Insta-Plug™

by

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Author's Note: This paper is prepared in response to a request from DLH Enterprises to provide a descriptive summary of the new "Insta-Plug™" product and its performance characteristics. After reviewing the material properties, method of production and installation, mechanical tests, and finite element analysis results, I have prepared the following paper on the present status of the product. In addition to the application presented here, DLH Enterprises is developing the "Insta-Plug™" for many other applications, tube sizes, and work conditions.

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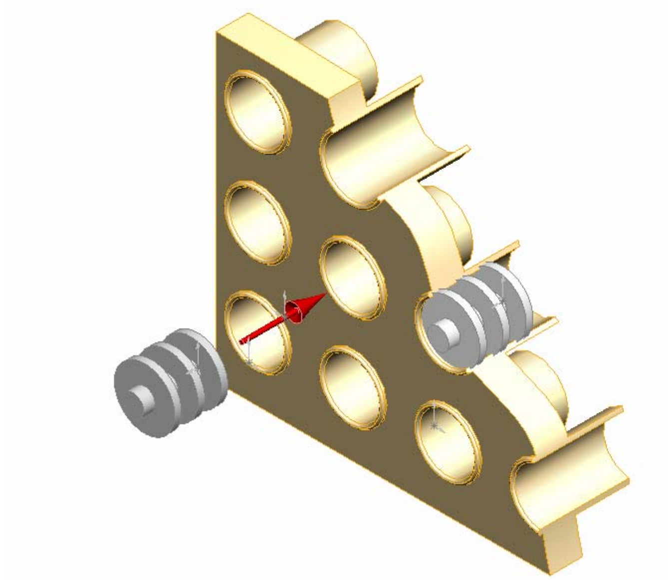
DLH Enterprises introduces Insta-Plug™ a simple, rapid and reliable device for removing from service leaking heat transfer tubes in wide range of tube-type heat exchangers including feedwater heaters, condensers, moisture separator reheaters, and boilers. These plugs provide the means for economically and safely continuing the operation of the heat exchanger until defective tubes can be replaced during major overhaul and re-tubing. These expansion plugs differ from all prior maintenance methods for removing tubes from service in their single piece construction and their inherent stability in the expanded state of tube closure. They are applied quickly, easily and positively.

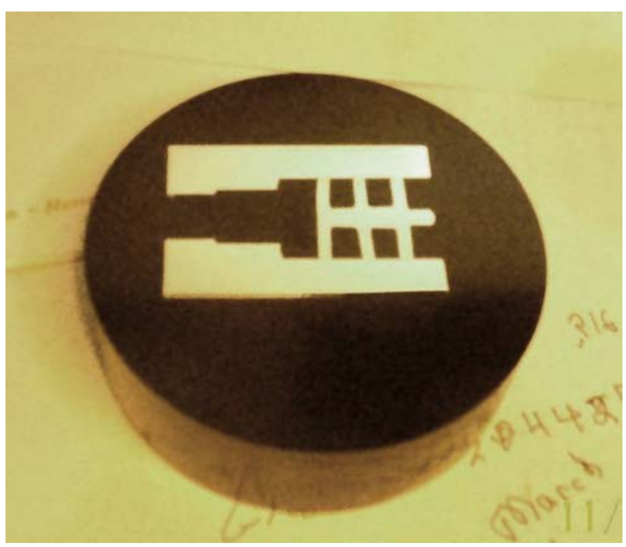
The Material Basis for Insta-Plug™ Insta-Plug™ is made from a novel, engineered alloy originally created by the Naval Ordinance Laboratory from a combination of nickel and titanium metals near their eutectic composition. This family of NiTiNOL (**Ni**ckel**Ti**tanium**N**aval**O**rdinance**L**aboratory) alloys exists in two allotropic forms, a ***martensitic*** lattice structure (the regular three dimensional pattern that the atoms align themselves), which occurs at very low temperatures, and an ***austenitic*** lattice structure occurs at elevated temperatures. Either lattice structure typically can be stable at normal room temperatures.

NiTiNOL has two very unique properties: it is super-elastic in the ***martensitic*** state, and more peculiar yet, it "remembers" the shape imposed on a structure made from it in its expanded, ***austenitic*** state. It is about eight percent, on a volume basis, larger in its ***austenitic*** state than it is in its ***martensitic*** state. These peculiar physical metallurgy properties provide the basic workings underlying the functioning of the InstaPlug™. NiTiNOL is approximately fifty per cent nickel and fifty per cent titanium, and its other properties are strongly related to these metals. It has tensile strength comparable to stainless steels (which it retains at elevated temperatures,) and it has corrosion and friction properties similar to nickel. It is an ideal material for use in service with high temperature steam and other corrosive environments.

A Simple Operation DLH Enterprises' Insta-Plug™ patented design provides a NiTiNOL plug in its martensitic or "shrunken" and specially deformed state so that it can be introduced into the end of a tube, heated by a simple propane torch, and allowed to expand to its high temperature, stable, austenitic or "expanded" state. The figure below shows the process.

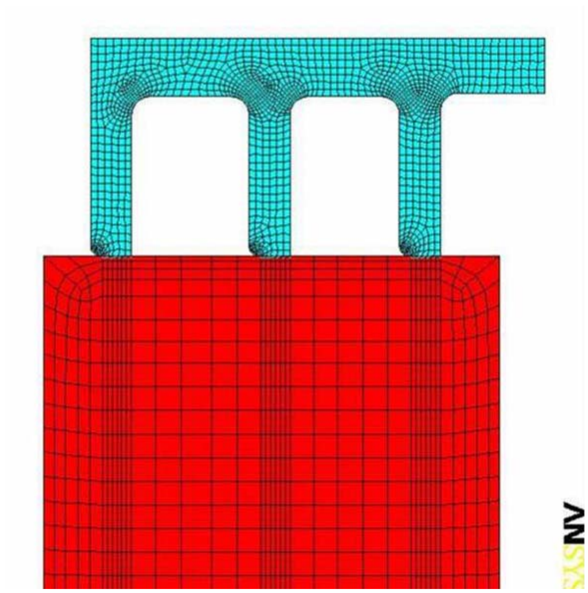


A Positive Operation Insta-Plug™ is designed for continued service over a wide range of temperatures and pressures from room temperature to 600F and from vacuum to more than 5,000 psi. Once the InstaPlug™ has been expanded to its stable, austenitic state in the end of the tube, it has the same effect as if it had been interference fit approximately two per cent oversize. The super-elasticity and shape memory properties of the NiTiNOL and the novel plug design assure a complete and stable seal for the continued operation of the heat exchanger. Proof tests have demonstrated that the plug will remain in position without leaking at temperatures of 600F and pressures of 5000 psi. When pressure at 600F was increased, failure did not occur until the pressure in the tube reached 13,000 psi,[1] many thousand psi above nearly all working environments. A photograph of a metallurgical cross-section of the expanded tube in a simulated tube sheet end is shown below.

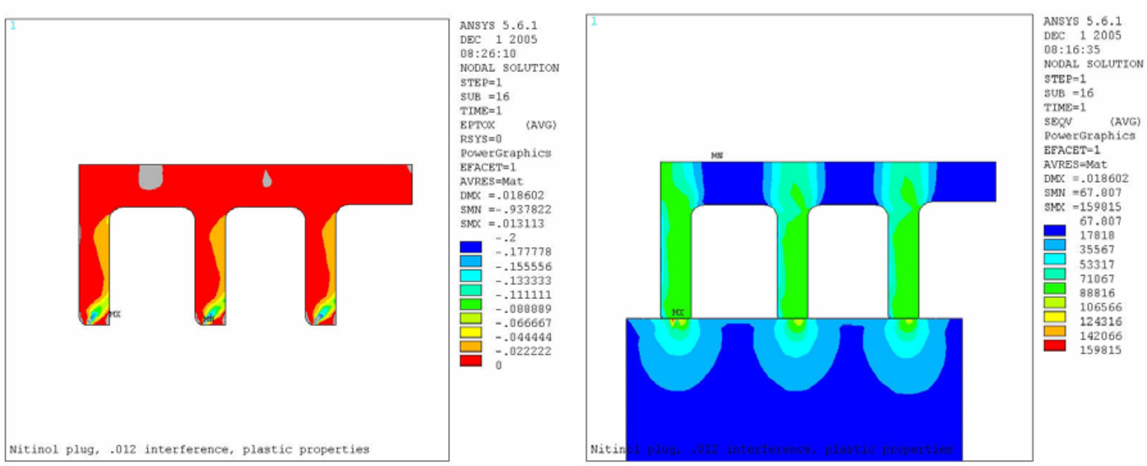


[1] Thielsch Engineering Inc. Report TEi Job No. UES-43-05-0013-1A October, 2005. Report available from DLH Enterprises, 8900 Glendale Milford Road, Suite 1B, Loveland, OH 45140

The Underlying Engineering/Design Insta-Plug^{TM} is designed to expand and recover its pre-installation deformation in a predetermined manner in response to the application of heat to the martensitic pre-form plug. Finite element methods were used to further understand the stresses and thermal dynamics of the experimental plugs, and results were in agreement with the experimental test results. Graphical results of these analyses are shown in the following figures.



Finite Element Model of plug in hole showing meshing for strain setup



Finite element analysis results for strain (left picture) and stress (right picture).

Note that there are wide variations in the strains in the plug model as evidenced by the number of colors and their rapid changes. This pattern shows that the material is deformed non-uniformly. However, the few numbers of colors and their relative constancy in the stress picture indicates that the load carried by the plug is relatively uniform throughout the fins. This uniform load "sharing" keeps the plug material from being overloaded under a wide range of plug insertions, and it is consequence of the unique stress/strain behavior of NiTiNOL.