

Critical nondestructive testing applications

Part one of two

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As NDT techniques have expanded, so have the applications which now encompass many critical products that are being used where it is extremely difficult and expensive to replace or repair, or where failure can cause serious and life threatening consequences. What follows are some specific testing situations that illustrate the use of NDT for ensuring the safety and quality of these products.

By Michael Rakos, District Manager, Magnetic Analysis Corporation

Oil and gas industry

Sheathed Tubing

The Prysmian Downhole Technology Group produces Seam Welded Sheathed Tubing, commonly known as "Tubing Encapsulated Cable" or TEC. The oil and gas industry uses TEC to provide power and communication to downhole gauges such as temperature and pressure. The tube alloy is typically 316L, 825, or 625. Diameters range from 1/8" to 3/8", and wall thicknesses from 0.022" to 0.049". The tubing protects insulated electrical conductor(s)

and/or optical fiber(s) electrical and optical components from mechanical abuse, pressure, and corrosive effects. Lengths can range from 5,000 to 35,000' in coil form⁽¹⁾. Because of the critical nature, ECT is performed in stages on the tube in line with welding and drawing processes. First, a special water cooled eddy current probe known as an "XIG Hot Probe" is mounted following welding to find common weld defects. The final inspection occurs at the end of the mill before the tube is coiled. A dual frequency test is performed using two separate encircling coils. At high frequency

(above 200 KHz), the eddy current energy is optimized on the outside surface of the tube, making it possible to find very small surface defects. A lower frequency set at what is known as "One Depth of Penetration" is calculated based on wall thickness and conductivity of the alloy. This specific frequency will have enough penetrating eddy current energy for inner wall defect detection. Flaw detection levels are set in accordance with ASTM 1016⁽²⁾ and E426⁽³⁾.

Pressure Tube

Also produced by Prysmian is Seam Welded Pressure Tubing, commonly referred to as "Control Line Tubing" pressure tube, which is used in oil and natural gas wells. The critical applications include chemical injection, instrumentation, and hydraulically actuated surface-controlled subsurface safety valves. Alloys include 316L, 825, 625, and 2205, and all are heat treated. Tubing diameters range from 1/8" through 5/8" OD, and lengths can be over 50,000'⁽⁴⁾. Orbital welding joins tubing sections to achieve these lengths. Radiographic testing is performed on all ECT detected orbital and strip splice welds. Similar ECT is done as with sheathed tube, but more demanding proprietary specifications dictate flaw detection levels.

Medical tubing

Stent Tube

Any human implantable medical use of material is by nature a very critical application. Early on, and to this day, ECT is the best NDT choice ensuring quality of the base tube for the manufacture of coronary stents. A stent is used to provide mechanical support to diseased arteries. It often takes the form of a flexible mesh, facilitating its insertion via catheter, and traditionally balloon expanded. The first metal stent was successfully implanted into a human heart in France in 1986, but not approved for use in the United States until 1994⁽⁵⁾. Modern Stent alloys include Nitinol (or NiTi), for a self expanding stent made possible by the temperature related memory deformation properties of this alloy.



"MultiMac® eddy current instrument provides the controls, analysis, and reporting for the testing of the sheathed tubing, stent tube, and thrombectomy catheter."

In the early days of large scale stent production, a long time customer of Magnetic Analysis Corp. (MAC), Superior Tube Company (STC) in Colleagueville PA, took up the challenge of producing and testing stent tube. STC already had an extensive NDT department, and long history of supplying tube for the most demanding NDT specifications, including nuclear and aerospace industries. This tube would be small diameter medical grade alloys of mostly L605 (cobalt-chromium-tungsten-nickel alloy). Originally, 316L had been the alloy choice for its known biocompatibility, but was mostly replaced by L605 having higher strength, and being more MRI-compatible with negligible iron content⁽⁶⁾. The tubing was supplied to Abbot Vascular and Guidant to be laser cut and formed into the final product. Tube size was in the range of 0.075" OD with a 0.004" wall thickness. MAC has engineered a specialized encircling coil ECT solution to find defects as small as 0.0006" deep in the ID of this tube. The key factor was a special tuned 3MHz test coil. This high frequency matches the electromagnetic skin depth to the tube wall thickness, and enables the

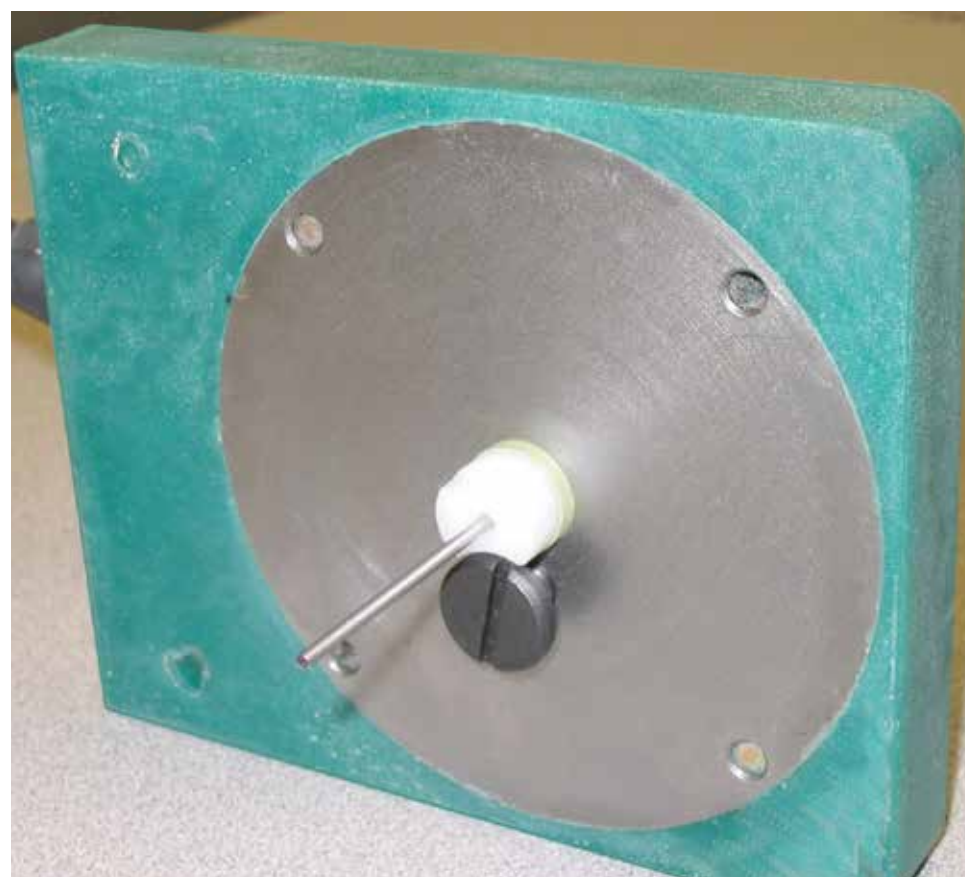


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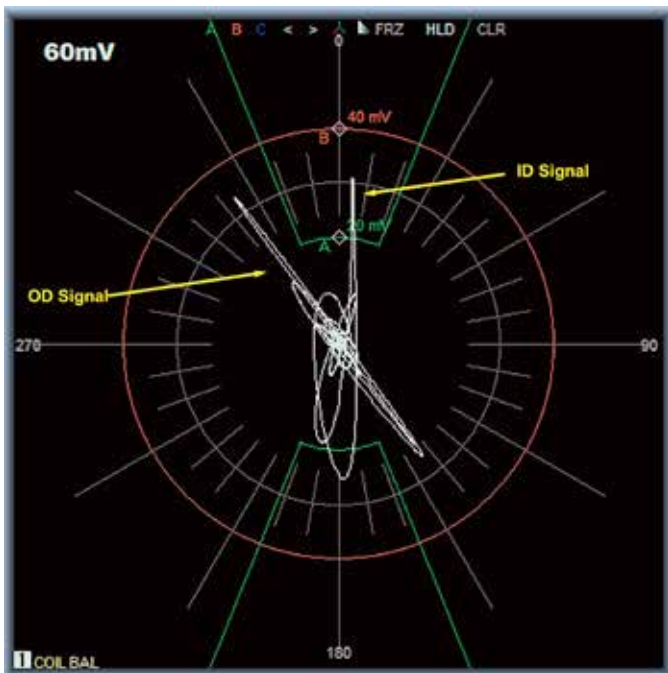


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ID and OD test signals can be clearly discriminated from each other using “phase shift”, shown in this polar view from MultiMac® eddy current instrument.

Don't miss part two!

Part two of this article will be published in the August issue of Stainless Steel World Americas under the heading 'Tech Talk.'



About the author

Michael Rakos, District Manager for Magnetic Analysis Corp., has over 20 years experience in the field of nondestructive testing. His background includes installing and implementing Eddy Current and Ultrasonic inspection systems, as well as customer technical support and sales. He holds an ASNT Level III certification in Eddy Current, and graduated cum laude from Penn State University with a B.S. degree in Electrical Engineering Technology.

response from the tube's movement in the coil (noise) to be discriminated from flaws with depth. This is made possible by a measurable delay in the eddy currents as they propagate through the wall, and is known as “Phase Shift” as represented on MAC's polar display.

Rheolytic Thrombectomy Catheter

Accumetrics Limited, in Royersford, Pennsylvania is a high-precision, small-diameter tubing manufacturer operating since 1979. They supply very small diameter tubing for use in the medical industry as Endoscopic tools. One noteworthy critical application is for use in a tool that uses high velocity saline jets to fracture and remove blood clots. The clot clearing system uses a catheter shaft that is dual lumen, meaning two passageways. One lumen provides high pressure saline to the catheter tip through a stainless steel hypodermic tube. The other larger lumen is used for the evacuation of thrombotic debris and for guide wire passage. Multiple high velocity saline jets travel backwards to create a localized low pressure zone, causing a powerful vacuum. The saline and clot particles are then evacuated into the exhaust lumen of the catheter and out of the body for disposal⁽⁷⁾. The tubing for the high pressure saline is a stainless steel 304L alloy. This alloy has a high corrosion resistance and low carbon content. These are key factors that make it suitable for medical applications over other grades of stainless. It can withstand cleaning products used to sterilize and the repetitive wear that many medical devices are subjected to⁽⁸⁾. This special tubing is approximately 0.020” in diameter with a wall thickness of 0.003”. Failure of this tube while in service could have severe consequences, so the best NDT techniques are used. High frequency ECT testing is done with MAC's 3MHz coils in much the same manner as stent tube. A library of naturally occurring defects is kept as reference standards to assist with optimal setup.

References

1. TEC Brochure. Prysmian Group North America. [Online] [Cited: April 26, 2017.] http://na.prysmiangroup.com/en/business_markets/markets/oil-and-gas/downloads/datasheets/TEC-Brochure.pdf.
2. ASTM . Standard Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes. West Conshohocken, PA : ASTM International,, 2017. ASTM A1016 / A1016M-17.
3. ASTM. Standard Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys. West

Conshohocken, PA : ASTM International, 2016. ASTM E426-16.

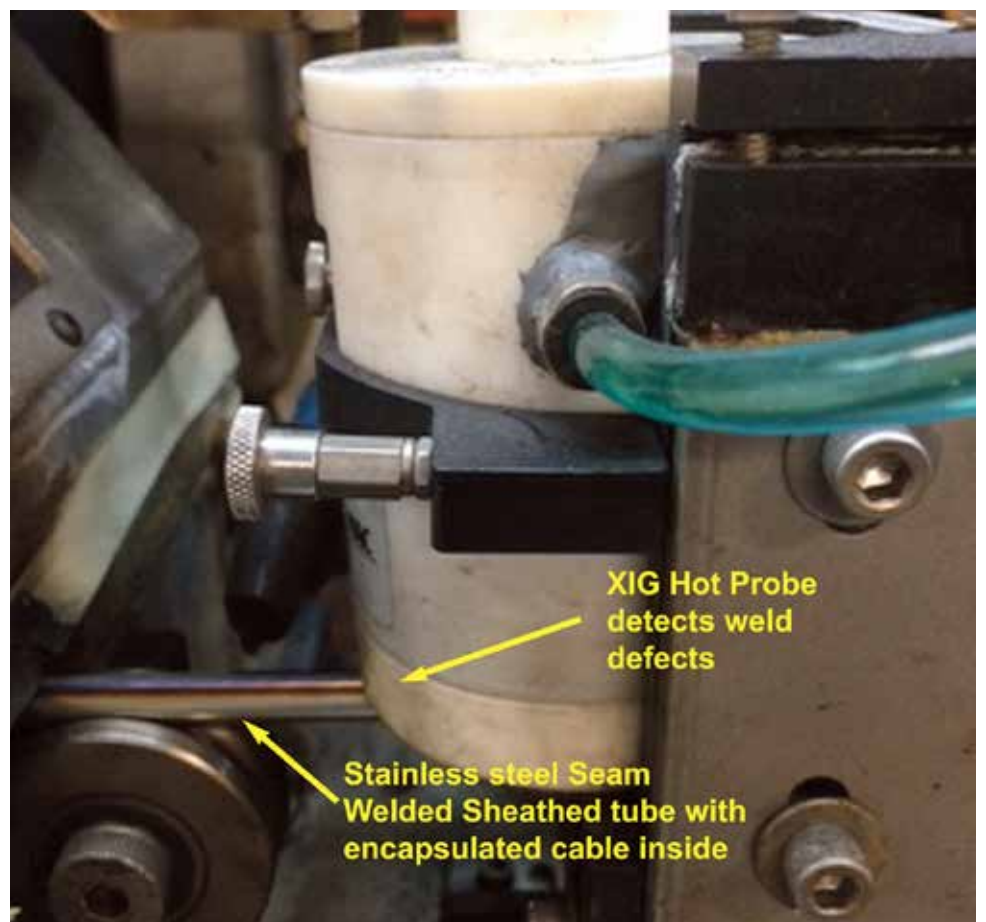
4. Specialty Tubing. Prysmian Group North America. [Online] [Cited: April 26, 2017.] http://na.prysmiangroup.com/en/business_markets/markets/oil-and-gas/products/down-hole-techniques/specialty-tubing/.

5. Javaid Iqbal, Julian Gunn, and Patrick W. Serruys. Coronary stents: historical development, current status and future directions. Oxford Journals. [Online] March 26, 2013. https://oup.silverchair-cdn.com/oup/backfile/Content_public/Journal/bmb/106/1/10.1093/bmb/ldt009/2/ldt009.pdf?Expires=149360.

6. Advantages of Cobalt Alloy for Coronary Stents. Medtronic. [Online] October 2003. [Cited: April 26, 2017.] <http://www.medtronic.com/newsroom/content/1110132739468.pdf>.

7. Clinical Application of a New Rheolytic ThrombectomyCatheter System for Massive Pulmonary Embolism. Voigtländer, T., Rupprecht, H.-J., Nowak, B., Post, F., Mayer, E., Stähr, P., Bickel, C. and Meyer, J. 1, s.l. : John Wiley & Sons, 1999, Vols. 47: 91–96.

8. Medical Applications of Stainless Steel 304 (UNS S30400). Azom Materials. [Online] [Cited: April 30, 2017.] <http://www.azom.com/article.aspx?ArticleID=6641>.



XIG Hot Probe, a water cooled eddy current probe, is mounted right after the welding operation to inspect for weld defects in down hole communication applications.



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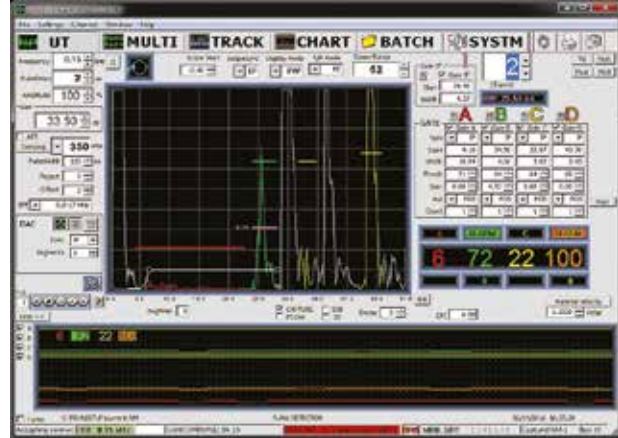
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Channel one with a gate interface and four gate thresholds for testing bar used in aerospace applications.

Aerospace applications

Shuttle Rocket Booster Structural Pins

During the years of the Space Shuttle program, SPS Technologies, in Jenkintown, Pennsylvania, with a long history of specialized fastener manufacturing, supplied clevis pins designed to hold the Solid Rocket Booster (SRB) sections together. Each section used a field assembled circumferential clevis and tang joint needing 177 pins⁽⁹⁾. Pin dimensions were 1.25" diameter and 2.5" long. They were made from a multiphase nickel cobalt alloy for withstanding temperature extremes while

maintaining a very high tensile strength. At the time, MAC supplied an ECT solution for the finished pin to meet this critical application. A focused differential probe and instrument was supplied to look for any surface defects developed during manufacturing that could act as stress risers. The testing technique used a small lathe to spin the pin under the probe. The moving carriage ensured the complete part surface is scanned.

Jet Turbine Engine Shafts

For jet turbine engines, all parts are of a critical nature, but of particular concern are

the rotating members such as the shaft. The shaft connects the turbine to the compressor, and runs most of the length of the engine. There may be up to three concentric shafts, rotating at independent speeds. Cooling air for the turbines may flow through the shaft from the compressor⁽¹⁰⁾.

For these demanding applications, CarTech's 901 alloy is often chosen being a chromium nickel-iron super alloy designed for high strength and corrosion resistance in the temperature range of 1000/1400°F (538/760°C)⁽¹¹⁾. The bar stock supplied for such applications can be large diameters in the range of 12" and as much as 20" long. The material undergoes a thorough ultrasonic inspection in a large immersion tank. The bar is supported at the bottom of the tank by sets of driven rollers that precisely rotate the bar at specific speeds without linear or transverse movement. A bridge across the top of the tank holds the fixed transducers that are mounted on a bar follower. This ensures the transducer maintains the proper position even with a certain amount of bar wobble during rotation⁽¹²⁾. The bridge indexes at a controlled linear speed so a full surface and volumetric scan of the bar can be achieved. The inspection technique commonly uses multiple shear and compression wave modes to examine the surface and subsurface. This includes a two-direction axial shear wave directed along the axis of the bar, along with clockwise and counterclockwise shear waves directed circumferentially. Larger bars often require two compression wave channels so one can be optimized for near surface resolution, while the other penetrates deep into the bar center. Setup is done with surface Electrical Discharge Machined (EDM) notches and Flat Bottom drilled Holes (FBH). The notch and FBH size/depth is governed by the specifications set forth by the end-user, and are sometimes proprietary. However, most applications call for aerospace specification AMS-STD-2154⁽¹³⁾ and AMS-STD-2630⁽¹⁴⁾. For this UT application, MAC

has supplied its latest model instrument, the Echomac® FD-6A. For GE aviation use, it is qualified per Procedure UT_1335 as of Sept. 6, 2016 for P3TF31 Class A and B, and P29TF82 Class A and B.

Nuclear power

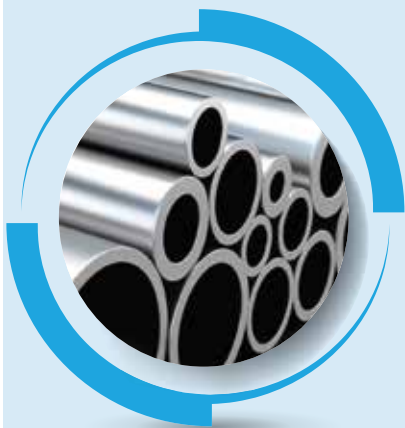
Nuclear Fuel Cladding

The majority of commercial nuclear reactors in the world today are light water reactors. The nuclear fuel used in these reactors is in the form of fuel rods, which consist of tubes approximately 4 m long, 1 cm inside diameter and 0.6-mm wall thickness, made from zirconium alloys and fuel pellets⁽¹⁵⁾. These pellets are cylinder shaped and approximately 1cm diameter and 1.5cm long, with one pellet containing the energy of 1780 lbs of coal⁽¹⁶⁾. They are formed from pressed uranium oxide (UO₂), which is sintered at high temperature. The tubes, termed the nuclear fuel cladding, constitute the first barrier against the release of fission products into the primary circuit. Because of this, it is crucial to nuclear safety to ensure cladding integrity during service. Zirconium alloys have been the cladding material of choice since 1960 when it replaced stainless steel alloys. It's primarily selected for its transparency to neutrons, and has proper mechanical properties and corrosion resistance at normal reactor operating temperatures. During assembly of the fuel rod, a free space is left between the top of the pellet stack and the welded end-plugs. This is called the plenum space, and accommodates pellet thermal expansion, fission product gases, and a spring to stabilize the pellet stack from movement. A very tight gap between the fuel pellets and cladding is critical during fuel rod manufacturing. Typical radial clearance between the oxide pellet and the cladding ID in cold state is 200 to 400 microns⁽¹⁷⁾. This gap space is connected to the plenum at the top of the fuel rod, and pressurized with helium from 1 to 3 MPa to partly compensate for outside pressure. The



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Echomac® Ultrasonic test system for inspecting welded stainless steel tube at Ratnamani Metals & Tubes Ltd., a major stainless tube producer in India for critical heat exchanger tube. The system detects transverse and longitudinal defects and measures wall thickness, ID and OD dimensions.



fuel pellet can swell while in use from both thermal expansion and internal fission gas formation. Along with increased temperature inside the reactor, the release of these fission gases into the free space can further increase internal pressure (68). At risk is the deformation or bursting of the cladding. Aside from flaw testing this tube with UT, we see dimensional measurement being just as critical. To meet this requirement, MAC has pioneered a UT technique for accurate inside/outside dimension measurement known as “Dimensional Package.” A three transducer mode of operation is used for simultaneous measurement of OD, ID, wall thickness, and eccentricity. Two transducers are diametrically opposed while the third transducer has a fixed artificial target for water velocity compensation due to temperature variation. The technique is ap-

plied using an immersion tank with spinning tube conveyor, or UT rotary for faster testing speeds. Initial dimensional tests on this tube during processing are for an ID tolerance of eight microns. With MAC’s new generation instrument, the Echomac® FD-6A, thickness resolution is improved to 1ns, or approximately three microns in metals.

In all these examples, applying ECT and UT to critical applications requires a thorough knowledge and understanding of the specific product and specifications the customer must meet. This is not a case of “one size” fits all. Fortunately, these two technologies provide a lot of flexibility and options for fine tuning them to the specific application. At this level, to ensure safety and reliability for the end product, NDT must be applied with precision, adherence to quality standards, and dedication.



Echomac® Ultrasonic test system inspecting stainless steel and titanium alloy heat exchanger tubing for at Schoeller Werk. The test rotary is the black unit beneath the monitor.



About the author

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References

9. Kennedy Space Center, SRB Mechanical Engineering MNE-7. Space Shuttle Program, Solid Rocket Booster Processing. nasa-klass.com. [Online] [Cited: April 30, 2017.] www.nasa-klass.com/Curriculum/Get_Oriented%20/...SRB.../SRB-processing.ppt.
10. Shafts. Beacon Industries. [Online] [Cited: April 30, 2017.] <http://www.beaconp.com/shafts.aspx>.
11. CarTech® 901 Alloy. Carpenter Technologies. [Online] [Cited: April 30, 2017.] <https://www.carttech.com/en/product-solutions/cartech-901-alloy/>.
12. Tactic Multi-Probe Followers For Large Immersion Tanks. TAC Technical Instrument Corp. [Online] [Cited: April 30, 2017.] <http://www.tacticstest.com/multi.htm>.
13. Inspection, Ultrasonic, Wrought Metals, Process For. s.l. : SAE International, 2012. AMS-STD-2154A.
14. Inspection, Ultrasonic Product Over 0.5 Inch (12.7 mm) Thick. s.l. : SAE International, 2010. AMS-STD-2630C.
15. Corrosion of Zirconium Alloys Used for Nuclear Fuel Cladding. T. Motta, Adrien Couet, Robert J. Comstock. s.l. : Annual Reviews, 2015, Annual Review of Biophysics, Vol. 44.
16. Nuclear Fuel Processes. Nuclear Energy Institute (NEI). [Online] [Cited: May 3, 2017.] <https://www.nei.org/Knowledge-Center/Nuclear-Fuel-Processes>.
17. Carpenter, David. Comparison of Pellet-Cladding Mechanical Interaction for Zircaloy and Silicon Carbide Clad Fuel Rods in Pressurized Water Reactors. MIT Department of Nuclear Engineering. [Online] December 11, 2006. [Cited: May 3, 2017.] <https://ocw.mit.edu/courses/nuclear-engineering/22-314j-structural-mechanics-in-nuclear-power-technology-fall-2006/projects/carpenter.pdf>.
18. National Nuclear Laboratory. Nuclear Fuel Cycle Science and Engineering. [ed.] Ian Crossland. Series in Energy. s.l. : Woodhead Publishing, 2012. Vol. 37.

Miss part one?

If you missed part one of this informative article you can find it in the June 2017 issue of *Stainless Steel World Americas* on pages 6 and 7.

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