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FOCUS

Removing Liquid Penetrant

Noel A. Tracy*

The underlying principles of liquid penetrant testing (Fig. 1) haven't changed since the late 1800s when oil and whiting were first used to examine iron and steel components. The liquid penetrant testing process, however, has evolved to include six steps.

1. *Preclean and dry test surfaces of object to be inspected.*
2. *Apply liquid penetrant to test surfaces and permit it to dwell.*
3. *Remove excess liquid penetrant from test surfaces.*
4. *Apply a developer.*
5. *Visually examine surfaces for liquid penetrant indications; interpret and evaluate indications.*
6. *Postclean the part.*

These basic steps are followed regardless of the type of visible color or fluorescent dye used to form the liquid penetrant indications. Step four, application of a developer, is sometimes omitted when testing newly manufactured parts with fluorescent liquid penetrants but at the cost of lower test sensitivity due to reduced visibility of indications.

Classification by Dye Type

The liquid pentrant testing process relies on liquid penetrant entering a discontinuity and subsequently being drawn back out where it is made easily visible on the surface of the part. If the discontinuity is to be detected, the very small amount of liquid penetrant entrapped in the discontinuity must be made visible with highly colored dyes. Based on the dye used, liquid penetrants are generally classified into three types.

Fluorescent. When exposed to near ultraviolet radiation (320 to 400 nm), the fluorescent dye in fluorescent liquid penetrants emits a yellowish-green light.

Visible. Visible dye or color contrast liquid penetrants contain dye visible under natural or white light. Application of a white developer further enhances visibility by providing a high contrast background for the colored liquid penetrant.

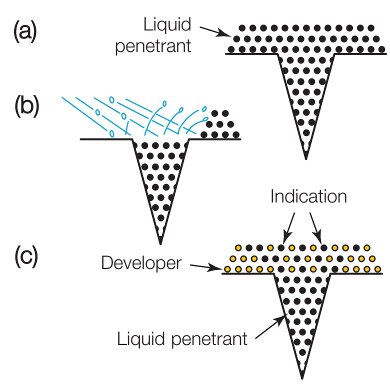

Figure 1. Basic principles of liquid penetrant testing: (a) apply liquid penetrant; (b) remove excess; (c) apply developer.

Dual Mode. Dual mode (visible and fluorescent) liquid penetrants contain dyes that are colored under white light and fluorescent under ultraviolet radiation.

Classification by Removal Method

A liquid penetrant is further classified by the technique used

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FROM THE EDITOR

Our July "Focus" article is adapted from Chapter 2 of ASNT's *Nondestructive Testing Handbook* on *Liquid Penetrant Testing*. In his preface for the volume, Technical Editor Noel Tracy begins by stating "What could be simpler than directly viewing a part with a suitable light to see an indication of a discontinuity produced by dipping the part in a colored liquid, washing excess liquid off with a water hose and drying the part?" Of course, the statement is tongue-in-cheek because he goes on to say that as one gains experience with liquid penetrant testing, the more appropriate question is "... how can a *simple* technique be so complex?". "Removing Liquid Penetrant" describes the underlying principles along with best use practices and the pros and cons of each removal method.

Ron Nisbet has provided us with another column on the significance of professional ethics in an increasingly complex world and the far-reaching effects of the decision process when it goes wrong.

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to remove it from the surface of a part. Liquid penetrants are formulated for specific removal techniques designed to minimize removal of the liquid penetrant that has seeped into a discontinuity. Each technique has advantages and disadvantages.

Water Washable. Most liquid penetrants contain an oil base that is insoluble in and immiscible with water; meaning that excess liquid penetrant on a part cannot be removed with water. However, some liquid penetrants are carefully compounded mixtures of an oil base and an emulsifier, while others have water or a surfactant as a base rather than oil. These alternative formulations are provided as ready-to-use liquid penetrants that can be removed with water immediately after the liquid penetrant dwell. Depending upon the requirements imposed by the applicable process specifications, removal may be accomplished by wiping the part surface with a wet lint-free cloth (after first wiping with dry lint-free cloth), by directing a controlled spray onto the part or by dipping and agitating the part in water.

Postemulsifiable. Liquid penetrants used in the postemulsification process can be formulated for higher sensitivity by optimizing their penetrating and visibility characteristics. Postemulsifiable liquid penetrants do not contain any emulsifying agent and are less likely to be removed from the discontinuity when the surface liquid penetrant is being removed with water. Removal from a surface is accomplished by applying an emulsifier in a separate process step, normally by dipping the part into a tank of the emulsifier or spraying the emulsifier onto the part. Depending on the type of emulsifier used, the emulsifier either converts the excess surface liquid penetrant into a mixture that forms an emulsion with the addition of water (lipophilic) or acts directly with the liquid penetrant to form an emulsion subsequently removed with water (hydrophilic).

A postemulsifiable liquid penetrant usually can be used with any emulsifier. However, qualifying or approving agencies may choose to qualify a liquid penetrant-emulsifier combination from the same manufacturer. The manufacturer may offer the same liquid penetrant for use with different emulsifiers. A user could use any liquid penetrant-emulsifier combination approved by the customer.

Lipophilic Emulsifiers. Lipophilic emulsifiers are composed of liquid blends that combine with oil based liquid penetrants to form a mixture that can be removed with a water spray (Fig. 2). Their mode of action is based primarily on diffusion and solubility into an oil base liquid penetrant. Parts are generally dipped into tanks of lipophilic emulsifier, withdrawn and placed at a drain station for a specified time. The diffusion rate (emulsification time) will vary depending on the viscosity of the emulsifier and the physical action of drainoff. Therefore, it is important to control the emulsification time to prevent emulsification of the liquid penetrant in the discontinuity.

Hydrophilic Emulsifiers. Often referred to as removers, hydrophilic emulsifiers are composed of emulsifying agents dissolved in water (Fig. 3). They are supplied in a concentrate form that is diluted with water at concentrations of 5 to 30 percent and used as an immersion dip with mild air or mechanical agitation or as a forced water spray rinse at dilution ratios up to a maximum of 5 percent. Pre-rinse with a water spray normally precedes the application of hydrophilic emulsifiers, so liquid penetrant contamination of the emulsifier is reduced.

Hydrophilic emulsifiers function through their detergent or scrubbing (kinetic) action. Diffusion does not take place in this mechanism of action. The surface active agent in the remover helps displace liquid penetrant from the surface and prevents redeposition. Removal of excess surface liquid penetrant with hydrophilic emulsifiers in an immersion or dip mode begins as the remover detaches the liquid penetrant from the surface. Mild agitation removes the displaced liquid penetrant from the part so that it cannot redeposit. When a spray is used, the impinging water droplets have the same effect as agitation in a tank. Hydrophilic emulsifier contact time is directly related to its concentration. This applies to both immersion and spray applications. The biggest advantage of the hydrophilic emulsification technique may be improved control of liquid penetrant process waste materials. Residual liquid

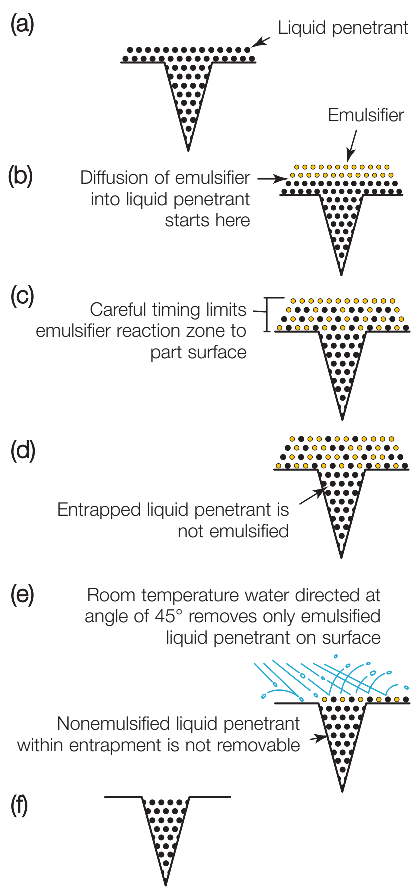

Figure 2. Action of lipophilic emulsifiers: (a) liquid penetration; (b) add emulsifier; (c) solution and diffusion begins; (d) diffusion proceeds; (e) rinsing; (f) clean surface.

penetrant removed in the pre-rinse is not water soluble. Less dense than the rinse water, it floats to the surface where it can be skimmed off, preventing discharge of oily waste into sewers and streams. In some cases, the materials collected in this manner can be reused.

Solvent Removable Liquid Penetrants. The term *solvent removable* is often used as if it applied to a discrete class of liquid penetrants. In fact, all liquid penetrants can be removed with solvents. In most applications, the liquid penetrants used in the solvent removable process are postemulsifiable; however, water washable liquid penetrants can also be used. For some applications a manufacturer may choose to offer a liquid penetrant qualified for the solvent removable process only.

The solvent removable technique is labor intensive and normally used only when necessary to inspect a localized area of a part or a part at its in-service site rather than in the production

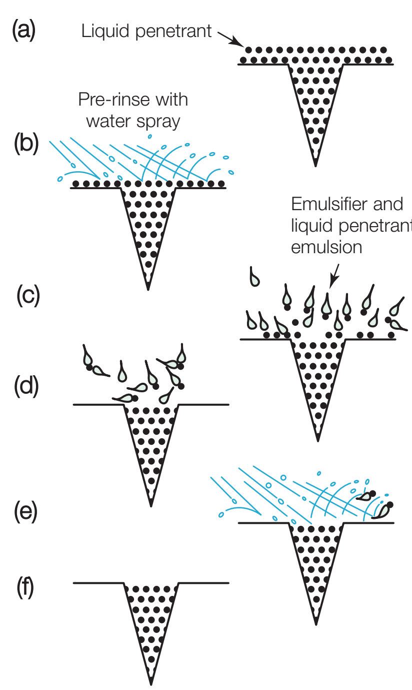

Figure 3. Action of hydrophilic emulsifiers: (a) liquid penetration; (b) prerinsing; (c) detergent scrubbing begins; (d) agitation and emulsification; (e) rinsing; (f) clean surface.

environment. Properly applied, it can be the most sensitive of liquid penetrant techniques.

Solvent Removers. Solvent removers have traditionally been petroleum base or chlorinated solvents. However, because the former is flammable and production of the latter ceased in December 1995, use of detergent cleaners or water base solvents has increased. Water itself can be used as a solvent for water washable liquid penetrants. Often an emulsifier contains enough solvency to function as a hand wipe remover also.

Removal Processes

Because the processes for fluorescent liquid penetrant and visible dye liquid penetrant are similar, the processes depicted in the flow chart shown in Fig. 4 can be applied to both. Processing variables — including liquid penetrant dwell time, emulsification time, rinse water temperature and pressure, drying temperature and time, and intensity of ultraviolet or visible radiation (visible light) — are established by customer designated processing specifications. Adherence to the established parameters is important for controlling test quality.

Water Washable Liquid Penetrant Process. To ensure that testing is reliable, reproducible and sufficiently sensitive for intended purposes, the water washable liquid penetrant test procedure includes these operational steps (Fig. 4).

1. Preclean and dry the surfaces (including crack surfaces) to be inspected. Contaminated surfaces do not provide reliable liquid penetrant indications. Surfaces subjected to any mechanical operation such as machining, grinding or media blasting, must be etched to remove smeared metal covering entrapment areas.
2. Apply liquid penetrant to the dry part surfaces and allow sufficient dwell

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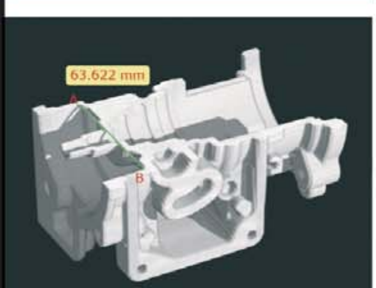

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time for the surface liquid penetrant to enter the discontinuities and form liquid penetrant entrapments. Liquid penetrant should wet the entire test surface area with a uniform liquid film. If the liquid penetrant pulls away leaving bare areas, the part surface is not clean enough.

3. Following a suitable dwell time, remove the excess surface liquid penetrant by room temperature water rinsing with a coarse spray applied at an angle as shown in Fig. 3e. Rinsing should continue until no traces of residual liquid penetrant are visible on test surfaces when viewed under suitable illumination. If wet aqueous developer is to be used, it should be applied to the wet part surfaces following water rinsing.
4. If dry or nonaqueous developers will be used later, dry the test parts thoroughly following removal of excess surface liquid penetrant. If wet aqueous developer was used, dry the test parts as soon as the excess developer coating has drained off the test parts. Oven drying may be desirable to reduce drying time. It is necessary to guard against excessive exposure to high oven temperature as this can degrade fluorescent dyes and reduce test sensitivity.
5. If aqueous developer has not previously been applied to the wet parts, apply dry or nonaqueous developer to the dry test parts. Liquid penetrant is drawn out of discontinuity entrapments to the part surface during the *developer dwell time.* As the liquid penetrant spreads into the developer coating, enhanced indications are formed.
6. Observe and interpret the liquid penetrant indications of surface discontinuities under suitable illumination. Evaluate each indication for rejection, rework, disposal or other action.
7. Perform postcleaning and treatment of test parts to remove liquid penetrant processing residue and provide corrosion protection.

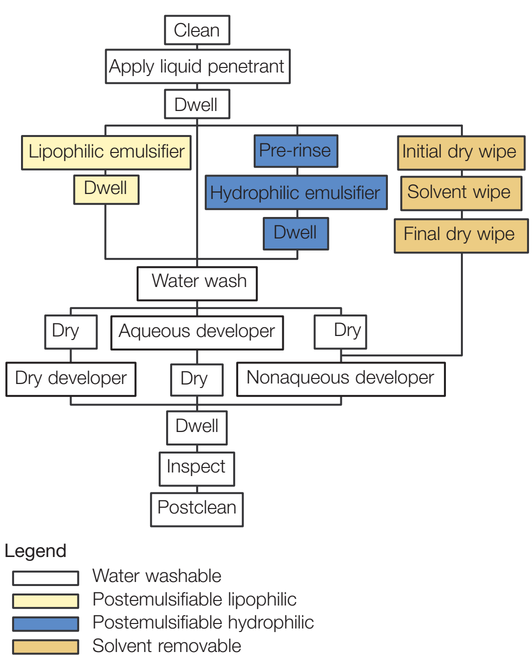

Figure 4. Liquid penetrant processes classified by removal method.

Lipophilic Postemulsifiable Liquid Penetrant Process. Procedure steps used with the lipophilic postemulsification liquid penetrant technique are shown in Fig. 4. The initial steps of precleaning, drying, applying liquid penetrant and allowing liquid penetrant to drain for an adequate dwell time are identical to those used with water washable liquid penetrants. Because the liquid penetrant does not contain an emulsifier, an additional step of applying emulsifier must be taken. A carefully controlled emulsifier dwell time must also be provided to make the excess surface liquid penetrant removable by water spray washing. Following washing to remove surface liquid penetrant, test parts are dried and developer is applied. Aqueous developers are applied before drying. Parts are inspected for liquid penetrant indications in the same way as in other liquid penetrant processes.

Hydrophilic Postemulsification Liquid Penetrant Process. The initial steps of precleaning, applying liquid penetrant and allowing for a liquid penetrant dwell and drain period are the same for the hydrophilic postemulsification liquid penetrant process as for all the liquid penetrant testing processes (Fig. 4). As with the lipophilic process, an emulsification/removal step is required. However, an additional pre-rinse is added immediately following the liquid penetrant dwell time. After this first wash, usually only a thin film of liquid penetrant held by molecular attraction remains on part surfaces. Through the mechanical action of a water spray, much of the excess surface liquid penetrant is removed. Application of the emulsifier/remover is accomplished by dipping the part in a hydrophilic emulsifier solution or spraying a much more diluted solution onto the part for a controlled amount of time. Subsequent processing steps are identical to the water washable and lipophilic postemulsification process.

Because the prior water rinse removes the bulk of the surface liquid penetrant, emulsifier contamination is minimized. Emulsifier diluted with three parts of water leaves only a thin surface film, reducing emulsifier dragout. The prewash hydrophilic emulsifier technique decreases emulsifier consumption thus lowering emulsifier cost.

Solvent Technique for Hand Wipe Liquid Penetrant Removal. Procedures for removing liquid penetrant by hand wiping or solvent removal are shown in Fig. 4. Materials used to remove excess surface liquid penetrant are referred to as *removers* or *cleaners*. However, the term remover is more appropriate to describe the solvents used for removal of excess

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surface liquid penetrant during processing of test parts in liquid penetrant testing, while the term cleaning refers to preparation of the surface before testing. In the solvent removal process, the available removers are often used also for precleaning and for postcleaning of test objects to remove liquid penetrant processing residues. However, their primary purpose is removal of excess liquid penetrant before application of developer.

Removers are normally petroleum base solvents but may be any solvent combination. Often an emulsifier contains enough solvency to function as a remover. Alternatively, a product may be formulated to function as either a remover or an emulsifier. Removers are subject to the same precautions in use as those described for use of liquid penetrants and emulsifiers.

Solvent Removal Procedure. Liquid penetrant removers are used to remove excess surface liquid penetrant following liquid penetrant application. Because removers function by solvent action, over-removal may be a problem if used to excess. The recommended hand wipe removal procedure includes:

- *Initial dry wipe.* Wipe excess liquid penetrant from test object surfaces with a dry wiping instrument such as a clean, dry, lint-free rag or soft absorbent paper.
- *Solvent wipe.* Remove remaining liquid penetrant residues with a wiping instrument such as a clean cloth slightly moistened with solvent.
- *Final dry wipe.* Wipe again with dry rag or absorbent paper to remove remaining solvent film on surfaces.

When fine, shallow discontinuities are under examination on smooth surfaces such as test panels with cracked chrome plating, dry wiping is sufficient. Use of any remover results in over-removal of liquid penetrant residues with resultant loss in sensitivity. The hand wipe technique is also difficult to use on test parts with rough surfaces or threads because wiping to the bottom of small, sharp recesses or cleaning deep grooves is impracticable. Additionally, the cleaning cloth or paper should only be lightly moistened with solvent for final removal of surface liquid penetrant residues. Never immerse the cloth in solvent nor saturate it with spray solvent when removing excess surface liquid penetrant from test parts. Excess solvent would then diffuse into liquid penetrant entrapments within discontinuities and tend to remove part or all of the liquid penetrant needed to form discontinuity indications.

Text and figures for "Removing Liquid Penetrant" adapted from the *Nondestructive Testing Handbook*, third edition: Vol. 2, *Liquid Penetrant Testing*. Columbus, OH: American Society for Nondestructive Testing (1999): pp 34, 36-38, 42-45.

Crossword Challenge

Magnetic Flux Leakage

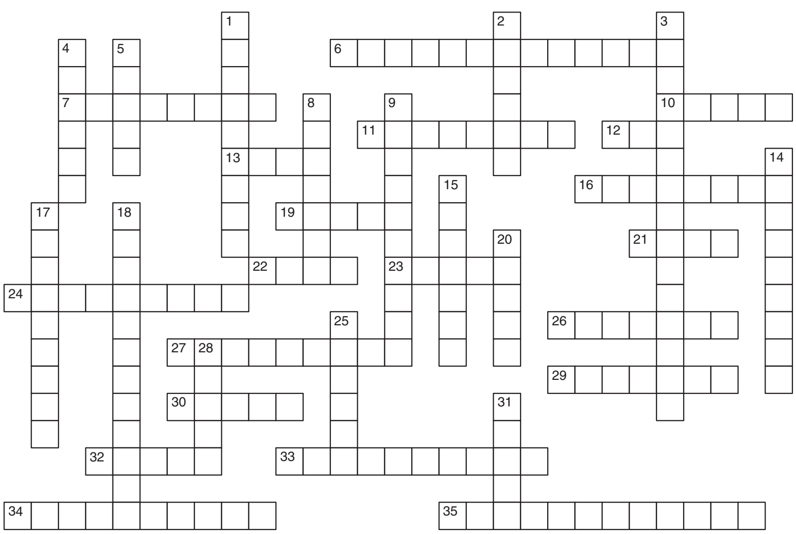
Roderic K. Stanley*

Across

6. Ampere-turn, unit expressing __________ force.
7. Smallest flux leakage sensor, magnetic ________.
10. More than one MFL sensor.
11. B-H curve region.
12. Subterranean animal used in magnetic flux leakage tests of pipeline.
13. Convenient concept for visualizing the vector field of magnetic induction that comprises a magnetic field.
16. Elongated steel product inspected by magnetic flux leakage testing.
19. Unit for magnetic flux density.
21. Downhole drilling material inspected by MFL.
22. This element measures B_x, B_y or B_z.
23. Unit for magnetic flux density.
24. Magnetic particle testing is a ________ of flux leakage testing.
26. Early investigator of magnetic metal properties.
27. Generation of a signal in a search coil by MFL.
29. Distance from inspected surface to sensor.
30. Flux lines form closed loops that do not _____.
32. Pole at which magnetic field enters a part.
33. Magnetic flux leakage sensor with ferrite core.
34. Phenomenon exhibited by a magnetic system wherein its state is influenced by its previous history.
35. Air in a crack has a __________ of one.

Down

1. Increases magnetic flux leakage signal.
2. Small, fully magnetized region of a part.
3. This happens at ends of magnetized parts.
4. SI unit of electric current.
5. Temperature at which a phase transformation causes ferromagnetic materials to lose their magnetic properties.
8. Old magnetic flux unit replaced by the weber.
9. Highest point in active induction.
14. Largest point in residual induction.
15. Obsolete centimeter, gram and second (CGS) measurement unit of magnetizing force; one is equal to 79.57747 $A{\cdot}m^{-1}$.
17. Ampere-per-meter, SI derived unit for magnetic field ________.
18. One-directional MFL probe whose resistance changes with field intensity.
20. Old CGS unit for magnetic flux density.
25. Reduces magnetic surface noise.
28. Pole at which magnetic field leaves a part.
31. One _____ per square meter is equal to 10,000 gauss.



Answers

Across

6. magnetomotive
7. particle
10. array
11. rayleigh
12. pig
13. flux
16. wirerope
19. weber
21. pipe
22. hall
23. tesla
24. technique
26. forster
27. induction
29. liftoff
30. cross
32. south
33. ferroprobe
34. hysteresis
35. permeability

Down

1. amplifier
2. domain
3. demagnetization
4. ampere
5. curie
8. maxwell
9. saturation
14. remanence
15. oersted
17. intensity
18. magnetodiode
20. gauss
25. filter
28. north
31. weber

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Falsifying and Failure to Report by Ronald T. Nisbet *

Ethical violations that escape detection at an early stage can cause critical failures over time. In the examples that follow, defects were detected and conscious decisions were made to not report the damage. The continued operation of the plants involved was considered more important than the potential for their failure. As you read through these examples, consider the influences that may have played a part in the misrepresentation or suppression of accurate and timely reporting.

Unreported Cracks In Reactor Head

On August 3, 2001, FirstEnergy Corporation, owner of the Davis-Besse Nuclear Power Station located near Oak Harbor, Ohio received a bulletin from the Nuclear Regulatory Commission (NRC). Primary water stress corrosion cracking had been detected in several plants with pressurized water reactors (PWR) like the one at Davis-Besse. The NRC bulletin required all PWR licensees to provide information on their programs for inspecting vessel head penetration. The NRC wanted to know how susceptible each of the plants was to cracking, what steps had already been taken to detect cracking, and what plans had been formulated for addressing the cracking problem in the future.[1]

Inspection Documentation. In the months following issuance of the bulletin, as the NRC contemplated whether to impose the first safety-related shutdown order for a nuclear plant since 1987, FirstEnergy Corporation submitted documentation for successful prior inspections conducted at the Davis-Besse plant. Based on the documentation and oral information from Andrew Siemaszko, reactor coolant system engineer for the facility, the NRC allowed FirstEnergy to delay shutdown of Davis-Besse until a scheduled refueling in February 2002. A jury would later learn the documentation was based in part on false information from Siemaszko regarding his own inspections of the reactor vessel head and video inspections made by others as well.[2]

Cavity Revealed. Inspections conducted during the refueling shutdown determined that five of the 69 control rod drive mechanism (CRDM) nozzles had developed axial cracking. Three were leaking borated water from the reactor coolant system. Nozzle repairs were performed remotely from underneath the head. At the completion of repairs, as a machining apparatus was being removed, the number three nozzle "tipped in the downhill direction until it rested against an adjacent CRDM."[3] Removal of the number three nozzle and boric acid deposits from the top of the reactor pressure vessel (RPV) head revealed a football-sized cavity on the downhill side of the nozzle. The only structure that remained in the wastage area was the 9.5 mm (0.375 in.) stainless steel cladding of the RPV head. If the Davis-Besse reactor head had been allowed to continue operating, the NRC estimated that it would have failed within two to 11 months and would have resulted in a serious loss of coolant accident. "A crisis was barely averted when the plant was shut down on February 16, 2002, six weeks later than what the NRC had originally proposed."[4] As a result of the incident, FirstEnergy was fined $5.45 million dollars, the largest single fine imposed by the NRC. They would eventually pay $33.5 million in fines. Repairs and upgrades to the aging reactor would reach $600 million and two years would pass before they were complete and the plant could be returned to service. Andrew Siemaszko and David Geisen (Siemaszko's supervisor and co-defendant) were fired by FirstEnergy Coporation after the cavity in the RPV head was discovered. They would be the only two convicted of deception charges. Geisen would be sentenced to three years of probation with 200 hours of community service and a fine of $7,500. Siemaszko would eventually receive three years of probation and a fine of $4,500. Both could have been fined $250,000 and sentenced to five-year prison sentences for each of the three felony deception charges they were convicted of.[5]

Crisis in Confidence

In a 2004 keynote speech in Seoul, South Korea, Shinzo Saito, president of the Atomic Energy Society of Japan and vice chair of the Atomic Energy Commission of Japan detailed a reduction in the average annual capacity

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of Japan's nuclear reactors that was brought about by a shutdown of all Tokyo Electric Power Company (TEPCO) power plants that began in August of 2002.[6]

Initial Growth Slows. In the mid 1990s, Japan's nuclear power industry was flourishing. Japanese nuclear power plants were operating at 80 percent capacity. In 1998, capacity would exceed 87 percent. Ten years later, however, the Japanese Nuclear Industrial Safety Agency (NISA) would report that the average annual capacity was languishing at 60 percent, the result of the suspended nuclear plant operations.[7]

Series of Incidents. Lacking sufficient domestic natural resources, Japan must import more than three-quarters of its energy requirements. During the oil crisis of the early 1970s, nuclear energy, as a means to energy independence, became a national priority. The effort was fully supported by a majority of the Japanese people until the mid-1990s when a series of incidents began to erode public confidence. The first of these was a major liquid sodium leak at the experimental Monju fast breeder reactor in December of 1995. This was followed in 1997 by an explosion at a bitumen solidification plant in Tokai-mura and, in 1999, two workers died from radiation exposure, the result of an illegal mixing operation at a fuel fabrication facility in Tokai-mura. In August of 2004, five workers died as the result of a steam pipe rupture in Mihama.[8,9]

Questions Emerge. In May of 2002, questions began to emerge regarding inspections made by the Tokyo Electric Power Company (TEPCO). In August, NISA announced that TEPCO had falsified voluntary inspection reports and concealed their actions for many years.[11] The falsified inspection records were an attempt to hide cracks in reactor vessel shrouds in 13 of the 17 nuclear power plants owned by TEPCO. In all, 29 cases of falsification related to damage in many reactor pressure vessel parts would eventually be uncovered. These would include an attempt to hide repair work by editing inspection videotape and the injection of compressed air into a containment vessel to pass a leak rate inspection.[4]

Replacement Power. By May of 2003, all 17 TEPCO reactors had been shut down. Seven would be returned to service by the end of the year but replacement power during the interim would prove expensive — 50 percent more than nuclear generation. Total expenditures would exceed 200 billion yen (US $1.9 billion).[2] The TEPCO scandal would widen to include numerous cover-ups at other nuclear utilities. Ensuing investigations would reveal a serious lack in systematic inspections of Japanese nuclear plants and would result in revisions to inspection related laws.

Conclusion

Stop for a moment and ask yourself the following questions:

- What influences to misrepresent or suppress accurate inspection results are present in your NDT working environment?
- How do you address them personally?
- How are they addressed by your employer?
- What would you do if you knew that a coworker or supervisor had falsified or misrepresented inspection results?

Consider the possibilities of a failure due to nonreporting or misrepresentation. Could someone's life or livelihood be jeopardized by your actions or inactions? Nondestructive testing plays an important role in equipment safety, reliability and longevity. Your professional ethics are as important as your knowledge and skills.

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PRACTITIONER PROFILE

Randy Jurgens

Randy Jurgens wanted to be a welder but, while attending a community college open house, he discovered the display of NDT processes and equipment. He spent the rest of the day talking with the instructors and students enrolled in the program. Before the day was over, he knew his career would be in NDT. Randy is now employed by Herzog Services and is the chief operator of a rail inspection vehicle. He has tested rail in locations as diverse as Mexico, the Northwest Territories of Canada, Nova Scotia and 40 of the lower 48 states.

Q: What NDT training is needed to operate a rail inspection vehicle?

A: Each operator must complete a 40-hour training program before becoming a Level II. The Level II is *SNT-TC-1A* compliant but limited to rail testing. After completing the program, it usually takes about a year to complete enough on-the-job training to become a chief operator, depending on the background and experience of the individual.

Q: Would you describe a rail inspection vehicle for us?

A: We have two types of trucks, a smaller pickup truck and a larger box type truck. Both have the same test equipment. The larger truck is really a mobile office. The trucks have standard road tires but attached to the truck about 12 in. (30 cm) in the air, are the high-rail wheels. The high-rail wheels and guide wheels are set down on the track hydraulically. There's also a hydraulic test carriage. When you get to the test location, it comes down and adjusting gear motors align the RSUs (roller search units) onto the gage side of the track. An air cylinder provides outward pressure to keep the wheels tight against the reference gage corner and the hydraulic system provides downward pressure. The hydraulic high-rail system is operated from inside the truck and guides the truck down the track. The truck's rear wheels remain in contact with the rail surface and provide the propulsion for the vehicle while it's on the track.

"To put it in simple terms, our job is to find rail breaks before they break. We can do that sometimes as much as a year in advance."

Q: What NDT method do you use to inspect rail?

A: Ultrasonic testing. There are thousands of miles of railroad track that require a continuous search for internal defects. UT lends itself to high speed continuous testing with real-time interpretation.

Q: How is the transducer configured? Does it contact the rail?

A: It does not. It's immersed in liquid inside the rubber RSU — a kind of squishy wheel. Water supplied from tanks carried on the back of the truck is sprayed on the rail and the outside of the tire as couplant. So, the signal goes through the liquid in the wheel, the rubber tire, the water coupling and into the rail.

Q: What indications do you look for?

A: Positive and negative response indications. The top of the rail is the head, the base is the bottom and the web connects them. As the roller search unit rolls along the head of the rail at, say, 10 mph, you see the base of the rail. You watch the bottom of the rail the entire time. If there's a defect in there, you won't see the bottom of the rail because the sound will either hit the defect and come back — a positive response — or hit the defect and bounce off to a different portion of the rail — a negative response. In continuous-weld track construction, where the rails are welded together for miles without any joints, a common indication is the detail fracture. It's a progressive fracture originating near the surface of the rail that progresses transversely across the head. In conventional track construction, rails are approximately 30 ft (9 m) long and are bolted together with joint bars. A common indication in this type of construction is the bolt-hole break — a linear fracture that originates at a bolt-hole when the joint isn't properly supported from below.

Q: What happens when you find an indication?

A: When the truck moves forward, the test scrolls forward. When the truck moves backward the test scrolls backward. Data for the entire test is recorded in real-time and can be replayed and displayed just as the test was conducted. An indication will stay on the screen for several seconds when traveling at 10 mph. When an indication is detected, the operator directs the driver to stop and back the vehicle up to the indication. You then get out of the truck with a hand scope and manually inspect the track with the appropriate transducer. If there's a defect, you do the client required taping of the rail, paintings and writings.

You return to the truck, icon it on the test, report it and then continue on. We have two linked computers that are used simultaneously. The first computer, the truck computer, receives the inspection data, controls test settings and allows the operator to label the track information onto the test. The operator enters the defect information and label indications into the truck computer. The truck computer sends the report information in real-time to a laptop computer that is used to generate reports, emails and client upload information. Sometimes there's a railroad section truck behind us carrying rail and safety bars. If we find a bad defect, they may need to fix it right away before another train goes over it. Another corrective action might be to slow the track speed down but that's a logistical nightmare on some high-traffic lines and the client will send a repair truck behind the inspection vehicle to fix stuff as we go. To put it in simple terms, our job is find rail breaks before they break. We can do that sometimes as much as a year in advance. We can find really small defects that will last sometimes well over a year before they break.

Q: What's the biggest source of damage to rail?

A: Surface conditions. A loaded coal car can weigh 100 thousand pounds and coal trains can get to be a 125 cars long. That's 12.5 million lbs of train, not including the engine, moving at 60 mph on top of 7 in. (18 cm) of steel. Over time, the surface of the track becomes cold-worked — harder than the subsurface. This causes a lamination effect where very small fractures can start. The surface starts to develop irregularities. The most common is shelling — kind of like a pothole. The force of the train wheel passing over the rough surface causes rail fractures that can progress very rapidly. With proper track maintenance however, rail is very durable and can last years. I've tested track rolled in 1906 that's still in service and I've seen track from the late 1890s that's still being used.

Q: What are the safety issues for rail inspection?

A: Each crew has to have safety classes before being allowed on railroad property. These are through our company but must meet client requirements. In some cases, the client provides them. Safety is a major concern, particularly in situations such as when testing a multiple track configuration. The test truck may be testing the center track of a triple main track configuration. A passenger train moving at 80 mph can pass six feet to one side of the test truck and a freight train moving at 60 mph can pass six feet away on the other side. We have to be aware of our surroundings.

Q: How much track is normally inspected in a day?

A: That depends. On high traffic lines, we may have to wait two hours to get the track for 30 minutes, a process that may be

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repeated over and over. On low traffic lines, we may get the track all day, every day until the test is complete. Continuous mainline testing means we start in one location and test in one direction all day on the same track. That's ideal for obtaining the most miles of test. Yard track testing is testing one small segment of track and then relocating to another. It's necessary work but not impressive for total miles tested in a day. Highly maintained, continuous-weld rail with excellent surface conditions can be tested at sustained speeds of 15-20 mph. Poor surface conditions such as excess shelling and grease on the rail surface can slow the test to a crawl. The client may also require additional manual inspections for portions of the track, such as switching components. Testing through a busy city with many industries or testing in high volume train yards can also require frequent stops.

Q: What are the best and worst parts of your work?

A: Testing up the east coast of Florida only a few miles from the beach every day and testing through Alaska stand out pretty strong as career highs for me. The worst part of my work is winter. We conduct inspections in temperatures well below zero. Things break down more often in the winter, hydraulics get stiff, air seals shrink and leak, snow drifts over the rail, crossings freeze over with ice. Verifying indications often requires shoveling and chiseling ice from the rail.

Q: How would you advise someone considering a career in NDT?

A: I strongly encourage anyone interested in NDT to go to an accredited school that offers a degree in NDT. I have an associate of applied science degree in nondestructive testing technology from Southeast Community College Nebraska and a bachelor of technology degree from Peru State College in Peru, Nebraska. After graduation in 1996, I was Level II equivalent in VT, LT, PT, MT RT, ET and UT. Demand for qualified inspectors was so high that I had signed to a job two months before graduating and employers were still coming to me.

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