Paper Towel Absorptive Properties and Measurement using a Horizontal Gravimetric Device

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RETHINK PAPER:
Lean and Green

Overview

- Provide background on absorbency methods for rate and capacity in paper towels;
- Discuss our ‘new’ instrument and method (CRT), and compare to others commercially available;
- Discuss our experimental approach and result calculations;
- Show experimental results for repeatability, accuracy, and sensitivity;
- Discuss of experimental variables and their impact
- Conclusions

Background – Previous Work

- Many methods for capacity of “dunk-and drain” variety.
  - EN ISO 12625-8, ASTM D-4250, INDA IST 10.1, Federal Spec UU-T-591d, 495c
- Rate and Capacity can be effectively captured using a horizontal radial wicking apparatus – this is not a new proposition.
  - ATS (Absorbency Testing System) – from Sherwood Instruments
  - GATS (Gravimetric Absorbency Testing System) – from M/K Systems, Inc.
- TAPPI Working Group 030803.10 Interim Report – 4/3/08
  - Evaluated ATS and GATS for rate and capacity
  - Could differentiate TAD from CWP, but insufficient repeatability and reproducibility – working group eventually was discontinued.
- P&G developed instrument: CRT (Capacity & Rate Tester)
  - Capable of running in test mode similar to ATS and GATS

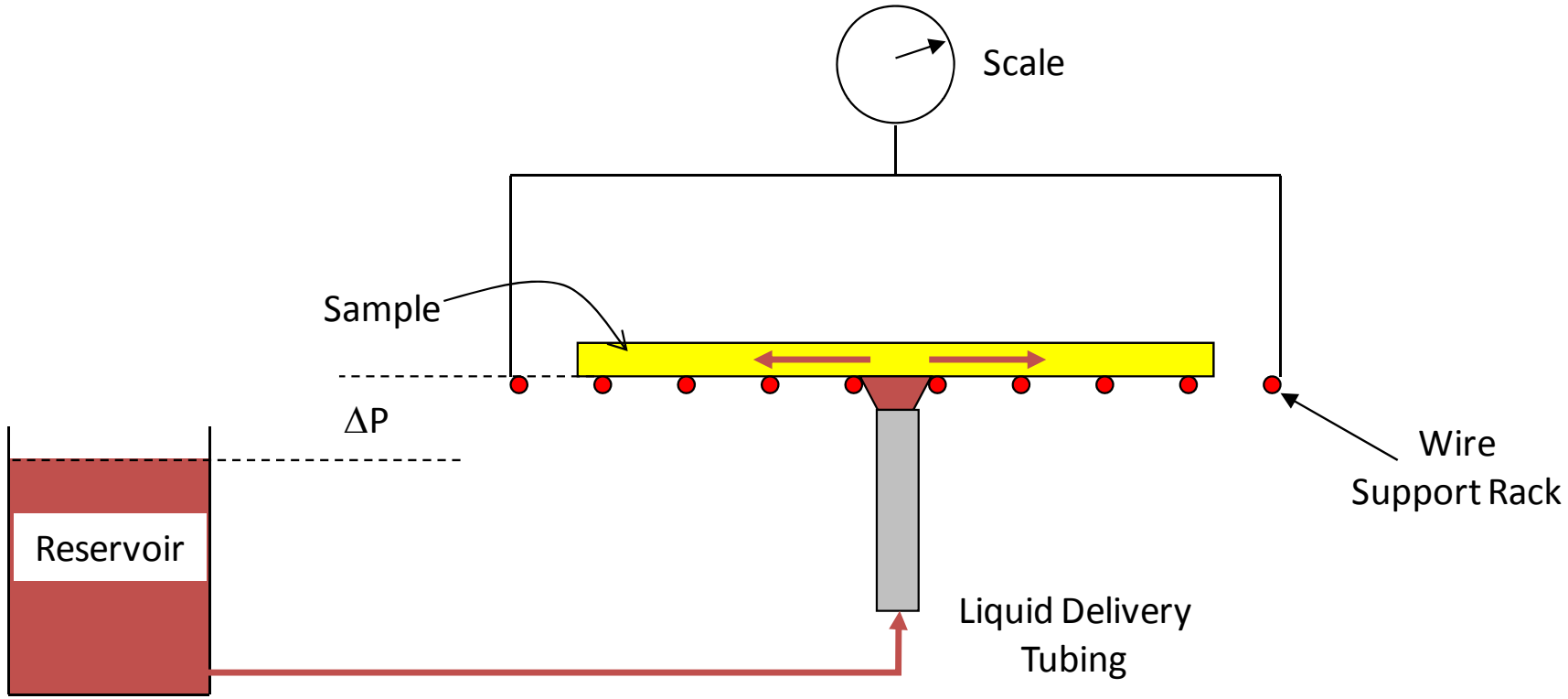
Experimental Approach

- Evaluated three key aspects of performance:
  - Repeatability – with comparison to ATS and GATS methods
  - Accuracy – ability to rank samples with known relative absorbency performance
  - Sensitivity – impact of basis weight for given technology and # plies
- 6 different commercially available paper towel samples (none P&G)

Structure	# Plies	BW (lbs/3000ft^2)
CWP	1	26.1
CWP	2	30.4
TAD	1	23.6
TAD	2	25.0
TAD	2	28.7
TAD	2	32.8

Experimental Approach

- CRT was set-up as follows:
  - Circular cut towel sample is placed on a platform which has a water supply orifice at its center, and from which radial absorption can be gravimetrically measured as a function of time (20 pps).



Experimental Approach

- Comparisons to GATS* set-up (*from Tappi Interim Report, 4/3/08)

	GATS	CRT
Sample Diameter	2 in	3.375 in
Sheets	1	1
Support Surface	Mesh	Mesh
Top Surface	Mesh	Top Cover
Negative hydrostatic Pressure	5mm	2 mm
Orifice Diameter	3 mm	7.9mm
End Point for Capacity	5 mg / 5 sec	9 mg / 6 sec

Calculation of Results

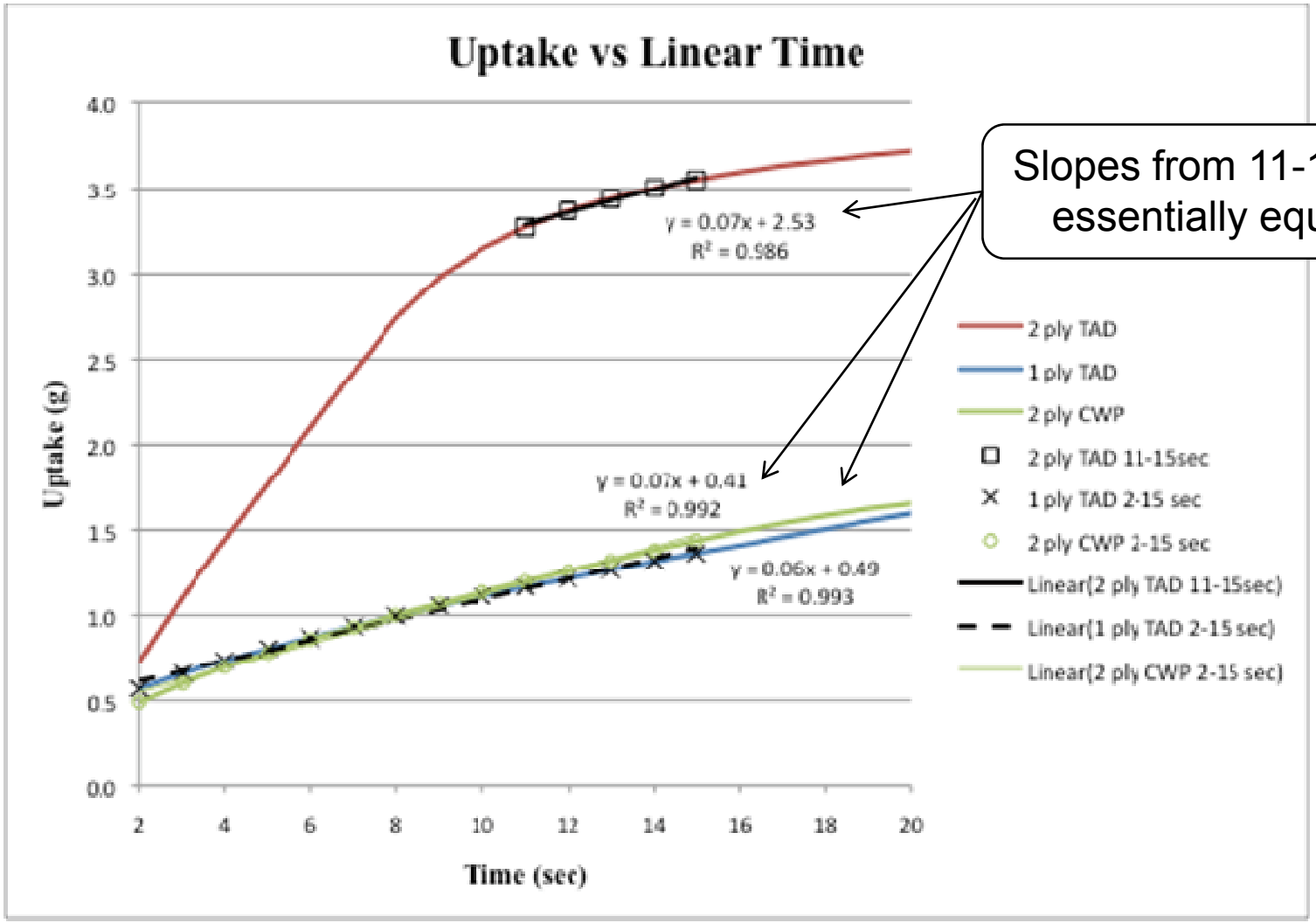
- Capacity
  - Sample absorbs until uptake rate falls at or below 9 mg / 6 seconds
    - Helps prevent a premature end that could be caused rate fluctuations
  - After hydraulic disconnection:
    - (Wet wt. – Dry wt.) / Dry wt. = g/g
    - (Wet wt. – Dry wt.) / Sample Area = g/in^2

Calculation of Results

- Rate
  - Cumulative Rate (from time zero) – g/sec
    - Mass of water taken up divided by the amount of time (from time 0).
    - Calculated at 2, 5, and 10 seconds (similar to TAPPI Interim Report)
  - Slope of water uptake vs. time
    - Linear regression between two non-zero times, 20 data point/sec
      - Avoided first 2 seconds of the test, since it is often noisy from the initiation surge
      - Investigated the impact of different termination times
    - Measures included:
      - 3-5 second tangent rate (*as described by Beuther) (g/sec)
      - Slope of Square Root of Time (SST) from 2-15 seconds ($g/sec^{1/2}$)

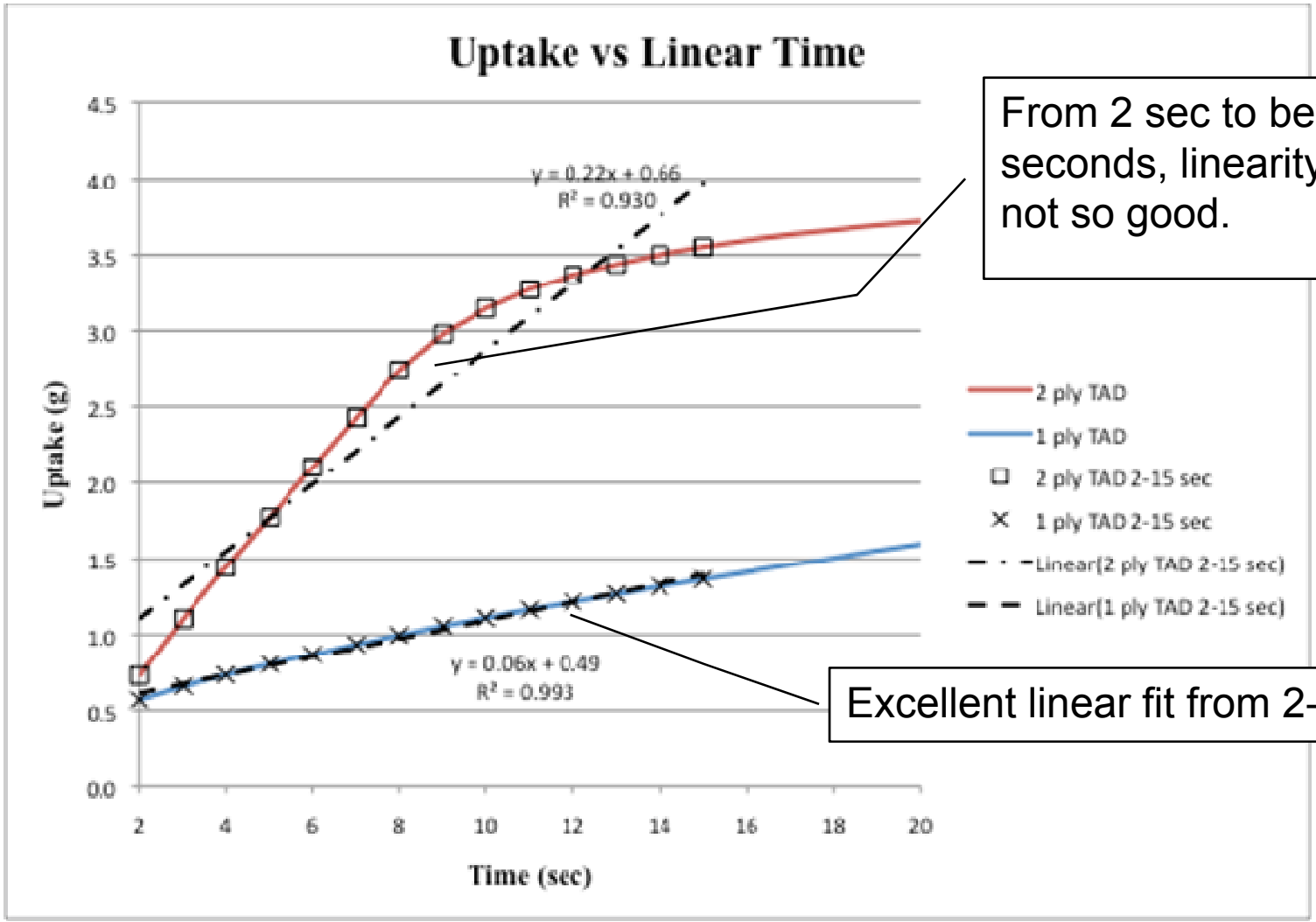
Calculation of Results

- 2-ply TAD rate ≥ 1-ply TAD and CWP up to 15 seconds



Calculation of Results

- Water Uptake vs. Linear Time - 1-ply vs. 2-ply TAD

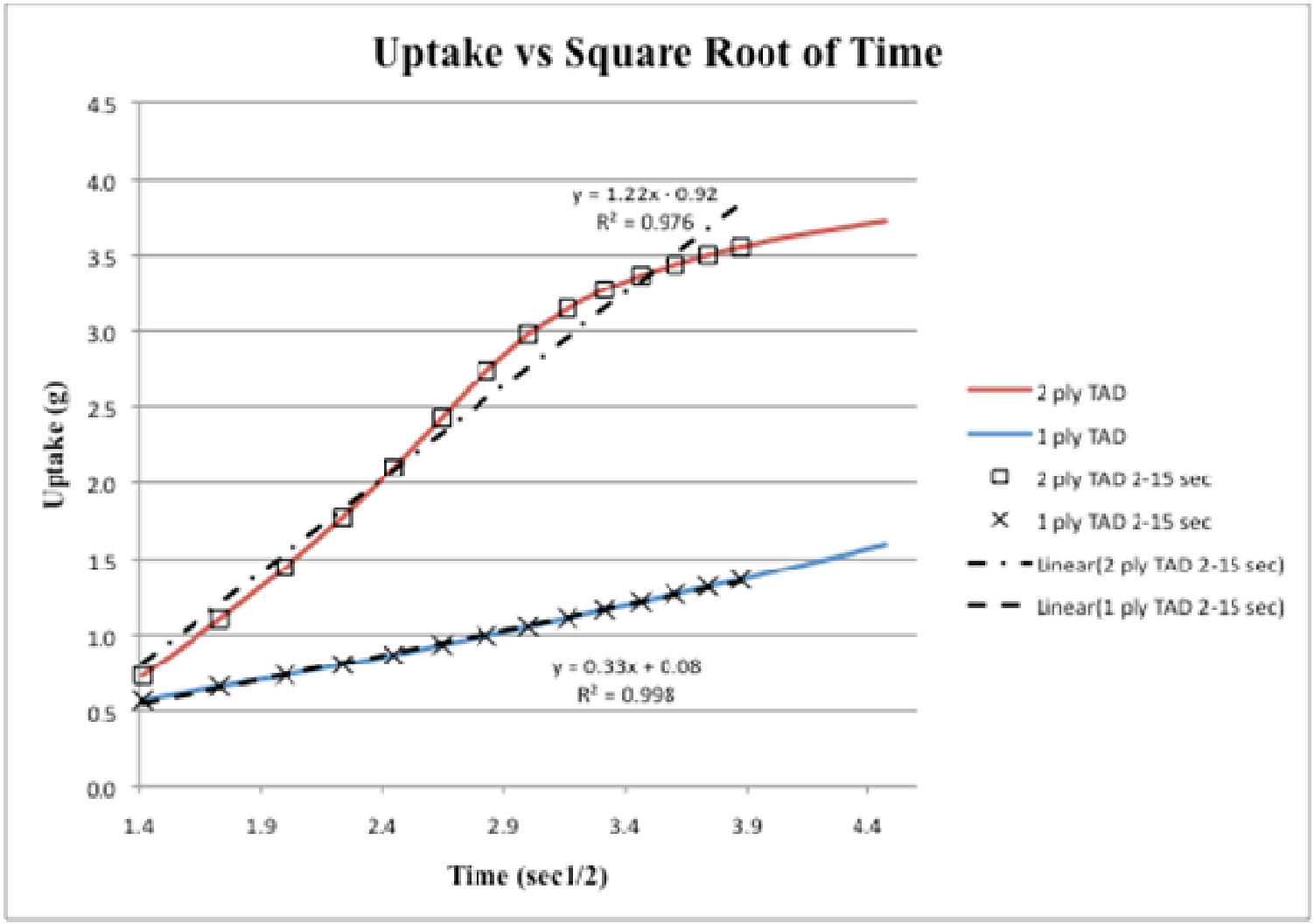


From 2 sec to beyond 10 seconds, linearity with time not so good.

Excellent linear fit from 2-20s

Calculation of Results

- Uptake vs. Square-Root of Time Improves Linear Fit to 15 sec



Results - Method Repeatability

- Used one of the 2-ply TAD products, measured 20 times
- Coefficient of Variation (COV) 4% or less

	SST 2-15 ($g/sec^{1/2}$)	3-5 sec tangent rate (g/sec)	Cumulative 2 sec (g/sec)	Cumulative 5 sec (g/sec)	Cumulative 10 sec (g/sec)	Detached Capacity (g/g)	Detached Capacity (g/in2)
Average	1.263	0.362	0.389	0.381	0.331	16.425	0.331
Std.Dev.	0.023	0.012	0.016	0.013	0.005	0.176	0.005
COV	1.5%	3.5%	3.4%	3.4%	1.6%	0.9%	0.9%

- This is comparatively better than reported values for ATS and GATS using similar set-ups (data from Tappi Interim Report 4/3/08).

COV (%)	Cum.Rate (g/s) 2 seconds		Cum.Rate (g/s) 5 seconds		Cum.Rate (g/s) 10 seconds		Capacity (g/g)	
	TAD	CWP	TAD	CWP	TAD	CWP	TAD	CWP
GATS	12.5%	19.0%	8.7%	13.3%	2.7%	10.0%	7.3%	1.6%
ATS	13.7%	27.8%	7.6%	17.2%	4.8%	11.9%	6.0%	8.1%
CRT	3.4%	-	3.4%	-	1.6%	-	0.9%	-

Results – Accuracy: Ability to Rank Samples

- In this study, we are referring to the ability of a method to produce an expected result.
- In general, 2-ply higher has higher absorptive rate and capacity than 1-ply paper
  - "lamellar flow channels are created between the plies, which considerably reduces the viscous flow resistance"
  - absorbent capacity gained by adding an additional ply is in general greater than absorbent capacity held within the added ply"
- It is also generally understood that structured paper has higher absorptive rate and capacity than conventional, wet pressed (CWP) paper.
- A desirable absorbency instrument and method should yield results consistent with these relationships.

Results – Accuracy: Ability to Rank Samples

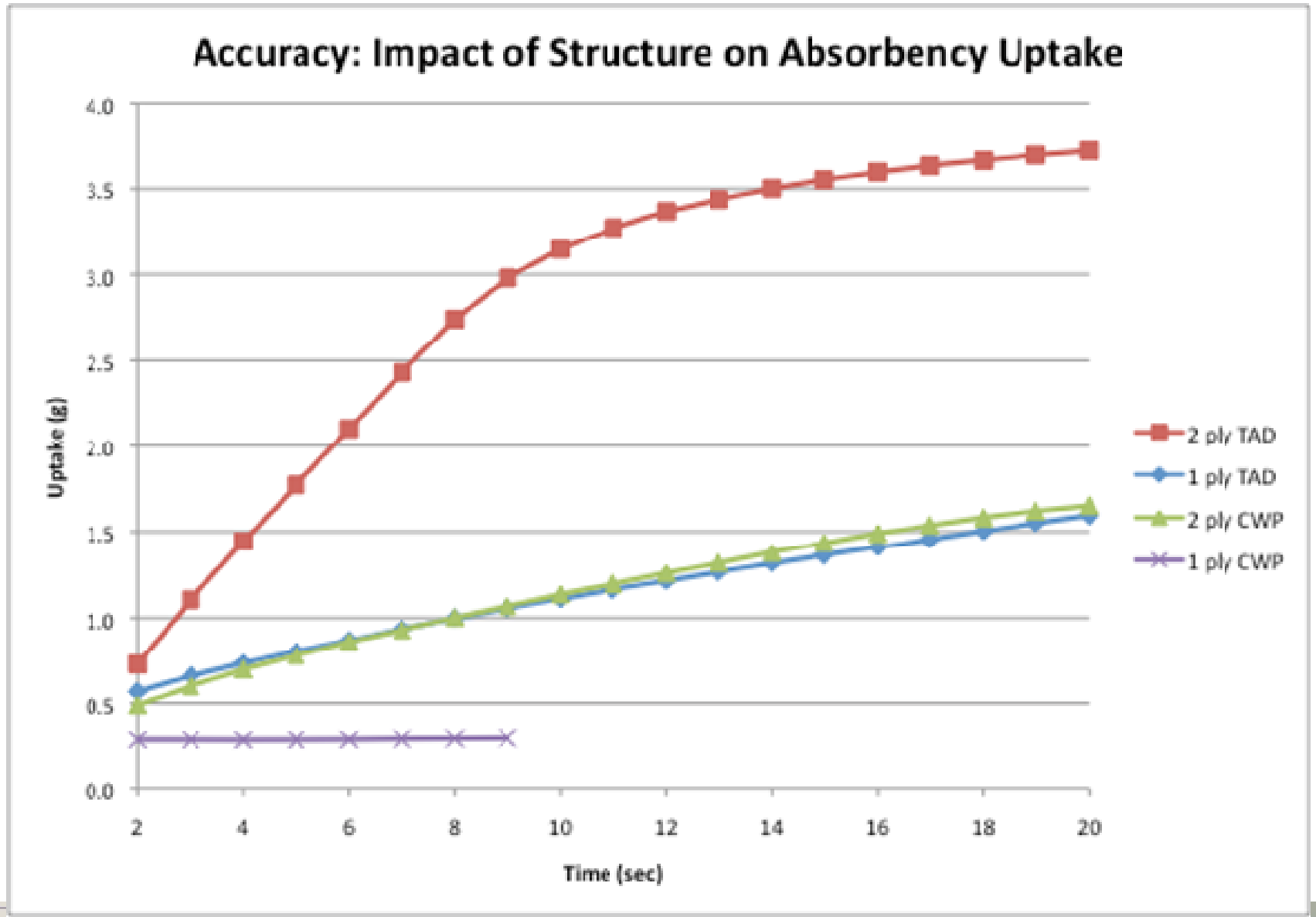
- CRT instrument was accurate in its measurements (in terms of ranking the products):

Product	BW (#/3000ft²)	SST 2-15 (g/sec$^{1/2}$)	3-5 sec tangent rate (g/sec)	Cumulative 2 sec (g/sec)	Cumulative 5 sec (g/sec)	Cumulative 10 sec (g/sec)	Detached Capacity g/g	Detached Capacity g/in²
2-ply TAD	25.0	1.243	0.334	0.364	0.354	0.315	16.2	0.42
1-ply TAD	23.6	0.327	0.074	0.284	0.161	0.111	13.8	0.34
2-ply CWP	30.4	0.387	0.089	0.244	0.155	0.113	6.6	0.21
1-ply CWP	26.1	0.005	0.000	0.147	0.058	0.034	0.66	0.018

- Two-ply samples showed faster rate and higher capacity than the one-ply samples across all of the rate and capacity measures reported.

- TAD samples showed faster rate and higher capacity than the conventional, wet pressed samples across all of the rate and capacity measures reported.

Results – Accuracy: Ability to Rank Samples



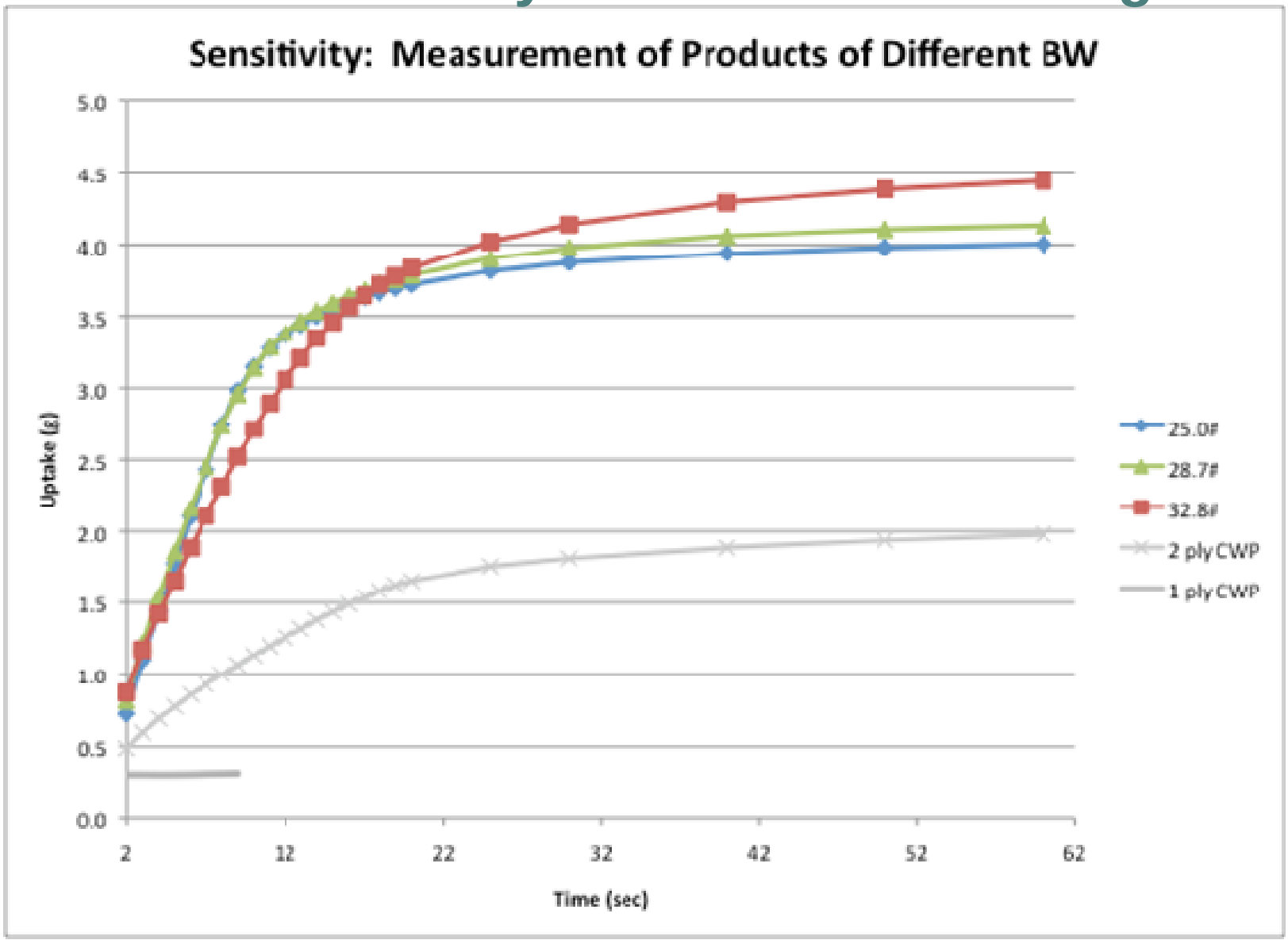
Results – Sensitivity: Effect of Basis Weight

- Measured 3 commercially available 2-ply TAD products (not P&G)
  - Different in basis weight (BW), but similar in terms of:
    - Manufacturer, production facility, fiber mixes, TAD process
- Results show:
  - CRT was sensitive in distinguishing rate and capacity differences
  - The effect of basis weight is much smaller than the effects for 1 vs. 2-ply and TAD vs. conventional drying.

BW	SST 2-15 ($g/sec^{1/2}$)	3-5 sec tangent rate (g/sec)	Cumulative 2 sec (g/sec)	Cumulative 5 sec (g/sec)	Cumulative 10 sec (g/sec)	Detached Capacity (g/g)	Detached Capacity (g/in^2)
25.0	1.24	[0.33	0.36	0.35	0.31]	17.2	0.424
28.7	1.19	0.32]	0.41	0.37	[0.31	15.4	0.439
32.8	1.09	0.24	0.44	0.33	0.27	14.7	0.487

* All results in table were significantly different (95% confidence) except for those bracketed

Results – Sensitivity: Effect of Basis Weight



Discussion Topics

- Impact of Basis Weight
- Impact of Experimental Variables
  - Hydrostatic Pressure
  - Initiation
  - Top Plate

Conclusions

1. The CRT instrument and methods described in this report have been shown to have better repeatability for rate and capacity measurements as compared to ATS and GATS as documented in TAPPI Interim Report on Absorbency.

2. The rate and capacity measurements discussed in this report appear to accurately rank the products by technology

   - (i.e., TAD > CWP) and number of plies (2-ply > 1-ply).

Conclusions

3. The CRT instrument and methods described in this report showed sensitivity to differences in product design. The instrument and methods were sensitive to changes in basis weight and showed that the effect of basis weight within a product technology (2-ply TAD) was significantly smaller than the absorbency differences measured between technologies (TAD vs. CWP) and number of plies (2 vs. 1).

4. Though measurable differences were observed, the overall effect of basis weight on absorbency rate requires more study. The samples included this study, though as similar as we could find in the market, might include other important differences in manufacture that could affect the measured absorbency rate and capacity.

References/Literature Cited

[i] Lundeen, Jeff, "Intrinsic Absorbency Rate and Capacity of Bibulous Paper Products", Interim Report of TAPPI Working Group 030803.10, April 3, 2008.

[ii] Federal Specification: Towels, Paper: Standard UU-T-591d.

[iii] Federal Specification: Towel, Wiping, Paper; Industrial and Institutional: Standard UU-T-495c.

[iv] EN ISO 12625-8 ,"Tissue paper and tissue products --- Part 8: Water-absorption time and water –absorption capacity, basket immersion test method."

[v] ASTM D-4250 "Standard Test Method for Water-Holding Capacity of Bibulous Fibrous Products" (Withdrawn 2009)

[vi] INDA Test method IST 101, "Method for Absorption of Water"

[vii] Lundeen, Jeff, "Intrinsic Absorbency Rate and Capacity of Bibulous Paper Products", Interim Report of TAPPI Working Group 030803.10, April 3, 2008, Table 1, "New TAPPI" method, page 5, using the mesh cover.

[viii] Beuther, Paul and Michael Veith, "Sources of Variability in Testing Absorptive Rate of Tissue Paper", TAPPI Engineering, Pulping, & Environmental Conference Proceedings, October 11-14, 2009, pg. 11.

[ix] Hollmark, Holgar: "Absorbency of Tissue and Toweling", *Handbook of Physical and Mechanical Testing of Paper and Paperboard*, Volume 2, ed. by Richard E. Mark, Chapter 20, pg. 155, 1984.

[x] US5,830,558, Column 1, lines 61-65. In the same patent a similar comment is made at Column 1, lines 46-49, "It is generally understood that a multiple ply structure can have an absorbent capacity greater than the sum of the absorbent capacities of the individual single plies which make up the multiple ply structure".

[xi] Lundeen, Jeff, "Intrinsic Absorbency Rate and Capacity of Bibulous Paper Products", Interim Report of TAPPI Working Group 030803.10, April 3, 2008, page 27.

[xii] US3,301,746. This patent was the original TAD patent and described a paper sheet with had substantially lower density, substantially higher absorbent capacity, and relatively high absorbency rates compared to the creped, wet pressed papers known before. These benefits come from molding into a textured fabric and drying the sheet with hot air instead of pressing the majority of the water out.

[xiii] US5,048,589. Paper designed to contain "high levels of absorbent capacity, absorbent rate, strength, and softness", Column 2, lines 42-43, paper produced by avoiding the pressing and creping processes found in conventional, wet pressed tissue making.