Converting Tensile Tests into Digital Data: *Data Rate & Bandwidth*

Instron® Webinar

May 26, 2009

Lorenzo Majno
Electromechanical Products

What This Is All About

ACTUAL EVENT

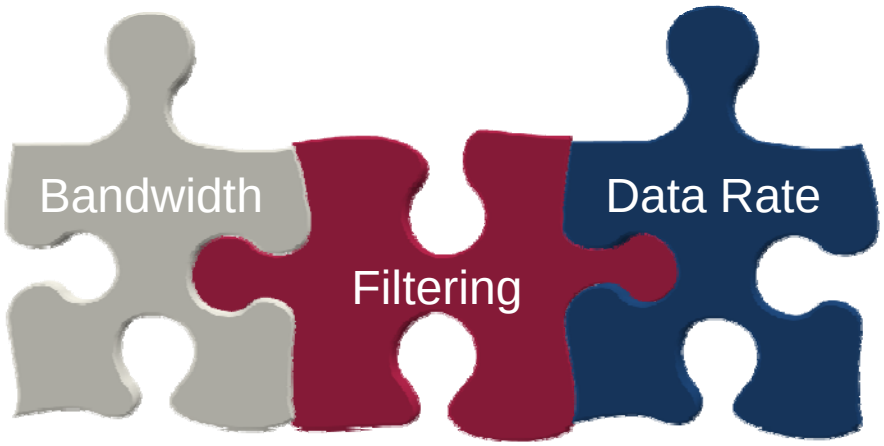
Test
Snap
Pop
Peak
Trough
"Time Event"

CONVERSION INTO ELECTRICAL SIGNAL

CAPTURE AS DIGITAL DATA

"Event" → Sensors & Electronics → Computer → Data File

EVENT



DATA FILE

Accurate Reproduction Of the Event

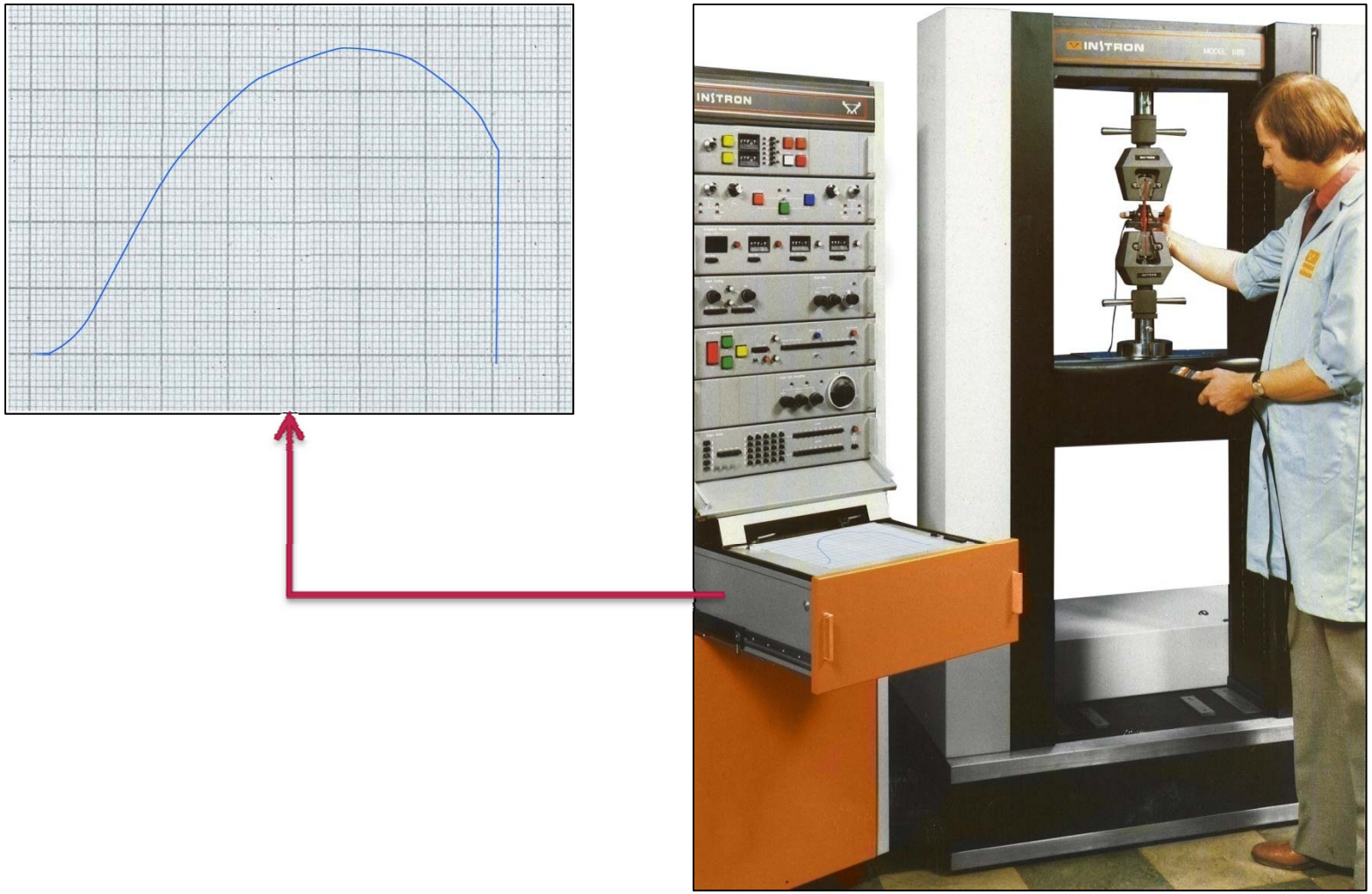
The case of the **“*Same Results Every Time*”**

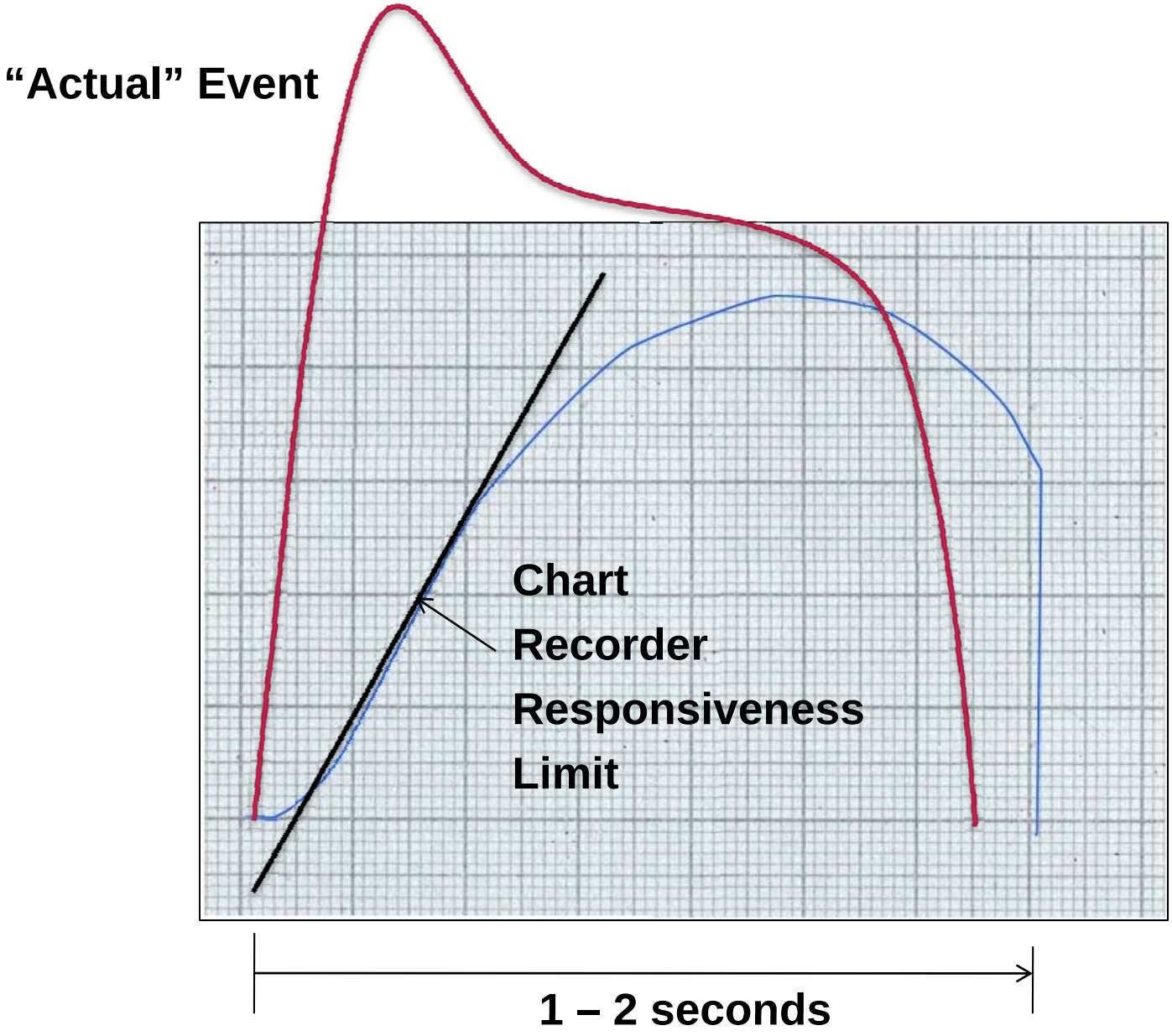
SCARY STORY #1

TEST CONDITIONS:

- Fiber tensile test
- “High” speed test
  (about 10 inches/minute)
- Extremely consistent results

A GOOD THING?...


INSTRON
INSTRON


"Actual" Event
Chart
Recorder
Responsiveness
Limit
1 – 2 seconds

Moral of Scary Story #1

ACTUAL EVENT

CONVERSION INTO ELECTRICAL SIGNAL

Error due to
Responsiveness
Of the electronics

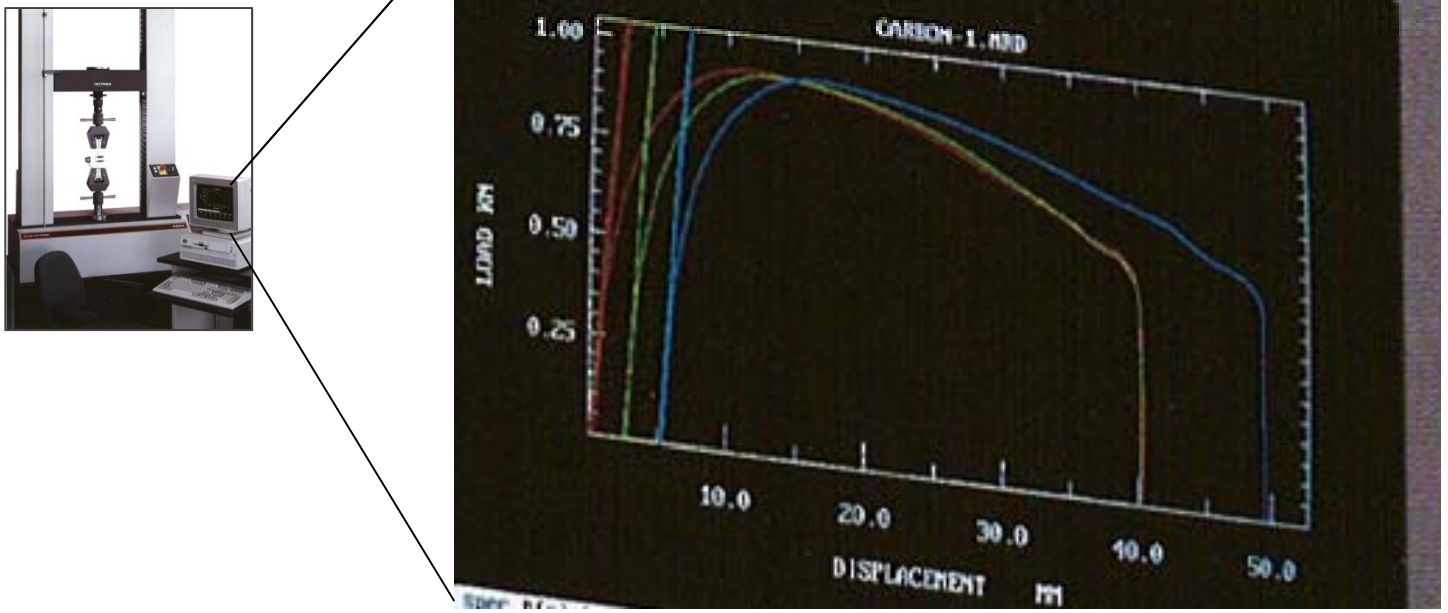
- Responsiveness of the Electronics defined by "**BANDWIDTH**"
- Bandwidth implies a "Time Constant" …or Rise Time
- Events shorter than the Time Constant will be **missed**!

The case of the “**Missing Peak**”

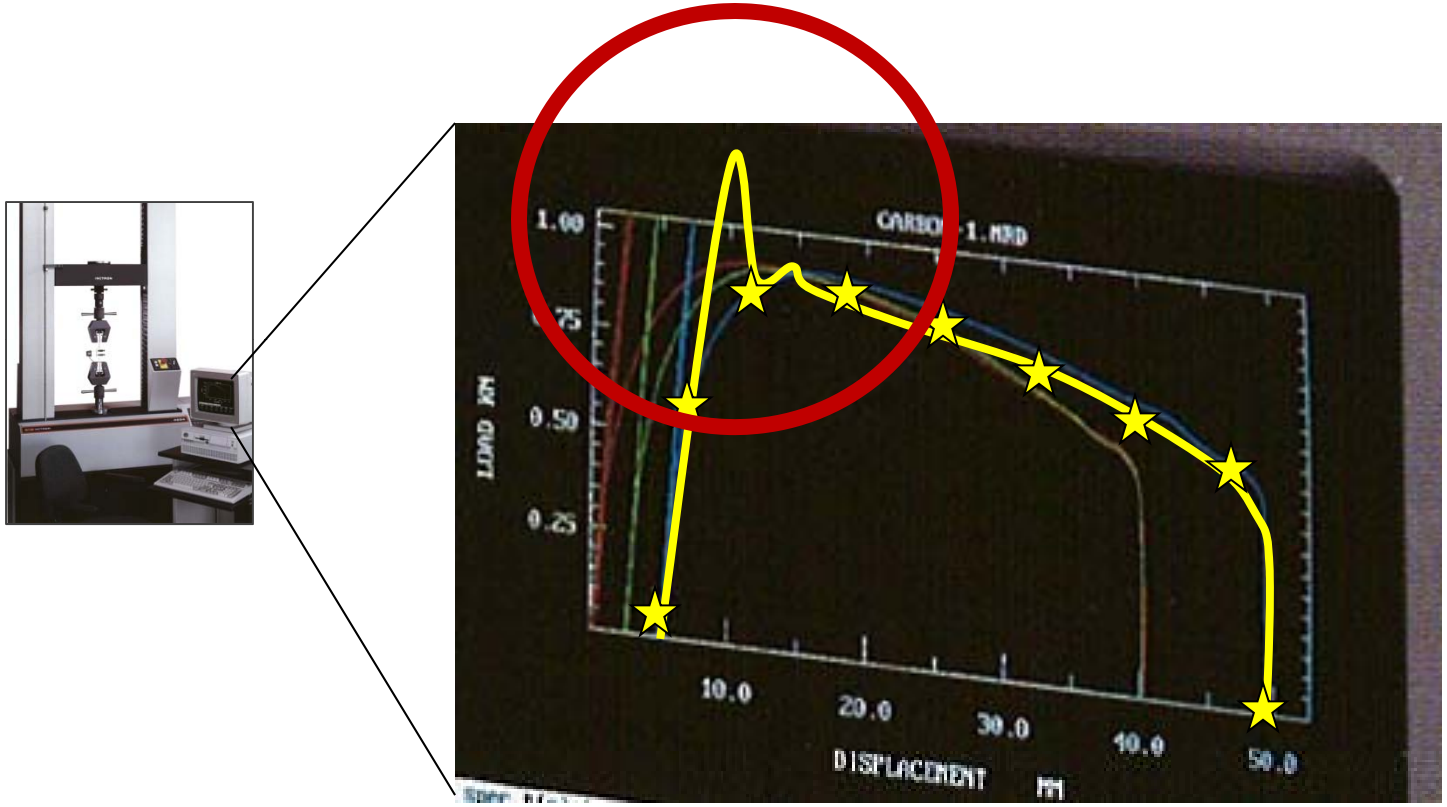
Scary Story #2

TEST CONDITIONS:

- Medical Device test
- Moderate Speed
- Some scatter in the results
- Mfg tolerances based on the results…


1.00
0.75
0.50
0.25
LOAD KN
CARBON-1.RSD
10.0
20.0
30.0
40.0
50.0
DISPLACEMENT
MM

MISSED PEAK DUE TO
SLOW SAMPLING (**DATA RATE**)



Moral of Scary Story #2

CONVERSION INTO ELECTRICAL SIGNAL

Error due to Sampling (**Data Rate**)

CAPTURE AS DIGITAL DATA

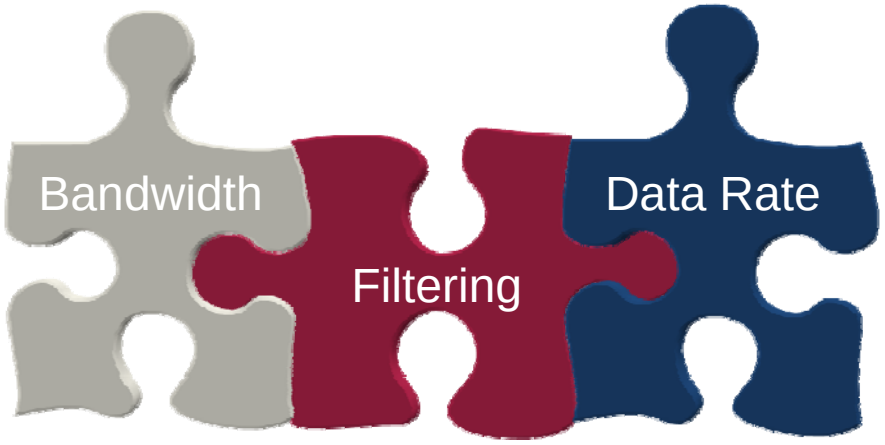
- Data Rate is critical to catching peaks
- Too low = missed peaks
- Too high = lots of data but no additional info

RULES OF THUMB

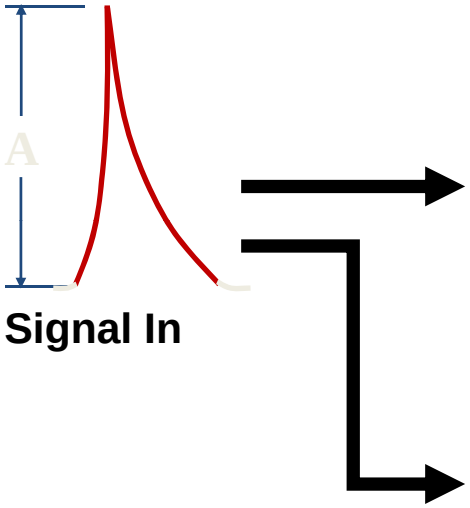
- **Understand the nature of the "EVENT" you are trying to capture**
  - How long does it last?
- **Understand the electronics being used**
  - Most "EM" systems between 1 and 10 Hz bandwidth
  - 10 Hz BW => ~50 milliseconds rise time (time constant)
- **Select the appropriate data rate**
  - Approx. 10 to 50 times the speed of the event (Depends on the "shape" of the event)
  - Ref ASTM Standard Guide E1942

A brief overview of

Bandwidth: “Responsiveness”


Bandwidth
Filtering
Data Rate

Why Worry About Bandwidth?



Circuit

High Bandwidth

= very responsive

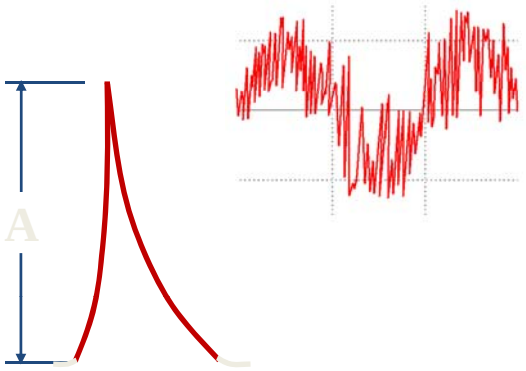
= noisy (jumpy displays, scatter in data)

Low Noise

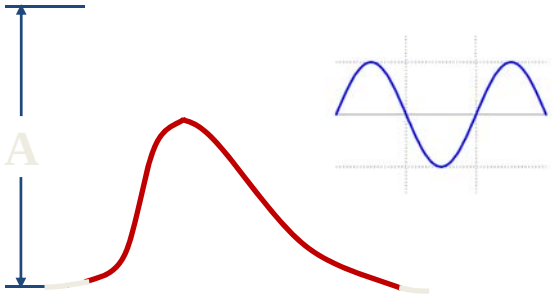
(**Low Bandwidth**)

= big range

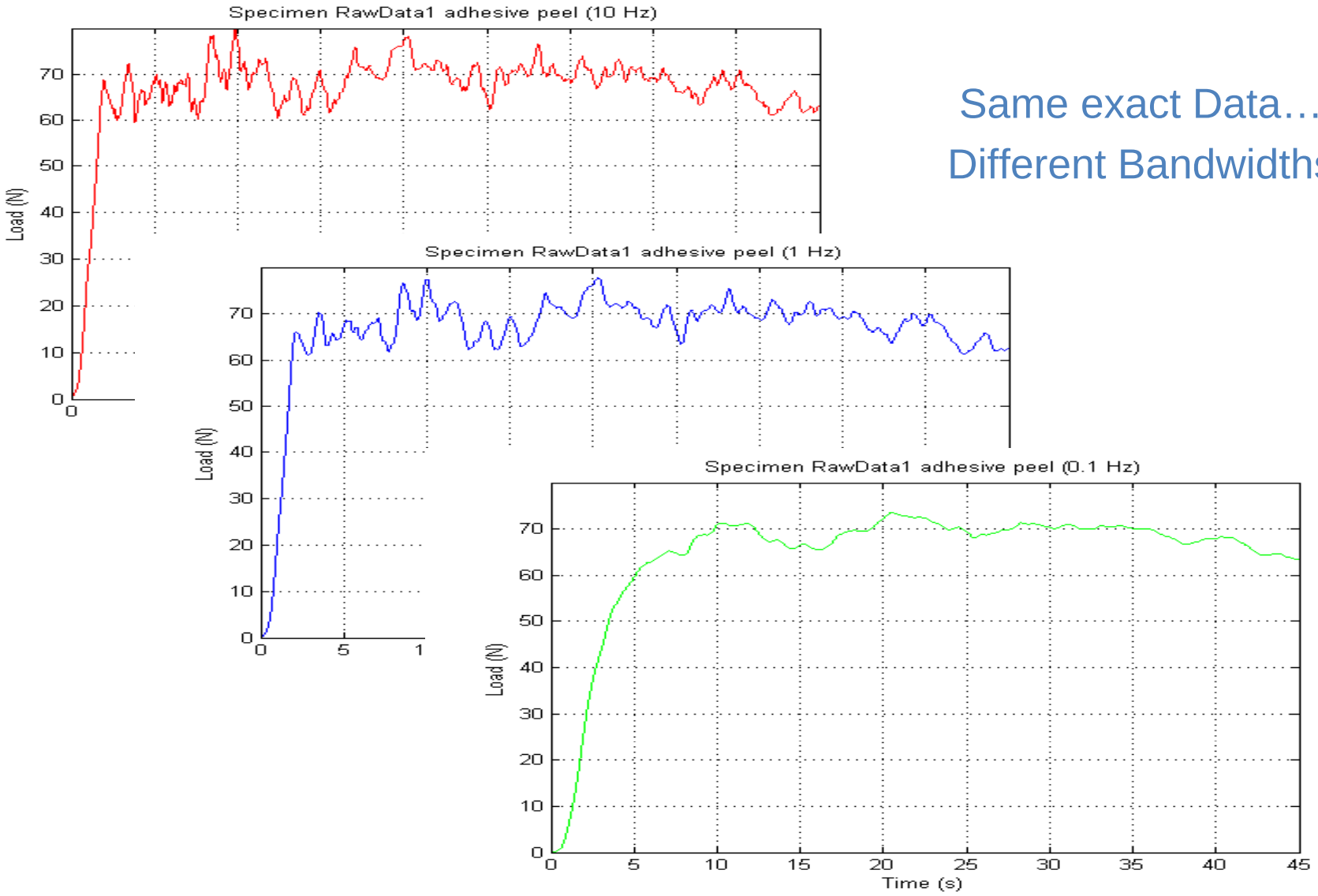
= clean signal



▪ **High Bandwidth**



▪ **Low Bandwidth**



Same exact Data…
Different Bandwidths

Peel Test Results

1 Hz Bandwidth

Results - Peel / Tear / Friction

	First Peak Load (oz)	Avg Load 5 Peaks (oz)	Max Peak (oz)	Avg Load 0.4 - 2.0 in (oz)
1	21.57	21.26	24.56	14.96
2	14.95	19.91	21.97	13.46
3	19.10	16.22	19.10	11.34
4	22.08	19.39	22.08	13.12
5	10.34	16.63	18.45	9.53
Mean	17.61	18.68	21.23	12.48
S.D.	4.95	2.18	2.48	2.09
C.V.	28.09	11.65	11.70	16.76
Minimum	10.34	16.22	18.45	9.53
Maximum	22.08	21.26	24.56	14.96

10 Hz Bandwidth

Results - Peel / Tear / Friction

	First Peak Load (oz)	Avg Load 5 Peaks (oz)	Max Peak (oz)	Avg Load 0.4 - 2.0 in (oz)
1	15.15	19.07	20.40	11.03
2	15.14	20.22	22.88	11.98
3	25.24	29.16	30.50	17.85
4	22.15	33.30	37.92	17.03
5	15.60	23.01	25.92	12.17
Mean	18.66	24.95	27.52	14.01
S.D.	4.73	6.09	6.92	3.17
C.V.	25.35	24.39	25.15	22.64
Minimum	15.14	19.07	20.40	11.03
Maximum	25.24	33.30	37.92	17.85

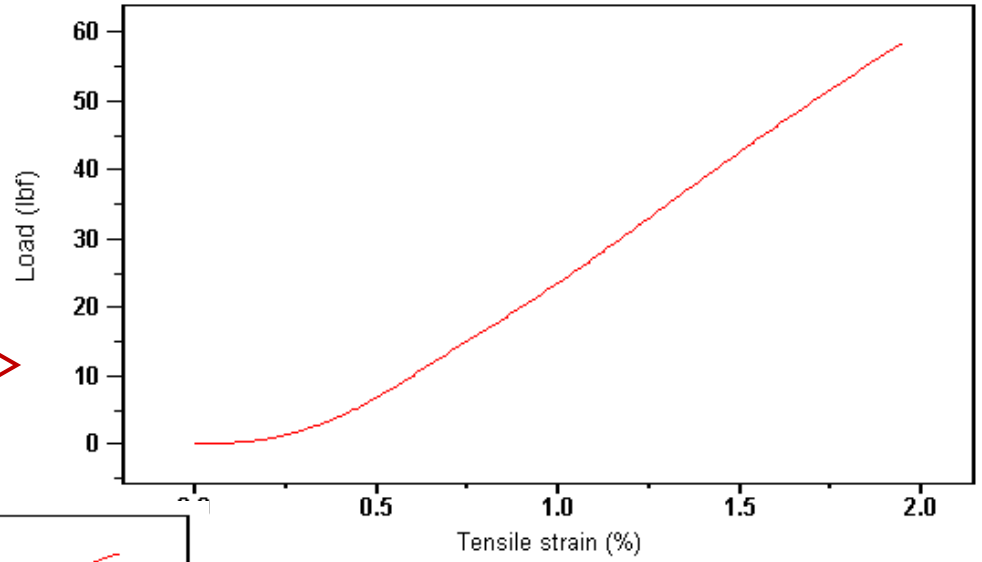
Note higher mean loads at 10Hz

5.9% ↑ 33.6% ↑ 29.6% ↑ 12.2% ↑

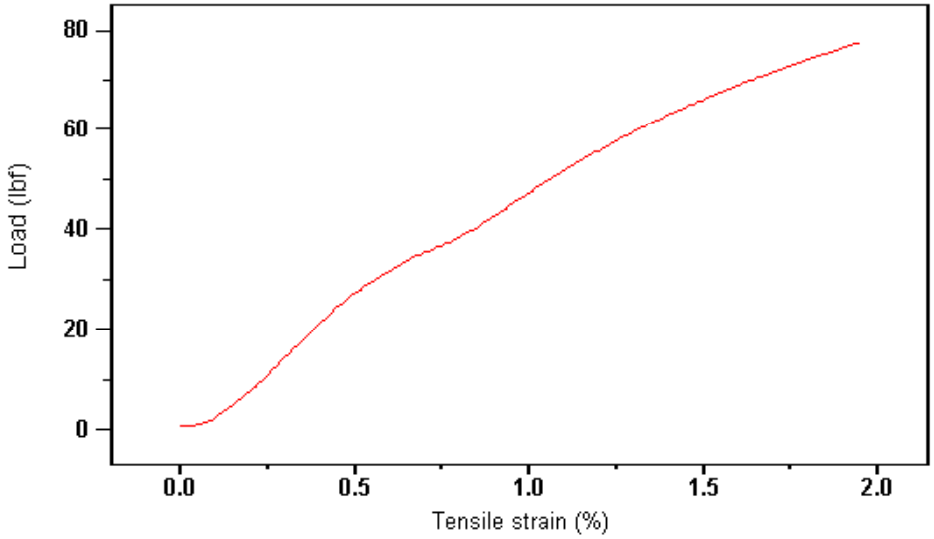
Tensile Test - Paper

- Tensile Test
- Specimens 1” wide x 0.01” thick paper with 5” GL
- Speed 12 in/min
- Test duration: 0.024 seconds

Note the slow rise in load and missing curve inflection at 1 Hz



Bandwidth = 1 Hz
Data rate = 500 Hz



Bandwidth = 10 Hz
Data rate = 500 Hz

Paper Tension Test Results
Bandwidth Matters !
(...for high speed events)

1 Hz Bandwidth

Results - Tension

	Maximum Load (lbf)	Strain at Break (%)	1% Secant Modulus (ksi)	TEA (in-lb)
1	55.22	1.95	212.1	0.037
2	63.80	2.23	223.9	0.052
3	57.75	1.95	227.4	0.039
4	63.64	2.23	215.7	0.052
5	58.34	1.95	236.0	0.040
Mean	59.75	2.06	223.0	0.044
S.D.	3.81	0.16	9.5	0.007
C.V.	6.38	7.54	4.3	16.656

10 Hz Bandwidth

Results - Tension

	Maximum Load (lbf)	Strain at Break (%)	1% Secant Modulus (ksi)	TEA (in-lb)
1	76.73	1.95	446.1	0.068
2	82.48	2.23	462.6	0.088
3	77.95	1.95	460.8	0.071
4	75.97	1.95	459.0	0.071
5	77.58	1.95	473.0	0.071
Mean	78.14	2.01	460.3	0.074
S.D.	2.54	0.13	9.6	0.008
C.V.	3.26	6.31	2.1	10.861

Note higher values at 10Hz

30% ↑ 2% ↓ 106% ↑ 68% ↑

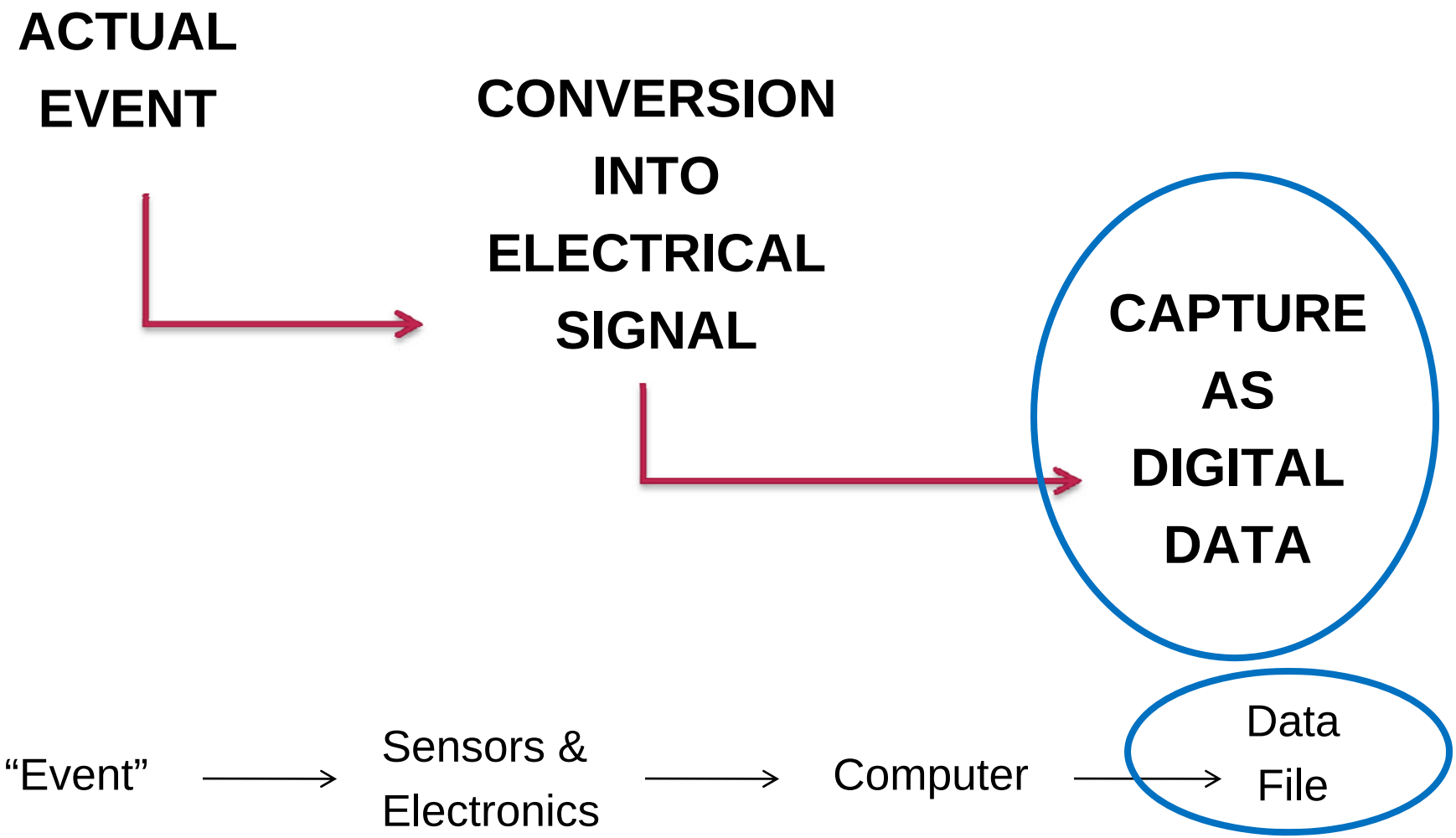
Bandwidth - Summary

- Bandwidth is a measure of the RESPONSIVENESS of the electronics
- It is most often designed in = users have no control
- It is a compromise between noise and responsiveness
- Most EM systems have bandwidths of ~1 to 10 Hz
  - 5500 systems settable to 100 Hz; 5800 to 500 Hz
- For 10 Hz bandwidth, the time constant is about 50 ms
  - If your “event” is shorter than 50 ms it will be clipped

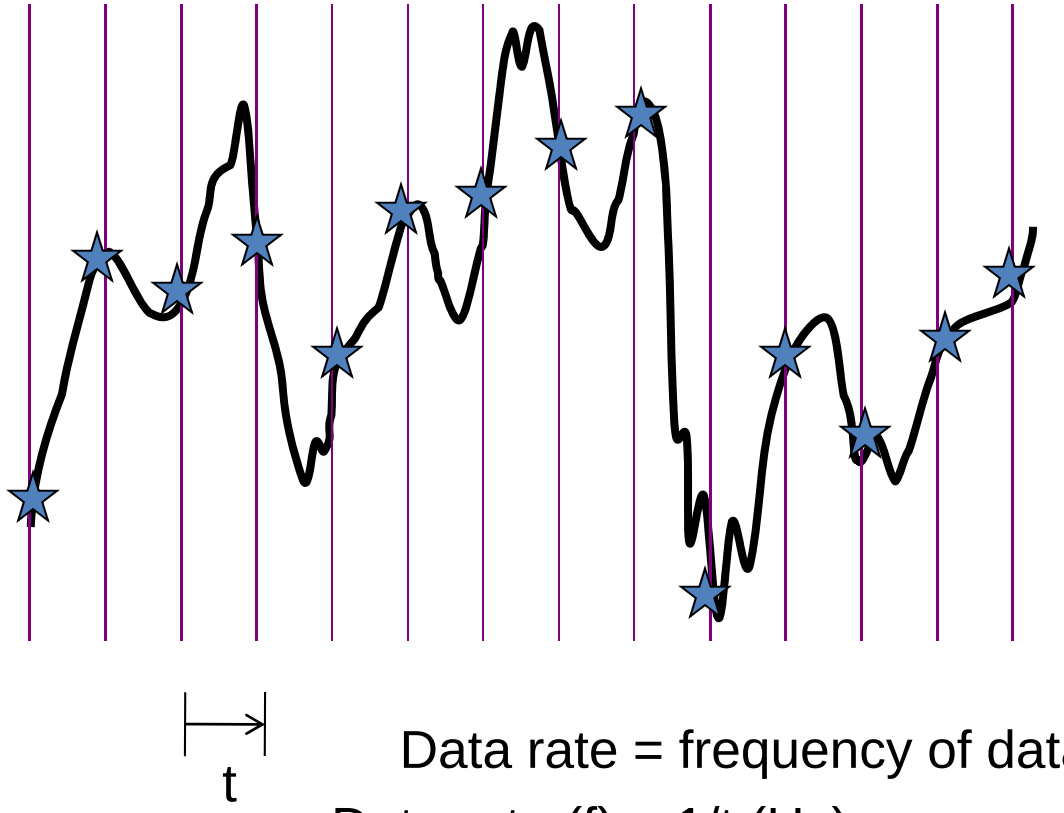
A brief overview of

Data Rate: What to use?

Again: What This Is All About



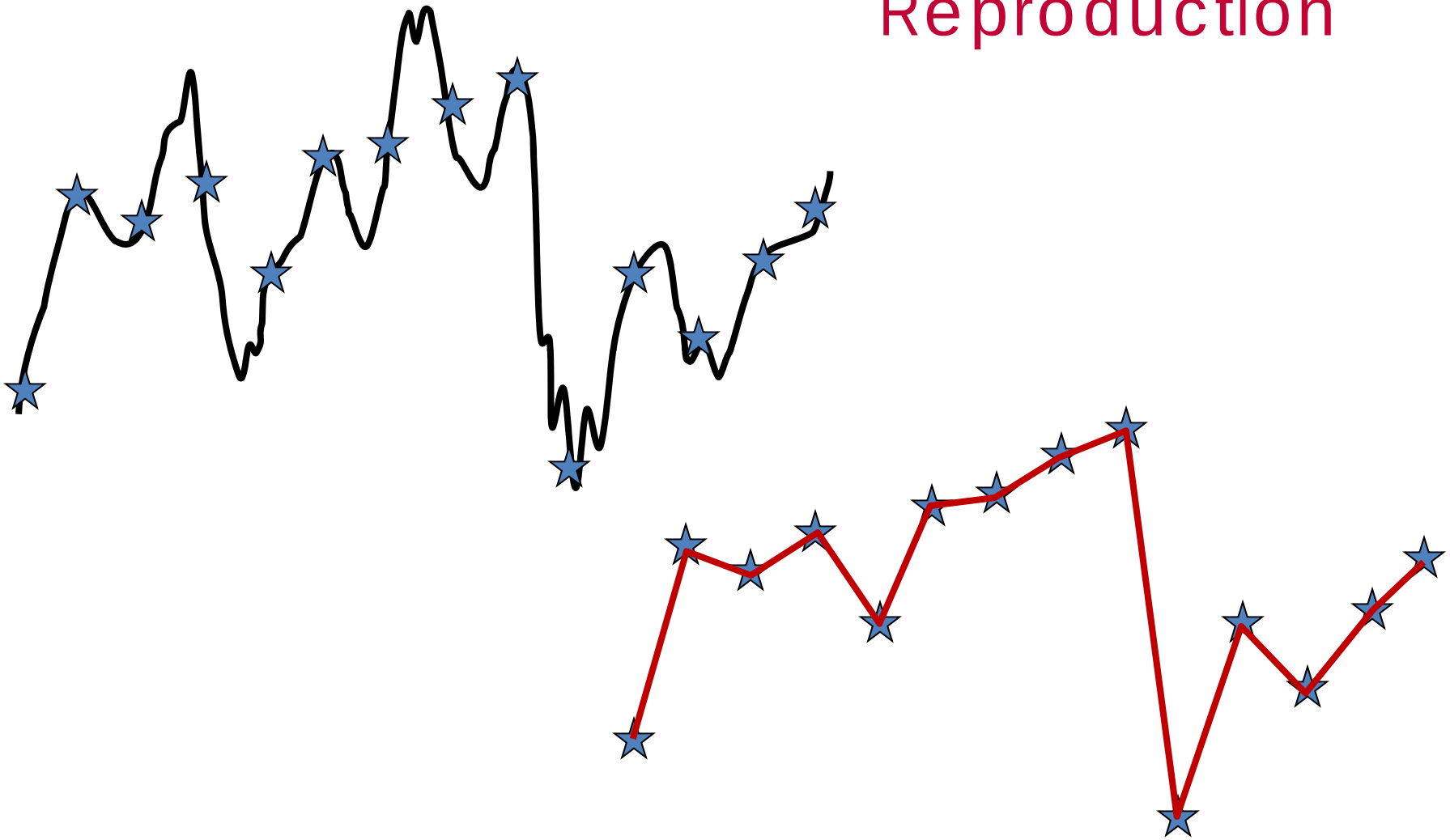
What is Data Rate?



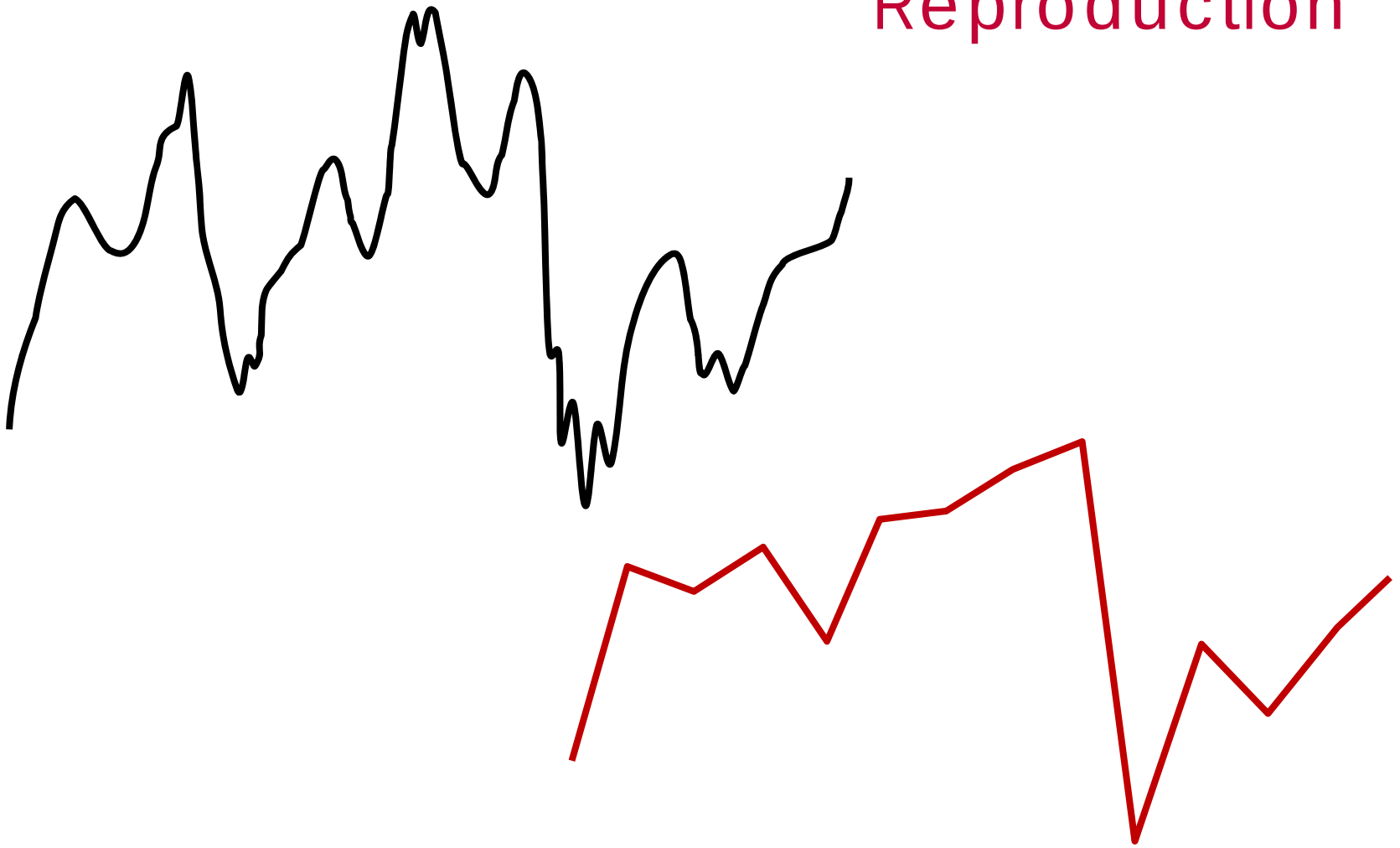
Data rate = frequency of data capture.

Data rate (f) = 1/t (Hz)

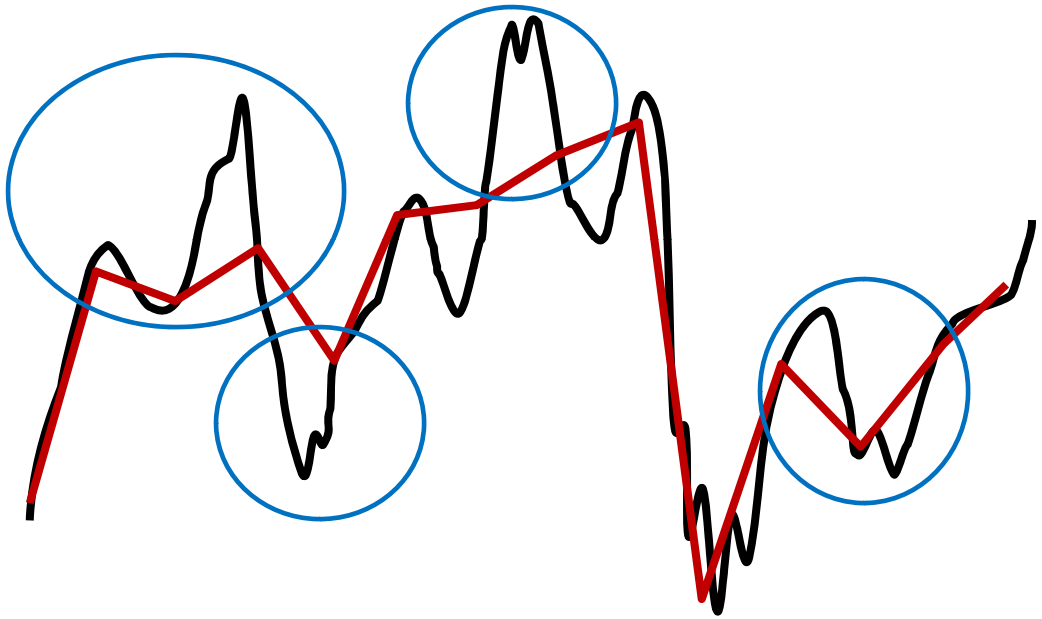
Data Rate Creates a Digital Reproduction



Data Rate Creates a Digital Reproduction



Effect of Slow Data Rate

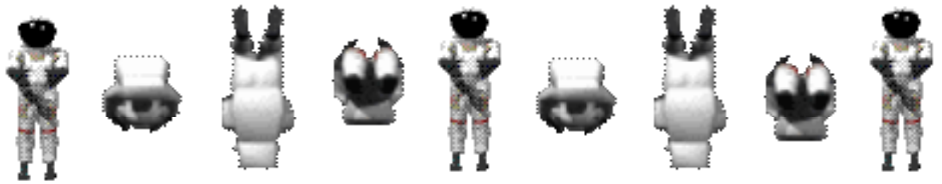


Another Way To Look At Data Rate

- A measure of how often a signal is sampled

Signal In (Analog):

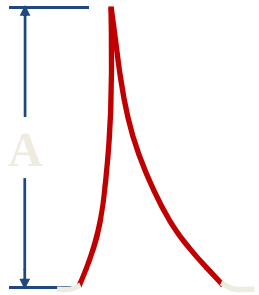
Signal Logged:



Data Rate: 2 Hz

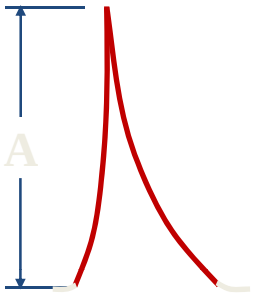
- Low data rate ruins output no matter what the input
- High data rate cannot salvage poor input provided by low bandwidth system

Event

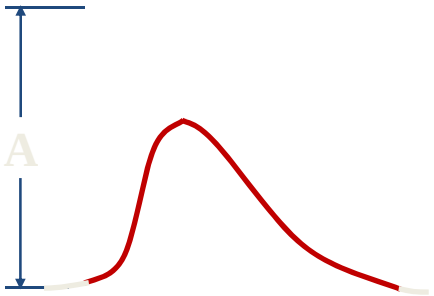


Signal In

Electronic "Conversion"

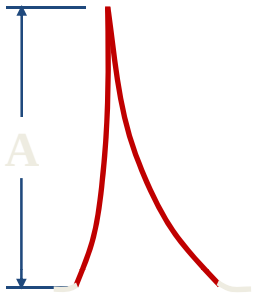


Good Bandwidth

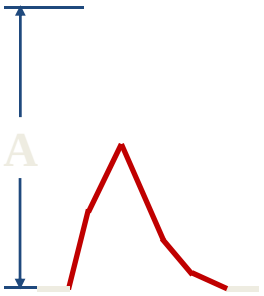


- Low Bandwidth

Data Logger "Capture"



Good Data Rate



- Slow Data Rate

Modern Data Capture Tools

- DATA RATE
  - Fixed
  - Set for the entire length of the test

- LOG ON INCREMENT
  - Variable rate
  - Only takes a snapshot when increment occurs

  - LOAD
  - EXTENSION
  - STRAIN…

Plastics Tensile, Metals Tensile, Syringe Test

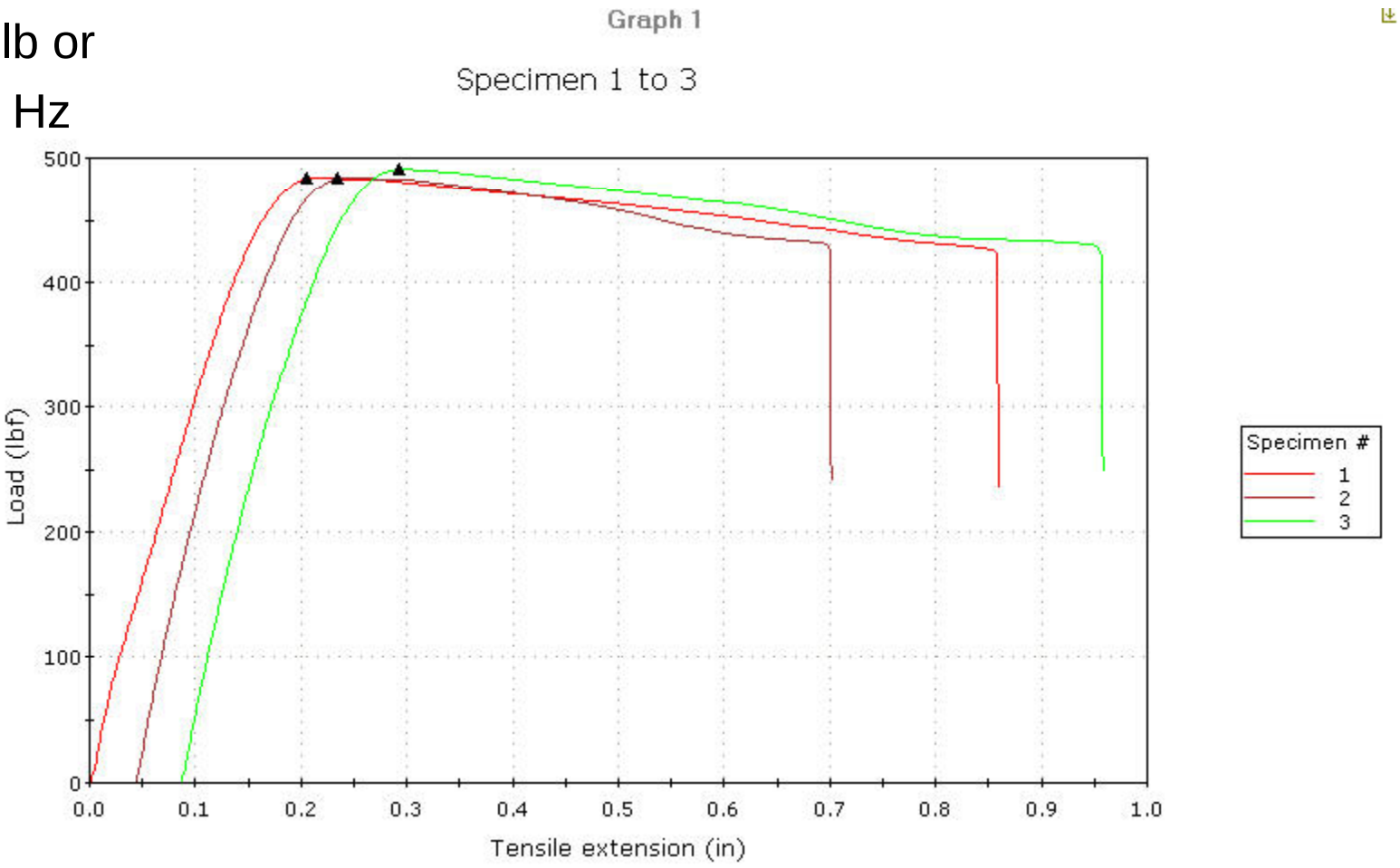
Some Examples

Plastics Tensile Test – vs. Extension

DATA RATE:

0.5 lb or

10 Hz

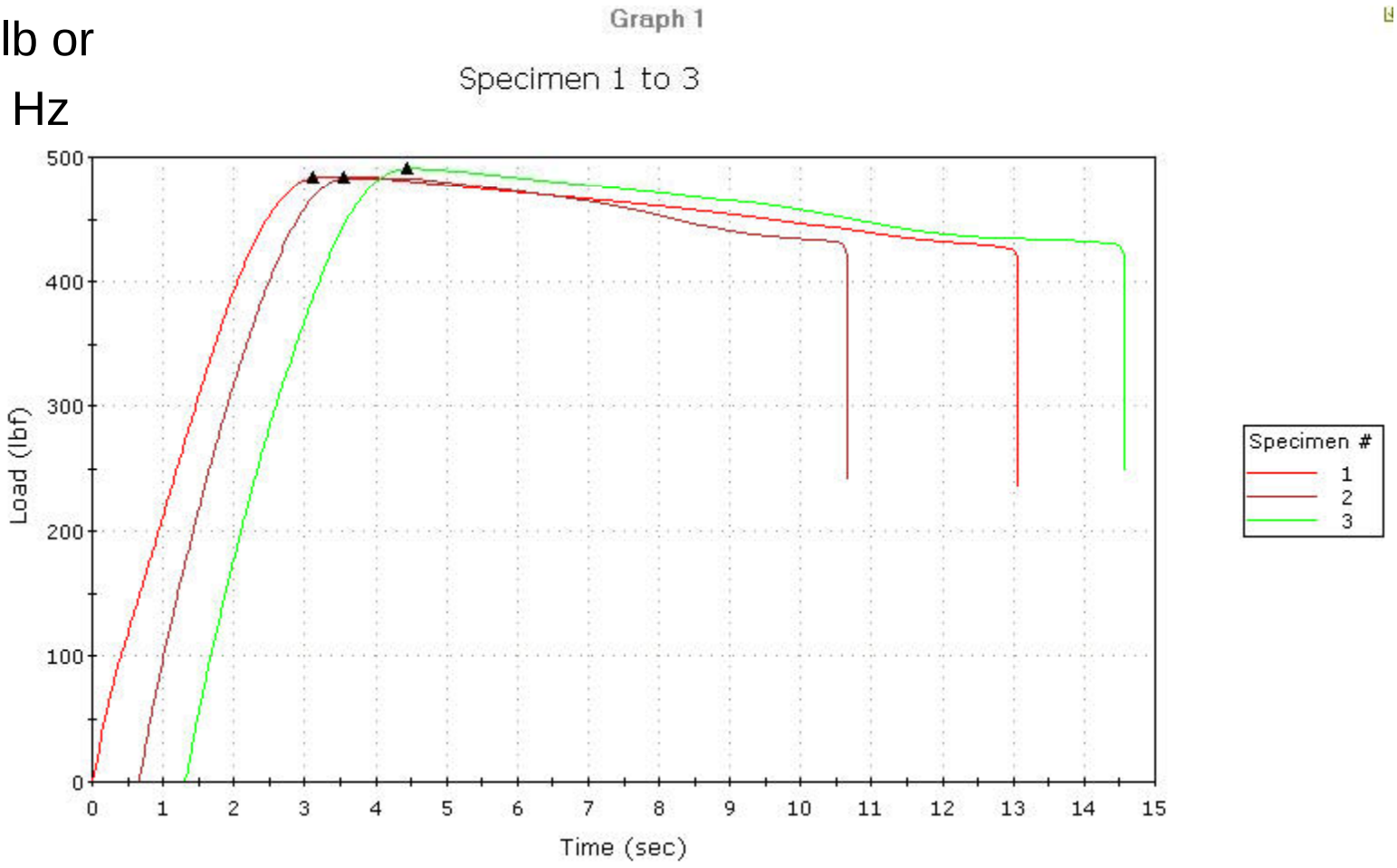


Plastics Tensile – vs. Time

DATA RATE:

0.5 lb or

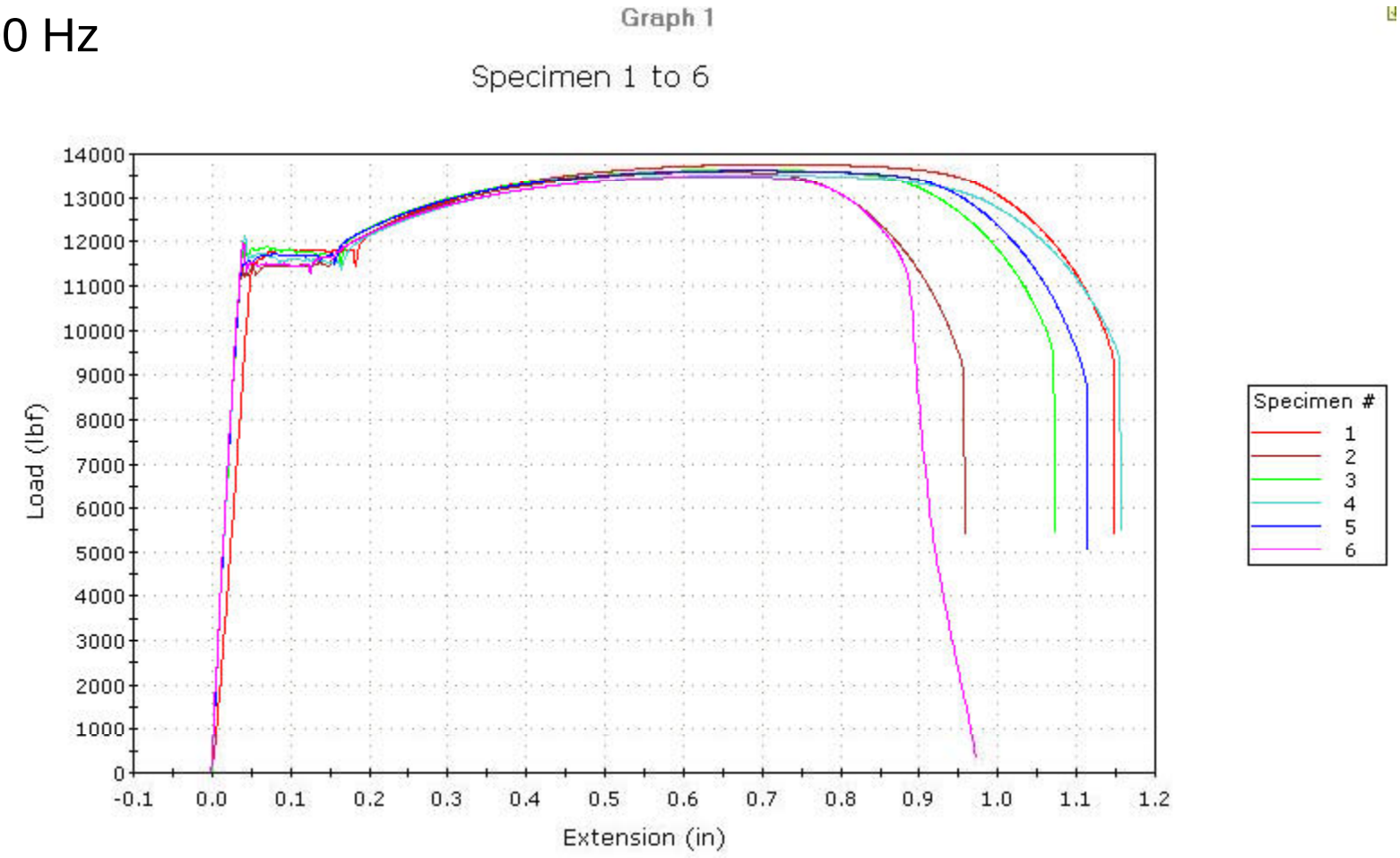
10 Hz



Metals Tensile Test

DATA RATE:

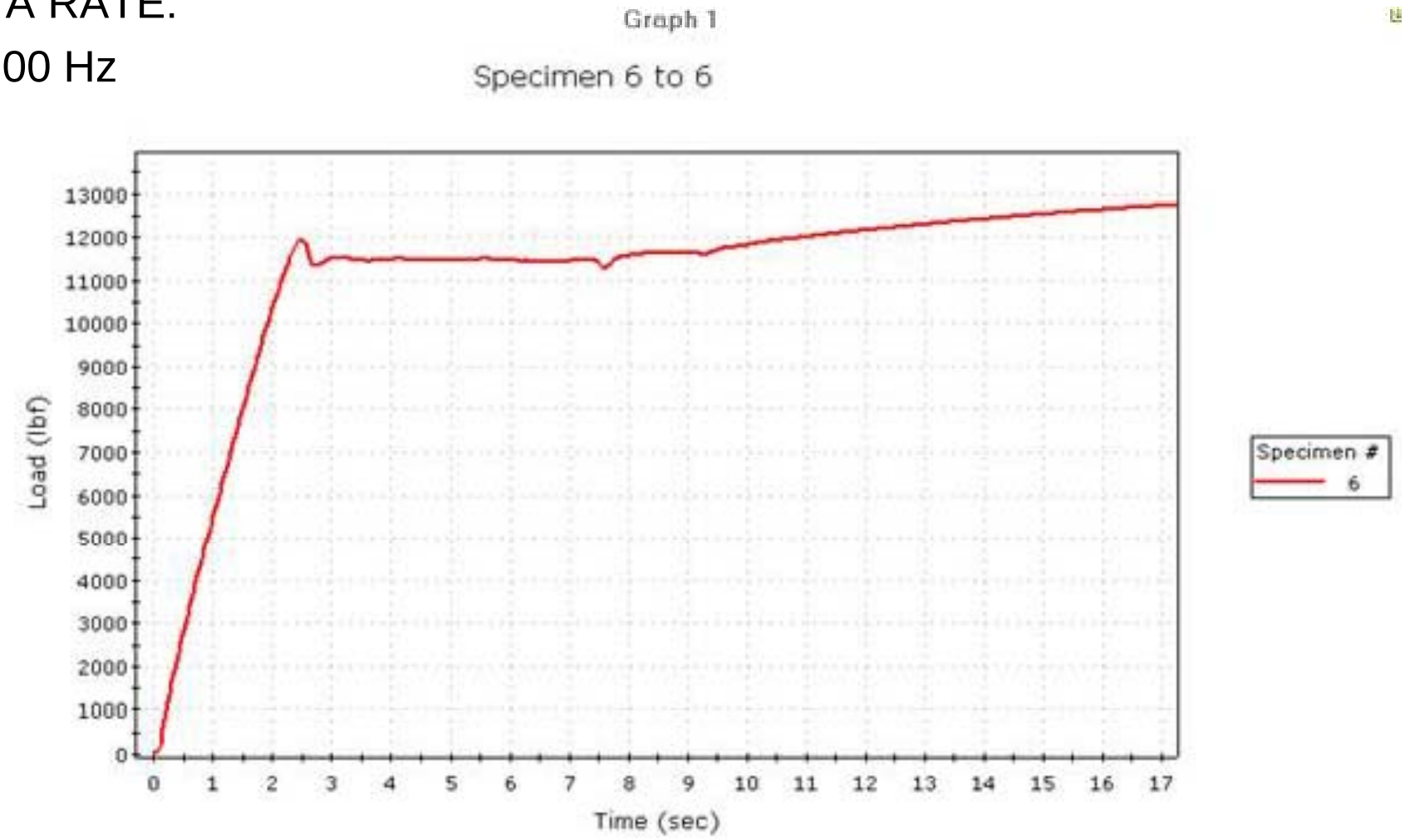
200 Hz



Metals Test - Detail

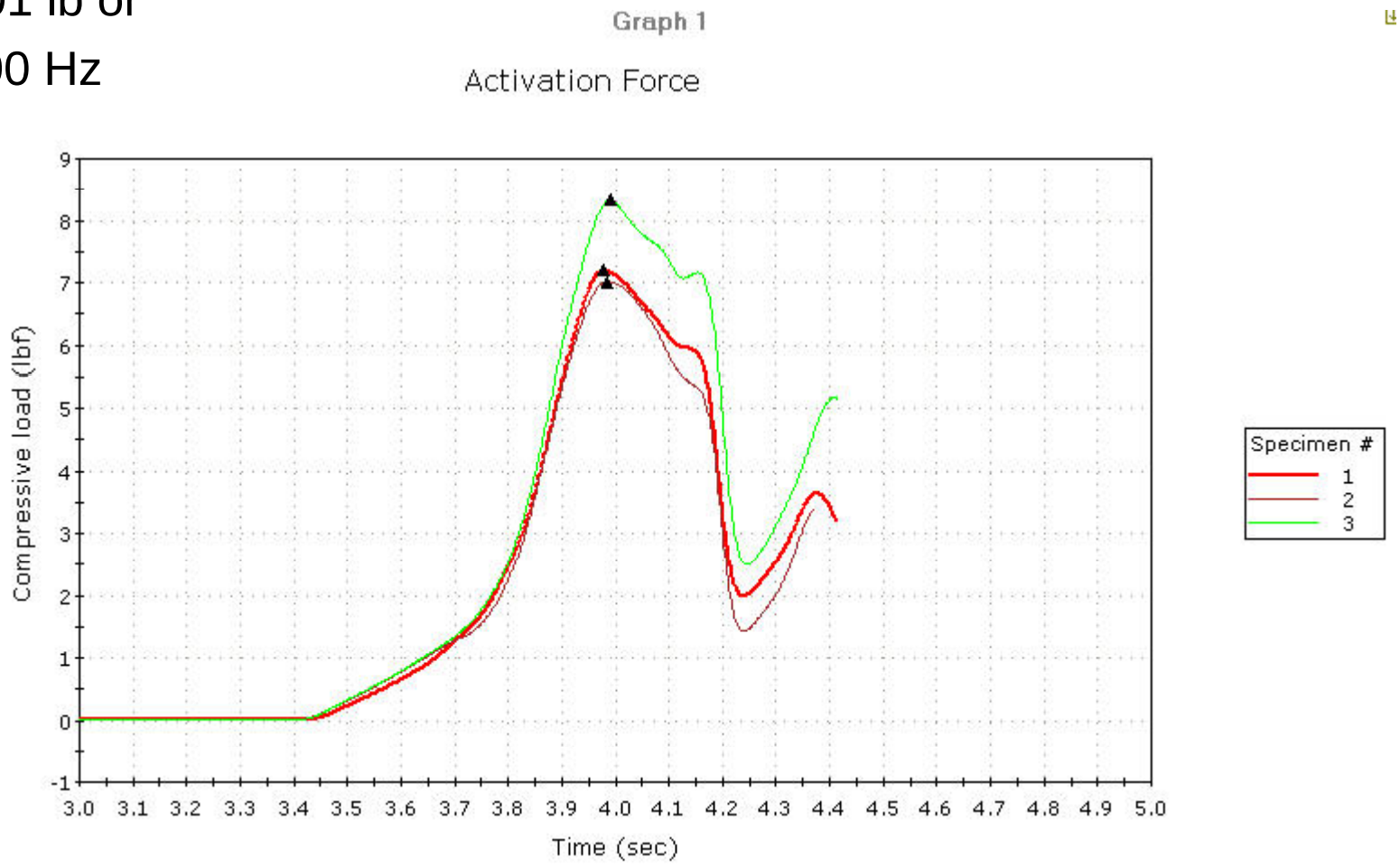
DATA RATE:

200 Hz



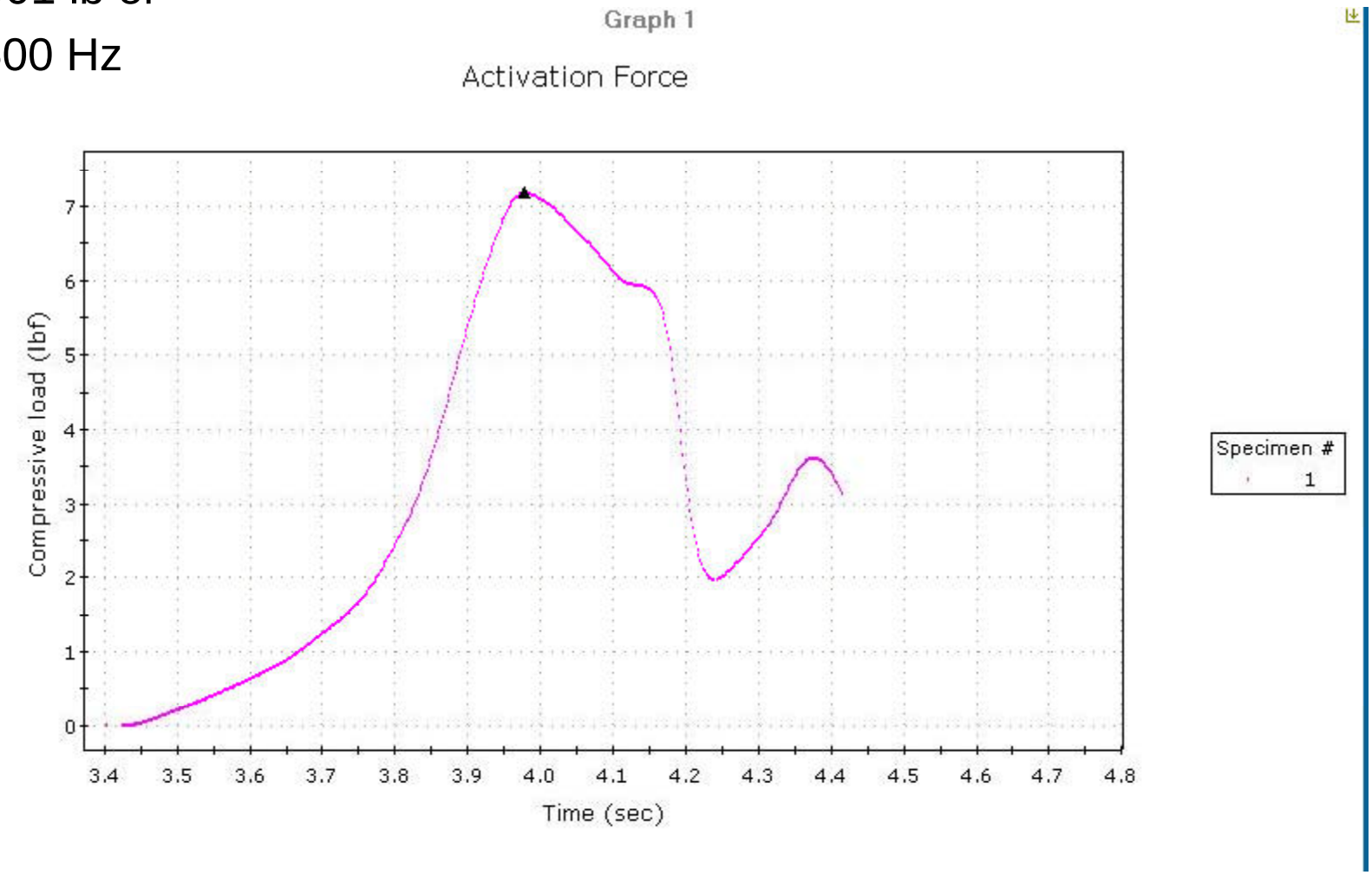
Syringe Test

DATA RATE:
0.001 lb or
500 Hz

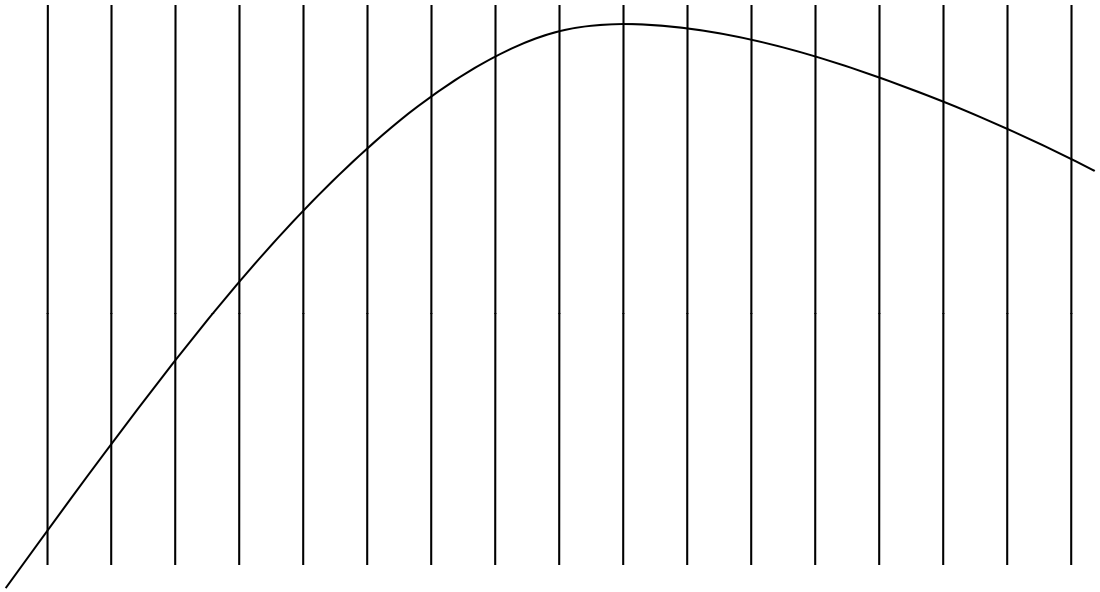


Syringe Test - Data

DATA RATE:
0.001 lb or
500 Hz



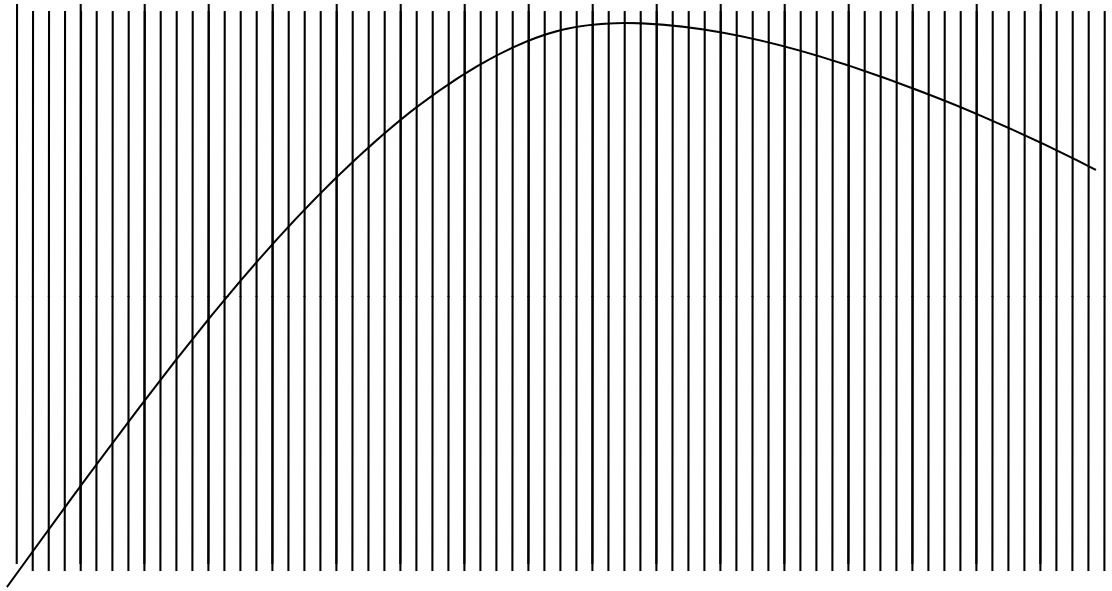
Higher Data Rates Than Needed



Appropriate data rate captures the curve within acceptable error

ASTM E1942 => on the order of 1% of the peak

Higher Data Rates Than Needed



Higher data rates do not yield any additional information,
…just bigger data files!

In Summary

- Our Mission is to:
  - Measure an event
  - Convert it to an electronic signal
  - Capture it digitally
  - …with the highest accuracy for our purpose
- Bandwidth matters, especially for fast events
- Data rate is critical:
  - Too slow = missed data
  - Too fast = lots of data with no additional information

In Summary

- For the majority of testing, bandwidth is not an issue. Beware when measuring fast events!

- Selection of data rate depends on the events to be captured:
  - Per ASTM E1942, anywhere from 10 to 50 times the duration of the event; depends on the shape (“sharp” events require closer to 50 times; “rounded” events closer to 10 times)
  - EX: sharp event with 10 Hz BW, use more like 500 Hz;
    dull event with 5 Hz BW, use more like 50 Hz

- Advanced data capture functions exist in advanced testing systems:
  - Ability to set bandwidth, data rate, “log increments” strain or load

THANK YOU!

Please email us your feedback @ denise_papa@instron.com