SYSTEMS ANALYSIS PROJECT ADVISORY COMMITTEE

and

MAPPS USERS GROUP

SLIDE MATERIAL

March 24-25, 1988
SYSTEMS ANALYSIS PROJECT ADVISORY COMMITTEE
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ADDITIONAL
SLIDE MATERIAL

March 24-25, 1988
EXPERT SYSTEMS

RECOVERY BOILER TROUBLESHOOTING
STUDENT WORK
WAYNE MCADAMS A190
CAPTURE IPC EXPERTISE
DEVELOP STAND-ALONE VERSION
COUPLE M APPS WITH ES
EXISTING PACKAGE NOKIA
COMPLETION BY SPRING 1989

EXPLORATORY ISSUES

CAD GRAPHICS
PROCESS CONTROL
STATUS

MARKETING

USER-FRIENDLY INTERFACE

PERFORMANCE ATTRIBUTES
- NEW MODELS
- VALIDATION
- IMPLEMENTATION

DEVELOPMENT ISSUES
- OPTIMIZER
- DYNAMIC SIMULATION
- EXPERT SYSTEMS

EXPLORATORY ISSUES
- CAD
- OTHERS

MARKETING

NEW CUSTOMERS  2
TOTAL CLIENTS  31

TAPPI VIDEO COURSE

PAPRICAN SYMPOSIUM
- DEMONSTRATION BOOTH
- PRESENTATION

USER-FRIENDLY INTERFACE

INITIAL RELEASE MID-JANUARY
- μMIP
- SALES ENCOURAGING
INTEGRATED INTERFACE

DEVELOP INTERACTIVE INTERFACE

STUDENT WORK

KEN THOMAS - A190

DEMONSTRATION

PERFORMANCE ATTRIBUTE

• MODEL DEVELOPMENT
  - DATA ANALYSIS
  - MODELS

• MODEL VALIDATION

• IMPLEMENTATION

DATA ANALYSIS

ALEXANDER & MARTON
YIELD, CWT, REFINING (CSF), WET PRESSING

TMP MILL
YIELD, REFINING, SCREENING, CLEANING

WMU
CALENDERING, SPECIES MIXTURES, MACHINE CONDITIONS

SETTERHOLM, FLEISCHMAN
ORIENTATION ANGLE, WET STRETCHING

KIBBLEWHITE, CLARK, ETC.
MODEL VALIDATION
ALEXANDER AND MARTON DATA

CONSTANTS
SPECIES, PULPING TYPE, KAPPA NO., BLEACHING

INDEPENDENT VARIABLES
CELL WALL THICKNESS (1.8, 3.5 μ) CWT
YIELD (48-60%) Y
REFINING (30-700 CSF) CSF
WET PRESSING PRESSURE (0-9200 psi) P

DEPENDENT VARIABLES

SHEET PROPERTIES
DENSITY
MODULUS
BREAKING LENGTH
BURST, TEAR
RUPTURE ENERGY
ELONGATION AT BREAK
SCATTERING COEFFICIENT

SINGLE FIBER PROPERTIES
MODULUS
BREAKING LENGTH
FIBRIL ANGLE
SWELLING
CROSS SECTIONAL AREA
MODELS DEVELOPED FROM A&M DATA

HANDSHEET PROPERTIES:
- DENSITY (JONES)
- MODULUS (PAGE)
- BREAKING LENGTH (PAGE)
- BURST (JONES, VANDENAKKER)
- TEAR, RUPTURE ENERGY (JONES)
- STRAIN AT BREAK (JONES)
- SCATTERING COEFFICIENT (MALMBERG)

FIBER PROPERTIES:
- EFFECTIVE FIBER MODULUS (JONES)
- TENSILE (JONES)

PROCESS:
- SURFACE AREA VS. CSF
- BONDING COEFFICIENT
- RELATIVE BONDED AREA
- COMPRESSIBILITY COEFFICIENTS
SHEET DENSITY ($\rho$)

\[
\frac{1}{\rho} = \frac{1}{\rho_u} + \left( \frac{1}{\rho_1} - \frac{1}{\rho_u} \right) \frac{1}{S_b^2}
\]

\[
\rho_u = \frac{1}{0.764 + 0.000477 \text{ CSF} + 0.1146 \text{ (CWT-1.5)}}
\]

\[
\rho_1 = \frac{1}{\rho_u - 0.05866 \text{ CSF} + 0.0783 Y + 43.142}
\]

\[
\rho_{1m} = 0.05 \text{ (CWT - 0.8)} + 0.002 \text{ (Y - 48)}
\]

$S_b = 1$ at high CSF, low wet pressing thick walled vessels

$\rho_u \sim 0.8$ to $1.1$ g/cc

$\rho_1 \sim 0.06$ to $0.3$ g/cc

HYDRODYNAMIC SPECIFIC SURFACE ($S_h$)

\[
S_h = 95.7 - 0.12 \text{ CSF (m}^2/\text{g)}
\]

BONDING AREA

\[
S_{bo} = C_1 \cdot S_h
\]

\[
C_1 = 0.0734 - 0.00654 Y \quad Y (\%)
\]
WET PRESSING EFFECTS

\[ S_b = S_{bo} f(\rho) \]
\[ f(\rho) = 1 + M \rho^N \]
\[ M = e^{144} + 0.00177 \text{ CSF} \]
\[ N = 0.003 \text{ CSF} - 0.000515 \text{ Y} \]

SHEET MODULUS

- CONFIRMED PAGE MODEL

\[ E = \left( \frac{E_f}{3} \right) \left( \frac{\rho}{\rho_f} \right) \left( 1 - \frac{k}{RBA} \right) \text{ (Page/Nissan)} \]

\[ k = \frac{W}{L} \left( \frac{E_f}{2G_f} \right)^\frac{1}{2} \]

\[ RBA = \frac{\rho - \rho_1}{\rho_u - \rho_1} \]
SHEET MODULUS

\[ E = \frac{E_f}{3} \left( \frac{\rho - \rho_1}{\rho_u} \right) \left( 1 - \frac{k}{RBA} \right) \] (Modified)

\[ E = E_0 \left( \rho - \rho_o \right) \]

\[ E_0 = \frac{E_f}{3\rho_u} \]

\[ \rho_0 = \rho_1 + (\rho_u - \rho_1) \left( \frac{W}{L} \right) \left( \frac{E_f}{2G_f} \right) \]

SHEET MODULUS

\[ E = 10.6 \left( \rho - .19 \right) \] LINEAR FORM (MALMBERG) \( (R^2 = .95) \)

\[ E = 13.6 \left( 1 - \frac{.4}{\rho + .4} \right) \] NONLINEAR FORM \( (R^2 = .95) \)

\[ \frac{E_f}{3\rho_u} = E_0 = \text{CONSTANT} \]

\[ E_f = 3 \ E_0 \ \rho_u = \frac{31.8}{.746 + .000477 \text{ CSF} + .115 \text{ CWT}} \]

DID NOT FIT SINGLE FIBER MODULUS DATA

\[ \frac{E_f}{3\rho_u \text{ CWT}} = \text{CONSTANT} \]
FIBER MODULUS

\[ E_f = 172.4 + 0.55 (CWT \cdot \rho_u \cdot 9) \quad \frac{Kg}{mm^2} \quad (R^2 = .89) \]

EFFECTIVE FIBER MODULUS IN SHEET \( E_f^* \)

\[ E_f^* = \frac{58 (E_f - 172.4)}{CWT g} \]

\[ \frac{E_f^*}{3\rho_u} = 10.6 = E_0 \]

BREAKING LENGTH (Z)

- PAGE MODEL CONFIRMED

\[ Z = \frac{9}{8Z_f} + \frac{12A_{ug}}{RBA b p L} \quad \text{(PAGE)} \]

\[ Z_f = \frac{P_1(p - P_3)}{(p + P_2)} \quad \text{(R}^2 = .85) \]

\[ P_1 = 24.51 + .414 Y - 3.5 \ CWT \]
\[ P_2 = 3.37 \]
\[ P_3 = .086 \]

FIBER TENSILE (Zf)

\[ Z_f = \frac{9}{8} P_1 = \frac{9}{8} \ (24.5 + .414 Y - 3.5 \ CWT) \]

-Z\( \text{f} \) does not fit single fiber data well
BURST (B)

VAN DEN AKKER MODEL

\[ B = C (E_1)^{\frac{1}{2}} \left( \frac{T_{MD} + T_{GD}}{2} \right) \]

\[ B = 5.1 (E_1)^{\frac{1}{2}} Z \quad (R^2 = 0.90) \]

LINEAR MODEL

\[ B = -15.1 + 10.175 Z \quad (R^2 = 0.92) \]

\[ C = 5.6 - 0.127 \text{ CWT (1 + 0.0015 CSF)} \]

STRAIN AT BREAK, \((E_1)\)

\[ E_1 = 0.85 + 0.02677 Z - 0.177 E \quad (R^2 = 0.85) \]

RUPTURE ENERGY \((R.E.)\)

\[ R.E. = 392 - 308E_1(1 - 0.237 Z) \quad (R^2 = 0.95) \]

TEAR

\[ \text{Tear} = 296 - 14 E - B - \frac{20.7}{\rho} \quad (R^2 = 0.8) \]
SCATTERING COEFFICIENT (SL)

$SL_u - SL = SL_k \rho - \rho_1 \quad (R^2 = .94)$
$SL_u = 874 + .04 \text{ CSF} - 77.5 \text{ CWT}$
$SL_k = 928 - 98 \text{ CWT} - 6.6 \text{ Y}$

POROSITY (POR)

$\text{POR} = A_0 + A_2/\text{CSF}$

$A_0 = 0$

$A_2 = 12000$

OTHER EFFECTS

- APPARENT FIBER CRUSHING, DAMAGE AT HIGH PRESSURE
- REDUCED DENSITY, MODULUS, TENSILE
- NOT ADEQUATELY ACCOUNTED FOR

FLEISCHMAN DATA (IPC)

- SHEET ANISOTROPY (WET STRETCH, ORIENTATION)
- MODULUS ($E_x$, $E_y$, $E_z$)
- TENSILE ($Z_x$, $Z_y$, $Z_z$)
- COMPRESSION STRONGTH ($C_x$, $C_y$)
- SINGLE SPECIES
MODULUS

\[ \frac{E_x}{E_y} = R + .335 - .583 \text{WS} + 0.708 \text{WS} \cdot \text{OR} + 0.6350R^2 \quad (R^2 = .95) \]

\[ \frac{E_x}{\rho} = 6.84 + 5.69 \text{OR} + 0.927\text{WS} \cdot \text{OR} \quad (R^2 = .96) \]

\[ \frac{E_y}{\rho} = 14.79 - 4.18 \text{OR} - .2880\text{OR} \cdot \text{WS} \quad (R^2 = .98) \]

\[ E_z = \text{interactions between WS, OR and } \rho \]

\[ E_z = .257 + (.124 \text{WS} - 1.106) \rho + (1.339 .02936 \text{OR} - .0241 \text{WS}) \rho^2 \]

TENSILE

\[ Z_x, Z_y \text{ similar to } E_x, E_y \]

\[ Z_x = -6.97 + 6.56 E_x \quad (R^2 = .90 \text{ con coef. } = .95) \]

\[ Z_y = 3.56 + 5.43 E_y \quad (R^2 = .94 \text{ con coef. } = .97) \]

\[ Z_z = .220 + 1.86 \cdot E_z \quad (R^2 = .943) \]

COMpressive STRENGTH

(HABEGER, WHITSITT MODELS)

\[ C_x = 3.38 + 5.51 E_x^{.75} E_z^{.25} \quad (R^2 = .95) \]

\[ C_y = 3.46 + 4.76 E_x^{.75} E_z^{.25} \quad (R^2 = .92) \]
OTHER MODELS UNDER DEVELOPMENT

- IPC DATA (BRIAN BURGER)
  - EFFECTS OF REFINING, SPECIES
  - ANISOTROPY, MODULUS, TENSILE

- WMU DATA
  - CALENDERING MACHINE EFFECTS
  - PAUL ROZIK (A190 WORK)

BRIGHTNESS

\[ C_K = C_{Lig}Lig + C_{cell}cell + C_{ext}ext \quad \text{(cm}^2/\text{g}) \]
\[ C_{cell} = 7.5 \]
\[ C_{ext} = 1.0 \]
\[ C_{Lig} = 250 \text{ to } 350 \]

\[ \text{Brightness} = \frac{C_K}{S_K} + 1 - \left( \frac{C_K}{S_K} \right)^2 + 2\left( \frac{C_K}{S_K} \right) \frac{\partial S_K}{C_K} \]

OTHER MODELS

- OTHER COMPRESSIVE PROPERTIES (RING CRUSH, ETC.)
- FORMATION (GRABER & GOTTSCING)
- LAMINATES
- EFFECTS OF UNUSUAL PULPING CONDITIONS
DENSITY MODEL VALIDATION

- FITS DATA OF
  KIBBLEWHITE - KRAFT 4 NEW ZEALAND BEECH PIECES (RANDOM)
  FLEISCHMAN - BLEACHED KRAFT - DOUGLAS FIR, SPRUCE MIXTURES
  TMP MILL (ASSUMED 100% YIELD, SPECIES UNKNOWN)
  CLARK BLEACHED SULFITE (SPECIES UNKNOWN)

PERFORMANCE ATTRIBUTES

YIELD
KAPPA
\( \bar{L} \)
\( \sigma_L \)
\( \bar{w} \)
\( \sigma_w \)
K-FACTOR
\( C_K \) ABSORPTION COEFFICIENT
\( R \) ANISOTROPY RATIO
\( \rho_v \) COEFFICIENT OF VARIATION IN SHEET DENSITY
\( \rho_f \)
CWT
\( E_f \)
\( Z_f \)
\( \rho_f \)
DATABASE DEVELOPMENT

SOURCES:
- ISENBERG DATA
- IPC DATA SUPPLEMENT
- FPL
- LITERATURE

REQUIRE:
- SPECIES
- $E_f$
- $Z_f$
- $P_f$
- BENDING MODULUS
- CWT
- $\bar{C}$
- $\bar{W}$
- COARSENESS

COMPOSITION:
- LIGNIN
- CELLULOSE
- HEMICELLULOSE

MODEL VALIDATION

TMP MILL DATA
FLOWSHEET DEVELOPED
MODELS VALIDATED
PROCESS MODELS

\[ \bar{Z} = \frac{A_1}{A_2} + (L_{in} - \frac{A_1}{A_2}) e^{-A_1 ZP} \]

\[ \sigma_1 = A_3 - \frac{A_4}{\bar{Z}} \]

\[ ZP = 10(\text{NSP} - \text{Ap})/B_p \]

(similar for \( \bar{W} \))

\[ S_h = 1 - \frac{1}{K} \sum_{i=1}^{n} X_i \ln \left( \frac{L_i}{2.4} \right) \]

\[ K = k_0 e^{k_2 \cdot \text{NSP}} \]

\[ k_2 = f(\text{NSP}, \text{Consistency}, K_0) \]

\[ S_h = a \ln (\text{CSF}) + b \]

(high yield)

SCREENING AND CLEANING-SEPARATION EFFICIENCIES

HANDSHEET MODELS - VENKATESH

PROPERTY = f(long fibers, shives, CSF)
<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>VENKATESH</th>
<th>JONES*</th>
</tr>
</thead>
<tbody>
<tr>
<td>BULK</td>
<td>10-20% LOW</td>
<td>CLOSE</td>
</tr>
<tr>
<td></td>
<td>TOO SENSITIVE TO SHIVES</td>
<td>NOT AS SENSITIVE</td>
</tr>
<tr>
<td>BREAKING LENGTH</td>
<td>TOO SENSITIVE TO SHIVES</td>
<td>NOT AS SENSITIVE</td>
</tr>
<tr>
<td>BURST</td>
<td>50% LOW</td>
<td>CLOSE</td>
</tr>
<tr>
<td>TEAR</td>
<td>REASONABLE</td>
<td>2 X TOO HIGH</td>
</tr>
<tr>
<td>SCATTERING</td>
<td>REASONABLE</td>
<td>2 X TOO LOW</td>
</tr>
<tr>
<td>OPACITY</td>
<td>CLOSE</td>
<td>NM</td>
</tr>
<tr>
<td>GURLEY POROSITY</td>
<td>INACCURATE</td>
<td>REASONABLE</td>
</tr>
<tr>
<td>ELONGATION AT BREAK</td>
<td>NM</td>
<td>REASONABLE</td>
</tr>
<tr>
<td>RUPTURE ENERGY</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>DRAINAGE TIME</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>WET WEB STRENGTH</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>ABSORPTION COEFFICIENT</td>
<td>NM</td>
<td>NM</td>
</tr>
<tr>
<td>Z-D TENSILE</td>
<td>NM</td>
<td>REASONABLE+</td>
</tr>
</tbody>
</table>

NM NO MODEL
ND NO DATA
* EXTRAPOLATION TO 100% YIELD
+ 8% SHRINKAGE
PROCESS MODELS

CSF
REASONABLE

FIBER LENGTH DISTRIBUTION
REQUIRED MINOR MODIFICATION

SHIVES
GOOD MATCH

L-FACTOR
GOOD MATCH

SEPARATIONS
REASONABLE EXCEPT AFTER MANY STAGES

CONSISTENCIES
REASONABLE EXCEPT AFTER MANY STAGES

MODIFICATIONS

ALTER LOG NORMAL DISTRIBUTION (HYRFN1)

LOCAL REVERSIBILITY IN SEPARATIONS (HYFRAC)

FINES LEAKAGE OPTION (HYFRAC)
SHEET MODULUS - DENSITY AND FREENESS

CWT 3.8μ Wet Pressing Pressure 30psi
Yield 60% Norwegian Spruce
DENSITY VS. CSF PREDICTED FOR 100% YIELD

Pressure: 30 psi
CWT: 3.8 µ

Canadian Standard Freeness, mL
EFFECT OF DENSITY ON SHEET STRENGTH

Pressure 30 psi
CMT 3.8 μ
Yield 48%
Norwegian Spruce

breaking length, Km
modulus dynes/cm² x 10^-10
extension, %

density, g/cm³
BURST AND TEAR VS. DENSITY

CWT  1.8
Yield  48%
Wet Pressing
Pressure  30 psi
Norwegian Spruce
EFFECT OF CELL WALL THICKNESS ON SHEET DENSITY

Yield: 48%
Pressure: 30 psi
Norwegian Spruce
EFFECT OF CELL WALL THICKNESS AND YIELD ON DENSITY

Pressure 30 psi
Norwegian Spruce

CWT, μ  Yield, %

- 2.8  48
+ 1.8  48
* 3.8  60
□ 1.8  60
× 3.8  90

CSF
EFFECT OF CELL WALL THICKNESS AND YIELD ON SCATTERING COEFFICIENT

Pressure 30 psi
Norwegian Spruce

Cut, μ Yield, %
- 3.8  48
+ 1.8  48
* 3.8  60
□ 1.8  60
EFFECT OF CELL WALL THICKNESS ON BURST

Pressure 30 psi
Norwegian Spruce
EFFECT OF CELL WALL THICKNESS AND YIELD ON TEAR

Pressure 30 psi

CWT, μ Yield, %
→ 3.8 48
□ 1.8 60
+ 1.8 48
* 3.8 60
BURST AND TEAR VS. FREENESS
AT TWO CELL WALL THICKNESSES

Yield  48%
Pressure  30 psi

- 1.8µ tear
- 1.8µ burst
- 3.8µ tear
- 3.8µ burst

CSF, mL
EFFECT OF CELL WALL THICKNESS AND YIELD ON ELONGATION AT BREAK

Pressure 30 psi

CWT, μ   Yield, %
3.8      48
1.8      48
3.8      60
1.8      60
<table>
<thead>
<tr>
<th>POSITION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SECONDARY REFINER DISCHARGE</td>
</tr>
<tr>
<td>2</td>
<td>PRIMARY SCREEN FEED</td>
</tr>
<tr>
<td>3</td>
<td>PRIMARY SCREEN ACCEPTS</td>
</tr>
<tr>
<td>4</td>
<td>PRIMARY SCREEN REJECTS</td>
</tr>
<tr>
<td>5</td>
<td>SECONDARY SCREEN ACCEPTS</td>
</tr>
<tr>
<td>6</td>
<td>REJECT REFINER DISCHARGE</td>
</tr>
<tr>
<td>7</td>
<td>PRIMARY REJECT CLEANER ACCEPTS</td>
</tr>
<tr>
<td>8</td>
<td>THICKENER DISCHARGE</td>
</tr>
</tbody>
</table>
Variation in Simulated Fiber Components Throughout Process
FORGAC'S L-FACTOR VS. POSITION

- Measured
+ Simulation
CANADIAN STANDARD FREENESS
VS. POSITION

Measured
Simulation
TAPPI SHEET DENSITY PROFILE THOROUGH TMP FLOWSHEET

Simulated Sheet Density Based on Extrapolating Model Developed for Chemical Pulps to 100% Yield

Pressure  60 psi
CWT       3.8 μ

Predicted Measured
+ Measured Simulation
BREAKING LENGTH PROFILES

- Simulation
+ Measured

Position

Breaking Length, km

5.3
5.1
4.9
4.7
4.5
4.3

0 2 4 6 8
BURST AND TEAR PROFILES

Predicted Burst
+ Measured Burst
* Predicted Tear
□ Measured Tear

Position

0 2 4 6 8
SCATTERING COEFFICIENT
VS. POSITION

Scattering Coefficient, cm²/g

Position

Measured
Simulation
ELONGATION AT BREAK PROFILE

Pressure  60 psia
CWT        3.8 μ

- Measured
- Simulation (Model Extrapolated to 100% yield)
IMPLEMENTATION

・ NOW UNDERWAY

・ MODULES AFFECTED

WOOD BLOCK (GENERATE STREAMS)
DIGESTER (YIELD AND KAPPA)
REFINERS (HYRFN1)
SCREENS (HYFRAC)
MIXING (STOMIX)
BLEACH MODULES

・ PAPER MACHINE

NEW MODULES

* WET END MODULE

ORIENTATION
WET STRETCH
WET PRESSING
WET END CHEMISTRY
FORMATION

* DRYING AND CALENDERING

DRAINAGE
- USE HYFRAC OPTIONS

DEVELOPMENT ISSUES

OPTIMIZER

DEVELOPMENT

・ LICENSE PACKAGE FROM DESIGN PRODUCTIVITY CENTER (DPC)

・ MODIFY FOR USE WITH MAPPS (MAINFRAME AND PC VERSIONS)

・ TEST AND DETERMINE BEST ROUTINES

・ DEVELOP IMPROVED INTERFACE
MARKETING

- DETERMINE PRICE FOR INTERFACE
- LICENSE INTERFACE AS SEPARATE PACKAGE TO RUN OPTIMIZER WITH MAPPs
- WORK OUT DPC LICENSING ARRANGEMENTS

OPTIMIZER

MAINTENANCE AND DEVELOPMENT
- MAPPs RESPONSIBLE FOR INTERFACE
- DPC RESPONSIBLE FOR OPTIMIZATION CODE

CUSTOMER RELATIONS
- DEFINE MAPPs AND DPC ROLES
- DETERMINE RESOURCES NEEDED
- WORK OUT ARRANGEMENTS WITH DPC

DYNAMIC SIMULATION

STUDENT WORK - BOB ALOISI

NEW MODULES
- EXECUTIVE
- FIRST ORDER LAG
- DEAD TIME
- CONTROLLERS

TESTING, EVALUATION

COMPLETION BY SPRING 1989