—
L. Crawshaw

Papers on straw (contd.)

FURTHER to the details given in this journal, No. 2, pages 116–117, the paper by Dr. F. M. Muller that has already been published in Dutch has now appeared in English as follows—

On the relationship between properties of strawpulp and properties of straw—F. M. Muller
Tappi, 1960, **43** (2), 209A

Autumn conference

EDINBURGH is to be the location for the autumn conference this year. The date is Friday, 28th October and the meeting will be held in the Adam Rooms of the George Hotel, George Street.

The following tentative programme has been planned—

Developments in coated papers for printing
Equipment for machine coating—R. S. Haven
Machine coating—past, present and future—R. C. Rose, Ph.D.
Traditional coating meets the challenge—W. A. R. Hilton

NEWS PAGE

Danger

THE use of anhydrous magnesium perchlorate (*Anhydrone*) as a desiccant in the British PBMA Method PT 19:1949, *Determination of the permeability to water vapour of sheet materials*, has the note (page 22) that there is considerable risk of explosion attached to the heating of this chemical when this is done to regenerate it as a desiccant.

Two articles in the technical literature emphasise this risk, especially if the chemical is contaminated with organic and oxidisable materials. Similarly, any material slightly contaminated with magnesium perchlorate during its use as drying agent will explode when heated subsequently. Experiences of this are described in the two articles cited—

Chem. Weekblad, 1958, **53**, 277 and
Chem. Zeitung, 1958, **82**, 467.

Attention is particularly drawn to the fact that even the brief cautionary note in PT 19 was omitted from this same method published as B.S. 3177:1959 by the British Standards Institution: a correction slip is now being issued.

Anhydrous magnesium perchlorate is therefore not recommended as a desiccant when other harmless materials such as anhydrous calcium chloride are readily available, unless the spent *Anhydrone* is disposed of without regeneration.

New film

TUFNOL IN THE MAKING
Tufnol Ltd., Publicity Dept., Perry Barr, Birmingham 22B

16 mm. Colour 24½ min. Sound Hire free

Content — The film shows the manufacture of Tufnol paper and fabric base laminated plastics sheet, tube and rod. Commencing with the delivery of a consignment of paper and other essential raw materials to the Tufnol Works, it follows the processing of paper and cotton through impregnation, cutting, pressing of sheets, rolling and moulding of tubes and rods. The process continues through sawing and grinding departments to testing, final inspection, storing and despatch. Emphasis is made on the rigorous testing and inspection that takes place from beginning to end to ensure a first class product.

(continued overleaf)

D.S.I.R.
TECHNICAL DIGESTS

THE new series of D.S.I.R. Technical Digests (since June 1959) contains information derived from some 300 British scientific and technical journals. They are published on a subscription basis and each item is printed on a separate loose sheet giving essential details in simple terms with a reference to the original article for readers seeking fuller information.

The Digests are published by the Department of Scientific and Industrial Research, 5–11 Regent Street, London, S.W.1, to whom all enquiries should be made.

Notes are given below of a few currently published items that are of paper industry interest. These items and a subject index covering the period June 1959–May 1960 (items No. 1001–1165) may be borrowed from the Technical Section library.

No. 1139. An all-plastic valve

The valve is designed for handling corrosive liquids and is made entirely from high-density polyethylene, all mechanical shafts and stuffing glands being eliminated from the design. The valve can be used either for *on/off* applications or partial throttling.

No. 1143. Flexible cable ducting

Flexible metallic ducting is designed to feed air, water, electric power, etc. to a moving point of consumption.

No. 1144. Aluminised asbestos cloth

Woven asbestos cloth coated with highly reflective aluminium has excellent insulating properties and is easily fitted and shaped.

No. 1150. Porous plastic material for industry

The material is manufactured from high-density polyethylene and can be made with porosity characteristics suited to specific requirements. It is flexible, light and strong and is being used in the filtration of air and of liquids and in the air-fluidised conveying of powders.

No. 1153. Seating of threaded pipe joints

Screwed pipe joints can be conveniently sealed with P.T.F.E. tape, which is resistant to all chemicals except molten alkali metals and gaseous fluorine.

No. 1155. A new filter material

By furnace welding woven wire gauze, it is possible to produce a filter material with a porosity that can be strictly controlled. Filters made of this material are particularly suitable for use with corrosive liquids.

Handle

THE Swiss journal *Textil-Rundschau* (1959, **14** (12), 699) reports that the Handle-O-Meter, an American instrument used in the textile industry, has been examined for its possible application as a means of measuring the handle of paper. Although the experiments were limited in scope, it was found that, while the instrument could give information on the stiffness and surface friction of a sheet of paper, handle was too complex a property to be evaluated in this way.

Electromagnetic speed indicator

WESTINGHOUSE Electric Corp. have recently marketed a speed indicator for use with small steam or gas turbines. The principal advantage of this type of instrument is that no mechanical coupling is required between it and the rotating shaft, the speed of rotation being sensed by an electromagnetic pick-up located in proximity to the gear shaft. The signal is then applied to an all static circuit, which transforms the pulses from the pick-up to a d.c. millivolt signal. The output signal magnitude is proportional to pulse frequency.

Moisture control

EARLIER this year, a report appeared in the technical press of work done in Finland on the control of moisture content in the paper web on the machine. Automatic control of the drying process is made more difficult by the large time lag that unavoidably appears in the control loop. Theoretical examination of the process indicates that control difficulties must be expected, especially for heavy grades of paper.

The experiences reported are of moisture control on a fine paper machine with a versatile production programme, with a hygrometer to measure the dielectric constant and using cascade control of the steam pressure. The introduction of a size press improved the uniformity of the moisture content in the paper web and reduced the risk of blackening when it was calendered.

No. 1159. An Archimedean screw elevator

Small solids in bulk can be handled very simply by a screw-type elevator, consisting basically of a long tube with a rotating worm driven by a motor at the upper end.

RUSSIAN PAPER INDUSTRY

No. 3, MARCH 1960

Science and technology

No. 4 APRIL 1960

Science and technology

Practical aspects

(continued overleaf)

Book reviews

One hundred and fifty years of papermaking by hand— J. Barcham Green

(J. Barcham Green Ltd., Maidstone, Kent, 1960; 29 pages)

IT is one thousand, eight hundred and fifty five years since the Chinese engineer, Tsai Lun invented the art of making paper by hand on a mould, from old rags.

It was about seven hundred years before the art of papermaking came out of China and about another five hundred years before it reached Europe.

It was in 1490 that John Tate started his mill at Stevenage in Hertfordshire and it was not until about 1806 that paper began to be made on a papermaking machine.

During the last one hundred and fifty years, enormous strides have been made, chiefly in the western world, in the making of all kinds of paper for every conceivable purpose on papermaking machines, which grow ever wider and faster. In spite of all this modernisation and automation, the firm of J. Barcham Green Ltd. has still continued during the last one hundred and fifty years, with the aid of real craftsmen of the highest class, to make and sell paper, made a sheet at a time, by a skilled vatman, coucher and other assistants.

Mr. J. Barcham Green of Hayle Mill, Maidstone, in his booklet entitled *One hundred and fifty years of papermaking by hand*, describes in detail the skills that have to be acquired by paper craftsmen and no one is more entitled than he to do it, as he is himself a craftsman who has mastered the art of all the many processes that go into the making and finishing of a sheet of hand-made paper.

His brief, but clear account of all the operations is supplemented by a series of very fine photographs, which will help the uninitiated to gather some idea of the great complexity of the operations involved in making and finishing a sheet of paper.

There is an interesting account of the making of a mould, the most important tool of the hand-made papermaker and also of the felts for handfelting.

It is a sad thought that new inventions are rapidly displacing the hand crafts of yesterday, but it is to be hoped that there will always be a demand for at least some of the hand-made papers, whose many highly desirable qualities cannot be reproduced by machinery.

R. H. Clapperton

Handbook of filtration

—Technical staff of The Eaton-Dikeman Company

(The Eaton-Dikeman Co., Mount Holly Springs, Pa., 1960, 124 pp., 45 illustrations, $2.50)

INDUSTRIAL filter papers in America are supplied almost exclusively by the firm publishing this book and the information is obviously for the American market. It is, moreover, designed as a practical handbook and for reference by the college student, laboratory technician and process engineer: this function it fulfils very well.

The eight chapters deal with—

The art and growth of filtration
Filter paper test methods
Retention
Permeability—theoretical aspects
Permeability—practical aspects
Laboratory applications
Industrial filtration
Special applications

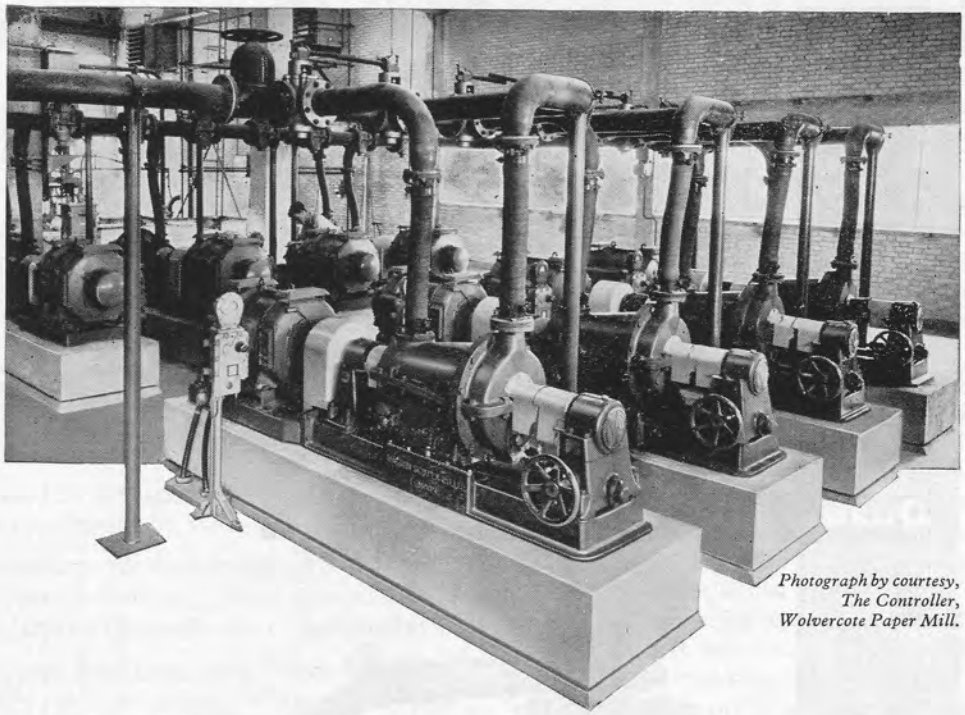
and it is claimed to be the first text devoted exclusively to paper filtration.

Much of this information is available elsewhere and has been so for some time. Little attempt has been made to prepare a scientific account and the style by European standards oversimplifies the subject matter, treating the book perhaps rather as a commercial vehicle.

As might be expected in a book dealing primarily with industrial filter papers, the sections touching on the analytical field (particularly with chromatography) are not really adequate. On this ground and also for the reason that 'filtration' is accomplished by many other means, it might have been more suitable if the title had been *A handbook of industrial filter papers.*

fmb

Russian Paper Industry (*continued*)



Photograph by courtesy, The Controller, Wolvercote Paper Mill.

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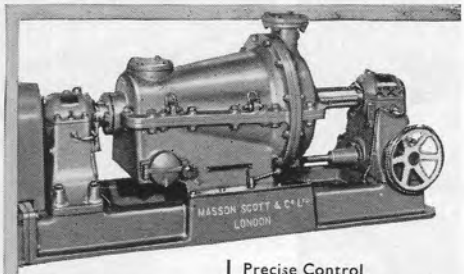
This is a complete stock preparation plant without beaters. The use of a number of Masson Midget Refiners has the advantage of allowing changes in treatment to be carried out speedily and simply by varying the combinations of bar width, speed and power. Progressive paper mills making high quality papers use Midget Refiners to form complete installations or as single units to achieve economic and flexible stock preparation under widely varying conditions.



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SUMMARIES from foreign journals

Translations in English of the originals of these summaries are available only on order at standard rates—details may be obtained on application to the Secretary

*

THE following are freely abridged versions of the original papers available in the original language through the Technical Section Library—

Beating hardwood pulp for use in the making of different grades of paper

F. Wultsch

Das Papier, 1959, **13** (17/18), 407–413

THE pulps used in the experiments on beating pulps either together or separately were—

1. Bleached spruce sulphite pulp, moist, Roe number 50
2. Bleached aspen sulphite pulp, moist, Roe number 38
3. Bleached birch sulphite pulp, moist, Roe number 55

The beating was done in an Escher-Wyss laboratory refiner, type R 1, at a consistency of 3 per cent., each pulp being beaten separately and a 50/50 mixture of each of the hardwood pulps with the spruce pulp being beaten together. Three samples of both the aspen and birch pulp were beaten to Schopper-Riegler values of 18–32° and mixed with 50 per cent. wet-beaten spruce pulp so that the beating degree of the mixture would be about 40° S.R. Determinations were made of the final wetness of the experimental pulps and of the bulk, opacity, tearing strength and fibre length of paper made from these pulps.

The results of the experiments confirmed that separate beating and subsequent mixing of free-beaten hardwood pulp with wet-beaten spruce pulp resulted in paper with better qualities than when the two pulps were beaten together. In this way, the improvements in bulk, opacity and surface properties resulting from the use of hardwood pulps are achieved without reducing the strength of the sheet and, in some cases, the strength is actually better than when the components are beaten together.

When components with different degrees of beating are mixed, it is found that the wetness of the mixture is lower than would be expected from a simple calculation of the average wetness and this means that drainage is facilitated on the papermachine.

From a consideration of the improvements in bulk, opacity, tearing strength and average fibre length obtained when the components are beaten separately, it would appear that the greatest advantages are to be obtained by beating the spruce pulp as much as possible and adding almost unbeaten hardwood pulp. This enables full advantage to be taken of the desirable properties of the hardwood and, at the same time, results in power economy, for less power is required to beat a spruce pulp to high stock wetness than to beat a spruce/hardwood mixture to a much lower wetness.

Pilot plant studies on stock preparation in a papermill confirmed the results found in the laboratory. The addition of hardwood pulp to the stock in the making of various grades of writings and printings resulted in improved drainage and a corresponding increase in machine speed. Separate treatment of the components made it possible to adjust beating pressure and consistency so that optimum strength, bulk and opacity were achieved and it was found that specific power consumption was reduced. When making high quality writings, the use of 50 per cent. bleached hardwood in the mixture gave a 10 per cent. increase in breaking length, a 20 per cent. increase in bursting strength and a 4 per cent. increase in opacity with an increase in machine speed of 20 ft./min.

Investigations on new methods of making semi-chemical pulps and their use in the preparation of viscose

V. Jacopian and P. Schorning

Zellstoff u. Papier, 1959, **8** (9), 332–340

Two new methods of semi-chemical pulping have been developed, one based on a modified method of 'base-free' sulphite pulping and pulping in the other is carried out with sodium sulphite and sulphuric acid in an aqueous alcohol medium. Experiments were made both with hardwoods and softwoods and it was found that these new pulp grades could simply be bleached or subjected to a combined bleaching and alkaline refining process to provide a new method of making viscose cellulose. The yield of viscose produced in this way was much higher than with any of the conventional methods and its chemical and physical properties were quite satisfactory. Some difficulties have been experienced, but the method is considered to be promising.

(*continued on page 427*)

for your reading

Attention is drawn below to a number of papers of interest to be found in recent journals available from the Technical Section Library.

Structural aspects of bonding
J. A. Van den Akker
Tappi, 1959, **42** (12), 940–947

Fibre geometry as related to paper bonding
R. Marton
Tappi, 1959, **42** (12), 948–953

The physical properties of wet webs
A. A. Robertson
Tappi, 1959, **42** (12), 969–978
1. Fibre-water association and wet-web behaviour.

Structure-property relationships in synthetic fibre papers
R. A. A. Hentschel
Tappi, 1959, **42** (12), 979–982

Rate phenomena in the resin-fibre-water system
E. F. Thode
Tappi, 1959, **42** (12), 983–985

Fibre surface area and bonded area
J. W. Swanson and A. J. Steber
Tappi, 1959, **42** (12), 986–993

Strength and resilience of polymer-impregnated paper—Comparison of saturants
P. J. McLaughlin
Tappi, 1959, **42** (12), 994–999

The mechanism of bonding
W. B. Campbell
Tappi, 1959, **42** (12), 999–1 001

Crystalline orientation in a flat sheet with respect to the plane of the sheet, with particular reference to paper
E. A. Aaltio and J. J. Hermans
Tappi, 1959, **42** (12), 1 002–1 006

Fibre attraction and interfibre bonding — The role of polysaccharide additives
M. L. Cushing and K. R. Schuman
Tappi, 1959, **42** (12), 1 006–1 016

Adhesives in the paper industry
Paper Ind., 1960, **41** (12), 854–855
Part 7 (*contd.*)—Important adhesive forms: water-dispersed adhesives, lacquer- and solvent-activated adhesives and pressure-sensitive adhesives.

Matching load and drive characteristics
C. G. Helmick
Paper Ind., 1960, **41** (12), 856–858
Part 2—Drive characteristics in papermills.

The colouring of paperboard
M. J. Landberge
Pulp and Paper Mag. Can., 1960, **61** (C), T91–T96

A laboratory investigation of dynamic drainage of vacuum boxes
B. W. Attwood
Pulp and Paper Mag. Can., 1960, **61** (C), T97–T103

Recent developments in electrical insulation
F. E. Barrett
Pulp and Paper Mag. Can., 1960, **61** (C), T104–T108

A few thoughts on papermachine pressing
R. W. Sulatycki
Pulp and Paper Mag. Can., 1960, **61** (C), T109–T123

Inverform – the third method
L. A. Lawrence
Pulp and Paper Mag. Can., 1960, **61** (C), T124–T129

The determination of corrugator starch consumption tapered glue-roll speed settings
W. A. Nikkel and J. McK. Limerick
Pulp and Paper Mag. Can., 1960, **61** (C), T137–T141

The control of microbiological deposits in pulp and paper mill systems
C. B. Bruce
Pulp and Paper Mag. Can., 1960, **61** (C), T142–T144

(*continued on page 371*)

ATTENTION

This is the fourth issue of the new journal

PAPER TECHNOLOGY

- The Journal combines and replaces the Technical Section's previous two publications, *Proceedings* and *Technical Bulletin*.

- PAPER TECHNOLOGY, 1960, vol. 1 follows on from *Proceedings*, 1959, vol. 40 and *Technical Bulletin*, 1959, vol. 39.

(see over)

● This journal is constituted from the same material that appeared formerly in *Proceedings* and *Technical Bulletin*, the two distinct sections being retained in each issue for those members who wish to file or bind them separately.

● With this in mind, additional page numbering of the *Proceedings* section has been provided on the top outer corner of the relevant pages. These page numbers are prefaced by the letter T and will commence from T1 with each volume.

● Sequential page numbering for the journal as a whole commences at page 1 with each volume and runs through the the whole of each year's issues.

● Six issues of PAPER TECHNOLOGY will be published each year—

No. 1 in February	No. 4 in August
No. 2 in April	No. 5 in October
No. 3 in June	No. 6 in December

● A number of cloth-board bound copies of the collated *Proceedings* sections from each of the six issues for 1960 can be prepared for special subscribers. The preparation and cost will depend on the demand and members interested in buying the bound volume should advise the Secretary of the Technical Section before 30th September 1960.

● Binders with gold blocking on the spine can be obtained from the Technical Section at special rate — enquiries are invited. Each binder will hold six issues.

● The register of members will be made up on 30th September 1960 for publication in the December issue of *Yearbook* 1960. Accuracy in the register details will be assured by members notifying the Secretary of any changes of position, address, etc. as soon as these occur.

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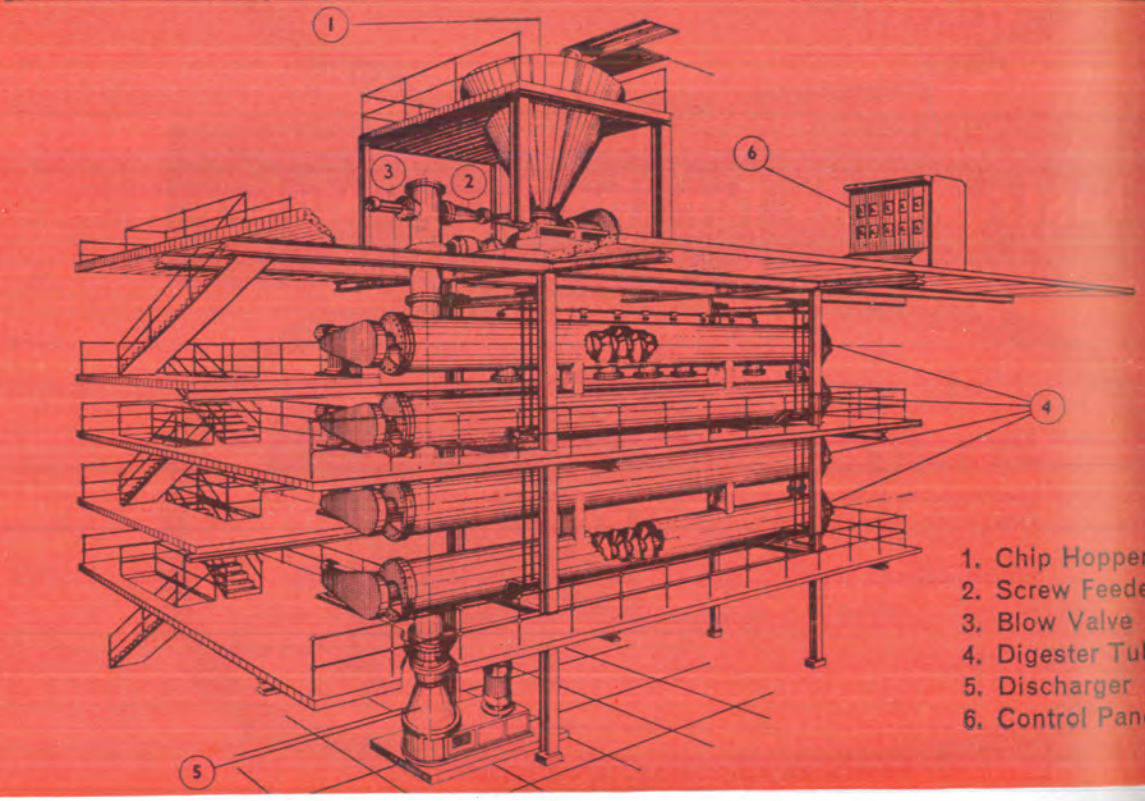

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For your reading continued from page 362)

Improvements, complete reconditioning and realignment of papermachine dryer sections at Bowater Corner Brook Mills

W. G. Smith

Pulp and Paper Mag. Can., 1960, **61** (C), T147–T154

White pigments and paperboard

W. R. Willets

Pulp and Paper Mag. Can., 1960, **61** (C), T155–T160

Sorption phenomena – their influence in the rapid forced penetration of dilute alkali into wood

E. J. Dostal, L. M. Marraccini and T. N. Kleinert

Pulp and Paper Mag. Can., 1960, **61** (C), T167–T173

Improvements in technique for Brecht initial wet strength test

W. R. Farrell and J. D. McLean

Pulp and Paper Mag. Can., 1960, **61** (C), T174–T176

Fundamental aspects of solids-gas flow

L. B. Torobin and W. H. Gauvin

Can. J. Chem. Eng., 1959, **37**, 224–236

Part III: *Accelerated motion of a particle in a fluid*—An analysis of the extensive literature on non-steady drag forces supports the correlation of the data by means of a total drag coefficient, which appears to be a function of the Reynolds number and of a reduced time parameter that is related to the number of particle diameters traversed since the initiation of the motion. The added mass concept is shown to be both completely inadequate and theoretically unsound. An increase in wake turbulence resulting from Reynolds number increases or, from the occurrence of surface roughness, seems to diminish the acceleration effects.

Fundamental studies of the flow fields around blunt bodies reveal the extreme complexity of the phenomena occurring during acceleration. Explanations offered for the characteristics of the non-steady drag coefficient behaviour are shown to be frequently at variance with these findings.

Determining minimum chest levels for continuous pumping applications

P. J. Olmstead

Paper Trade J., 1960, **144** (9), 30–31

Care of rubber-covered rolls

R. M. Leighton

Paper Trade J., 1960, **144** (9), 32–33

Plastic wires for Fourdrinier machines now proven in regular operation

J. C. W. Evans

Paper Trade J., 1960, **144** (14), 36–39

How to improve felt performance when using wet strength resins

R. N. Prince

Paper Trade J., 1960, **144** (14), 43–45

How to keep getting maximum quality high-yield pulp from disc refiners

D. Sharp

Paper Trade J., 1960, **144** (14), 46–49

Main concern of the modern supercalender is its filled rolls

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Tritium exchange between cellulose and water: accessibility measurements and effects of cyclic drying

A. R. G. Lang and S. G. Mason
Pulp and Paper Research Inst. Can. Series, 1960
from *Can. J. Chem.*, 1960, **38**, 373–387

Tritium exchange between cellulose and water vapour was used to measure the accessibilities of amylopectin, amylose, regenerated cellulose, woodpulp, bacterial and Valonia cellulose and cellulose trinitrate using both gas counting and solid counting techniques. The results compare satisfactorily with other accessibility and crystallinity measurements.

The incomplete reversibility of the exchange reaction was used to study directly changes in the accessibility of regenerated cellulose during repeated wetting and drying from water. The results indicated that a partial interchange of accessible and inaccessible regions occurs during wetting and drying.

Flow of entrapped bubbles through a capillary

R. N. Marchessault and S. G. Mason
Pulp and Paper Research Inst. Can. Contribution Series, 1960, **52** (1)

Air bubbles are an important factor impeding flow through porous media. The mechanism was studied by considering the hydrodynamics of the liquid film surrounding an air bubble in a capillary tube.

A model of the mechanism of electrochemical conversion from active to passive states

W. A. Mueller
Pulp and Paper Research Inst. Can. Contribution Series, 1960
from *Electrochem. Soc. J.*, 1960, **107** (3), 157–164

A model is developed of the mechanism of passivation of metals by oxide films. It is based on the assumption of the formation of a passivating film caused by the reaction of hydroxyl ions with the metal surface.

Particle motions in sheared suspensions

O. L. Forgacs and S. G. Mason
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Fundamental aspects of solids-gas flow

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(*continued on page 424*)

The effect of filming amines on heat transfer in paper-drying cylinders

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GIVEN AT A MEETING OF LONDON DIVISION: YORK HALL, CAXTON STREET, S.W.1 ON 11th FEBRUARY 1960, Mr. G. THOMPSON IN THE CHAIR

Synopsis

The continuous film of condensate and the corrosion layer on the inside surface of paper-drying cylinders offer an appreciable resistance to heat transfer. The filming amines are known to eliminate this resistance by removal of corrosion products and by promoting dropwise condensation. The mechanism of operation and the effect of various factors are discussed.

Increases in production on a number of American and Finnish papermachines, resulting from the ability of the filming amines to improve the drying capacity in the range 5–15 per cent., have been claimed.

Tests in our laboratory showed that an increase of 13 per cent. in heat transfer was obtained by the addition of a dropwise promoter to the steam, but, unfortunately, the industrial application did not prove to be as successful as at first envisaged; however, further work is being carried out in this direction.

Introduction

THE fundamental relationship for heat transfer may be stated as follows—

$$Q = U \times A \times \Delta t,$$

where Q = heat transfer rate, in B.T.U./hr.,
U = overall coefficient of heat transfer, in B.T.U./(hr.) (sq. ft.) (°F),
A = heat transfer area, in sq. ft.,
Δt = temperature difference in °F between the hot and cold side of the body through which the heat is transmitted.

When space requirements prevent an increase in dryer area and the dryers are operating at the maximum allowable steam pressure, it is obvious from the equation stated above that it is only possible to increase the amount of heat transferred (which is proportional to the drying capacity) by raising the coefficient of heat transfer or by reducing the drying temperature. In practice, the temperature of vaporisation is lowered by forced ventilation systems.

In studying the effect of the numerous factors affecting the overall coefficient, it is necessary to consider separately the individual coefficients.

The value U satisfies the equation—

$$\frac{1}{U} = \frac{1}{h_1} + \frac{1}{h_2} + \frac{1}{h_3} + \frac{1}{h_4},$$

where h_1 = steam side film coefficient,
h_2 = coefficient of conductance of the inside scale, dirt, corrosion, etc.,
h_3 = k/L, for which
k = thermal conductivity of the metal, in B.T.U./(hr.) (sq. ft.) (°F per ft.),
L = thickness in ft. of the metal cylinder wall through which heat is transferred,
h_4 = paper side coefficient, including fuzz and air contact.

[h_1, h_2, h_3 and h_4 are all expressed in B.T.U./(hr.) (sq. ft.) (°F)]

Two of these factors (h_1 and h_2) can be influenced by the action of some organic chemical compounds, of which the filming amines are the most commonly employed in industry. Appreciable improvements in dryer efficiency on papermachines through the application of a filming amine have been claimed. These will be discussed later.

The resistance presented by the wall of the metal cylinder, $1/h_3$, will remain constant (unless the metal is corroding rapidly). The paper side coefficient, however, may vary very considerably. In particular, it will be influenced by—

1. The type of paper being made.
2. Its substance.
3. Its moisture content entering the drying section.
4. The condition of the dryer surface.
5. The tension of the felts.
6. The tightness of the draws.

Because of this, it is hardly possible to predict a realistic figure of the extent to which the application of a filming amine will improve the total heat transfer.

For the same reason, it is difficult to determine quantitatively, by means of a mill trial, the improvement brought about.

Dropwise condensation

Dropwise versus film type condensation

THE result of work by several investigators shows that there is a considerable advantage in preserving dropwise condensation of steam, since the steam side film coefficient for dropwise condensation is of the order of ten times that for condensation of steam as a continuous film.[1–4] According to Hampson,[4] this is due to—

1. The conduction of heat through the surfaces, with drops being greater than with an equal quantity of liquid spread as a uniform film over the same area.
2. The high heat transfer rate through the exposed areas between the drops.
3. The more rapid removal of condensate in drop form, owing to coalescence with drops rolling down and these sweeping an even greater area free of condensate.

An example of dropwise condensation is given in Fig. 1.

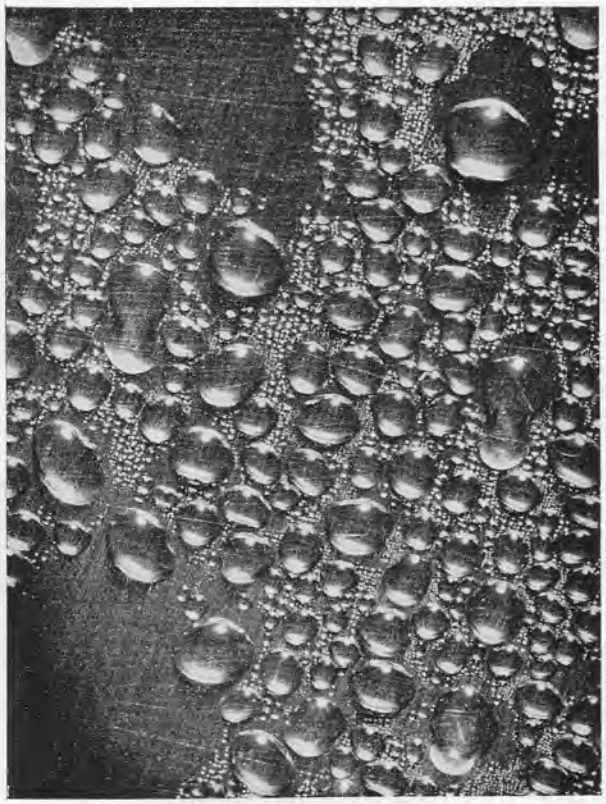

Fig. 1

Most investigators on the subject of dropwise condensation[5,6] agree that film type condensation is always obtained with chemically clean steam, condensing on clean metal surfaces, whether rough or smooth, regardless of the presence of non-condensable gases; moreover, that all metal surfaces require a promoting agent to produce pure dropwise condensation.

Dropwise promoters

All dropwise promoters must have a very low affinity for the steam (condensate) and, at the same time, have a surface-active group that would be adsorbed on the metal surface in question, so that they will not be washed off too easily by the condensate. Such substances in contact with a metal surface will coat this surface completely with a thin film of great lateral strength. Emmons[5] confirmed that a single complete layer of molecules of the promoter, oriented more or less normal to the condensing surface, is responsible for dropwise condensation and that all promoter molecules beyond one complete layer are removed immediately by the condensing steam.

Even a smear of grease will produce dropwise condensation, but the duration of the effect is very short, because the steam soon washes the grease away. Although many substances (including hydrocarbon oils) will make the surface non-wettable temporarily, only those that are adsorbed firmly to the condensing surface have significance as promoters.

Since 1931, several investigators have studied the phenomenon of dropwise condensation,[4,5,7–11] but, although some promoters were found to make the condensing surface non-wettable for a number of hours, such periods were considered much too short for a possible industrial application.

By a more fundamental approach to the chemical aspects of the problem, Blackman[2] managed to prepare promoters for copper and copper alloys, which offer a definite possibility of industrial application. They consist of a range of compounds, in which long hydrocarbon chains are attached to groups containing sulphur or selenium. The sulphur or selenium of the compound enables a bond to be made with the copper condensing surface and the hydrocarbon chains form a water-repellent monomolecular layer, on which the steam condenses in the form of drops.

Another type of effective dropwise promoter is a group of coal fractions, obtained by solvent extraction.[12] Other substances such as silicones and fluor compounds have also been developed for the

promotion of dropwise condensation, but these have not yet been extensively studied. At present, certain amines are also finding wide application in promoting dropwise condensation, as will now be considered.

Use of filming amines

The amines used for the promotion of dropwise condensation are the straight chain primary amines and amine salts, containing 10–18 carbon atoms per molecule. In practice, the most successful results have been obtained with the commercially available *n*-octadecylamine and its acetate salt.

It is to be regretted that the term *filming amines* has been established as a description of these compounds, since the name may cause some confusion with respect to the term *film-type condensation*. It is the amine itself that forms a (monomolecular) film and its effect on the condensation of steam is to convert the normal film-type condensation into a dropwise condensation.

Removal and inhibition

THE filming amines not only promote dropwise condensation, but they also remove and inhibit corrosion in industrial steam plant and other condensing systems.[1,3,13–18]

The principal causes of corrosion in steam condensing systems are dissolved carbon dioxide and dissolved oxygen. Protection by chemical means has been obtained through the application of neutralising agents such as ammonia and the lower amines. These agents, however, give no protection against oxygen attack and they become expensive when the carbon dioxide concentration in the steam is high.

The filming amines provide complete protection from both oxygen and carbon dioxide attack. They do this, not by neutralising carbon dioxide, but by depositing an impermeable, water-repellent film on the condensing metal surface, thus preventing corrosive gases and water coming into contact with the metal. Since filming amines do not neutralise, their protection is independent of the concentration of carbon dioxide in the steam.

The film formed through the use of these amines is of monomolecular thickness and does not increase in thickness with continued treatment. Because of the substantial life of this monomolecular layer, the material is required only in small quantities.

Not only does filming amine treatment inhibit corrosion, but, when applied to an already corroded system, the surface-active nature of the film allows it to penetrate under and loosen existing corrosion products, so that the protective coating is built up between rust and metal surface. Because the amine has no affinity for the corrosion products, these will eventually break away. If they are removed too rapidly, serious clogging of steam traps may be experienced. This difficulty may be minimised by starting at a low dosage rate.

Factors influencing the effect of filming amines

Introduction

FILMING amine treatment, then, enhances the heat transfer rate in steam condensing systems, both by the removal of corrosion deposits (thereby eliminating the fouling factor, $1/h_2$) and by dropwise condensation of the steam. There will, of course, be the resistance of the amine film instead, but, owing to the extreme thinness of this (monomolecular) film, it is of no significance.

The protective agent withstands high temperatures, for it is reported to have been used at pressures of over 900 lb./sq. in.[16] According to Streatfield,[14] the amine is known to be stable under boiling conditions of 1 200 lb./sq. in. and 1 000°F, no appreciable breakdown and release of ammonia taking place. The film is stable over the pH range 4–8.6.[14] The upper value should be noted, since boiler entrainment (which will permit alkali to enter the condensate) may raise the pH value of the condensate water to a level at which the protective film will be broken down.

Rimming of condensate

In paper-drying cylinders, the diameter of the cylinder, the speed of rotation and the amount of condensate affect the extent to which condensate will be carried up the rotating surfaces.

Even with an efficient condensate removal system, there will be an accumulation of condensate in the bottom of a drying cylinder and, when the dryer is in motion, some area of the surface will be coated with a layer of condensate much thicker than the normal film. As the machine speed increases, the centrifugal forces increase to the stage when the gravitational forces are overcome. The tendency to form this thicker continuous film is known as *rimming* and the speed at which this starts to occur is called the *rimming speed*.

Two undesirable consequences stem from this effect—

1. Dropwise condensation ceases to be possible, because a continuous layer of condensate is introduced (which

resists the transfer of heat to a much greater extent than does the normal condensate film).

2. In the neighbourhood of the rimming speed, the power demand fluctuates considerably.[19–21]

Cirrito[22] has confirmed that the depth of the static pond of condensate in drying cylinders has an appreciable effect on the thickness of this layer. As the thickness of the condensate film increases, it can become the controlling factor in heat transfer.[1,22]

White[21] proposes as an empirical formula, possibly limited to speeds above 800 ft./min. for 5 ft. diameter cylinders, from which rimming speeds can be predicted—

$$V = (5\,720 - 2\,160/D)\,L$$

where V = critical rimming speed at the inner surface in ft./min.,
D = inside diameter of the cylinder in ft.,
L = volume of condensate per unit area of the inside surface in cu. ft./sq. ft.

In addition to White's own results, this formula holds reasonably well for those of other workers on this subject.[19,22] For a 5 ft. diameter cylinder, having a wall thickness of 1 in. and a face width of 180 in., some typical values of rimming speeds have been calculated as in Table 1 ($D = 4.83$).

TABLE 1—CALCULATED VALUES OF RIMMING SPEEDS

Depth of pond of condensate, in.	*Amount of condensate, lb.*	*L*	*V*
1	63.10	4.62×10^{-3}	879
1.5	115.60	8.46×10^{-3}	1 074
2	177.5	13.0×10^{-3}	1 240
4	496.7	36.4×10^{-3}	1 750
6	902.5	66.0×10^{-3}	2 140

It is to be supposed that, at speeds below 800 ft./min., centrifugal forces are insufficient to bring about rimming. It has been reported[1] that papermachines, running at speeds higher than the theoretical rimming speed, are operating better through the use of filming amines. This could well result from removal of old corrosion products.

Possible influence of variation in heat load

The heat load (or heat flux) is defined as the amount of heat transferred per unit area [in B.T.U./(sq. ft.)(hr.)] and may be compared with the drying rate, which is expressed in lb. (of water evaporated) per sq. ft. and per hr. For multi-cylinder papermachine dryers, it is 3 000–6 000 B.T.U./(sq. ft.) (hr.).

The steam side film coefficient (h_1) may well depend on the heat load. The evidence for this, however, is conflicting, perhaps in part due to the different ranges of heat flux considered and in part to the different dropwise promoters employed, which in none of the cases in Table 2 was a filming amine.

TABLE 2—INFLUENCE OF HEAT LOAD ON h_1 WITH DROPWISE CONDENSATION

Reference number	*Range of Q/A, B.T.U./(hr.) (sq. ft.)*	*Is h_1 dependent on heat load?*	*Dropwise promoter employed on what surface*
8	80 000–250 000	Yes	Benzyl mercaptan no copper
10	68 000–252 000	No	Benzyl mercaptan on copper
11	60 000–370 000	No	Benzyl mercaptan/oleic acid on copper
23	10 000– 90 000	Yes	Sulphur and selenium compounds on copper
24	12 000–150 000	No	Dodecane-thiosilane on cupro-nickel

Presence of non-condensable gases

Hampson[4] found that the presence of a little non-condensable gas in the steam increases the life of a dropwise surface, thus confirming the findings of Emmons.[5] The presence of non-condensable gases in the condensing steam will, however, reduce h_1 considerably.

Feed and dosage

THE filming amines (or their salts) may be fed—

1. Directly to the boiler water;
2. Directly to the steam lines;
3. To the boiler feedwater lines, under certain conditions.

When the material reaches the boiler (or the steam line), it volatilises and passes over with the steam in the vapour phase. When the steam condenses, the amine will also return to its liquid phase, in which state it migrates to the liquid/metal interface and forms a completely impermeable and non-wettable barrier between the condensate and the metal surface.

Injection directly to steam lines is advantageous when it is desired to coat only a certain part of the steam-condensing system with an amine film. Application directly to the boiler water or feedwater both ensure addition of free filming amines to steam by distillation. Alkalinity may cause the amine to precipitate, but it has been found in practice that, providing the amine is injected into the feed line and

not into the feed tank, an alkaline pH in the feedwater causes no trouble.

Streatfield[14] and Wilkes *et al.*[25] state specifications for preparing the amine solution to be fed into the steam system (temperature, pH and hardness of the water). The optimum dosage rate is between 2 and 5 p.p.m., but, if corrosion products are expected to be displaced, the initial feed should be no more than 1 p.p.m. (solid amine to feedwater). After the system becomes clean, the feed rate is then gradually increased.

Continuous feed of filming amine is essential for maximum protection against corrosion and maintaining dropwise condensation. Test results have shown that, if the amine feed is discontinued, the protective film is soon removed and a high rate of corrosion returns.[1,25]

Case histories

In various articles, cases are cited of corrosion rates that have been reduced to a minimum by the proper application of the film-forming octadecylamine. Tanzola and Weidman[26] mention that in 1954 over 500 plants were employing filming amines for corrosion prevention. Tanzola[13] states that, from data obtained from steam-condensing plants of varying operating characteristics, corrosion rates were reduced by 80–99 per cent. after the application of filming amines. This range is also found in results collected by others.[1,15–17,25–28]

Increases in production in certain American and Finnish papermills,[1,17,26–28] resulting from the ability of the filming inhibitors to contribute to increased heat transfer (by promoting dropwise condensation or by removal of corrosion deposits or by both), in the range 5–15 per cent. have been claimed.

Résumé of work in our laboratory

Initially, qualitative experimental work was carried out in our laboratory to confirm that filming amines are able to promote dropwise condensation. Steam of low pressure was made to condense on a set of two watercooled steel tubes, one of which was treated with filming amine on the steam side. The tube that had been coated with the amine gave definite dropwise condensation, whereas the untreated tube showed film type condensation of the steam.

These preliminary experiments justified continuation of the work and the apparatus was redesigned to obtain quantitative results. A single steel steam pipe was enclosed inside a rigid, transparent plastic tube, which had been halved longitudinally. Each half of the jacket had separate cooling water inlet and outlet connections. One half of the inside of the steam pipe, corresponding to one of the water jackets, was covered with adhesive cellulose tape. Amine vapour was passed through the inner tube for about 15 min. and, after the amine was allowed to condense, the adhesive tape was stripped off and any of its remaining adhesive removed. One half of the inside of the steel pipe was now coated with a film of amine, while the other half was still untreated. The cooling water flow was adjusted so that equal flows were maintained in the two halves of the jacket. Steam was passed through the inside of the steel pipe and temperatures of inlet and outlet of cooling water were noted. From the amount of cooling water passed through in a given time and from the temperature readings, the increase in heat transfer through the application of the filming amine was found to be 13 per cent.

Experiments on two papermachines

A series of tests was carried out on two slow running machines. The drying section of each of the two machines is divided into two parts by a surface size press. The amine compound was injected as an aqueous solution, dripping into the boiler feedwater tank over a period of four weeks. The dosage rate was 3 p.p.m. (solid amine to feedwater). During this period, also prior to and following the actual experiment, the moisture content of the paper was determined (by oven-drying) at certain locations along the machines. With the aid of additional information (machine speed, basis weight, etc.), the drying rates for the two sections (before and after the size press) of the machines could be calculated, except for the second section of one of the machines, as it was impracticable here to obtain paper samples immediately after the size press.

The results have been statistically analysed and the following conclusions reached.

Machine A—before the size press

(*a*) Averaging the conditions obtaining before the addition of the amine and several hours after the addition had ceased, there was no significant change in drying rate upon adding the amine.

(*b*) The drying rate increased significantly upon the addition of the amine, but did not decrease significantly after the amine supply was stopped.

Machine A—after the size press

(*a*) Averaging the conditions obtaining before the addition of the amine and several hours after the addition was ended, there was a significant increase in drying rate on adding the amine.

(*b*) There was no significant increase in drying rate upon the addition of the amine, but there was a significant decrease when the amine supply was stopped.

Machine B—before the size press

Whether averaged or not, there was no significant change in drying rate caused by the amine treatment.

It should be emphasised that a lack of significance does not necessarily imply that no improvement has been made, but simply that the uncertainty in the data, owing to other operating variables, is such as to mask any increases.

The actual mean value obtained for the increase in drying rate for the first section of machine *A* is 4.1 per cent., but the true value lies 19 out of 20 times at $\pm$ 4.7 on either side of this—thus, from –0.6 per cent. to 8.8 per cent. For the section after the size press of the same machine, the improvement in drying rate from the amine treatment is 9.2 per cent. $\pm$ 7.4 (also in 95 per cent. of cases), which makes the range 1.8–16.6 per cent.

The present results do not appear to be convincing enough to permit any positive conclusions that octadecylamine treatment of the steam improves the drying capacity of machine *A*. There may be several reasons for this—

1. Certain machine conditions—atmospheric conditions, steam consumption, steam pressure and stock freeness—may have varied appreciably throughout the test.
2. It is not always practicable (and was not in this case) to maintain the paper side coefficient h_4 reasonably constant.
3. As has been mentioned, there is some disagreement about the effectiveness of dropwise promoters at low heat loads.
4. The variation in the behaviour of this machine during operation may be of the same order as the increase in drying capacity looked for.
5. A larger number of observations might have reduced the variability of the final result.

Conclusion

ALTHOUGH it is not possible from this trial to state with confidence that the use of filming amines is advantageous, the results would appear to justify a further trial on a different machine. It is intended to carry out further work on the use of filming amines.

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discussion

MR. R. P. NUKI: Mr. Schoonen mentioned in his interesting paper that experiments were carried out on two machines, with the result that no increase in the drying rate could be found on one machine, though an increase in the drying rate was found on the other machine. Here, the increase in drying rate was 4.1 per cent. on the cylinders before the size press and 9.2 per cent. on the cylinders after the size press. Can Mr. Schoonen explain why the latter should be more than double the former?

It appears that the scatter of figures leading to the averages is—

–0.6—8.8 per cent. leading to an average of 4.1 per cent.
1.8—16.6 per cent. leading to an average of 9.2 per cent.

This scatter appears so wide that it may be difficult to judge results.

MR. J. P. SCHOONEN: There is no real difference in drying rate improvements for the two sections of machine *A*, since the upper limit of confidence of the lower value is much higher than the lower limit of the larger value.

MR. D. M. WYLLIE: Since Mr. Schoonen has referred to the well-known difficulties of assessing drying performance by experiment on the paper web (with which difficulties I fully agree), is it possible for him to quote examples from other industries where drying efficiencies, etc. can more easily be measured? When filming amines have been applied to such industries, their beneficial effects could therefore be more easily noted than in the paper industry.

MR. SCHOONEN: I have only found one reference [3] to the use of octadecylamine for promoting dropwise condensation in other industries. Garrett shows that on a pilot-plant single tube heat exchanger a 30 per cent. increase in capacity was possible, but the full-scale application in a brine evaporator was entirely unsuccessful. On the other hand, filming amines have been used in papermills in the United States and Finland with varying degrees of success.

THE CHAIRMAN: What were the speeds of the machines on which the experiments were carried out?

MR. SCHOONEN: The speed of machine *A* was approximately 275 ft./min. and machine *B* had an average speed of 225 ft./min.

MR. G. F. J. MANSELL: I would like to ask Mr. Schoonen firstly whether he experienced any corrosion products such as oxides coming away and causing blockages in the system when he commenced filming amine treatment; secondly, has he been able to keep track of the quantity of filming amine present in the system? If not, what means is used to determine the dose rate of amine addition?

MR. SCHOONEN: We did not experience any noticeable displacement of corrosion products during the trial. The oxidised material probably broke up into harmless particles, much too small to cause trouble by clogging traps.

At the time when the test was carried out, there was no method available for the quantitative determination of a filming amine in steam condensate. A constant feed rate of 3 p.p.m. was maintained for the duration of the test; this value is recommended for nearly all types of condensing systems.

MR. S. A. CLEAREY: What was the state of the internal surfaces of the cylinders before the experiments? Was there a significant change in the surface temperature of the cylinders after addition of the amines?

MR. SCHOONEN: The interior surfaces of the drying cylinders on these machines did not appear to be as dirty as might be expected after so many years of operation. The thermal conductivity of ferrous oxide is, however, very low and a very thin, seemingly negligible, layer of rust will cause a noticeable reduction in the heat transfer rate.

There was a drop of about 2 per cent. in the average surface temperatures of the first section of machine *A*, which remained after the amine supply was stopped.

MR. NUKI: Has Mr. Schoonen any experience of corrosion inside cast iron cylinders? I have inspected many cast iron drying cylinders in the course of my work, but have found them perfectly clean inside even after many years of operation. Therefore, I have found no rust that could impede the heat transfer.

I agree that rust can be swept into the system initially from the mild steel steam pipework, but such deposits usually lodge in the traps and amines could not help.

The only advantage I could see in the application of amines would be that mild steel condensate pipework would be protected from rusting. The condensate usually carries gases that attack the condensate pipework. It takes years, of course, before the corrosion becomes apparent.

MR. SCHOONEN: I also have inspected the interior surfaces of many cast iron cylinders and I have always found some rust. As I have already mentioned, even an extremely thin film of rust will bring about a significant change in the heat transfer rate.

Filming amines *are* used in condensate return lines for removing existing corrosion deposits and inhibiting further corrosion, but their application is not confined to this. Since they have the ability to promote dropwise condensation, they will be most useful in paper dryers, even if these are free of any corrosion.

MR. W. F. E. ROBINSON: How long did the experiments last, was this sufficiently long to clear away any corrosion scale in the cylinders and were the figures taken after this had happened?

Were the temperatures of the cylinders controlled? If so, an increase in transfer rate of heat through the cylinder would cause the cylinder temperature to rise. Under automatic control, the amount of steam would then be reduced to compensate and, although no increase in drying rate were found, this would be shown as a reduction in consumption of steam.

MR. SCHOONEN: Our primary object was to increase drying rate (and production), regardless of whether this was achieved by dropwise condensation or by cleaning the system. We considered that, for a first experiment on the machine, a month of amine-injection would be long enough to measure an appreciable change in drying rate. Apparently, a month is *not* long enough for a test of this kind. In the very near future, we shall carry out a more extensive trial on a different machine. This will be over a much longer period and we hope to obtain more reliable results.

As far as I am aware, no change in the steam consumption was experienced.

MR. C. H. SAILER: What was the effect of adding amines on the condensate removal system, say, buckets in MG cylinders? Has Mr. Schoonen noticed during his investigations on MG cylinders that the old-fashioned buckets across their interior have a paddle-wheel action and assist in the formation of a water rim or ring?

MR. SCHOONEN: I do not understand the sense of your question very well. If the speed of an MG machine is higher than that of a Fourdrinier, it does not necessarily indicate that rimming will take place sooner. The critical speed at which rimming occurs is proportional to the square root of the diameter and, therefore, if the diameter of an MG cylinder is $2\frac{1}{4}$ times that of a Fourdrinier drying cylinder, the critical speed of an MG dryer will be 1.5 times as high.

MR. NUKI: In reply to Mr. Sailer's question about condensate removal from cylinders, there are various types of buckets and siphons (stationary and rotary), combined bucket siphons with or without orifice restrictions. The choice is usually made according to cylinder diameter and machine speed. The methods of condensate removal are an independent problem. Condensate must be removed efficiently before one could think of applying amines. It has been found that steam circulation gives a higher heat transfer than stagnant steam and removes condensate efficiently from the cylinders. Special consideration would have to be given to drying cylinders in high speed machines, where up till now a certain amount of condensate remains distributed over the inner cylinder surface by centrifugal action.

MR. O. FELSNER: What amine was used?

MR. SCHOONEN: The amine used was a combination of free octadecylamine and its acetate salt, the latter being more soluble in water.

New instruments for control of the papermachine

M. I. MacLAURIN
Wiggins Teape Group Research Organisation

GIVEN AT A MEETING OF LONDON DIVISION: YORK HALL, CAXTON STREET, S.W.1
ON 11th FEBRUARY 1960, MR. G. THOMPSON IN THE CHAIR

Synopsis

The Shirley moisture meter is an inexpensive low voltage d.c. resistance type, originally for use on textiles, now developed for the papermachine. The minimum moisture content normally measured is 6 per cent. It is claimed that, when suitably applied, the instrument appears unaffected by normal machine variation other than moisture content.

Three other instruments are described—

The W.T. continuous opacity meter can be used on the machine for continuous measurement or control of transmission opacity: it is self-standardising.

The W.T. continuous formation meter for use on the machine gives a measure of opacity modulation that is useful as an indication of formation.

The W.T. pneumatic thickness profiler is a quality control instrument that records thickness variations along a strip across the machine. The magnifications available are 1 000:1 and 5 000:1.

Introduction

MY employers have always pioneered the use of instruments both on and off the papermachine to obtain as much information about paper quality as quickly as possible. The rapid detection of faults and corrections made thereby give the least variability in the product. At various times, these have been mentioned in technical papers.[1–3]

This paper concerns four more recent instruments. The first of these is the Shirley moisture meter. This instrument was originally developed for use in the textile industry, but its adoption for use on papermachines has been entirely within my own company. The second is the W.T. continuous opacity meter; the third is the W.T. continuous formation meter and the fourth is an instrument designed, not for use on the papermachine, but to assist the quality control department. It is a pneumatically operated thickness profiler for use on end of reel samples.

These last three instruments have been invented by Mr. Robert Gladstone of our Production Department and well known to the industry as a prolific and original designer of instruments. Much of this paper is due to his work and I should like to acknowledge my debt to him now.

The Shirley moisture meter

IN 1955, Mr. C. A. Chester, Chief Technologist at our Hylton Mill, having heard of the success of the Shirley instrument for textile usage, obtained one for papermachine trials. The textile electrode was found to be unsuitable, so he developed a new electrode and conducted the first assessment of the equipment (Fig. 1).

The meter measures d.c. resistance using a low voltage. By selecting sensitivity ranges, measurements varying from tens of kilohms to thousands of megohms may be made. Other factors being constant, the instrument may be expected to give readings on papers having moisture contents in the range 6–60 per cent. and it is possible under extremely favourable conditions to measure as low as $3\frac{1}{2}$ per cent. moisture content.

The instrument has several limitations. Firstly, a suitable electrode is required; secondly, the readings must be correctly interpreted; thirdly, the other factors affecting readings must be considered and, finally, many papers are made at moisture contents below 6 per cent., its lowest normal reading.

Electrodes

Resistance through the sheet is proportional to sheet thickness and resistance across the sheet is roughly inversely proportional to sheet thickness. Hence, an electrode arrangement combining the two can be arrived at that is more or less independent of sheet thickness. This is the method used on our machines. The usual electrodes consist of five spring steel fingers that ride on the web. The fingers are connected alternately to earth and to the measuring lead and the measurement is taken whilst the paper is

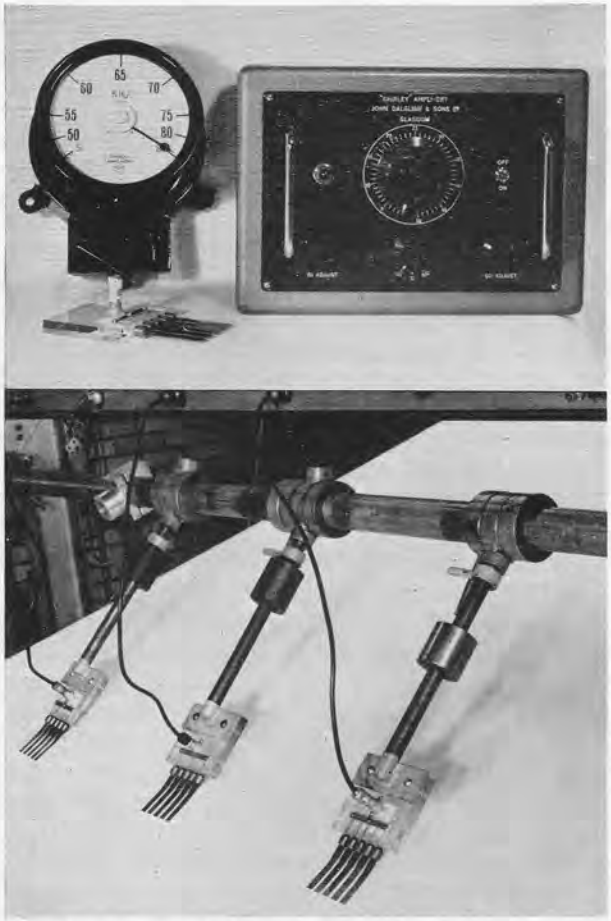


Fig. 1 *(above)*—Shirley moisture meter with W. T. electrode
Fig. 2 *(below)*—Shirley moisture meter electrodes on the machine

riding on an earthed roll (Fig. 2). For dry papers, about 50 000 megohms insulation is required. The weight of the electrode on the sheet must be constant and the mounting should have castoring action. For special applications, other electrodes have been tried—for example, a roller electrode made of alternate rings of conducting rubber and plastic.

Interpretation of readings

As designed for use with textiles, the meter readings indicate the relative humidity of the air with which the textile is in moisture equilibrium. The scale is calibrated 50–80 per cent. R.H. Suppose the textile is in equilibrium with an atmosphere at 65 per cent. R.H. The 50-position sensitivity control provided is adjusted until a reading of 65 per cent. R.H. is obtained. The meter will then indicate correctly other equilibrium values for the same textile. Naturally, this use of the instrument presupposes a knowledge of the humidity history of the substance being measured.

Commercial papers must be in equilibrium with the atmosphere in the warehouse in order to prevent wavy edges, etc. For other papers, it is sometimes more important to know the actual moisture content—indeed, some customers specify moisture content with their orders. A considerable amount of work has been carried out to investigate the use of the instrument as a moisture meter and as an equilibrium atmosphere meter. The work is lengthy and somewhat involved and I do not propose to discuss it now; however, the general conclusions for a given mill's papers are that it is possible to use the instrument as an equilibrium atmosphere meter with a standard sensitivity setting and taking into account whether the paper has been dried down or subsequently humidified (Fig. 3). Different mills may have to use different sensitivity settings. It is also concluded that the instrument may be used as a moisture meter with confidence, provided it is calibrated for each class of paper to allow for the fact that papers differ considerably in their moisture contents at any given atmospheric condition (Fig. 4). In the following discussion on the effects of different variables, I will refer to the calibration as a moisture meter, because most of us are more familiar with this method of expression.

Effects of other variables

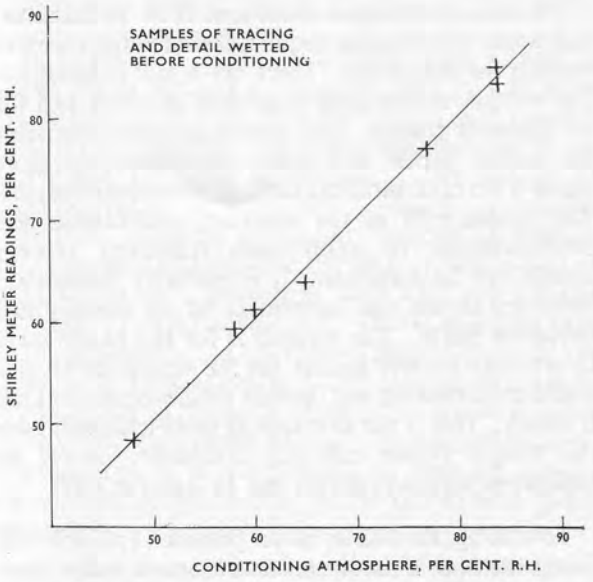
Thickness—Negligible over the range 1.1–14 mils.

Substance—Negligible over the range 17–270 g./sq.m. (The greatest recorded effect is approximately + 0.016 per cent. moisture content per + 1 per cent. substance.)

Speed—Negligible during a making, but troublesome on supercalenders (Fig. 5). The effect may be due to polarisation currents.[4] In laboratory work, no appreciable error is found, provided the electrode is kept moving at a reasonable speed.

Electrode pressure—In practice, this should be constant (Fig. 5).

Fibre and loading furnish—Negligible on equilibrium atmosphere readings, but the humidity/moisture content curves are affected. This implies calibration for each furnish when used as a moisture meter. When absorbed to 65 per cent. R.H. equilibrium, for example, unloaded, bleached sulphite has a moisture content about $8\frac{1}{2}$ per cent., but is $7\frac{3}{4}$ per cent. for 10 per cent. loading and 6 per cent. for 40 per cent. loading. A rag furnish increases the Shirley readings somewhat for a given moisture content.



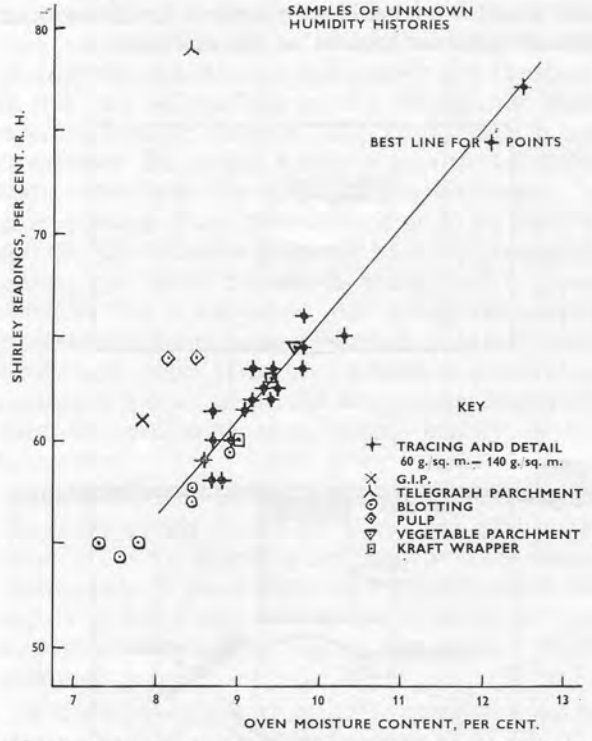


Fig. 3 (*above*)—Shirley meter used as 'equilibrium atmosphere meter'

Fig. 4 (*below*)—Shirley meter used as a moisture meter

pH factor—Negligible over the range pH 8.5–4.2, but has a small effect for lower values owing to the logarithmic relationship. The pH value does not indicate total salt or acid content and mills having relatively high conductivity backwater obtain elevated readings. Variations from making to making in the same mill have caused no reported trouble, except in one instance: in this case, the combination of low pH and 4 per cent. moisture content was difficult.

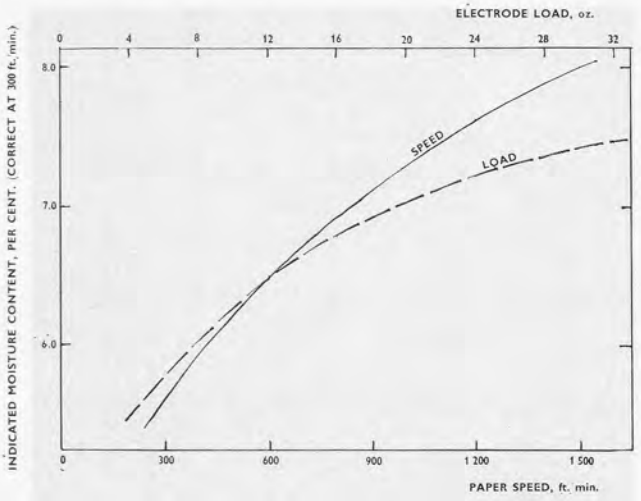


Fig. 5—Typical effect of speed and electrode load on Shirley readings

Beating—Negligible from blotting paper to greaseproof paper.

Sizing—Negligible for gelatine, starch and rosin. Some size press additives change calibrations.

Sheet smoothness—One smooth paper (Bendtsen reading about 200 cc./min.) reads 2 per cent. moisture content higher than the matt quality (Bendtsen about 1 000 cc./min.). The effect of smoothness is complicated by the interaction with moisture content on the machine. It is thought that the effect is small for normally tolerated smoothness limits within a making.

Electrode wear—Repeat calibrations show no drift over at least 6 months. Electrodes usually last for years, but wear rapidly on some grades such as greaseproof paper.

Mains voltage—Linear at — 0.075 per cent. R.H meter reading per volt.

Temperature—The effect is of the order of 0.03—0.056 per cent. moisture content per °F,[5,6] but temperature variations do not give trouble on well-planned installations.

Static electricity—Electrodes must be carefully sited to avoid trouble.

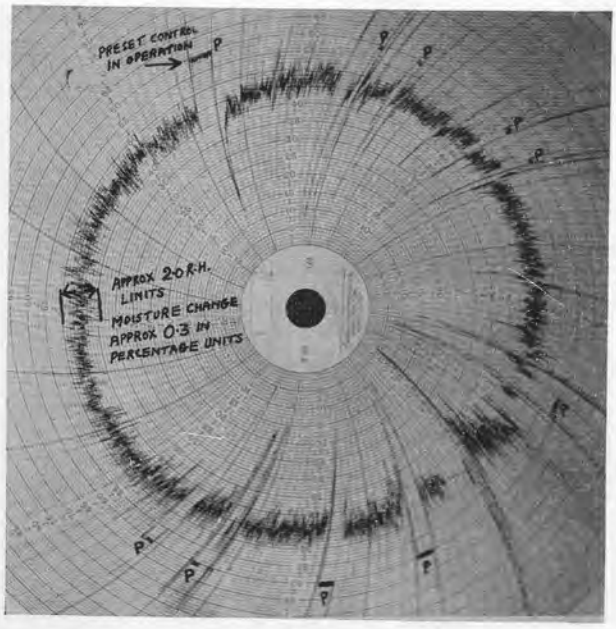


Fig. 6—Moisture control chart

General results

In this group of papermills, there are now nearly 40 Shirley installations, of which 24 are controlling drying automatically. The systems vary from simple proportional direct moisture control to complex cascade loops employing steam pressure or temperature as the control. Some machines have both main bank and after-dryer control and it is hoped to extend this system.

The results vary a little from mill to mill, but generally speaking it seems possible to control to $\pm \frac{1}{4}$ per cent. or $\pm \frac{1}{3}$ per cent. moisture content for most papers. Fig. 6 is a control chart $2\frac{1}{2}$ years old, obtained by using a simple proportional control only. The results with this relatively crude system speak for themselves: however, the final criterion for quality of control is the variance obtained from oven-dried samples from the controlled machine with due allowance for the measurable variance attributable to the error of the sampling and oven-drying method.[7] One of our machines is used as a guinea-pig for work of this kind and moisture samples are taken daily. It is therefore possible to quote accuracy of control with a fair degree of confidence. Cross-web profile can be measured either by traversing an electrode or by controlling on one electrode and switching other electrodes situated across the web to another meter. This latter system has been more in favour.

What are the snags? Firstly, it must be admitted that some installations require considerable effort to remove the difficulties. There are a few installations that remain substandard regardless of effort and for no apparent reason. The system appears unsuitable for coated papers and will not normally measure below 6 per cent. moisture content on ordinary papers. The hidden cost of the necessary calibrations and determinations of appropriate sensitivity settings should not be forgotten. It is perfectly reasonable, however, to use the instrument as an uncalibrated deviation meter. The method is for the papermaker to establish correct drying, set the sensitivity to give a mid-scale reading and instruct the dryerman to keep it steady. This is the first step at most mills and even this simple system can pay dividends: merely an indication with no control can be had for £200.

To sum up, the Shirley meter provides a reliable and cheap method of moisture measurement under most normal conditions. When it is suitably applied, the instrument is not affected by normal variations, other than in moisture content on the machine.

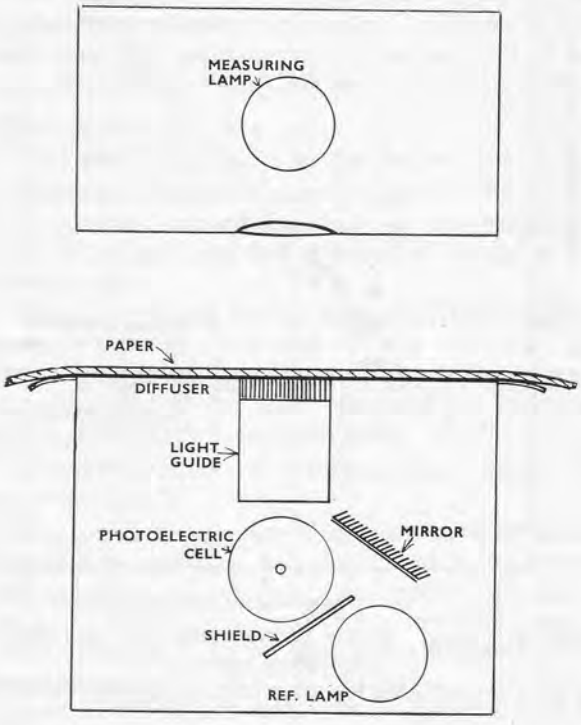


Fig. 7—The principle of the W.T. opacimeter

The W.T. continuous opacity meter

If 10 per cent. of the light falling upon a sheet of paper passes through it, the paper may be said to be 10 per cent. translucent or to have 90 per cent. opacity. This is not a standard definition and does not necessarily give the same figures as printing opacity or contrast ratio: however, it is clearly a sensible approach. In order to measure opacity as defined, it is necessary to determine the ratio of the amount of light falling on a given area both with and without the sheet of paper covering it. This is relatively easy in the laboratory, but continuous measurement on the machine is another matter. The instrument must be self-checking at frequent intervals to avoid troubles from drifts in photocell and light source performance. Furthermore, it is not possible to measure directly the amount of light falling on the cell without paper present.

It is wise to avoid as far as possible any effect from dispersion of the light beam by the paper, since this may be affected by formation, loading or finish. The ideal condition would be to have a non-reflecting photoelectric detector in actual contact with the sheet. In this way, all the light passing through the sheet would fall on the detector. This arrangement is not practicable. An optical system is required to ensure that any divergent rays of light are directed through the glass envelope of the photocell and on to its sensitive surface. The orthodox method is to use an integrating sphere, but this is difficult to arrange on a paper-machine. As a substitute, this instrument uses a permanent diffusing screen, followed by a transparent plastic light guide. It has been possible to obtain close agreement with a commercial densitometer commonly used for measuring transmission opacity in the laboratory.

For continuous use, the light source must provide absolutely steady illumination and any changes in sensitivity of the detecting cell must be compensated in some way. It goes without saying that the electronic apparatus and meters must possess a stability at least as high as the smallest change that requires to be measured.

The action of the instrument for continuous use on the machine is explained by reference to Fig. 7. The two light sources are nominally identical. The reference lamp illuminates the cell directly; the measurement lamp shines through the paper being measured. The sequence of operations is as follows, the cycle taking 10 sec. to complete and being repeated continuously and automatically—

Fig. 8 (*above*)—W.T. opacity meter control unit

Fig. 9 (*below*)—Combined measuring heads for opacity and formation

1. Reference lamp switches on and the cell output is used to adjust the brightness until the output is at a predetermined level (set zero opacity).
2. Both lamps are extinguished and the cell now responds to any ambient light there happens to be. This unwanted signal is balanced out electronically to give a true zero (set infinity opacity).
3. The measuring lamp is switched on. The control circuit remembers the setting from *1* and holds the brightness in strict proportion to that of the reference lamp, although the brightnesses are not necessarily identical. The cell output is taken to the measuring system. In setting up, the circuit is adjusted to read 100 per cent. (zero opacity) when there is no paper in the gap. Once this setting has been made, the first two steps in the cycle will adjust the lamp brightness so that the photocell will always give 100 per cent. output with no paper. This system compensates for drifts in photocell sensitivity and changes in ambient light.
4. Both lamps are extinguished: output is zero with or without paper in the gap.

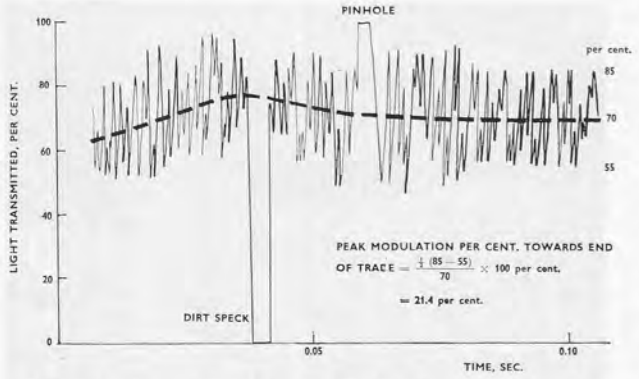


Fig. 10—Type of signal seen with a formation meter

When the instrument is in use, the output during the measuring period is the only one of interest. The measurement circuit includes a memory that maintains the meter reading until altered by the next measured output.

Fig. 8 shows the control unit, Fig. 9 a measuring head arrangement combining units for opacity and formation. The opacimeter heads are nearest the camera.

The opacity meter has three switchable ranges scaled 50–100, 80–100 and 90–100 per cent. opacity. When used, a recorder will follow the meter. Check positions and other facilities are provided. The voltage supplied to the lamps is indicated by a small meter. Increase of lamp voltage indicates approaching lamp failure.

The presence of dust on the measuring lamp window may cause errors, but this will be apparent when a zero check is made. Dust is unlikely to collect on the lower window, because of the rubbing of the web across it. Mains stabilisation is excellent.

The instrument has been used to measure opacity continuously on several papermachines during the past 3 years. A recent installation uses the opacity meter as the measuring element in an automatic control loop. On the machine concerned, the opacifying agent is titanium dioxide slurry and is added continuously to the stock at a rate controlled by the opacity meter that operates at the reel-up. The time delays in the system necessitate a rather complex control arrangement, but results to date have been promising.

The W.T. continuous formation meter

WHAT is meant by formation? The chances are that good formation does not mean exactly the same to you as it does to your neighbour.

If a light shines through a small hole and a web of paper is passed across this hole, the percentage of the light passing through from moment to moment will vary. Fig. 10 illustrates the type of record that could be obtained. The mean level (broken line) about which the rapid variations occur is determined by the opacity of the sheet. The opacity meter measures this mean level, whilst ignoring the rapid changes.

A study of traces of this kind, using wave analysis and correlation factor techniques, has shown that opacity variations depending on the formation do not show much evidence of resonance in fine papers. The distribution of light and dark areas is very nearly random, even in papers with apparently regular patterns. Formation measurement can be largely covered by a single figure and a convenient measurement is the peak modulation of the light transmitted.

Fig. 11—The W.T. formation meter measuring head and control unit

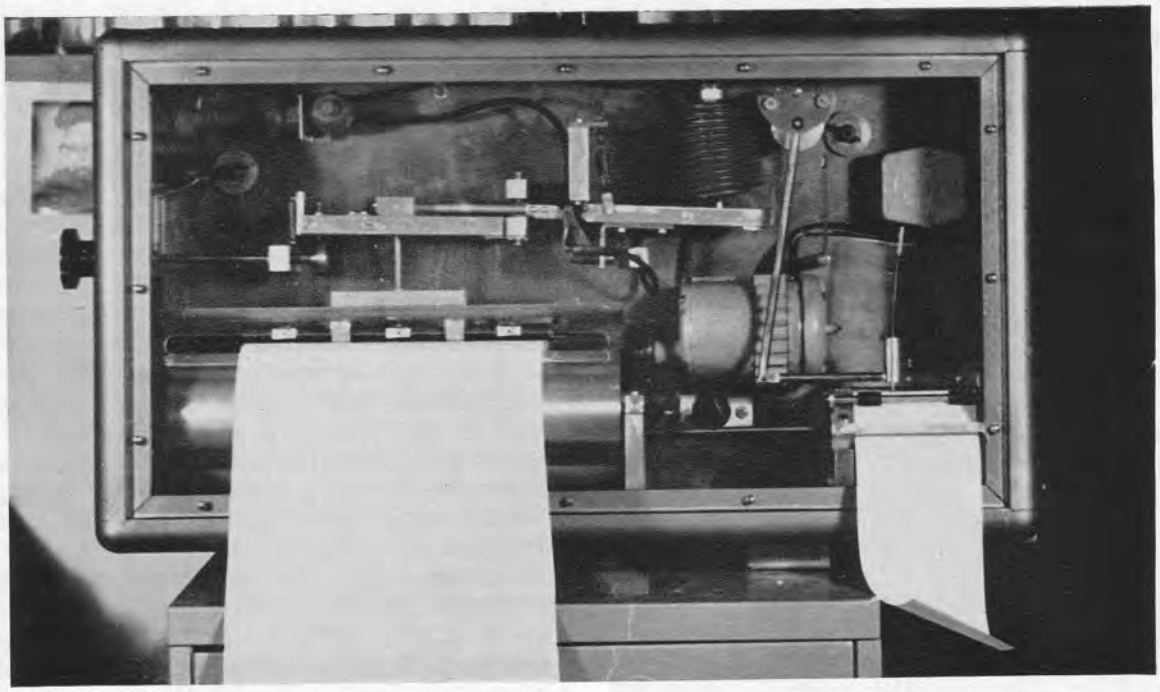


Fig. 12—Thickness profiler

The figure must be expressed as a percentage of total transmission, otherwise thick papers with good formation would give similar figures to those for less opaque papers with bad formation as usually judged by eye.

The W.T. formation meter directs a beam of light from a source whose brightness is automatically controlled, through the sheet under examination, then through a window of appropriate size on to a photo-multiplier cell. The mean level of the response is used to control the lamp brightness, so this response level is held steady regardless of opacity changes. As the paper moves, the output of the cell will vary as light and dark patches pass the window and this varying voltage is measured on an a.c. valve voltmeter. In other words, the formation meter measures the rapid fluctuations, whilst maintaining the general level constant.

The window diameter can be chosen to suit the type of formation to be measured. Small windows show up the finer structure and give higher readings. Sizes 1 mm.–3 mm. diameter have been usual, but there is no great advantage in either extreme and 1 mm. diameter is now commonly used. The use of even smaller windows reduces the light to the cell and the signal is comparable with background noise in the cell unless specially selected components are used.

Fig. 11 illustrates the control unit and a standard measuring head arrangement. The measuring heads are similar in appearance to the opacity meter heads and are mounted so that the paper runs in light contact with the camera head. The control unit includes a meter that gives warning of incorrect head alignment or excessive flapping of the paper. The sensitivity of the unit may be adjusted to suit the opacity of the papers being measured and so let the lamp run over a convenient range of voltage. It is usual for one setting to suffice for all papers made on one machine. The instrument has three switchable ranges scaled 0–10, 0–20, 0–50 per cent. peak modulation and the record is in the form of a deviation trace ranging 5 per cent. on either side of a chosen level.

Formation meters have proved invaluable on some machines and are often useful investigational tools; however, some papers of the very wild, rag-based type can vary in appearance without change in reading.

One machine making special grades of paper has formation meters at both wet and dry ends. Another well-known machine has automatic refiner control in a feedback loop from the reel-up formation meter.

The W.T. thickness profiler

THIS instrument is extremely simple in principle, but, like many simple conceptions, it required considerable development before a satisfactory production model was available.

This thickness profiler is intended for permanent wall mounting or it may be mounted on top of a substance profiler in order to conserve effort in the quality control department.

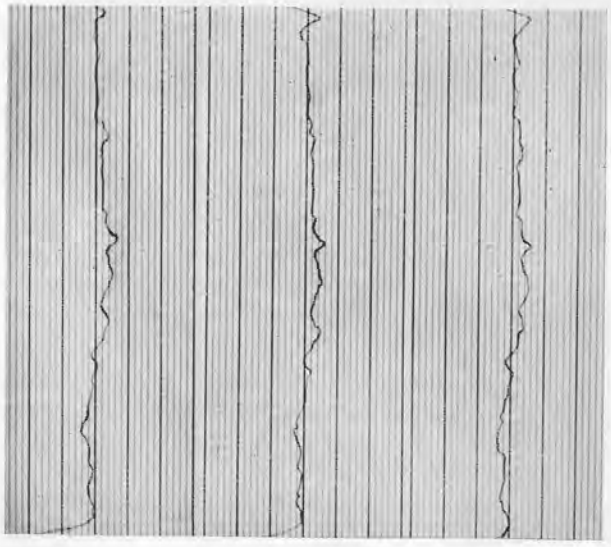


Fig. 13—Three traces by passing the same sample through the instrument three times—each small division represents 0.0001 in. change in thickness

Fig. 12 shows the instrument. The method of use is to feed a cross-machine strip into a slot at the left side of the case. The sample is guided throughout its passage by curved plates and emerges from a slot beneath the instrument. As the sample passes through, a strip chart record is drawn and this is available at a slot at the right side. The record is one of variations about an unknown thickness value, which must be determined separately, if required. Fig. 13 demonstrates the reproducibility of the instrument. It must be remembered that it is almost impossible to traverse exactly the same part of the sample in each case.

The profiler requires an electricity supply for its drive motor and a clean air supply within 8–80 lb./sq. in. pressure. The principle of operation is illustrated in Fig. 14. The specimen is drawn between pairs of anvils. The lower anvils are fixed and the upper anvils can move in a vertical direction only. This movement is imparted to a beam carrying a plate, which interrupts the flow of air between two nozzles. The pair of nozzles is carried by a second beam, the position of which is controlled by a pair of bellows. As the bellows are fed by air that has crossed the gap between the nozzles, the system is self-balancing. Hence, the second beam follows accurately the movements of the first beam. A light metal ribbon is attached to the end of the second beam and passes over a drum carrying an articulated pen arm. The total mechanical magnification is 1 000, so that 0.0001 in. change in paper thickness gives rise to a pen movement of 0.1 in.

The record is produced at one tenth of the feed rate for the sample. The nominal feed rate is either 1 in./sec. or 2 in./sec. The lower speed is intended for use in conjunction with a substance profiler; however, it is not always easy to make the two instruments work together for some types of paper.

In order to ensure ease of operation with thin tissues, it has been found desirable to produce a version with a belt feed and this system gives little trouble. This version is further modified to give a magnification of 5 000:1. The instrument has been very successful and at least 17 are in use at the present time.

Acknowledgements

As previously acknowledged, this paper owes a great deal to the work of Mr. R. Gladstone of Wiggins, Teape & Co. Ltd. I should like to thank also many of the technical staff in my company for their contributions in connection with the Shirley meter work: in particular, I am indebted to Mr. C. A. Chester of Hylton Mill and Mr. W. F. E. Robinson of Chartham Mill.

Finally, I wish to thank the Directors of Wiggins, Teape & Co. Ltd. for permission to present the paper.

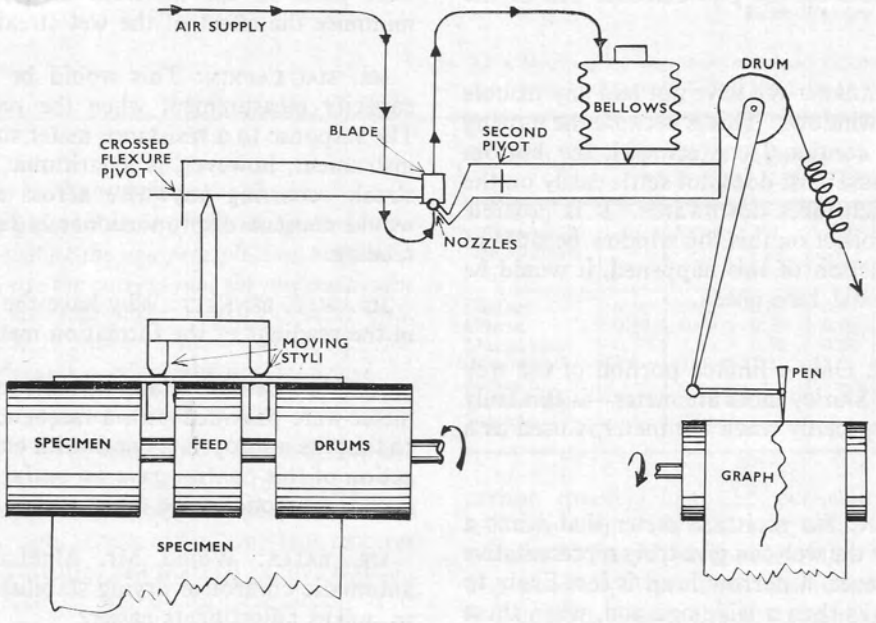


Fig. 14—The principle of the W.T. pneumatic thickness profiler

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discussion

MR. H. R. W. MARSH: Has any trouble been experienced with dust on the photoelectric cell of the opacity meter?

MR. M. I. MAC LAURIN: We have not had any trouble from dust on the windows. This is because the moving paper web is in continual contact with the bottom window and because dust does not settle easily on the top window, which faces downwards. It is possible that dust might collect on this top window because of electrostatic attraction; if this happened, it would be apparent at the next zero check.

MR. F. CHURCH: Only a limited portion of the web is scanned by the Shirley moisture meter—is this truly representative, especially when the meter is used as a controller?

MR. MAC LAURIN: No moisture meter that scans a limited portion of the web can give truly representative indications; however, a narrow head is less likely to pick up wet streaks than a wide one and, when these streaks do occur under the electrode, the effect is extremely obvious. If necessary, a limit warning device could be fitted in the system to cope with this eventuality.

MR. B. W. BALLS: If a wide measuring electrode were used on the moisture meter, would not this minimise the effect of the wet streak?

MR. MAC LAURIN: This would be the case with a capacity measurement when the response is linear. The response to a resistance meter such as the Shirley instrument, however, is logarithmic and a small wet streak occurring anywhere across a wide electrode would cause a disproportionately large effect in the reading.

MR. W. E. BENNETT: Why have the cyclic variations in the readings of the formation meter been ignored?

MR. MAC LAURIN: Early models of the formation meter were provided with a frequency selector device so that the appropriate bandwidth could be used. The action of this control gave no useful effect and it was found in practice to be unnecessary.

MR. BALLS: Would Mr. MacLaurin agree that automatic control of drying stabilises conditions and so makes adjustments easier?

MR. MAC LAURIN: Yes, I would entirely agree with you, provided great care is taken to eliminate integral effects at start-up and other such troubles.

Corrosion-resisting steels for papermaking plant

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GIVEN AT A MEETING OF WESTERN DIVISION: COUNTY HOTEL, TAUNTON ON 23rd OCTOBER 1959, MR. L. A. LAWRENCE IN THE CHAIR

Synopsis

A description is given of some of the many corrosion-resisting steels, including the new precipitation hardening types. How to choose the correct type for any particular application in the pulp and paper industry is dealt with. Welded fabrication is much applied and affects the choice of steel. Various applications are described.

Introduction

THE first point to be emphasised is that there are many different analyses of corrosion-resisting steels and it is most important to choose the correct analysis for any particular job. Even today, one still receives many letters and drawings just marked 'stainless steel', not giving any idea of the quality required. It is important in the first place to choose a quality that will stand up to the corrosive conditions anticipated and, secondly, a quality suitable for the chosen methods of fabrication. As much of the corrosion-resisting plant made today has to be fabricated by welding, it is necessary to consider whether a particular steel is or is not suitable for welding. This point will be borne in mind in the subsequent discussion on different steels.

Martensitic and ferritic steels

THE group of steels usually referred to as the martensitic and ferritic types is shown in Table 1. It will be noticed that all these steels contain a substantial percentage of chromium, as it is the chromium in the main that imparts the resistance to corrosion. The first steel is a low carbon, 13 per cent. chromium steel; but, even with the carbon at only 0.10 per cent., this steel is fairly strongly air-hardening and it is therefore not particularly suitable for welding. The same remarks apply to the second steel, which, as well as containing 13 per cent. chromium, has sulphur and molybdenum added to improve the machining properties: this steel is therefore supplied mostly in the form of bars and rods. The third steel (a low carbon quality) has 12.5 per cent. chromium and 0.07 per cent. carbon and, with this low carbon content, it is suitable for welding. The next steel has also about 0.25 per cent. aluminium added and this is claimed to lessen the air-hardening tendency of the steel, so helping to make it more suitable for welding. With both these steels, however, it is desirable whenever possible to give a tempering treatment after welding in order to soften the hardened zones and to relieve internal stresses. The F.G. quality with its higher carbon content is more strongly air-hardening and can be given a variety of mechanical properties by suitable heat treatments. Owing to its air-hardening characteristics, it is not suitable for welding. The low carbon, 17 per cent. chromium steel finds extended application in decorative trim for motor cars. It is not very suitable for welding, however, as this operation lowers the resistance to corrosion. The last steel in this table is made to meet a specification 2S.80 and it is a particularly useful steel with very good mechanical properties and rather higher resistance to corrosion than the other steels shown in this table, though it is strongly air-hardening and therefore not recommended for welding.

TABLE 1—TYPICAL ANALYSES OF MARTENSITIC AND FERRITIC STEELS

Contents of the elements, %	*F.I.*	*F.C.I.*	*F.I. (low carbon)*	*F.I. (A1)*	*F.G.*	*F.I.17*	*S.80*
Carbon	0.10	0.12	0.07	0.07	0.25	0.06	0.16
Silicon	0.30	0.60	0.30	0.70	0.30	0.30	0.30
Manganese	0.50	1.30	0.50	0.50	0.50	0.80	0.50
Chromium	13.0	13.0	12.5	12.5	13.0	17.0	16.50
Nickel	—	—	—	—	—	—	2.50
Molybdenum	—	0.28	—	—	—	—	—
Sulphur	—	0.23	—	—	—	—	—

Austenitic steels

TABLE 2 gives some of the austenitic corrosion-resisting steels and it will be noticed that these all contain approximately 18 per cent. chromium, also a

substantial percentage of nickel. This combination of chromium and nickel entirely alters the constitution of the steels compared with those in Table 1. On cooling from a high temperature, these steels do not change from the austenitic to the ferritic condition like other steels, but remain austenitic and, therefore, non-magnetic. The first steel is the one known throughout the world as 18/8 steel. The welding of this steel is usually carried out only when the corrosive conditions are not severe and on thin sections.

Not long after the 18/8 steels were introduced in 1924, it was found that adjacent to welds there was a belt of material susceptible to corrosion. Research into this problem showed that the trouble was due to the formation of chromium carbides, particularly near the boundaries of the crystal grains. The chromium carbide formed has an analysis approximating to Cr_4C, which means that a small amount of carbon can lock up a large percentage of chromium and make it useless for imparting corrosion resistance. This results in chromium impoverishment at the grain boundaries and therefore a lower resistance to corrosion. If such a steel in this condition is subjected to corrosive conditions, intercrystalline corrosion may occur, examples of which will be shown later. There are two ways of getting over this: the first is by lowering the carbon sufficiently to prevent the formation of the chromium carbide and the second is to add a strong carbide-forming element that will form carbides in preference to the chromium.

TABLE 2—TYPICAL ANALYSES OF AUSTENITIC CORROSION-RESISTING STEELS

Content of the elements, %	*F.S.T.*	*F.D.P.*	*F.S.L.*	*F.C.B.*	*F.M.B.*	*F.M.B.Ti*
Carbon	0.08	0.08	0.05	0.08	0.07	0.07
Silicon	0.60	0.80	0.60	0.60	0.30	0.30
Manganese	0.80	0.80	0.80	0.80	1.5	1.5
Chromium	18.0	18.0	18.25	18.0	17.75	17.75
Nickel	8.75	9.0	10.0	9.0	10.0	10.0
Titanium	—	0.50	—	—	—	0.30
Niobium	—	—	—	0.85	—	—
Molybdenum	—	—	—	—	2.75	2.75

In the 18/8/Ti steel, titanium has been added to prevent the formation of chromium carbides and to make the steel safe against intercrystalline corrosion. In order to be effective, the titanium should contain at least four times the carbon content. In the 18/8/Nb quality, niobium is used as the stabilising element, but it is not so potent as titanium and the niobium should be ten times the carbon content. In the very low carbon quality, we have an 18/10 steel with carbon 0.05 per cent. maximum and it is safe at this carbon content to use the steel in the 'as welded' condition. During welding, the time in the dangerous range of temperature is not long enough to cause trouble. It is not recommended for use at elevated temperatures, however, as this would give time for carbides to form with subsequent susceptibility to intercrystalline corrosion. The four steels on the right of the table all contain molybdenum, which in general increases the resistance of these steels to corrosion. They are all suitable for welding and, because of this combination of properties, they find extended application in the pulp and paper industries in Canada, the Staybrite F.M.B. and F.M.B.Ti. types being used for digesters both in the sulphite and sulphate processes.

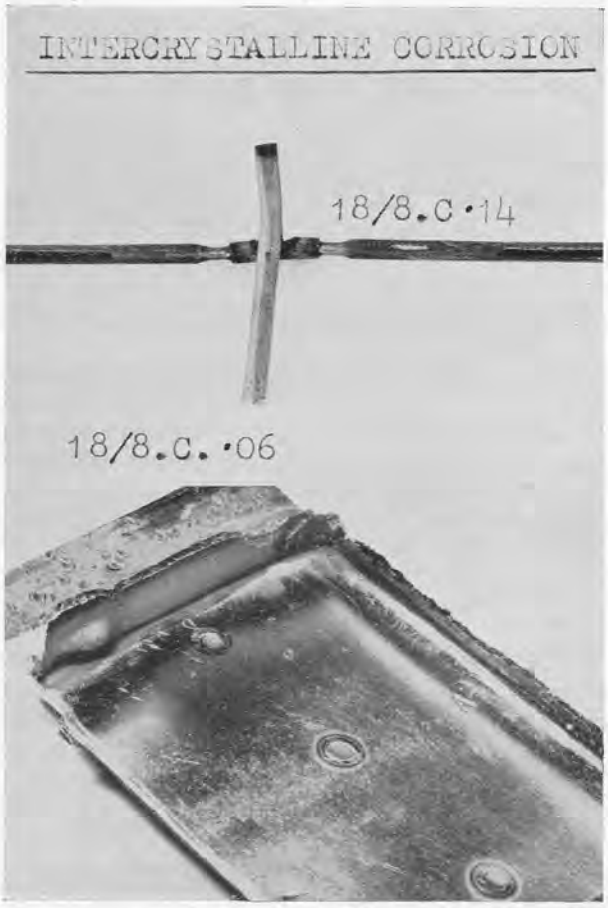

Fig. 1 *(above)* and ***Fig. 2*** *(below)*

Fig. 1 shows the failure of some 18/8 steel wires used in a pickling basket. These wires had been

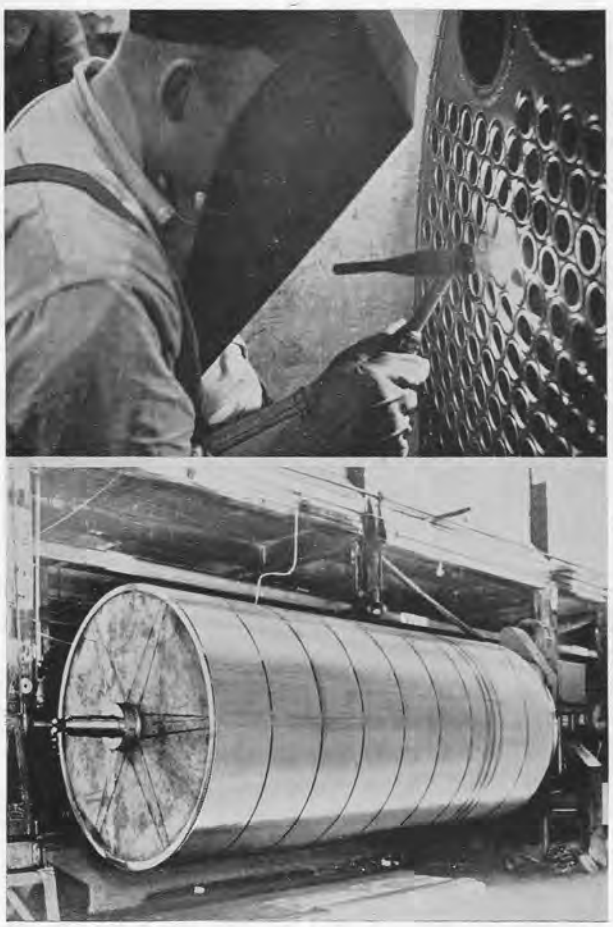

Fig. 3 *(above)* and ***Fig. 5*** *(below)*

joined by electric resistance welding and one of the wires showed severe corrosion on either side of the welded joint, whereas the other wire was unaffected. A check of the carbon content of the wires showed that the unaffected wire contained only 0.06 per cent. carbon, whereas the corroded wire contained 0.14 per cent. carbon. Fig. 2 shows part of a small dye tank that failed because of intercrystalline corrosion. The corrosive conditions were such that the F.M.B. quality was required and, in fact, this sheet was used for the back of the tank, but the two adjoining sheets were plain 18/8 steels. As can be seen, they had failed by severe intercrystalline corrosion adjacent to the welds. This underlines the importance of choosing a suitable welding quality of stainless steel, when using welded fabrication.

In Table 3, showing physical and mechanical properties, probably the most important items are thermal conductivity and coefficient of thermal expansion. The thermal conductivity is rather lower than for ordinary mild steel, whereas the coefficient of expansion is about 50 per cent. greater than that of mild steel. In the section giving mechanical properties, it will be noted that both the yield point and maximum stress are somewhat higher than for mild steel. The high elongation and reduction of area show that these steels are all very ductile.

Welded fabrication

FABRICATION by welding is of primary importance and the process that has made greatest strides in recent years is the argon arc welding process. In this process, the welding arc is between a thoriated tungsten electrode and the work to be welded. Both the electrode and the work are protected by an annular stream of the inert gas argon. Fig. 3 shows a heat exchanger in which the 18/8/Ti seamless tubes are being argon arc welded to the tube plate. Before welding, an annular groove was machined round each hole in the plate in order to leave a land of thickness approximately equal to the wall thickness of the tube. This method makes the welding of the tubes into the tube plate easier.

Argon arc spot welding is now being used when two thicknesses of steel have to be welded together, particularly on assemblies where it is not possible to

TABLE 3—PHYSICAL AND MECHANICAL PROPERTIES OF AUSTENITIC STAINLESS STEELS

Property	*F.S.L.*	*F.S.T.*	*F.D.P.*	*F.C.B.*	*F.M.B.*
Specific gravity	7.93	7.93	7.9	7.93	7.96
Specific heat	0.12	0.12	0.12	0.12	0.12
Thermal conductivity at 20°C (c.g.s. units)	0.038	0.036	0.038	0.038	0.039
Electrical resistivity at 20°C (microhms/cm.³)	70	72	73	72	78
Coefficient of thermal expansion 20–700°C	0.000019	0.000019	0.000019	0.000019	0.000019
Permeability (soft condition)	1.005 to 1.03	1.005 to 1.03	1.5 to 2.0	1.005 to 1.03	1.005 to 1.03
Mechanical properties—					
Yield point, tons/sq. in.	15	18	18	17	18
Maximum stress, tons/sq. in.	40	40	42	41	40
Elongation, %	60	50	45	58	50
Reduction of area, %	65	50	50	65	50
Brinell hardness	160	170	180	175	180

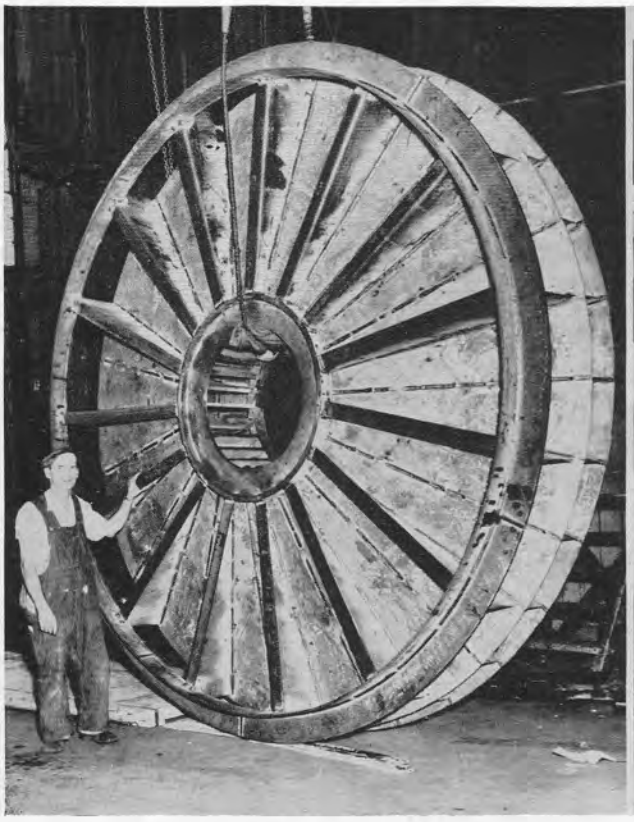

Fig. 4

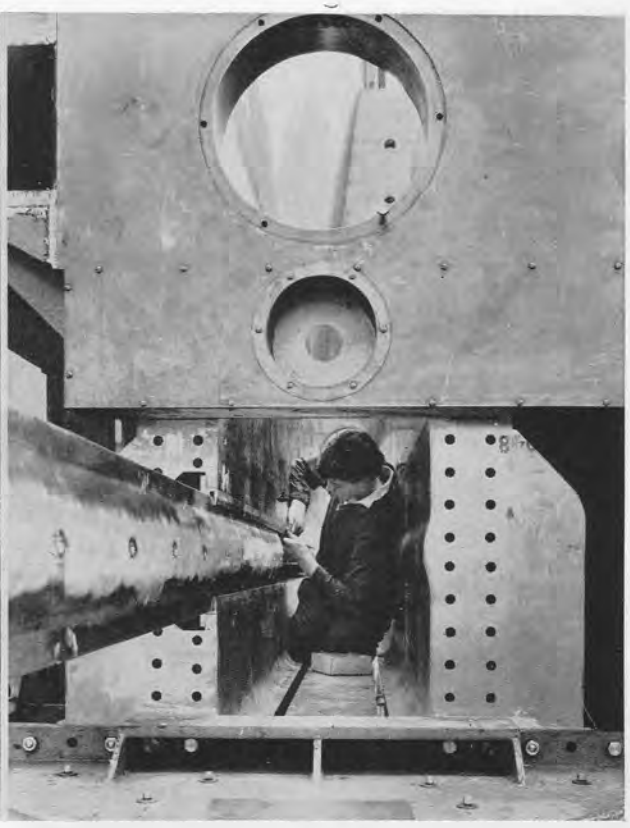

Fig. 7

use electric resistance spot welding. Shielded inert gas metal arc (SIGMA) welding uses as an electrode a consumable wire of the 18/10/Nb or 18/10/Mo types.

The pulp and paper industry in Canada has for many years made considerable use of corrosion-resisting steels. For the more corrosive conditions, they use A.I.S.I. type 316 steel, which is an 18/10 steel containing molybdenum. Fig. 4 shows a metal arc welded fabrication made in Canada from British type 316 steel. It is the centre drainage section of a vacuum filter and can be used either as a washer for removing bleaching chemicals from pulp stock or for thickening stock by removal of water. It is 11 ft. 6 in. in diameter and made from $\frac{1}{4}$ in. plate on the inner sections and $\frac{3}{16}$ in. thick plate on the facing. It was welded in Canada using molybdenum bearing electrodes. These electrodes are designed not only to give a strong weld, but also to produce a weld that is equally as resistant to corrosion as the parent plate.

In Canada, type 316 steel has been used for the linings of digesters in both sulphate and sulphite mills. The pulp is also conveyed by type 316 pipes welded from sheet and with flanges made from this same quality.

The author's company is now making centrispun castings in 18/10/Mo steel, used as flanges for the pipelines conveying pulp. These taft rings have the advantage that, being machined from centrispun castings, they do not leave any nick in which pulp may lodge and afterwards produce lumps in the stock. These centrispinnings normally range 4–18 in. in diameter. The L-sections are parted off from 'pots' and compare favourably for price with the pressed out type and have a further definite advantage, because, even with the most careful pressing, there is always a nick in which pulp may lodge.

An open type gravity mould made in Canada from type 304 (18/8, low carbon) steel is as shown in Fig. 5. The diameter is 6 ft. 6 in. and the length of face 14 ft., the end being made from $\frac{3}{8}$ in. thick plate. This is a completed unit, showing perforated plate covered by fine mesh 18/8 steel wire cloth and 18/8 banding wire.

TABLE 4—F.V.520(B) STEEL

Typical analysis, %	C 0.06	Si 0.35	Mn 0.80	Cr 15.0
	Ni 5.5	Mo 1.5	Cu 1.5	Nb 0.3
Physical properties—				
Structure	Martensitic			
Melting point (approximate)	1 435°c			
Specific gravity	7.80 (= 486 lb./cu. ft.)			
Modulus of elasticity (tons/sq. in.)	13 000			
Thermal conductivity (c.g.s. units)	At 50°c, 0.038			
	At 450°c, 0.055			
Electrical resistivity, microhm-cm.[3]	At 20°c, 85			
Coefficient of thermal expansion 20–100°c	0.000012			
Coefficient of thermal expansion 20–300°c	0.000013			
Coefficient of thermal expansion 20–500°c	0.000013			
Magnetic properties—	Magnetic			
Induction B for H = 250	10 500			
Permeability	110			
Typical mechanical properties ON ROLLED BAR MATERIAL UNLESS OTHERWISE STATED	*Over-aged 620*	*Over-aged 560*	*Precipitation hardened*	
0.1% proof stress, tons/sq. in.	40	56	68	
Maximum stress, tons/sq. in.	60	65	85	
Elongation, %	25	25	15	
Reduction of area, %	60	60	50	
Izod impact, ft. lb.	80	75	25	
Brinell hardness	290	310	380	
Fatigue limit, tons/sq. in. (100 000 000 reversals of stress, unbroken)	38	36	40	
Heat treatment—				
Hot working	Start 1 150°c Finish 950°c			
Overaged 620	A.C. 1 000°c + 2 hr. 750°c; A.C. + 1 hr. 620°c			
Overaged 560	A.C. 1 000°c + 2 hr. 750°c; A.C. + 2 hr. 560°c			
Precipitation hardened	A.C. 1 000°c + 4 hr. 450°c			
Maximum service temperature	500°c			
Welding properties	Good			
Machining properties	Good			
Pressing or forging properties Cold	Poor			
Pressing or forging properties Hot	Good			

TABLE 5—F.V. 520 (S) STEEL—TENSILE TESTS ON ARGON BUTT WELDS

Procedure	*Yield point*	*Maximum stress*	*Elongation, % on 2 in.*	*Elongation, % on 2 in. including weld*	*Position of fracture*
Weld + 550°c A.C.	39.8	60.7	8	24	Weld joint line
Weld + 2 hr. 700°c A.C. + 2 hr. 15°c + 1 hr. 550°c A.C.	64.0	68.2	11	8*	½ in. from weld

* Mean of two tensile tests with weld metal at mid-gauge length

Beater bars are made from 18/8/Ti steel, bright cold-rolled to Brinell No. 300–360. This can be increased to 360 minimum Brinell by tempering at 400°c for 2 hr. The cold-rolled bars stand up much better to wear than the soft bars, which have a Brinell of only about 180. Bulb section beater bars are also bright cold-rolled. Sutherland refiner discs in 18/8 steel also stand up well to wear and corrosion.

Fig. 6 shows a papermachine flow box in which the mild steel and cast iron parts have been covered throughout with 18/8/Ti steel sheet. Fig. 7 shows another part of the flow box during assembly.

The steel beams covered with 18/8/Ti steel sheets, using welding, are shown in Fig. 8. These beams support the Fourdrinier wire section. 18/8 Fourdrinier wires have been tried instead of bronze, but the wear on the plastic tops of the suction boxes was too high

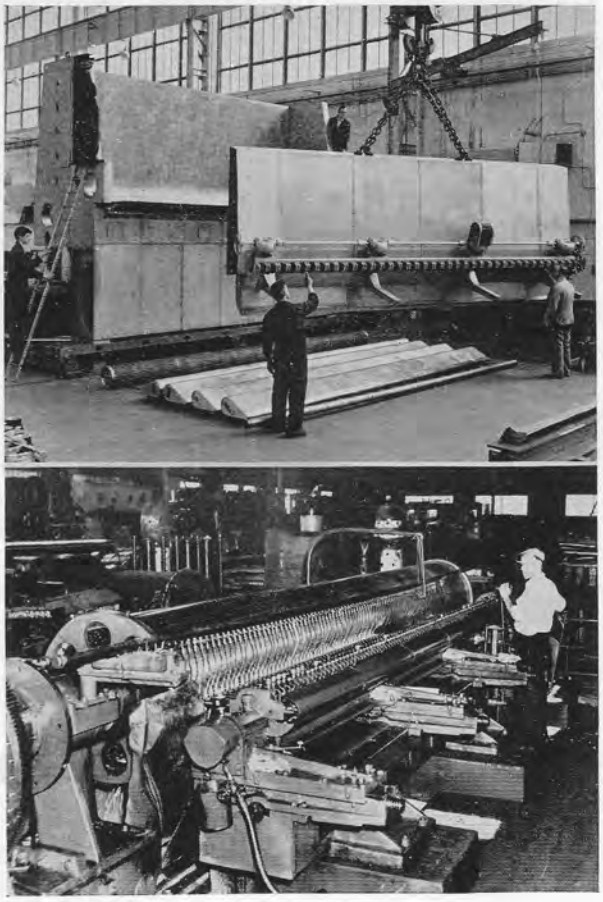

Fig. 6 *(above)* **and** ***Fig. 9*** *(below)*

and there was wear also on the bronze rolls. Suction boxes are now made from 18/8/Ti steel.

Fig. 9 shows an F.C.S. stainless steel suction roll supplied to Canada. One of the largest of these rolls was, for example, 40 in. outside diameter, 35½ in. bore and 280 in. long. The Brinell hardness is 200–250. Similar papermill rolls have been made in type 316 (18/10/Mo steel).

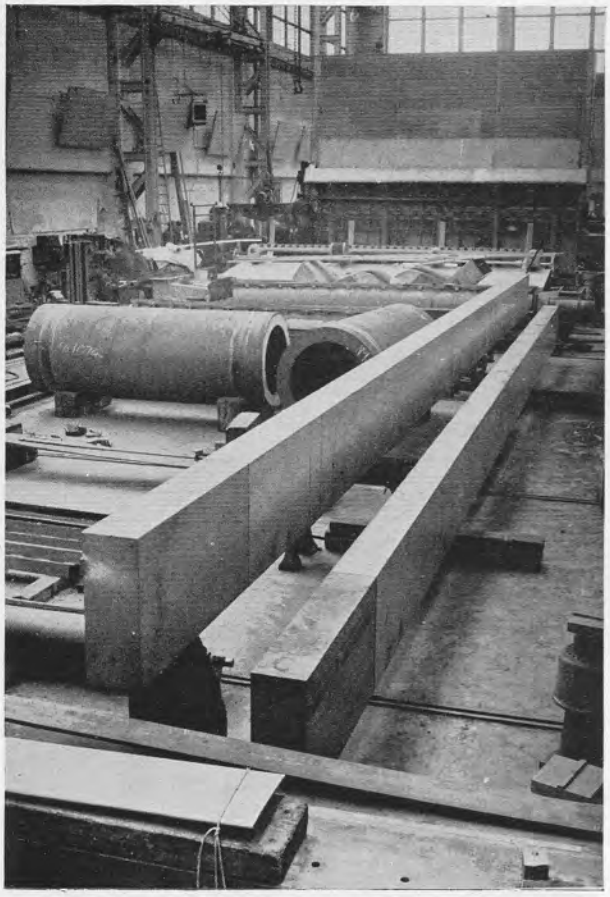

Fig. 8

High tensile precipitation hardening steels

FOR many years, there has been a demand for a steel with corrosion resistance equal to the 18/8 types, but with better mechanical properties. This has now been achieved by the production of F.V.520(B) steel (details in Table 4). This is a precipitation hardening steel and the full treatment to give the best mechanical properties is given in this table. Another attractive feature of F.V.520(B) steel is that it can be welded without risk of cracking or undue hardening adjacent to the weld.

F.V.520(S) in the form of sheet and strip may be supplied in the soft austenitic condition for forming and has a slightly different composition from F.V.520(B). Tensile tests on argon arc butt welds are shown in Table 5. The sheet used for these tests was 12 s.w.g. and has been heat-treated by air cooling from 1 050°C, followed by 2 hr. at 700°C and air cooling. The filler wire was also F.V.520(S) steel and the results of post-weld heat treatment can be seen in the table.

Summary

CORROSION resisting steels have for over 30 years played an important part in the production of paper and board. For the more onerous conditions such as sulphite digester parts, the 18/8/3Mo steels are used, while the 18/8/Ti steel meets the requirements for general welded fabrication. The free-machining type of 13 per cent. chromium steel has recently found extensive use in hollow forged suction rolls. The new precipitation hardening steels can be used when high tensile strength is needed.

The use of non-numerical data

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Wiggins Teape Group Research Organisation

GIVEN AT THE STATISTICS SYMPOSIUM: OXFORD CORNER HOUSE, LONDON, W.1
ON 29th FEBRUARY 1960, Mr. A. F. TOUT IN THE CHAIR

Introduction

WE want to start this talk with a very simple question—why do people prefer one paper to another? In particular, why does the customer prefer one paper to another?

There will be many answers to this simple question. Typical answers are—

'I like the colour.'
'Because it is glossy.'
'Because it feels right.'
'Because it is free of odour.'
'Because it rattles.'
'It gives me better prints.'
'It is clean.'

All these reasons are based on the effect the paper has on one or more of the physical senses. These are subjective properties and, in view of their importance, it is surprising that so little work that has involved subjective assessments has been done in the paper industry.

It is our intention to present a number of cases in which we have used subjective data to illustrate how rewarding this type of work can be and, at the same time, to present some of the difficulties we have experienced for discussion by the following speaker.

Observers

ALL subjective assessments involve the use of observers. It is most important to ensure that the observers used are truly representative of the population concerned. It must be decided whether the people in whom you are ultimately interested have any particular training or ability that is likely to bias their group assessment. If so, whenever possible, observers from this population should be used for the assessment; if impossible, a correlation should be investigated between the observers who will do the subsequent assessments and the people in whom you are ultimately interested.

There are two other principal considerations—

1. The number of observers should be as large as possible. This is because, firstly, a single observer is liable to be biased; two observers' combined result is, on the average, less biased; generally, the more observers there are, the less bias in the final result.
2. There should be a high level of agreement in their assessment of samples being considered. This is also common sense. Unless the observers agree as a whole, we are not justified in taking their combined opinion.

To take a specific example, we were at one time very interested in selecting the most suitable glossmeter for measuring the gloss of art papers. It was most convenient to use people from our research laboratory as observers; at the same time, it was recognised that all assessments of gloss up to that time had been made by people in our coating mill and it was decided that it was their opinion that should be accepted.

In Tables 1 and 2 are the rankings that were given to a set of papers by the mill and by the laboratory people. By inspection of these tables, one would feel tempted to conclude that the mill observers were in better agreement in the ranking of the samples than were the laboratory observers. We wanted some statistical test that would confirm this. There is the statistical coefficient of concordance, which can be used as a measure of the degree of agreement among observers and the magnitude of this coefficient is therefore given with each table.

The coefficient of concordance

IT can be seen that the coefficient of concordance is high in both cases, indicating that a high level of agreement existed between members of each group. Unfortunately, however, Kendall[1] states that the coefficient of concordance cannot be used to decide which group of observers is in best agreement.

TABLE 1—RANKING OF 10 PAPERS FOR GLOSS BY 7 COATING MILL OBSERVERS

Paper	Ranking									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
	Most gloss									*Least gloss*
D	7	–	–	–	–	–	–	–	–	–
J	–	7	–	–	–	–	–	–	–	–
H	–	–	4	3	–	–	–	–	–	–
F	–	–	3	4	–	–	–	–	–	–
E	–	–	–	–	4	3	–	–	–	–
C	–	–	–	–	3	4	–	–	–	–
G	–	–	–	–	–	–	6	1	–	–
A	–	–	–	–	–	–	1	6	–	–
B	–	–	–	–	–	–	–	–	7	–
K	–	–	–	–	–	–	–	–	–	7

Coefficient of concordance, $W = 0.985$

TABLE 2—RANKING OF 10 PAPERS FOR GLOSS BY 7 LABORATORY OBSERVERS

Paper	Ranking									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
	Most gloss									*Least gloss*
D	6	1	–	–	–	–	–	–	–	–
J	–	4	3	–	–	–	–	–	–	–
H	1	–	3	3	–	–	–	–	–	–
F	–	2	1	4	–	–	–	–	–	–
E	–	–	–	–	3	3	1	–	–	–
C	–	–	–	–	4	2	1	–	–	–
G	–	–	–	–	–	2	5	–	–	–
A	–	–	–	–	–	–	–	7	–	–
B	–	–	–	–	–	–	–	–	5	2
K	–	–	–	–	–	–	–	–	2	5

Coefficient of concordance, $W = 0.955$

We followed up this difference, however, to find that the reasons for what we believed was a better agreement among the mill observers was because they all examined the paper in the same way. This was a most important conclusion and explained subsequently why one of the glossmeters was the best for our purposes.

Combining the rankings by observers

So far we have dealt with the degree of agreement between a group of observers. Not only is it important that the observers should agree among themselves, but that collectively they should agree with the people in whom you are ultimately interested.

There is another statistical coefficient that can be used when two sets of ranks are to be compared—Spearman's rank correlation coefficient.

One of the problems that we have found, however, is deciding what rank we should use. Consider the results in Table 3, which were obtained when 20 observers ranked papers for gloss. It is immediately apparent that the rank totals for the second and third papers are very nearly equal. Should we then rank these equally at $2\frac{1}{2}$ each or as 2 and 3? The former method appeals intuitively, since it preserves the information that these papers are very close together, but, if so, how far apart should these rank totals be before the papers can be regarded as different?

The example we have given here of gloss assessments is just one of a number of similar cases that we could describe in detail. We have done the same when we have been investigating print quality assessment and when we have compared our assessments of mottle with those of our customers. Results of these investigations have always been rewarding, but we have encountered the same difficulties in each case: we cannot attach any significance to the relative degrees of agreement of two groups of observers and we are unable to put any precision to a rank.

Mean ranks

IT is interesting to note that other experimenters using subjective assessments, in particular Maynard and Newman[2] and Poulter,[3] have used mean ranks.

Mean ranks also appeal intuitively, since they preserve the information that papers are very close together; however, the question of significant difference still remains.

There is another problem too. If two sets of mean ranks are to be correlated, should one use a rank correlation or correlation in the normal variate sense?

TABLE 3—RANKING OF 10 PAPERS FOR GLOSS BY 20 OBSERVERS

Paper	Ranking										Rank totals
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	
H	8	8	3	1	–	–	–	–	–	–	37
D	8	3	7	–	1	1	–	–	–	–	46
J	3	8	8	1	–	–	–	–	–	–	47
F	1	1	–	10	6	1	1	–	–	–	86
E	–	–	1	6	8	5	–	–	–	–	97
G	–	–	1	–	4	12	2	1	–	–	117
C	–	–	–	2	–	1	16	1	–	–	134
A	–	–	–	–	1	–	–	17	1	1	160
B	–	–	–	–	–	–	–	1	12	7	186
K	–	–	–	–	–	–	1	–	7	12	190

Use of standards

WE have found it a very useful technique in many instances to use a number of standard papers, ranging from good to bad in our assessments. To take a specific example, a mottle can occur when some of our paper is coated. The only satisfactory way of evaluating paper for this property is to coat it and rank the coated papers for mottle. The coating operation itself is variable. By this, we mean that, although papers are consistently placed in the correct order from coating to coating, the best paper coated on one occasion could appear as bad as the worst paper coated on another. Thus, it is impossible by direct visual inspection to compare papers that have been coated on separate occasions.

It is most important that we should be able to compare papers coated on different occasions, so that a large number of results can be used when we are trying to assess the effect of papermaking variables on the degree of mottle. We have overcome this difficulty to a certain extent by the inclusion in each coating of 5 standard papers that range from good to bad. This provides us with a 'mottle thermometer', having five graduations on its stem. This is a distinct improvement on no thermometer at all.

There are, however, quite a number of problems in the use of this simple device. Firstly, we do not know that the standards are equally spaced—in fact, by examination of the papers, we feel that the best two are close together and that the worst two are relatively far apart. Secondly, although we know that from coating to coating these papers are ranked in the same order, we are not certain that the spacing of the standards remains constant. This could be important, since a paper could be ranked between standards 1 and 2 in one coating and between 2 and 3 in another. Generally, we work on the assumption that the paper we are examining is variable and that the standards are fixed; in fact, the reverse could well be the case.

Another important difficulty arises when we wish to compare two papers that have been ranked on different occasions between two standards. There are several cases that can arise, some of which we are presenting here (Table 4).

TABLE 4—RANKING OF 5 COATINGS BY 1 OBSERVER

Paper	*Coating*					*Rank totals*
	1	*2*	*3*	*4*	*5*	
A	1	1	2	2	1	7
X	2	2	1	1	2	8
B	3	3	3	3	3	15
A	1	1	1	1	1	5
Y	2	3	2	3	2	12
B	3	2	3	2	3	13
A	1	1	1	1	1	5
L	2	2	2	2	2	10
B	3	3	3	3	3	15

In this example, A and B are fixed standard papers; X, Y and L are papers we wish to compare. The results given are the rankings obtained by coating these papers with the standards on 5 different occasions.

Using common sense, it would seem that X is indistinguishable from A, but is clearly distinguishable from B, Y is indistinguishable from B, but is distinguishable from A. Since L is clearly distinguishable from A and B, the relative order of merit of these papers is X, L, Y. We do not know, however, if L is nearer to X than it is to Y.

To calculate the positions of X, Y and L, we have given A the value 1, B the value 2 and estimated the relative values of X, Y and L from the following formula—

$$X = 1 + (R_X - R_A)/(R_B - R_A)$$

where R_B, R_A, R_X are the rank totals of B, A and X, respectively. We know of no justification for doing this, but it is important that some relative assessment should be possible. It is impossible to make any comparisons at all when there is no confusion of the papers with the standards. This leads us to the important conclusion that the standard papers should be close together.

We have been stressing the difficulties we have experienced in the use of standards. We should like to emphasise that the advantages of using standards far outweigh the disadvantages.

Apart from the specific case mentioned, a range of standards has been used to define unsatisfactory defect levels for salle inspection schemes and for print quality evaluation.

The correlation of a subjective assessment with the results obtained with an instrument

NUMEROUS cases have arisen when we have attempted to do this, some of which are the correlation of—

1. Print quality with roughness.
2. Carbon copy legibility with roughness, thickness and substance.
3. Show-through with opacity and oil resistance.
4. Look-through (that is, wildness) with formation meter readings.
5. Roughness by subjective assessment with roughness by instrument.

This latter investigation has been reported by Maynard and Newman.[2]

In all the cases mentioned, we have had a considerable amount of success and, as a result, we have confidence that the measurements we make measure properties important for the purpose of the paper. The principal problem here is to compare ranked data with variate data. To return to the assessment of glossmeters to illustrate the types of problem that arise, there are two possible methods of approach. The first is to convert the rank data to variate data and use the normal variate statistical correlation coefficient; the second is to convert the variate data to ranks and use a rank correlation coefficient.

In an example of the successful application of this first technique, Howarth and Oliver in an assessment of fabric handle[4] considered they were justified in using the method of Fisher and Yates[5] for converting rank data into normal deviates. In converting ranks to normal deviates, it is assumed that the papers in the middle of the rank are close together and that they are well spaced at both ends of the range. We did not feel justified in making this assumption in the case of our samples for gloss measurement, since we felt the samples were very close together at the high gloss end and well spaced at the low gloss end.

We do not believe that this is an isolated case. It is our experience that the difference between papers at the high quality end are small in many cases of this nature. It would be expected that this would be the case, since it is usually much simpler to make a paper poorer in quality than it is to improve it.

In view of this difficulty, we decided to adopt the second method of approach—that is, to convert the variate data into ranks. The difficulty here was that, when the actual measurements were compared, some of the papers were not significantly different from their neighbours. Should we regard these as equal or disregard the significance and rank them solely on the magnitude of their mean values? Since we did not know what significance could be attached to the ranks obtained in the subjective assessment, it seemed illogical to worry about the significance of the variate results, so we decided on the latter and obtained the results in Table 5.

By tackling the problem in this way, we were able to decide which glossmeter was the most suitable. At the same time, we were very aware of the assumptions we were making.

We think one other approach to this problem is worth mentioning. In ranking techniques, it is assumed that an observer can place the samples in order of preference only and that he can put no degree to this order of preference. This, we believe, is contrary to general experience. Frequently, we can say that two papers are very different, while two others are quite close. Accordingly, in this assessment of glossmeters, we asked the observers firstly to rank the papers, then, assuming that the worst paper had a value 100 and the best a value 0, to give values to the intermediate papers (Table 6). A normal statistical correlation was then carried out.

TABLE 5

Paper	*Rank based on rank totals (Table 3)*	*Instrument reading, mean (%)*	*Rank based on instrument reading*
H	1	76.2†	1
D	2	75.5†	2
J	3	73.2	3
F	4	69.3*	4
E	5	67.2	6
G	6	60.2	7
C	7	69.0*	5
A	8	52.8	8
B	9	24.0	9
K	10	12.4	10

†* Not significantly different

We think this is a particularly interesting approach, since it provides some estimate of the precision and spacing of the samples in the subjective assessment.

Multiple correlation

In many subjective assessments, a multiple correlation is required rather than a simple correlation—for example, letterpress print quality and its dependence on surface smoothness. This is the most important relationship, but, if surface smoothness is equal, what properties then influence print quality? We have so far done no work on multiple correlation with subjective properties.

TABLE 6

Paper	*Percentage ranking by observer*										*Mean*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	
H	0	0	2	0	4	0	0	10	0	2	2
D	10	15	0	10	0	10	11	20	6	0	8
J	15	21	12	30	2	5	22	0	5	2	11
F	25	27	10	25	10	15	44	35	20	2	21
E	20	28	17	40	15	25	38	40	10	2	24
G	30	48	22	60	40	35	50	60	30	5	38
C	27	40	25	65	30	47	55	50	40	30	40
A	50	45	30	70	60	55	72	70	45	40	54
B	90	95	80	100	95	90	89	100	95	90	92
K	100	100	100	95	100	100	100	95	100	100	99

(*continued on page T164*)

Theoretical background to the use of non-numerical data

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GIVEN AT THE STATISTICS SYMPOSIUM: OXFORD CORNER HOUSE, LONDON, W.1
ON 29th FEBRUARY 1960, Mr. A. F. TOUT IN THE CHAIR

MR. TRUEMAN said—". . . it is surprising that so little work that has involved subjective assessments has been done in the paper industry." Very little work has been done anywhere over the whole field of ranking. Starting with the basis on which Mr. Abbott and Mr. Trueman arrived at their conclusions, I shall discuss some of the problems arising from their methods.

The principal tool used was the coefficient of concordance, independently discovered by a number of writers, including Prof. Kendall, much of whose work on this subject is in his book *Rank Correlation Methods*. Suppose there are N papers and there are M people ranking them. M is not too large a number— 2–12 people in practical work. Each of these M people, expert or non-expert, arranges the N objects in rank order—in fact, produces a permutation of the numbers 1–N. There are M such rankings.

The problems raised are—how can we test that these people are not just guessing, that they have some power of discrimination? How can we find some statistical coefficient reflecting the degree of agreement, because the hypothesis is that, if there is some underlying distinguishable quality, they will tend to agree in their judgments?

It was for this purpose that the coefficient of concordance W was invented. Its rationale is very simple: you add up the M ranks allotted to each object and obtain N rank totals T_A, T_B, etc. If the people have no power of discrimination, these totals will tend to be equal; they will assign the same total rank—that is, the same average rank—to each of these objects. So it is natural to find some measure of discrepancy among these totals.

The statistical method of measuring scatter is to calculate the variance. If the people are guessing the ranks and not discriminating, this variance will tend to be small, because the rank totals will all be rather similar. If, on the other hand, the people are really good judges and all giving the same rank (or very nearly the same rank) to each object, then these are going to be about as different as possible.

If the rankings were in perfect agreement in every case, the average ranks would be exactly 1, 2, 3, 4, 5, etc., because object A would be getting the rank 1 all the way down, object B would be getting the rank 2 all the way down and so on. So, with perfect agreement among the rankers, you would get rank totals of M, $2M$, $3M$, etc.

Those are the two extremes. On the other hand, people know nothing, in which case you expect the variance of the rank totals to be close to zero, because, apart from any sampling fluctuations, the average rank for all objects is going to be the same. On the other hand, if the people agree absolutely, they will give you total ranks M, $2M$, $3M$, etc. So what you do is to say, "This is the maximum agreement", work out what the variance would be if you had this situation, divide the actual variance by its maximum and call that W, the coefficient of concordance. It is just the sum of the squares of the deviations of the rank totals divided by its maximum value and must therefore lie between 0 and 1.

We can actually simplify W even more—the details are given in Kendall's book. Having decided how to measure the degree of agreement, how are you to carry out your test? You know that W will be small when agreement is weak, large when agreement is strong, but you want some critical value of W to enable you to decide with some degree of probability how much agreement you are justified in dismissing.

This is called the problem of M rankings and there is a very simple test to apply, as described in Kendall's book. You calculate W and see whether it exceeds a

certain tabulated value, which depends only on the numbers M and N. Knowing the number of rankers and the number of objects being ranked, for a given level of probability—say, 0.95—there is a critical value of W given in the book.

That is a very useful test in some fields, but when dealing with a real problem you *know* that there is agreement. It is usually fairly strong and the question is then how much agreement. Is it good enough for your purposes and can you say that one set of observers is agreeing more than the other? Although this problem sounds reasonably easy, it is extremely difficult, as I found when I tackled it. My problem was not to test whether people were just guessing, but to see whether they tended to give all the objects an equal rank (that is, there could be differences in the dispersion of the ranks allotted to different objects). That was a very slight generalisation of the problem and I soon realised that the amount of computation was prohibitive. The difficulty in practice is that N and M are usually fairly small. If N and M were ranging 3–20, it would not be good enough to work out suitable approximations for N and M equal to 100.

In a problem of ranking occupations in order of social class, we had some hundreds of rankings of 30 occupations, the problem being to decide, when the total ranks of occupations were close together, whether there was any true difference. Suppose you are interested particularly in occupations B and D. There is a total rank for B and one for D, but is there any true difference in the average ranks given to B and D? I gave a solution to this problem in *Biometrika* in 1951. You can test the significance of the difference in mean ranks between any two predesignated objects (that is, you must choose them in advance). As the number of rankers M becomes large, the difference between these two mean ranks has a normal distribution, the variance being given in the paper quoted. This does not solve the more general problem, if you are interested in a group of objects (say, B, C and D) to decide whether any in that group as a whole is different. This problem has recently been solved when N and M are large. It is not stated what large means, because it has not yet been computed, but the average ranks in the group of objects are used to calculate the sum of squares between them. If the group is homogeneous, this sum will be near zero. The paper is by Linhart and will probably be published in 1961.

Although this last solution is a large-sample approximation and is better than nothing, it involves a large amount of computing, but it is perfectly easy in principle. For one sample of rankers, this is an important gap that has been filled.

That is the situation in examining a group of rankers for their opinions on a particular set of objects. The more interesting case is when you have two such groups—one group of M_1 rankers, the other group of M_2 rankers, both groups ranking the same objects. Calculate the coefficient of concordance for the two sets of rankers to give a value of W for each group, say, W_1 and W_2. The question is—when is this difference significant? This, too can be solved, but is a tedious calculation requiring a large sample formula for testing the equality of two concordance coefficients when there are two groups of rankers not necessarily of the same size. What remains open is how large M_1 and M_2 have to be for the approximations to be accurate; seeing how far the computed results agree with the large-sample theory.

Linhart actually improves on this test by deriving a test for the hypothesis that the set of mean ranks in the first group is the same as the set of mean ranks in the second. That implies that $W_1 = W_2$, but the converse is not necessarily true. This test is a little less onerous than that testing the equality of concordance coefficients. Subject to some sampling experiments that will have to be carried out on computers to see how low M_1 and M_2 can be for his results to be valid, I think that his work effectively answers the relevant questions.

Therefore, one can say that, if this test is satisfactory and the approximation holds at a reasonable level, the problem is solved. That was the first of the questions and it is really solved by Linhart.

The second question is, if M observers are ranking N objects, given the N rank totals, what is the best way of estimating the true ranking of the objects? This is treated in Kendall's book. It turns out that the best thing is to take them strictly in the order of rank totals no matter how close together they are. By best, I mean that it is in a generally acceptable sense the best way of ordering; it can be shown to have superior qualities theoretically to any other way.

So there seems to be every reason to take the thing literally and, even if you get a result like 45 and 46, you should not allow that to deter you because you have some theoretical support for taking them in the order of the rank totals. So your first and second questions happen to have some theoretical answers.

There are a few general points, the first being related to the choice of observers for ranking experiments of this kind. 'It is most important to ensure that the observers used are truly representative of the population in which you are interested.' It seems almost

impossible to overstate the importance of this point. I was not absolutely clear in Mr. Trueman's example whether the mill observers or the laboratory hands were the better or whether you really should have taken a sample of the general population.

The second point is that when you say 'truly representative', I hope you mean a random sample of the population. When you say that it is most important that the observers should be truly representative, I think it is impossible to ensure that anything is truly representative of anything but itself. If you draw a sample of a population by the most rigorous and fair method, you may be unlucky and get all lefthanded people—that is the way it is. With statistical methods, you cannot command success, only deserve it.

The next point is a general one about the conduct of the glossy paper experiment. In comments on the results of the experiment, Mr. Trueman said it was found that mill observers were all looking at the paper in the same particular way and others were not, so this accounted for the slight difference. It seemed to me that in an experiment of this kind, it would have been advisable to lay down standardised conditions for viewing, if you were interested in getting standardised results. This is the opposite of what happens in judgments from the public, who habitually do anything they like with the paper. For public reaction, there is no point in trying to standardise the conditions in your experiment to an unreal degree. From the remarks, I suppose that standards would probably have made no difference in judgments between the mill people and the laboratory people.

On the use of the rank totals to estimate a true ranking, at one place this estimated true ranking was tested against some other ranking as if it were a single ranking. I do not think this is valid, because here is an average of M rankings, not a single one: it is inappropriate to use the theory of Spearman's ranking coefficient for this test, as this is a theory designed for something else. If you test it against one single independent ranking, the properties it will have will not be the same as if it were a single ranking.

On the whole, it has been found in a fairly wide range of ranking work that, whereas you can ask people to put 2, 3 or 4 things (maybe even 5 things) in order, when you give people 10 things, they really do not know what they are doing. In other words, there is a limit to just how much ranking you can do visually, tactually or in any other way. There is some kind of saturation point to the number of things people can compare with any accuracy; for example, in Table 5 you have 10 papers: I do not know the conditions under which these were compared, but I would seriously question whether people can arrange them. There are serious difficulties when the number of objects to be ranked becomes as large as 4 or 5 and in most work only 2 or 3 are compared at a time.

If you have 10 things to compare and if you accept that you can compare them only 2, 3 or 4 at a time, you are presented with a new kind of problem. To compare them altogether is rather like the situation in Table 4, where standards enabled grading the number of papers X, Y and L against the standard papers A and B. There, to grade X, Y and L, each was tested independently against A and B combined: X was presumably tested against A and B and, on separate occasions, Y against A and B, then L. The tendency would be to try to design an experiment in which A, B, L, X and Y were all in together. It may well be that for various reasons no more than 3 of these can be tested on any one occasion. What one would do then would be to carry out an experiment in incomplete blocks and test A, B and L; A, B and X; then A, B and Y—which was what Mr. Trueman did. In addition, you would test A, L and X; A, L and Y; A, X and Y, etc.; taking every possible selection of three from those five, giving ten combinations.

That sort of design in incomplete blocks, in which you compare them symmetrically, would be called a balanced incomplete block design, very familiar in the field of agricultural experimentation. You can do this in ranking studies in exactly the same way. With balanced designs of this kind, you can also compute the coefficient of concordance. The important general point is that the mere fact that it is physically or administratively impossible to compare more than two or three things at a time does not mean that you cannot do any ranking studies involved in the group as a whole. As long as you lay it out in a balanced way like this, you can put together the pieces of information from the separate blocks and arrive at a true ranking in exactly the same way as before.

The other general point is concerned with the correlation of a subjective assessment with the results obtained from an instrument. This sort of problem arises very frequently in ranking studies. Sometimes you have a reliable instrument; on the other hand, subjective readings are quicker and easier. Therefore, for routine work, you want to use subjective measures. You are interested in the relationship between the subjective assessment and the objective measurement, but the direction of interest is to predict the exact measurement from the subjective judgment.

In Mr. Truman's case, it was the other way round: a number of instruments purport to measure the same thing and the question is which instrument to use. In other words, the instrument is fallible, the true aim is the subjective assessment. In any case, it seems to be undeniable that you are interested not in correlation, but in regression. There is no symmetry between the variables. There is a direction, so to speak, in the situation. Your interest is predicting what the instrument will do and, with what is in essence a prediction problem, I consider that regression would be appropriate. This leads straight to the problem of how to carry out regression when all there is at hand is a ranking rather than a measured variable on one axis. In other words, you have the problem of converting the ranking into a suitable form.

In similar problems (the situation the other way up), I have left the ranking (in whole numbers) alone and treated it as if it were a variable without doing anything to it: the results are very satisfactory, though crude. In your case, this corresponds to working out the regression of the instrument reading on the ranking, without changing the ranks or anything of that kind.

To treat a ranking as a variable presents the genuine difficulty of deciding how to convert it. Take the rank, then look up a table answering the following question. Suppose you have a sample of N observations from a standardised normal distribution and suppose you arrange the N observations in order, what on the average will be the value of the smallest one, the second one and so on to the last one? These are called the expected values of the normal order statistics or *normal scores*. You then deal with these normal scores instead of the ranking.

If you are concerned genuinely to represent variables numerically, you are right to doubt whether this would be appropriate to your situation, when the distribution clearly is not symmetrical and when the gloss is much more concentrated at the high end than at the low end of the scale. The point that is not obvious is that, if you are just concerned to carry out tests and not to make estimates, then this is a perfectly valid procedure for any distribution whatsoever. It does not matter therefore what your original distribution looks like: if you take these normal scores and carry out your tests on them, perfectly valid tests of significance are obtained, whatever the underlying distribution. That applies only to testing, not to estimating and these normal scores are given in Fisher and Yates' tables. There is a genuine and sharp distinction between using normal scores for test purposes and using them for estimating the shape of an underlying distribution, which I think you quite rightly did not do in this case. To carry out any kind of test—for example, comparing two distributions—the normal scores can be used quite freely.

One other general theoretical point is that you have used the ranks to replace observations and now you are using normal scores to replace the ranks. Using normal scores, you get valid tests, but you would not expect them to be very efficient or sensitive, yet it seems most remarkably that this is not always the case. For example, suppose you have two populations and samples of N_1 and N_2 observations respectively from them: suppose you want to see whether the means of these two populations differ. The populations might perhaps be a standard and a new process: you are interested in whether the average value obtained by the new process is different from that of the standard. What you do is to pretend that the two populations are normal distributions with the same variance and use Student's t test for testing the difference between the two means. This is a polite pretence that we are now accustomed to and it is fairly reasonable. If we know that it is roughly a symmetrical distribution and does not look too odd, we are prepared to go the whole way and say that the distribution is normal.

Instead of doing this and using the standard Student's t test, suppose we remove this pretence, take these $N_1 + N_2 = N$ observations and rank them 1–N, then look up the tables of the normal scores and write those in place of the ranks, finding out to which samples they belong. You take all the normal scores from the observations of the first sample and add them up. This sum of a certain number of normal scores is used as your test statistic and with the distributions normal it turns out, when these sample sizes are reasonable, that this is as good as Student's t test. If the distributions are not really normal, this is, surprisingly, better than Student's t test. In other words, by avoiding the assumption of normality and using normal scores instead, you get better tests than those recommended by the textbooks. The reason I mention this is partly because of its interest and partly because it lends one confidence in using these normal scores—but remember that I am talking about a test. I look forward to the day when a textbook is published that does not mention Student's t test for two samples; I think it will come.

discussion

For the third session, a number of people who have been intimately concerned with methods of handling non-numerical data had been brought together to describe their work and answer questions. This panel, nnder the chairmanship of Mr. Alan F. Tout, comprised—

Dr. R. Harper of Leeds University

Prof. G. A. Barnard of University College, London

Mr. W. N. Jessop of Courtaulds Ltd.

and the speakers—Mr. Alan Stuart, Mr. I. H. Trueman and his co-author, Mr. P. H. J. Abbott.

Before the general discussion, Mr. Ivor Trueman, Dr. Harper, Prof. Barnard and Mr. Jessop spoke in turn about work that had yielded non-numerical data and about their methods of handling this data.

DR. R. HARPER described work that had been carried out on the streakiness of knitwear made from yarns with two colours of fibre, the two colours of fibre being blended together in various proportions. Thirty five different samples of knitwear were ranked for streakiness by forty individuals and the results were presented graphically. The fundamental question was—What are the important variables? Dr. Harper was able to show that the ranking method, in spite of its limitations, yielded strong indications of the relative importance of different process variables, namely, the fineness of the threads and the coarseness of the wool.

PROF. G. A. BARNARD reinforced the suggestion made by Mr. Trueman in the first session that it was preferable, when possible, to allow the assessors to score the objects (that is, to allot marks) rather than just to rank the objects. This provides results that are similar to those obtained from ordinary objective measurements and therefore appropriate standard methods of statistics can be used. As a corollary, Prof. Barnard opined that one should mould the situation to the condition for which those standard methods are appropriate.

Prof. Barnard considered that the method of scoring zero for the best and 100 for the worst in relation to gloss was an excellent one, as standard methods of statistics could then be used.

The problem of deciding whether differences between neighbouring ranks are significant was also mentioned by Prof. Barnard and he outlined a method in which the group means are plotted along a line and a scale model of the t distribution, based on the residual sum of squares, is able to slide along this line. Thus, it is possible to judge whether the distribution will cover all the group means in a plausible way. The possibility of a logarithmic transformation for the gloss results was also mentioned, as there is a natural limit to gloss and such a transformation would not affect the validity of the normal scores for ranking.

Finally, Prof. Barnard said that the best rank order test in his opinion was the one set down by Fisher and Yates in 1938.

MR. W. N. JESSOP described the work he had carried out with the results of laboratory assessments, in the form of paired comparisons, on a certain property of fabrics, also with the results of usage trials in which a number of experimental garments were issued to a panel of judges and the preference of each judge was considered.

For the laboratory assessments, the results were used to form a paired comparison table. In addition to significance testing, however, some scaling of the objects was required and methods due to Gullman and Sheffay were used. Sheffay's method was particularly useful.

Several methods of analysis for the usage trial results were attempted and the normalised score method was found to be particularly useful by Mr. Jessop, as this also allowed estimates to be made of the spacings of the different objects on a linear scale.

THE subject was then thrown open for general discussion. The first feature of non-numerical data discussed was the problem of ties in the results of ranking experiments. It was considered by the panel that, if the number of ties is small, then there is no real trouble; if 40 per cent. of the results are ties, then a special technique such as that given by Fisher and Yates is required. It was also suggested that, if a scoring system is employed, tied results do not have the same effect.

The number of objects that could be ranked satisfactorily caused a great deal of discussion and it was generally agreed that the manner in which the

assessment was made did restrict the number of objects that could be handled. When visual assessment is being made, it is possible to lay the objects on a table and by re-arranging their order to arrive finally at a ranking. When memory is required, however (such as in assessing objects by taste, smell or touch), it was considered that the maximum number of objects that can be ranked is probably between five and seven.

The problems of the type of assessor required were discussed and it appears that the choice of type or class of assessor should be settled by those who are going to use the data that will be produced. The influence of rogue observers was also touched upon and it was the general opinion of the panel that, providing the observers or assessors were reasonably chosen, there could be no excuse for rejecting the results of any one judge. The advantage of a jury system over the normal system of independent observers was also discussed and it was suggested that the interchange of views with a jury system would finally provide a better ranking system, as a number of variables would be sorted out. It was considered that a jury system would be of advantage only when visual examination was the assessing method.

For education of those with biased opinions who tended to ignore data, the panel considered that the value of figures over opinions should not be underestimated and that, in time, the value of data would become clear to all.

The possible use of standards to provide better rankings was discussed and it was generally considered that a range of standards would be of advantage in many instances of visual assessment, as it would tend to overcome the difficulties introduced by assessors who tend to give high or low scores to the majority of the objects.

The symposium was concluded by the Chairman thanking the members of the panel.

The use of non-numerical data — P. H. J. Abbott and J. H. Trueman

(Concluded from page T 158)

Summary

WITH the limited number of examples presented, we think we have shown that the investigation of subjective properties is important and can be very rewarding. At the same time, we have frequently run into difficulties in the design and analysis of our experiments, because we have not found suitable techniques for our practical problems. We should like guidance on the following—

1. Methods for assessing the relative degree of agreement of two groups of observers.
2. What rank we should obtain from rank totals and what precision we can put to a rank.
3. More effective use of standard papers.
4. The correlation of subjective assessments with instrument results and also methods for multiple correlation of physical and subjective properties.

Acknowledgement

The authors wish to express their thanks to the Directors of Wiggins, Teape & Co. Ltd. for their permission to publish this paper.

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Fibre-to-fibre bonds

Part 1—A method for their direct observation

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British Paper and Board Industry Research Association, Kenley

COMMUNICATION RECEIVED 17th JUNE 1960

Synopsis

A light-microscopical technique is described that permits for the first time the direct observation of areas of optical contact between fibres in a paper sheet. The theory of the contrast mechanism is given. Strong evidence is put forward in favour of the view that adhesive forces are distributed over the whole of these areas of contact and thus that these are the fibre-to-fibre bonds responsible for sheet strength. The direction of future work exploiting this technique is indicated.

Introduction

OVER the years, there has been considerable conjecture as to the nature of the forces holding fibres together in a paper sheet. Even in quite recent publications it has been maintained that substantial components of the forces arise from mechanical entanglement and friction[1] or from the cohesive effect of fibrillation.[2] There is considerable evidence now, however, that the hydrogen bonds[3,4] or other Van der Waals' forces at the regions of contact between fibres are by far the most important, at any rate during the early stages of beating. Very little direct work has been carried out on the nature and importance of fibre-to-fibre adhesion, no doubt owing to the absence of suitable techniques. Indeed, the phrase *fibre-to-fibre bonds* has been used by research workers in the paper industry with little concept of its meaning. The only reported work on regions of fibre-to-fibre contact in paper sheets is that of Asunmaa and Steenberg,[5] who sectioned thin handsheets for the electron microscope. They revealed that quite large areas of contact could exist between fibres and that this contact was perfect even at a resolution of 20 Å.; however, without resorting to the tedious procedure of serial sectioning, these workers could not gain information on the shape of the bonded areas and, furthermore, their work could not be put on a statistical basis. This work describes a method by which it is possible for the first time to examine individually the areas of contact between fibres in a paper sheet and to do so in a sufficient number to permit statistical treatment of the results.

Method

THE technique that has been developed uses the light microscope under conditions of polarised vertical illumination (P.V.I.). The use of this type of illumination for the examination of dry-mounted, papermaking fibres was suggested by Emerton and Watts,[6] who produced micrographs similar to that shown in Fig. 1. Typically, these showed dark areas within the fibres and also bright areas in which interference fringes could often be seen. These authors at first interpreted the fringes as arising from a spacing between the primary and secondary walls of the fibre and the dark areas as showing absence of primary wall, but they admitted in an addendum to their paper that the dark regions could be caused by optical contact between the primary and secondary walls. Both these interpretations were shown to be erroneous by Carlsson and Hartler,[7] who conclusively demonstrated that the dark areas were not related to the structure of the cell wall, but merely showed optical contact between the fibre and the supporting glass slide. (These authors also put forward the hypothesis that in this area of optical contact Van der Waals' forces form a bond between the fibre and the glass.) The explanations given by Carlsson and Hartler of the genesis of the bright areas, however, is that "other parts of the fibre which are not in contact with the slide shrink and develop an uneven surface from which far more light is reflected and this changes the angle of polarisation thus making these parts visible in reflected polarised light". This explanation also can be shown to be incorrect and, because of the confusion that has arisen from the publication of two papers containing erroneous interpretations, the correct theory of the image formation of fibres examined in vertical polarised illumination will be discussed.

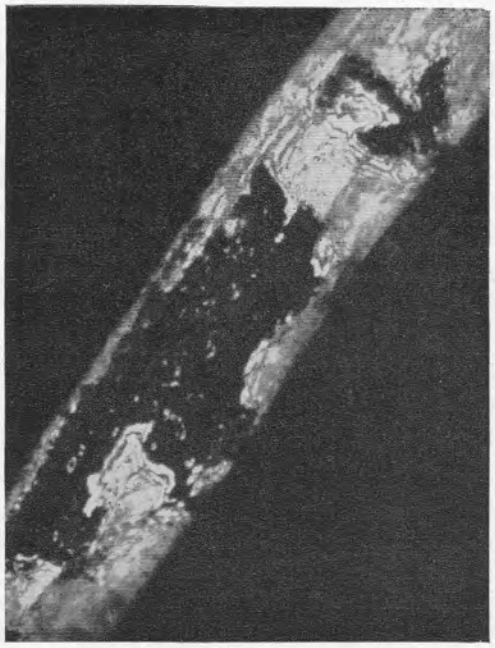


Fig. 1—Spruce sulphite fibre on glass slide [P.V.I. ×430]

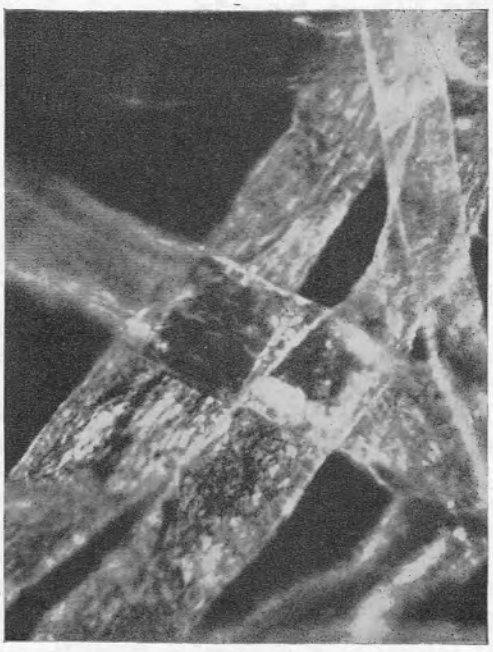


Fig. 3—Fibre-to-fibre bonds in a thin handsheet [P.V.I. ×430]

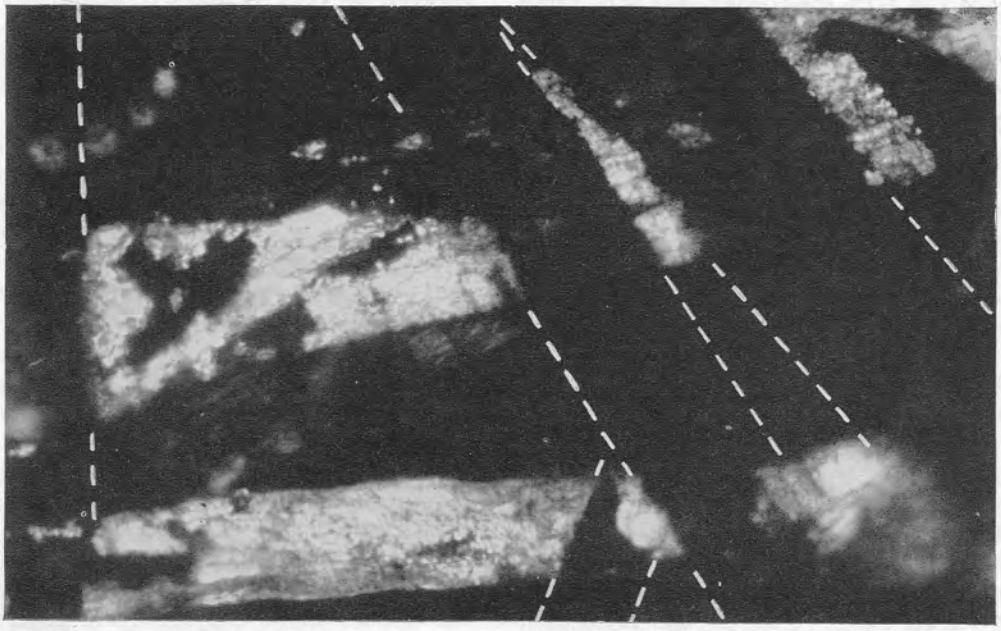


Fig. 5—Bonded areas between undyed fibres and underlying dyed fibres in thick handsheet of spruce sulphite [×650]

Fig. 2 shows diagrammatically in cross-section a fibre partly bonded to a glass slide. In normal vertical illumination, the image is formed from light reflected from the upper surface of the fibre (*A*), the lower surface of the fibre (*B* and *B'*) and the upper surface of the glass slide (*C* and *C'*). In the area of optical contact, *B'* and *C'* are equal but in antiphase and thus interfere to give zero intensity. In the regions of close proximity (but not optical contact), *B* and *C* interfere to give a set of fringes; when the surfaces are not close, only *B* contributes to the image. Under favourable conditions, it is thus possible to detect the areas of optical contact in vertical illumination without resorting to polarised light, although the contrast is extremely low (*see* Fig. 2 (*d*) of ref. 6). (Under very favourable conditions, bonds can be seen also in dark field or even oblique illumination.)

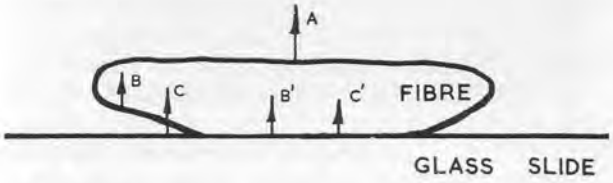


Fig. 2—Diagrammatic cross-section of fibre bonded to glass slide

When crossed polars are used, two main effects are observed. Firstly, the light reflected from the upper surface of the fibre (*A*) and from the glass slide are almost completely extinguished, as there is no appreciable depolarisation of light on reflection from these surfaces. This has the effect of greatly increasing the contrast in the image. Secondly, the rays *B* and *C*, which have travelled twice through the fibre, are now, in general, elliptically polarised so that the fringes arising from interference between them appear bright. In the special cases in which the fibre lies along the direction of polarisation of the analyser or polariser, *B* and *C* are plane polarised and are extinguished by the analyser. This extinction of the bright areas four times per revolution of the specimen is a fact that appears to have been missed by Emerton and Watts,[6] who state that the bright areas are almost unaffected when the stage is rotated. When the fibre is at 45° to the direction of polarisation, the maximum intensity of the bright areas is achieved and this is the position that gives maximum contrast to the image.

The major characteristics of the image are explained by the above theory, although in practice effects are frequently noticed that are not in accordance with it. Certain simplifying assumptions that are not generally valid have been made in the formulation of the theory and the effect of a divergence from these ideal conditions will be considered. In the first place, it has been assumed that both the upper and lower surfaces of the fibre are flat or nearly so. While this is a reasonable assumption for springwood fibres of softwoods, many other fibres such as esparto deviate considerably from this condition, resulting not only in distortion and aberration of the image of the dark areas, but in a reduction of the contrast owing to undesirable reflections within such a structure. It has also been assumed that the fibre behaves as a single crystal; this is not necessarily true, because the optic axis of the cell wall does not coincide with the axis of the fibre. Thus, the fibre can be treated as two superimposed crystals of equal thickness and birefringence with their optic axes separated by twice the micellar angle; Hartshorne[8] has shown that this arrangement can behave in polarised light in a complex manner. Only those fibres with the thickest walls suffer from this complication and, once again, from the point of view of the observation of the dark areas, the effect is a reduction in the contrast.

A further complication arises in the case of fibres with uncollapsed lumens. Reflection from the upper and lower surfaces of the lumen can give rise also to interference fringes, which are extinguished four times per revolution of the specimen, but the position of extinction in this case occurs when the *micellar* direction is parallel to the direction of polarisation. (This is incidentally a method of determining the micellar angle.) It will be seen that these three deviations from the simplified theory are most pronounced in the case of the more cylindrical thick-walled fibres, whereas collapsed thin-walled fibres such as occur commonly in spruce approximate to the ideal conditions of the simplified theory.

It is worth noting that the degree of bonding between a fibre and a glass slide is a measure of the fibre flexibility and this aspect is being examined in the author's laboratory.

The fact that fibre-to-glass bonds can be seen in polarised vertical illumination led the author to investigate the possibility of the application of this technique to the direct observation of fibre-to-fibre bonds. This was found in fact to be possible under certain circumstances, but the contrast is often extremely low. Examples of fibre-to-fibre bonds in a thin handsheet with a spruce sulphite furnish are shown in Fig. 3. The mechanism of the image formation is similar to that outlined above, but with

the complicating effect of the lower fibre. Fig. 4 shows that, in addition to the light components *A*, *B* and *C* previously considered, the component *D*, the reflection from the lower surface of the lower fibre, must be taken into account. The effect of *D* can be minimised by a suitable orientation of the specimen with respect to the polars. The theory of this minimisation is straightforward, but will not be dealt with, since the divergencies from the simple theory are magnified in the case of fibre-to-fibre contact and the condition of maximum contrast is found in practice simply by rotating the specimen.

Bonds between fibres in paper sheets of typical basis weights can only just be detected under very favourable conditions, because the light reflected and scattered from the surrounding and underlying fibres in the sheet completely swamps the image. This difficulty has been overcome by preparing handsheets from stock in which about 70 per cent. of the fibres have been heavily dyed to give maximum absorption of the light used. Of the dyes examined, Chlorazol Black BHS was found to give the best results for green light and this combination was used throughout. By absorption of the unwanted reflected and scattered light, the bonds between the remaining undyed fibres become clearly visible. In the regions where undyed fibres lie above dyed fibres and are bonded to them, exceptionally high contrast results owing to the absorption in the lower fibre of the light component *D* (Fig. 4). Examples of fibre-to-fibre bonds shown up by this method are seen in Fig. 5. Two undyed fibres show up brightly and the dark areas along their length are regions of bonding between them and the underlying dyed fibres. For greater ease of interpretation, some of the underlying fibres are outlined.

A thorough investigation of the effect of the dyeing procedure on the strength properties of the sheets showed that in some cases it gave a very small though significant change in tensile and bursting strengths, but it is not thought that this effect in any way invalidates the assumption that the results obtained from the experiments on dyed sheets can be applied to the behaviour of undyed sheets.

Since optical contact implies a proximity of a few hundred Ångstrom units, whereas hydrogen or Van der Waals' bonds operate over a distance of a few Ångstrom units, it has been put forward (for example, Van den Akker[9] and Andersson[10]) that bonded areas estimated from measurements of scattering coefficients might be considerably larger than the actual area of bonding. The factors that lead the author to believe that bonding forces exist over the whole of the area shown up by this technique must be considered. Ingmanson and Thode[11] have quoted Ratliff as having reasoned that, if fibre surfaces were brought near enough to cause optical interference, the surface tension forces during drying would ultimately lead to bonding between them. Moreover, the work of Asunmaa and Steenberg[5] indicates that mere optical contact between fibres dried together is rare and that, where contact occurs, it is usually so close that no separation is detected in the electron microscope.

In support of the belief that optical contact implies bonding, the author has accumulated various pieces of evidence. Firstly, no difference in size or shape of contact areas could be observed when different wavelengths of light were used. Furthermore, an interesting experiment is illustrated in Fig. 6 (*a*) and (*b*), which show on the left a region of the surface of a handsheet of spruce sulphite that has been solvent-dried. In this sheet, there were virtually no areas of optical contact between fibres. On the right is shown exactly the same field after the sheet had been soaked with water, pressed again and dried; this has resulted in the formation of obvious areas of interfibre optical contact; simultaneously, the tensile strength of the specimen increased approximately sixfold. Finally,

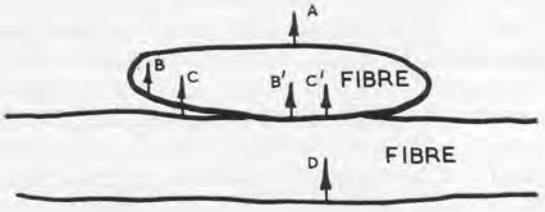
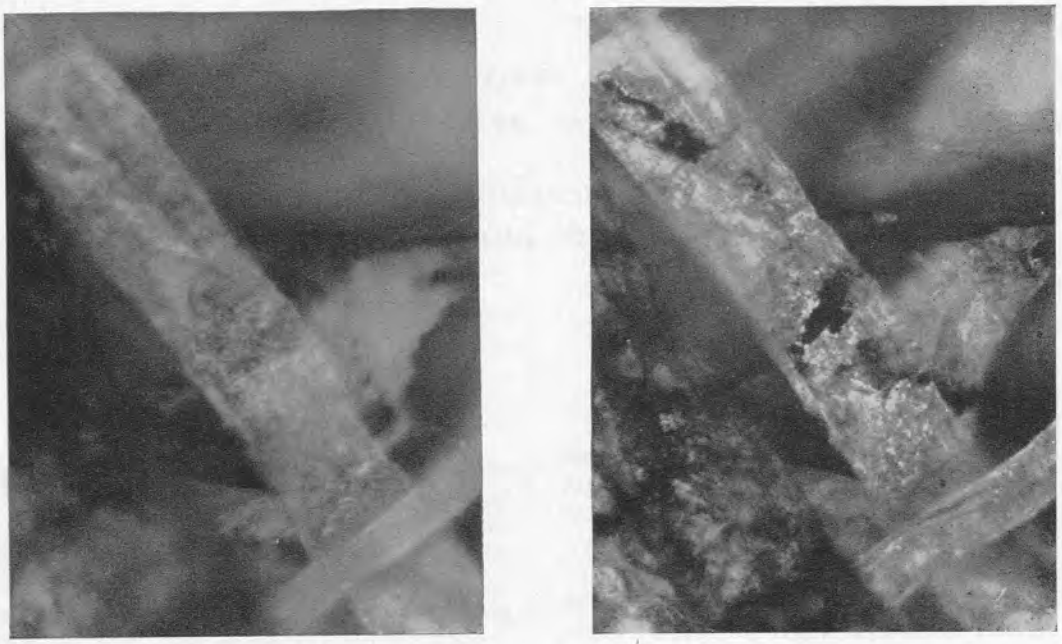


Fig. 4—Diagrammatic cross-section of fibre-to-fibre bond

when paper sheets were strained, there was no detectable change in the size and shape of the dark areas during the early stages of straining; mere optical contact without bonding might be expected to change under the slightest strain. Thus, there is considerable evidence that over virtually the whole of each area of optical contact adhesive forces exist—in other words, these areas are bonds.



(a) (b)

Fig. 6—(*a*) Solvent-dried handsheet of spruce sulphite, which after wetting and drying gives (*b*) [×430]

Conclusion

THIS work has opened up a completely new line of attack on the problem of the nature of fibre-to-fibre bonding and its role in the structure and physical properties of paper. The technique is being actively exploited in the author's laboratory to determine the way in which the size, shape and spatial distribution of bonded areas vary with furnish, beating, wet pressing, drying conditions and other papermaking variables, also the behaviour of bonded areas in a sheet under dynamic conditions. It is worth noting that the technique of optical contact between two fibres or between a fibre and a glass substrate will be of value in the examination of strengths of individual contact areas and this aspect is also being considered.[12]

Part 2 of this series will describe the preliminary work in these directions and will be published in the October issue (No. 5).

Acknowledgement

I am indebted to my colleague Mr. P. A. Tydeman for the micrographs and for carrying out the experiment of Fig. 6.

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U. Poggianti and G. Moltedo

Chlorination by gaseous chlorine in strawpulp production

Influence of semi-pulp consistency and chlorination time

GIVEN AT THE SECOND EUCEPA SYMPOSIUM
HELD AT NOORDWIJK, HOLLAND IN JUNE 1959

Basis of the investigation

THE researches made in the past few years on the reaction of lignified fibres to chlorination by elemental chlorine and on the resulting phenomena refer principally to treatments with chlorine solutions (called, for brevity, chlorine water treatments) during multi-stage bleaching processes at pulp consistencies not exceeding 6 per cent. The literature dealing with this subject is very ample.(1) On the other hand, apart from the operating technology, very little is known about delignification by gaseous chlorine of semi-pulps—especially straw semi-pulps—which, in the alkali-chlorine process, is the second stage of the treatment.

From a general chemical point of view, one cannot make a neat distinction between chlorine-water chlorination of an unbleached pulp and the chlorination by gaseous chlorine of a high lignin-content semi-pulp. Anyhow, in this latter case, the most significant factors are those that affect the reaction—that is, pulp consistency, pH, temperature, reaction time, lignin content of the pulp—with respect to the high pulp consistency and to the greater concentration of the reagent.

In the production of alkali/chlorine pulp from straw, the treatment of the cooked semi-pulp with gaseous chlorine is preceded, as is well known, by a series of physical operations such as washing, high density squeezing and thickening, which, in addition to the degree of cooking of the semi-pulp, affect the chlorination process.

Our investigation aimed at obtaining broader information on the influence of variations in these parameters on the process. This paper, however, restricts the investigation to three of these parameters—degree of cooking, semi-pulp consistency and chlorination time.

In a separate study, we shall deal particularly with the influence of the pH of chlorinated semi-pulp, the variations of which, on an industrial basis, can be noted in the efficiency of the semi-pulp washing that precedes gaseous chlorination.

Taking for examination three semi-pulps with different degrees of digestion (obtained from the same straw quality), a study was made of the effect of chlorination in relation to variations in pulp consistency and the time of treatment, with the same conditions for the treatments preceding chlorination, that is, cooking degree, washing, thickening.

The following tables summarise the data obtained from the experiments and analyses (average of three comparable readings) referring to three groups of ten test series to each group—

First group

Material used—Semi-pulp (obtained from Puglie straw) with a cooking yield of 69.78 per cent.

Chlorinations—

(*a1*) Five test series made on semi-pulp brought to 20, 25, 30, 35 and 40 per cent. consistencies. Chlorination time: 30 min.

(*a2*) Five test series made on semi-pulp brought to 20, 25, 30, 35 and 40 per cent. consistencies. Chlorination time: 90 min.

Second group

Material used—Semi-pulp (obtained from the same quality of straw as in the first group) with a cooking yield of 64.70 per cent.

Chlorination—

(*b1*) Five test series made as per series (*a1*).

(*b2*) Five test series made as per series (*a2*).

Third group

Material used—Semi-pulp (obtained from the same quality of straw as in the first group) with a cooking yield of 60 per cent.

Chlorinations—

(*c1*) Five test series made as per series (*a1*).

(*c2*) Five test series made as per series (*a2*).

Experimental

THE tests were carried out, after dusting in the mill's Grunbach plant, on a sample of about 150 kg. of straw harvested in Puglie in 1957, the composition of which is shown in Table 1.

Cooking

In order to obtain the three semi-pulps with a different degree of digestion, three series of digestions were carried out in a fixed laboratory autoclave, heated by an oil bath, under the following conditions—

	First	*Second*	*Third*
Titre of the cooking liquor, NaOH, g. per litre ..	22	26	30
Straw/cooking liquor ratio	1:4	1:4	1:4
Sodium hydroxide per kg. of straw, g.	88	104	120

Digestion schedules for the three series—

(*a*) 30 min. required to bring the temperature from 70° to 100°C.
(*b*) 30 min. required to bring the temperature from 100° to 125°C.
(*c*) 30 min. required for temperatures of 125°C.

The cooked stuff from each series, after washing and thickening, was thoroughly mixed to give one homogeneous semi-pulp sample to be used in all the chlorination processes.

Table 2 shows the essential analytical data relating to the three semi-pulps obtained.

Chlorination

For the tests, the three semi-pulps were brought by pressing and, when necessary, by evaporation at room temperature to 20, 25, 30, 35 and 40 per cent. consistencies. For each test, the chlorinations were done on 500 g. of oven-dry semi-pulp in a suitably cooled 12 litre wide-necked glass flask closed by a stopper, equipped with a thermometer and two glass tubes, one of which (the inlet), reaching to the bottom of the container, was connected to the chlorine cylinder by means of a Mariotte flow meter; the other tube (the outlet) was connected to two flasks in series, each containing sodium hydroxide for determining the chlorine residue at the end of each chlorination.

During each chlorination process, the same quantity of excess chlorine was always used. At the end of each test, the residual chlorine was expelled from the container by blowing through it: the amount of chlorine corresponding to the hypochlorite produced in the flasks was so determined. Water was then introduced into the chlorination vessel sufficient to make up to 10 litres in each case. Next, the fibrous suspension was dispersed in a Wenberg disintegrator for 60 sec. and samples were drawn from it for determining—

(*a*) the quantity of active chlorine,
(*b*) the hydrochloric acidity produced

in the filtered liquids.

The hydrochloric acid content was determined by titration with silver nitrate (the Mohr method). It is important to note that, if the titration is done with sodium carbonate (methyl-orange indicator), as has been done by Kress and Voigtman,[2] lower values are obtained. The difference between the two determinations, which was constant in all the tests, is probably due to the fact that part of the hydrochloric acid formed during chlorination is neutralised by alkaline and alkaline earth ions chemically bound to or absorbed by the semi-pulps. Hence, taking into account the absence of chlorides in the semi-pulps before chlorination, the real acidity value results from the total chlorides used proportional to the silver nitrate. This is also in accord with D. H. Graangard's method.[3]

TABLE 1—STRAW COMPOSITION

(PERCENTAGES, OVEN-DRY)

	Percentage
Extracted by benzene	1.00
Extracted by alcohol	4.70
Cross and Bevan cellulose (free of ash, lignin and pentosans)	32.60
Total pentosans*	27.58
Total lignin (ash-free)†	
Total ash	9.58
Undetermined constituents (by difference) ..	6.75
Cellulose/pentosan ratio	1.18

TABLE 2—THREE SEMI-PULPS COMPOSITION

Sodium hydroxide, g./kg. straw in digestion	88	104	120
	Percentages		
Yield semi-pulp from straw ..	68.79	64.5	60.29
Cross and Bevan cellulose (free of ash, lignin and pentosans) ..	46.47	49.91	50.48
Total pentosans*	29.78	30.07	30.35
Total lignin (ash-free)†	9.91	8.85	7.32
Total ash	7.88	6.32	4.61
Cellulose/pentosan ratio	1.56	1.65	1.66

* TAPPI Method T450 m-44 † Hägglund standard method

Alkaline extraction and cleaning

After washing, the chlorinated straw was treated at 5 per cent. consistency with cold 4 per cent. soda on the pulp for an hour. This was washed again and cleaned on a Wenberg washer equipped with a plate having 0.2 mm. slots.

Examination and discussion of the results

THE above tables show the data from the various tests, giving the average of three comparable readings for each determination.

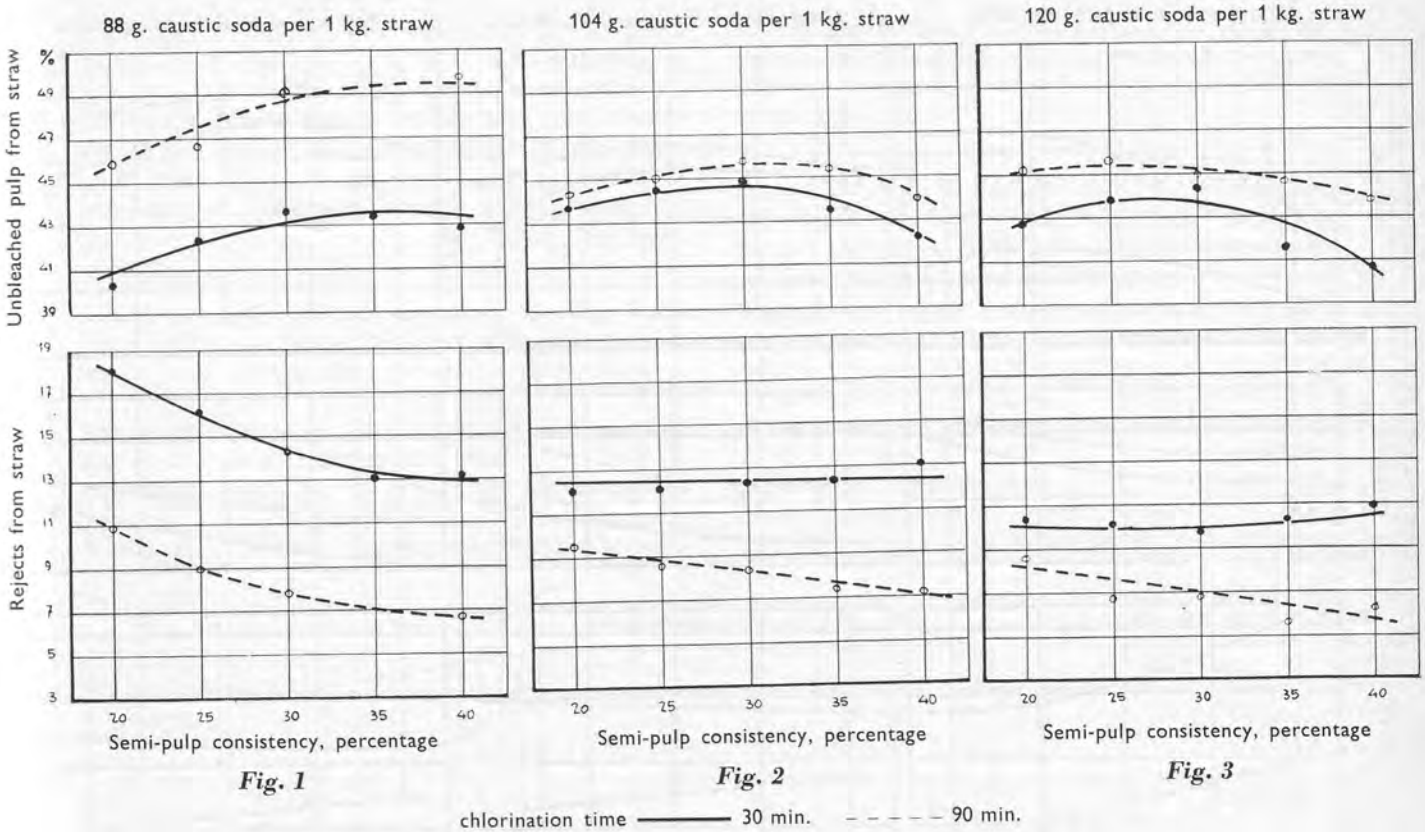

Fig. 1

Fig. 2

Fig. 3

Considering the three test groups as a whole, an examination of the tables and graphs reveals that the pulp yields for straw (Fig. 1–3) vary with the consistency at which the semi-pulps are chlorinated.

A detailed examination of the graphs for pulp yields based on the semi-pulps, reveals the following—

1. Using the same quantity of sodium hydroxide for digestion, the yields of unbleached pulp are higher when chlorination lasts longer.
2. The yield curves of unbleached strawpulp tend to rise or level out when semi-pulps with higher lignin content are chlorinated at consistencies varying from 20 per cent. to 40 per cent. (Fig. 1). On the other hand, they tend to fall off for consistencies over 30 per cent., in the case of semi-pulps with lower lignin content, bending more sharply towards the axis, proportionally with the higher degree of delignification (Fig. 2 and 3).

   This is explained by the fact that the hemicelluloses of the semi-pulps with lower lignin content are less protected against hydrolysis or oxidation, which are favoured by the higher temperature and the greater amount and concentration of the acid formed (Fig. 7–9).
3. The yield curves of the 30 min. chlorinations tend to rise as the consistency increases up to 30 per cent.; in addition, they show a quicker downward tendency compared with the corresponding yield curves for 90 min. chlorination. The latter curves reach a higher level and are more flattened. The reason is that, extending the chlorination time especially for semi-pulps with higher lignin content, the cellulose material is utilised to a larger extent, whereas a portion of it goes to waste in 30 min. chlorinations. Such utilisation prevails over the hydrolysing action that occurs during the chlorination, resulting in a yield increase even for semi-pulps chlorinated at 20 per cent. consistency.
4. The influence of chlorination time upon yield is much more pronounced in the case of a semi-pulp with higher lignin content (Fig. 4) that has undergone shorter chemical treatment in the cooking stage.
5. The waste curves for 30 min. chlorinations show a tendency to flatten out, whereas the corresponding curves for 90 min. chlorinations are on a distinctly lower level and show decreasing change as the semi-pulp consistency increases (Fig. 4–6).
6. The curves for the dissolved matter show a similar trend to the corresponding curves for the pulp yields (Fig. 4–6)—in other words, they go up as the yields decrease. In 90 min. chlorinations, the dissolved matter is more than that in the 30 min. chlorinations.

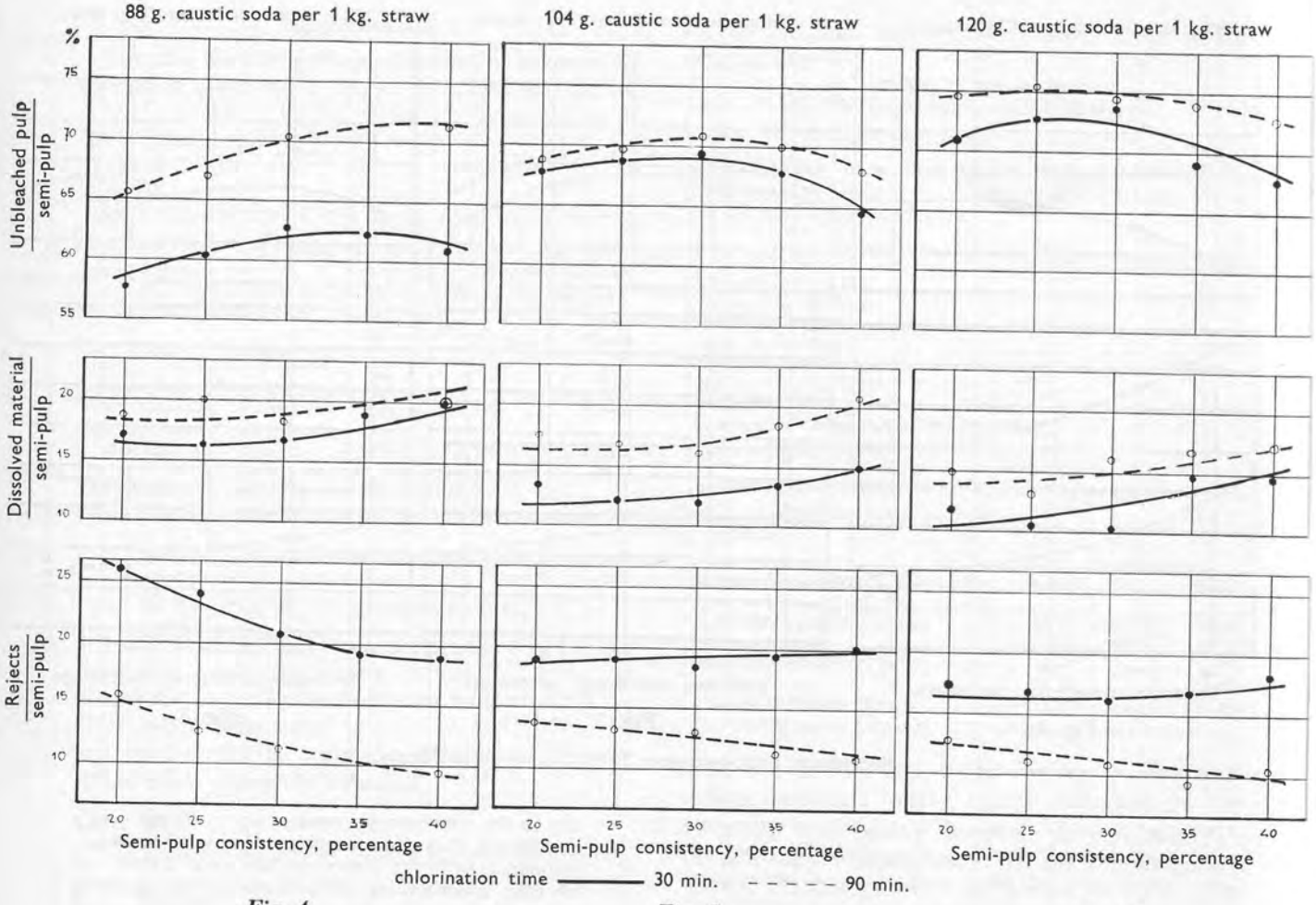

Fig. 4 *Fig. 5* *Fig. 6*

During the first series of chlorinations, the dissolved carbohydrates in 90 min. treatments show very little difference from those treated for 30 min., since the material is very well protected (Fig. 4). In the next two series (Fig. 5 and 6), using semi-pulps with lower lignin contents, the extension of the chlorination time to 90 min. results in greater losses by solution, especially for pulp consistencies over 30 per cent., as well as giving greater utilisation of the semi-pulp and therefore less waste. The amount of such losses, which are related to the average residual lignin contents of the unbleached pulps, helps to throw light upon the yields and chlorine consumption.

An examination of Tables 3 and 4 reveals that, throughout the test series, the residual lignin content of the unbleached pulp has an average value not very far from 1.8 per cent. No significant indications, it seems, can be drawn from the small variations noted during the different determinations, either because such variations may come within the experimental errors of the analysis or because they may be due to changes in lignin content in the course of treatment. The fact that, from the three semi-pulps with different lignin content, treated under different conditions, there is for unbleached pulps a residual lignin value oscillating around an average figure that is nearly constant leads us to suppose a fraction of modified insoluble lignin in the pulps obtained.

Fig. 3–9 show that, as the semi-pulp consistency passes from 20 per cent. to 40 per cent. and the chlorination time from 30 min. to 90 min., there is a slight increase in the lignin solubility with increasing

chlorine consumption only with material having a higher lignin content (Fig. 7). With semi-pulps having a lower lignin content, however, the dissolved lignin curves are almost parallel to the axis and coincide for 30 min. and 90 min. chlorinations. These curves show therefore that, starting at a given degree of semi-pulp delignification, increase in consistency and duration of attack has no effect upon the lignin solubility.

The semi-pulp chlorine consumption (Fig. 7–12) rises in all three cases with increasing consistency and, at the same time, so does the total acidity produced. It should be noted that, as the lignin content of the semi-pulp falls, so do the chlorine consumption and the acidity, as well as their rise with respect to pulp consistency. As a matter of fact, the curves tend to turn less toward these axes when the product gradually loses part of its lignin. The general difference between 90 min. and 30 min. chlorinations lies only in greater chlorine consumption with proportionally greater acidity as a consequence and in less marked flexing of the curves.

An examination of Fig. 7–9 reveals that, as the amount of lignin in the semi-pulp (Fig. 7) decreases (Fig. 8 and 9) in both 30 min. and 90 min. processes, there is an increase in the ratio of chlorine consumption to dissolved lignin, whereas these latter—in an absolute sense—have a downward tendency. Actually, the increase of this ratio is only apparent, because, relative to the initial lignin content of the semi-pulps, a greater percentage of lignin is dissolved as treatment of the semi-pulps with higher lignin content passes to those with lower content; also because the chlorine consumption must be considered in relation to the hemicellulose solubility increasing with the consistency, the reaction time and the degree of delignification.

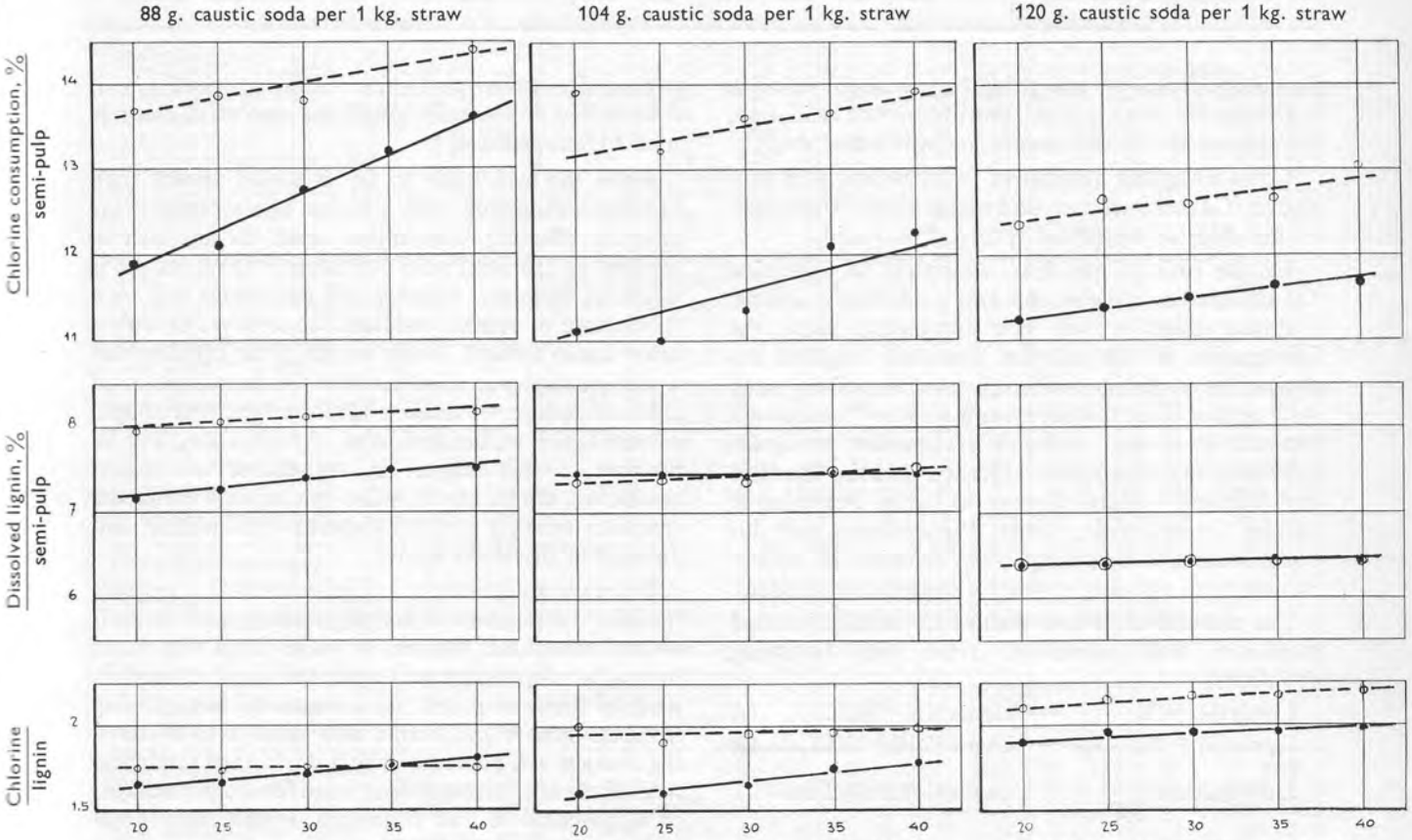

Fig. 7 *Fig. 8* *Fig. 9*

——— chlorination time 30 min. – – – – chlorination time 90 min.

TABLE 3—CHLORINATION AT DIFFERENT CONSISTENCIES FOR THREE SEMI-PULPS WITH DIFFERENT DEGREES OF DIGESTION (CHLORINATION TIME 30 MIN.)

Sodium hydroxide, g./kg. straw in digestion	*88*					*104*					*120*				
Semi-pulp consistency, per cent.	20	25	30	35	40	20	25	30	35	40	20	25	30	35	40
Increase in temperature (initial temperature 20°c) ..	14.5	19.5	26.5	34	33.5	13.5	17	21	30	35.5	11.5	19	21	27.5	33.5
Chlorination consumption on semi-pulp, per cent. ..	11.99	12.09	12.77	13.21	13.58	11.14	11.00	11.35	12.13	12.24	11.24	11.40	11.53	11.64	11.65
Hydrochloric acid formed in chlorination as a percentage of the semi-pulp	8.74	8.86	9.59	9.77	10.42	8.17	7.95	7.92	8.11	8.52	8.04	8.23	8.20	8.16	8.24
Unbleached screened pulp from straw, per cent.	40.32	42.29	43.76	43.31	42.71	43.76	44.44	44.89	43.49	42.21	42.73	43.86	44.46	41.50	40.71
Rejects from straw, per cent.	18.10	16.25	14.35	13.19	13.23	12.12	12.12	12.42	12.37	13.05	10.44	10.16	9.79	10.34	10.9
Dissolved matter/straw, per cent.	41.58	41.46	41.89	43.50	44.06	44.12	43.44	42.69	44.14	44.74	46.83	45.98	45.75	48.16	48.39
Unbleached pulp analytical data—															
Cellulose, per cent. ..	58.41	58.14	58.14	59.79	59.77	62.67	62.06	63.03	62.70	63.40	63.69	62.38	63.49	64.07	64.95
Pentosans, per cent. ..	29.13	28.96	28.92	29.29	28.18	30.87	29.91	31.00	29.87	29.04	29.82	29.99	31.00	30.63	30.55
Lignin (ash-free), per cent.	1.97	1.99	2.44	1.80	1.91	1.92	1.56	1.44	1.44	1.45	1.17	1.49	1.21	1.71	1.70
Ash, per cent.	4.58	4.67	5.26	4.97	4.60	2.22	2.33	2.40	2.39	2.50	1.70	1.51	1.76	1.60	1.55
Cellulose/pentosans ratio	2.01	2.01	2.02	2.04	2.12	2.09	2.07	2.02	2.10	2.18	2.14	2.08	2.05	2.13	2.13

In view of what we are going to say about chlorine consumption varying with substitution and oxidation, our researches on this matter are still under way.

Considering the amount of hydrochloric acid produced, it is reckoned that on average about 70 per cent. of the chlorine consumed is turned into acid.

On the basis of our data, we sought to apportion the chlorine to substitution and oxidation reactions. Chlorine addition was not considered, since the information in the relevant literature requires experimental conditions differing somewhat from ours. As a matter of fact, Hibbert and Sankey[4] obtained a product by partial addition of bromine to lignin, operating in non-aqueous solvents. Harris, Sherrard and Mitchell[5] added chlorine to lignin, operating in carbon tetrachloride, while Freudenberg and his collaborators,[6] operating with bromine in hydrobromic acid, obtained entirely a substitution product.

The chlorine to be apportioned to substitution and oxidation was calculated from the following equations—

$$\text{Lignin (H)} + Cl_2 \longrightarrow \text{Lignin (Cl)} + HCl \quad (1)$$

$$\text{Lignin (H)} + Cl_2 + H_2O \longrightarrow \text{Lignin (OH)} + 2HCl \quad (2)$$

(Lignin (H) and carbohydrates → HClO; Lignin (OH) and oxidised carbohydrates)

The difference between the total chlorine consumption and the chlorine corresponding to the total acidity developed represents the amount of chlorine organically bound to lignin. From equation (*1*), it follows that double this value is the amount of chlorine used for substitution.

From the tests made so far, it would appear that, in chlorinating stuff with a higher lignin content, the chlorine effecting substitution tends to diminish in amount as the semi-pulp consistency increases. It is doubtful, however, whether this percentage will tend to increase or remain constant for semi-pulps with a lower lignin content. Since we are of the opinion that a relationship may exist between the consumption of chlorine acting as oxidising agent and the percentages of non-lignin matter dissolved, greater study will be devoted to this subject in the course of current researches, which are intended to elucidate better the reactions existing between chlorine consumption and amount of dissolved lignin.

From the analytical data (Tables 3 and 4), it appears that the composition of the pulps within each series is almost invariable, whereas it varies from one series to another depending only upon the initial characteristics of the semi-pulps. As a matter of fact, passing from the first to the second and third series of tests, the average ash contents have a downward tendency, while there is a corresponding trend for the percentages of alpha-cellulose and pentosans, whose ratio, however, remains unchanged.

This ratio (1.18 for straw and 1.60 for semi-pulp) is in practice equal to 2 for unbleached pulps. It is

interesting to note that, depending upon the different chlorination conditions, even though there were variations in yields and chlorine consumptions, these have not affected this ratio.

The preceding facts would suppose that the straw hemicelluloses coming undissolved out of the first soda process should be considered as closely bound to the pulp and, at variance with the reaction of the

TABLE 4—CHLORINATION AT DIFFERENT CONSISTENCIES FOR THREE SEMI-PULPS WITH DIFFERENT DEGREES OF DIGESTION (CHLORINATION TIME 90 MIN.)

Sodium hydroxide, g./kg. straw in digestion	*88*				*104*					*120*				
Semi-pulp consistency, per cent.	20	25	30	40	20	25	30	35	40	20	25	30	35	40
Increase in temperature (initial temperature 20°C) ..	15.5	22.5	27.5	36	14.5	21	22.5	30	36.5	14.5	19.5	23	29	34.5
Chlorination consumption on semi-pulp, per cent. ..	13.72	13.85	13.79	14.42	13.90	13.23	13.58	13.64	13.96	12.37	12.63	12.57	12.68	13.04
Hydrochloric acid formed in chlorination as a percentage of the semi-pulp	10.10	10.02	10.18	10.79	9.48	9.58	9.25	9.63	10.07	9.01	8.69	8.61	9.21	9.33
Unbleached screened pulp from straw, per cent.	45.86	46.69	49.13	49.75	44.29	45.06	45.75	45.29	43.92	45.14	45.62	44.79	44.64	43.82
Rejects from straw, per cent.	10.78	8.94	7.86	6.77	9.54	8.55	8.36	7.27	7.20	8.47	6.67	6.76	5.48	6.26
Dissolved matter/straw, per cent.	43.36	44.37	43.01	43.48	46.17	46.39	45.89	47.44	48.88	46.39	47.71	48.45	49.88	49.92
Unbleached pulp analytical data—														
Cellulose, per cent. ..	60.87	60.05	60.95	61.28	63.44	62.40	62.46	62.61	64.17	64.03	63.83	64.42	64.22	64.71
Pentosans, per cent. ..	28.54	28.40	29.16	28.20	28.93	28.52	28.74	28.44	28.48	29.96	30.23	29.59	29.65	30.06
Lignin (ash-free), per cent.	1.70	1.51	2.07	1.91	1.64	2.38	2.58	2.07	1.86	1.91	1.77	1.48	1.45	1.28
Ash, per cent.	4.32	4.08	5.14	5.35	2.99	2.94	2.84	2.97	3.11	1.65	1.58	1.67	1.42	1.74
Cellulose/pentosans ratio	2.13	2.12	2.09	2.18	2.20	2.19	2.17	2.20	2.25	2.13	2.12	2.17	2.17	2.16

TABLE 5—RESIDUAL PERCENTAGES OF STRAW CONSTITUENTS IN UNBLEACHED PULPS (CHLORINATION TIME 30 MIN.)

Sodium hydroxide, g./kg. straw in digestion	*88*					*104*					*120*				
Semi-pulp consistency, per cent.	20	25	30	35	40	20	25	30	35	40	20	25	30	35	40
Cellulose*, per cent.	72.23	75.43	78.40	79.41	78.28	84.11	84.57	86.77	83.61	82.08	83.46	83.89	86.56	81.53	81.10
Pentosans, per cent.	42.56	44.37	45.86	45.97	43.61	48.98	48.19	50.45	47.10	44.44	46.20	47.69	49.97	46.08	45.09
Lignin (ash-free), per cent.	4.70	5.00	6.31	4.64	4.82	5.00	4.13	3.85	3.73	3.64	2.97	3.89	3.20	4.22	4.12
Ash, per cent.	19.27	24.22	24.02	22.46	20.50	10.14	10.80	11.24	10.84	11.01	7.58	6.91	8.16	6.93	4.58
Cellulose/pentosans ratio ..	1.69	1.69	1.70	1.72	1.79	1.71	1.75	1.71	1.77	1.84	1.80	1.75	1.73	1.76	1.79

* Standard German method

TABLE 6—RESIDUAL PERCENTAGES OF STRAW CONSTITUENTS IN UNBLEACHED PULPS (CHLORINATION TIME 90 MIN.)

Sodium hydroxide, g./kg. straw in digestion	*88*				*104*					*35*				
Semi-pulp consistency, per cent.	20	25	30	40	20	25	30	35	40	20	25	30	35	40
Cellulose*, per cent.	85.61	85.98	91.84	93.49	86.16	86.22	87.63	86.96	86.44	88.65	89.29	88.49	87.91	86.96
Pentosans, per cent.	47.45	48.07	51.94	50.86	46.45	46.6	47.67	46.70	45.35	49.03	50.00	48.05	47.99	47.76
Lignin (ash-free) per cent.	4.64	4.20	6.06	5.66	4.32	6.4	7.03	5.58	4.86	5.13	4.81	3.95	3.85	3.34
Ash, per cent.	20.68	19.88	26.35	27.78	13.82	13.8	13.50	14.04	14.25	7.77	7.52	7.80	6.61	7.95
Cellulose/pentosans ratio ..	1.80	1.78	1.76	1.83	1.85	1.8	1.83	1.86	1.90	1.80	1.78	1.84	1.83	1.82

* Standard German Method

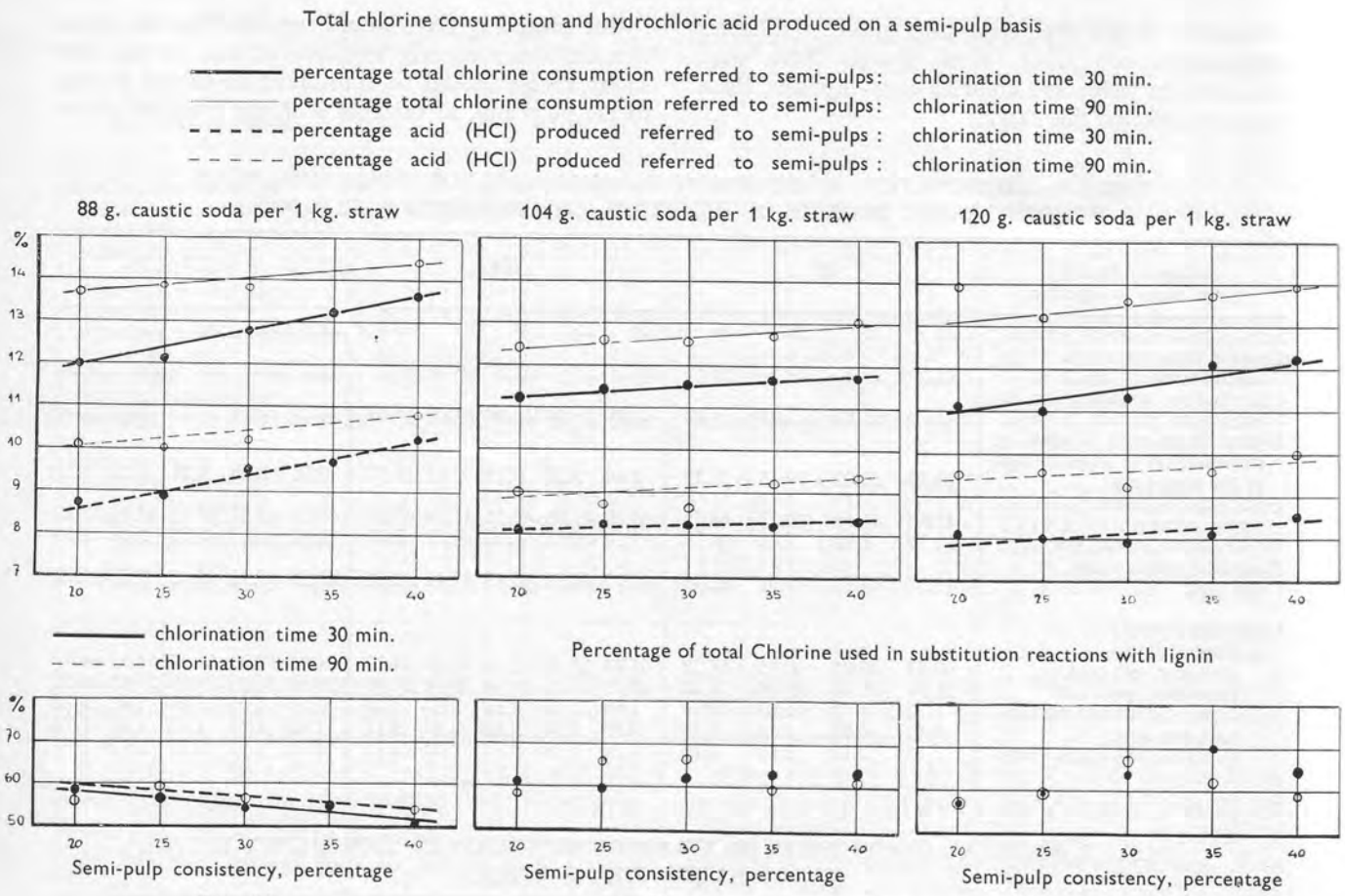

Fig. 10 *Fig. 11* *Fig. 12*

hemicelluloses present in other plant materials, cannot be eliminated without a proportional loss of pulp occurring at the same time. This is at least within the limits and under the conditions of treatment described in this paper.

Conclusions

THE influence of three variables that play a role in the chlorination of the straw semi-pulps, was examined—

(*a*) Degree of cooking.
(*b*) Pulp consistency.
(*c*) Chlorination time.

The result of the tests shows that, as these three parameters vary, appreciable variations occur in the yields, in the chlorine consumptions and in the production of hydrochloric acid.

The solubility of lignin is influenced by the initial cooking degree of the semi-pulp and varies in relation to the consistency and chlorination time only in the case of a semi-pulp with higher lignin content. On the other hand, so far as semi-pulps with lower lignin content are concerned, the influence of these two parameters is almost irrelevant.

The carbohydrate solubility increases when chlorination lasts longer and the pulp consistency increases.

In the products obtained, independently of yield variations, the proportions of cellulose and pentosans are equal in all cases.

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6. Freudenberg, K. *et al.*, *Berichte*, 1929, **62**, 1554

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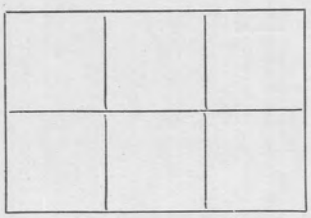

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TAPPI Routine Control Methods
(*Technical Association of the Pulp and Paper Industry, New York, 1959*)

RC–104 Consistency of pulp (centrifuge)
RC–105 Consistency of pulp (lever press)
RC–106 Consistency of pulp (groundwood)
RC–267 Block-tensile test of bonding quality
RC–268 Speed of grab adhesion test
RC–269 Pin test of bond quality in corrugated board
RC–270 Film identity tests
RC–271 Iron in cellulosic materials colorimetric method
RC–272 Test for bonding strength of adhesives on flexible adherends

Preservation of Documents by Lamination (Monograph 5)—W. K. Wilson and B. W. Forshee (*National Bureau of Standards, Washington, D.C., 1959, price 20 cents*)

The chemical stability and physical properties of cellulose acetate film used to preserve and restore old or damaged documents by lamination were investigated. Pretreatment of documents with alkaline media before lamination is desirable if the paper contains an appreciable amount of acid. The lamination process does not degrade cellulose acetate film to a measurable extent. Acid-free papers are not degraded during lamination, but papers containing acid are degraded in proportion to the amount of acid present. Tissue added to the laminate increases the tensile strength and internal tear resistance, but decreases edge tear resistance compared with that of film alone extending beyond the paper.
The loss of plasticiser with time from a cellulose acetate laminating film does not impair the properties of the laminate. Composition and performance specifications for a cellulose acetate laminating film suitable for archival use are presented. The properties of polythene and polyethylene terephthalate films of interest in connection with their possible use for the protection of documents are discussed.

Paper-Making Practice—H. Hardman and E. J. Cole (*Manchester University Press, 1960, price 45s.*)

Contents — Groundwood; neutral sulphite semi-chemical pulping; sulphite pulping; sulphite pulp; the kraft (sulphate) pulping process; the screening of woodpulp; the bleaching of woodpulp; strawpulping; stock chest design; stock flow systems; beating; sizing; head box design; drainage on the wire; the dandy roll; the wire; changing the wire; paper-machine drives; wet felts; suction rolls; the press section; suction pick-up; some problems of drying; reeling, slitting and rewinding; running the paper-machine; slime control.

Pulp and Paper from Annual Plants—O. Wurz (*Eduard Roether Verlag, Darmstadt, 107 pp. (63 references), 1960, 34s.*) [German text]

I. Occurrence and testing

II. Straw:

Structure and chemical composition—
(*a*) Wheat straw; (*b*) Maize straw; (*c*) Rice straw; (*d*) Fine straw; (*e*) Chemical composition

Properties of pulps made from various types of corn straw

Sources, harvesting and storage of straw—
(*a*) Sources; (*b*) Harvesting and storage

Pulping—

(*a*) Unbleached and semi-chemical strawpulp;
(*b*) Strawpulp—

1. Straw preparation;
2. Soda and kraft pulping: hot method, cooking liquor, chemical reaction during pulping, pulping technology, preparation of cooking liquor, cold process;
3. Sulphite pulping (neutral sulphite): preparation of cooking liquor, cooking;
4. Chlorine process, De Vains process, Pomilio-Celdecor process;
5. Rice straw pulping; 6. Continuous pulping

(*c*) Pulp screening; (*d*) Bleaching; (*e*) Yields, chemicals, water, steam and power requirements for the various processes; (*f*) Pulp properties; (*g*) Papermaking with strawpulp

III. Esparto:

Sources, harvesting and structure; Pulping technology; Pulp properties and use in papermaking

IV. Bamboo:

Sources, harvesting and structure; Pulping technology; Pulp properties and use in papermaking

V. Bagasse:

Sources and structure of sugar cane

Availability, composition and structure of bagasse

Pulping—

(*a*) Removal of pith from raw bagasse; (*b*) Storage of bagasse; (*c*) Pulping processes:—soda process, kraft process, neutral sulphite process, Pomilio-Celdecor process, mechano-chemical process, continuous pulping

Pulp properties and papermaking

VI. Other annuals used for pulping:

Phragmites; Thypha; Arundo donax; Other grasses

(*continued overleaf*)

TRANSLATIONS FROM FOREIGN JOURNALS

FIVE announcements have been made (**Technical Bulletin** 1954, **31** (6), 197; 1957, **34** (1), 8; 1958, **35** (5), 153 and 1959, **36** (4/5), 73; **Paper Tech.**, 1960, **1** (1), 70) and a sixth supplement is now given. Copies of all these items are available and interested members are requested to obtain from the Librarian details of charges of those already published, as well as of those listed below.

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Increasing wire life on the Fourdrinier machine — A. Unden
Zellstoff u. Papier, 1958, **7** (12), 363–364

A simplified method of making wet strength spinning papers — L. A. Kantor and S. M. Kozina
Bumazh. Prom., 1959, **34** (7), 12

Disinfection of waste paper — L. A. Kantor and Ts. E. Knepel'
Bumazh. Prom., 1959, **34** (9), 12

Synthetic wires for papermachines — M. Veinfurt
Bumazh. Prom., 1959, **34** (9), 7

Sizing paper with a mixture of rosin size and sulphite liquor waste — V. N. Sokolov
Bumazh. Prom., 1959, **34** (12), 16

A size press and its possible applications — H. Kirchoff and H. Friedrich
Wochbl. Papierfabr., 1958, **86** (21), 917

Fourdrinier wires from plastics — M. Weinfurt and M. Chromy
Papir a Celulosa, 1959, **14** (1), 7–9

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The Ancient Papermills of the Former Austro-Hungarian Empire and Their Watermarks—G. Eineder: General Editor—E. J. Labarre
(The Paper Publications Society, 1960, Part VIII, £11 15s.)

★ *Publications received*

Mechanical Pulping Manual—Tappi Monograph Series No. 21—Edited by E. H. Johnson
(Technical Association of the Pulp and Paper Industry, New York, 1960)

Contents — History of mechanical pulping; Properties and uses of groundwood pulp; Effect of condition and kind of wood on groundwood pulp quality; Mechanical pulping processes (groundwood, mechanical pulp from chips, chemigroundwood, the caustic extraction of aspen groundwood); Grinding equipment (types of grinder, pulpstones); Screening, refining and thickening (screening and centrifugal cleaning, refining of screenings, thickening of pulp); Bleaching of mechanical pulps; Testing and control (general considerations, description of tests); Glossary of common terms; Bibliography of mechanical pulping (author index to bibliography); Index
[Text 104 pages, bibliography 1 068 references]

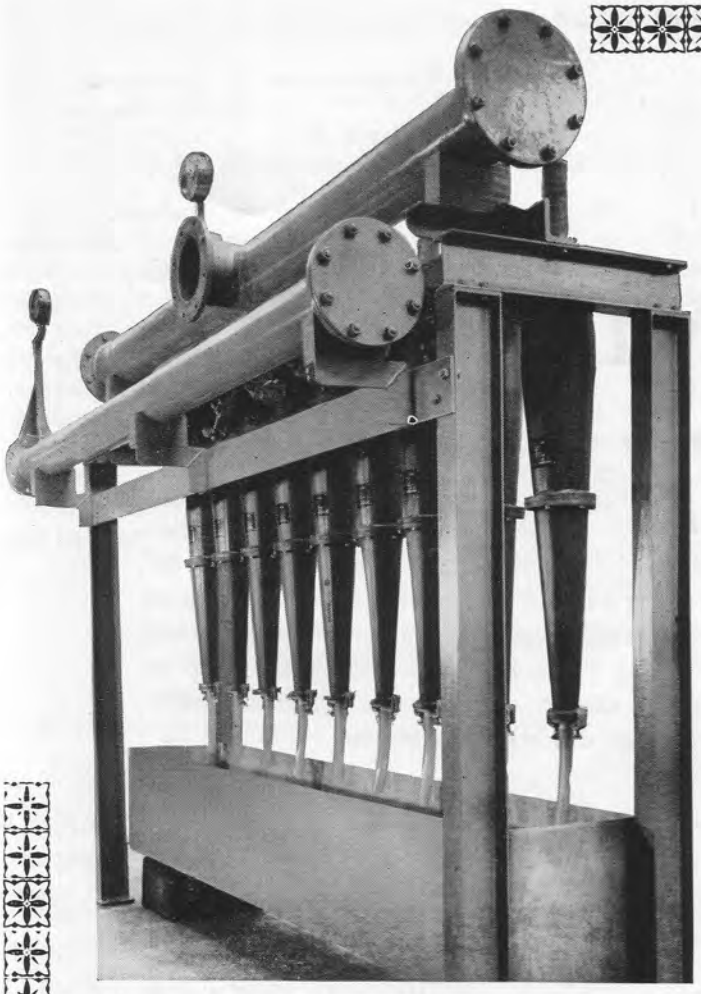
Testing of packaging materials—
VVK Merkblatt 16/59—Water repellency of solid board
(Verband Versand-Kartonagen, Frankfurt on Main, W. Germany, March, 1960)

For your reading *(continued from page 372)*

Increased slimicidal efficiency with new mercurial complexes
S. J. Lederer and W. J. Delaney
Pulp and Paper Mag. Can., 1960, **61** (4), T250

Magnefite 'vapour phase' pulping
J. W. Wilson and D. O. Meara
Pulp and Paper Mag. Can., 1960, **61** (4), T259–T262

A chemical comparison of kraft and sulphite pulps
J. K. Hamilton and N. S. Thompson
Pulp and Paper Mag. Can., 1960, **61** (4), T263–T272



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An evaluation of an electrical method for measuring stock flow

W. Brecht and K. Wimmer
Wochbl. Papierfabr., 1959, **87** (21), 895–900

IN comparison with conventional methods of measuring the volume of a liquid flowing through a pipe, the operation of the Altoflux instrument is based on the electrical and not on the hydraulic properties of the medium. The basis of measurement is derived from Faraday's law that, if a conducting material is moved through a magnetic field in a direction at rightangles to the field, then a certain voltage will be induced in the conductor and this voltage will be proportional to the field strength of the magnetic field and to the length and speed of the conductor. This can be expressed as—

$$e \backsim H.\ L.\ V,$$

where e = induced voltage,
H = field strength,
L = length of conductor,
V = speed.

In the case in question, this can be expressed as—

$$e \backsim H.\ D.\ V,$$

where D = inside diameter of the pipe.

From this relationship then, if the field strength and the pipe diameter are known, by measuring the induced voltage e, it is possible to obtain a value for the speed V; by multiplying this by the pipe diameter, a measurement of flow per unit time is obtained.

Faraday's induction law can be applied only when the liquid is conducting, its resistance does not exceed a certain value, the pipe is non-conducting and circular in section, the liquid fills the pipe and the magnetic field is uniform over the pipe's cross-section.

The apparatus was fitted into circuit on an experimental installation, consisting of mixing chests, pumps and a conventional type of measuring chest, so that the conditions could be changed and a simultaneous check made on the new instrument's accuracy.

It was found from a series of experiments that the readings given by the Altoflux instrument were largely independent of the composition and conditions of the liquid flowing through the pipe. There was a linear relationship between flow-through and instrument reading and this held true both with highly acidic water and with stock suspensions. The stock suspensions used covered a wide range of pulps, stock consistencies, filler contents and temperatures.

The instrument gave inaccurate results only when air was entrained in the water or stock and the flow-through figure then was equal to the actual volume of liquid plus whatever air was also present.

The Altoflux is designed to operate over a flow-through range of 0–500 litre/min., but it could be tested only over a range of 25–130 litre/min. in these experiments owing to limitations in laboratory equipment. The results should, however, be generally applicable.

This apparatus provides a convenient and accurate method of measuring stock flow to the papermachine and is easy to install and maintain, though its cost may be too high for small mills.

Asbestos paper for electrical insulation

J. Jaroszewski and H. Poradowska
Polish Paper Rev., 1959, **15** (5), 150–154

THE experimental work was undertaken to study the problem of making asbestos paper that would conform to the following specification—

1. Caliper (mm.): 0.2; 0.3; 0.4; 0.5.
2. Apparent specific gravity: above 0.50 g./c.c.
3. Moisture content: less than 3 per cent.
4. Loss on heating: less than 20 per cent.
5. Total iron content: less than 3.6 per cent.

The required tensile strengths and penetrating potentials are as given in Table 1.

TABLE 1

Caliper, mm.	*Tensile strength, kg.*		*Penetration potential,* V.*
	Machine-direction	*Cross-direction*	
0.2	2.0	0.6	1 200
0.3	2.2	0.8	1 400
0.4	2.5	1.2	1 700
0.5	3.0	1.4	2 200

*Current of frequency 50 cycles/sec. at 20 ± 5°C

Three different grades of asbestos were examined, two of them being chrysotiles (Chinese and Russian) and one crocidolite (African). Initial laboratory tests were carried out to find which of these was most suitable for making asbestos paper and, although the product made from the Russian asbestos was inferior to the other two, it conformed to the specification above and it was chosen, as drainage is good and this is an important consideration in practice.

The asbestos for making the laboratory handsheets was beaten in a laboratory Hollander for given times and a known amount of starch (3 or 5 per cent.) was added. The sheets of asbestos paper were then made in a Rapid-Köthen apparatus and tested in accordance with the Polish standard methods. This work enabled some preliminary conclusions to be arrived at—

1. Increasing the amount of starch added improves the strength properties of the sheet, but has little effect on the dielectric properties.
2. Strength, apparent specific gravity and electrical resistance increase with increasing caliper of the sheet.
3. The effect of beating is to decrease the tearing strength of the sheet, but the effect on tensile strength is variable and depends on the kind of asbestos used.
4. The penetration potential increases somewhat with beating.

On the industrial scale, this type of asbestos was found to be suitable for making asbestos paper conforming to specification, if the asbestos is carefully purified and beaten in a Hollander with steel bars for 30 min. at a consistency of about 3 per cent. Starch, 3 per cent. calculated on the dry weight of asbestos, is then added and thoroughly mixed before the stock is pumped to the machine chest. If the electrical resistance of the product is too low, it can be improved by increasing the amount of starch to 5 per cent., but it is possible that this may cause drainage difficulties on the wire.

The interference of starch and titanium dioxide in rosin size retention

G. Jayme and K. Reimann
Das Papier, 1959, **13** (19/20), 475–483

THE investigation was designed to evaluate the effect of starch and titanium dioxide on size retention by analyses of the paper produced and of the backwater and effluent when various amounts of the two materials were added to the stock. The machine used was a small one making 15.4 tons/day of speciality paper at a moisture content of 8 per cent. The pulp was mainly spruce sulphite pulp with a small amount of added broke. The rosin size was completely saponified with a dry solids content of 25 per cent. (calculated on moist rosin), 20 per cent. rosin acids and 3 per cent. unsaponifiable fraction. Alum was used as precipitant and the starch was the water-soluble, Dutch product 'Fiberjel', which was added to the beater. Sodium aluminate was added to the process water and the pH was then found to be 7.6 at the slice; in the wire pit 7.2; 7.0 at the Adka saveall.

The methods for separation and determination of starch, titanium dioxide and rosin size are described. It was found that starch and titanium dioxide considerably reduced the retention of rosin size by the paper, this being due mainly to the formation of complexes with starch. In one of the experiments, size retention was only 63 per cent., with 26 per cent. being lost in the effluent, the remainder recirculating in the backwater. Retention of starch and titanium dioxide was lower still, typical values being 28 per cent. retention for the former and 39 per cent. for the latter, with losses of 40–50 per cent. in the effluent.

It is considered that there are three possible factors responsible for these losses—

1. The addition of sodium aluminate causes precipitated size to go back into solution.
2. Starch forms a water-soluble complex with rosin soaps.
3. Rosin acids are finely dispersed by titanium dioxide.

It is not known which of these factors is the most important and much work remains to be done on the subject.

A new instrument for measuring (paper) smoothness and its uniformity

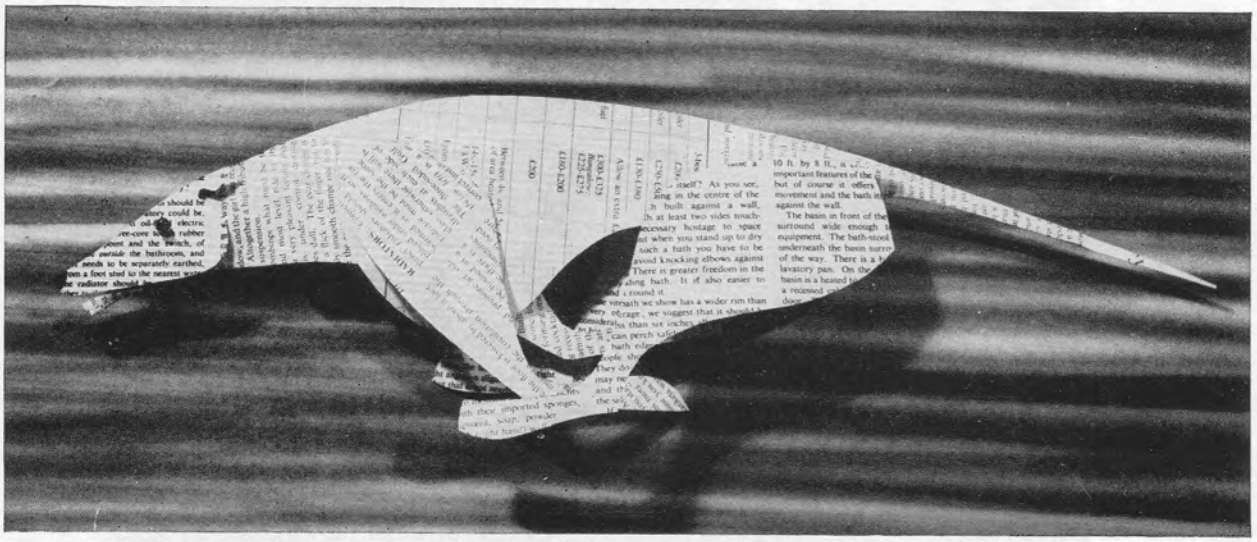
W. Brecht and H. Geenan
Das Papier, 1959, **13** (21/22), 519–530

SINCE it was considered that none of the available smoothness or roughness testers was satisfactory, a new instrument has been designed at the Darmstadt Institute of Paper Technology. This new instrument not only measures roughness, but also provides information on the extent of variation over the surface of the sheet. Like the conventional instruments, it is based on the principle of measuring airflow over the surface of the sheet being tested, but it is claimed that the results obtained correlate better with the results found from printing tests. The strip of paper to be tested moves slowly over the thin edge of the measuring head and the airflow between this edge and the paper is continuously measured by a hot-wire ammeter, the pulses in voltage being recorded on an electronic counter. The sample strips used are 42 mm. (1.65 in.) wide and at least 100 mm. (3.89 in.) long and the pressure exerted by the measuring head is only 0.1 kg./sq. cm. (1.42 lb./sq. in.). The measuring edge of the instrument is 30 mm. (1.18 in.) long and the air pressure in the measuring head is 250 mm. (9.84 in.) water gauge. When the test has been completed, the percentage distribution frequencies for roughness are read and the mean roughness value is calculated.

(*continued on page 433*)

Out ahead

Spence aluminium sulphate is used to ensure good sizing for a wide variety of papers.



Specialised farina starches are also available for direct beater addition and size press application.
Further details on aluminium sulphate, sodium aluminate, and farina starches may be obtained on request.

SPENCE **ALUMINIUM SULPHATE**

PETER SPENCE AND SONS LIMITED
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(continued from page 428)

The applicability of the instrument was tested by taking fourteen different papers and comparing the results given by this tester with the results obtained using the Bekk and Bendtsen instruments and the results obtained when the papers were printed. The results of this investigation are given in Table 1.

The values given by the new instrument agree well with the results from printing tests and it is claimed that the error arising in the Bekk and Bendtsen instruments from air actually penetrating the sheet (and not moving over the surface being tested) is greatly reduced with the new design. This source of error in the Bekk and Bendtsen instruments gives particularly misleading results in testing paper or chrome board that has been glazed on one side only, since the rough surface on one side provides an easy passage for air passing through the sheet.

The new apparatus was then used to study three glazing methods applied to several wood-free papers and mechanical printings. The three methods were as follows—

1. Dynamic method, using a supercalender with steel and paper bowls.
2. Dynamic method, using only steel bowls.
3. Static method of compression between polished steel plates.

It was found that the degree of glazing was highest and most uniform with the static method and lowest with the supercalender. The latter method, however, gave the most stable degree of glazing as was seen from measurements made after the various types of paper had been conditioned for 16 hr. at 20°C and 65 per cent. R.H., which decreased the smoothness of the supercalendered paper much less than was the case with paper glazed by the other two methods.

The new apparatus was also used to assess the effect of each bowl of a supercalender on the degree of smoothness achieved: it was found that there is very little increase in smoothness after the third bowl.

TABLE 1—COMPARISON OF SUITABILITY FOR PRINTING WITH SMOOTHNESS OR ROUGHNESS FOR DIFFERENT COATED PAPERS

Type of paper	*Suitability for printing*	*New apparatus*		*Bendtsen apparatus—mean roughness, ml./min.*	*Bekk apparatus—mean smoothness, sec.*
		Mean roughness, ml./min.	*Range, ml./min.*		
4 OG	1.0	4.4	2.9	no reading	259
1 OHG	1.0	5.2	5.0	8.2	61
6 OHG	1.2	4.2	2.3	9.2	60
3 OHG	1.2	5.3	5.2	7.7	72
5 OHG	1.4	5.1	3.8	8.2	58
2 OHG	1.4	5.4	4.4	6.6	67
13 BG	1.4	8.5	7.1	6.1	298
7 BG	1.4	9.8	9.3	4.7	1 471
8 BG	1.6	19.0	14.9	11.3	2 280
9 BG	1.8	16.7	12.9	15.7	963
12 BG	1.8	19.0	10.6	15.0	577
14 BG	2.0	16.0	11.0	14.6	169
10 BG	3.0	40.0	18.6	31.4	369
11 OG	3.0	45.0	26.4	35.5	258

1–8 highly glazed art paper
OG — one side glazed
BG — both sides glazed
9–14 art paper
OHG — one side highly glazed

Comparative evaluation of stiffness testers

O. Billing and G. Gavelin

Svensk Papperstidn., 1959, **62** (8), 284–288

THE instruments evaluated were two manufactured by the Lorentzen and Wettres Engineering Co. (designated *A* and *B*) and one designed by Stark and supplied by Rausing and Crafoord, called *C* in these experiments. Instruments *A* and *B* are alike, except for the manner of loading, both being motor-driven and equipped with resistance strain gauges. In apparatus *A*, the test strip is held, but not clamped, between two holders, one of which is connected to the strain gauge, while the other is mounted on a swivel and the force is applied in the plane of the strip. In apparatus *B*, one end of the strip is held by a clamp mounted on a swivel and the other end just touches a pressure-sensitive receptor connected to a strain gauge. In both cases, the test strip is fixed in the vertical plane so that the weight of the strip does not affect the result. The swivel on which the holder or

clamp is mounted is turned by an electric motor that is automatically stopped when the swivel has turned through 15°. Apparatus *C* operates on a different system, one end of the test strip being clamped and a flexural force being applied to the strip by a compressed air source acting through a system of levers; pressure adjustments are made by means of a throttle valve in the tubing. This instrument was not used in the later tests, as it was found that a great deal of practice was necessary to achieve uniform load increase on the sample and it was difficult to ascertain the bending angle.

It was concluded from the experiments that the instruments are not directly comparable, as different bending radii are found on similar samples of board. Both *A* and *B* are sensitive to lateral forces, but this is not the case with *C*. None of the instruments measures the moment, which gives rise to complications, particularly if the test piece is not absolutely straight at the beginning. The testing error with *A* and *B* is great, but accuracy probably depends on how punctiliously warped test pieces are removed from the series and how precisely the pressure element is adjusted before testing. The actual accuracy of reading is quite good, but the time factor is of great importance, for the measured force continually decreases because of creep in the sample. The investigation showed that such stiffness tests only give relative values, without reliable agreement with results from other instruments.

An evaluation of the instrument designed by the Leipzig Printing Institute for measuring printability

F. Wultsch and K. Schubert

Wochbl. Papierfabr., 1959, **87** (17), 739–741

THE amount of ink p transferred from the forme to the paper by this experimental instrument is given by the equation—

$$p = (1 - e^{a^2 m^2}) \times \left\{ w_o \left(1 - e - \frac{m}{w_o}\right) + \alpha \left[m - w_o \left(1 - e - \frac{m}{w_o}\right)\right] \right\}$$

where m = initial quantity of ink,
a, w_o and α are constants for a given paper.

The equation thus contains 3 unknowns and can be solved by making a suitable number of determinations of m and p and substituting appropriate values. The figure a is the reciprocal of the amount of ink required for covering; that is, the greater a is, the smaller the amount of ink required for complete coverage of the sheet. The value a represents a complex, since it depends on the smoothness, softness and wettability of the sheet, but for evaluation of printability it is a simple quantity varying between 0.15 for very coarse papers to 1.0 for very smooth papers.

The factor w_o represents the amount of ink absorbed by the paper during the actual printing and bound in the paper; thus, it is an expression for the absorptive power of the sheet and has values between 0 for non-absorbent papers to 5 for extremely absorbent papers.

The constant α shows whether ink separation takes place nearer to the forme (represented by large α values) or nearer to the sheet. The larger α is, the less the quantity of ink required: in the majority of cases, α is found to be in the range 0.3–0.5.

A high a value is thus an indication of good printability, while the value of w_o is not so important. A high w_o is certainly desirable for rapid drying, but this involves a danger of strike-through and thus the type of paper must also be considered.

In the experiments, the results were given as pick resistance and printability and it was found that both these factors were considerably improved by using 20 per cent. birch pulp in the furnish of the paper. Higher porosity and absorptive capacity combined with greater softness gave improved printing properties with little danger of strike-through when used for bulky book printings.

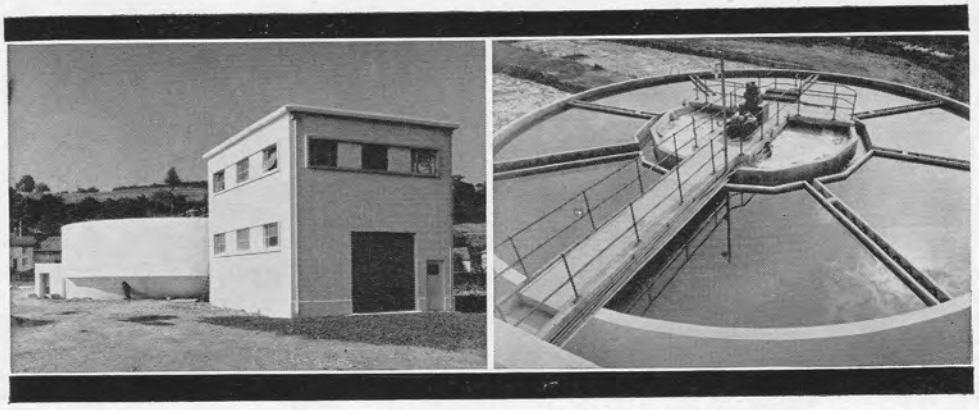
From the experimental results, it is concluded that this instrument is of great value to the paper industry, since it gives fundamental information on the effect of additives, beating time and machine conditions on the printability of the paper. The apparatus is particularly useful in those cases when different additives are used or when adjustments are made to the stock preparation equipment to improve the printability of the product, since it enables the effect of these alterations to be determined.

The apparatus is of less use for process control, as it requires too much time for constructing the ink distribution curves. It is, however, suitable for measuring pick resistance during production and is better than either the Bekk instrument or the Dennison wax test for this purpose, because it uses actual printing ink and the correlation between experimental and practical results is therefore better. The IGT tester also employs ink and is more rapid in operation, but the Leipzig instrument is more accurate.

This instrument is of value to both the printing and paper industries for its versatility—for example, the drying rate and strike-through can be determined and the suitability of a particular paper for a given job can be accurately predetermined.

(*continued on page 437*)

A 'TAILOR MADE' TREATMENT PLANT FOR GLORY MILL



External view of treatment plant showing Chemical House and Accelator tank

View of Accelator clarifier from Chemical House

The new Paterson water treatment plant for the Glory Mill of the Wiggins Teape Group is the result of extensive research and pilot work carried out two years ago. In designing the plant it was decided that the limits set for the quality of the effluent should not exceed 30 p.p.m. suspended solids and the B.O.D. 20 p.p.m.

The background to this decision is interesting. At Glory Mill, a new sewage disposal works some miles away will receive the polluted effluent via a main sewer. To finance the new scheme, users in the area were asked to subscribe to the cost according to the estimated quality and quantity of their effluent. It was found more economical to treat the effluent at Glory Mill to a high degree of purification *before* discharge, and the limits already mentioned were set.

More details as to how the plant operates are given in the Paterson Engineering Co. Ltd. Technical Publication 707, a copy of which will be sent to you upon request.

ANOTHER Paterson PLANT FOR INDUSTRY

THE PATERSON ENGINEERING CO. LTD., 129 KINGSWAY, LONDON, W.C.2

(continued from page 434)

Investigation of the rub resistance of paper

M. Maciejko and T. Nierychlevski
Polish Paper Rev., 1959, **5** (15), 129–133

THE rub resistance of paper is defined as the resistance of fibres to separation from the sheet by a frictional force acting tangentially to the surface of the sheet. In the wider sense, rub resistance also includes resistance to the removal of coating or size from the surface of the paper by friction.

The basic features of the rub resistance tester built by the Polish Paper Research Institute are a carborundum disc, with diameter 150 mm. (5.9 in.) and grit size no. 60J and a clamp to hold the paper samples against this disc with a known pressure. The carborundum disc is rotated by an electric motor and a tank is fitted in the disc cover so that determination can be made under wet conditions by filling this tank with water or other liquid. The sample strip is held in contact with a quarter of the disc's circumference and a 50 g. weight is attached to the end of the strip to break the circuit when the strip breaks and thus to disconnect the revolution counter. The strips themselves are 15 mm. (0.59 in.) wide and the disc rotates at 100 rev./min. The number of revolutions necessary to cause the strip to break is recorded by the counter and used as a measure of rub resistance. After each determination of rub resistance, the carborundum disc is cleaned with a wire brush.

In preliminary tests to determine the accuracy of the method and reproducibility of the results, it was found that the scatter of results was considerable when determinations were made under dry conditions. This was taken to indicate that the method is not perfect, but also that the phenomenon of rubbing is affected by local differences in the structure of the paper such as thickness, apparent specific gravity and surface finish. Under wet conditions, the scatter of results was relatively small and reproducibility was good, but at least 6 parallel determinations should be made and the mean value taken.

In general, it was found that rub resistance was directly proportional to basis weight and, among papers with the same basis weight, those with high strength properties also had good rub resistance. Beating appeared to increase rub resistance and rosin sizing also produced large increases, surface sizing proving to be much more efficient in this respect than engine sizing. It was also found that rub resistance was usually higher in the machine-direction than in the cross-direction and that unbleached sulphate pulps had better rub resistance when their Sieber number (that is, hardness) was high.

An apparatus for the determination of the thermal conductivity of cast iron cylinders

L. Janson
Svensk Papperstidn., 1959, **62** (7), 241–244

SINCE the efficiency of a Yankee cylinder depends, among other factors, on the thermal conductivity of the cast iron shell, it is important that this be accurately measured, especially when new drying cylinders are being ordered. Even small variations in the composition of the iron can cause large variations in the thermal conductivity and two cast irons of the same composition may have different thermal conductivities, if the castings have been cooled at different rates.

The theory of the method is based on the fact that a heat wave moving through a body has a velocity depending, among other things, on the thermal conductivity of the material. In practice, a temperature oscillation is produced on one surface of the shell being tested and the rate of transmission of the wave through the material is then determined.

For this, a variable heat source is necessary and is provided by using a battery of 9 spiral heating elements connected to a 380 V., 3-phase, a.c. source with a variable transformer in each of the three phases. The three transformer spindles are mechanically coupled and the common spindle rotates so that a sinewave effect is produced at the heating elements. A thermocouple and a thermistor are used to measure the phase difference between the entrant and emergent waves and are connected to a potentiometer via a resistance box or Wheatstone bridge. Maximum possible temperature oscillations must be obtained on both sides of the material, if the phase difference is to be determined accurately. To achieve this, the applied voltage was varied over the limits 20–380 V.

The other data necessary for the calculation are the thickness of the material (which is most readily determined by the ultrasonic method), its specific gravity and specific heat. It is estimated that the accuracy of this method is $\pm$ 5 per cent., which is considered sufficient to enable valuable information on drying cylinder performance to be obtained.

Speeds and speed differences on the papermachine

K. Vesterinen

Paper and Timber (*Finland*), 1959, **41** (5), 261

THE practical aspects of speeds and speed differences of the moving paper web are considered, taking a modern high-speed machine making newsprint as an example. Factors affecting the rate of flow at the slice and means of controlling flow rate are considered. It is concluded that the basis weight variation is equal to half of the corresponding head box pressure variation.

In the press section, there are many different types of apparatus for measuring the circumferential speed of rolls and cylinders, the simplest and most widely used being small d.c. tachometers geared to the roll shaft. The voltage generated by the tachometer is directly proportional to the number of revolutions of the roll and, hence, to the speed of the paper web running on the roll surface. When the speed difference between two rolls is to be measured, the voltages from the two tachometers are combined and the voltage difference, which is proportional to the speed differences, is measured. The accuracy of measurement with such a system is usually about 0.2 per cent. Since the accuracy of this method depends on the roll diameter remaining constant, allowance must be made for roll wear and for alterations in roll diameter caused by regrinding or changing the roll.

Measuring speed difference is more difficult than measuring only speed, since in this case the revolution difference between the two rolls in question must also be known. The accurate calculation of the difference in the number of revolutions of two rolls is not always easy and accuracy can only be improved by counting revolutions over a lengthy period, but this is a slow method. An easier and more rapid measurement is provided by the stroboscopic method.

In this method, a gear is fitted to the shaft of one roll so that, when the circumferential speed difference of the rolls is zero, the gear shaft on this roll is revolving at the same number of rev./min. as the shaft of the second roll. A round disc with a distinguishing marking such as a projecting pin or a white line is fitted on the gear shaft and another disc with a slot about 2 cm. wide is fitted on the shaft of the second roll. When the two rolls are rotating at different circumferential speeds, the pin or line will be visible intermittently through the slot and, if the time (t) between two consecutive appearances is measured with a stop-watch, the web on the second roll will have travelled a distance πd further in this time than on the first roll and the speed difference is $\Delta v = \pi d/t$. In this method, the determination of speed difference is independent of the number of revolutions of the roll. If the circumferential speed of the second roll is higher than that of the first roll, Δv is greater than zero and the mark comes into sight from above and moves donwards; if Δv is less than zero, it appears from below and moves upwards. Should the mark not appear in the slot after a considerable lapse of time, it can be assumed that the speed difference is negligible. When a graph of speed difference as a function of time has been drawn, results can be converted by reading off the appropriate value.

Recently, d.c. tachometers have been supplemented by impulse counters and a.c. tachometers. In the impulse counter, a permanent magnet gear is coupled to the roll either directly or through a gear train and an electric pulse is produced on rotation each time the magnetic tooth passes the adjacent coil. The number of these impulses is proportional to the circumferential speed of the roll. The impulses are then fed to a subtraction circuit, where a difference frequency is produced and a voltage proportional to the speed difference is thus developed. An adaptation of the impulse generator uses two three-phase synchronous generators to produce a difference frequency, which causes a rotating magnetic field in the a.c. synchronous motor and results in this motor rotating at a speed proportional to the difference frequency. A small d.c. generator is installed on the motor shaft and the developed voltage is measured.

The hot presses on a Yankee machine

L. Janson

Svensk Papperstidn., 1958, **61** (16), 501–503

THE experimental work reported was done on a laboratory papermachine with a Yankee cylinder 2.8 m. (110.2 in.) in diameter and a face width of 1.05 m. (41.4 in.). There were two press rolls 0. 425 m. (16.7 in.) in diameter, the hardness of the rubber covering being 20° P & J. These press rolls are not cambered and are installed at 4° and 28°, respectively, from the vertical through the centre of the Yankee cylinder. The second press roll is easily removable from the machine.

The experiments were concerned with three different systems—

1. One press roll and one felt.
2. Two press rolls and one felt.
3. Two press rolls and two felts.

The machine was operated at 75 m./min. (246 ft./min.), using a bleached sulphite pulp beaten to 33°–36° S.R. to make paper with a basis weight of

25–45 g./sq. m. Further experiments were done on no. 1 system to find the effect of linear pressure on the moisture content after hot pressing. This work was done at a machine speed of 50 m./min. (164 ft./min.) with unbleached sulphate pulp beaten to 24° S.R.

The results of the work showed that the system of two press rolls and two felts always gave the lowest moisture content, but it is an open question whether this advantage can compensate for wear on two felts instead of on one. It is known, however, that the system using two press rolls and one felt results in greater felt wear than with either of the other arrangements. When low basis weight papers are being made, it is probably best to operate with one press roll and one felt, but each case must be decided relative to the factors of basis weight and utilisation of free cylinder surface.

The improved water removal in a hot press compared with that in a wet press is due not to the higher linear pressure, but to the increased temperature and consequent lowered viscosity of the water.

New aspects of the tensile strength of paper

W. Brecht and H. Erfurt

Das Papier, 1959, **13** (23/24), 583–592

A NEW apparatus was designed to investigate the tensile stretch of paper that would measure not only the force necessary to break the fibrous web, but would also give the force as a function of the tensile stretch from zero to breaking point. The apparatus was therefore designed to operate over a wide range of applied force and to have a high degree of accuracy over the whole range.

A three-phase motor drives a shaft, which moves the extension clamp and thus stretches the paper sample at a constant speed. The force associated with this stretch is transmitted to a leaf spring by the other clamp, which is free to move in the horizontal direction. The force/tensile stretch graph is obtained using an optical system. The applied force and stretch are measured by means of two small mirrors mounted on axes at rightangles to one another. In this way, the linear displacement of the extension clamp is converted to a rotational motion of the mirror measuring the stretch about a vertical axis, while the mirror for measuring the applied force rotates about its horizontal axis by an amount proportional to the force at the leaf spring. A thin diaphragm slit narrows the beam from the light source, this beam traverses the mirror system and is then focused on a screen. The applied force/stretch graph which is the resultant of the motions of the two measuring mirrors can either be followed visually on the screen or can be recorded on high sensitivity bromide paper. The applied force is variable over the range 30–1 000 g. and the range of stretch is 0.1–18.5 mm. The breadth of the test strips can be anything up to 50 mm. and the length can be varied 3–100 mm.

The experiments were carried out using test strips from sheets made on the Rapid-Köthen sheetmachine under constant conditions of drainage. These test sheets were then dried to various moisture contents by pressing lightly between sheets of blotting paper. The pressure exerted on the sheets in this method of drying is slight so that shrinkage can take place without hindrance. This is the only way of achieving uniform moisture content throughout the test piece, as well as ensuring reliable and exact measurements of the tensile properties. The clamps for the test pieces are so constructed that only a very small amount of water is extruded at the clamping zones even when papers with very high moisture contents are used. If there is any danger of the test strips losing water during testing, which might occur with very moist papers, the test is carried out in a conditioned atmosphere.

In the experiments, the moisture contents of the test strips varied over the wide range of 8–87 per cent. moisture content. The preliminary investigations on the general rheological properties of wet fibrous webs confirmed the results of earlier work that the rheology of wet paper is only slightly different from that of dry paper, although the tensile strength of dry paper is 10–100 times greater than that of the same paper at a moisture content of 80 per cent. and the wet tensile stretch is 4–8 times the dry tensile stretch. The influence of the test conditions and of the test strip dimensions proved to be very slight.

The main work was done with several pulps, including a semi-chemical pulp and a groundwood pulp; it was proved that the tensile strength varies exponentially with the dry solids content. Moreover, swelling (which in turn depends on the composition of the pulp and on the processes of beating and drying) has a favourable effect on tensile strength whatever the moisture content of the sheet.

Special attention was paid to the effect of the fines and long fibre fractions on tensile strength and it was found that the relationships between these factors were valid both for wet and for dry paper. This relationship is based on the tensile strengths of the different component fractions, on their proportions in the mixed pulp and on their apparent density. It is

concluded that the initial wet strength up to a limiting dry solids content, which is 35–50 per cent. depending on the swelling power of the pulp, is caused by frictional forces between fibres and is, hence, influenced by any alteration in the number of fibre contact points. Above 35–50 per cent. dry solids content, the influence of fibre-to-fibre bonds becomes more important and gradually exceeds the effect of frictional forces.

This scheme gives no explanation for the fact that the tensile strengths of wet fibrous webs can be the same, but may be vastly different when the webs are dried, though it certainly gives some idea of the operative factors in strength development and how this may be improved.

Studies on the distribution and retention of fillers in paper

H. Mack

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THE method used to study the filler distribution through the thickness of the sheet was to prepare microsections parallel to the surface and then to find the ash content of each section. Ash content determinations were made using the stainless steel bomb designed by Huber. Into this bomb is put a mixture of calcium chlorate, calcium nitrate and calcium/sodium carbonate, together with a test piece of the paper (about 2 g.), sodium peroxide and ethylene glycol and ignition is brought about by external heating. This method makes it possible to convert unreactive fillers and those that dissolve only with difficulty into a water soluble melt. The organic fibrous material is degraded and can be removed by treatment with soda solution. The temperature in the bomb is 300–400°C and the process takes only a few seconds, so that errors arising from losses in aqueous solutions are eliminated. The usual analytical methods are used to estimate the contents of titanium, barium, calcium, etc.

The experiments, which were carried out both on experimental laboratory machines and on production machines, were mainly concerned with the effect of dandy rolls on filler dispersion. On the industrial scale, three papermachines were studied, one making halftone printing paper, one mechanical printings and one medium grade rotogravure printings. In all cases, it was found that a dandy roll increased the ash content on the top side of the sheet, that is, the two-sidedness of the sheet was increased. In each of the three grades studied, this increase was about 8 per cent.

Somewhat different results were found with a 90 g./sq. m. paper being made on a fine paper machine at 292 ft./min. In this case, the dandy roll was not between the suction boxes, as in the other cases, but was positioned directly above the mid-point of the fourth suction box. The filler content in the middle layer of the paper was less than that in the adjacent layers on both the wire side and the top side. As with higher speed machines, however, the filler content was greater on the top side than on the wire side.

These results agree with the theory of dandy roll action, according to which the dandy roll forces water from the interior on to the top side of the sheet. This water contains large amounts of filler, which is deposited on the top side of the sheet and is then largely prevented from returning to the inside of the web, because the pressure of the dandy roll closes up the web structure.

The samples made with and without dandy rolls were then tested for smoothness using the Bekk apparatus and for pick resistance with the FOGRA apparatus. The results of these experiments are given in Table 1.

TABLE 1—SMOOTHNESS (BEKK) AND PICK RESISTANCE (FOGRA)

Property	*Halftone paper*		*Mechanical printing*		*Rotogravure printing*	
	Dandy	*No dandy*	*Dandy*	*No dandy*	*Dandy*	*No dandy*
Top side smoothness, sec.	114.0	139.0	20.2	23.7	7.35	7.7
Wire side smoothness, sec.	103.5	155.0	12.6	13.95	7.35	8.95
Top side pick resistance, m./sec.*	1.1	1.28	1.1	1.32	1.6	1.26
Wire side pick resistance, m./sec.	1.45	1.46	>2.0	1.45	1.5	>2.0

* Printing speed at which paper starts to show picking

All three papers had higher smoothness values on both sides when the dandy roll was not used. The top sides of the sheets showed a greater tendency to pick if the dandy roll were used, but the results from investigations on the pick resistance of the wire side were so divergent that no conclusions could be drawn.

The study concludes with an investigation on filler retention and its dependence on pH.

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