THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

SLIDE MATERIAL

for the

Engineering Project Advisory Committee

October 22-23, 1986
The Institute of Paper Chemistry
Continuing Education Center
Appleton, Wisconsin
<table>
<thead>
<tr>
<th>Project 3309:</th>
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<td>Project 3556:</td>
<td>Fundamentals of Kraft Liquor Corrosivity</td>
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<td>Project 3607:</td>
<td>Evaluation of Structural Coatings for Pulp and Paper Mill Service</td>
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FUNDAMENTALS OF CORROSION CONTROL IN PAPER MILLS

Ronald Yeske

October 22-23, 1986
PROJECT 3309

FUNDAMENTALS OF CORROSION CONTROL
IN PAPERMAKING APPLICATIONS

LONG TERM OBJECTIVE

ELIMINATE COSTLY SUCTION ROLL FAILURES

SHORT TERM OBJECTIVE

DEVELOP A LABORATORY TEST THAT PREDICTS SERVICE PERFORMANCE

- ALLOY RANKING
- MECHANISM OF FAILURE
- ALLOY DEVELOPMENT
PREDICTIVE TEST DEVELOPMENT

INITIATION VS. PROPAGATION

NEAR-THRESHOLD FATIGUE CRACK GROWTH

STRESS INTENSITY CONCEPT

\[ \Delta K = (\text{STRESS RANGE}) (\text{CRACK LENGTH})^{\frac{1}{2}} (\text{GEOMETRY}) \]
\[ = S_R(a)^{\frac{1}{2}} f_n (a/w) \]
MEAN STRESS EFFECTS

"R" RATIO = $K_{\text{max}}/K_{\text{min}}$

Schematic illustration of three alternating load forms as a function of time (t) in fatigue.
Schematic diagram showing the dependence of crack growth rates on the cyclic stress intensity.

\[ \frac{da}{dn} \]

\[ \Delta K_{th} \text{ determination} \]
- Crack Sharpness
- Load Shedding
- Compressive Residual Stresses
### SIMULATED WHITEWATERS

<table>
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<tr>
<th>ENV</th>
<th>Cl&lt;sup&gt;-&lt;/sup&gt; ppm</th>
<th>SO&lt;sub&gt;4&lt;/sub&gt;&lt;sup&gt;2-&lt;/sup&gt; ppm</th>
<th>S&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt;&lt;sup&gt;-&lt;/sup&gt; ppm</th>
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<td>B*</td>
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<td>1000</td>
<td>0</td>
<td>3.5</td>
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<td>C**</td>
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<td>F</td>
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* TAPPI 1
** TAPPI 2

### NEAR-THRESHOLD FATIGUE CRACK GROWTH

- ENVIRONMENTAL EFFECTS
- MEAN STRESS EFFECTS
- ELECTROCHEMICAL POTENTIALS
- CRACK MORPHOLOGY
ENVIRONMENTAL EFFECTS

- A75 shows good resistance in 1000 ppm Cl\(^-\), pH 3.5
- A75, VKA171 show good resistance in 50 ppm S\(_2\)O\(_3\)\(^-\)
- 3RE60 shows lowest resistance in both environments
- VKA378 and A63 are intermediate
- Small differences among alloys in air environment
MEAN STRESS EFFECTS (1000ppm Cl-)

- CRACK GROWTH_THRESHOLDS DECREASE WITH INCREASING MEAN STRESS
- ALLOY 75 EXHIBITS SMALLEST MEAN STRESS EFFECT
- AT R = 0.5, A75 > VKA3278 = VKA171 = A36 > 3RE60
- RELATIONSHIP TO RESIDUAL STRESS
### MEAN STRESS SUMMARY

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<tr>
<th>Residual Stress</th>
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<tr>
<td>A75</td>
<td>LOW</td>
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<tr>
<td>VKA378</td>
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<td>VKA171</td>
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<tr>
<td>A63</td>
<td>HIGH</td>
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<tr>
<td>3RE60 (MODERN)</td>
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<td>3RE60 (PREVIOUS)</td>
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### ELECTROCHEMICAL BEHAVIOR

- Activation by crack growth
- Dependent on environment
- Unrelated to cracking susceptibility
CRACK MORPHOLOGY

- CAST
- WROUGHT
CONCLUSION

NEAR THRESHOLD CRACK GROWTH BEHAVIOR AGREES WITH SERVICE PERFORMANCE, PROVIDED RESIDUAL STRESS EFFECTS ARE CONSIDERED.

CORROSION FATIGUE LIFETIME

S - N TESTS
- SMOOTH SPECIMEN, ROTATING BENDING
- NOTCHED SPECIMEN, ALTERNATING BENDING
**RO...**

**ROTATING BENDING ENVIRONMENT E**

- A75
- A63

**Stress Amplitude (ksi)**

**Cycles to Failure**

- VKA171
- VKA378
- 3RE60
- A75
- A63
CONCLUSIONS - CRACK INITIATION STUDIES

- S-N CURVES IN AIR DO NOT PREDICT SERVICE PERFORMANCE
- S-N CURVE IN 1000ppm Cl\textsuperscript{-}, pH 3.5 ALSO NOT PREDICTIVE
- MODEST ENVIRONMENTAL EFFECT ON A75
- NO SIGNIFICANT NOTCH EFFECT ON A75
STRESS CORROSION CRACKING

• WELD REPAIR
• RESIDUAL STRESS DETERMINATION
• HIGH TENSILE RESIDUAL STRESS (45ksi)

PLANS FOR NEXT PERIOD

CRACK PROPAGATION

• MORE AGGRESSIVE WHITEWATERS
• OTHER ALLOYS (BRONZE, CA-15, A86)

CRACK INITIATION

• MORE AGGRESSIVE WHITEWATERS
• MEAN STRESS EFFECTS
• NOTCH EFFECTS
STRESS CORROSION CRACKING

- RESIDUAL STRESSES
- WELDED COUPON EXPOSURE

CONCLUSIONS - CRACK INITIATION STUDIES

- S-N CURVES IN AIR DO NOT PREDICT SERVICE PERFORMANCE
- S-N CURVE IN 1000ppm Cl⁻, pH 3.5 ALSO NOT PREDICTIVE
- MODEST ENVIRONMENTAL EFFECT ON A75
- NO SIGNIFICANT NOTCH EFFECT ON A75
Project 3556

FUNDAMENTALS OF KRAFT LIQUOR CORROSIVITY

David Crowe

October 22-23, 1986
PROJECT 3556
FUNDAMENTALS OF KRAFT LIQUOR CORROSIVITY

OBJECTIVE

UNDERSTAND CAUSES OF CORROSION OF CARBON STEEL IN KRAFT LIQUOR, AS THE BASIS FOR DEVELOPING METHODS FOR REDUCING CORROSION DAMAGE.

APPROACH

• DEVELOP CORROSION MONITORING METHODS AND EQUIPMENT
• MONITOR CORROSIVITY
• TRACE ORIGINS OF HIGH CORROSION RATE
• CORRECT

PREVIOUS RESULTS

• QUALIFICATION OF MONITORING EFFECTS
• DEVELOPMENT OF MICROPROCESSOR BASED DATA ACQUISITION SYSTEM
LIQUOR CORROSIVITY IS MORE IMPORTANT THAN GRADE OF CARBON STEEL

FLUCTUATION OF CORROSION RATE COULD NOT BE CORRELATED WITH LIQUOR COMPOSITION CHANGES

LIQUOR LEVEL CYCLING DRAMATICALLY INCREASED CORROSION RATES

LAB TESTS OF CORROSION RATE IN WHITE LIQUOR WITH SULFITE ADDITIONS

RECENT PROGRESS

IN-MILL TESTING COMPLETED AT 2 MILLS
- LINEAR POLARIZATION RESISTANCE
- WEIGHT LOSS
- LIQUOR ANALYSIS
- EFFECT OF SHUTDOWN: HIGHER THIOSULFATE
- TRACING ORIGINS OF THIOSULFATE
- TWO TANKS IN ONE MILL
WEIGHT LOSS

1018 STEEL

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A283 STEEL

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WEIGHT LOSS

A285C STEEL

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A285 SPEC STEEL

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RECENT PROGRESS

- NEW TEST ELECTRODE CONSTRUCTED
- SLOW STRAIN RATE TESTS IN ACTUAL DIGESTER LIQUOR TO IDENTIFY DIFFERENCES IN STRESS CORROSION CRACKING SUSCEPTIBILITY
MILL M5
Top Circulation Liquor

% REDUCTION IN DIAMETER

20 30 40 50

POTENTIAL, V (VSSE)

0.330
0.190
0.050
-0.090
-0.230

3 4 5 6 7

LOGARITHM OF CURRENT DENSITY, nA/cm²

MILL P6
Top Separator Liquor

% REDUCTION IN DIAMETER

20 30 40 50

POTENTIAL, V (VSSE)

0.330
0.190
0.050
-0.090
-0.230

3 4 5 6 7

LOGARITHM OF CURRENT DENSITY, nA/cm²
### DIGESTER LIQUOR COMPOSITION

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### RECENT PROGRESS

- SLOW STRAIN RATE TESTS IN SIMULATED WHITE LIQUOR WITH ORGANIC ADDITIVES
- LAB TESTING WITH COMBINATIONS OF THIOSULFATE AND POLYSULFIDE
  - NO DRAMATIC ADDITIVE EFFECT
- TESTING IS UNDERWAY IN SIMULATED GREEN LIQUOR COMPOSITIONS
. . . THERE IS MUCH THAT REMAINS UNCLEAR REGARDING THE EFFECTS OF ORGANIC SPECIES ON CAUSTIC CRACKING OF CARBON STEEL

R. YESKE, A SUMMARY OF DIGESTER CRACKING RESEARCH COMMITTEE PROJECTS

I RECOMMEND FURTHER INVESTIGATION TO DETERMINE THE SPECIES CONTROLLING THE POTENTIAL . . . THE ORGANICS SHOULD BE INVESTIGATED.

W. ROGERS - A291 FINAL REPORT

\[\begin{align*}
\text{CATECHOL} & \quad \text{PYROGALLOL} & \quad \text{GALLIC ACID}
\end{align*}\]
TANNIN CONTENT IN WHITE LIQUOR MAY BE THE REASON SOME DIGESTERS CRACK WHILE OTHERS DO NOT.

J. HAYFORD - A190 PROPOSAL

RECENT PROGRESS

- SLOW STRAIN RATE TESTS IN SIMULATED WHITE LIQUOR WITH ORGANIC ADDITIVES

- LAB TESTING WITH COMBINATIONS OF THIOSULFATE AND POLYSULFIDE
  - NO DRAMATIC ADDITIVE EFFECT

- TESTING IS UNDERWAY IN SIMULATED GREEN LIQUOR COMPOSITIONS
Project 3556

Slide Material

80 g/L NaOH + 20 g/L Na₂S + Na₂S₂O₃

- 0 g/L
- 2.5 g/L
- 5.0 g/L
- 25.0 g/L

2 Week Exposure

120 g/L NaOH + 40 g/L Na₂S + Na₂S₂O₃

- 0 g/L
- 2.5 g/L
- 5.0 g/L
- 25.0 g/L

2 Week Exposure
120 g/L NaOH + 40 g/L Na₂S + Na₂S₂O₃

- 0 g/L
- -- 2.5
- --- 5.0
- --- - 25.0

8 Week Exposure

80 g/L NaOH + 40 g/L Na₂S + 25 g/L Na₂S₂O₃

g/LS

- 0.5
- -- 1.0
- --- 1.5
- --- - 0.5

POTENTIAL (E), V/VSSE
PLANS FOR NEXT PERIOD

- IMPROVED REFERENCE ELECTRODE DESIGN
- MICROPROCESSOR BASED TESTING SYSTEM
- STUDY EFFECT OF LIQUOR VELOCITY ON CORROSION RATES VIA ROTATING ELECTRODE
- TRACE SOURCES OF THIOSULFATE BY SAMPLING THROUGHOUT THE PROCESS
- POTENTIOSTATIC TESTING IN MILL WHITE LIQUOR TO IDENTIFY CORROSION RATES WITH POLARIZATION BEHAVIOR

SIGNIFICANCE TO THE INDUSTRY

- CORROSION MONITORING METHODS MAY BE APPLIED RELIABLY IN WHITE LIQUOR SYSTEMS
- EFFECTS OF MAJOR LIQUOR CONSTITUENTS ON CORROSIVITY OF WHITE LIQUOR HAVE BEEN DETERMINED
- SOME OPERATING PARAMETERS WHICH INCREASE CORROSION RATE HAVE BEEN IDENTIFIED
PROJECT 3607

EVALUATION OF STRUCTURAL COATING
FOR PULP AND PAPER MILL SERVICE

Ronald Yeske

October 22-23, 1986
PROJECT 3607
EVALUATION OF STRUCTURAL COATINGS
FOR PULP AND PAPER MILL SERVICE

OBJECTIVE

EXAMINE DURABILITY OF STRUCTURAL COATINGS
IN AGGRESSIVE MILL ENVIRONMENTS

APPROACH

PHASE 1 —
- ARRANGE KTA PANEL COATINGS BY VENDORS
- EXPOSE IN MILL LOCATIONS
- EVALUATE COATING DURABILITY (VISUAL)

PHASE 2 —
- COATINGS ON PRE-CORRODED PANELS
- EXPOSE AND EVALUATE
MILL LOCATIONS

- RECOVERY & RECAUSTICIZING
- PAPER MACHINE WET END
- BLEACH PLANT

PROGRESS (NEW PROJECT)

- PANELS ORDERED
- COATING VENDORS, MILL SITES BEING ARRANGED

PLANS FOR THE NEXT PERIOD

- COATING APPLICATION
- COUPON EXPOSURE

SIGNIFICANCE TO THE INDUSTRY

- RANKING OF DURABILITY OF STRUCTURAL COATINGS UNDER ACTUAL MILL CONDITIONS
- HEAD-TO-HEAD COMPARISON
PROJECT 3606
CORROSION IN HIGH YIELD PULPING PROCESSES
David Crowe

October 22-23, 1986
PROJECT 3606
CORROSION IN HIGH YIELD PULPING PROCESSES

OBJECTIVE
IDENTIFY PROBLEMS AND SOLUTIONS TO CORROSION AND CORROSION-ASSISTED CRACKING IN MECHANICAL PULPING

APPROACH

- IDENTIFY CORROSION PROBLEMS
- DETERMINE PROCESS CONDITIONS WHICH CAUSE CORROSION
- DEFINE - LIMITS FOR SAFE OPERATION
  - SOLUTIONS

PROGRESS

- LITERATURE SURVEY
- IDENTIFICATION OF PROBLEM AREAS
  - LOW pH
  - CHLORIDES
  - ADDITIVES
  - ACID CONDENSATION
- ARRANGED TO OBTAIN SOME FILTRATE SAMPLES
PROGRESS

- POLARIZATION STUDY OF 304 & 316 STAINLESS STEEL IN REPRESENTATIVE ENVIRONMENTS AT 90°C
- ORDERED HASTELLOY C276 AUTOCLAVE

FUTURE PLANS

- MEASURE CORROSION RATE OF STAINLESS STEEL IN LIQUID AND VAPOR PHASE
  - ALKALINE SULFITE
  - BISULFITE
  - ACID SULFITE
- SLOW STRAIN RATE TESTS TO DETERMINE SUSCEPTIBILITY TO STRESS CORROSION CRACKING
- STUDY EFFECT OF ADDITIVES
- RANK ALTERNATIVE MATERIALS
PROJECT 3384

REFINING OF CHEMICAL PULPS FOR IMPROVED PHYSICAL PROPERTIES

Ted Farrington

October 22-23, 1986
PROJECT 3384
REFINING OF CHEMICAL PULPS

AGENDA

- BEATER TRIALS
- REFINER START-UP
- FUTURE PLANS

PROBLEMS IDENTIFIED AT LAST REVIEW

- POOR CORRELATION BETWEEN PULP/PAPER PROPERTIES AND PRESSURE HISTOGRAM DATA
- NOISY SIGNAL FROM STRAIN GAUGE
- LACK OF STATISTICAL SIGNIFICANCE OF PRESSURE DATA

ATTEMPTED SOLUTIONS

- OBTAIN PIEZOELECTRIC PRESSURE TRANSDUCER
- COLLECT MANY MORE PRESSURE POINTS PER HISTOGRAM
RESULTS

- PZ SIGNAL ALSO NOISY
- HISTOGRAM DATA BECOME MORE VALID BUT SOMEWHAT IMPractical

CONCLUSION

- SIGNAL WILL ALWAYS BE NOISy
- TECHNIQUE IMPractical FOR USE ON REFINER
- MOVE PROJECT EMPHASIS TO LARGER REFINER
- ONE LAST BEATER TRIAL AS PRELIMINARY TO REFINER WORK
PROJECT 3479

HIGHER CONSISTENCY PROCESSING

Ted Farrington

October 22-23, 1986
PROJECT 3479

HIGHER CONSISTENCY PROCESSING
(FLASH X-RAY IMAGING)

AGENDA

- BACKGROUND
- RESULTS SINCE LAST PAC MEETING
- CURRENT ACTIVITIES
- PLANS FOR NEXT PERIOD

BACKGROUND

- PROBLEM
- APPROACH
- STATUS AT LAST REVIEW

DECISIONS BASED ON LAST REVIEW

1. PUT HIGH PRIORITY ON OBTAINING H-P AND/OR LLNL FLASH X-RAY CAPABILITY AT IPC.
2. PURSUE TRACER QUESTIONS, IF POSSIBLE.
3. PUT MD HEADBOX IN PLACE TO GET "HANDS ON" EXPERIENCE.
4. PERFORM QUICK TEST OF TWO POTENTIAL SPIN-OFF ACTIVITIES.
PROGRESS SINCE LAST REVIEW

(ITEM 1)

- FLASH X-RAY IMAGING ROOM DESIGNED, DESIGNS SUBMITTED TO STATE DHHR
- LICENSE ISSUED 6/86 (1000 ppw)
- LEAD SHIELDED ROOM COMPLETED 9/1/86

PROGRESS SINCE LAST REVIEW

(ITEM 1)

- LEASE AGREEMENT EXECUTED WITH H-P FOR 300 KVp FLASH X-RAY UNIT

PROGRESS SINCE LAST REVIEW

(ITEM 1)

- LLNL VISITED AGAIN TO OBTAIN CONSTRUCTION DETAILS FOR HIGH RESOLUTION FLASH X-RAY SYSTEM
- CONSTRUCTION OF LLNL DEVICE AT IPC COMPLETED 9/15/86

PROGRESS SINCE LAST REVIEW

(ITEM 1)

- PRELIMINARY TESTS OF H-P & LLNL SYSTEMS UNDERWAY
PROGRESS SINCE LAST REVIEW

(ITEM 2)

- SUMMER STUDENT TESTED SEVERAL TRACER FIBER OPTIONS, INCLUDING:
  - VERY THIN WIRES
  - SYNTHETICS LOADED WITH TUNGSTEN POWDER
  - PAPER FIBERS LUMEN LOADED WITH POWDER
  - PAPER FIBERS LUMEN LOADED WITH MERCURY
- TESTS PERFORMED ON "FAXITRON" CONTINUOUS X-RAY SYSTEM

PROGRESS SINCE LAST REVIEW

(ITEM 3)

- PREVIOUSLY USED MC HEADBOX OBTAINED FROM THERMO ELECTRON CORP.
- MC HEADBOX MOUNTED ON PILOT LINE FOR PRELIMINARY TRIALS

PROGRESS SINCE LAST REVIEW

(ITEM 4)

- USE OF VERY LOW ENERGY X-RAYS FOR MEASURING SHEET FORMATION AND QUALITY

PROGRESS SINCE LAST REVIEW

(ITEM 4)

- IMAGING OF KRAFT BLACK LIQUORS AT OPERATING CONDITIONS
CURRENT ACTIVITIES

- PRELIMINARY TESTING OF BOTH FLASH X-RAY SYSTEMS
- EARLY TRIALS OF MC HEADBOX

PLANS FOR THE NEXT PERIOD.

- A SYSTEMATIC ASSESSMENT OF EACH FLASH X-RAY SYSTEM’S CAPABILITIES WILL BE COMPLETED
- AN INVESTIGATION OF CONCENTRATED FIBER SUSPENSION MICRORHEOLOGY IN THE CASE OF CONVERGING CHANNEL FLOW WILL BE UNDERTAKEN WITH THE APPROPRIATE FLASH X-RAY SYSTEM
- CAPABILITIES OF THE THERMO ELECTRON MC HEADBOX AND BELOIT CONVERFLOW HEADBOX WILL BE SYSTEMATICALLY INVESTIGATED

KEY TECHNICAL HURDLES

- TRACER SYSTEM
- RESOLUTION & DEPTH OF PENETRATION
- IMAGE ANALYSIS
## APPLICATIONS LEVERAGE

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<td>HIGH SPEED FLOW</td>
<td>NSF</td>
</tr>
<tr>
<td></td>
<td>VISUALIZATION</td>
<td>COMPANIES</td>
</tr>
</tbody>
</table>

## APPLICATIONS LEVERAGE - CON'T.

<table>
<thead>
<tr>
<th>X-RAY SYSTEM</th>
<th>APPLICATION</th>
<th>LEVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLASH CINERADIOGRAPHY</td>
<td>DRAG REDUCTION</td>
<td>DOD, DOE,</td>
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<td></td>
<td>HIGH SPEED FLOW</td>
<td>NSF</td>
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<td></td>
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<tr>
<td>REAL TIME</td>
<td>FILLED POLYMERS</td>
<td>NSF</td>
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<td>COMPOSITES</td>
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<td>CONTINUOUS</td>
<td>FORMATION</td>
<td>IPC</td>
</tr>
<tr>
<td>IMAGE ANALYSIS</td>
<td>ALL</td>
<td>DOE</td>
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</table>
PROJECT 3470/3595
FUNDAMENTALS OF DRYING
Hugh Lavery

October 22-23, 1986
IMPULSE DRYING: THE USE OF A PRESS NIP WITH ONE HOT ROLL TO REMOVE WATER FROM A PREVIOUSLY WELL PRESSED PAPER WEB
MTS electrohydraulic press nip simulator with impulse drying head installed.
IMPULSE DRYING MECHANISMS

1. Thermally Augmented Wet Pressing
2. Vapor Displacement of Liquid
3. Pressurized Flash Drying
4. Unpressurized Flash Drying

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Water Removal</th>
<th>Density</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Thermally Augmented Wet Pressing</td>
<td>2(L)</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>2. Vapor Displacement of Liquid</td>
<td>7(L)</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>3. Pressurized Flash Drying</td>
<td>5(V)</td>
<td>-2</td>
<td>2</td>
</tr>
</tbody>
</table>

A simplified illustration of the major dewatering and densifying mechanisms and regimes in impulse drying. An extended nip press is used to illustrate the process.

Diagram of drying apparatus.
DRYING CONDITIONS

1. 300°F/400 psi (150°C/2760 kPa)
2. 300°F/700 psi (150°C/4825 kPa)
3. 525°F/400 psi (275°C/2760 kPa)
4. 525°F/700 psi (275°C/4825 kPa)

OTHER EXPERIMENTAL VARIABLES

PULP TYPE: UNBLEACHED SOUTHERN SOFTWOOD KRAFT
FREENESS: 625 ml CSF
HANDSHEET BW: 42 lb/1000 ft.² (250 g/m²)
INITIAL MC: 57% (43% DRYNESS)

Heat flux data showing high heat transfer rates to the sheet during compression.
# LIQUID DEWTERING DATA FROM HEAT TRANSFER MEASUREMENTS

<table>
<thead>
<tr>
<th>Drying Condition (°F/psi)</th>
<th>Average Liquid Dewatering (Heat Transfer) (%)</th>
<th>Average Liquid Dewatering (Lithium Loss) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300/400</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>300/700</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>525/400</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>525/700</td>
<td>31</td>
<td>27</td>
</tr>
</tbody>
</table>

Internal sheet temperature data.
Sheet temperature and caliper data showing that the temperature near the hot surface exceeds 212°F before the saturation caliper (15.6 mils) is reached.

Caliper data showing relatively slow, but uniform initial sheet compression rates.
FUNDAMENTALS OF DRYING

OBJECTIVE: TO DEVELOP THE INFORMATION NECESSARY FOR THE COMMERCIALIZATION OF IMPULSE DRYING

IMPULSE DRYING GIVES:

- EXTREMELY HIGH DRYING RATES
  - VERY SMALL DRYERS
  - HIGH PRODUCTION RATES
- LIQUID PHASE WATER REMOVAL
  - LESS DRYING ENERGY
- SHEET DENSIFICATION
  - PROPERTY DEVELOPMENT
  - PRESS DRYING EFFECTS
TOPICS FOR DISCUSSION

- PROJECT OVERVIEW
- ENERGY USE EXPERIMENTS
- PILOT ROLL IMPULSE DRIER DESIGN
- PLANS FOR THE COMING YEAR

1. EXPLORATORY AND FEASIBILITY STUDIES
2. INVESTIGATION OF WATER REMOVAL MECHANISMS
3. TECHNICAL PERFORMANCE DATA
4. PRELIMINARY ENGINEERING CONCEPTS
5. ECONOMIC ANALYSIS
6. LABORATORY VERIFICATION AND EVALUATION
7. TECHNICAL/ECONOMIC ASSESSMENT
8. DEFINE BEST SYSTEMS AND APPLICATIONS
9. (OPTIONAL) PILOT VERIFICATION
   COMMERCIALIZATION (BY OTHERS)
REVIEW OF PREVIOUSLY REPORTED DATA

- WATER REMOVAL RATES
- DENSITY DEVELOPMENT
- STRENGTH DEVELOPMENT

GRADES TESTED TO DATE

- LIGHTWEIGHT COATING
- WRITING
- NEWSPRINT
- TISSUE
- CORRUGATING MEDIUM
- LINERBOARD - VIRGIN KRAFT
  - RECYCLED FIBER (100%)
  - CMP (74 & 88% YIELD)

IMPULSE DRYING PERFORMANCE FACTORS

- WATER REMOVAL RATE
- SPECIFIC ENERGY CONSUMPTION
- PAPER PROPERTY DEVELOPMENT
ELEMENTS OF PERFORMANCE EVALUATION

Virgin Linerboard Base Sheet
127g/m²

- 150 psi
- 300 psi
- 600 psi
- 400 psi
- 700 psi
- 750 psi (IMPULSE DRIED-TWO SIDES)

WATER REMOVAL RATE, lb/hr/ft²

TEMP/√(NRT)

INGOING SOLIDS

65.2

72.4

82.7

PREDRIED SHEETS
ADVANTAGE OF IMPULSE DRYING: PROPERTIES

- SMOOTHNESS: ↑
- POROSITY: ↓
- ABSORBENCY: ↓
- INK PENETRATION: ↓
- PICK RESISTANCE: ↑
- OPTICAL:

CONVENTIONAL DRYING - IMPULSE DRYING

![Graph showing TAPPI brightness and TAPPI density against outgoing solids](image-url)
Progress over the past 6 months

- Energy use studies
- Expanded properties studies
- Roll impulse drier design and construction

Major results

- Energy use decreases strongly with increasing sheet moisture ratio
  - Indicates an opportunity to implement impulse drying in the usual third-press position
PROJECT 3470/3595

ENERGY USE EXPERIMENTS

OBJECTIVE: TO MEASURE ENERGY USE AND WATER REMOVAL RATE OVER A WIDE RANGE OF OPERATING CONDITIONS

DATA WILL BE USED IN LATER DESIGN AND ECONOMIC ANALYSIS WORK

ENERGY USE EXPERIMENTS

VARIABLES:
- TEMPERATURE
- PRESSURE
- NIP RESIDENCE TIME
- MOISTURE RATIO
- ONE SIDED/TWO SIDED IMPULSE DRYING

ENERGY USE EXPERIMENTS

GRADES STUDIED:
- LINERBOARD
- NEWSPRINT
- 88% YIELD CMP

ENERGY USE EXPERIMENTS

KEY MEASUREMENTS:
- WATER REMOval RATES
- SPECIFIC ENERGY USE (BTU/LB WATER REMOVED)
- HEAT FLUX HISTORY IN NIP

ENERGY USE EXPERIMENTS

METHODS USED:
- LIQUID WATER REMOVAL BY LITHIUM CHLORIDE TRACER
- HEAT FLUX HISTORY FROM METAL SURFACE THERMOCOUPLE READINGS USING A SEMI-INFINITE SLAB HEAT TRANSFER MODEL.
\[ e_{\text{min}} = \frac{E_{\text{min}}}{(RMR)_{\text{min}} w_o} = \left( \frac{C_f}{m r_o} + \frac{C_w}{RMR} \right) (T_B - T_o) + (1 - \alpha_L) \Delta h_B + \frac{C_f (T_H - T_B)}{2 m r_o} \]

**Initial sensible heating of wet web**

**Latent heat**

**Final sensible heating of "dry zone"**

**ENERGY USE EXPERIMENTS**

**RESULTS:**

- **SPECIFIC ENERGY USE (BTU/LB)**
  DECLINES RAPIDLY WITH INCREASING SHEET MOISTURE CONTENT

THIS MAY ALLOW COST-EFFECTIVE IMPLEMENTATION OF IMPULSE DRIERS AS THIRD-PRESS REBUILDS

**LINERBOARD HEAT USE**

![Graph showing the relationship between BTU/LB water removed and moisture ratio (water/fiber).](image-url)
NEWSPRINT HEAT USE

88% YIELD CMP ENERGY USE
MULTIPLE REGRESSION CORRELATIONS FOR ENERGY USE

\[ \text{BTU/FT}^2 \text{ PAPER} = A + B \times P (\text{PSI}) + C \times T (\text{°F}) + D \times NRT (\text{MS}) + E \times MR \]

<table>
<thead>
<tr>
<th>GRADE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEWSPRINT</td>
<td>-4.782</td>
<td>.00232</td>
<td>.00642</td>
<td>.017</td>
<td>4.285</td>
<td>0.909</td>
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<tr>
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<td>-7.042</td>
<td>.00127</td>
<td>.00727</td>
<td>.128</td>
<td>4.953</td>
<td>0.897</td>
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<tr>
<td>88% YIELD CMP</td>
<td>-4.880</td>
<td>.00379</td>
<td>.00205</td>
<td>.054</td>
<td>6.805</td>
<td>0.741</td>
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MULTIPLE REGRESSION CORRELATIONS FOR WATER REMOVAL RATE

\[ \text{WRR (LB/HR/FT}^2) = A + B \times P (\text{PSI}) + C \times T (\text{°F}) + D \times NRT (\text{MS}) + E \times MR \]

<table>
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<th>C</th>
<th>D</th>
<th>E</th>
<th>R^2</th>
</tr>
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<tbody>
<tr>
<td>NEWSPRINT</td>
<td>-448</td>
<td>.401</td>
<td>1.574</td>
<td>-30.2</td>
<td>1000</td>
<td>0.953</td>
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<tr>
<td>LINERBOARD</td>
<td>-2237</td>
<td>804</td>
<td>2.218</td>
<td>-13.0</td>
<td>2223</td>
<td>0.922</td>
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<tr>
<td>88% YIELD CMP</td>
<td>-1112</td>
<td>1.473</td>
<td>.917</td>
<td>-71.4</td>
<td>3494</td>
<td>0.902</td>
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</tbody>
</table>
LINERBOARD, 125 G/M²
700 PSI, 600°F, 25 MILLISECONDS

PREDICTED LINERBOARD RESPONSE

LINERBOARD

LINERBOARD, 125 G/M²
700 PSI, 600°F, 25 MILLISECONDS

LINERBOARD

CONVENTIONAL DRYING

IMPULSE DRYING

% SOLIDS OUT

% SOLIDS IN

BTU/ADT

% SOLIDS IN
EXPANDED PROPERTIES STUDY

OBJECTIVES:

- TO EVALUATE THE EFFECTS OF VARYING INITIAL MOISTURE RATIO ON PROPERTIES DEVELOPMENT
- TO BUILD A DATABASE ON THE STRENGTH EFFECTS OF TWO-SIDED IMPULSE DRYING

EXPANDED PROPERTIES STUDY

GRADED STUDIES:

- NEWSPRINT
- LINERBOARD

EXPANDED PROPERTIES STUDY

STATUS:

- ALL IMPULSE DRYING WORK HAS BEEN COMPLETED
- RESULTS FROM PHYSICAL TESTING ARE NOT YET AVAILABLE
IMPULSE ROLL PRESS
DESIGN OVERVIEW

GENERAL SPECIFICATIONS

A. SIZE
1. PRESS ROLLS: 24" DIA. x 24" FACE
2. FELT ROLLS: 24" FACE
3. FELT: 12" WIDE
4. SHEET: 14" WIDE, ANY LENGTH
   3" DIA. CORE FOR ROLLS

B. SPEED - 0 TO 350 FT/MIN.

C. NIP LOAD
1. FRAME CAPACITY: 1500 pli
2. IMPULSE ROLL CAPACITY: 750 pli

HEATING SYSTEM

A. TYPE
1. COMMERCIAL ELECTRIC INFRA-RED LAMPS
2. EXTERNAL TO ROLL
3. 120 kw TOTAL POWER PER ROLL

B. CONTROL
1. SCR PHASE ANGLE POWER CONTROLLERS
2. TWO ZONES IN C.D.
3. P.I.D. PROGRAMMER/CONTROLLER
4. TO 750°F.
5. ROLL SURFACE THERMOCOUPLES FOR FEEDBACK-
CONTROL SYSTEM

A. SENSORS
1. ROLL SPEEDS
2. HOT ROLL TEMPERATURE
3. NIP LOAD

B. CONTROL
1. PROGRAMMABLE LOGIC CONTROLLER (PLC)
2. MANUAL OR AUTOMATIC

INSTRUMENTATION SYSTEM

A. SENSORS
1. MACHINE SPEED
2. HOT ROLL TEMPERATURE (5 M.D., 5 C.D.)
3. NIP MECHANICAL PRESSURE (5 C.D.)

B. DATA ACQUISITION
1. PROGRAMMABLE MULTIPLEX-BASED A TO D CONVERTER
2. 100 MICROSECOND SAMPLING TIME
   (200 DATA POINTS PER 20 msec.)

OTHER FEATURES

A. LINE SHAFT DRIVE
1. 75 H.P. D-C SCR DRIVE
2. SEPARATE STOP-START ON ALL ROLLS
3. FELT DRIVE

B. ROLL BEARING LUBRICATION SYSTEM

C. FELT CONDITIONING

D. SLITTERS

E. TENSION CONTROLLED REWIND
PLANS FOR THE COMING YEAR

- ROLL IMPULSE DRYER WORK
- ECONOMIC EVALUATIONS OF IMPULSE DRYING

ROLL IMPULSE DRYER WORK SEQUENCE:

- COMPLETE CONSTRUCTION (THROUGH JAN., 1986)
- STARTUP EFFORTS (JAN.-MAR., 1986)
- PRIORITY TESTS (MAR.-SEPT., 1986)

OBJECTIVES OF PRIORITY TESTS:

- TO CONFIRM PREVIOUS OBSERVATIONS IN ROLL GEOMETRY
- TO PERFORM CONVERTING TESTS (NOT DONE TO DATE DUE TO SAMPLE SIZE LIMITATIONS)
PLANS FOR THE COMING YEAR

GRADES TO BE STUDIED:

- LINERBOARD
- MEDIUM
- COATING RAWSTOCK
- WRITING PAPER
- NEWSPRINT

ALL AS SIMILAR AS POSSIBLE TO THE
TECHNICAL OVERVIEW STUDIES FURNISHES

PLANS FOR THE COMING YEAR

CONVERSION ISSUES:

- PRINTING QUALITY
- CORRUGATION AND GLUING
  OF MEDIUM AND LINER
- COATING DRAWDOWN PERFORMANCE
  OF COATING RAWSTOCK