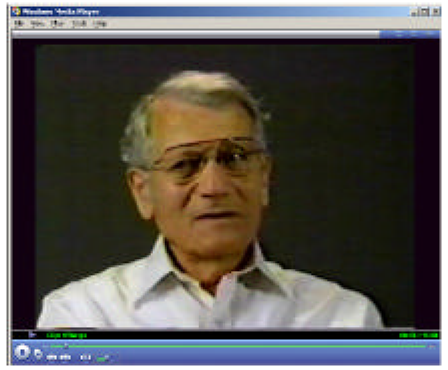
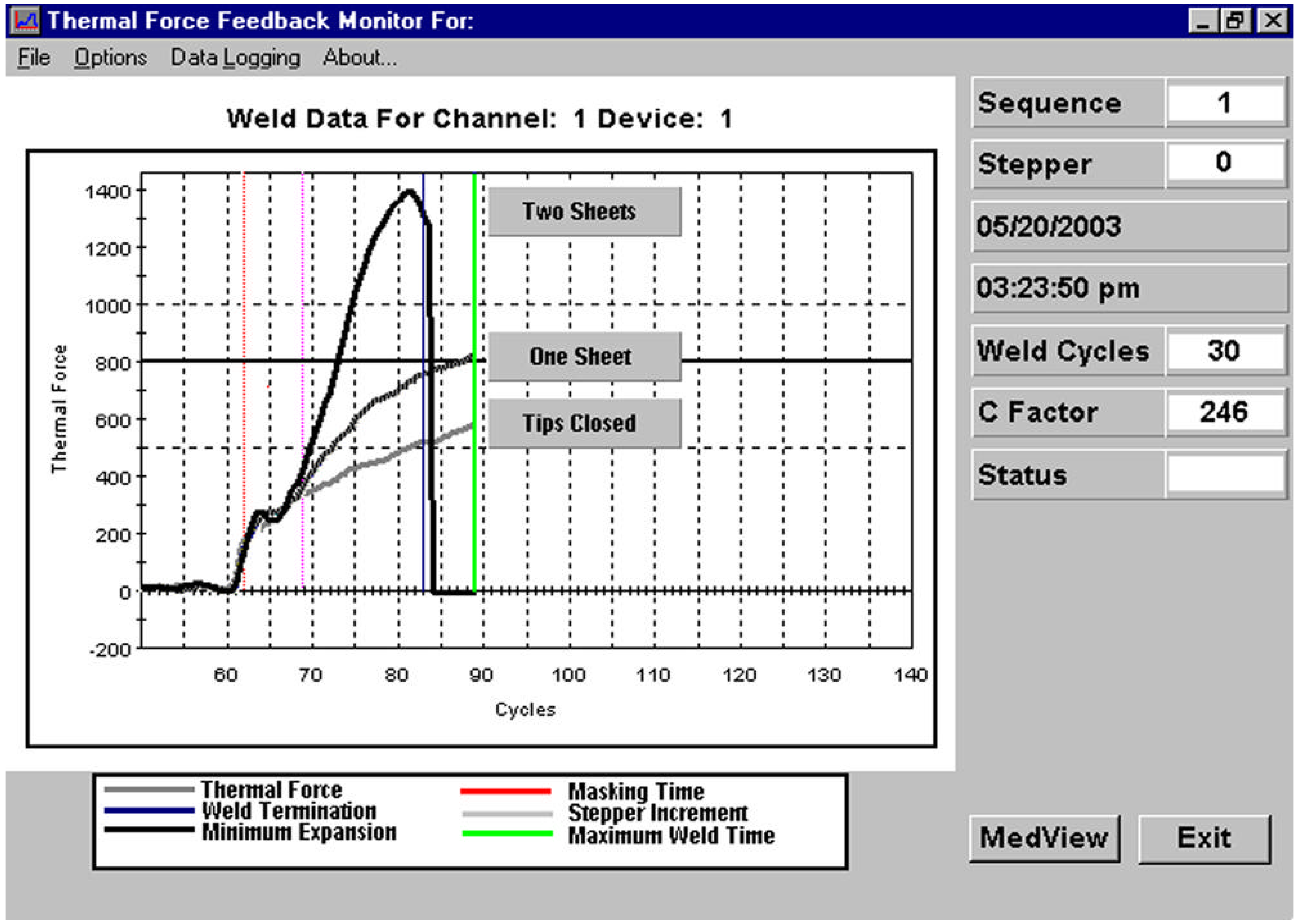


Listen to the Inventor:

A video interview of Mr. Ariel Stiebel is available on-line at http://www.weldtechcorp.com under the "Processes & Applications" tab.

This video dates back to the early 1990s however the principles discussed in the interview still apply today. With the advent of servo welding guns, more applications will become candidates for TFF systems.

Listen to this knowledgeable speaker concerning the reasons why TFF is by far the best method for determining if a weld is good while it is being processed.



The chart above is the observed thermal forces detected under three different conditions of which two does not produce a weld. When you close the weld gun tip-to-tip without any metal, there will be thermal expansion that creates increased forces on a braking gun system. The increase in force rises almost linearly. A similar observation is observed when one puts only one sheet thickness between the electrodes. The force gradually rises. When there are two sheets of metal and a weld is produced, we observe the classible TFF signal response as described in the inside of this document.

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WTC products are supported with parts, service and training from ITS

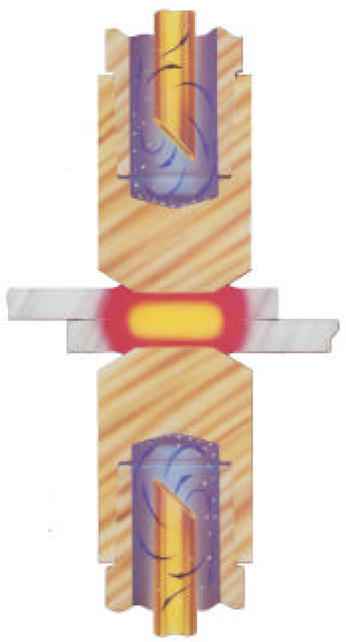
Welding Technology Corporation

Adapting to Welding Excellence!

Thermal Force Feedback (TFF) ... for resistance welding

Thermal Force Feedback is an innovative method for assuring quality resistance spot welds for the most demanding applications. We can "feel" the weld grow right in between the electrode tips and let you know if the weld is good. The concept is simple yet very rugged and is most applicable for requirements outside the welding lab right onto your factory floor.

Good Weld!



The weld control is monitoring welding electrode force each half cycle while the weld nugget is being produced.

Thermal expansion caused by the growing weld nugget will be felt by the welding gun as "Thermal Forces". This will indicate to the controller whether sufficient weld nugget growth has been achieved.

Thermal force monitoring is a method of observation that is clearly better than either micro-displacement measures of welding electrodes or complex methods and apparatus of ultrasonic detection systems.

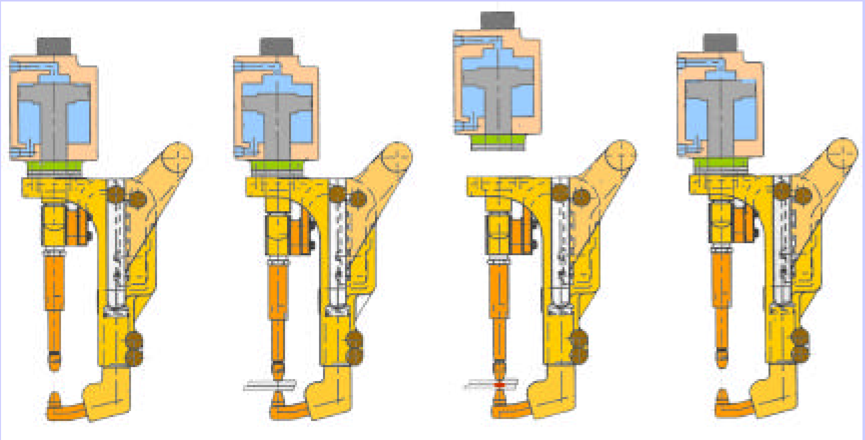
- Performs quality welds with assurance
- Reduces weld cycle times
- Increases welding electrode life
- Eliminate destructive testing
- Good for Dual Phase metals that can not be chisel tested
- Most advanced Closed Loop system available today!

The TFF feature is protected under the following US patents:
5,789,719; 5,504,297; 5,254,828; 5,111,020 and 4,419,558.
Other patents are pending.

Easier than linear displacement or ultrasonic measurements

Containing the Weld Using a Uni-Directional Blocking Gun

This series of drawings illustrates the concept of a uni-directional blocking welding gun that is used for Thermal Force Feedback systems. Stage 1 is starting position ready for the introduction of the work piece. Stage 2 involves the movement of the welding electrodes to the work pieces to work up to a stable welding force.

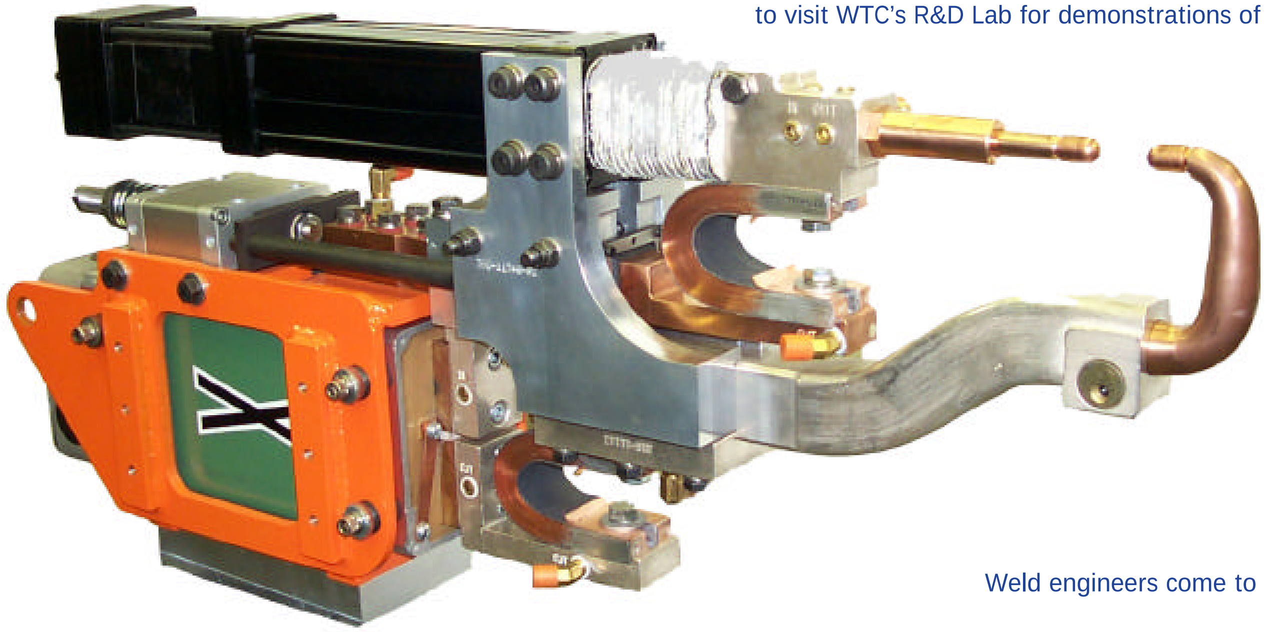


1 2 3 4

Once the electrodes have stabilized to a proper welding force, the blocking operation takes place (stage 3) *as if the cylinder is no longer part of the system*. This means that the electrodes can not move away from the weld or back into the cylinder. The blocking will create a force ring along the perimeter of the welding gun. In that force ring includes the formation of the weld nugget. Electrodes can however continue to move towards each other. Forward motion will occur during corrections of part fit-up conditions and during the weld indentation period. After the weld is made, the braking is removed and the electrodes are retracted (stage 4).

Electric Servo Welding Gun

Welding Technology Corporation invites welding engineers to make an appointment to visit WTC's R&D Lab for demonstrations of the Thermal Force Feedback System.

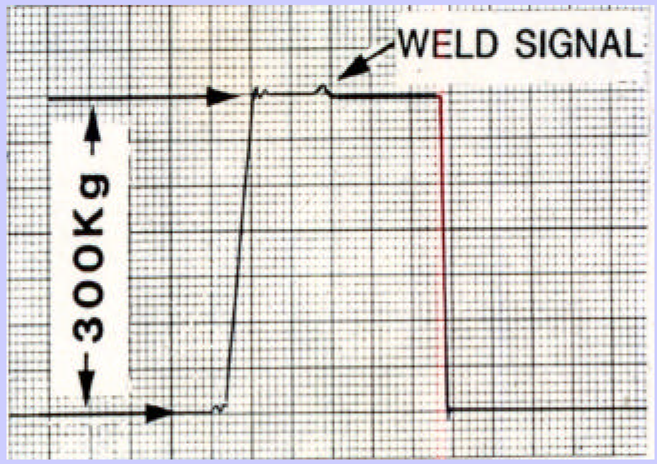


Patent # 6,596,958 issued for welding gun shown above.

Weld engineers come to ***WTC*** … ***W**hen* ***T**echnology* ***C**ounts!*

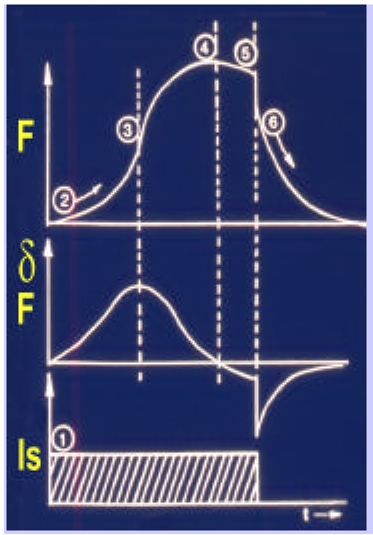
An electric servo actuated welding gun as shown here must be robust in order to transfer the TFF signals to the control. The algorithm for controlling the servo must abide by TFF rules so that the electrodes will not be allowed to back up while weld nugget expansion occurs.

Evidence of Thermal Forces



A noticeable increase in welding force is detected when welding current flows. The reason for this is that the heat that creates a welding nugget causes thermal expansion in the metal.

When the cylinder is prevented from backing away from the weld, the change of force caused by thermal expansion is magnified.



Expanded View of the Thermal Force Signal

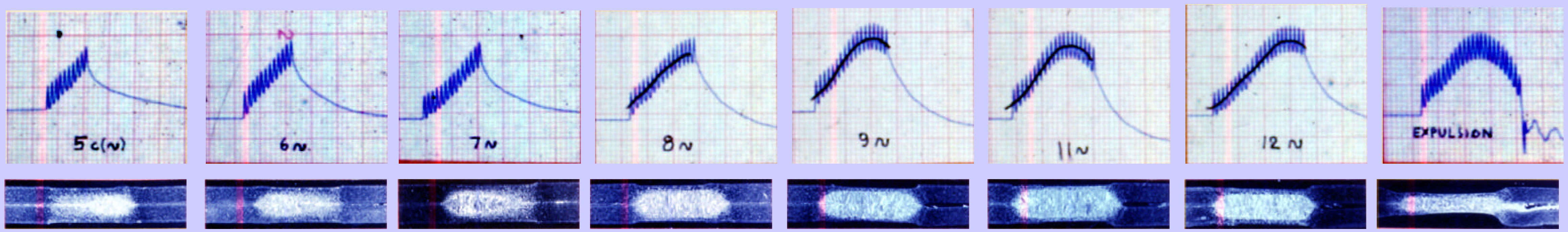
Monitoring the signal resulting from the thermal expansion of the weld nugget, we get a clear picture of the growth of the welding nugget. As soon as (1) weld current begins to flow as shown in graph "Is", we begin to see a rise of "thermal force" (2) as shown in graph "F". The rate of change in force is shown in graph "δF".

Thermal force increases at a rapid rate until an inflection point (3) where the rate of change begins to diminish. Thermal force is maximized when thermal expansion no longer occurs (4). This is where the rate of change of thermal force is nul as shown in "δF".

When weld indentation period begins, the thermal forces begin to drop (5). At this point, the rate of change as shown in "δF" becomes negative.

Once it has been determined that the weld nugget has maximized and that indentation has begun, the flow of welding current is terminated (6) and the system will identify a "Good Weld". If the signal does not behave in this classic form, the system will identify a suspected "Bad Weld".

This series of individual welds show the progression of weld nugget formation with the corresponding thermal forces observed on a welding gun equiped with back motion restraint. All the welds shown are made on two sheets of 1mm SAE 1010 steel with an initial electrode force of 330 Kg and 9000 amperes of welding current. Weld times were fixed as shown on the graphs. Notice that the weld samples that use 9, 11, or 12 cycles have indications of a maximized thermal expansion with evidence of weld indentation. Welding futher towards expulsion reveals severe and sudden drop of thermal expansion. The TFF system is designed to halt the current at the proper welding time.



Signal shown is from a load cell mounted on a TFF welding gun equiped with braking system. This was monitored with a digital oscilloscope and traced on graph paper.

This series of weld show completion at the 9th weld cycle. Going into expulsion reduces weld quality, uses more cycle time, and creates premature damages to the welding electrodes.

Expulsion as shown in the last sample to the right will immensely weaken the weld joint since much of the base metal is gone. Weld current must stop prior to expulsion as ensured by the TFF method.