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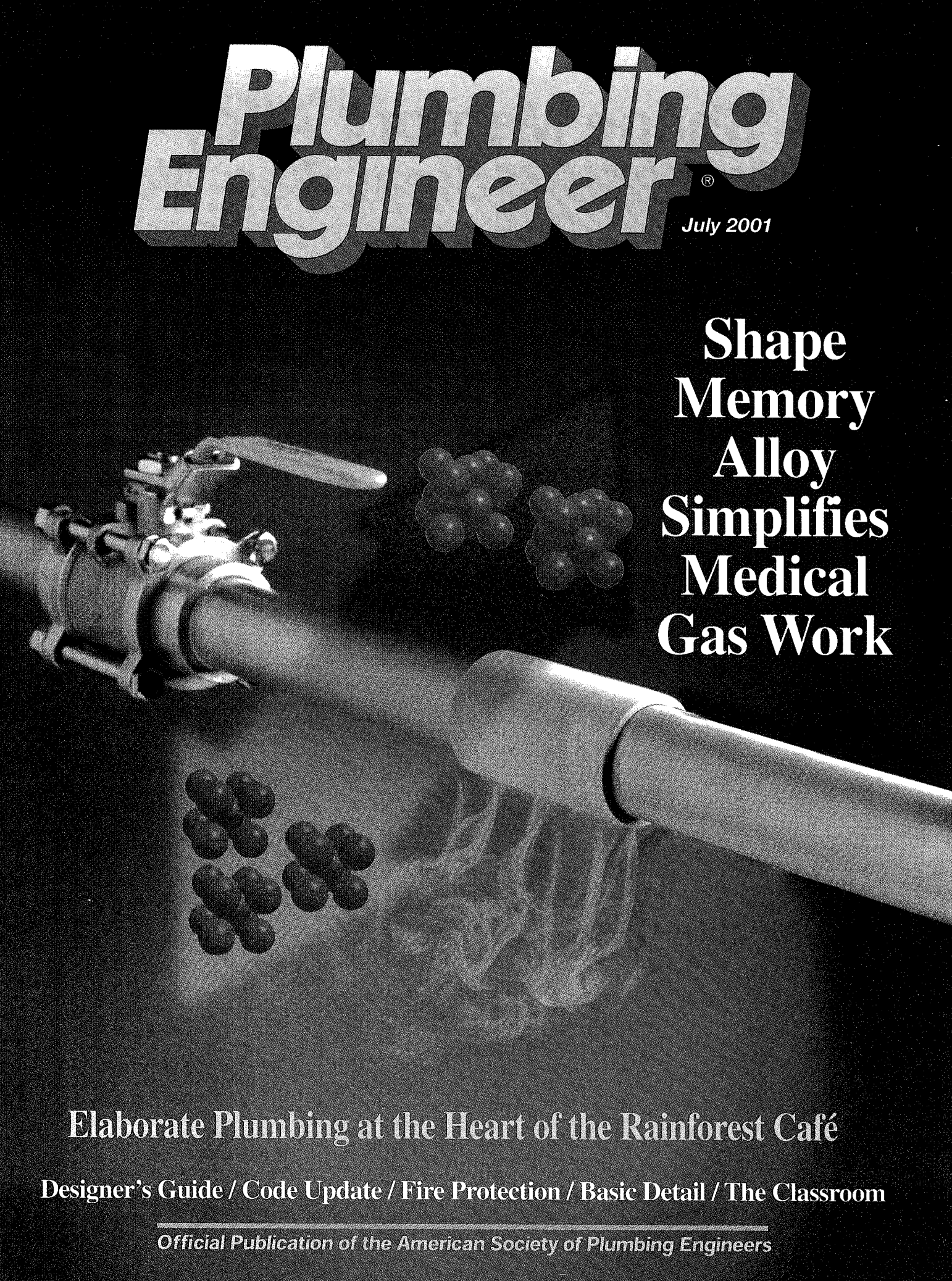

Shape Memory Alloy Simplifies Medical Gas Work

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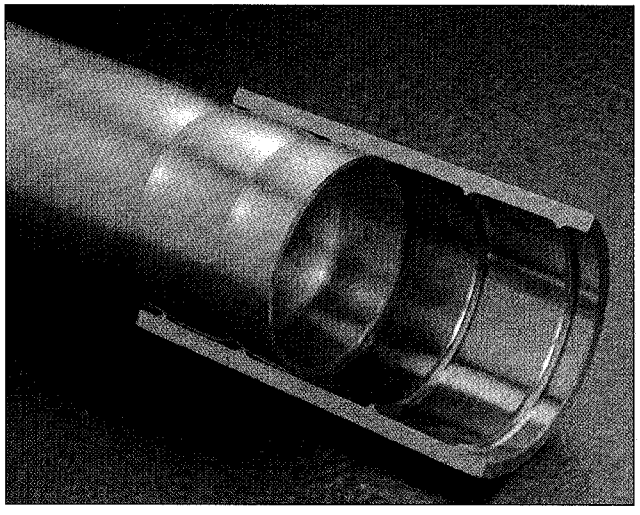
Shape Memory Alloy Simplifies Medical Gas Work

By Felix P. Mummolo, D.Eng.

For hospitals and healthcare facilities, the word "shutdown" is a harbinger of endless planning meetings, scheduled overtime, costly rentals, purging, re-certification, and just plain aggravation, not to mention the introduction of another potential risk to patients — all just to tap into and gain access to the existing medical gas piping system.

The cost of a medical gas system shutdown is considered a "gray" cost. In most cases there is not one account where all the costs are collected. There is the overtime charged to



Using a coupling made of a shape memory alloy, similar in appearance to stainless, allows connection to an existing piping system without brazing or the need for heat or an open flame.

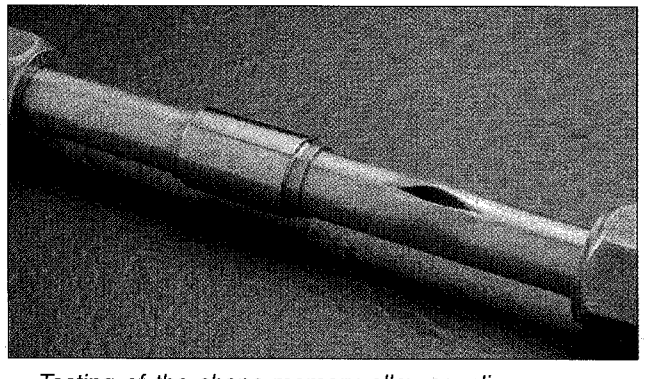
the nursing staff; overtime charged to the maintenance department; cost usually charged to respiratory care for rental of bottled gas and regulators; cost of re-certification; and cost of down time, which upsets the normal routine of patient care.

More importantly, the shutdown creates an inherent risk to patients as they are removed from the centrally piped medical gas system and put on temporary supplies until the shutdown and re-certification is completed. In fact, we are often reminded, through trade periodicals and industry guidelines, how important it is for a hospital to have a formal, rigorous procedure for the shutdown of the medical gas system and the orderly return to service of the system. In the case of the medical gas system, the risk associated with "mistakes" that occur in the various phases of the shutdown — in planning, during the shutdown or in the re-connection afterward — go far beyond inconvenience. In this case, the risk is the potential loss of life.

In 1996, we began thinking of a better way to gain access to the hospital's main piping system while avoiding a shutdown and its associated hazards. The question was how to tap into the system, keep it live, avoid contamination resulting from the brazing process and reconnect without a major disruption to the normal functioning of the facility. In October 1999, SMART Technology, Inc. was issued US Patent #5,967,191, "Method for Servicing a Live Pipeline." Using this process, hospitals now have an alternative to a medical gas system shutdown. An inline shutoff valve or any configuration of piping can be installed in the existing piping system while the facility's main medical gas system remains fully operational.

How it's done

The multi-step procedure begins with the installation of a perpendicular line block with bypass. This block is converted to an axial line block prior to the required component (valve, manifold, etc.) being installed. The connection to the existing piping system is joined using a coupling made of a shape memory alloy (see sidebar). This joint is made without brazing and without the need for heat or an open flame. This succession of steps permits the installation to be completed in a short period of time without contamination of piping and therefore the line is able to be placed back in service immediately.



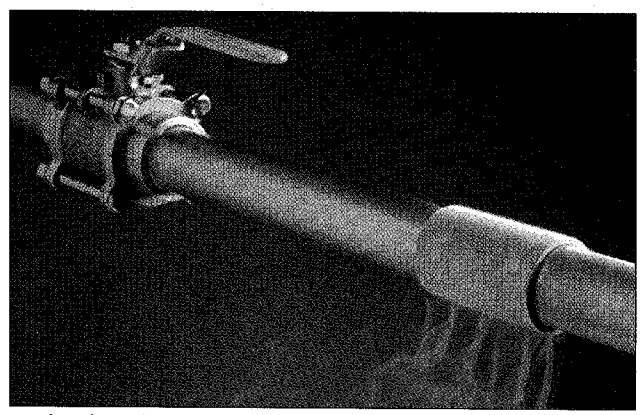
Testing of the shape-memory alloy coupling on copper tube showed no leaks in joints up to 7500 psi. At that pressure, the tube failed while the coupling stayed in place.

No contamination, simplicity, and speed of application of the space age shape memory alloy, Tinel, are the key elements of the procedure. Tinel is an alloy comprising nickel and titanium from which a sleeve coupling is fabricated. Through an elaborate machining process, a sleeve coupling is made to a diameter that is 3 percent smaller than the outside diameter of the pipe being joined. The cou-

Shape Memory Alloy

pling is then "sent to school" where it is trained to remember its shape. Immersing the coupling in a bath of liquid nitrogen reduces its temperature to minus 320 F and allows the coupling to be mechanically deformed (a characteristic of the NiTi alloy). While at the reduced temperature (for the metallurgist, the alloy is in its martensite state) a mandrel is hydraulically forced through the coupling, increasing its inside diameter to a size that is 5 percent larger than the outside diameter of the pipe being joined. As long as the coupling remains in liquid nitrogen (thus, below its transformation temperature) it will remain in the expanded state. When the coupling is returned to room temperature it "remembers" its original shape, smaller than the outer diameter of the pipe, and tries to return to that size.

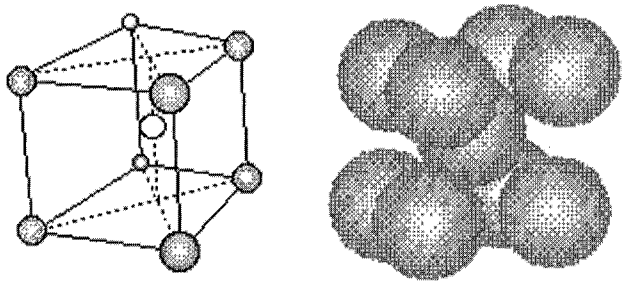
Joining the piping while the coupling is in the reduced temperature (martensite) state, the technicians slip the coupling over the joint and wait until the coupling returns to



As the shape memory alloy coupling warms to room temperature, it exerts tremendous radial force, forming a leak-free, metal-to-metal seal between the coupling and the tubes or pipe.

Shape Memory Alloys

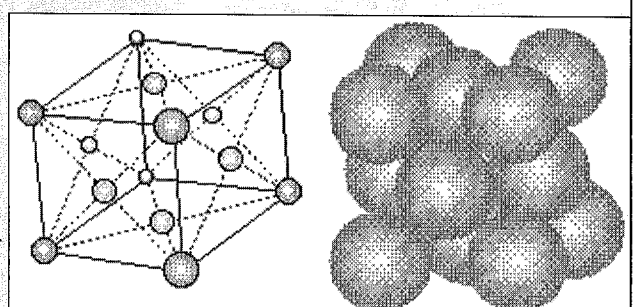
Shape memory alloys (SMAs) are a group of materials which have the ability to return to a predetermined shape when heated. The shape memory effect is caused by a temperature-dependent crystal structure. When an SMA is below its phase transformation temperature, it possesses a low yield strength crystallography (the twin crystal structure) referred to as martensite. While is this state, the material can be deformed into other shapes with relatively little force. The new shape is retained provided the material is kept below its transformation temperature. When heated above this temperature, the material reverts to its parent, high strength structure known as austenite (box centered cubic crystalline structure) causing it to return to its original shape. This phenomenon can be harnessed to provide a unique and powerful tool.



Face-centered cubic (fcc) crystalline structure.

The shape memory effect in nickel-titanium alloys was first discovered at the Naval Ordnance Laboratory in 1962. The commonly known name of NiTiNOL was coined by this organization. In 1967, the Raychem Corporation extended the research on the family of NiTiNOL metals leading to the Raychem trade name, Tinel. The formulation of Tinel is the alloy used by SMART Technology, Inc. for its Smart Fit coupling.

Products with shape memory alloys are quite common; most people have used, or at least have seen, some of them. For instance, eyeglass frames or cell phone antennas made from "superelastic" NiTiNOL are now successful commercial applications. The more popular "thermal shape memory effect" characterized by the extraordinary ability of metals to recover any shape upon heating is less often applied in commercial products. Both effects, superelasticity and thermal shape memory, can be achieved with the alloy by special "thermo mechanical treatment." This special metallurgical treatment gives the alloys their particular properties and is of high importance for the success of the respective application. In the case of the thermal memory effect, very high forces are generated by the metal in the process of heat induced transformation from martensite to austenite. Research has shown that a 4 mm diameter actuator wire made of NiTiNOL is able to lift a 1-ton load for at least one time. This same high-performance characteristic is taken advantage of in medical gas coupling system developed by SMART Technology.



Body-centered cubic (bcc) crystalline structure.

Presently the most interesting applications of the superelastic effect can be found in medical implants and instruments, where for example, the availability of SMA thin-walled tubing has opened the markets for stents in medical procedures. Due to the high elasticity, the stents can be folded into a catheter sheath and pushed into a partially restricted vessel, where they expand and provide a force to keep the vessel open.

Shape Memory Alloy

room temperature exerting tremendous radial force. This permanent, live crimp action, establishes a leak-free, metal-to-metal seal between the coupling and the tubes or pipe throughout the life of the joint. In fact, testing of the shape-memory alloy coupling on copper tube showed no leaks in joints up to 7500 psi. At that pressure, the tube failed while the coupling stayed in place. The transformation back to its original, high strength state (again, for the metallurgist, the austenite state) takes approximately one minute. Thus an extremely high strength joint is made without brazing, without contamination and without the potential hazard of an open flame.

The Naval Ordinance Research Laboratory discovered the shape memory alloy effect in the early 1960s. The first commercial application was for the hydraulic system of the U.S. Navy's F-14 Tomcat Jet Fighter. In 1975, this system was extended to the Trafalgar-class nuclear submarine. In the 1980s, the National Fire Protection Association adopted the shape-memory alloy coupling as an approved alternative to brazed joints in NFPA 99-1987.

Fast forward to the present

Using this patented procedure, the shape-memory alloy, in the form of a sleeve coupling, is installed in over 100 hospitals from Maine, south into Florida and west to New Mexico. The procedure has been used nearly 300 times allowing for the installation of inline shutoff valves, emergency oxygen connections and various configurations of tie-ins without the need for a shutdown and without the contamination that is present when a fitting is brazed onto the piping. The shape-memory alloy, a product of space age technology, has been brought down to earth and has become a valuable, economic tool for the healthcare community.

Using the shape-memory alloy in concert with the patented procedure, hospitals and their designated piping contractors have a tool that allows for a safe, efficient and economical expansion of medical gas piping systems while avoiding the need for a shutdown. □

About the Author

Felix P. Mummolo holds graduate degrees in mechanical engineering and laser physics. His background consists of 25 years of engineering experience in the pharmaceutical, medical and process gas industries. His experiences as a medical gas system designer