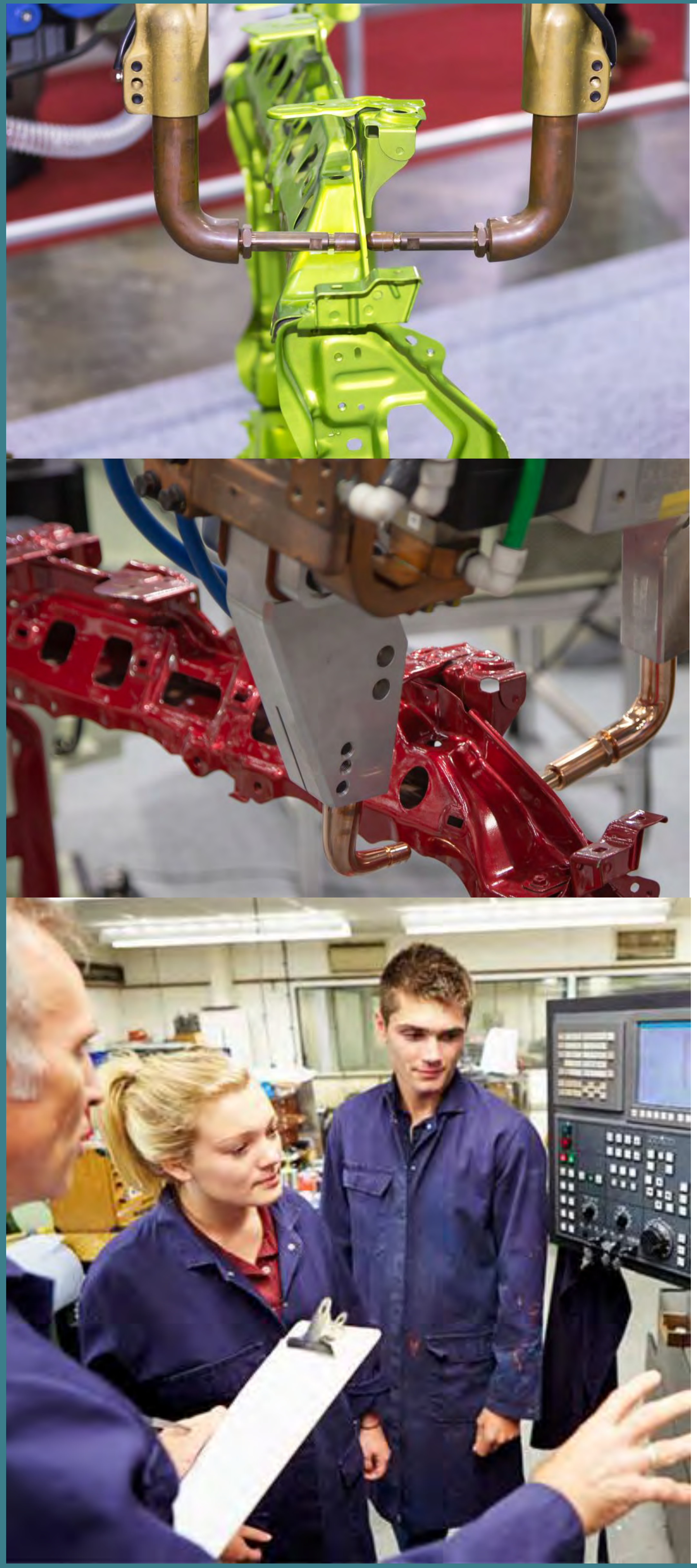


WeldComputer
The Technology Leader in Resistance Welding

Taking Advantage of Clauses in the D17.2 MIL-SPEC for Resistance Welding to:

- Eliminate Destructive Testing
- Improve Weld Quality
- Reduce Machine Maintenance

Bob Cohen
WeldComputer Corporation

Provisions in the January 2013 publication of the AWS D17.2/D17.2M:2013

Specification for Resistance Welding for Aerospace Applications

— 5.2.3 Alternate Testing Requirements.

— 5.1.5.2 Allowance of adjustment to limit part damage.

— 5.1.5.1 Conditions for constraining control adjustments.

— 5.1.4.2 In-process micro-ohms monitoring.

— 4.2.2.1 Preconditioning steps to compensate for fit-up.

— 4.3.3 Jigs and Fixtures.

— 4.3.4 Maintenance of Equipment.

Provisions in the January 2013 publication of the AWS D17.2/D17.2M:2013

Specification for Resistance Welding for Aerospace Applications

5.2.3 Alternate Testing Requirements

As an alternate to the testing requirements of 5.2.2(1) real time nondestructive system may be used when approved by the Engineering Authority. As a minimum the system shall address: part fitup, precleaning, electrode monitoring, and in-process monitoring of critical process parameters. This system of controls shall include but is not limited to, real time adaptive controls or in-process NDT methods. Destructive testing must still be used to establish and verify that the capability of this system will identify welds complying with strength or size requirements with 99.5% reliability.

5.2.3 Alternate Testing Requirements

— Real time adaptive controls or in-process NDT methods shall be employed

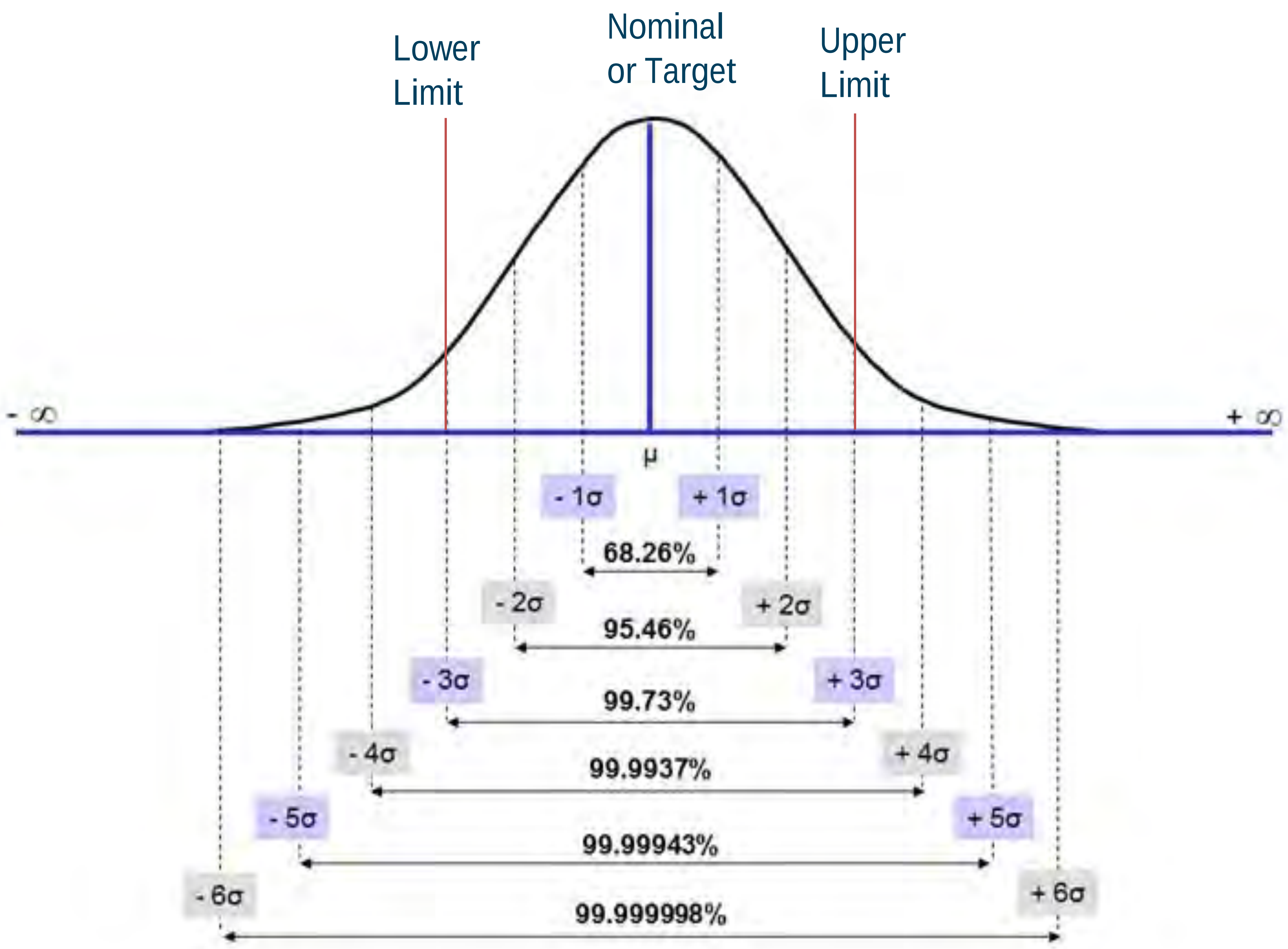
— The system shall identify welds complying with strength or size requirements with 99.5% reliability

— As a minimum the system shall address:

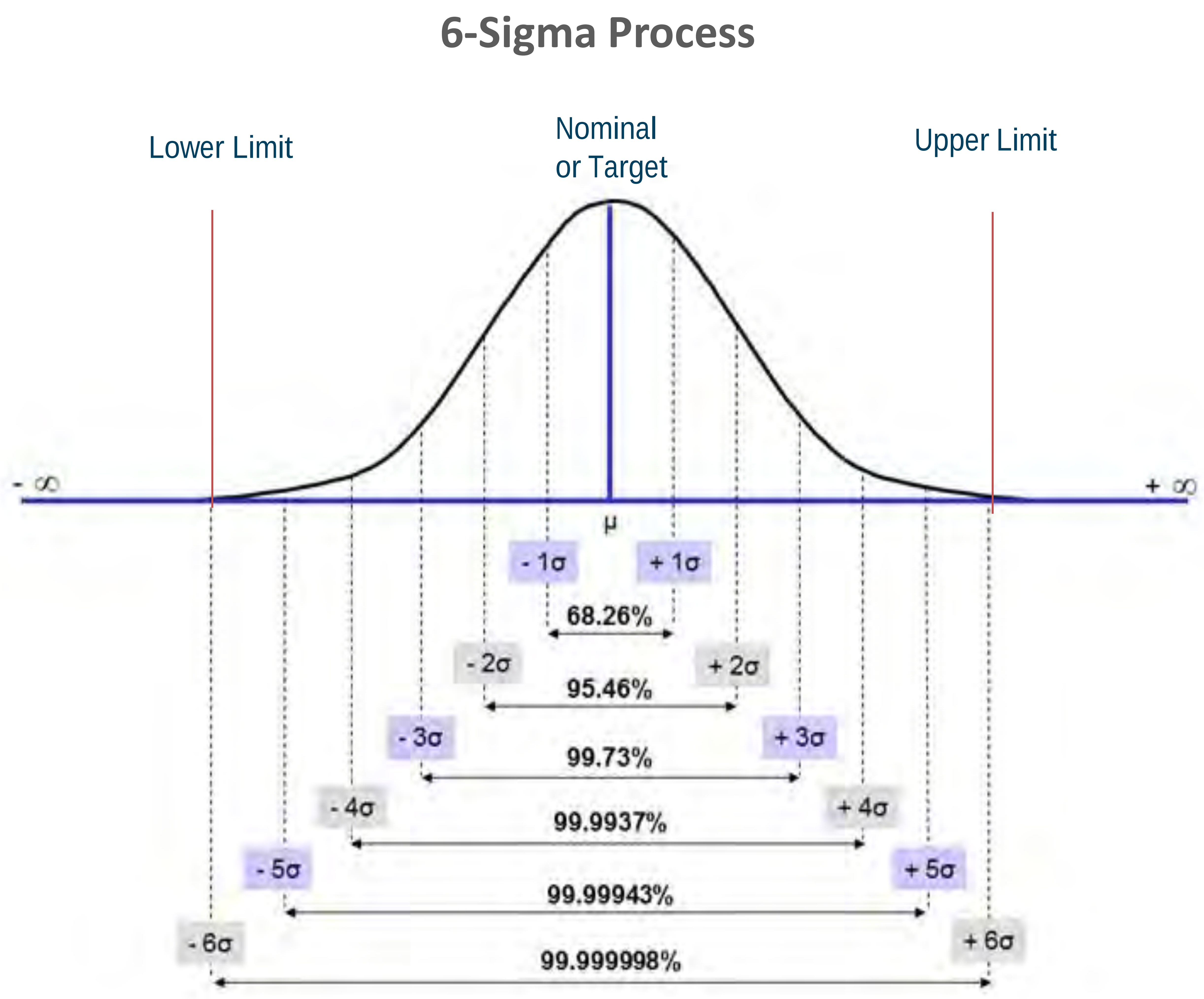
- part fitup,
- precleaning,
- electrode monitoring, and
- in-process monitoring of critical process parameters.

Process Characterization

3-Sigma Process

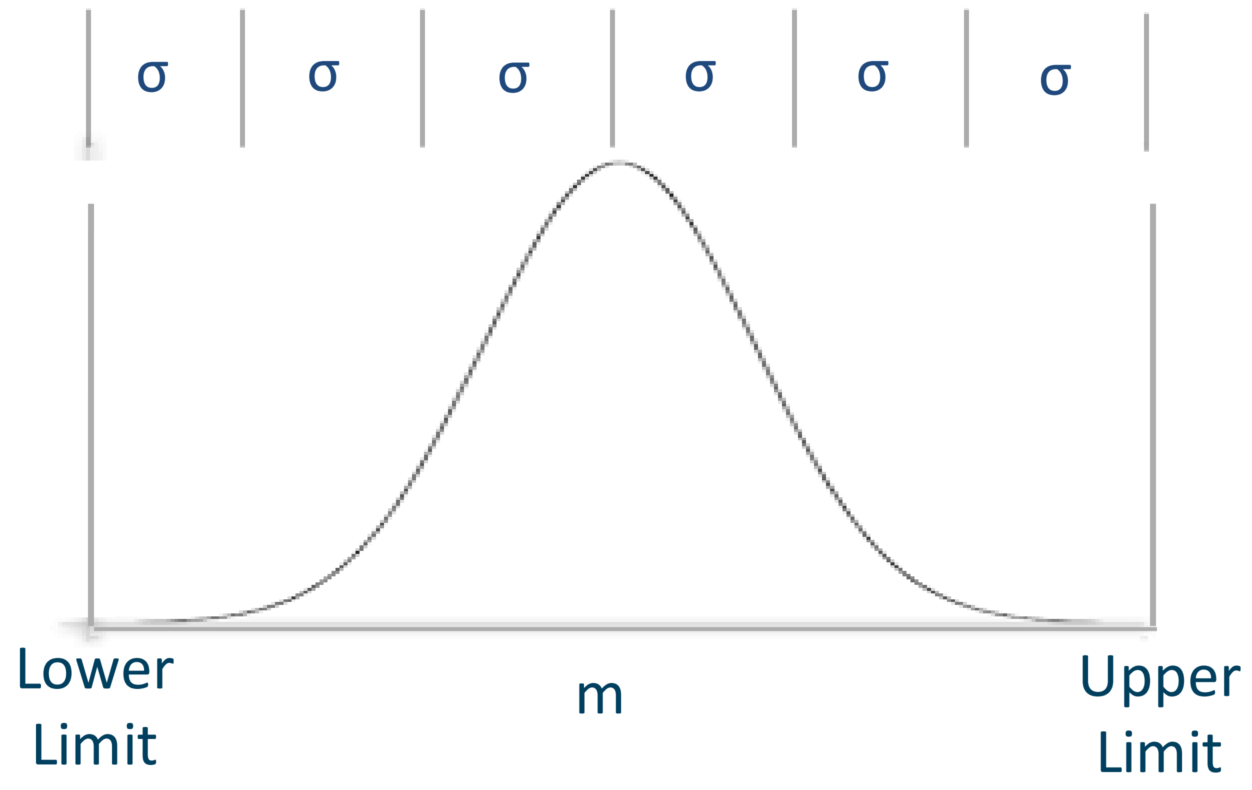


Process Characterization

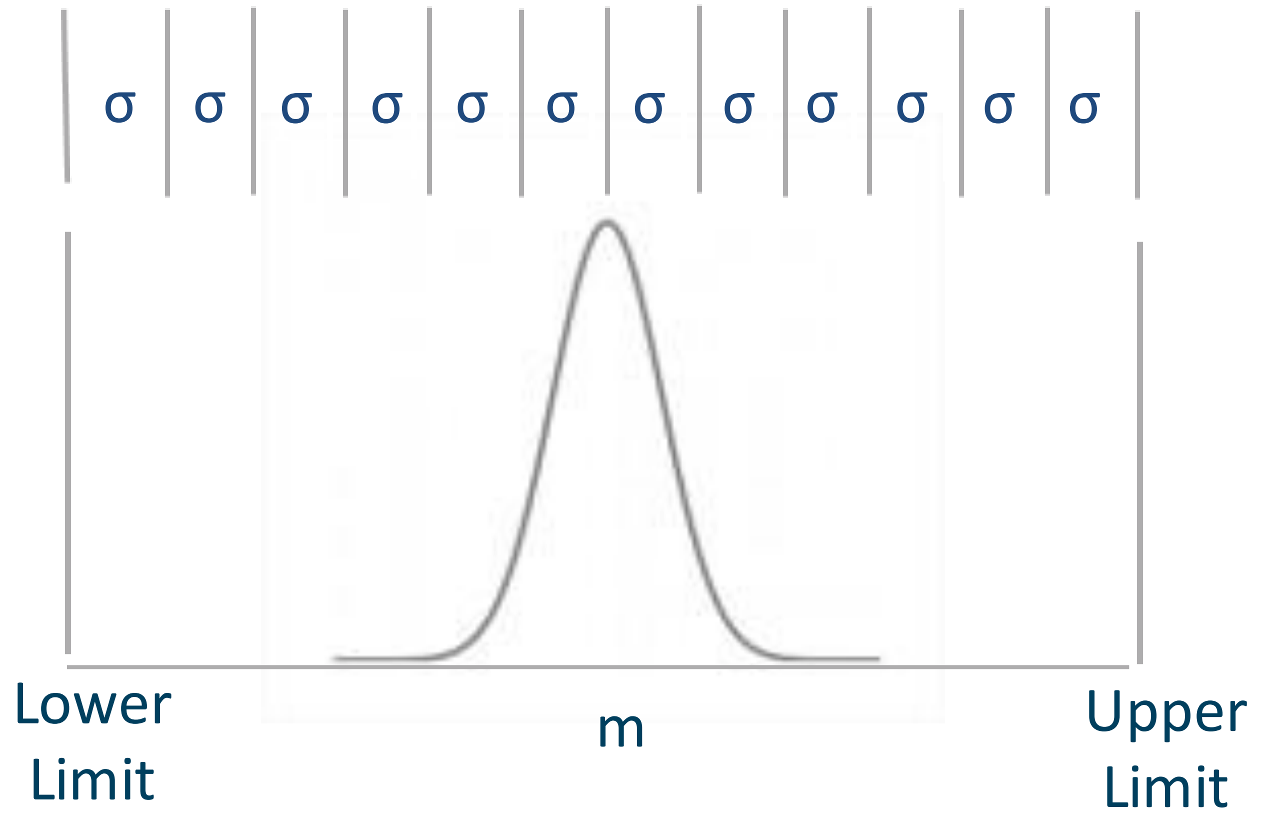


Improving Process Capability Increases Weld Consistency

3 Sigma

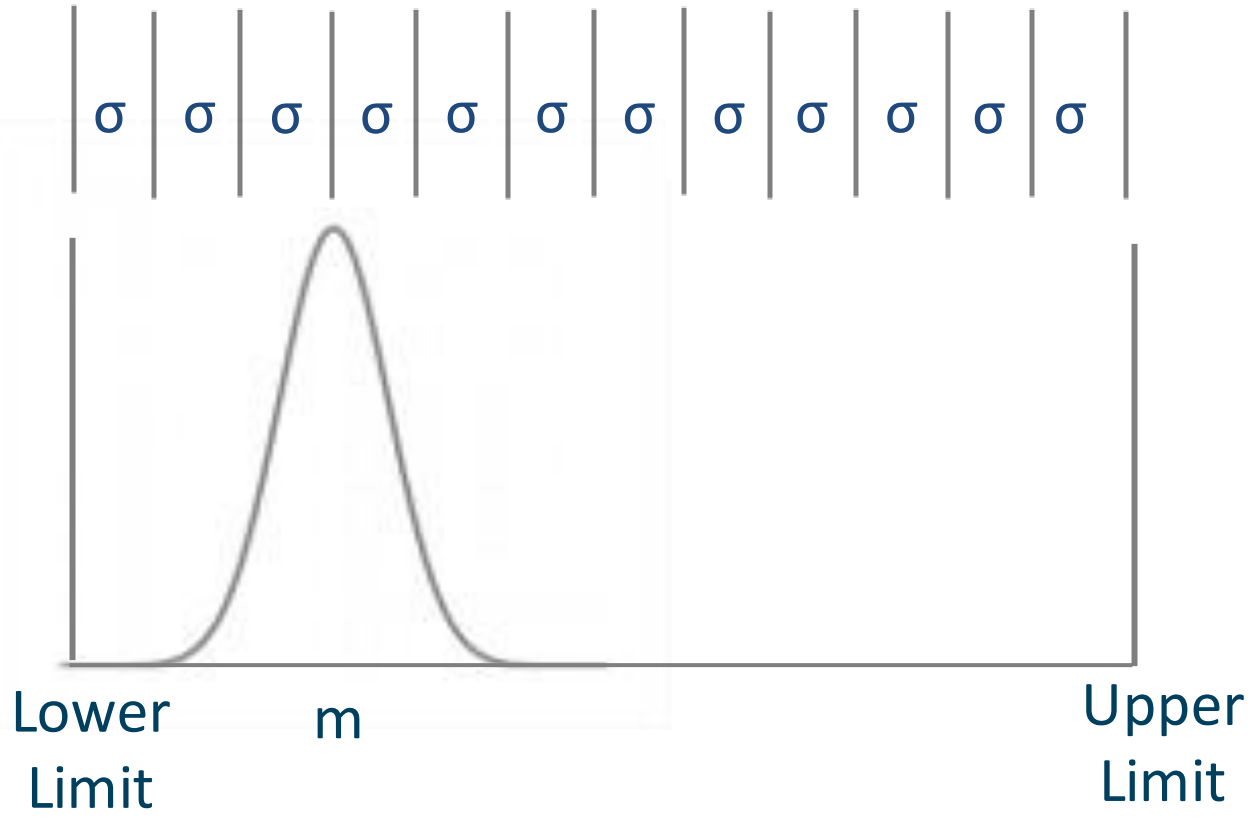


6 Sigma



Improving heat control regulation reduces standard deviation and increases Process Capability

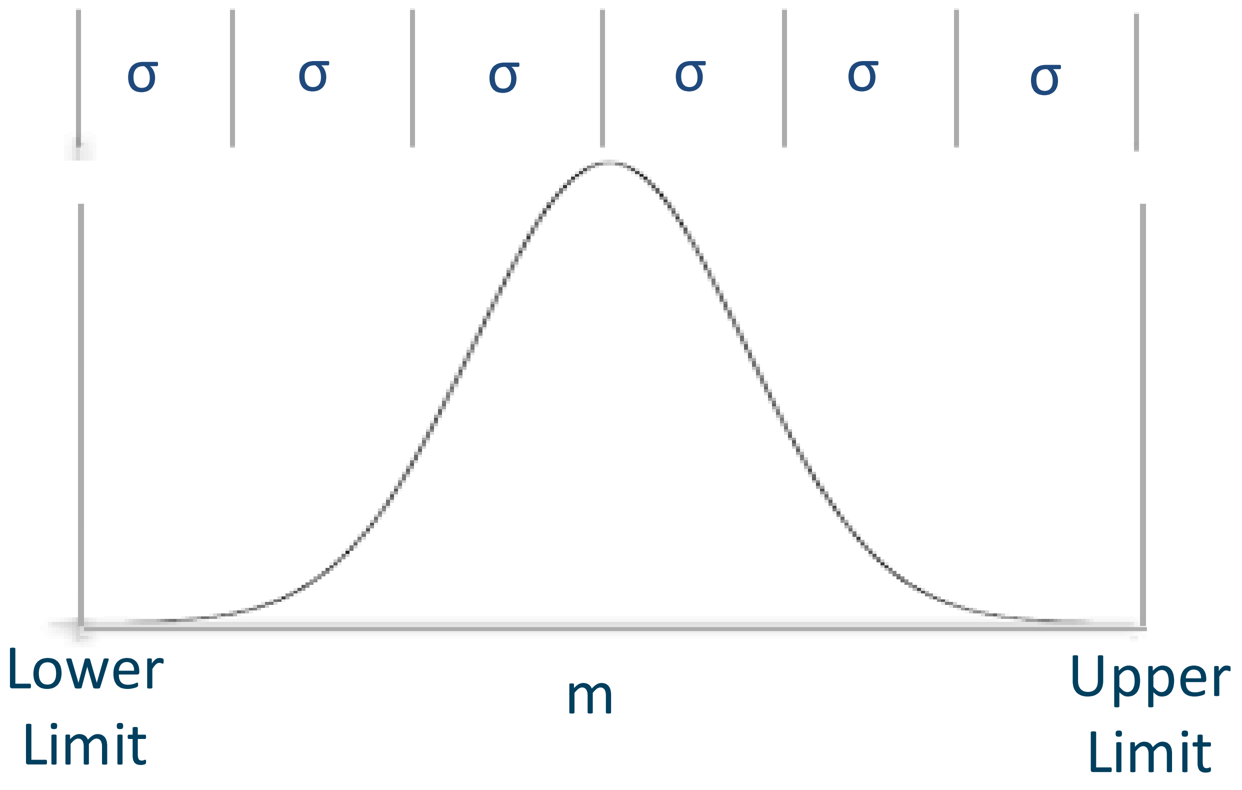
Shift in Mean



Adaptive Control reduces the shift in Mean and further increases Process Capability

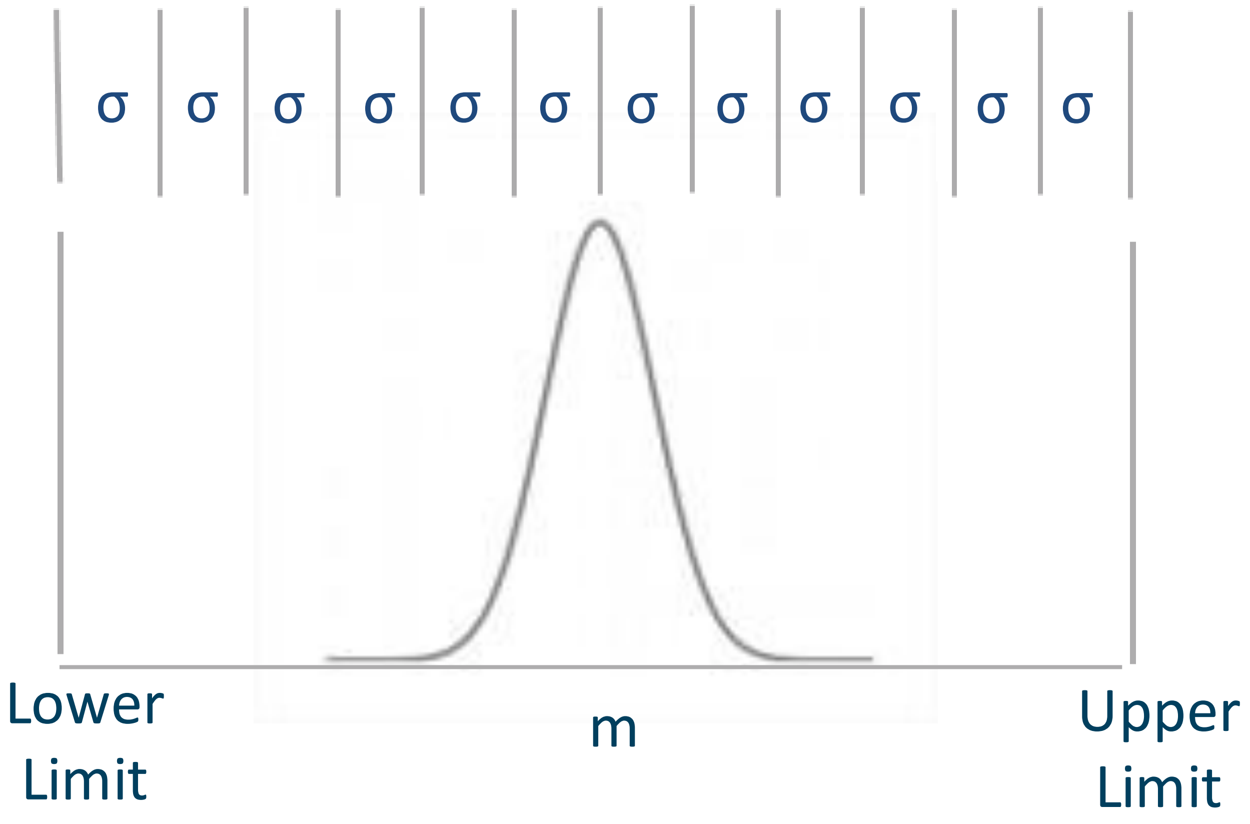
Improving Process Capability Increases Weld Consistency

3 Sigma



Process Capability = 1

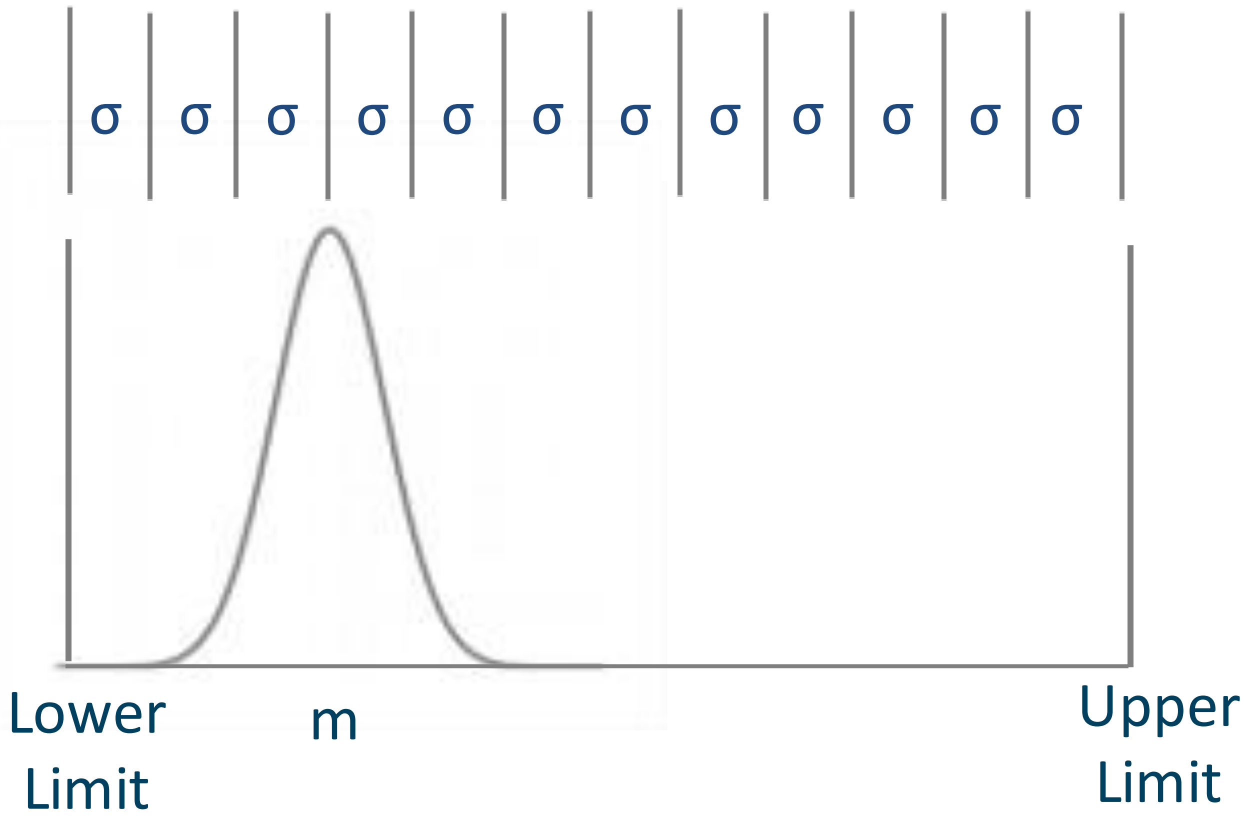
6 Sigma



Improving heat control regulation reduces standard deviation and increases Process Capability

Process Capability = 2

Shift in Mean



Adaptive Control reduces the shift in Mean and further increases Process Capability

Process Capability = 3

Process Capability Definition

— Process Capability = $\dfrac{\text{[Upper Tolerance Limit - Mean]}}{\text{3 [Standard Deviation]}}$

— Process Capability = $\dfrac{\text{[Mean - Lower Tolerance Limit]}}{\text{3 [Standard Deviation]}}$

— Choose the one which produces the lower value.

Process Capability vs. Percent of Welds Outside of Tolerance Limits

Process Capability	Percent of Welds Outside of Tolerance Limits
0.50	13.4
0.75	2.4
0.94	0.5
1.00	0.27
1.30	0.0096
2.00	0.0000002

How to Determine Process Capability of Welding Job

Sample #	Shear Force
1	90
2	101
3	112
4	109
5	80
6	99
7	106
8	89
9	104
10	86
11	113
12	108
13	104
14	105
15	94
Mean	100
Sigma	10.0

— Tabulate shear forces from destructive testing of 15 samples

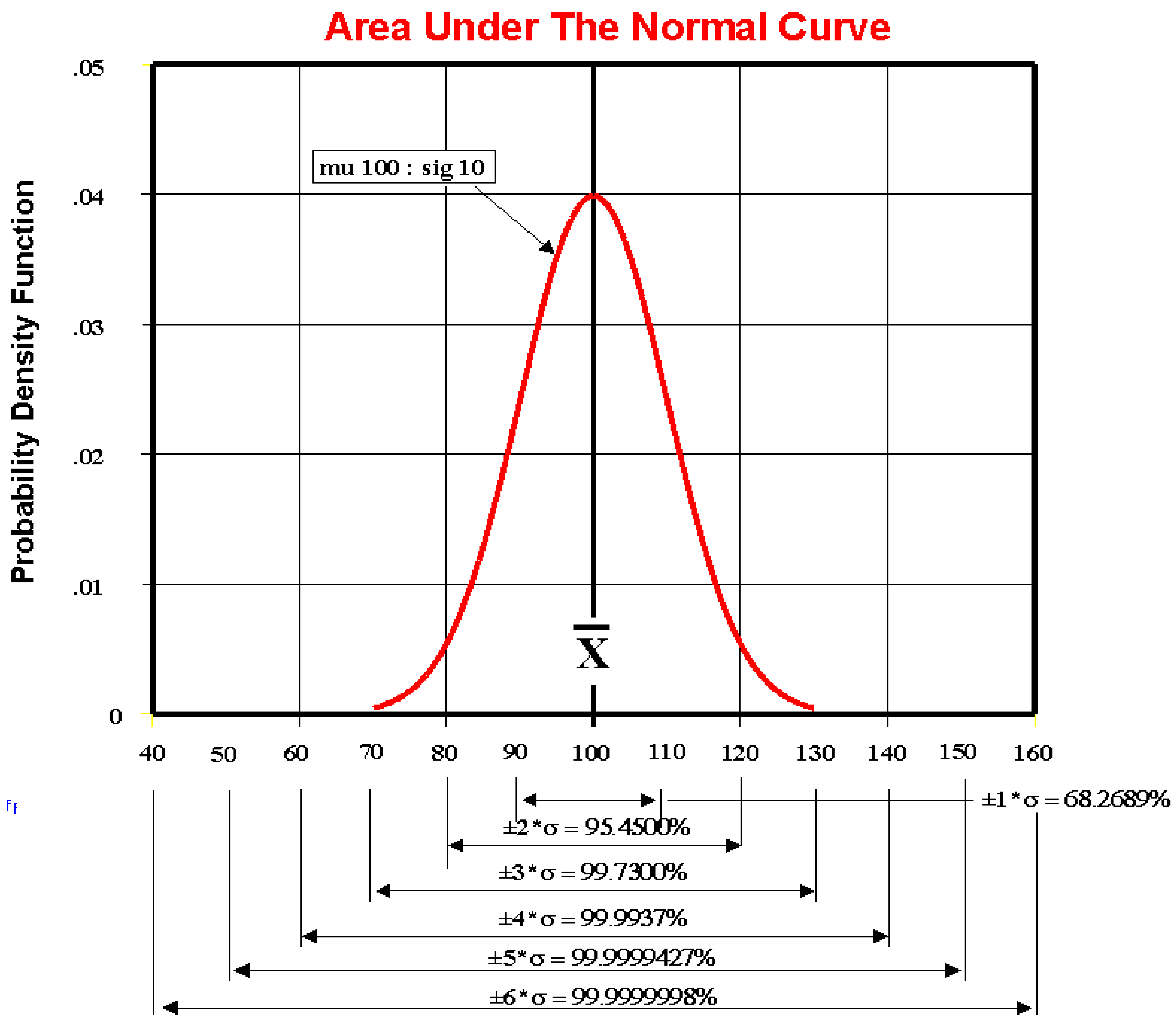
— Calculate Mean and Standard Deviation

— Suppose this weld job has a Lower Tolerance Limit of 70 lbs. then,

Process Capability = [100 – 70] / [3 * 10.0] = 1

Process Characterization

Process Capability = [100 – 70] / [3 * 10.0] = 1



Impact of After The Fact NDT Methods on Production

— X-RAY Testing

- Severe impact on productivity
- Can detect porosity, cracks, lack of fusion. Difficult to determine weld penetration

— Ultrasonic Testing

- Severe impact on productivity
- Can detect porosity, cracks, lack of fusion. Difficult to determine weld penetration

Ability to meet the 99.5% reliability requirement demanded by the MIL-SPEC has not been demonstrated

Impact of Process Monitoring on Production

— Displacement Monitoring:

- No production slow-down
- Speeds up production when used in conjunction with adaptive control
- More reliable than destructive testing, because destructive testing doesn't measure the size of any weld except the one that is destroyed

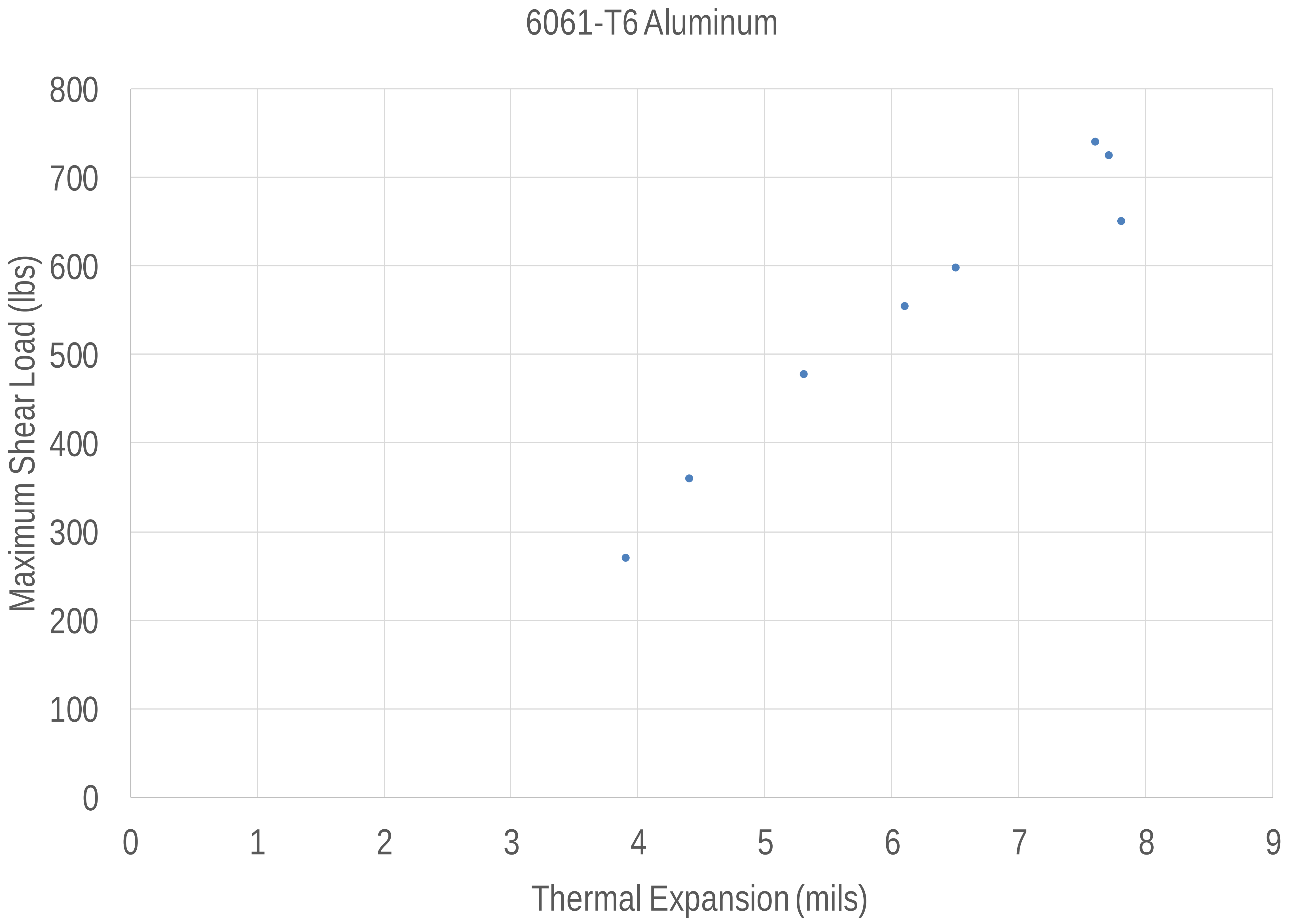
Ability to meet the 99.5% reliability requirement demanded by the MIL-SPEC has been demonstrated

Instrumentation to Monitor Thermal Expansion

Side view (left) and front view (right) of displacement sensor mounted on seam welder

Correlation of Thermal Expansion with Shear Load

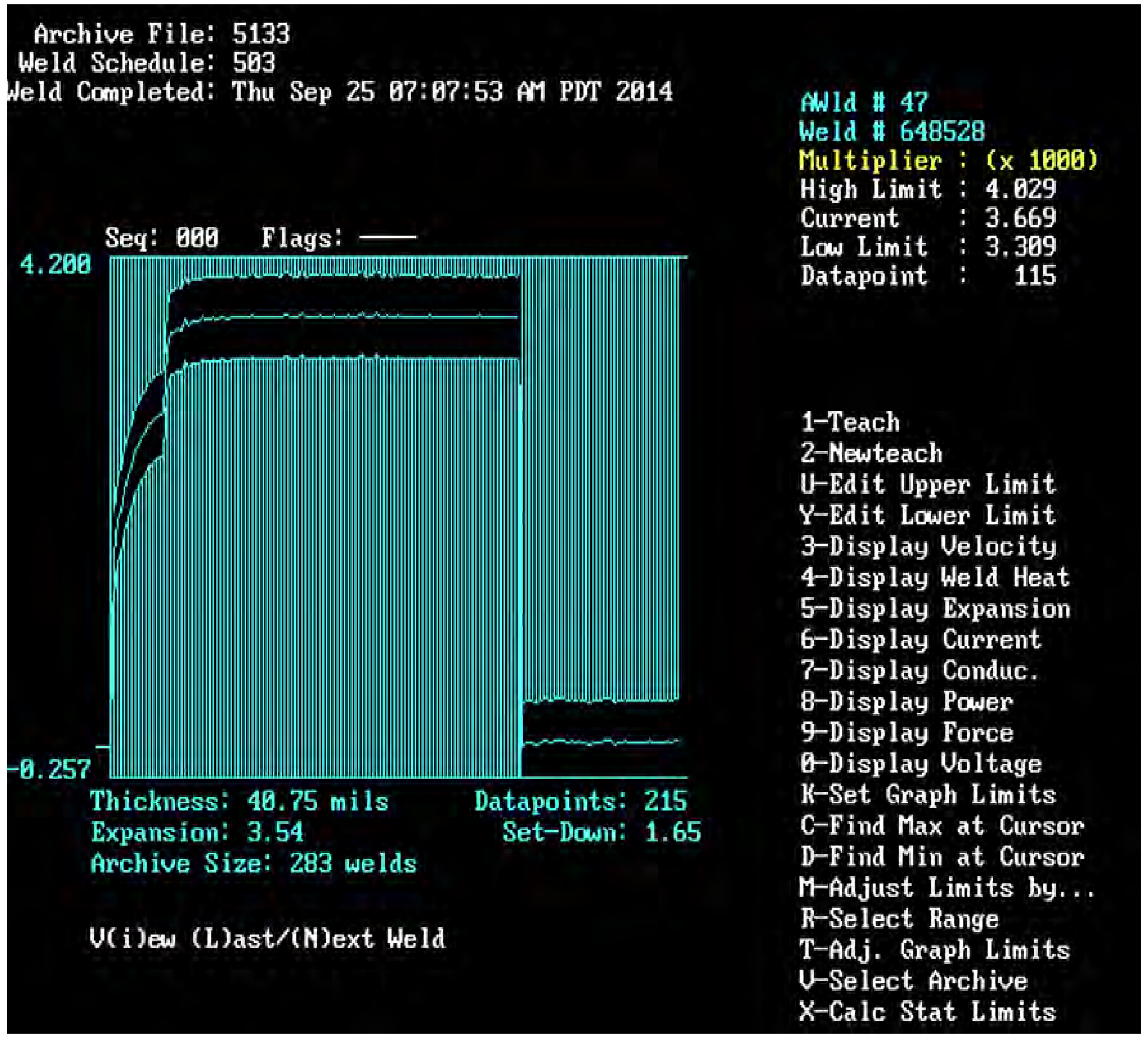
Data supplied courtesy of Allied-Signal Aerospace Company AiResearch Los Angeles Division



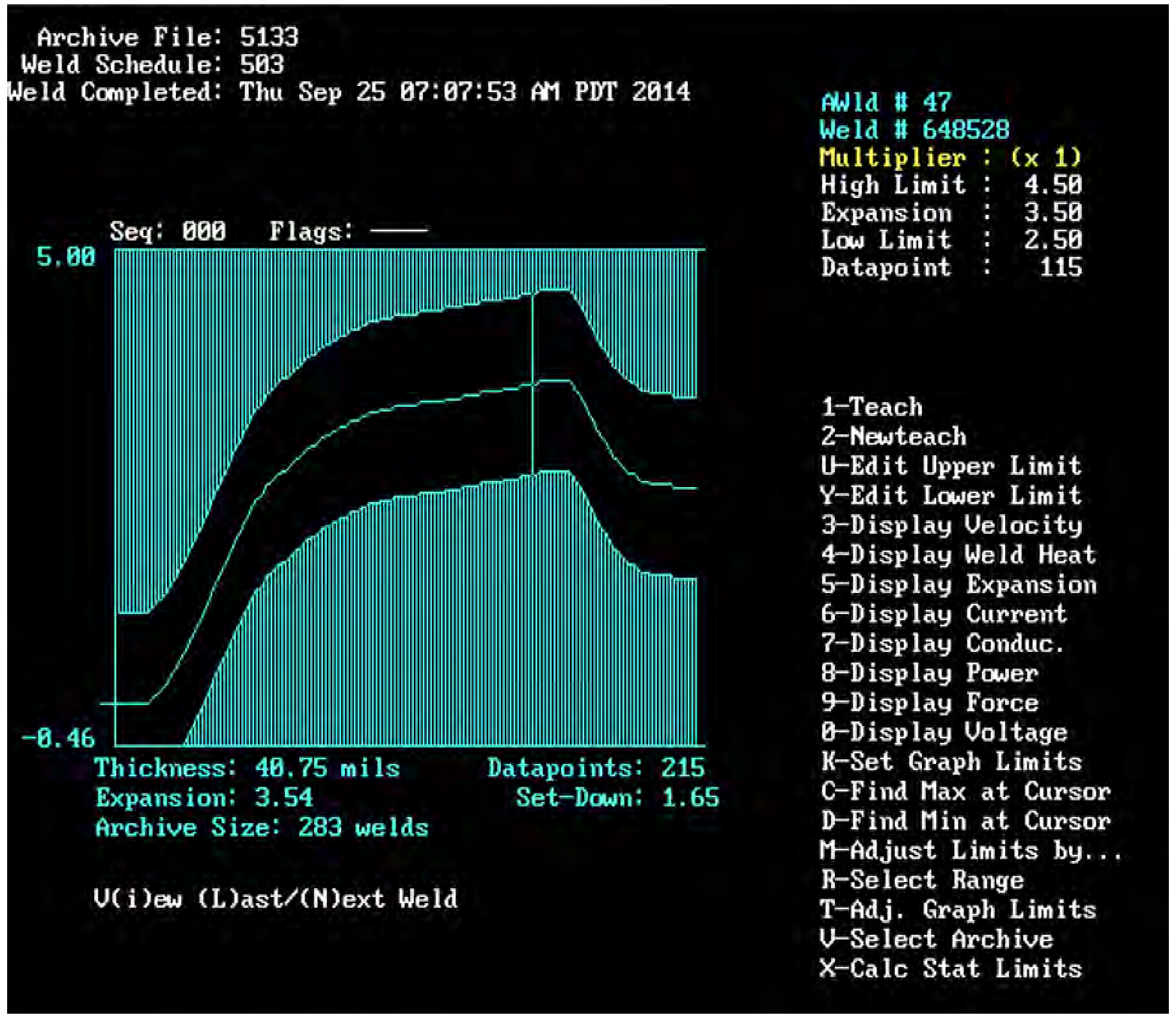
Data collected with WeldComputer® Adaptive Control

Adaptive Weld Schedule Nominal Current and Thermal Expansion Response

Current



Expansion



Data collected with WeldComputer® Adaptive Control

Adaptive control is able to:

— Recognize when a process variability exists that would affect the outcome of a production weld

— Identify the underlying condition responsible for the variability

— Take corrective action to compensate for the variability as the weld is taking place

— The end result is to prevent the occurrence of a bad weld in the first place and to increase the consistency of all welds produced

— When it's impossible to correct the problem and make a good weld, notify the operation about the problem

D17.2/D17.2M:2013 Specification allows manufacturers to apply process monitoring and adaptive control to:

— Reduce reliance on destructive testing

— Prevent random problem welds from passing through production undetected

— Automatically take corrective pre-conditioning and compensating actions to prevent out of spec welds from being produced

— Increase consistency of all welds

— Substitute:

- In process monitoring in place of manual surface resistance checks
- In-process monitoring of the weld machine in place of periodical machine inspection

Process Variability Conditions Addressed By Adaptive Control

— Flattening electrodes

— Surface contamination

— Poor parts fit-up

— Shunt condition and other geometry variations

— Work piece thickness variation

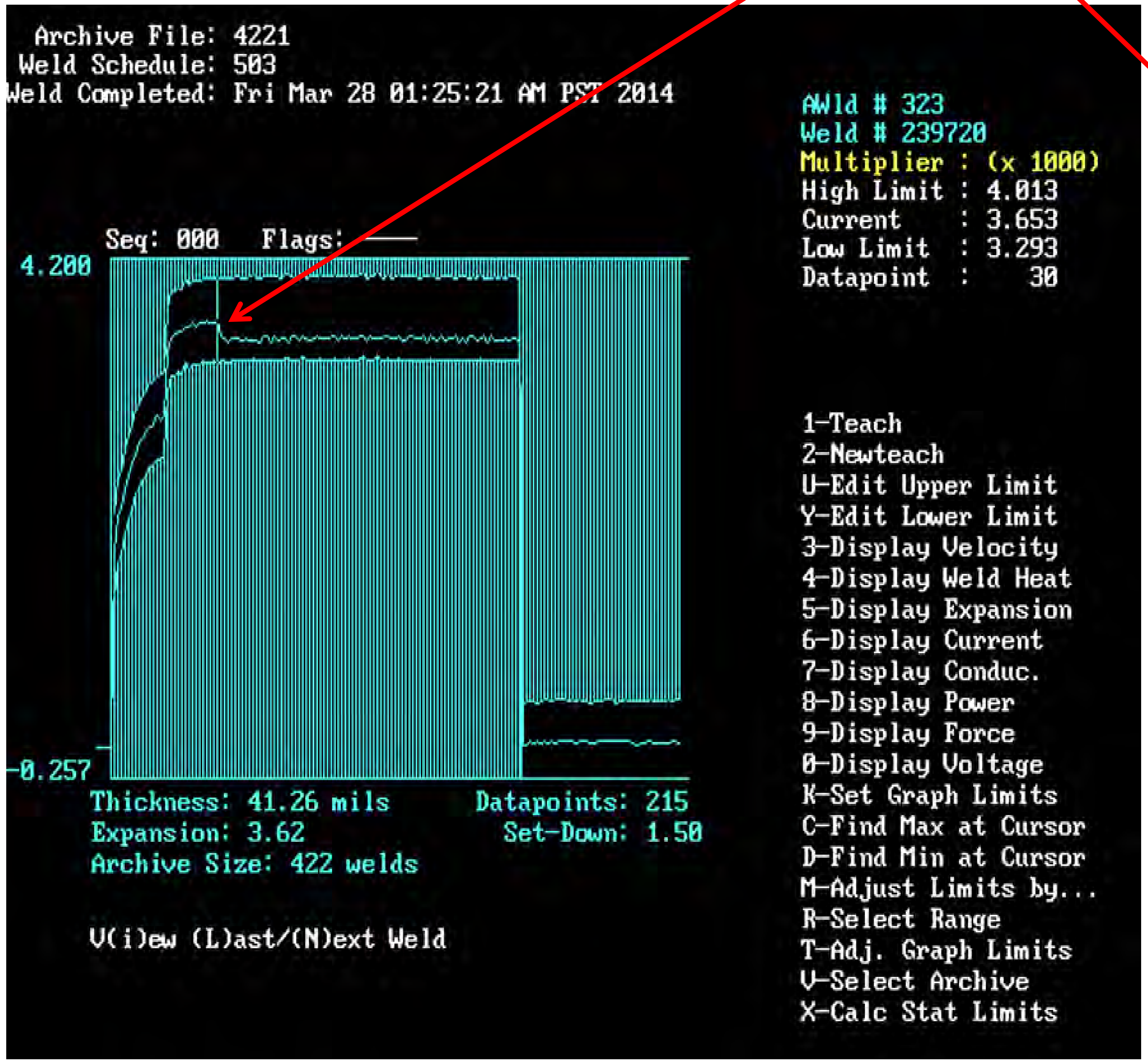
— Electrode force variation

— Wheel/brush contact resistance variation

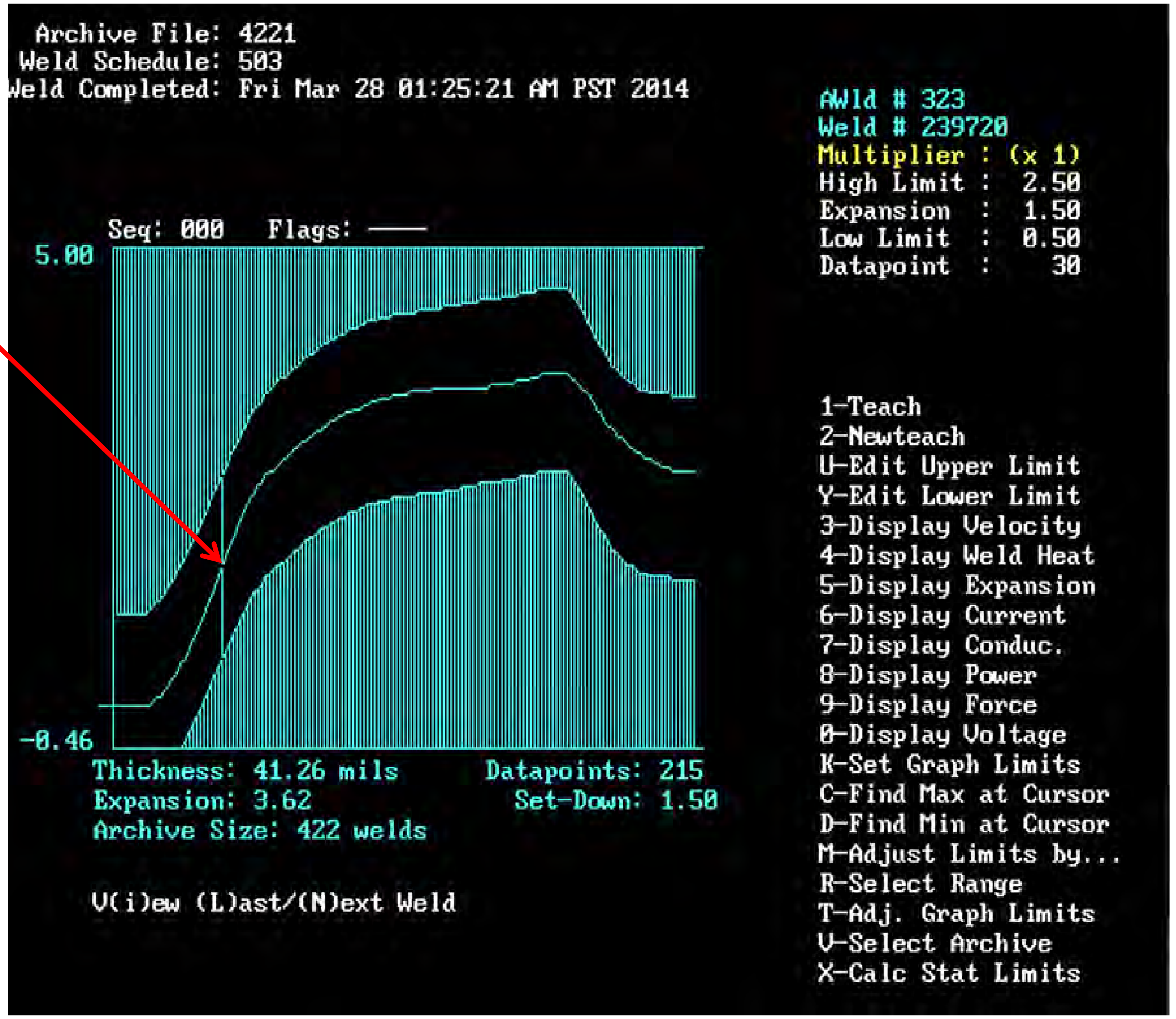
— Wheel velocity variation

Adaptive schedule detects greater than normal thermal expansion rate and reduces current to prevent expulsion from occurring

Current



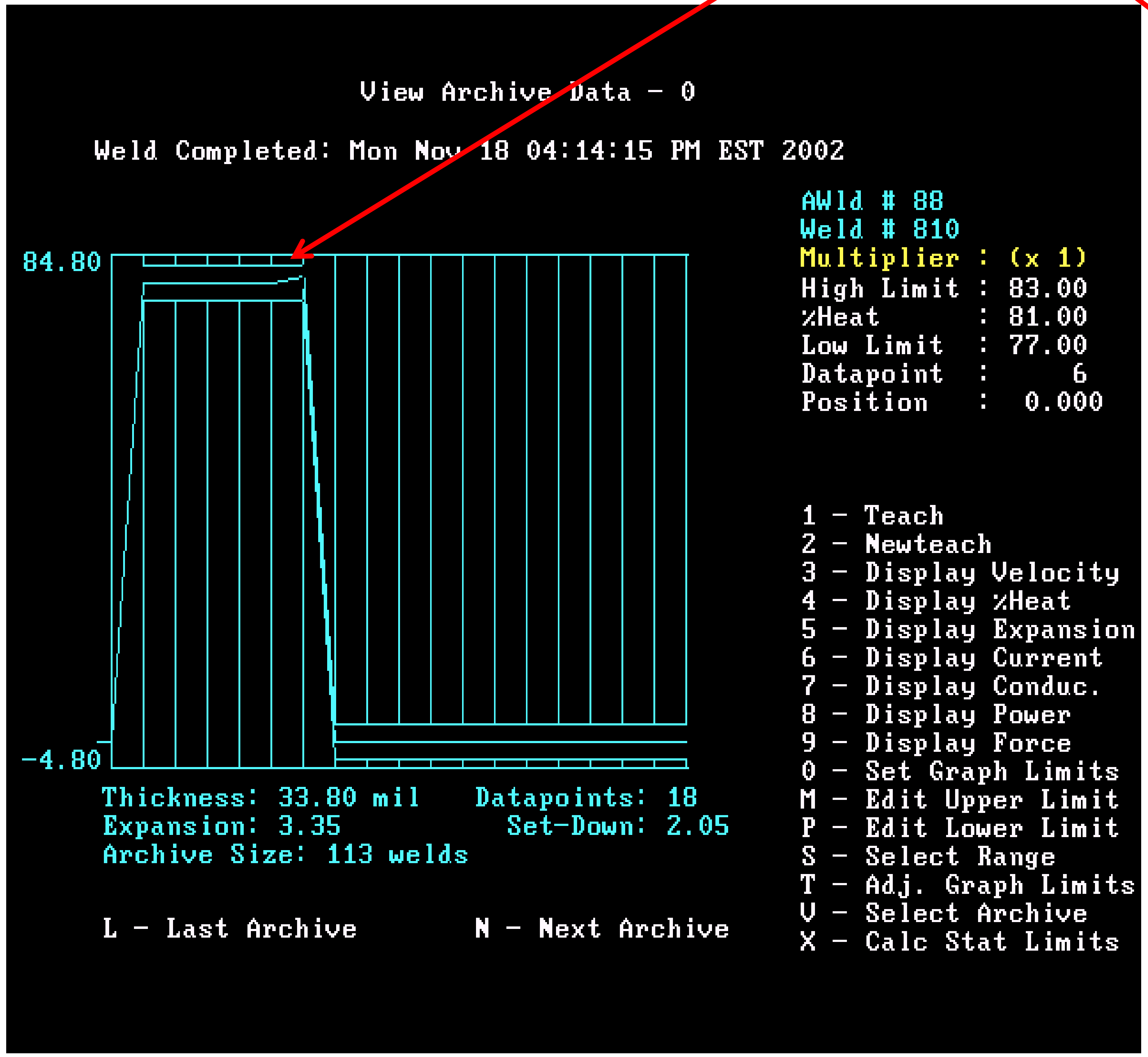
Expansion



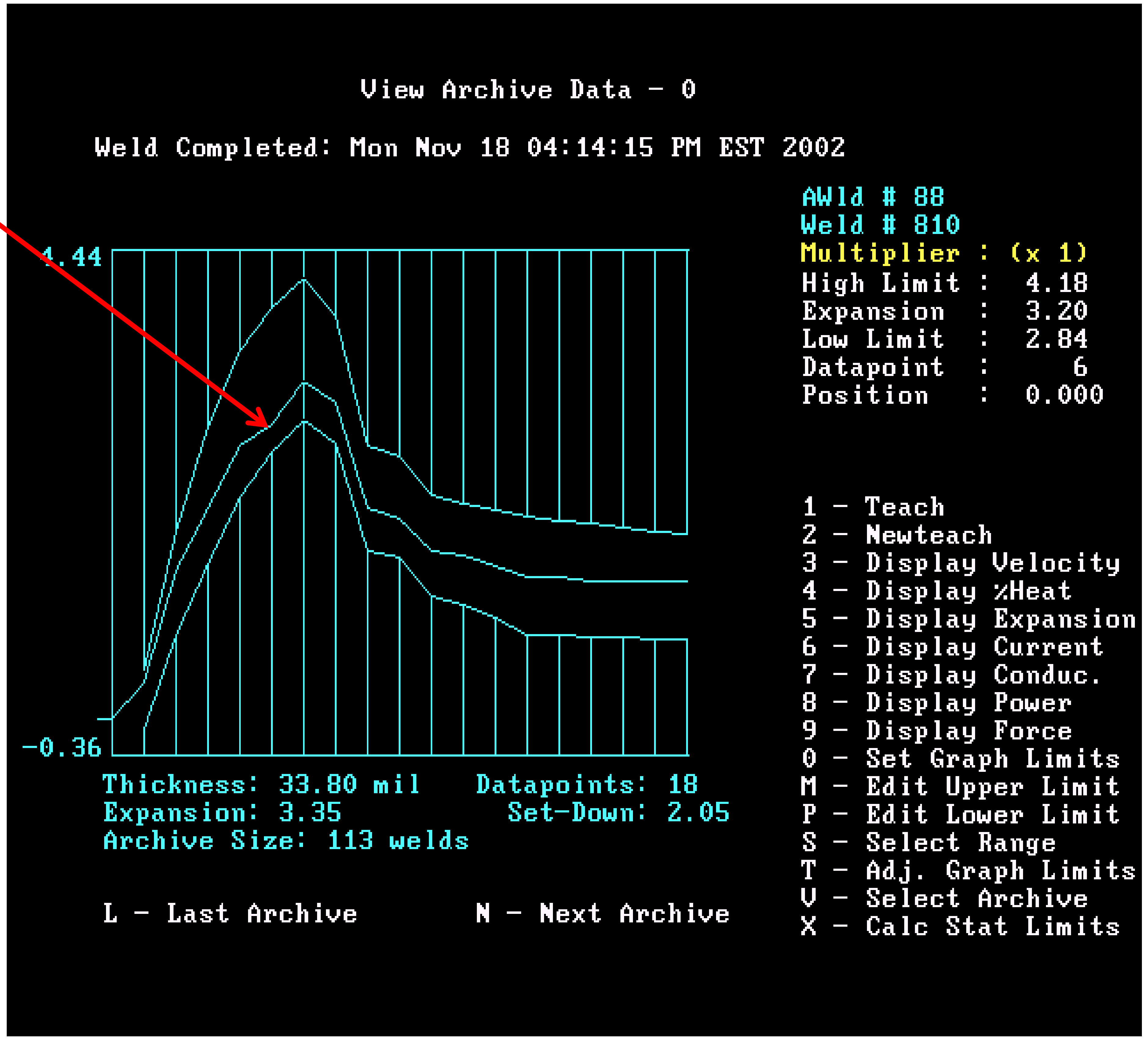
Data collected with WeldComputer® Adaptive Control

Adaptive control increases heat on cycle 6 by 1% in response to low expansion on cycle 5

Current



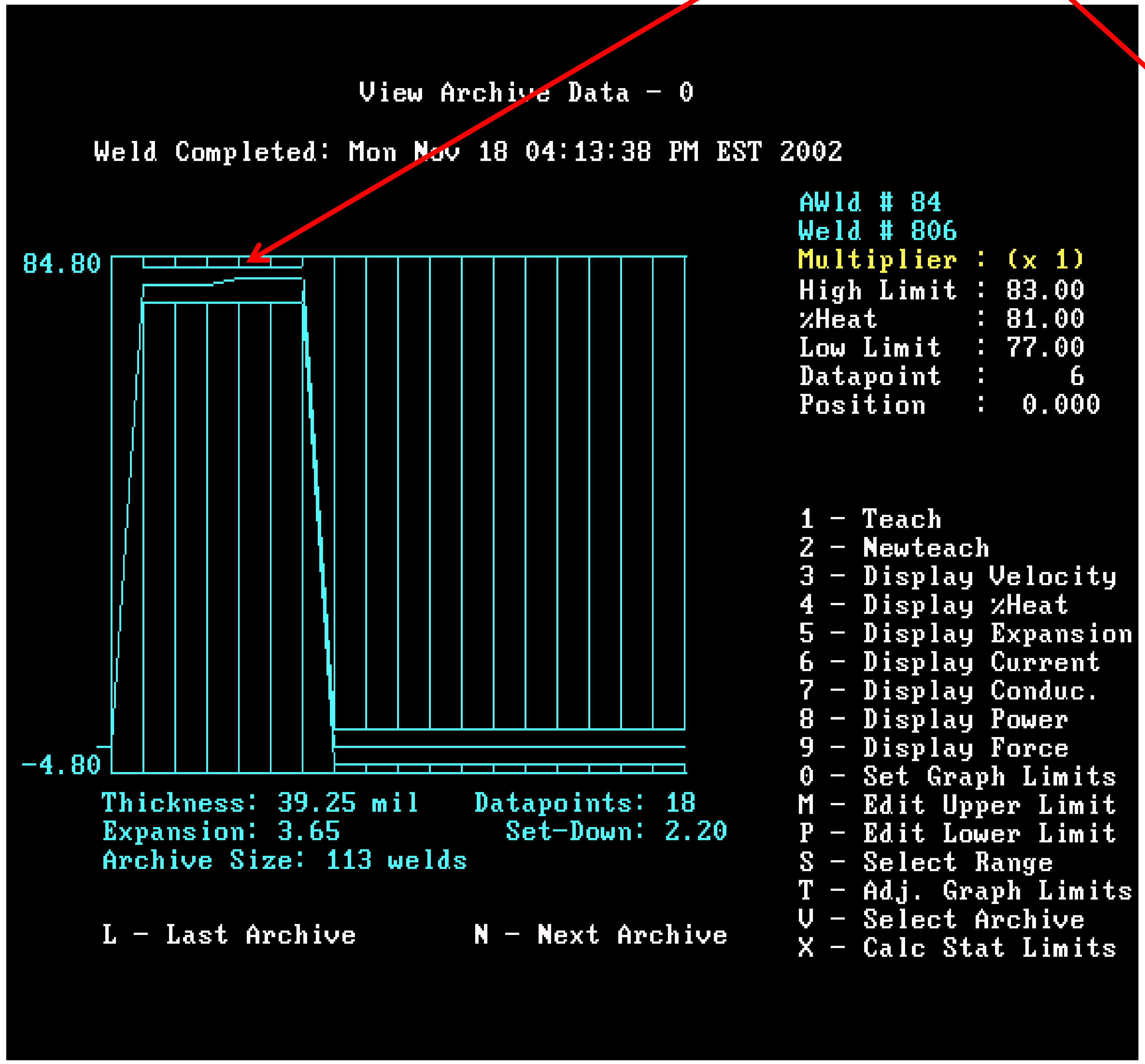
Expansion



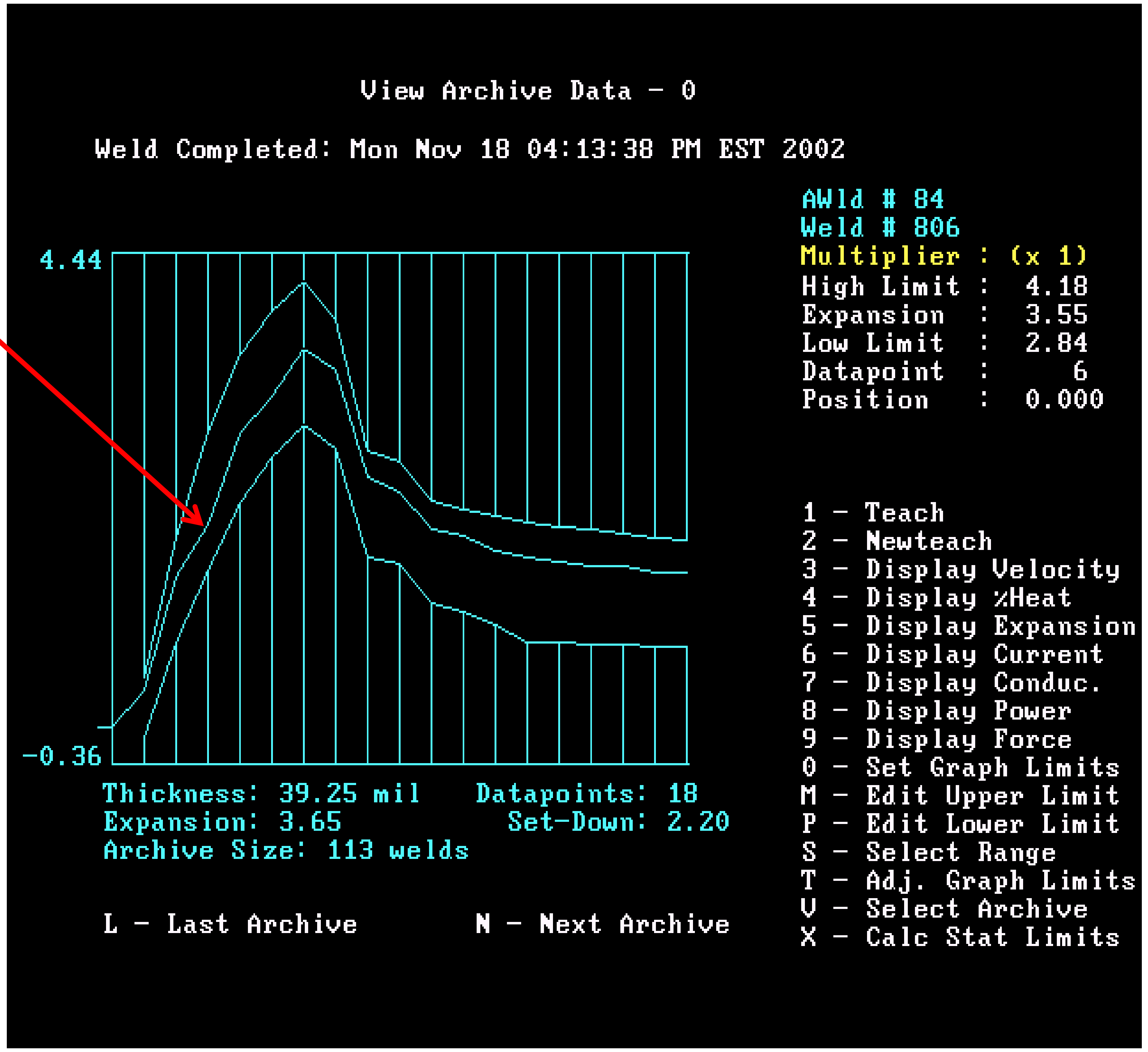
Data collected with WeldComputer® Adaptive Control

Adaptive control increases heat on cycle 4 by 1% in response to low expansion on cycle 3

Current



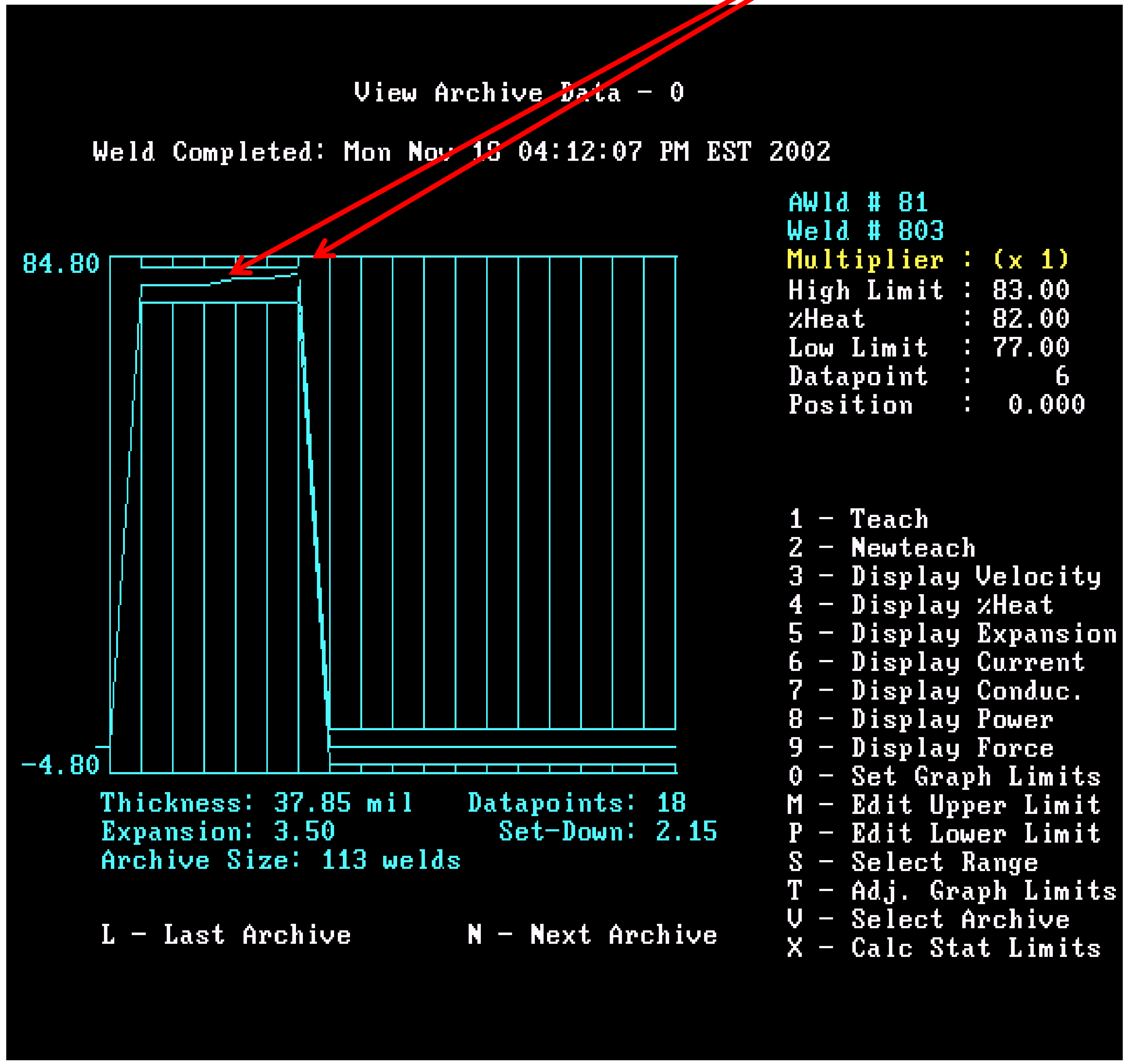
Expansion



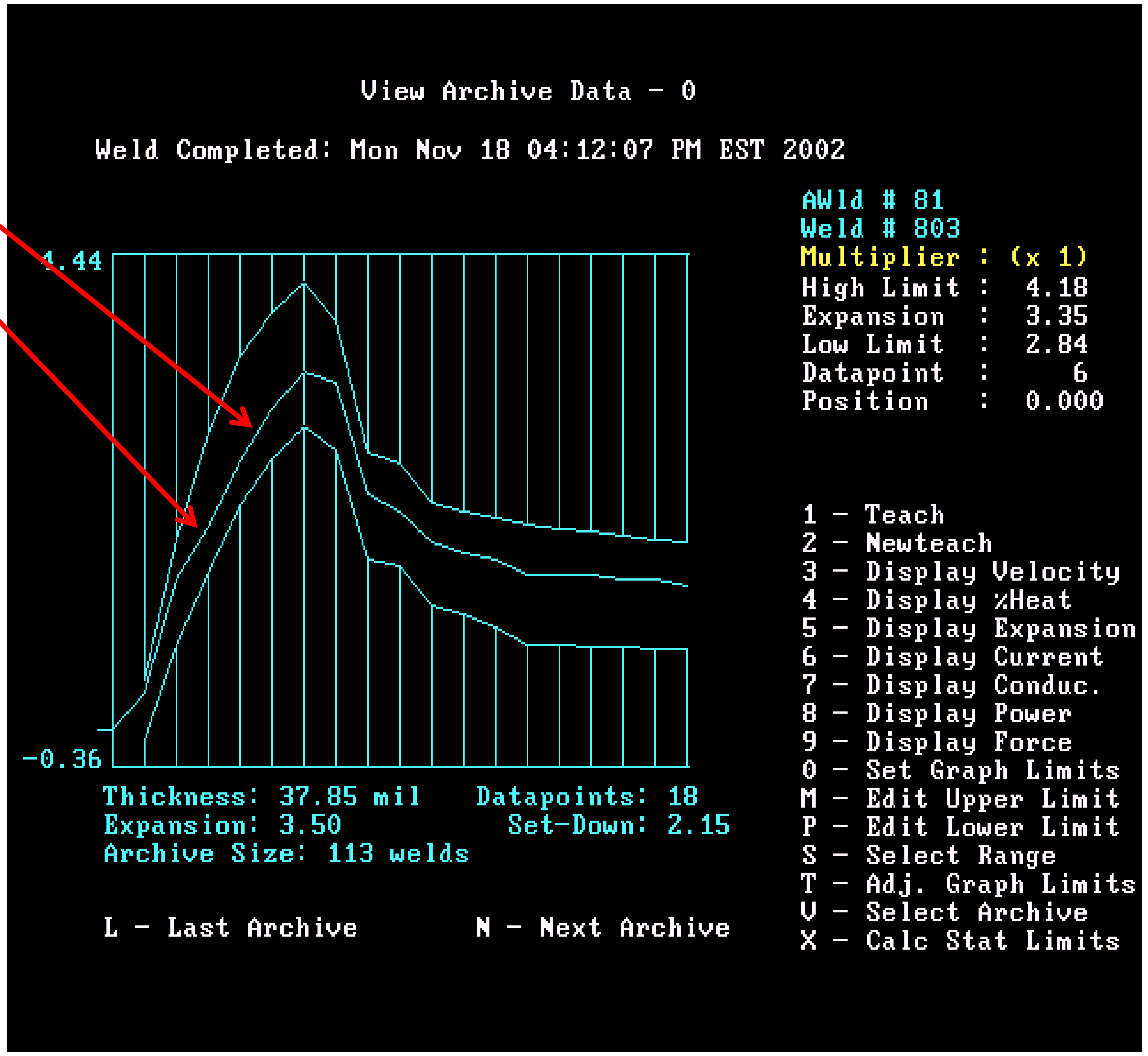
Data collected with WeldComputer® Adaptive Control

Adaptive control increases heat on cycle 4 by 1% in response to low expansion on cycle 3, and an additional 1% heat increase on cycle 6 in response to low expansion response on cycle 5

Current



Expansion



Data collected with WeldComputer® Adaptive Control

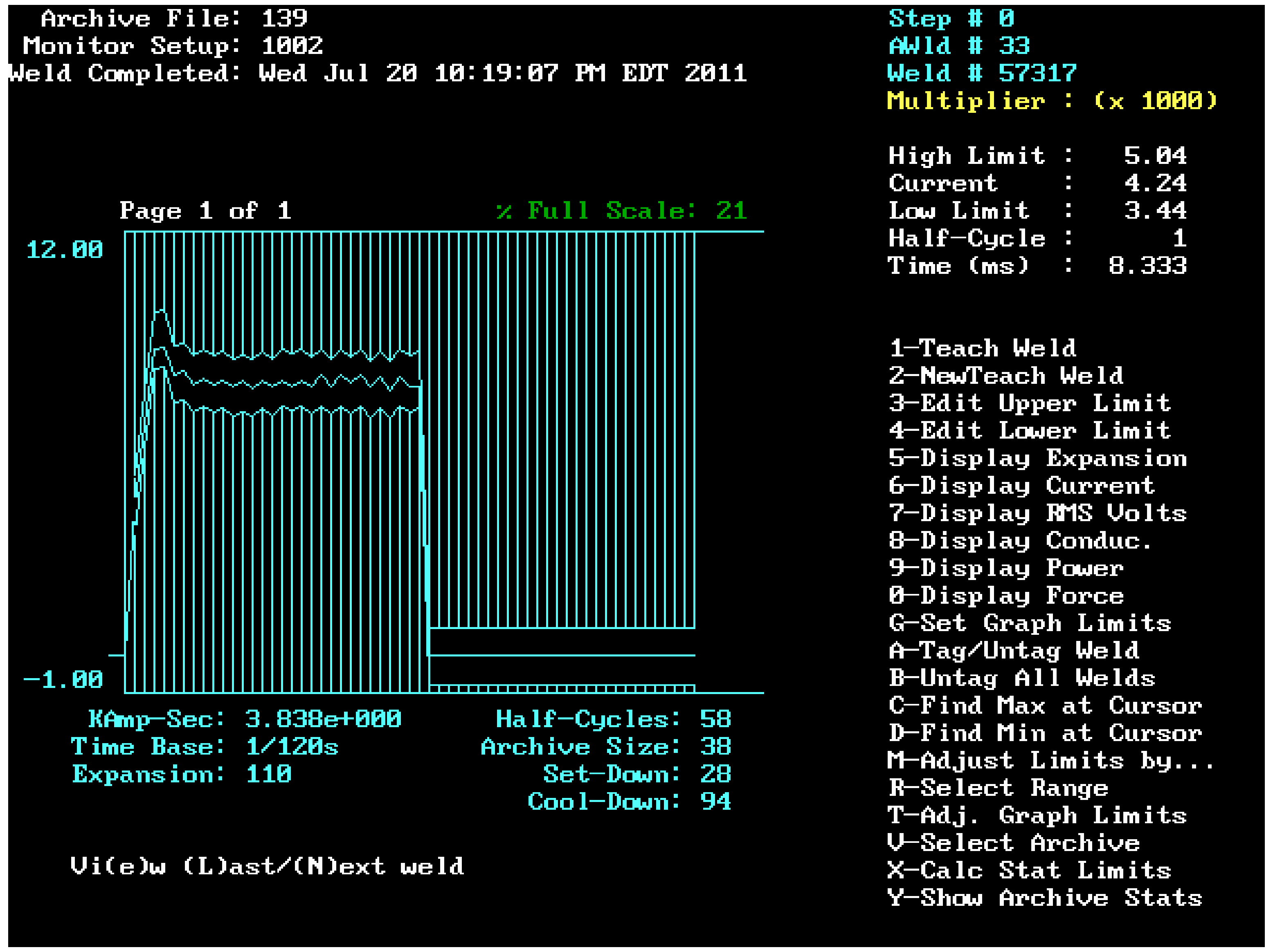
AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

5.1.5 Control Adjustments.

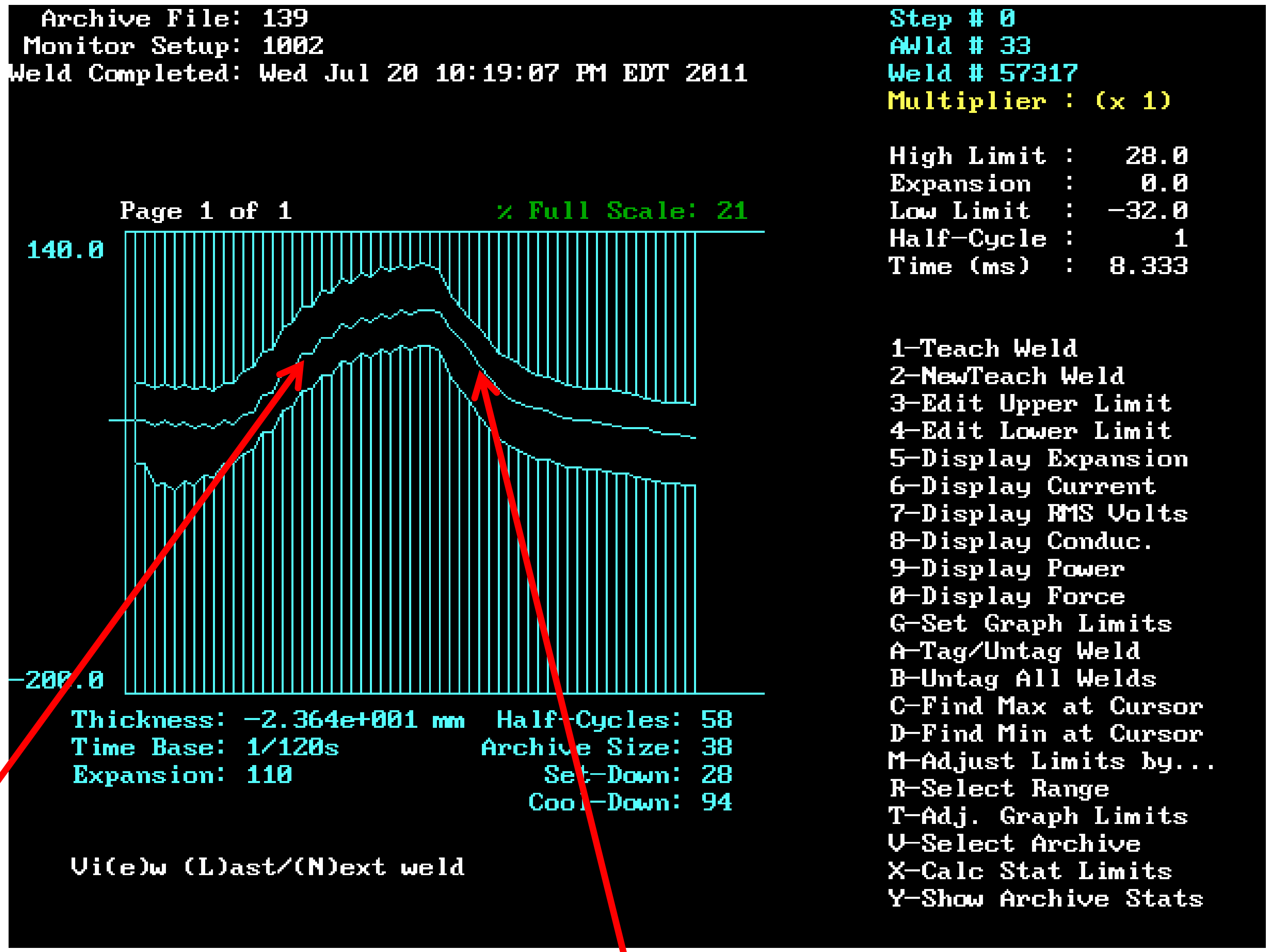
The settings may be varied by ±5% from the established certification values, or by ±10% when only one setting is adjusted.

Current and Expansion Response of Spot Weld Produced with Conventional Control

Current



Expansion



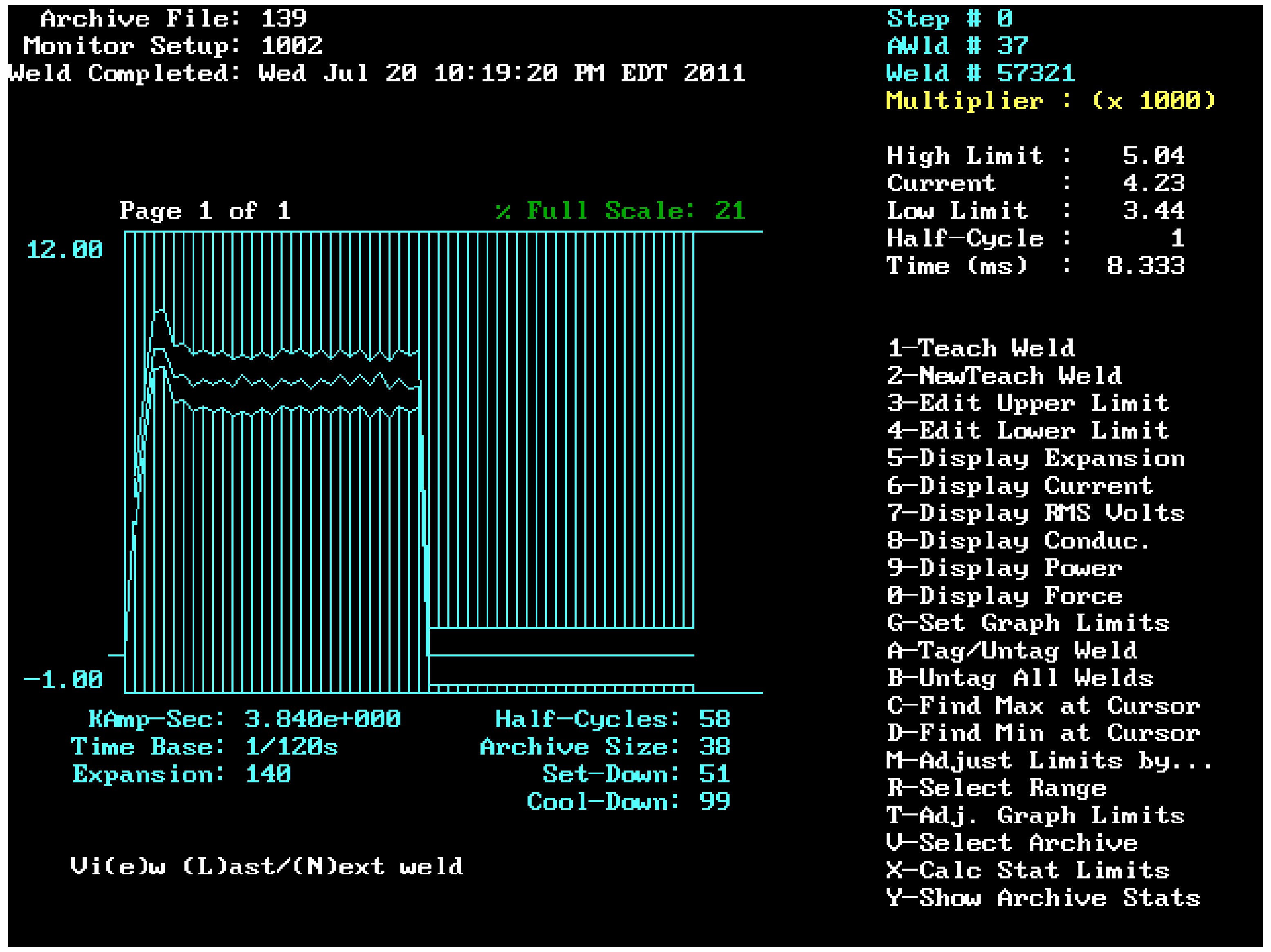
Material thermally expands while weld current is applied

Material thermally contracts after weld current stops

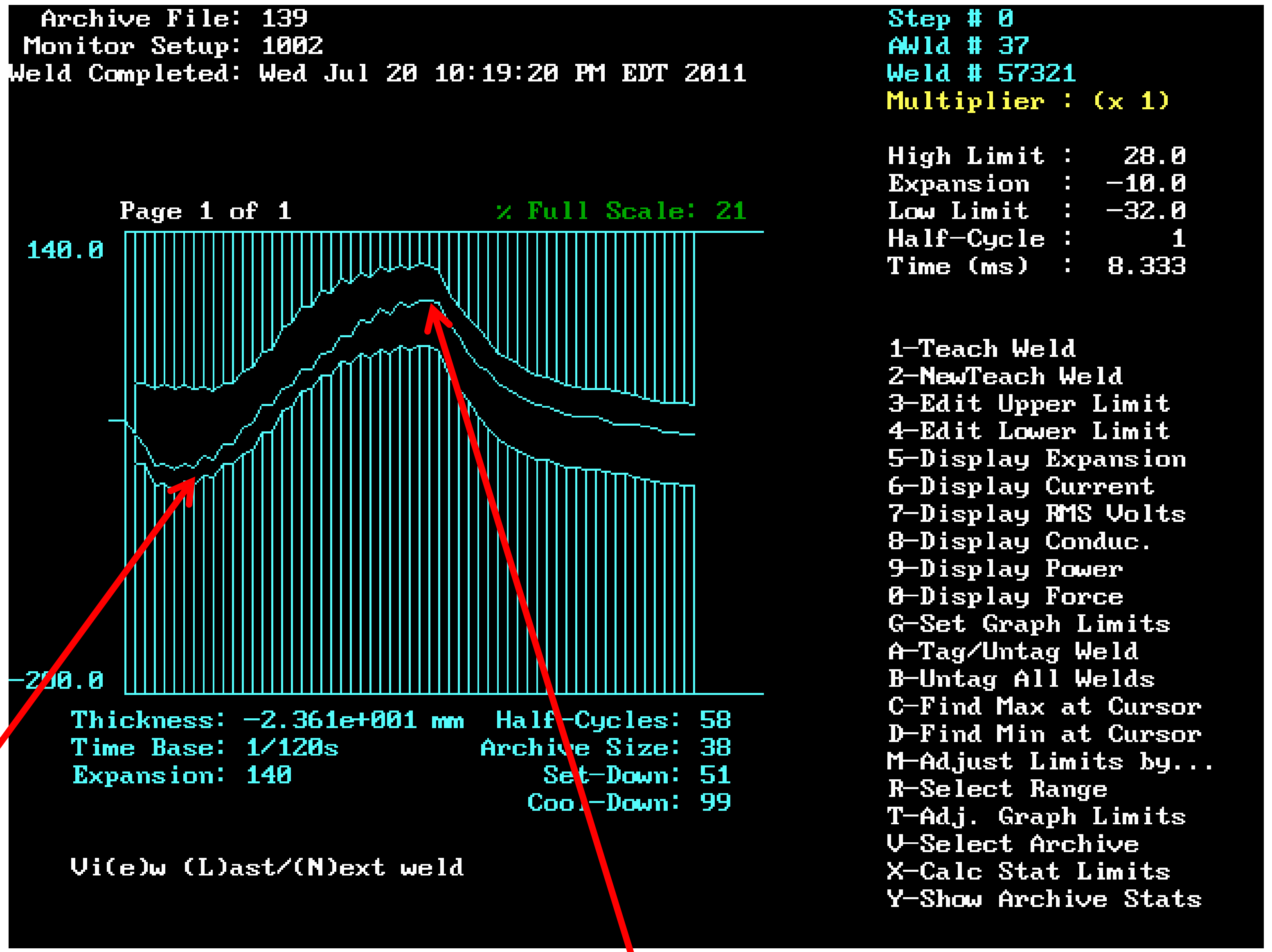
Current trace (left) & Expansion response trace (right) recorded with WeldView® Monitor

Spot Weld Produced with Conventional Control has Slight Fit-Up Problem

Current



Expansion



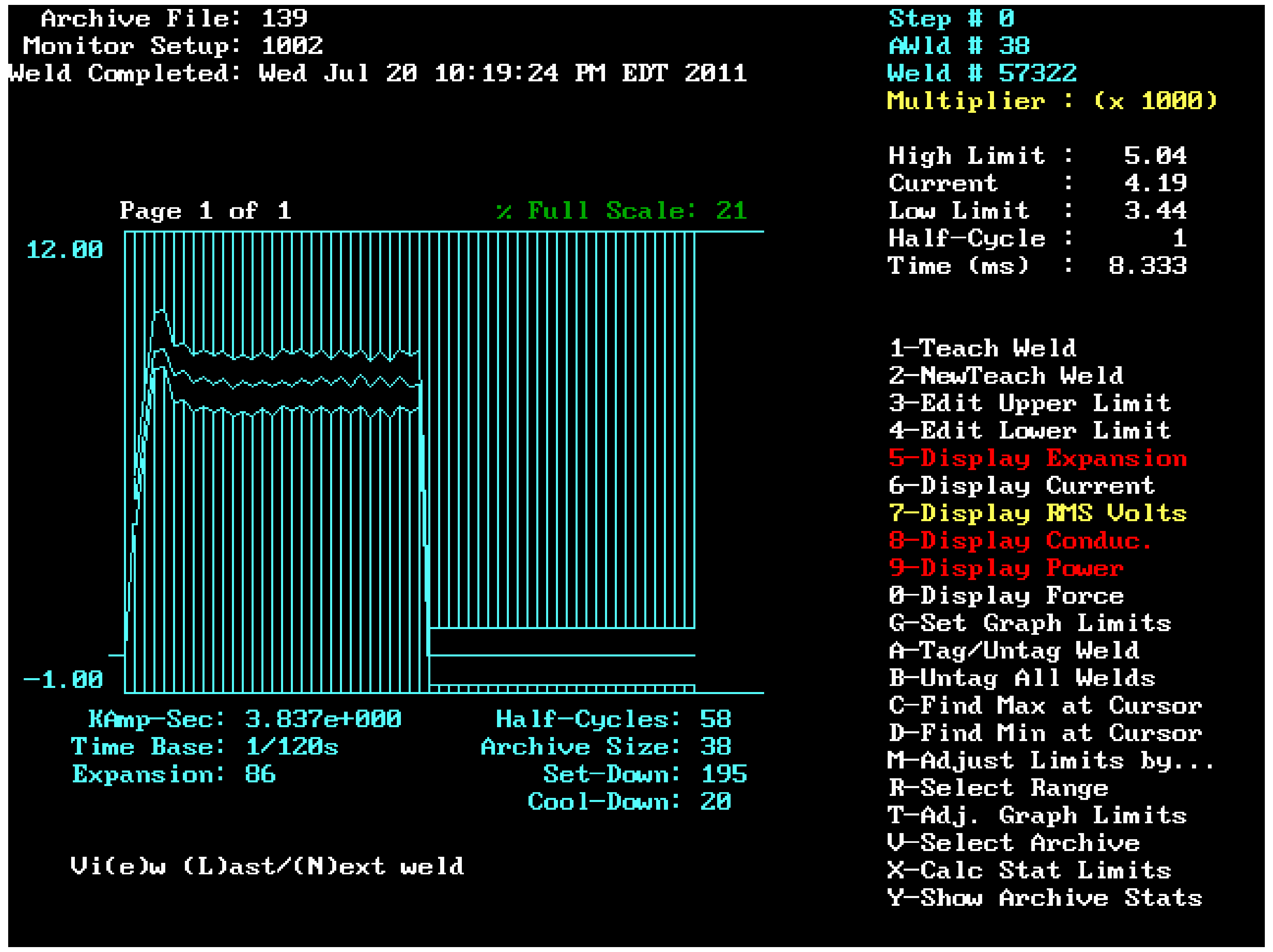
Negative movement documents parts fitting together before material starts to thermally expand

Material has acceptable thermal response despite slight fit-up problem

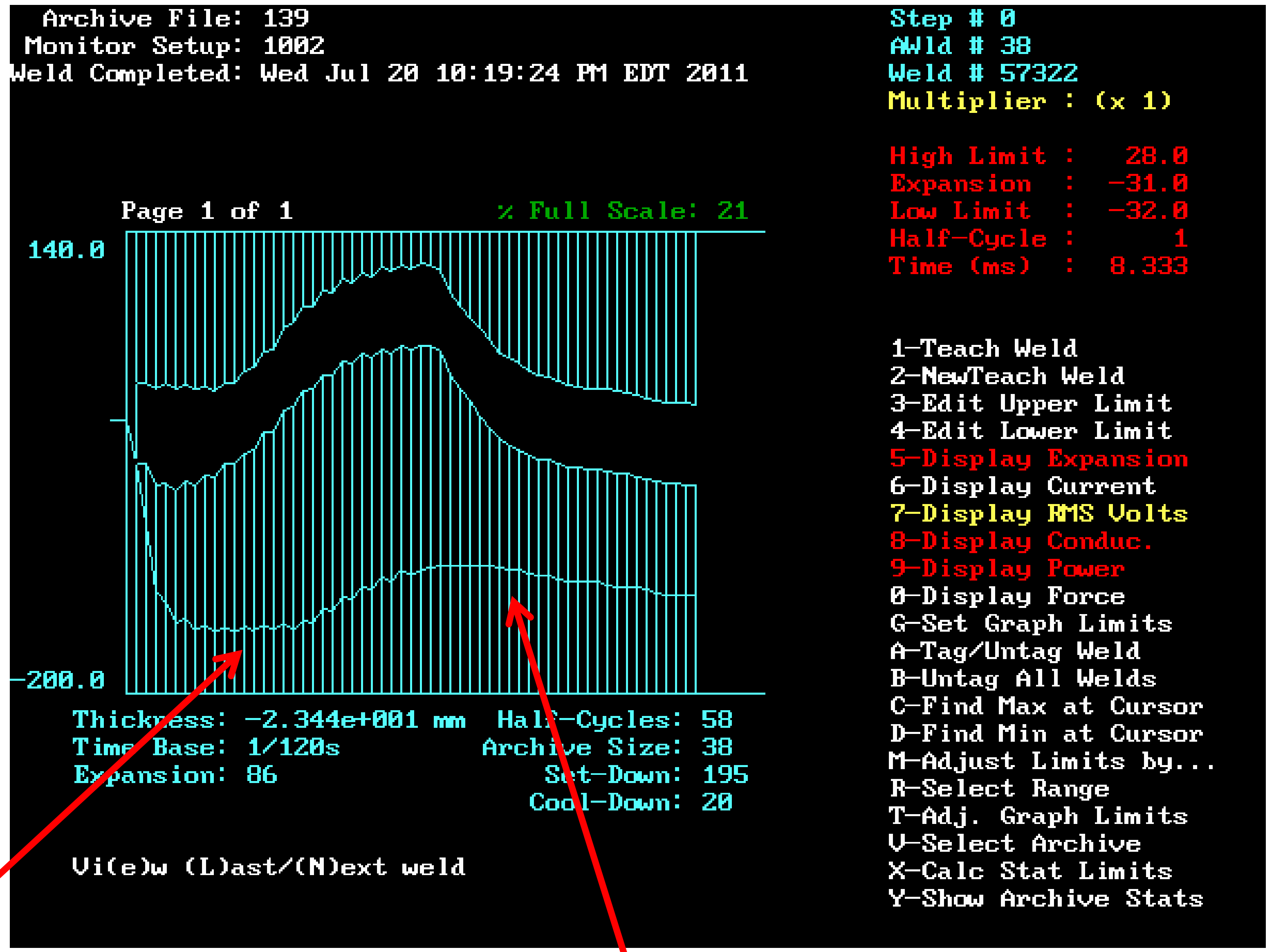
Current trace (left) & Expansion response trace (right) recorded with WeldView® Monitor

Severe Fit-Up Problem with Conventional Control Results in Undersized Weld

Current



Expansion



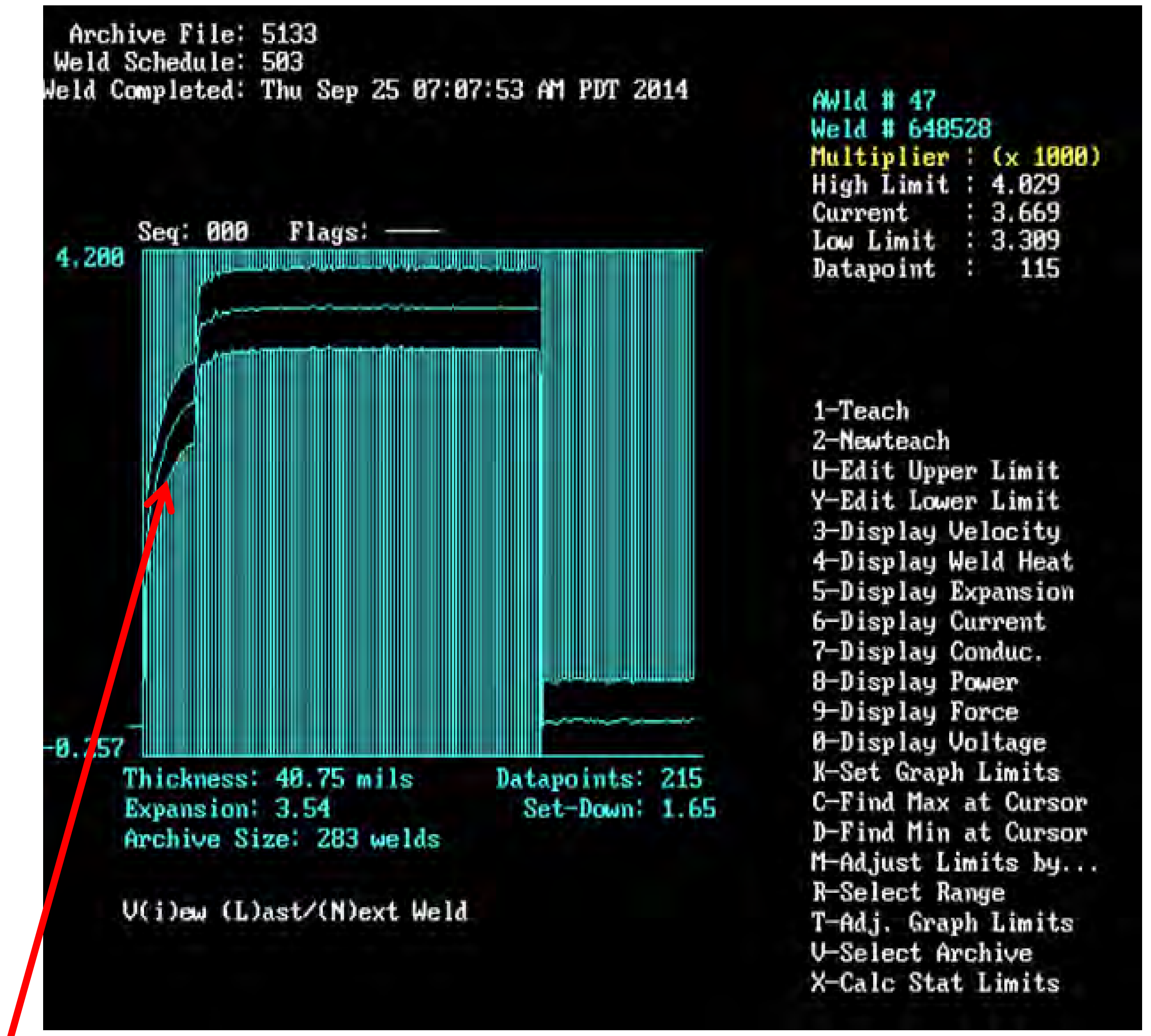
Weld time is lost squeezing parts together

Not enough weld time remaining after parts fit together results in undersized weld

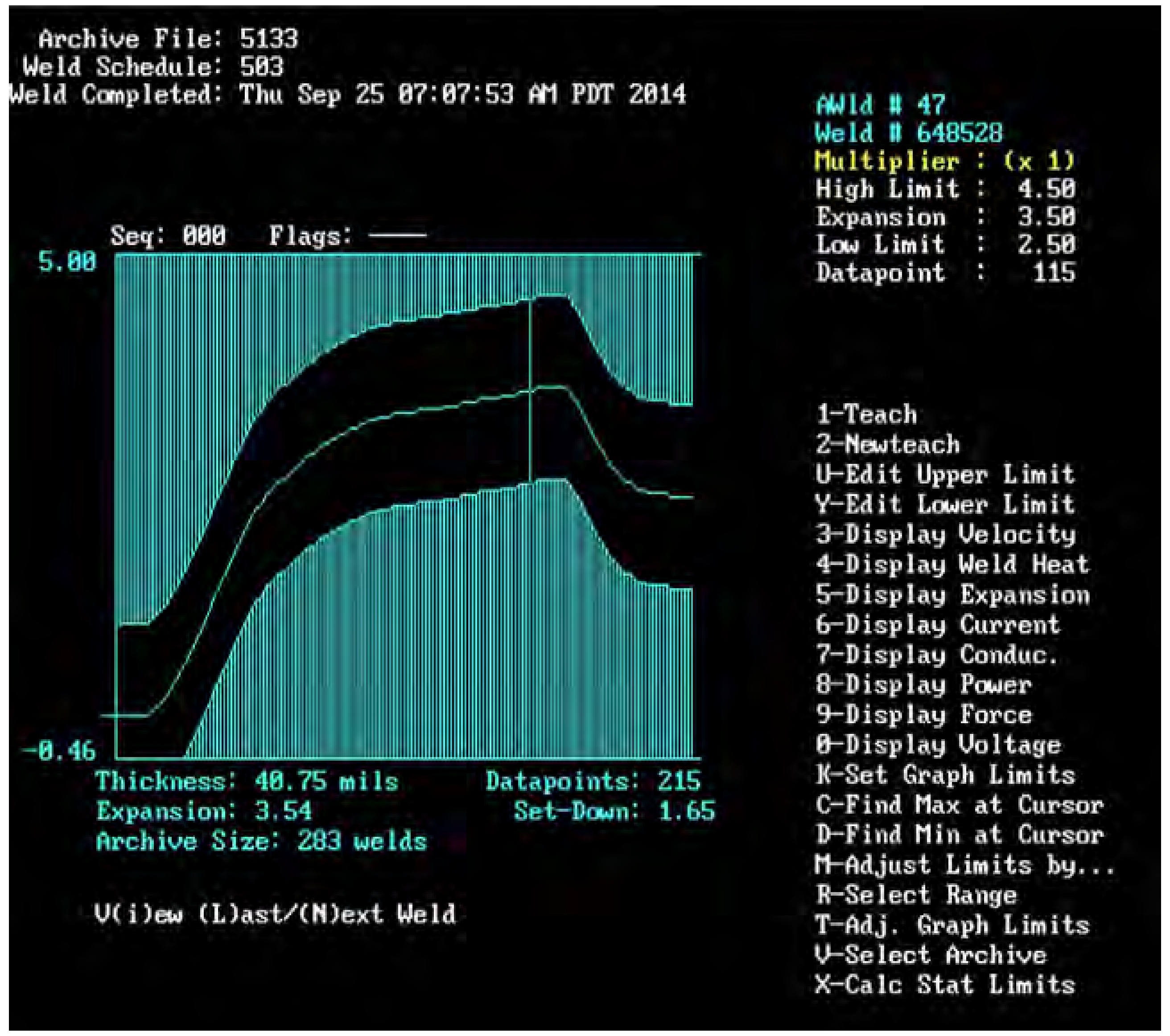
Current trace (left) & Expansion response trace (right) recorded with WeldView® Monitor

Adaptive Weld Schedule Nominal Current and Thermal Expansion Response

Current



Expansion

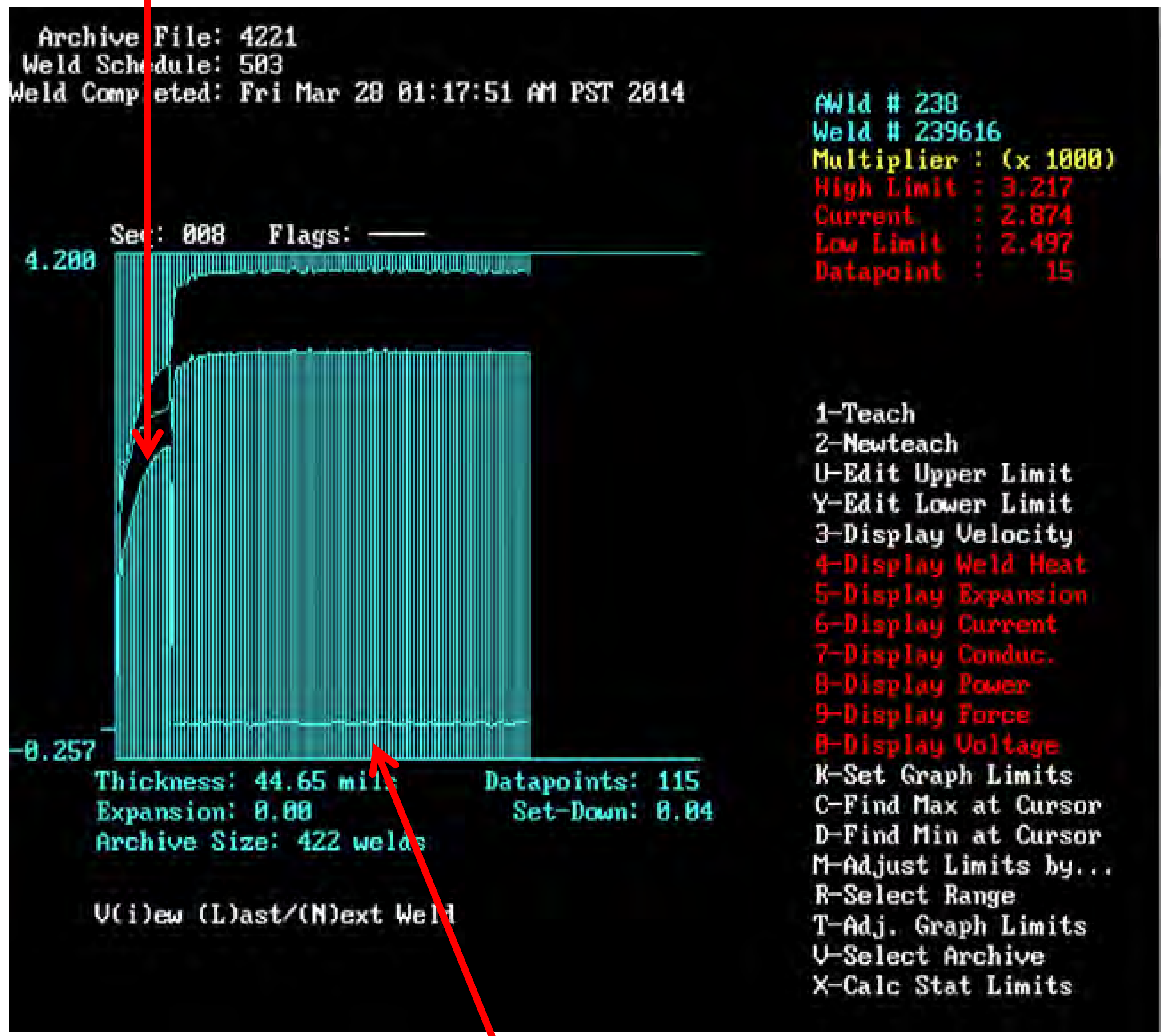


Diagnostic/Pre-Conditioning Heat Pulse

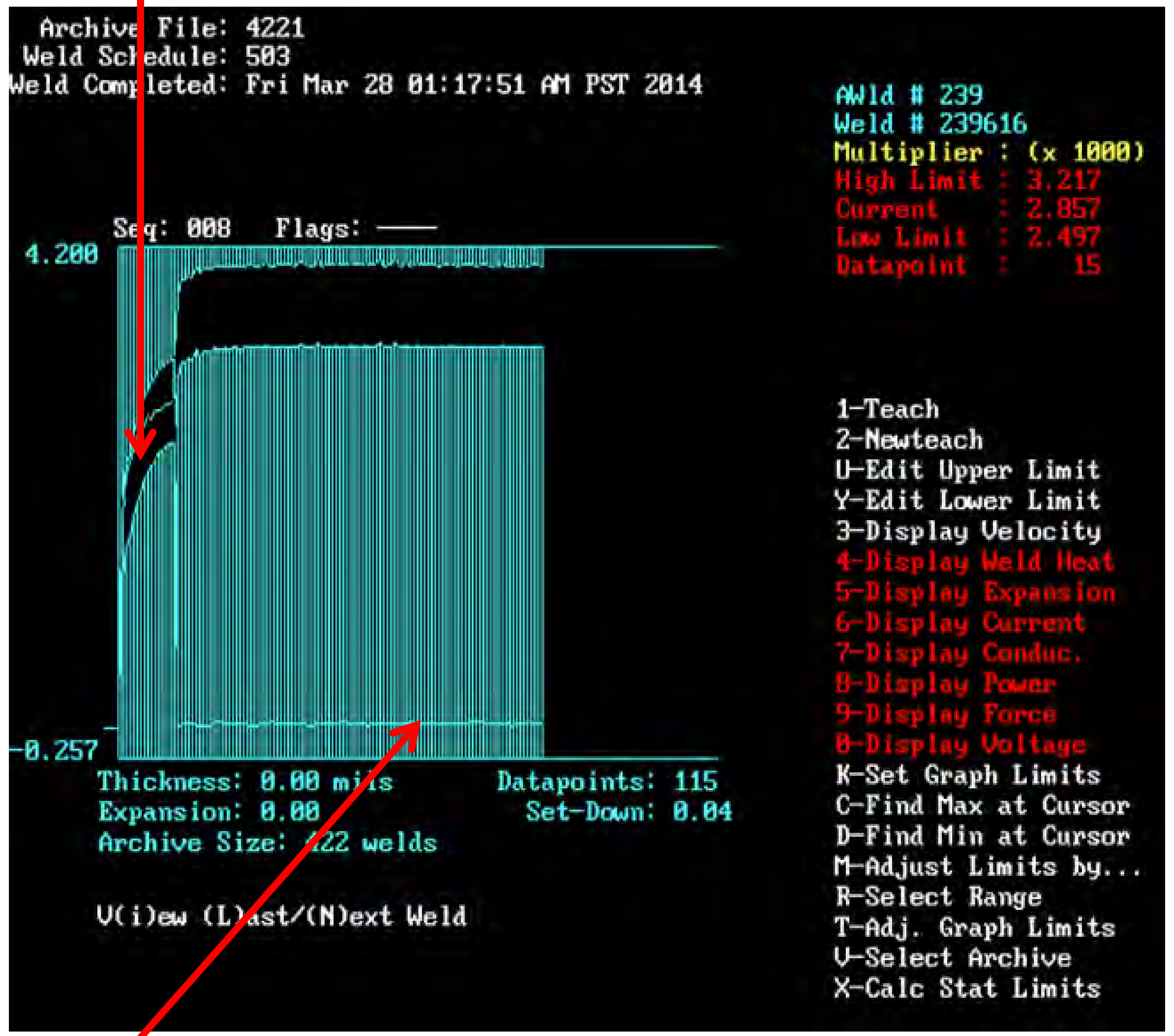
Data collected with WeldComputer® Adaptive Control

Monitor upset profile response

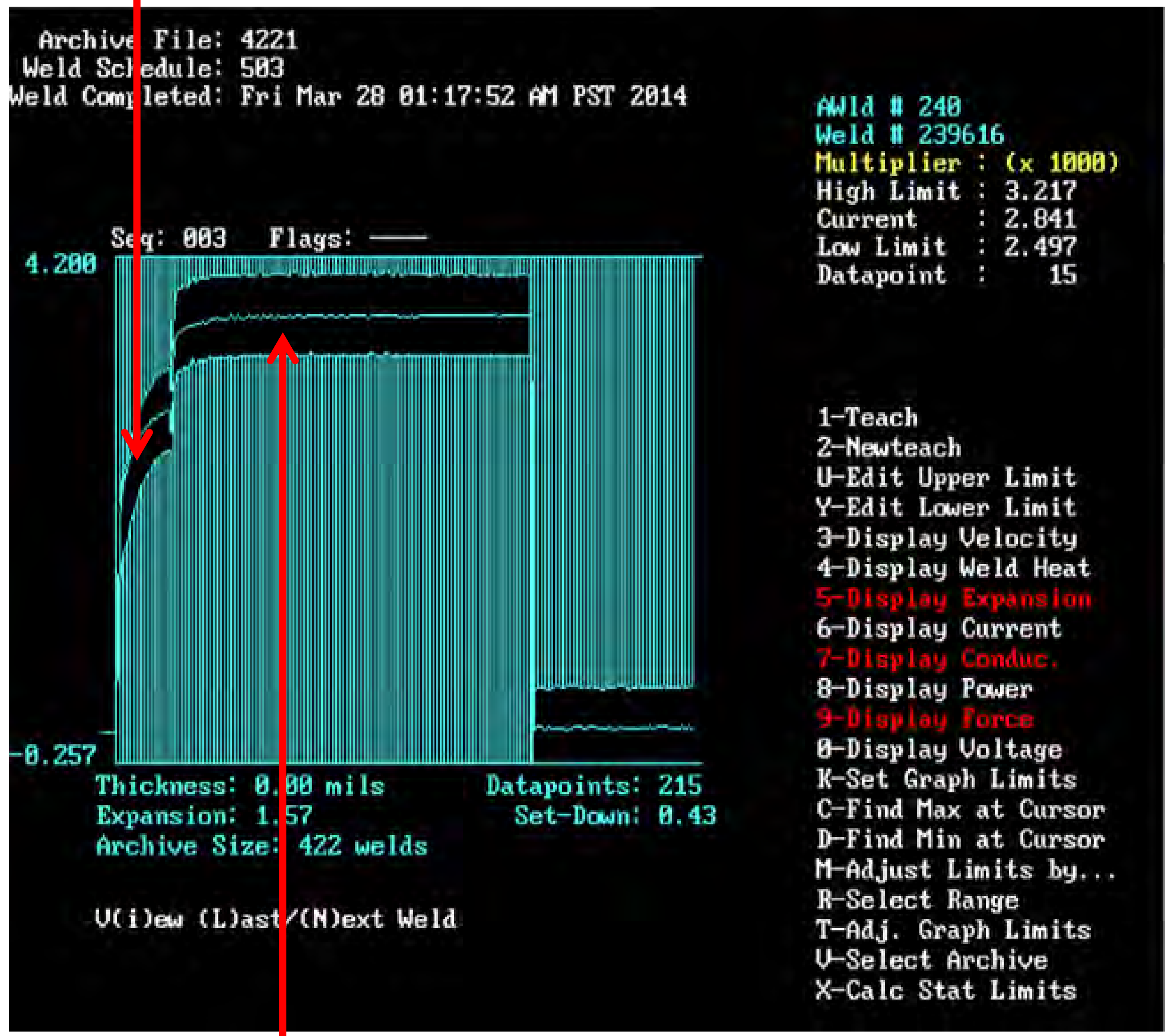
Pre-conditioning heat pulse 1



Pre-conditioning heat pulse 2



Pre-conditioning heat pulse 3



Pre-conditioning pulse didn't fully correct fit-up problem, so weld heat is inhibited, and a cool down delay applied before repeating process

Weld heat occurs after 3rd pre-conditioning pulse succeeds in correcting fit-up problem

Data collected with WeldComputer® Adaptive Control

AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

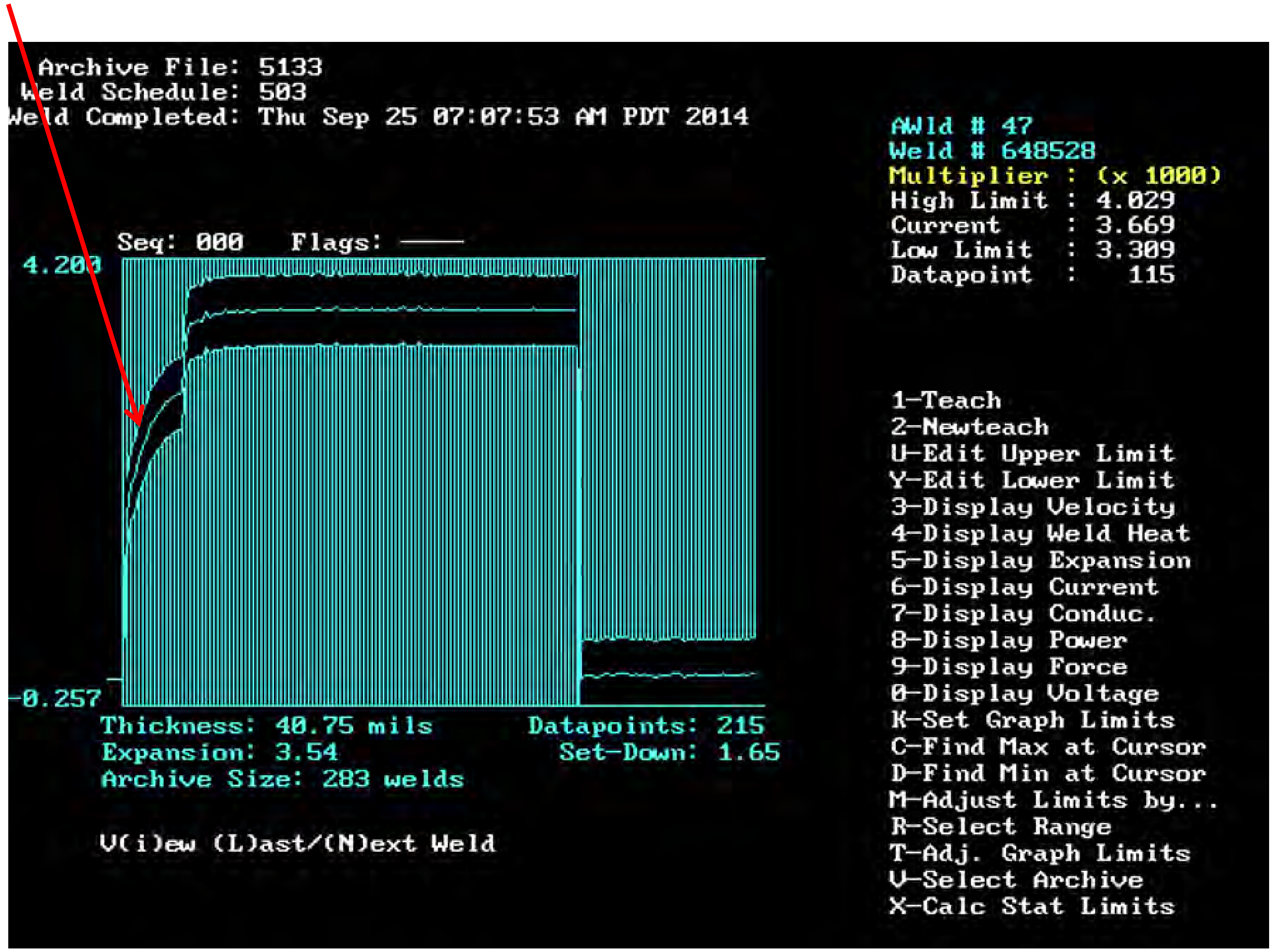
4.2.2.1 Preconditioning steps to compensate for fitup variations that involve the controlled application of heat and/or force may be employed.

AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

5.1.5.1 Control adjustments shall apply from start to finish of the weld nugget formation.

Substitution of In-Process Micro-Ohm Measurements

Diagnostic/Pre-Conditioning heat pulse measures resistance on every weld



Data collected with WeldComputer® Adaptive Control

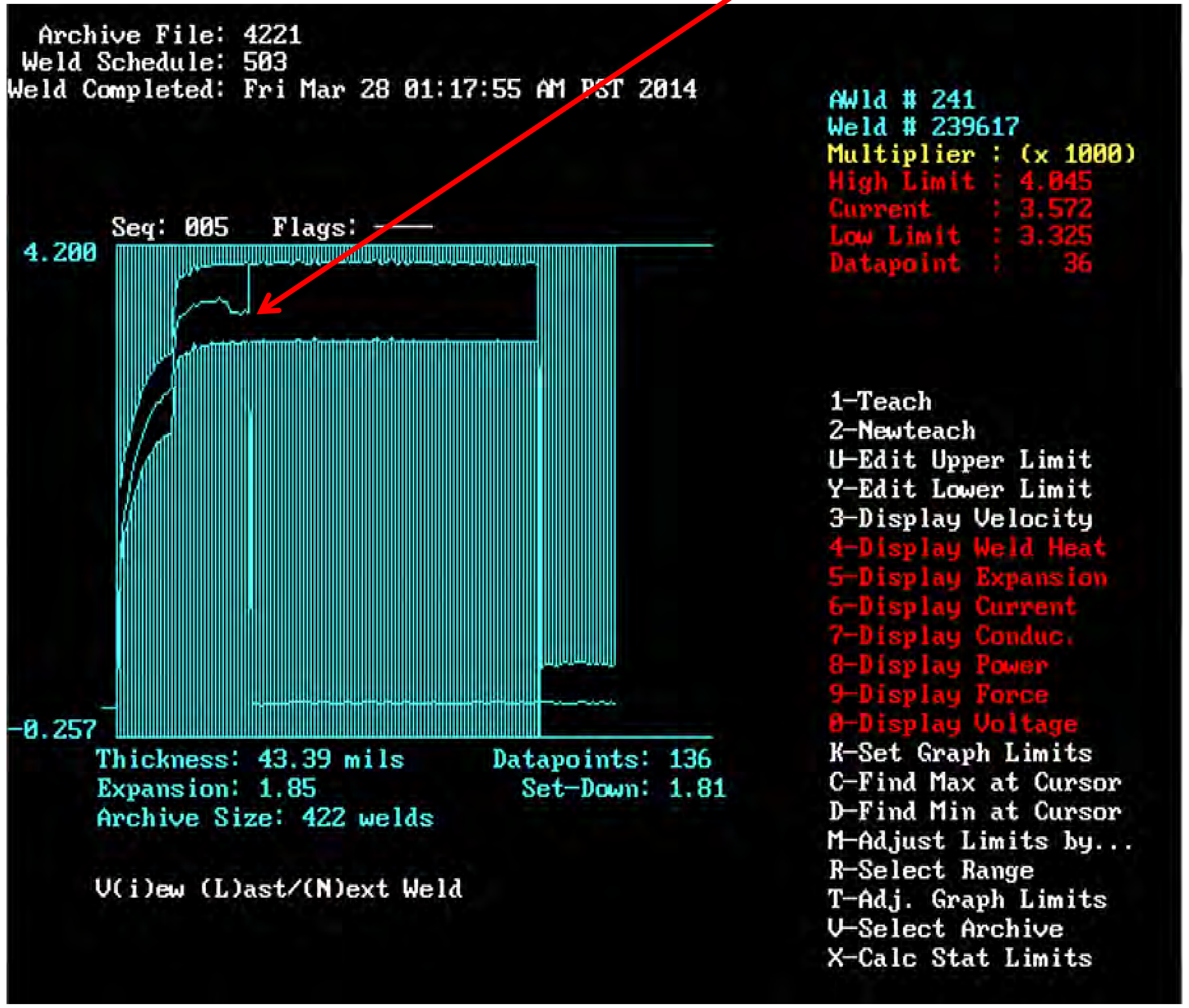
AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

(January 2013 Release)

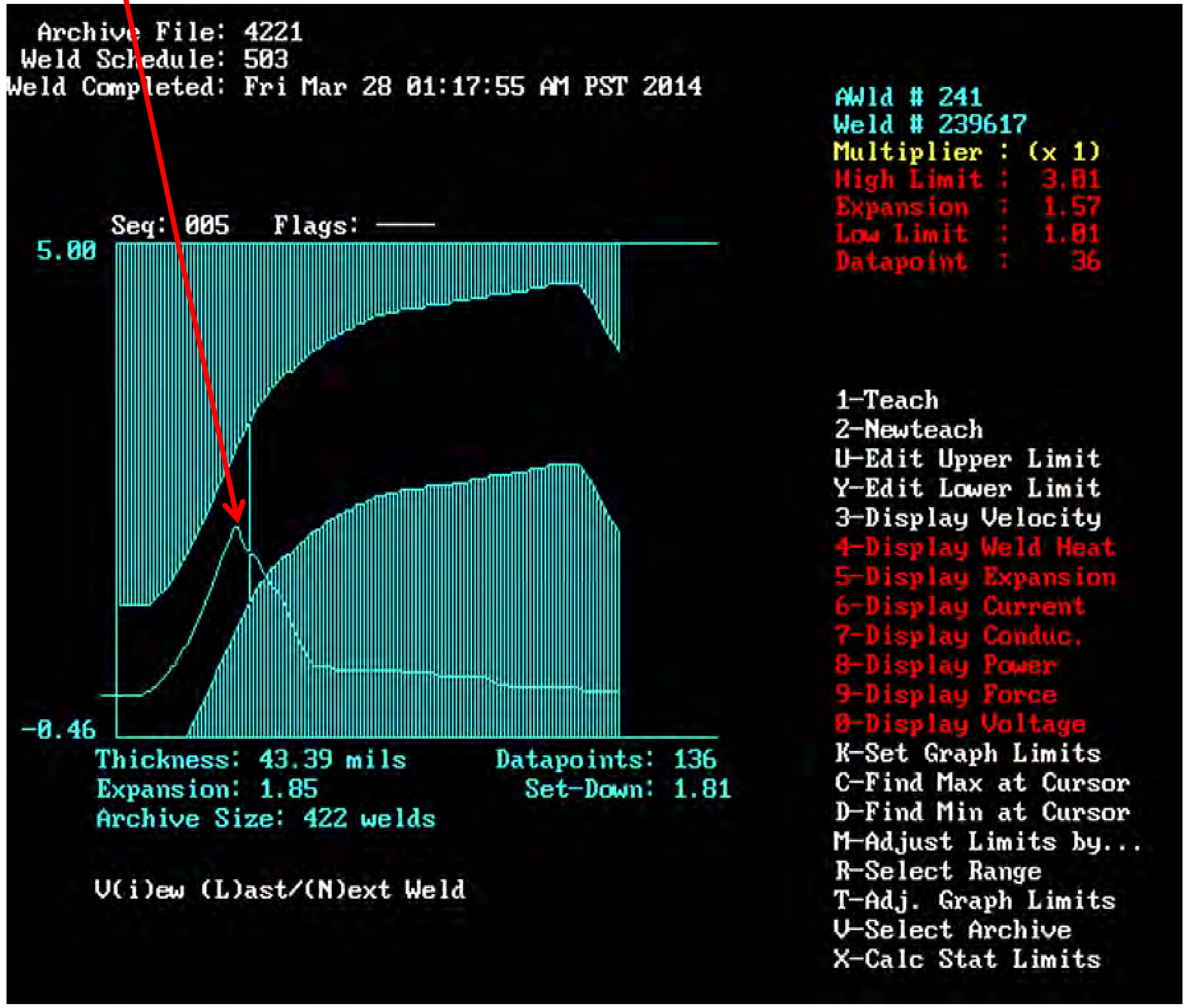
5.1.4.2 Use of in-process weld control monitoring capable of detecting when a micro-ohms shift outside of the specification range occurs may be substituted for the surface resistance checks as deemed appropriate by the Engineering Authority.

Adaptive schedule responds to expulsion occurrence by instantly terminating weld current to minimize part damage, then automatically performs a repair weld operation

Current



Expansion



Data collected with WeldComputer® Adaptive Control

Adaptive Weld Schedule Expulsion Management

— Instantly cut off heat upon detection of expulsion

— Keep electrodes clamped on part and wait for weld to cool

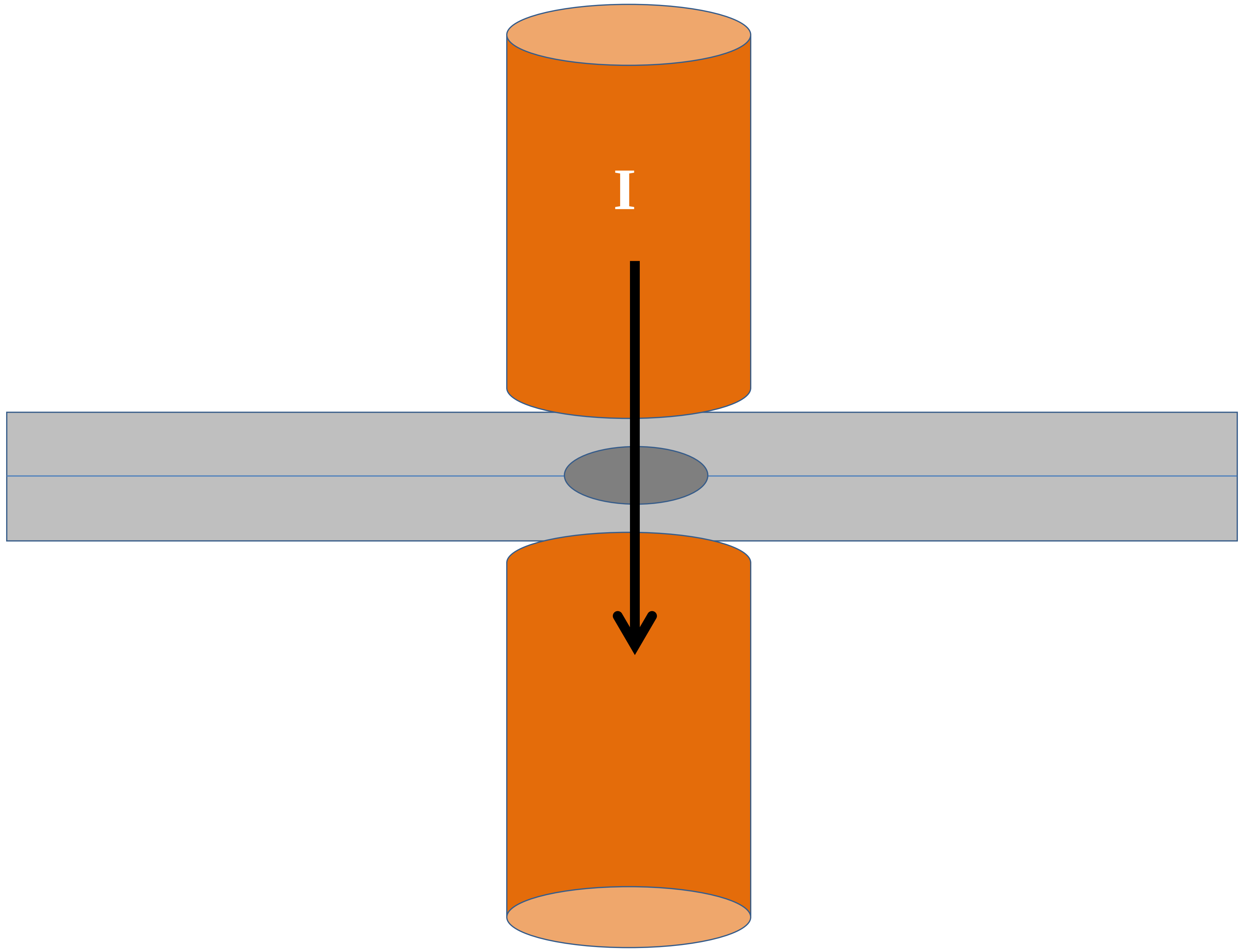
— Perform re-weld operation

AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

5.1.5.2 Any control adjustment made beyond the constraints set forth in 5.1.5 taken to minimize part damage during the occurrence of a welding fault shall be excluded as a condition that would require the establishment of a new certified welding procedure.

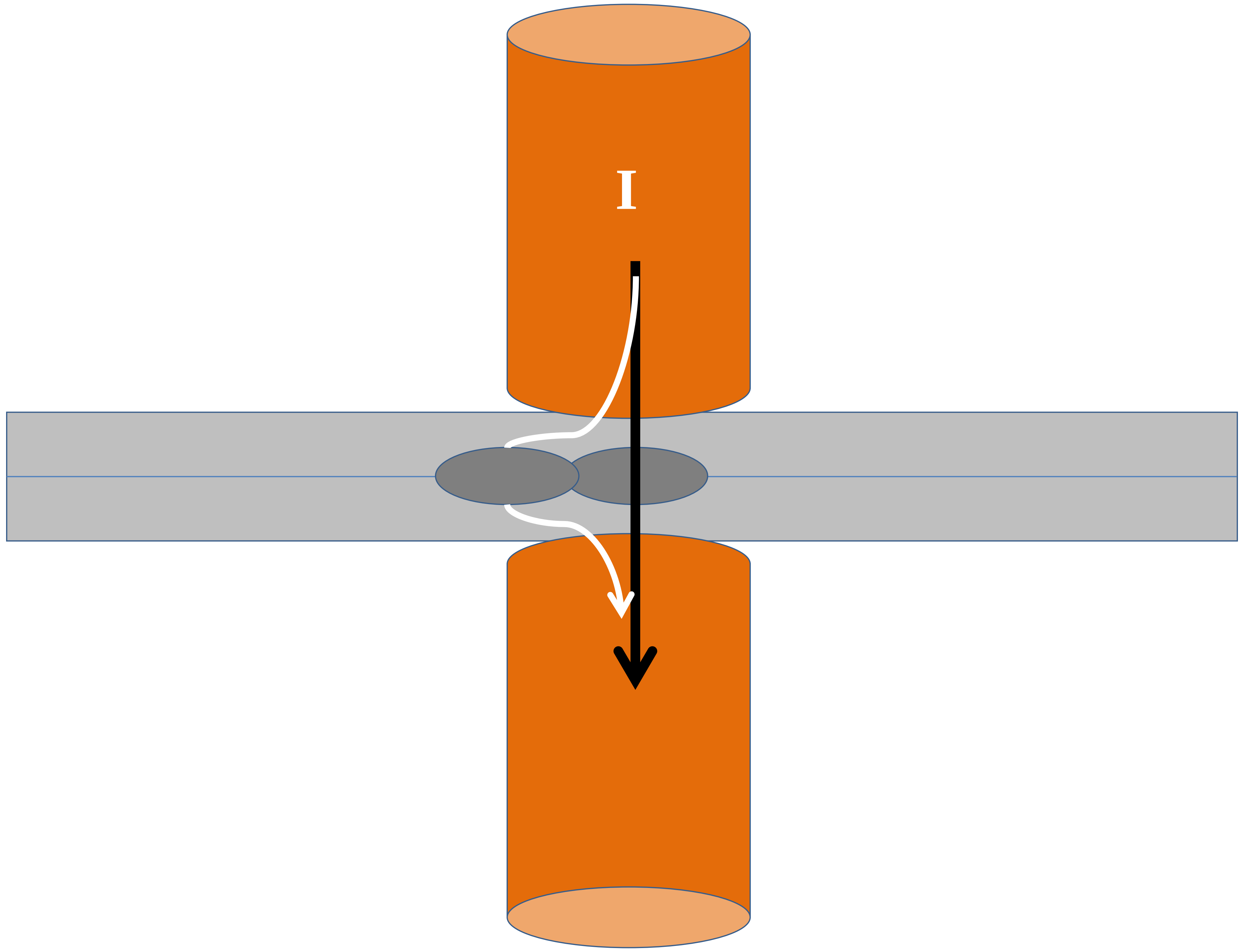
AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

Use right machine, control, electrodes, force & current to make weld.



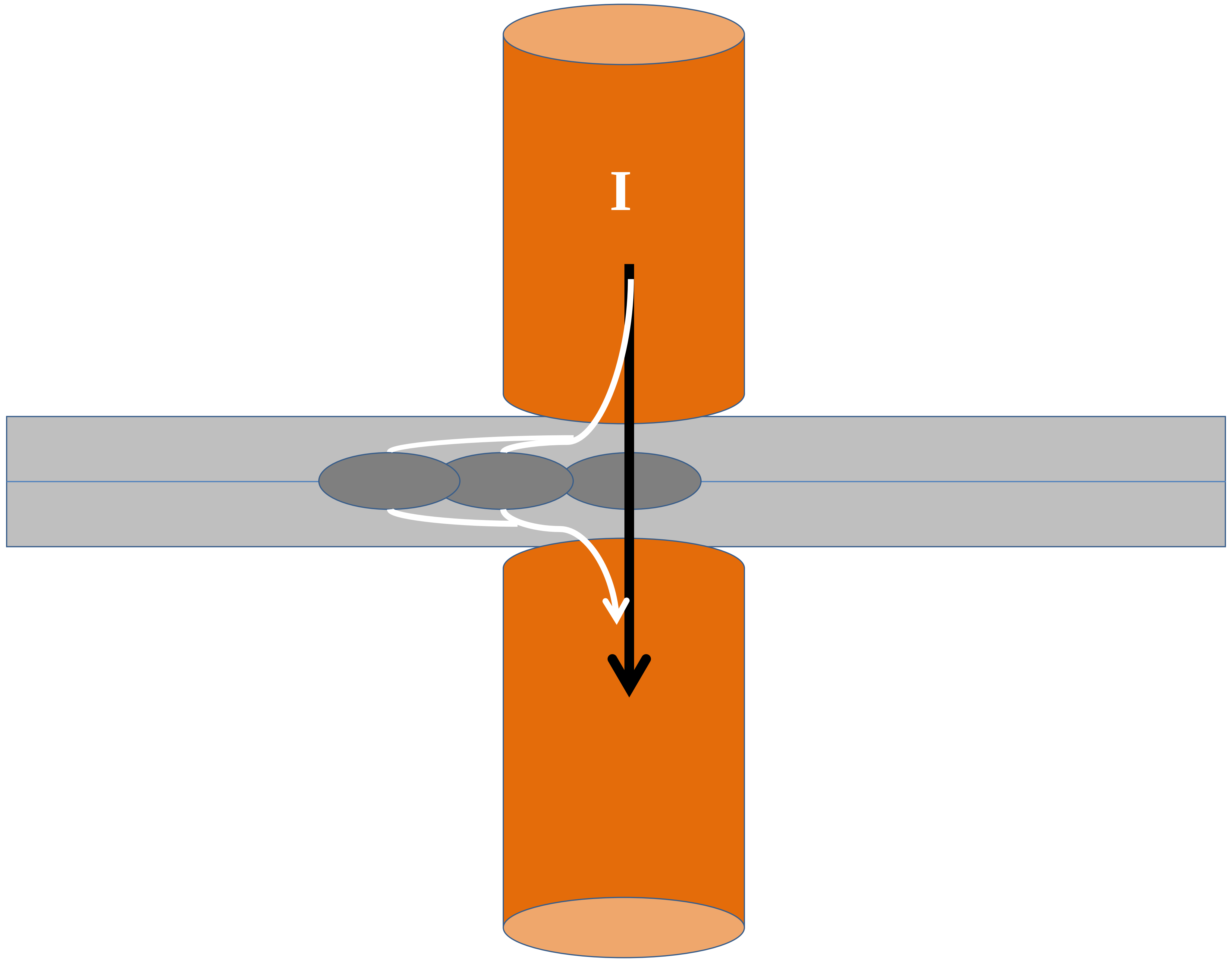
AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

2nd weld is smaller than 1st because some current shunts through 1st weld



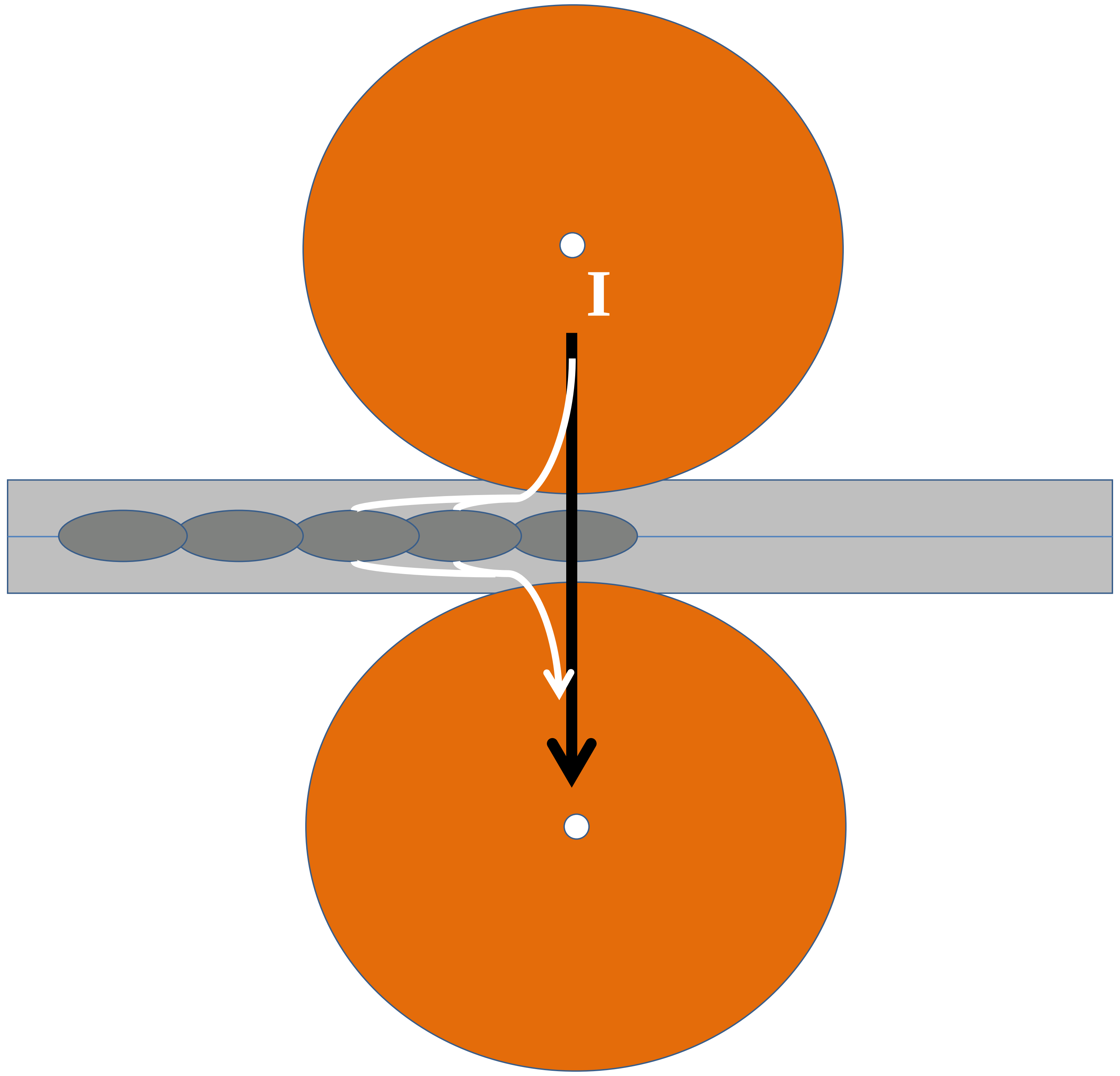
AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

3rd weld is smaller than 2nd because current shunts through 1st & 2nd welds



AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

Shunting makes welds hotter at start of seam



AWS D17.2/D17.2M:2013 Specification for Resistance Welding for Aerospace Applications

4.3.3 Jigs and Fixtures.

Where shunting cannot be avoided due to part design, the effects of shunting shall be factored into the production weld schedule and necessary adjustments made to ensure acceptable welds are produced.

Operations that make all of these welds with the same current setting:

— produce smaller nuggets than they really want throughout the entire length of the seam, in order to avoid having the first few welds on the seam be too hot and possibly expulse material,

Or…

— suffer from having the first few welds be too hot and expulse material, just so the rest of the welds in the seam are the size they want

Continuous Seam Welding

Wheel velocity is a major parameter of control, as significant as force and current

For a given applied force and current:

— Lower velocity causes hotter welds

— Higher velocity causes colder welds

Machine Stability

Velocity fluctuations:

— can be compensated for with adaptive control

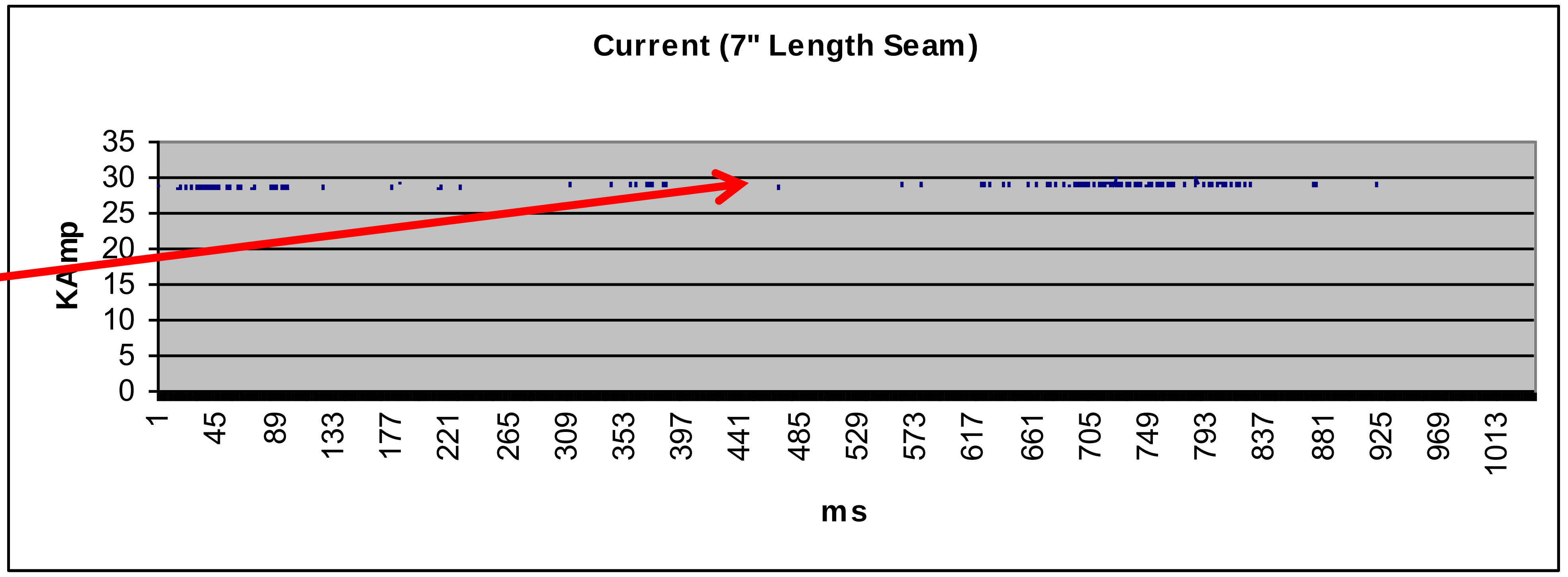
Force fluctuations:

— can be compensated for with adaptive control

Conductance/Resistance Process Monitoring

Current

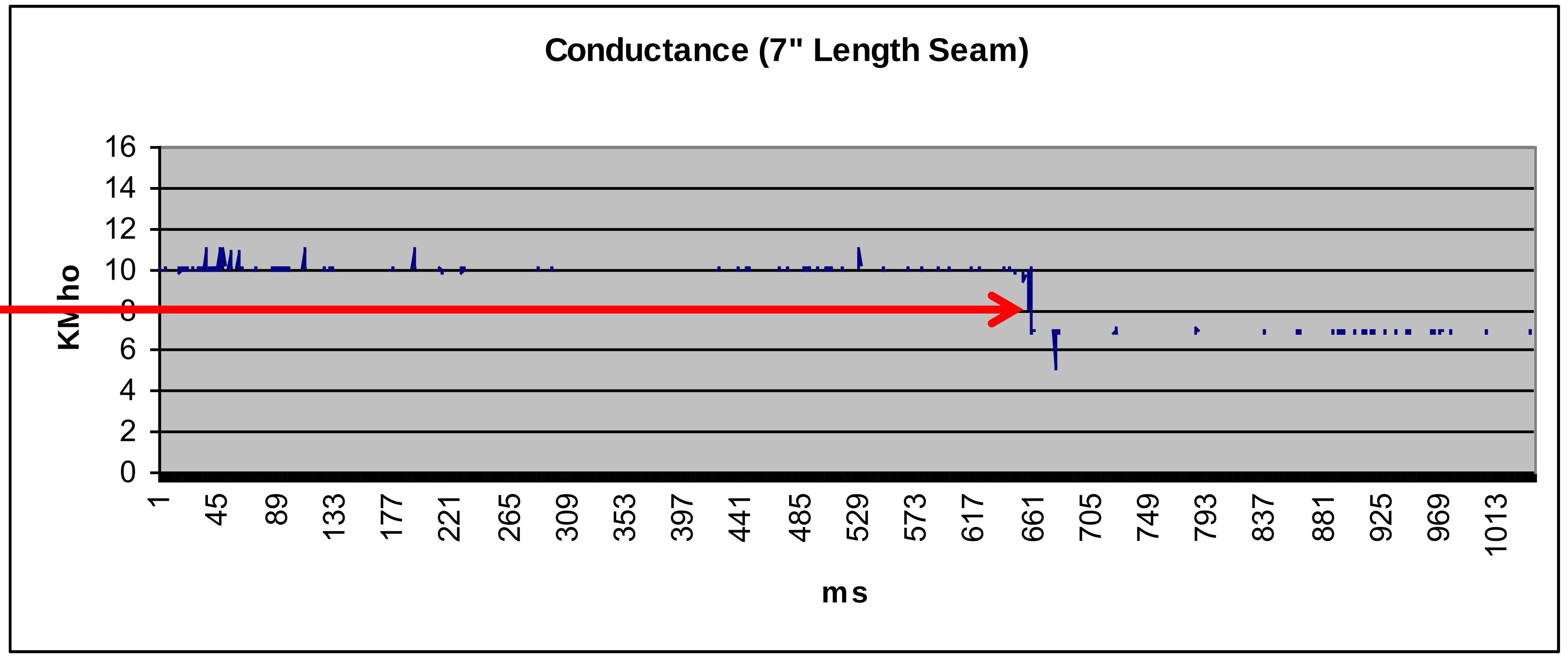
Current is consistently maintained at 29 KA over length of seam.



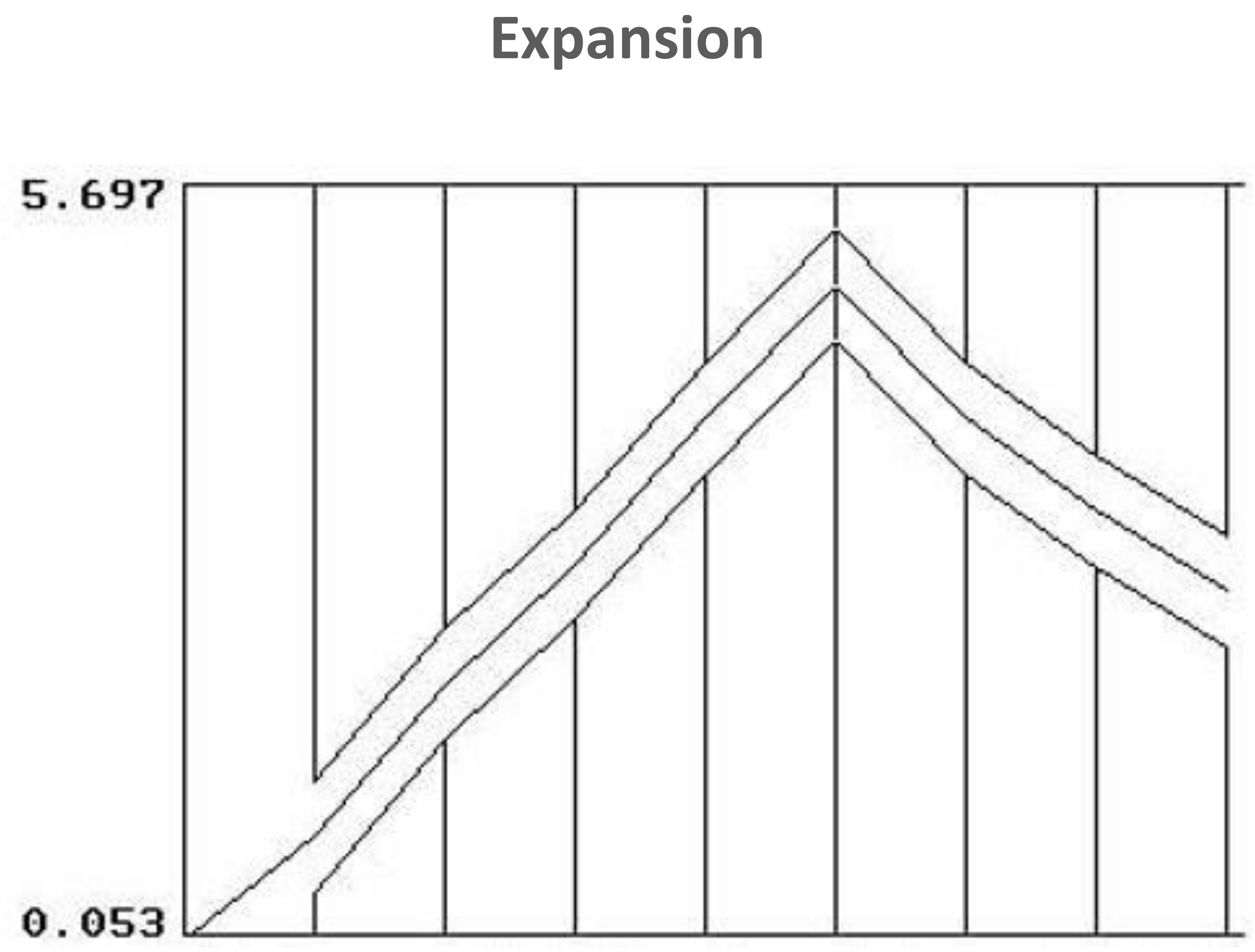
Conductance

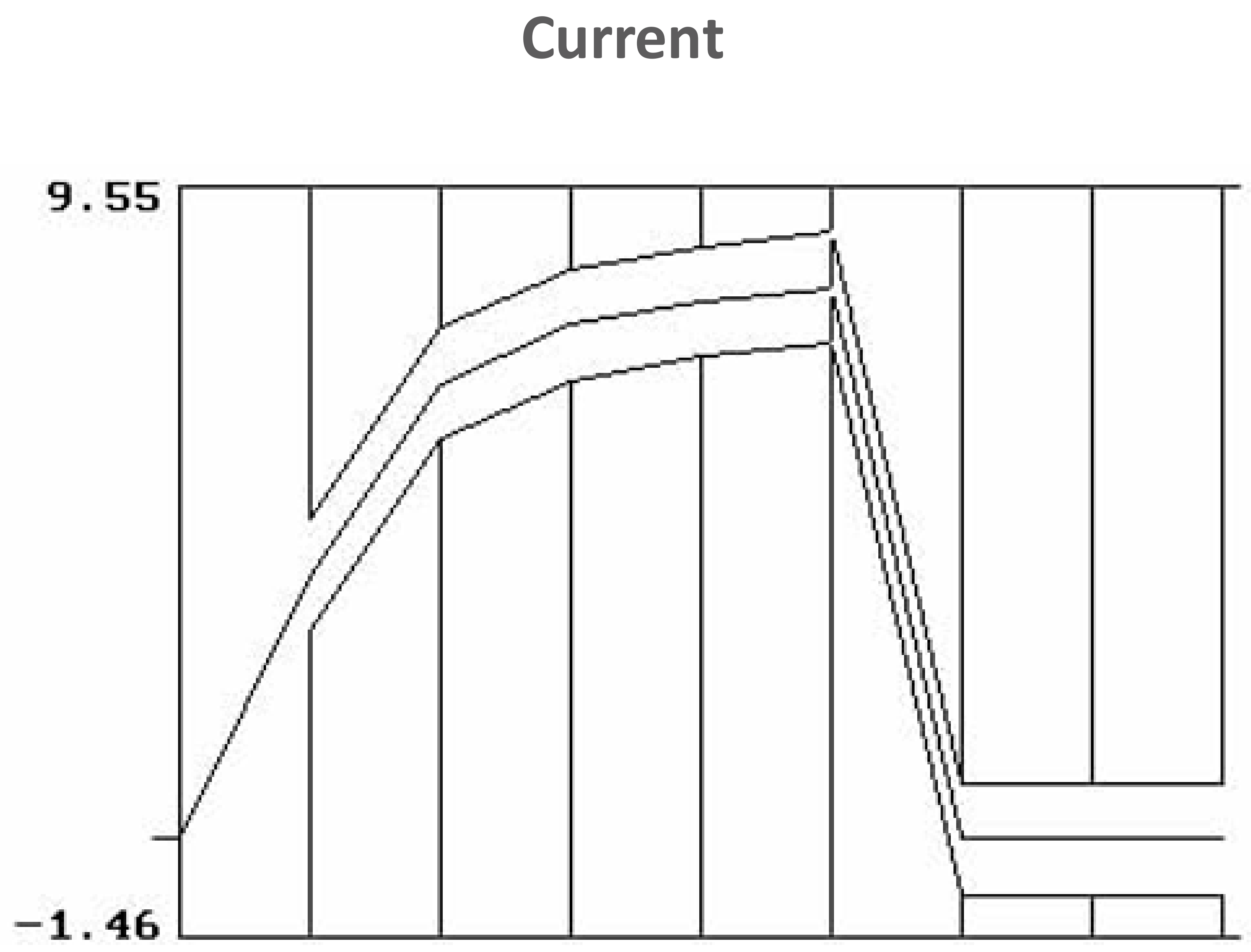
Conductance reveals 3.1 KMho drop after completing 4.45” of welding on seam.

Maintenance Required



Displacement Monitoring Detects Abnormal Ram Performance

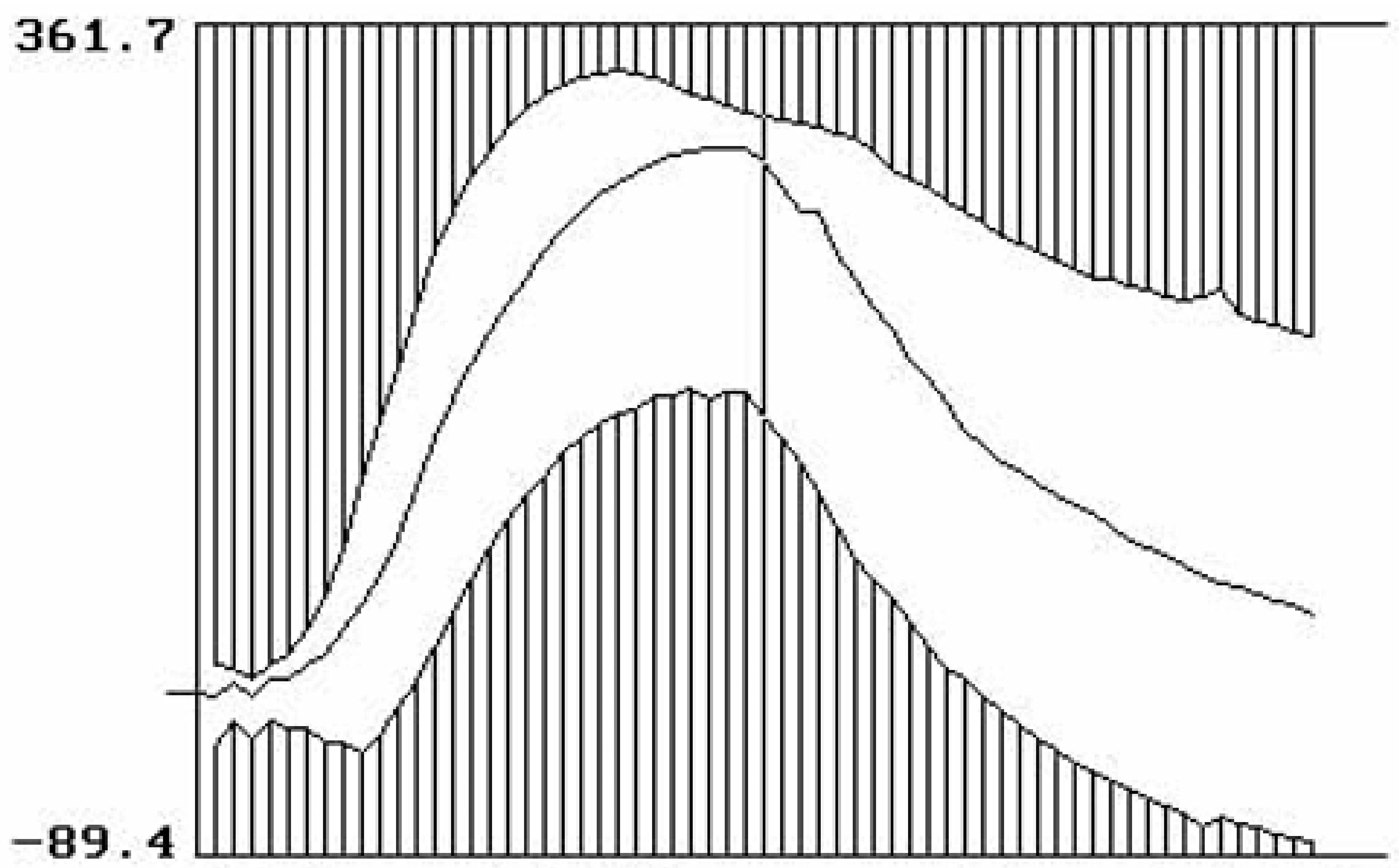




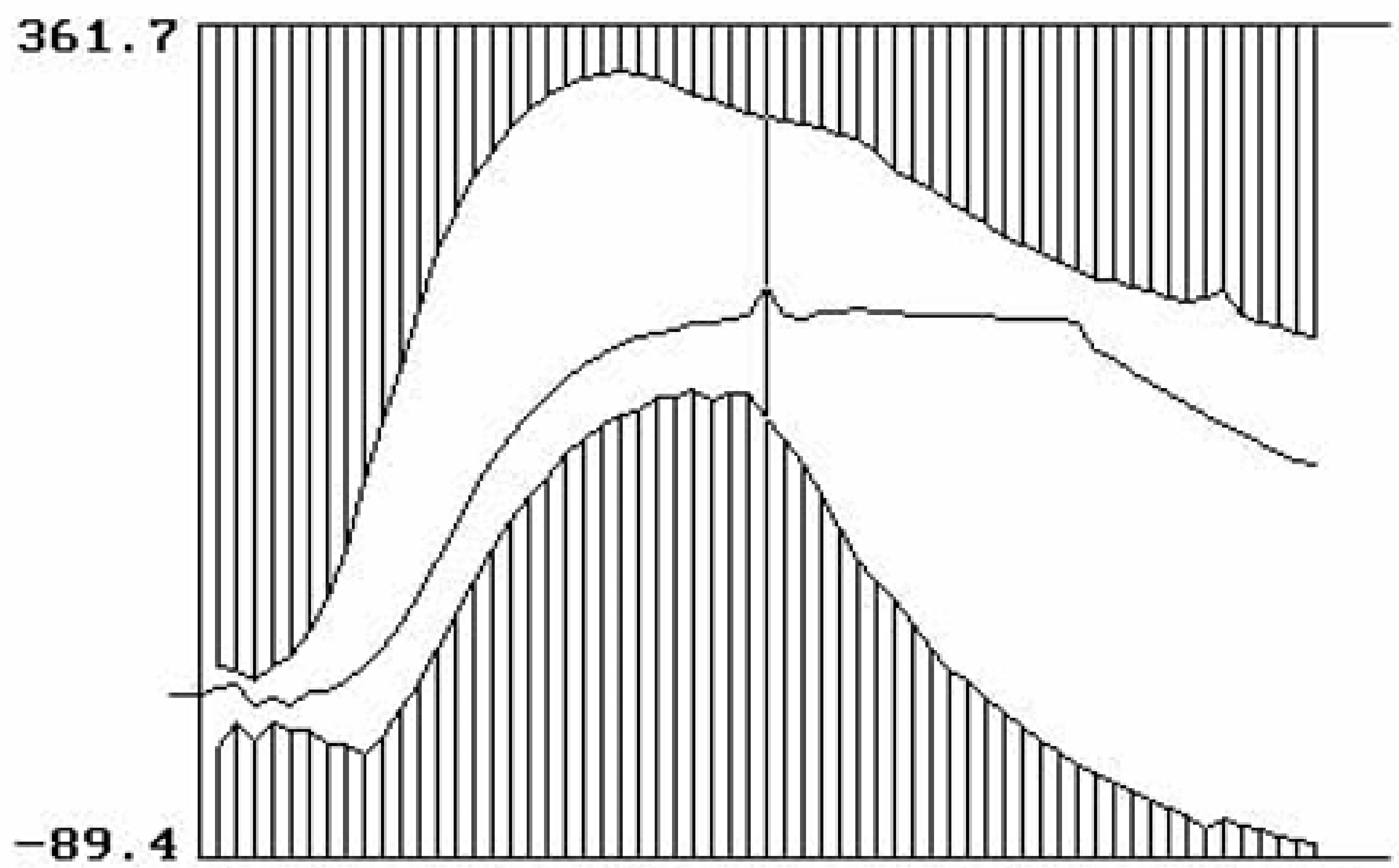
Properly performing ram is responsive to weld heating and cooling

Displacement Monitoring Detects Abnormal Ram Performance

Ram with high friction has sluggish response



Ram with excessive friction gets stuck during welding operation



Maintenance Required

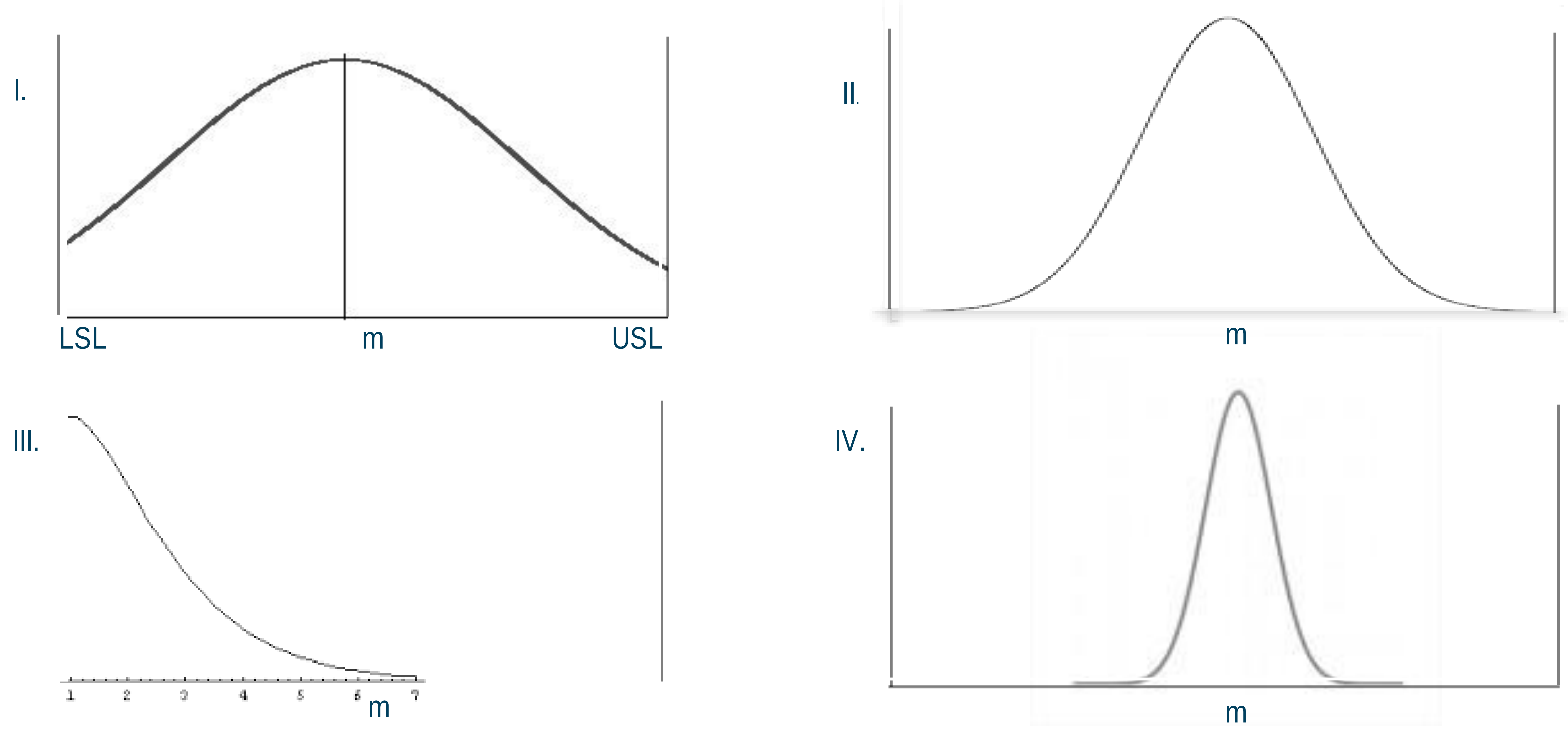
In-Process Machine Monitoring

4.3.4 Maintenance of Equipment.

For machine characteristics wherein the behavior of the machine can be monitored, and criteria exists for those monitored parameters that would trigger maintenance when required, such monitoring techniques may be employed in place of periodical machine inspection.

Process Characterization

y = Quality characteristic (Nominal the best)   m = The normal value



Suppose four factories, I. II. III. IV, are producing the same product under the same specification, and the outputs are as shown here…

Which factory would you choose for your welds?

MIL-SPEC Aluminum Welding Operation

Sample #	Shear Force
1	349
2	376
3	407
4	406
5	297
6	368
7	389
8	329
9	386
10	334
11	412
12	374
13	385
14	381
15	356
Mean	369.93
Sigma	32.06

0.016 material with 145 lb lower acceptance limit

Application of Consistent Heat Control Yields 7 Sigma Reliability

Process Capability = [369.93 – 145] / [3 * 32.06] = 2.34

Data supplied courtesy of Geater Machining & Manufacturing, Co.

Process Capability vs. Percent of Welds Outside of Tolerance Limits

Process Capability	Percent of Welds Outside of Tolerance Limits
0.50	13.4
0.75	2.4
0.94	0.50
1.00	0.27
1.30	0.0096
2.00	0.0000002

MIL-SPEC Aluminum Welding Operation

Sample #	Shear Force
1	401
2	332
3	405
4	402
5	357
6	400
7	384
8	404
9	395
10	385
11	389
12	366
13	383
14	366
15	380
Mean	383.27
Sigma	20.61

0.016 material with 145 lb lower acceptance limit

Adaptive Control Increases Reliability to 11.5 Sigma

Process Capability = [383.27 – 145] / [3 * 20.61] = 3.8

Data supplied courtesy of Geater Machining & Manufacturing, Co.

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Take Advantage of Clauses in the D17.2 MIL-SPEC for Resistance Welding