META-LAX® RESEARCH SUMMARY

SUMMARY OF RESEARCH DATA USING *META-LAX* TECHNOLOGY

1. U.S. DEPARTMENT OF ENERGY, 1989

"There is evidence that the Meta-Lax system is performing comparable to the thermal stress relief process on A36 carbon steel."

"The 4140 plates not sub-resonant [sub-harmonic] vibrated during welding were cracking at the weld crater at the end of each pass made. This did not occur when sub-resonant [sub-harmonic] vibrating. This could be very significant when welding high strength materials where there are weld starts and stops in the middle of a weld assembly."

Test plates, A36 (or 4140), being Meta-Lax Weld Conditioned (i.e. Meta-Lax DURING welding).

Test plates were restrained for up to 30 days.

Table 1. Weld Joint Strength 30 Days After Welding, A36 Material.

	PSI	MPa
Untreated:	45,000	310
Heat-Treat Stress Relieved	63,000	434
Preheated	69,000	476
***Meta-Lax* Stress Relief**	**89,200**	**615**
***Meta-Lax* Weld Conditioning**	**86,500**	**596**

Meta-Lax Stress Relieved weldments were 98% stronger than untreated and 41% stronger than heat treat stress relieved weldments. Meta-Lax Weld Conditioned weldments were 92% stronger than untreated and 25% stronger than preheated weldments.

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2. LMSC / RICHARD SKINNER, P.E., 1987 & 1993

"The findings demonstrate that the frequency [for vibration stress relief] is always in a sub-harmonic range." This mathematical study verifies what Bonal refers to as Meta-Lax Principle #1.

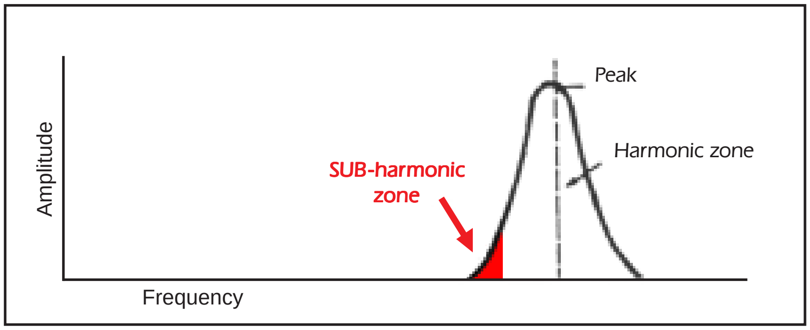


Figure 1. Meta-Lax Principle #1: The optimum frequency for stress relieving when using vibrational energy must correspond to the SUB-harmonic portion of the harmonic curve. Mr. Skinner mathematically verified that the sub-harmonic frequency was the optimum frequency for vibrational stress relief on the following materials (as examples):

1018 hot rolled steel	5083 aluminum	7075-T6 aluminum
1020 hot rolled steel	6061-T6 aluminum	6A1-4V titanium

3. UNIVERSITY OF CALIFORNIA - BERKELEY / WONG & JOHNSON, 1987

"The findings regarding the shift in natural frequency as a result of residual stress may provide a method for examining the effectiveness of stress relieving processes." This mathematical study verifies in two ways what Bonal refers to as Meta-Lax Principle #2. First, the natural [harmonic] frequency of a part, which has residual stress, is in an unnatural location. Second, the *"shifting"* phenomenon that occurs as the stress level is reduced can be used to *"examine the effectiveness of the stress relief process."*

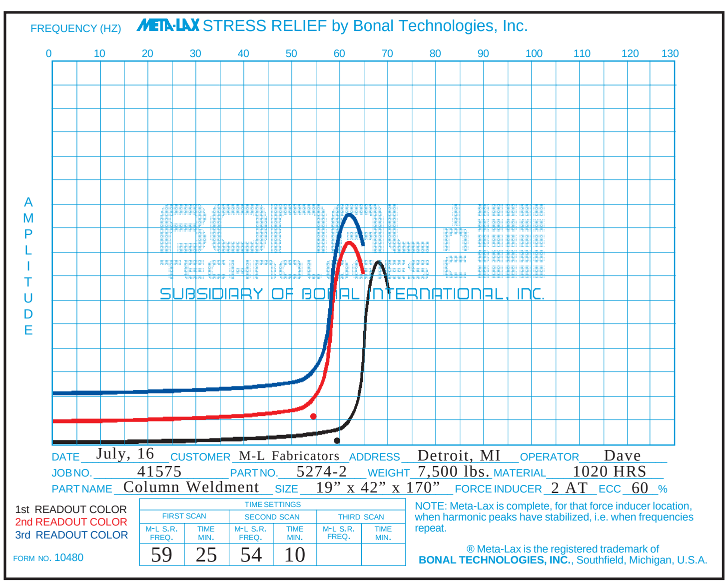


Figure 2. Meta-Lax Principle #2: The harmonic curve of a thermally stressed workpiece will shift and eventually stabilize in a new frequency location as the workpiece becomes stress relieved.

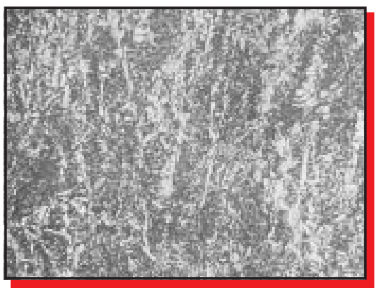
4. GRUMMAN AEROSPACE, 1988

Table 2. Strength Summary from 6061-T6 test plates.

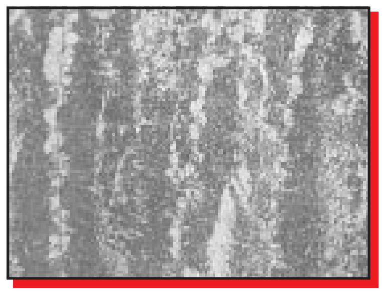
	Yield Strength	Ultimate Strength
***Meta-Lax* Weld Conditioning**	**71,000 psi**	**80,000 psi**
Heat Treat Stress Relief	60,000 psi	72,000 psi
Meta-Lax Weld Conditioned plates were 11-18% higher strength than heat treated plates.		

Meta-Lax Weld Conditioning of 6061-T6 test plates.

6061-T6 test plates after welding.



Photomicrograph of Meta-Lax stress relief during & after welding.



Normal weld metal following standard thermal stress relief.

Table 3. Distortion Summary of 6061-T6 Fixtures After Saw Cut.

	Distortion
***Meta-Lax* Weld Conditioning (-5)**	**0.161 inches**
Heat Treat Stress Relief (-7)	0.524 inches
Meta-Lax Weld Conditioned fixtures had 69% less distortion than heat treat stress relieved fixtures.	

Meta-Lax Weld Conditioning of aluminum fixtures.

Side-by-side comparison after saw cut.

Table 4. Distortion Summary for 6061-T6 Wing Supports After Machining.

	Distortion
***Meta-Lax* Stress Relief**	**0.002 inches**
Heat Treat Stress Relief	0.003 inches
Normal	0.029 inches
Meta-Lax Stress Relieved supports had 50% less distortion than heat treat stress relief. Meta-Lax Stress Relieved supports had 97% less distortion than untreated.	

Two 6061-T6 wing supports at inspection station.

Table 5. Distortion Summary After Welding 10-foot diameter A36 disks.

	Distortion
***Meta-Lax* Weld Conditioning**	**0.375 inches**
Normal	5.5 inches
Meta-Lax Weld Conditioned disk had 93% less distortion.	

Meta-Lax Weld Conditioning of 10 foot diameter A36 disk.

10 foot diameter disk after welding.

5. WATERVLIET ARSENAL/ALFRED UNIVERSITY, 1994

"We interpret these data to show that [Meta-Lax] treatment has completely eliminated the rejects due to distortion apparently caused by residual stresses. Evaluation of available data shows that, without [Meta-Lax], 12 of 18 barrels were rejected due to distortion." The barrels, 120mm mortars, were of 4135 forged steel.

Meta-Lax reduced scrap rate from 67% to 0%.

Nine mortar barrels being Meta-Lax Stress Relieved simultaneously.

6. CHARLES BRONSON, (Metallurgist and Instructor at LeTourneau University) 1974

"In evaluating all of the tests that we have made so far the evidence indicates that vibrating while welding [using Meta-Lax] and also after welding definitely results in less residual locked-in stresses that could be detrimental to the endurance of the welded structure while in service."

Table 6. Distortion Summary of N-20 Test Plates.

	Distortion
***Meta-Lax* Weld Conditioning**	**0.031 inch**
Normal Welding	0.375 inch
Meta-Lax Weld Conditioned plates had 92% less distortion.	

Table 7. Cracking Summary of N-30 Plates Welded to 4820 Shaft.

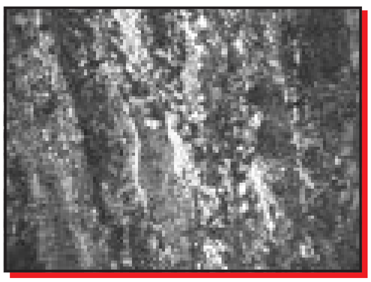
	Crack Length
***Meta-Lax* Weld Conditioning**	**0.1875 inches**
Normal Welding	11.750 inches
Meta-Lax Weld Conditioned plates had 98% less cracking.	

Table 8. Charpy Impact Value Summary from N-20 Plates.

	Charpy Impact Value (-50° F)
***Meta-Lax* Weld Conditioning**	**6.4 ft.-lbs.**
Normal Welding	3.6 ft.-lbs.
Meta-Lax Weld Conditioned plates had 77% higher impact value.	

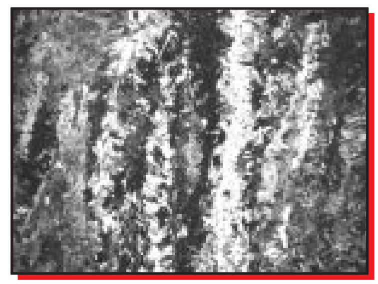
7. BONAL CORPORATION, 1984

"Using Meta-Lax stress relief during welding on two different setups resulted in grain refinement of the weld metal from both setups compared to the untreated weld."



Setup #1: Meta-Lax Weld Conditioning.

Setup #2: Meta-Lax Weld Conditioning.



Normal Weld Metal.

8. BONAL TECHNOLOGIES, 1996

Table 9. Distortion Summary on Plates after Heat Treating.

3 Each 1/2 x 3 x 48 inch - A36 Material	Distortion AFTER Heat Treating
***Meta-Lax* Treated Plates Before Heat Treating**	**0.0089 inch average**
Untreated Plates	0.023 inch average
Meta-Lax Stress Relieved plates had 69% less distortion than untreated plates.	

Six A36 test plates after grinding.

Table 10. Distortion Summary on Bars after Flame Hardening.

1.5 x 1.5 x 60 inches - 1045 Material	Distortion After Flame Hardening
***Meta-Lax* Treated Bars Before Flame Hardening**	**0.0110 inch average**
Untreated Bars	0.0155 inch average
Meta-Lax Stress Relieved bars had 29% less distortion after flame hardening than untreated bars.	

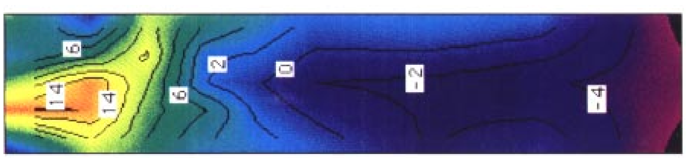
9. WAYNE STATE UNIVERSITY, 1982

Table 11. Ductility Summary of 1020 Plates.

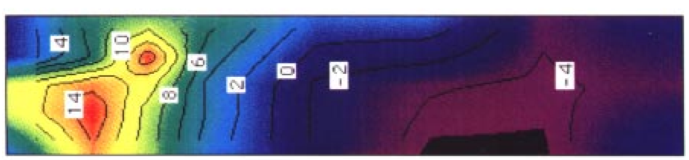
	Ductility Value
As Welded	5.4%
***Meta-Lax* Weld Conditioned**	**22.0%**
Heat Treat Stress Relieved	28.0%
Base Metal	32.0%
Meta-Lax Weld Conditioned plates were 307% more ductile than untreated plates. **Meta-Lax Weld Conditioned plates were 79% as high as the heat treat Stress Relieved plates yet without using any heat.**	

10. OAK RIDGE NATIONAL LAB, 1993

"On the basis of these residual stress measurements no degradation of mechanical properties from vibratory [Meta-Lax] treatment during welding is expected."



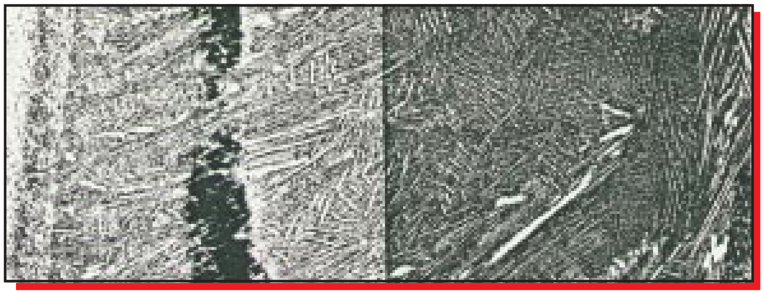
Meta-Lax Weld Conditioning



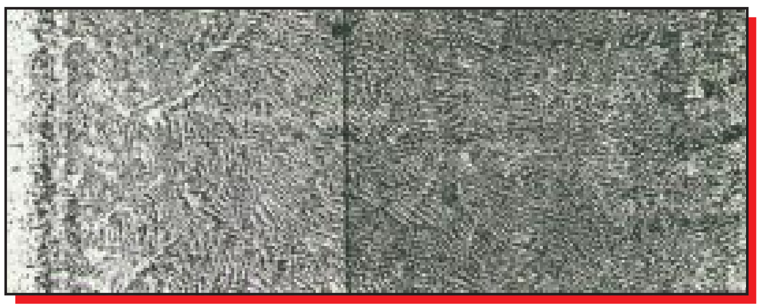
Normal

11. OHIO STATE UNIVERSITY, 1986

"Refinement occurred in the cupronickel alloy when vibrational waves were applied. The greatest refinement was obtained when 40% of the resonant peak frequency was induced to the base material during welding."



Top section of cupronickel, welded at 5 i.p.m. without vibration.



Top section of cupronickel, welded at 5 i.p.m. with vibration 40% of resonant peak.

12. SHOU UNIVERSITY, CHINA, 1998

"Residual stress in weld samples subject to [sub-harmonic] vibration is significantly reduced relative to samples either subjected to resonant vibration or not subjected to any vibration."

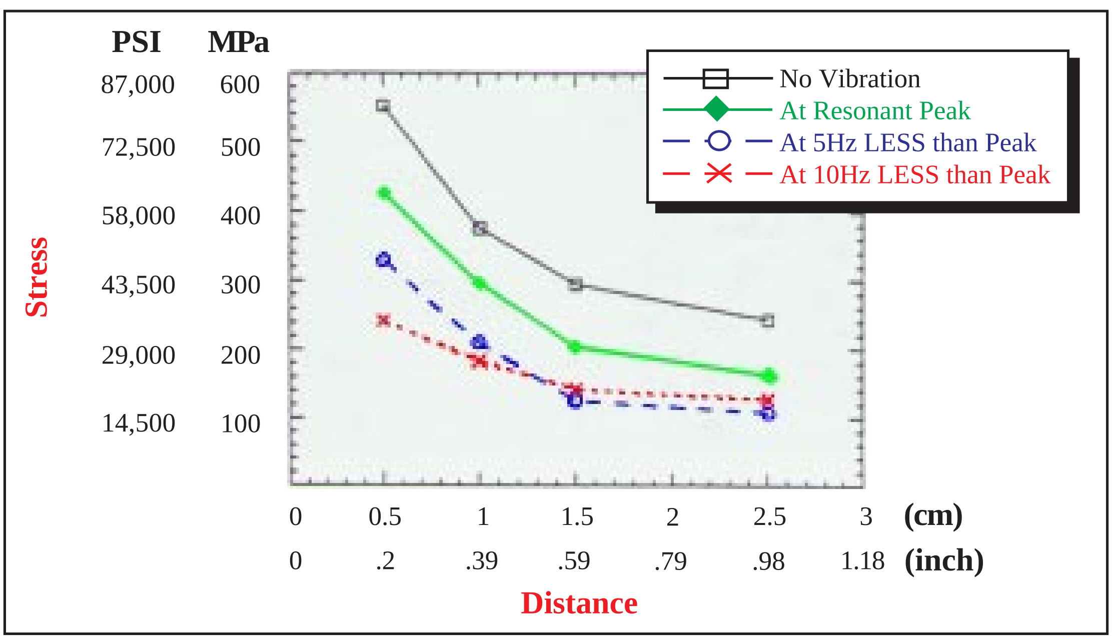


Figure 3. Residual stress distribution of weldments.