



4/10/09

“Certified Nondestructive Testing of Infrastructure ”

By Jesse A. Grantham, P.E., NAFE 597M

INTRODUCTION

Forensic Engineers use certified Nondestructive Testing (NDT) specialists and apply scientific and mathematical principles to practical uses for the in-service examination of infrastructure. The Forensic Engineer knows how to confirm the original designer’s intent for implementing maintenance NDT and repair NDT methods. This information is then used to select the best NDT methods for the present condition of an infrastructure component. The Forensic Engineer uses practical information that is often not found in handbooks and is only gained by hands-on experience.

Infrastructure is the basic physical systems of a country's or community's population, including roads, utilities, water, sewage, etc. These systems are considered essential for enabling productivity in the country’s economy. Current trends in Forensic Engineering investigations of infrastructure items are applied to confirm fitness-for- service of components that have reached or exceeded the original design life or need to remain safely in-service. The fundamental NDT method used is visual examination. Removal or paint, coverings and debris that prohibit examination and access to the part are a requirement. Figures 1 and 2.



Figure 1. Leak inside Pipe from Ground Water



Welding & Joining Management Group

FORENSIC EXPERTS • METALS TESTING



Figure 2. Failed Beam

NONDESTRUCTIVE TESTING

The Forensic Engineer uses NDT personnel who follow an approved and audited Quality Management System (QMS) as their guidelines and procedures for examinations. The purpose of utilizing a NDT method within a procedural system is to consistently determine the universal truth from an examination. Forensic Engineers use fundamental math and science, along with an understanding of acceptance criteria by unobstructed visual examination during infrastructure inspections.

The Forensic Engineer knows that it is reasonable to expect a hired professional certified inspector to follow ethical guidelines, Rules of Conduct, and corporate policies. The Forensic Engineer is always obligated to safeguard the health and well being of the public, maintain integrity, and high standards of skills, practice and conduct in the occupation of forensic examinations. The Forensic Engineer is cognizant of the following principles and the scope to which they apply.

- The NDT technician must act with complete integrity in professional matters and be forthright and candid on matters pertaining to inspections.
- The NDT technician must act to preserve the health and well being of the public by performing duties required of inspection in a conscientious and impartial manner to the full extent of the inspector's moral and civic responsibility.
- The NDT technician should undertake and perform assignments only when qualified by training, experience and capability.
- The NDT technician should be completely objective, thorough and factual in any written report, statement or testimony of the work and include all relevant or pertinent testimony in such communications or testimonials.
- The NDT technician must sign only for work that the technician has personally inspected, or for work over which the technician has personal knowledge through direct supervision of the test.
- The NDT technician should neither associate with nor knowingly participate in a fraudulent or dishonest venture or activity.

While the Forensic Engineer may have established excellent credentials, certification alone may not legally qualify the Forensic Engineer to provide inspection services to the public on infrastructure items. Contract documents, building codes, or jurisdiction laws may require inspection to be performed under the direction and responsibility of others, such as an AWS-Certified Welding Inspector (CWI).



Welding & Joining Management Group

FORENSIC EXPERTS • METALS TESTING

An acceptable forensic NDT investigation will follow the NDT Quality Management System (QMS) and adhere to the acceptance criteria contained in codes and quality standards.

The practical NDT QMS provides:

- Cumulative experience of engineers and craftsmen.
- Validated procedures for a systematic reduction of variation.
- Standardized personnel qualifications and certifications.
- Approved procedures for intelligent and skillful execution of techniques.
- Proper means and methods to formally report findings.

The fundamental types of discontinuities located by technicians for the Forensic Engineer are:

Surface discontinuities. Visual Testing (VT) is the most common and least costly inspection method for locating discontinuities on the welds, bolts and adjacent surfaces. To enhance surface VT, Magnetic Particle Testing (MT) or Penetrant Testing (PT) is used. While welding, VT, MT or PT, may be used by the welder to reveal discontinuities while welding is in process.

Subsurface discontinuities. Welds, bolts, metal and concrete may be examined by Radiographic Testing (RT) commonly called x-ray or gamma ray, and Ultrasonic Testing (UT). These techniques locate volumetric discontinuities that are not visible on the surface.

Five common NDT methods used by in forensic investigations include: VT, MT, PT, UT and RT. Table 1.

Table 1. Common NDT Methods Used by Forensic Engineers to Examine Infrastructure

Visual Testing	VT	Primary method of welding inspection.
Magnetic Particle Testing	MT	Magnetic field applied from two directions on weld.
Penetrant Testing	PT	Reveals discontinuities open to the surface.
Ultrasonic Testing	UT	Instrument for straight beam and shear wave tests.
Radiographic Testing	RT	Gamma rays and provides a film for interpretation.

CODES

Infrastructure is generally constructed in accordance with applicable building codes. A building code is a systematically arranged, comprehensive set of rules, standards and specifications for published applications to secure uniformity in construction and to protect the public and property. A code consists of a set of conditions and requirements relating to a particular subject and indicating appropriate procedures by which it can be determined that the requirements were met. Routine NDT of infrastructure components is often a requirement in the codes.

When a force is applied to any member, the member becomes stressed. The stresses cause strains, or movements which are explained by the material properties. In-service conditions cause stress, distortion, fatigue and corrosion. Loads always produce incremental movement in materials and structural members.

Designs for welds and bolted connections are determined on the basis of load requirements. Routine inspection practices must address many applicable material engineering topics. Several of these are:

- Preparatory Work for infrastructure inspections that includes confined spaces, purging, cleaning, ventilation, gas testing and protective equipment.
- Nondestructive testing equipment used for the inspection is subject to safety requirements.



Welding & Joining Management Group

FORENSIC EXPERTS • METALS TESTING

- Modes of deterioration and failure. When developing an inspection plan for equipment operating at elevated temperatures, the following should be considered in assessing the remaining life:
 - Creep deformation and stress rupture.
 - Creep crack growth.
 - Effect of hydrogen on creep.
 - Interaction of creep and fatigue.
 - Possible metallurgical effects, including a reduction in ductility.
- Common Forensic NDT techniques can be applied to find and characterized elevated temperature damage. The inspection plan should be prepared in consultation with an engineer having knowledge of elevated temperature and metallurgical effects on pressure vessel materials of construction.
- Inspect all accessible parts and surfaces. Examine the surfaces of shells, heads, beams, plates, bolts, and welds carefully for possible cracks and other signs of deterioration. Examine welded joints and adjacent heat-affected zones for service-induced cracks or other defects. Examine the surfaces of manways, nozzles and other openings for cracks and other defects, paying particular attention to the welding used to attach the parts and their reinforcements.
- Repairs, alterations, and rerating of pressure vessels have to be performed by qualified and certified personnel. The applicable requirements of the codes to which the items were originally built or other specific pressure rating codes shall be followed.
- Acceptance criteria for a welded repair or alteration inspection should include nondestructive examination techniques that are in accordance with the applicable sections of the Code.

CHOICES

Forensic Engineers use NDT and must be capable of interpreting examinations and reporting their findings. Forensic Engineers must adequately explain the NDT findings to Owners, Lawyers, Accountants, and Adjusters.

Characteristics of a qualified forensic NDT technician are to ability to:

- Interpret drawings and welding symbols.
- Initially apply the required acceptance criteria by visual examination.
- Determine methods to make NDT dispositions within the allotted time for inspections.
- Wear suitable personal protective equipment.
- Service NDT equipment and keep extra parts and consumables.
- Follow established and proven nondestructive testing methods.
- Write accurate and understandable reports.

The Forensic NDT Engineer and NDT technician often use visual samples as aids to compare the appearance of acceptable metal surfaces, welds and bolts with in-service items. It is important that the Forensic Engineer knows what is expected and is capable of providing results in an assignment.

The Forensic Engineer knows that quality cannot be inspected into an in-service part. "Quality" is relative term and means compliance with the code and the designer's intent.

Forensic Engineers know that weld quality may vary between different types of infrastructure components. Figures 5, 6, 7, and 8 are examples of failed materials:

Safety information and specific training for NDT technicians during forensic examinations are the NDT firm's responsibility. These duties are to ensure that all assigned tasks are performed in a reasonably



Welding & Joining Management Group

FORENSIC EXPERTS • METALS TESTING

safe manner. The NDT employer has the responsibility to take action when required so that workers may use equipment and materials in the workplace with reasonable safety.

Adequate repair procedures are required when using most industrial products for commercial use has been defined in numerous standards that address hazardous conditions in the workplace for many years. The methodology for achieving adequate repair procedures depends upon factors present in each individual workplace, which is under the supervision and control of each individual employer. The MQS contract inspector is always warned to follow established procedures.

In addition to repair NDT procedures, all persons who may be possibly exposed to any repair operation hazards and start-up conditions should be informed and trained about the hazards associated with welding operations and pressure vessel welded repairs. Failure to do so may result in an unnecessary increase in exposure to hazards addressed in the MIP. The fundamental purpose of the MIP is to provide information, which if followed, alters human behavior in such as way that exposure to a hazard is eliminated or minimized.



Figure 3. Fatigue Failure of a Large Shaft



Figure 4. Heat Exchanger Tubes



Figure 5. Ruptured Copper Pipe

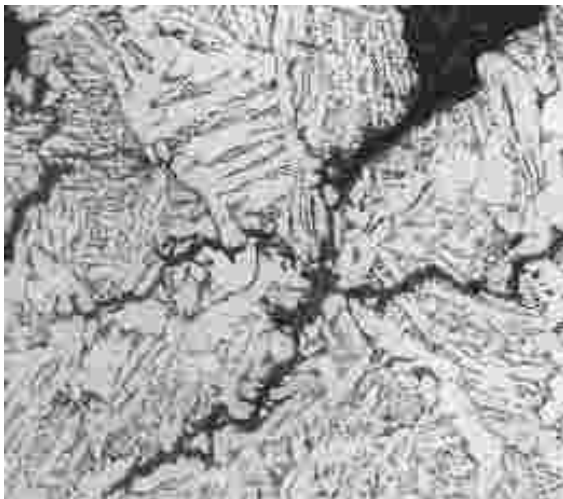


Figure 6. Stress Corrosion Cracking, 100X

CONCLUSIONS

Forensic Engineers perform assessments to determine with reasonable accuracy the fitness for continued service for infrastructure items. Forensic Engineers may hire certified NDT personnel who are proficient and capable of ethically providing the truth in their reports. The Forensic Engineer's acceptance of NDT reports for a component represents the last line of defense for accurate verdicts in the court room and the continued life of the infrastructure component.

The Forensic Engineer knows that education, experience and certification are fundamental requirements for successful examinations of aging infrastructure. NDT is used in forensic investigations and must be accurate to properly confirm that the component continues to meet the code requirements and fitness-for-service quality expected by the owner and original designer.

In the Forensic Engineer's assessments, the necessary quality of an in-service component is that it continues to meet the original designer's intent as validated by certified NDT personnel.

Select References:

Nondestructive Testing Handbook, 2 volumes
www.asnt.org - Recommended Practice SNT-TC-1A

The American Society of Nondestructive Testing
American Society of Nondestructive Testing



Welding & Joining Management Group

FORENSIC EXPERTS • METALS TESTING

www.aisc.org - Codes, standards, specifications
www.asme.org - Codes, standards, specifications
www.astm.org - Standards, specifications
www.aws.org - Codes, standards and specifications

American Institute of Steel Construction
American Society of Mechanical Engineers
American Society of Testing and Materials
American Welding Society