Nondestructive Tubular Goods Inspection

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One of the serious problems which faces the oil producer is tubular goods failure. With the trend toward more deep wells and higher pressures, pipe failure has become increasingly expensive. Failure of a length of pipe can generally be attributed to one of two primary causes: either to the existence of a manufacturing-origin defect or of a service-induced defect in the tube. This paper will outline the common types of manufacturing-origin and service-induced defects, and describe various commercially available inspection methods which can be utilized to locate these defects before they lead to expensive failure.

DEFECTS ORIGINATING FROM MANUFACTURING

The characteristics of the operations performed in manufacturing seamless tubular goods give rise to several types of manufacturing origin defects. These defects include seams, overlaps, slugs, pits, longitudinal cracks, eccentricity, transverse cracks, and hardness variation.

Seams and Overlaps

These are fissure-type defects which are characteristically oriented nearly parallel to the long axis of the tube and which may exist on either the inside or the outside surface of the pipe. The overlap is distinguished from the seam by the relative orientation of the two faces of the fissure. In the overlap one face extends over the other at the surface of the tube, while in the seam, the two faces meet parallel.

Slugs

These defects result from the impression, during manufacture, of foreign matter into the tube wall. They may exist on either the inside or the outside of the tube wall and may have nearly any configuration.

Pits

These depressions in the surface of the tube may result from several manufacturing operations and may exist on either tube surface.

Longitudinal Cracks

Cracks, especially those located in the bottoms of plug scores (gouges on the inside surface of the tube produced in the piercing operation) have been observed more frequently of late. These defects probably result from residual stresses in the pipe.

Eccentricity

In most seamless tubes, the ID is not exactly concentric with the OD. In some cases this eccentricity is so pronounced that the thin portion of the tube wall fails to meet API dimensional specifications.

Transverse Cracks

Transverse cracks are produced primarily in the end areas of the tube during the upsetting operation but do sometimes occur in the body of the pipe. These cracks may exist on either surface. High strength and special upset tubular goods are particularly prone to this type of defect.

Hardness Variation

When heat treating of the tube is not properly performed, injurious hardness variation may be produced in the pipe.

REASON FOR INSPECTION OF NEW TUBULAR GOODS

The defects described above exist in significant quantities in new pipe. Recent inspection of over 40,000 lengths of new 2-3/8 in. tubing located defects in the tube wall exceeding API or customer specifications in 960 of these lengths. But this conclusion does not include the additional defects found in the couplings. This figure represents an average of 2.4 per cent, or 7 lengths in every 10,000 ft string. Even more important, however, is the fact that in 1 out of every 5 inspection jobs involving over 3,000 ft of pipe, the percentage of defective lengths exceeded 5 per cent. Additional defects discovered in new couplings add to the number of potential failures present in every new string.

The possibility of these defective lengths causing premature failure is greatly increased in deeper wells and wells with high pressures. While the cost of premature failure varies greatly, it is usually much greater in deep wells, multiple completions, wells in inaccessible locations, and wells with high pressures.

A reliable inspection, by locating and rejecting defective lengths, can greatly reduce or eliminate premature failure. The cost of inspection is almost incidental to the time and money cost of premature failure.

NEW PIPE INSPECTION METHODS

Combination Mechanical-Optical, Magnetic Particle Inspection

This inspection is performed to locate manufacturing origin defects in all sizes of new tubing, drill pipe and casing. It consists of a visual and magnetic particle inspection of the outside of the tube, and a bore-view instrument inspection of the inside of the tube.

Magnetic Particle Inspection: This inspection is designed to locate longitudinally-oriented defects on the outside surface of the tube. To accomplish this end, a transversely oriented residual magnetic field near saturation is induced into the tube by conducting a large (900-2000 amps) DC electric current through the pipe. Depending upon the grade and type connection of the pipe, one uses either prods which conduct magnetizing current directly into the tube, or rods through which magnetizing current is separately conducted.

After magnetization, fine iron powder is applied to the outside of the tube. Wherever an outside longitudinal defect exists, the magnetic flux disturbance that it creates attracts these iron particles. The powder "build-up" thus produced clearly outlines the defect.

It is standard practice to inspect the full length of one-third of the circumference of the pipe in one pass

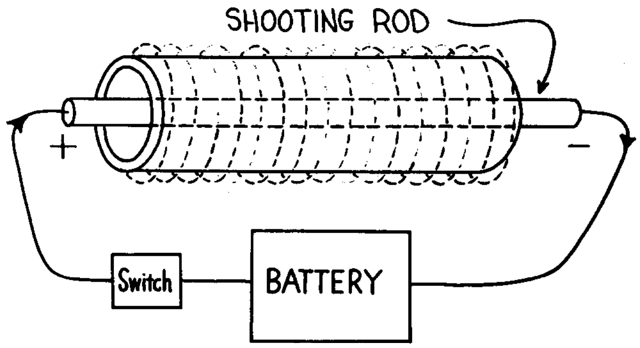
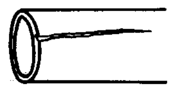


Fig 1. - Magnetizing tubing with a "shooting rod"



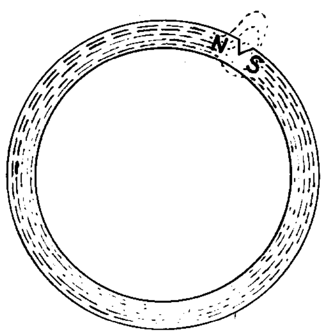


Fig. 2 Diagram showing flux bridging across longitudinal defeat.

then to roll the tube and to repeat this inspection until its full circumference has been covered. During the course of this inspection, other defects such as pits, or gouges, which may not yield magnetic particle indications, are visually located.

When an outside defect is located by this method, it is evaluated by grinding to the point of its deepest penetration or to the API allowable limit, whichever occurs first, and evaluating its depth with a depth gauge of + .001 in. accuracy. If the defect does not exceed API specifications, the grind mark is faired into the tube body.

Optical Inspection: This inspection is designed to locate all visible defects on the inside surface of tubular goods. The inside surface of the tube under examination is first cleaned with a power-rotated wire brush of appropriate size for the I D to be examined. The inside of the tube is then critically examined with a bore-view instrument specially manufactured for this purpose.

The usual optical instrument consists of a maximum of five 6 ft long tubes, each 1-7/16 in. O D. The instrument views simultaneously the complete circumference of the tube. Resolution of the instrument should be 2' 30" of arc or better and the field of view should be approximately 90°.

To provide optimum illumination of all sizes of pipe, various light sources of either the mercury vapor or iodine vapor type are used with these instruments. The light source is attached to the instrument immediately ahead of the objective lens.

Defects located through optical inspection are evaluated visually by the inspector.

Fig. 3 Applying magnetic particles and evaluating defeat in new tubing.

Amalog (R) Inspection

Amalog is a new electromagnetic method of inspection for all defects exceeding API specifications in new tubing, casing, or drill pipe.

Field Amalog

This inspection is performed on a semi-automatic pipe handling rack. The pipe is magnetized with a circumferential field using a high-amperage, direct current conducted through an insulated shooting rod.

The tube is then, at a fixed rate of speed, conveyed through a rotating scanning head. Detector units or "shoes" in this head scan the full length of the tube body, and flux leakages detected by the scanning unit are transmitted to the console or control desk where six seam styluses and one eccentricity stylus permanently record in log form this information.

A second scanning device is mounted directly behind the rotating head. As the tube enters the second head, a longitudinal field is induced, and causes transversely-oriented defects to produce a flux leakage. Here, stationary detector units scan the tube for flux leakages which again are transmitted to the console and permanently recorded. In this phase eight detector channels are recorded on one stylus by the Minimax system.

All log indications are interpreted by the operator who, where necessary, performs complete evaluation of potential defects.

If indications of eccentricity warrant further investigations, the actual wall thickness is measured by the use of an ultrasonic device.

Shoe sensitivity and amplifier gain for all channels are periodically standardized with a pipe sample containing controlled, artificial defects.

A scanning-circuit checking device is built into the console. After each length is run, all detector devices are checked automatically. If a faulty detector is present, the system will display a warning light indicating the appropriate channel in which the defective detector may be found. It also sounds an alarm over the audio system and locks out the paper drive system until repairs or replacements are made.

Amalog inspection on special upset pipe is supplemented by a Special End-Area Inspection. The operator arrives at the final grade of each length by correlating the recorded log indications with the results of the end-area inspection and any other tests performed. Each length is then color-coded to indicate its final grade.

Plant Amalog

This inspection is performed in a similar manner to Field Amalog inspection, except that the tube itself is rotated over stationary shoes. This system allows the handling of larger sizes of pipe. A plant installation allows inspection under extreme weather conditions.

Fig. 4 Optical inspection to locate harmful defects inside tubing.

Special End-Area Inspection

This inspection is performed to detect and evaluate defects resulting from upsetting or swaging operations. All scale and foreign matter are removed from the outside end-area surfaces by sandblasting. Longitudinally and circumferentially-oriented magnetic fields are then induced into the end-area surfaces, and magnetic particle inspections performed to detect both transverse and longitudinal defects AC magnetization equipment is employed for increased skin sensitivity.

Hardness Testing

Rockwell scale hardness tests may be performed on new tubular goods to locate injurious hardness variation or for other purposes as specified by the customer. Portable hardness testers operated by personnel trained in their use are available. The instruments available include Riehle, Ames and Wilson portable hardness testers.

SERVICE INDUCED DEFECTS

The service environment and operating stresses which tubing and sucker rods are required to withstand produce several types of service-induced defects. The most common of these are the following:

Defects in Used Tubing

Common defects occurring in used tubing include corrosion pitting, rod wear and mechanical damage.

Corrosion Pitting: Corrosion pitting is the most common used tubing defect. It may occur on either surface of the tube and may cover the entire length of the pipe or exist only in isolated areas.

Rod Wear: Rod wear is the wearing of a longitudinal groove into the inside tubing wall by moving sucker rods. It is common in pumping wells.

Mechanical Damage: This may result from any handling which the tube undergoes. It is particularly common in the slip area where high-level stresses occur.

Defects in Used Sucker Rods

Common defects in used sucker rods include fatigue cracks, corrosion pitting, mechanical damage and abrasive wear.

Fatigue Cracks: These defects result from the cyclic stressing to which sucker rods are subjected. They are transversely oriented.

Corrosion Pitting: By reducing cross-section, these defects weaken the rod. They also serve as focal points for the initiation of fatigue.

Mechanical Damage: Mechanical damage such as gouges, bends and cracked hammer marks (on couplings) are common in used sucker rods.

Abrasive Wear: The abrasion of the rod against the inside tubing wall may significantly reduce its cross-section.

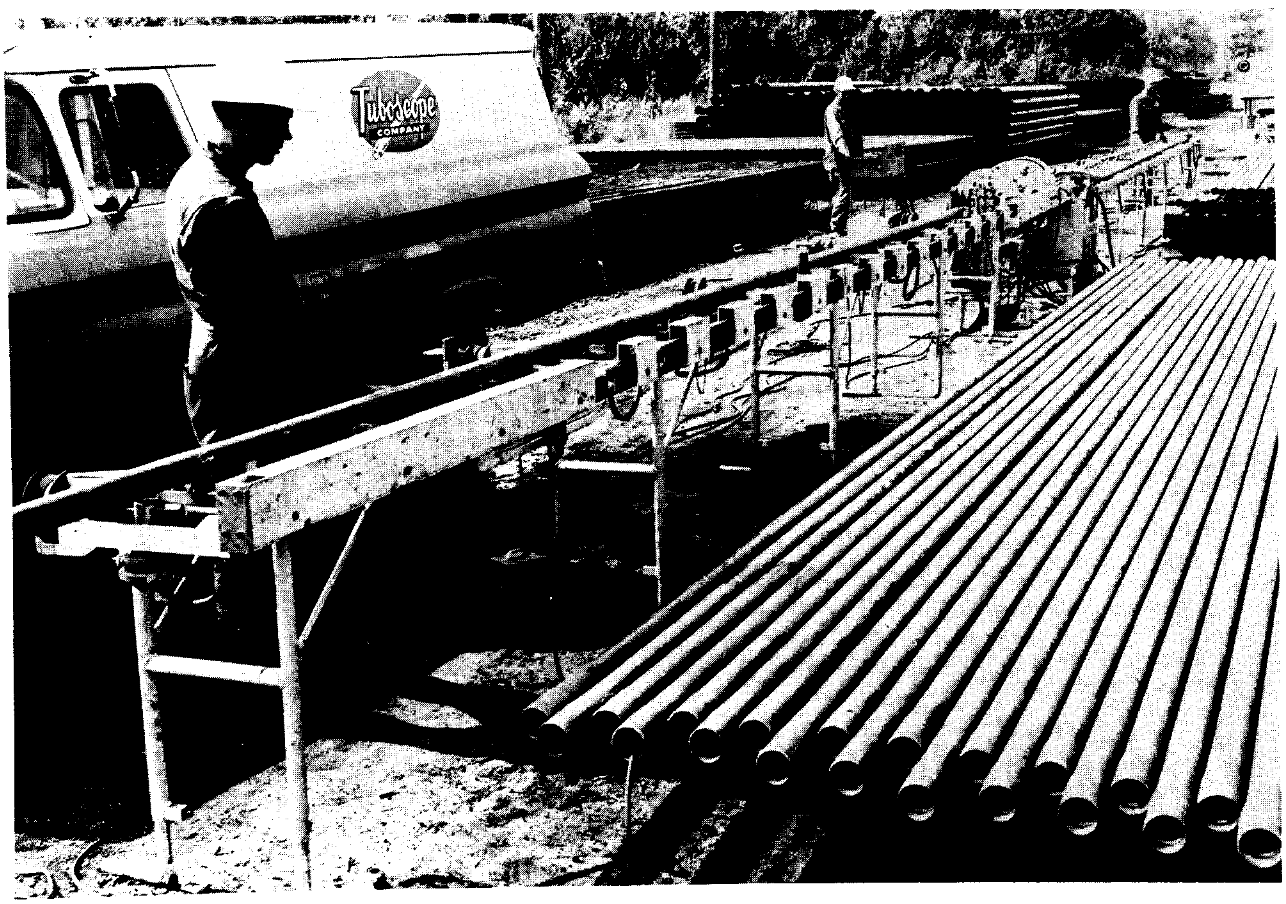


Fig. 5 AMALOG$^{(R)}$ inspection of new tubular goods.

REASON FOR INSPECTION OF USED TUBULAR GOODS

Inspection of used tubing has proved an invaluable aid in eliminating defective lengths and returned the maximum amount of good pipe to service.

All service-induced damage such as corrosion pitting, cracks, splits, abrasive wear and mechanical damage can be located and evaluated by competent inspectors. Pipe fit for well service can be safely returned to the well, but damaged pipe can be put in limited service or discarded completely.

Considering today's new pipe replacement costs and workover costs, it is easy to see the savings realized by competent inspection of all used tubing.

Inspection of used sucker rods offers the operator savings in time and materials comparable to that realized in used tubing.

USED PIPE INSPECTION METHODS

The mechanical-optical, magnetic particle inspection system outlined above may be utilized for the inspection of used tubing and sucker rods. However, the electromagnetic inspection method is more effective and in wider use.

Electromagnetic Used Tubing Inspection

This inspection of used tubing is designed to locate all service-induced defects. It includes electro-mechanical I D gauging to locate possible rod wear, drifting of the end areas, electromagnetic inspection of the pipe body and supplementary inspections of the upset areas.

The Electromagnetic Principle: In this inspection of the pipe body, the tube is magnetized near saturation with an active DC longitudinal field. Defects existing on either the inside or the outside wall of the tube cause disturbances in this magnetic field. When a detector containing a pickup coil encounters areas of magnetic flux disturbance, a voltage is induced into the detector and is amplified, electronically analyzed, and recorded in graph form on paper by a pen-writing galvanometer.

The actual electromagnetic inspection unit contains detector shoes arranged to cover the circumference of the tube simultaneously. Through this system, a continuous record of only the worst condition of the tube in any one transverse plane is recorded on the inspection log. Inspection log indications are evaluated by the inspector in terms of defect seriousness.

Used Tubing Inspection Operation: Electromagnetic used tubing inspection equipment is portable. It consists of a console, which houses the electronics and recording mechanism, the detection device or buggy through which the tube under examination is propelled, the conveyor racks by means of which the tubing is electrically moved through the inspection head, a magnetizing coil, and appropriate power supplies, cables, and supplementary inspection equipment. This tubing inspection is usually performed as follows:

1) Setting Up Unit: The operator verifies that drive rack, buggy, mag coil, extension racks, etc., are set up and adjusted properly on the location, so the tube to be inspected will traverse the entire system of inspection in a true and level manner. Thus, the tube will travel through the buggy at the proper speed and the pickup shoes will fit the pipe properly.

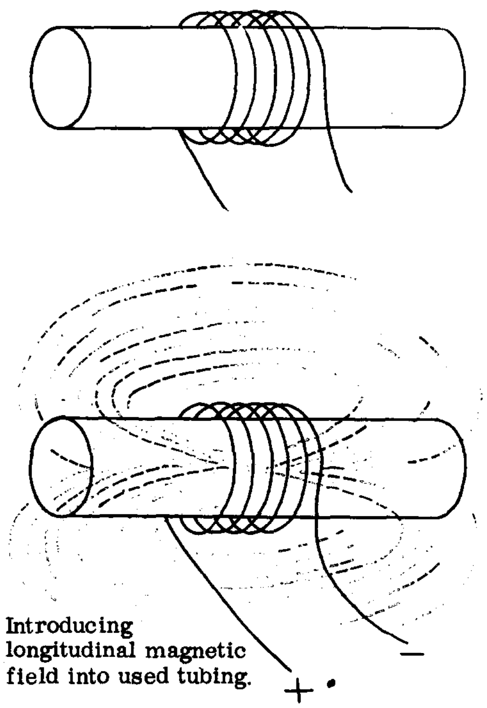


Fig. 6 Introducing longitudinal magnetic field into used tubing.

2) Cleaning Ends of Pipe: The end areas of the tubing, (approximately 5 ft from each upset) are cleaned on the inside by the rotary wire brush method or other methods if necessary.

3) Drift Testing: The ends of each length are drifted a distance of approximately 5 ft using a standard API drift.

4) Visual Inspection of the End Areas: The end areas of all lengths are inspected by the mechanical-optical method on the inside surface and visually on the outside surface for a distance of approximately 18 in. from the end.

5) Internal Diameter Gauging (Rod Wear Gauging): All tubing with a history of pumping service is subjected to an ID caliper inspection to locate and evaluate possible rod wear.

6) Visual Thread Inspection: As part of the standard inspection of used tubing, each length is visually examined for obvious thread damage.

7) Electromagnetic Inspection:

Standardizing the Unit: The equipment is calibrated with a pipe sample containing defects of known depth.

Inspecting the Pipe: A crewman places on the incoming rack the first length to be inspected. A second crewman stations himself at the pickup buggy to watch the condition of the pickup shoes and pipe outside surface and to control the rack drive motor at such times as the operator wishes to reverse the direction of travel of the length.

A crewman is stationed at the end of the outgoing rack to receive the inspected length after it has traversed the inspection table.

The operator evaluates the condition of the

Fig. 7 Typical used tubing and sucker rod inspection equipment.

Fig. 8 Color coding used tubing to reflect inspection grade.

tube under inspection by examining the inspection log indications recorded.

As the end of the length moves out of the buggy and the pipe is graded by the operator, he informs a crewman of the final classification of the length.

8) Identification and Racking: A crewman places the finished length on a rack and identifies it by paint bands adjacent to the coupling upset to reflect its final classification.

Tubing is often classified as follows:

Penetration of Defect	Color Code
0-15% wall penetration	Yellow
15-30% wall penetration	Blue
30-50% wall penetration	Green
Over 50% wall penetration	Red

Electromagnetic Sucker Rod Inspection

This inspection is mechanically identical to used tubing inspection described above with the following exceptions:

1) No "internal" supplementary inspection are required.

2) The OD of the rod is mechanically gauged for wear.

In sucker rod inspection all pits and cracks are recorded on the log. The operator correlates the inspection results from this log with the results of OD gauging and magnetic particle end area inspection to arrive at the final inspection classification.

Used sucker rods are usually graded as follows:

	Color Code
No. 2: Rods recommended for normal service	Yellow
No. 3: Rods recommended for limited service	Blue
No. 4: Rods not recommended for further service	Red

Fig. 9 Fatigue crack located in sucker rod by electromagnetic inspection.