Change for a Penny

No pocket change here. In pipeline x-ray jargon, 'penny' is slang for penetrameter

BY THOMAS D. REEDER

A "penny" is a device used in radiographic testing to evaluate the quality of radiographic images. The idea is to place a penetrameter (often shortened to penny) on a specimen that is being radiographically tested. Demonstrating the detail of the penetrameter alongside the specimen shows that a certain level or percent of radiographic sensitivity has been achieved. Radiographic sensitivity is defined as the smallest or thinnest material change that a radiograph reveals. In Europe, penetrameters are referred to as image quality indicators (IQI), but no matter what you call them, the idea remains the same.

Penetrameters come in a wide range of shapes, sizes, and configurations. They can be small metal plates containing the same- or variable-sized holes, or they can be a series of variable-diameter wires contained in plastic packets.

Penetrameter wires or plates are made from the same type of material as the specimen being tested. Codes and standards differ widely in specifying the type, style, thickness, and placement of penetrameters. The changes to penetrameters as referenced by American Petroleum Institute (API) Standard 1104, *Welding of Pipelines and Related Facilities*, is the focus of this article.

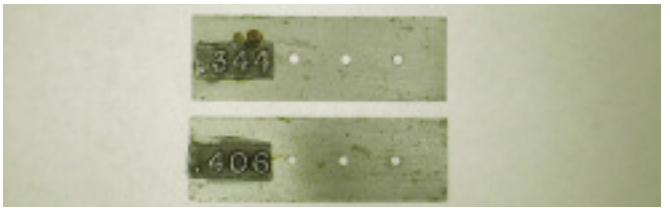


Fig. 1 — Early API 1104 penetrameters.

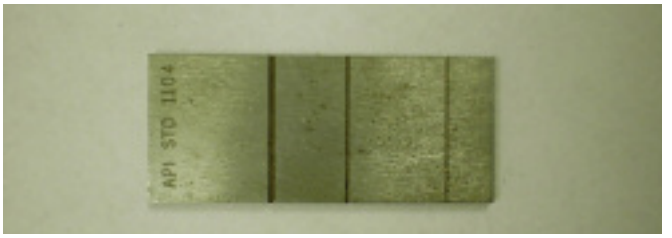


Fig. 2 — A comparator shim.

Penetrameters of the Past

The vintage early 1950s API 1104 penetrameters were small plates of steel with a series of holes — Fig. 1. They were identified by numbers made of lead that corresponded to the pipe wall thickness they were to be used on. The thickness of each of these penetrameters was approximately 2% of the designated pipe wall thickness, with a different penetrameter thickness used for each wall thickness of pipe. When many welds made in pipes of various wall thicknesses were to be tested, a radiographic technician might have needed to use 30 to 40 penetrameters of different thicknesses.

During the mid 1960s, the requirements in API 1104 for penetrameters were changed and one penetrameter of a specific thickness was designated for a range of pipe wall thicknesses. The thickness of the penetrameter specified for each group was equal to 2% of the thickest pipe wall in the group, thereby retaining the established 2% radiographic sensitivity. This greatly reduced the total number of different thickness penetrameters needed to radiograph all of the pipe wall thicknesses manufactured.

A device known as a penetrameter comparator shim was introduced during the 1970s — Fig. 2. The concept was that a comparator shim would provide a gauge to use in determining the depth of undercutting adjacent to the cover pass of welds. The comparator shim is a $\frac{3}{32}$-in.-thick steel plate measuring 1¾ in. long × ¾ in. wide with three V-shaped grooves machined across the face of the plate. The grooves are 0.008, 0.016, and 0.032 in. in depth. The comparator shim is placed under a penetrameter with or without other blank shims to equal the average weld buildup. The theory was that the depth of undercutting could be determined by comparing images of the undercutting to the images of the grooves in the comparator shim. In field applications this practice proved to be unreliable and the use of the penetrameter comparator shim was dropped from API 1104 requirements. However, the idea of placing blank metal shims under penetrameters caught on, and is still in use today, as is the wall thickness grouping and penetrameter numbering scheme.

What Is Used Today

API 1104 currently references two different hole-type and one wire-type penetrameters — Fig. 3. Tables 5, 6, and 7 of API 1104 list the different types of penetrameters and suitable pipe wall or weld thickness ranges. Table 5 lists six pipe wall thickness ranges and the six thicknesses of ASTM E 1025 hole-type penetrameters to be used for stated pipe wall thickness ranges. Table 6 lists ten pipe wall thickness ranges and ten thicknesses for API 1104 standard hole-type penetrameters, and Table 7 lists six pipe thickness ranges and two letter set packets of ASTM E 747 wire-type penetrameters. Each ASTM letter set packet con-

*THOMAS D. REEDER (*dtreeder@yahoo.com*) is president, Central NDT, Inc., Yale, Okla. He is a member of the API 1104 Committee and holds ASNT NDT Level III certification. He has more than 40 years' experience in the pipeline nondestructive examination industry.*

Table 5 — Thickness of Pipe vs. Thickness of ASTM E 1025 Penetrameter (from API Standard 1104, Nineteenth Edition, September 1999. Reproduced courtesy of the American Petroleum Institute.)

Pipe Wall or Weld Thickness		Maximum Penetrameter Thickness		
Inches	Millimeters	Inches	Millimeters	Identifying Number
0–0.250	0–6.4	0.0125	0.32	12
>0.250–0.375	>6.4–9.5	0.0150	0.38	15
>0.375–0.500	>9.5–12.7	0.0175	0.44	17
>0.500–0.750	>12.7–19.1	0.0200	0.51	20
>0.750–1.000	>19.1–25.4	0.0250	0.64	25
>1.000–2.000	>25.4–50.8	0.0300	0.76	30

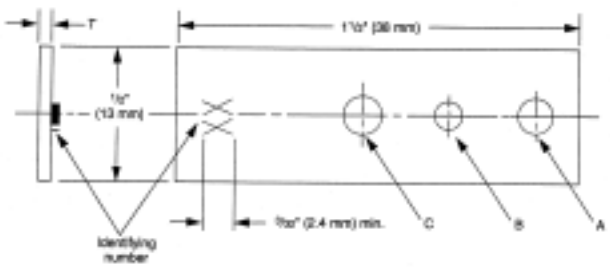
Table 6 — Thickness of Pipe vs. Thickness of Penetrameter[a] (from API Standard 1104, Nineteenth Edition, September 1999. Reproduced courtesy of the American Petroleum Institute.)

Pipe Wall or Weld Thickness		Maximum Penetrameter Thickness		
Inches	Millimeters	Inches	Millimeters	Identifying Number
0–0.250	0–6.4	0.0050	0.13	5
>0.250–0.375	>6.4–9.5	0.0075	0.19	7
>0.375–0.500	>9.5–12.7	0.0100	0.25	10
>0.500–0.625	>12.7–15.9	0.0125	0.32	12
>0.625–0.750	>15.9–19.1	0.0150	0.38	15
>0.750–0.875	>19.1–22.2	0.0175	0.44	17
>0.875–1.000	>22.2–25.4	0.0200	0.51	20
>1.000–1.250	>25.4–31.8	0.0250	0.64	25
>1.250–1.500	>31.8–38.1	0.0300	0.76	30
>1.500–2.000	>38.1–50.8	0.0350	0.89	35

(a) See Figure 21.

Table 7 — Thickness of Pipe vs. Diameter of ASTM E 747 Wire Penetrameter (from API Standard 1104, Nineteenth Edition, September 1999. Reproduced courtesy of the American Petroleum Institute)

Pipe Wall or Weld Thickness		Essential Wire Diameter		
Inches	Millimeters	Inches	Millimeters	ASTM Set Letter
0–0.250	0–6.4	0.008	0.20	A
>0.250–0.375	>6.4–9.5	0.010	0.25	A or B
>0.375–0.500	>9.5–12.7	0.013	0.33	B
>0.500–0.750	>12.7–19.1	0.016	0.41	B
>0.750–1.000	>19.1–25.4	0.020	0.51	B
>1.000–2.000	>25.4–50.8	0.025	0.64	B

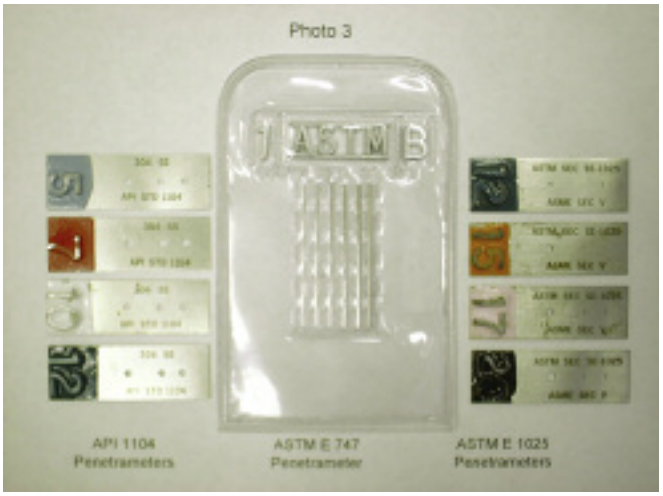


Notes:
1. *T* = thickness of penetrameter; Diameter A = 2*T*; Diameter B = *T*; Diameter C = 4*T*.
2. No hole need be less than 1/16 in. (1.6 mm) in diameter.
3. The holes shall be round and drilled perpendicular to the surface. The edges shall be free from burrs but shall not be chamfered.
4. Each penetrameter shall carry a lead identification number.
5. The tolerances for penetrameter thickness and hole diameter shall be ± 10% or one-half the thickness increment between penetrameter sizes, whichever is smaller.

Fig. 21 — Standard penetrameter (from API Standard 1104, Nineteenth Edition, September 1999. Reproduced courtesy of the American Petroleum Institute).

tains six wires of different thickness. That works out to 22 listed thickness ranges and 18 possible different pennies. These possibilities can be more than a little confusing, especially when you consider that penetrameter selection may be based on the nominal thickness of the pipe, or the thickness of the weld.

When hole-type penetrameter selection is based on the nominal wall thickness of the pipe, the selection process is simple enough: the radiographer simply locates the thickness group that includes the nominal wall thickness of the pipe being used and selects the penetrameter for that group. The penetrameter is then placed on the pipe wall adjacent to the weld and a radiograph is made. When hole-type penetrameter selection is based on the weld thickness, it becomes a little more complicated. The technician must first determine the weld thickness and then add a shim or shims between the pipe wall and the penetrameter. This compensates for the difference between the thickness of the pipe and the thickness of the weld. In theory, this idea is sound, but in practice it is quite difficult to locate pipeline welds that have the same thickness all the way around the entire circumference. Weld reinforcement varies enough around the circumference of many welds that several shims of different thicknesses would be required if a tolerance of ± 1/32 in. is maintained. When the ASTM E 747 wire-type penetrameter is used, penetrameter selection becomes simple. The radiographer determines if the weld or pipe wall thickness exceeds ¼ in. If



A **B** **C**

Fig. 3 — The different types of penetrameters referenced in API 1104. A — API 1104 type; B — ASTM E 747 type; and C — ASTM E 1025 type.

it does, he or she uses the B letter set packet. If it does not, he or she uses the A letter set packet. The radiographic technician then places the packet on the weld (with the wires extending across the weld) and makes a radiograph. The essential wire diameter, or wire that must show in the radiographic image, is listed in Table 7 for each weld or wall thickness group. With only two wire penetrameters to choose from, and with the B letter set packet covering approximately 90% of the weld thickness applications, selecting an incorrect penetrameer becomes difficult. The new problem is determining which wire is the essential one and being sure the essential wire is shown in the image.

Summary

It would be difficult to tally up all of the changes that API 1104 has made to the penny over the years. Some items that have changed, been added, or have been deleted are numbers, colors, thickness, placement, shims, grooves, holes, notches, slits, and wires. The next — and last — change to the penny may occur in the next few months. The 1104 Committee has proposed eliminating the penetrameter and replacing it with an image quality indicator (IQI). Depending on how the committee members vote, when you open the 20th edition of API 1104 you could find that the ASTM E 747 wire IQI is listed and the penny is gone forever.

One last note about pennies and IQIs: It would be easy to think that when an image is sufficient to reveal a penny or an IQI that a variation in material thickness equal to the thickness of the penetrameter or diameter of the IQI wire can also be detected in the test specimen. Such a conclusion would be false because changes in the thickness of the specimen may be quite subtle while the thickness change from the pipe wall to the IQI wire is rather abrupt. ❖