"FORMULA 62"
Vibratory Stress Relief Equipment

"FORMULA 62" Vibratory Stress Relief Equipment offers a number of advantages over the older thermal stress relieving technique:

- **The equipment is compact and portable, and can easily be moved to any location on the production floor for on-the-job stress relieving**
- **The investment cost is low, as are the operating and maintenance costs**
- **Short process time, ranging from 15 to 30 minutes per location depending on the weight and configuration of the component or fabricated structure**
- **Easy to use with no extensive operator instructions required**
- **Can be used on a wide variety of materials:**
  - **Components made of dissimilar materials (non-heat treatable)**
  - **Non-heat treatable alloys**
  - **Material with fine finish (ground, polished, etc.)**
- **There is no detrimental effect on the workpiece material(s)**
  - **Will not change mechanical properties**
  - **Will not change the metallurgy; structurally or chemically**
  - **Will not change the hardness**
  - **Produces a surface clean and free from discoloration, slag and scale**
- **Part tolerances can be held to limits impossible or impractical to achieve with thermal stress relieving methods**
- **Can be used during the fabrication process:**
  - **During and after welding**
  - **In between machining steps**

RESIDUAL STRESSES DEFINED

One of the major problems encountered in the metalworking industry is the build up of stresses that cause distortion and loss of dimensional stability. Anyone involved in metalworking, whether they are a steel fabricator, manufacturer of machine tools or mold maker, can experience problems holding dimensional tolerances in their workpieces.

The technical definition of residual stress is any stress in an elastic body that is free from external force or restraint and temperature gradients (changes). A common cause of residual stress is an incompatibility between adjacent regions of the metal that can distort neighboring regions.

Stresses cause distortion in metal when they are unequal. Heavy stresses on one side of a piece of metal will cause movement or distortion. If the stresses are the same all through the metal, even heavy stresses will not cause movement. The higher the imbalance of stresses, the greater the movement. If the imbalance is high enough, the grains become permanently distorted and the workpiece cannot be returned to its previous condition by stress relieving.

In residual stress there are two components: tension and compression. The laws of physics and mathematics require a balance between compression magnitude and tension magnitude. Unfortunately, metalworking does not produce a uniform balance.

In the metalworking field, the goal is to produce a good metal component or structure with low residual stress, and therefore, requires a program for stress relief, or the reduction of residual stress, in order prevent damage to the metal.

A simpler explanation involves you and your body during sports activities. If you were playing tennis and you developed a very bad cramp or strain in a leg muscle, this is similar to residual stress. And, if you were to continue to play, without reducing the residual stress (cramp or strain), you could severely and possibly permanently damage the muscle. If, however you were to massage the muscle, allowing it to relax, you could continue to play and finish the game. This is an example of a stress relief program.

Residual stresses are introduced into many metal structures and components during their fabrication - in castings through contraction forces setup within the casting as it solidifies, in metalforming because of the elastic characteristics of the metal, in metalcutting because of the shearing action which is accompanied by deformation, and in welding, which can produce particularly severe residual stress, as the metal expands and contracts, due to changes in temperature.

Although difficult to calculate and measure, residual stress left untreated can make itself known in a number of undesirable ways over time, often causing parts to prematurely weaken or crack, to deform or warp, and often

undermining the integrity of key welds. And, leading to a shorter life span of otherwise well-made components. With today's strict tolerance requirements, the need for stress relief to achieve dimensional stability and freedom from distortion is becoming increasingly important.

TREATMENT OF RESIDUAL STRESSES

To treat the crystal lattice structure, energy must be introduced into the metal to allow the atoms to move in such a way as to reduce these stresses. While the thermal stress relief method is commonly known, it is not the only means by which stresses can be reduced.

In the thermal process, high temperature produces lower residual stress. This type of stress relief, while usually effective, has several shortcomings and limitations. The cost is high, the process is time consuming and frequently it results in deterioration of material properties, which may be caused by using the wrong recipe for heating, temperature maintenance, and final cooling. Its use is also restricted to homogenous structures. The fabricator may also experience other indirect costs if a suitable oven is not available on site resulting in transportation and other handling costs as well as an additional loss of time.

In addition, many in the metalworking industry have also expressed their desire for facilities to reduce stresses as needed during the fabrication process. This may be cost prohibitive and not logistically possible with the thermal stress relief process.

A part can also be stress relieved by allowing it to age outdoors. Here, the necessary energy to realign the crystal lattice structure is supplied by small, natural ground movements and normal temperature fluctuations. However, this process is uncontrollable and it is hard to determine at what moment stresses have reduced sufficiently to allow work to progress satisfactorily. And, in this aging process, the stress level is reduced more rapidly during the warmer climates, and less during the colder climates. Who wants to wait for a year or more for stress to dissipate?

The vibratory method introduces energy into the workpiece by means of vibrations. To the stressed atomic lattice, there is no difference between thermal energy and energy introduced by vibrations. This applied energy realigns the lattice to relieve stress and stabilize the part without distortion.

This process can be used to relieve stresses caused by machining, milling, grinding, punching, broaching, stamping, boring, planing, cutting, forging and welding. It is particularly useful for very large structures, where thermal stress relieving would be costly or impossible and for precision machined parts to eliminate metal distortions that could hinder holding close tolerances.

THE “FORMULA 62” VIBRATORY STRESS RELIEF EQUIPMENT AND PROCESS

The Stress Relief Engineering Company first developed, and for more than 35 years, refined the use of a highly-effective, non-thermal, resonance based method of vibratory stress relief. Now, a widely-accepted industry standard, the "FORMULA 62" easy-to-use process makes it possible to improve dimensional control and increase yield strength, without any loss of fatigue strength.

The "FORMULA 62" process introduces low frequency, high amplitude vibrations, for a short period of time based on the weight of the workpiece. This process relieves the residual stresses in metal workpieces and weldments without distorting or changing the tensile strength, yield point or fatigue strength of the workpiece. This allows the residual stresses to be reduced to a much lower level where static equilibrium is restored.

Resonant vibrations have been found to be the most effective means for reducing residual stresses by vibration. The resonant frequency vibration method has a more pronounced stress redistribution compared to the subresonant, or subharmonic, frequency methods. It is the low frequency vibrations that are the carrier of high amplitude energy which is very efficient in significantly reducing peak residual stresses in the metal workpieces and weldments.

APPLYING “FORMULA 62”

"FORMULA 62" consists of a variable speed, heavy duty vibrator which is clamped to the workpiece, and an electronic console, housed in a portable cabinet that can be wheeled to any part of the production floor.

Also clamped to the workpiece is an accelerometer that senses the vibrations and transmits a signal by cable to an electronic circuit in the console. The resonant point of the workpiece is then determined and displayed on a panel mounted meter. On chart recording units, a graph can be produced showing the adjustment procedure while establishing the resonant point.

The resonant point can be determined by varying the speed of the vibrator until the desired amplitude is reached. Two minutes is the average time required to reach resonance frequency. When the resonant frequency is reached, the workpiece is vibrated for a period of time which is based on weight per each application. Treatment time can range from 10 minutes to an hour or more, depending on the size of the workpiece. On very large, very long or open space frame type structures, "FORMULA 62" may need to be applied at several locations which does require more time. Workpieces can be vibrated for longer periods of time without suffering any fatigue damage or loss of tensile strength.

"FORMULA 62" can also be run in the automatic mode, where the vibrator unit will run for 15 minutes in three different cycles of selected speed, each cycle for five minutes. This is sufficient for stabilizing a workpiece up to 10 tons. For workpieces over 10 tons, two consecutive 15 minute periods may be used.

Two simple rules that must be followed for all applications are:

- isolate the workpiece, as much as possible, so it is free to vibrate;
- the vibrator unit must be directly connected to the workpiece in order to fully transfer the vibration energy into the workpiece.

The "FORMULA 62" process can be used on a wide range of ferrous and non-ferrous metals, including carbon steels, stainless steel, aluminum, cast iron, manganese, and on a wide variety of shapes. Sizes range from small castings, shafts and

gears to very large welded and machined fabrications that are too large for thermal treatment.

For small parts, precision parts and odd-shaped castings and weldments, SRE makes available the "Loadmaster 2000 Vibration Table". The table has a fully adjustable air-lift suspension, for excellent isolation, that operates on any shop air supply. The vibration table makes it possible to stress relieve molds, die sets, small precision engineered workpieces and to treat numerous parts at one time.

LIMITATIONS OF "FORMULA 62"

There are limitations to the "FORMULA 62" Vibratory Stress Relief process, as with any metalworking process. "FORMULA 62" is not as effective on cold rolled, extruded, strain hardened, cold worked and precipitation hardened materials. Very small items in large quantities may be more easily treated thermally in batches, unless the thermal process itself would harm the workpieces. The vibratory process is used solely for relieving residual stresses in metals and does not anneal, normalize or temper, or supplant any other type of heat treatment (including post weld heat treatment). The vibratory process does not change the mechanical or metallurgical properties of the material. Lastly, "FORMULA 62" cannot prevent or eliminate distortion, warping or buckling due to effects of heat and will not flatten or straighten warped, distorted or buckled materials.

One of the more important benefits of using "FORMULA 62" is the ability to stress relieve parts at any point in the manufacturing process such as after rough machining, boring or grinding.

For welded fabrications, stress relieving can be performed during welding which is very helpful in preventing residual stress build up that can cause weld cracking or distortion of some sections. "FORMULA 62" is most compatible with SMAW, GMA and GTAW welding processes. Other welding practices may present formidable logistical problems.

Because welding produces changes in temperature in a relatively short period of time, residual stresses are more dynamically active in the workpiece which may require stress relief during welding or immediately after welding. Since large magnitude tensile residual stresses can reduce the fatigue life of welded workpieces, "FORMULA 62" can easily be used to stress relieve these workpieces.

DETERMINING STRESS RELIEF

A basic question often arises as to how one can determine when stresses have been reduced. Evaluating residual stress fields after treatment by thermal or vibratory methods is equally difficult and expensive.

One of the best methods for measuring residual stress is the X-Ray Diffraction method, which is generally reserved for laboratory use due to the alignment requirements needed for accurate measurement.

Residual stress fields are complex and cover a rather broad area. Within the area of observation, there are both tensile and compressive residual stresses having various magnitudes. A stress relieving process causes a redistribution of these stress levels in order to balance the stress energy between tensile and compressive zones, restoring equilibrium to the region.

Therefore, one cannot measure just one point on a structure, observe a value, and declare that the workpiece is stress relieved. Extensive mapping of a field and statistical averaging of the results would be needed before the results would be obvious. For this reason, single point or other measurements are not made on workpieces stress relieved by the thermal or vibratory process, before or after treatment.

Quite simply, there is no simple, inexpensive way to measure stresses after any treatment process. At best, one can only rely upon following the recipe for treatment correctly, whether it is so many degrees per hour per inch of thickness as in the thermal process, or so many minutes of vibration based on the weight of the workpiece in the vibratory method. When properly followed, the results using either method will be satisfactory.

Since dimensional stability is usually the determining factor for acceptance, workpieces that remain dimensionally stable after treatment are considered to be satisfactorily stress relieved.

CLARIFICATION OF CODE FOR THERMAL AND VIBRATORY STRESS RELIEVING

Because high temperature can severally damage metals, it needs to be controlled and applied up to what is known as the critical temperature where phase transformations or other undesirable metallurgical changes take place. This is the basis for code existence; to go far enough, but through regulation of the applied temperature, not cause damage. Different materials require different temperatures. Different thickness requires different soaking periods. In essence, the recipe is manipulated so as not to damage the goods.

Since heat treatment can be arbitrary and capricious at times, it is not at all unusual for some thermal treatments to be conducted at 1/2 to 3/4 of the actual temperature called out because of the fear that the part will be damaged. And, as is typically the case, the thermal treatment is called out only once during the manufacturing chain of events which does not take into consideration the stress build up that occurs during fabrication, which is long before the thermal treatment is to take place.

Therefore, code required thermal stress relief treatments are not an absolute by which other stress relief methods can be compared. The actual detail given in code specification manuals is vague and even goes so far as to not recommend heat for certain types and grades of material. For example: AWS D1.1 does not recommend thermal treatment of A514, A517, A709 or Grade 100 material. Other carbon or low alloy steels may undergo undesirable changes in the microstructure, causing a deterioration of mechanical properties, cracking, or both. Additional consideration must be given to possible distortion, oxidation, loss of corrosion resistance or intergranular cracking.

In many situations, vibratory stress relieving can be used as a much more cost effective replacement to the thermal method when that thermal process is used solely to promote dimensional stability of the part for alignment purposes, surface integrity or service conditions.

Because there are so many factors involved, **"FORMULA 62"** non-thermal vibratory stress relief is not designed to be a wholesale substitute for code requirements. Before one can decide if vibratory stress relief can be used as a replacement for thermal stress relief treatment, the following should be considered:

1. Whether or not the thermal process is required to reduce residual stress to it's lowest possible level and to provide a homogenous base metal and weld metal.

2. Whether or not the thermal process was selected for no other reason than the fact that "this is how we've always done it"!

3. Or, that no stress relieving is being done because of the fear of potentially damaging the material or it's surface conditions which would be the case thermally.

The last two situations present a clear opportunity to use the vibratory method instead of heat. This would provide a more cost effective solution when compared to the direct and indirect cost of the thermal process.

Currently in the U.S.A., it is becoming more common to find several recommendations as to which method is to be used for stress relieving. In specifications written by some U.S. governmental agencies, one will find references to stress relieve some components according to A.S.M.E. Section VIII, A.W.S. D.1.1 and others to be treated specifically by "FORMULA 62". Some specifications actually contain "FORMULA 62" product brand name and Stress Relief Engineering Co. as the source. Example: U.S. Department of the Interior specifications for dam gates and other components.

In conclusion, "FORMULA 62" is not designed to be a substitute for all thermal "stress relief" practices, although it is often approved to replace the thermal method when elective on the part of the fabricator. In some cases, it is highly recommended to use the thermal method and Stress Relief Engineering Company strongly advises it for nuclear, pressure vessel, power generation and petrochemical applications. In these cases the costs are outweighed by the benefits. However, there is nothing in the codes that prohibits a fabricator from using vibratory stress relieving as an elective procedure, specifcally during the manufacturing process when dimensional stability is an important issue, provided that the call out of the code is followed and effected properly.

STRESS RELIEF ENGINEERING COMPANY