"Demonstration of Pulsed X-ray Machine Radiography as an Alternative to Industry Radiography Cameras, Demonstration Pilot Project"

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1. BACKGROUND

The Radiation Protection Division of the Environmental Protection Agency (EPA) is dedicated to minimizing incidences of lost radioactive sources that enter into consumer metal supplies and the public domain. Industrial devices and consumer products containing radioactive sources routinely fall out of regulatory control. Once out of regulatory control, these devices and products may be subjected to harsh conditions capable of producing a breached source, with the potential of harmful exposure incidents and significant economic impacts to industry.

Providing alternative technologies for devices and products which utilize radioactive sources is one approach to minimize lost source incidences. The current focus of EPA's efforts in this regard is to conduct those studies and assessments necessary to support the implementation of such alternative technologies in industrial practices – alternatives that are technologically and economically advantageous.

The approach suggested by Southwest Research Institute® (SwRI®) is to identify an industrial sector that routinely uses isotopic radiation sources and to demonstrate that an alternative technology to isotopic sources can provide equivalent capability. One industrial sector that regularly uses isotopic sources to perform radiography of pipeline welds is the pipeline industry. The industry uses Co60, Cs137, and Ir192 which have gamma ray energy lines of 1.17 and 1.33 MeV, 0.66 MeV, and 0.31, 0.47, and 0.60 MeV. Ir192 is perhaps the most often used source for pipeline welds because the pipe wall thicknesses usually range between 0.25 and 0.4 inches. Ir192 has a half life of 74.3 days. Sources are usually purchased with an activity of approximately 100 curies. The radiography conducted is usually double wall for detecting cracks, inclusions, and porosity in the welds as illustrated in Figure 1. To verify the quality of the radiography, the code that regulates the radiographic inspection usually calls for a "penetrameter" or "image quality indicator (IQI)" and the image sensitivity required. In these radiographs an IQI was used, and the quality requirement was that all the wires had to be detected.

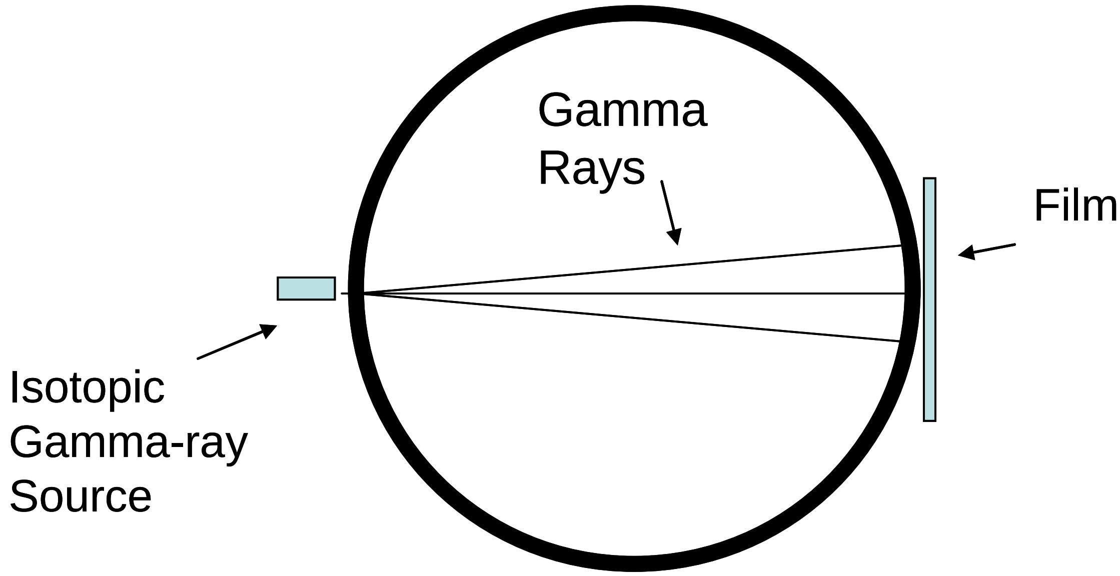


Figure 1. Illustration of double-sided pipeline radiography used to inspect pipeline welds

Isotopic radiography has been used for many years. The advantages of isotopic radiography include portability, no need for electricity, no requirement for source cooling, and high energy. The disadvantages of isotopic sources are the regulatory requirements, need for two licensed radiographers to conduct the work, and the potential for mishandling/loosing radioactive source material.

An alternative approach might be to use pulsed x-ray sources. These sources are now capable of peak beam energies close to 300 KVP with sufficient intensity output to be used for radiography of welds.

2. TECHNICAL APPROACH

The goal of this project was to demonstrate a radiography technology for inspection of pipe welds that does not require the use of isotopic sources. The technical approach to be followed included (1) developing procedures for inspection of schedule 40 pipe in the range of 3 to 16 inches in diameter, (2) producing radiographs with both an Ir192 source and a pulsed, battery operated, portable x-ray source with a peak x-ray energy of 270 kV and (3) comparing the results obtained as well as the operational issues associated with using the x-ray source compared to the isotopic source.

3. SCOPE OF WORK

The following sections describe the scope of work that was conducted to demonstrate the feasibility of pulsed x-ray source technology.

3.1 Isotopic Source and Pulsed X-ray Source

Isotopic sources (called "pills") are very small, often on the order of approximately ¼ inch diameter by ¾ inch long. The pill is usually contained in a shielded housing usually called a "camera." Although these sources are highly regulated, because they are so small they can easily be inadvertently or intentionally removed from the regulatory information stream.

Isotopic source technology has a number of advantages over existing large x-ray sources. For example, the source technology employees a very compact geometrical envelop and does not require any electrical power. Conventional x-ray sources, on the other hand, require 220V power and room for a cooling system (often water based). In addition, Ir192 provides very good radiographs, and this source has been used for many decades so that the knowledge base on its use is well accepted.

However, recent advancements have been made in pulsed x-ray sources that operate using 14.4-volt battery power and have a geometrical envelop similar to the isotopic source shielded housing. For example, a common isotopic source is shown in Figure 2 and the XRS-3 is shown in Figure 3.

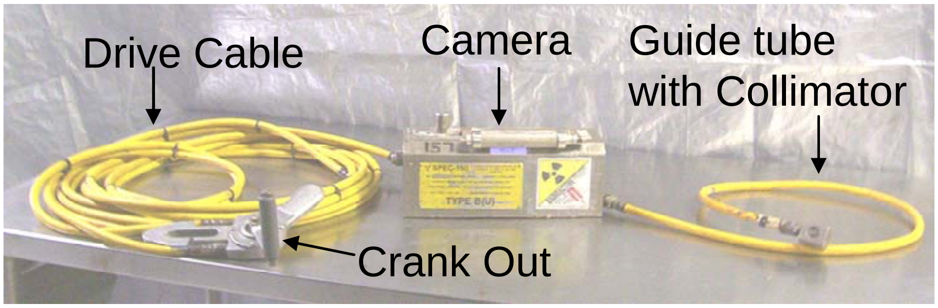


Figure 2. Photograph of a gamma ray camera

The XRS-3 is a light duty X-ray machine that requires little maintenance. The modular design makes component replacement easy and cost effective. The DeWalt® 14.4V battery and battery charger are commercially available in retail stores worldwide.

Lead shielding in the XRS-3 protects the user by minimizing radiation leakage outside of the X-ray beam while a time delay button and remote cable allow the operator to move a safe distance from the unit when it is in operation. Visual and audible indicators in the unit alert the operator when the XRS-3 is activated. Also, the XRS-3 contains no radioactive material. The unit produces radiation only when it is pulsing.

Specifications

Size (Including battery pack)	14" (35.6 cm) x 4.5" (11.5 cm) x 7.5" (19.0 cm)
Weight (Including battery pack)	12lbs (5.4kg)
Output dose	4.0 mR/pulse max, 2.6 mR/pulse min, measured 12 inches from source
Pulse rate	15 pulse per second nominal
X-ray source size	1/8 in. (3 mm)
Maximum photon energy	270 KVP
X-ray pulse width	50 nanoseconds
Current draw	20 amps @ 13.4 volts
Power supply	DeWalt® 14.4 volt, removable, rechargeable, nickel-cadmium battery
Battery recharge time	1 hour with standard DeWalt® charger, 15 minute charger available
Number of pulses per battery charge	4000
Temperature range	-10 to 120 degrees F (-23 to 50 degrees C)
Maximum duty cycle	200 pulses every 4 minutes (3000 pulses per hr)
Warm-up	None required
X-ray leakage	3 mR per 100 pulses measured 2 inches behind the unit
Warranty	1 year limited warranty

Figure 3. Specifications for XRS-3 Pulsed X-ray Source

The camera is approximately 15 inches in diameter by 4 inches wide and weighs approximately 40 lbs. This camera holds the isotopic source. It is connected to a drive cable that allows the isotopic source to be cranked out of the camera into a collimator placed on the pipe. The collimator is approximately 1 inch in diameter and 1½ inches long. The conventional 300-KVP x-ray unit is approximately 36 inches long, 14 inches in diameter, and weighs approximately 100 lbs. In addition, a cooler is needed, which is an additional box. The XRS-3 is 14 inches by 4.5 inches by 7.5 inches and weighs 12 lbs. The specifications for the XRS-3 are also provided in Figure 3. Since it is a pulsed source, it does not require a coolant system. However, the pulsed x-ray source must be used with a real-time imaging plate. The real question is “will a pipe inspection company be willing to utilize this technology for actual inspection work?”

3.2 Work Conducted

Procedures for both the isotopic and x-ray inspection techniques were developed and formalized. The procedures developed for each pipe size for double wall isotopic radiography are in Appendix 1. The procedures for double wall pulsed x-ray radiography are contained in Appendix 2.

Approximately five pipe samples were used in this project (shown in Table 1).

Table 1.
Pipes Used for Pilot Demonstration

NOMINAL PIPE DIAMETER (inch)	PIPE WALL THICKNESS (inch)	PIPE LENGTH (inch)	LOCATION OF WELD AND TYPES OF DEFECTS
4	0.225	24	Weld located mid-length, lack of penetration, porosity
6	0.200	24	Weld located mid-length, lack of penetration, porosity
10	0.250	24	Weld located mid-length, lack of penetration, porosity, lack of fusion
14	0.350	24	Weld located mid-length, lack of penetration, porosity, lack of fusion
16	0.200	24	Weld located mid-length, lack of penetration, porosity, lack of fusion

The welds were made so that naturally occurring flaws were produced in each weld including porosity, slag, lack of penetration and lack of fusion. Ground truth data were collected using a panoramic x-ray technique where the source is placed inside the pipe and single wall radiographs were obtained.

Isotopic, double wall radiographs were obtained for each pipe using the procedures provided in Appendix 1.

Double wall radiographs were obtained (by SwRI) using the XRS-3 x-ray source and the x-ray procedures are provided in Appendix 2 with the Vidisco real-time imaging system. Glenn Light (SwRI Level III RT), Steve Winterberg (SwRI licensed radiographer and Level II RT) and Mr. Bryan Lancon of All American Inspections (licensed radiographer and Level III RT) compared the radiographs and realtime images obtained.

This report serves as the progress report that provides details of the work conducted and the results obtained. A conference call with the contracting office representative and other project representatives will occur in November 2006.

The following sections of this report provide a discussion of how the pulsed x-ray source worked and a comparison of images obtained with that system with respect to the industry standard (double wall isotopic) and the impressions of a vendor in the field of pipeline inspection. Key issues discussed include time required to obtain the images, density of the radiograph, detection of defects, and general image quality.

3.3 Discussion

The approach suggested by SwRI was to demonstrate the capabilities of a 270KVP pulsed, battery powered x-ray unit and to compare the double wall pipe radiographs generated using the pulsed x-ray source with the real-time imaging device to radiographs generated with Ir192 and film. The demonstration application was double wall radiography (where the source is placed on one side of the pipe and the film or imager is on the other side of the pipe) for a variety of pipe welds (ranging in diameter from 4 to 16 inches) as illustrated in Figure 4. The pipes were fabricated with intentionally placed defects. The welders intentionally used poor welding techniques to generate regions of lack of fusion, lack of penetration, porosity, and slag. The intent was to develop a number of regions where natural defects occurred as well as a number of regions where there were few or no defects. Examples of the pipes and the types of defects are illustrated in Figure 5.

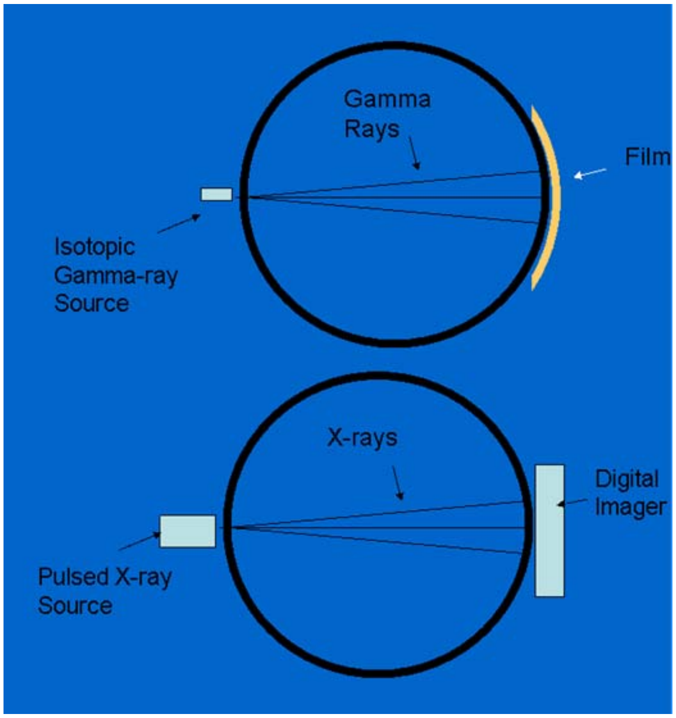


Figure 4. Illustration of source size and film/detector set used for the isotopic and pulsed x-ray sources

Figure 5. Photographs of portions of each pipe size showing some types of defects generated in the welds

Photographs showing how the single wall and double wall radiographs were obtained with the isotopic source and the pulsed x-ray source are shown in Figures 6-8.

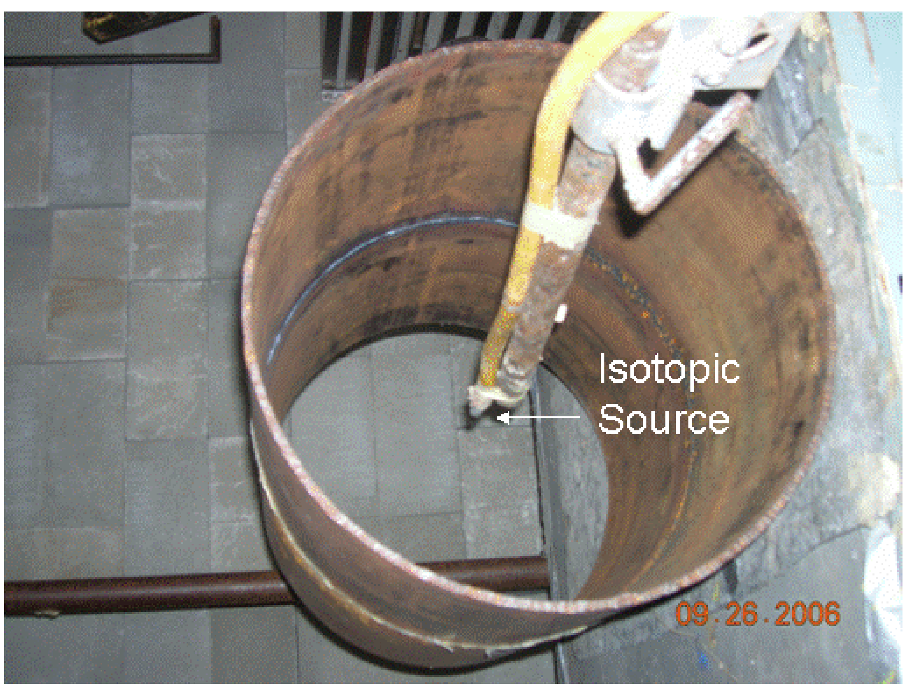


Figure 6. Photograph showing isotopic source being used to take single-wall radiographs

Figure 7. Photograph showing isotopic source used for double wall radiographs

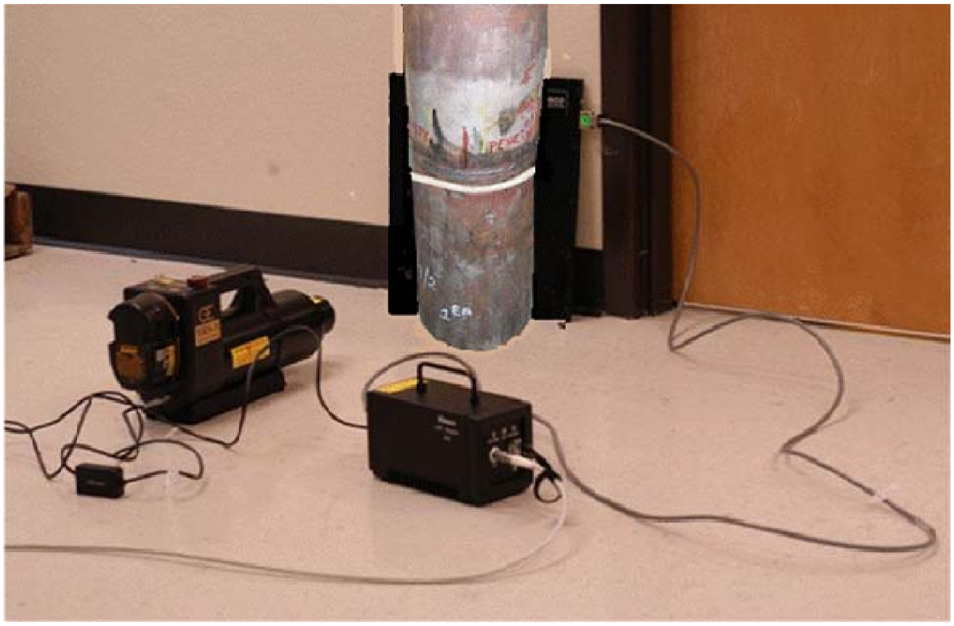


Figure 8. Pulsed x-ray source with Vidisco real-time imaging used for double wall radiographs

Single wall isotopic radiographs were taken as a standard to verify defect detection. An example of a single wall radiograph is shown in Figure 9. The report of defects detected in each pipe weld is provided in Tables 2-1 to 2-5.

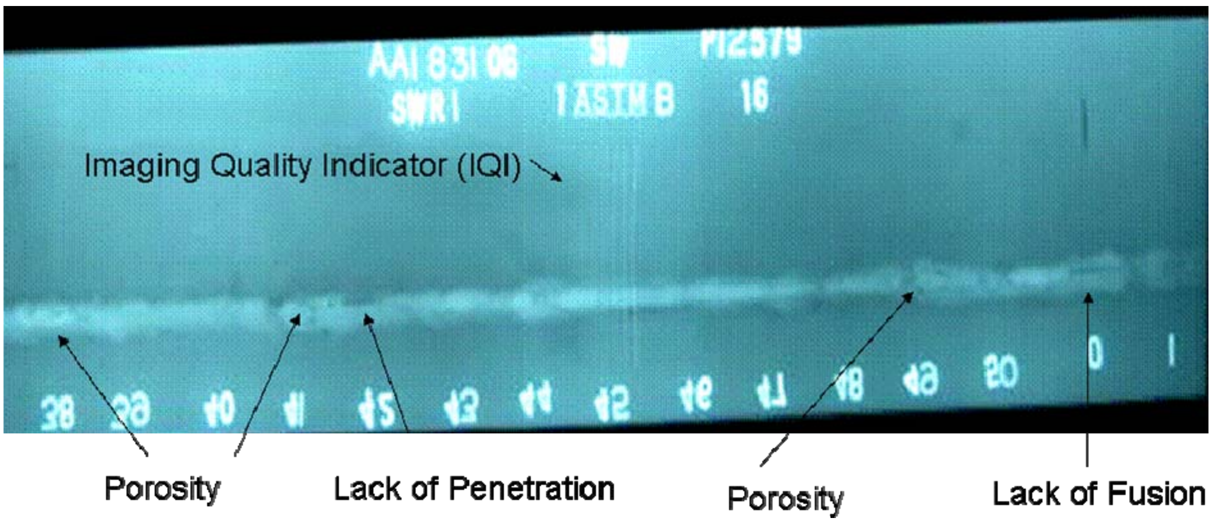


Figure 9. Single wall isotopic radiograph on 16-inch-diameter pipe

Table 2-1

Single Wall/Single View Isotopic Radiography Data for 4-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Slag	Center @ 0-1	0.13
Slag	US @ 0-1	0.13
Slag	DS @ 0-1	0.13
Lack of penetration (LOP)	DS @ 0-1	0.13
LOP	DS @ 1-2	0.60
LOP	US @ 1-2	0.10
LOP	US @ 1-2	0.10
Slag	Center to US @ 3	0.13
Lack of fill	US @ 4-5	0.38
LOP	Center @ 6-11	4.00
LOP	Center @ 11-0	1.50

Table 2-2

Single Wall/Single View Isotopic Radiography Data for 6-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Lack of material	DS @ 1-2	0.80
Lack of fusion at wall	DS @ 1-2	0.25
Slag	DS @ 2-3	0.13
Slag	US @ 2-3	0.13
POR	Center @ 2-3	0.08
LOP	Center @ 2-3	0.25
Elongated porosity	US @ 3-4	0.06
Slag	DS @ 4-5	0.13
Lack of fill	US to DS @ 5	0.25
Lack of fusion at wall	DS @ 6-7	0.20
Crater crack	US to DS @ 6-7	0.30
Porosity cluster	US to DS @ 7	Total 0.3
Porosity cluster	US to DS@ 8-9	Total 0.3
Porosity cluster	Center@ 11-12	0.3 total
LOP	US to DS@ 12-13	0.50
LOP	Center @ 12-13	0.30
Lack of fusion (LOF)	Center @ 15-21	5.30
POR	Center @ 17	0.25
Porosity cluster	US to DS @ 19	0.40

Table 2-3

Single Wall/Single View Isotopic Radiography Data for 10-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Scattered Porosity	US - DS @ 0-4	Range: 0.04 -0.08
LOP	Center @ 11-12	0.60
Porosity	Center @ 11-12	0.08
Porosity cluster	US - DS @ 14-15	0.50
Lack of fusion	Center @ 15-17	1.30
Lack of fusion	Center @ 17-21	3.40
Porosity cluster	US - DS @ 22-23	0.75
Slag - 4 each	US @ 23-24	Total 0.5
Lack of fill	US @ 25-26	0.25
Scattered Porosity	US - DS @ 26-29	Range: 0.04 -0.1

Table 2-4

Single Wall/Single View Isotopic Radiography Data for 14-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
LOP	Center @ 43-1	2.00
LOP	Center @ 1-3	1.90
LOP	Center @ 12	0.13
Lack of fill - Intermittent	US - DS @ 14-16	Total 1.0
Lack of fill	US @ 14-17	0.60
Porosity cluster	DS @ 17-18	0.50
Slag	US @ 19-20	0.20
LOP	Center @ 26	0.30
Scattered Porosity	US @ 35-37	Range: 0.03-0.05
LOP	US @ 26	0.30
Scattered Porosity	US @ 35-37	Range: 0.03-0.05
LOP	Center @ 37-39	2.00
Slag	US @ 41-42	0.13
Porosity cluster	US @ 43-0	0.60

Table 2-5

Single Wall/Single View Isotopic Radiography Data for 16-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Porosity Cluster	US - Center @ 0	0.60
Lack of Fusion	Center @ 0-18	18.00
Scattered Porosity	US - DS @ 7-11	Range: 0.03-0.08
Scattered Porosity	US - DS @ 14-18	Range: 0.03-0.07
Porosity	Center @ 21-22	0.10
Porosity	Center @ 24	0.10
Scattered Porosity	US - DS @ 26-34	Range: 0.03-0.14
Slag	US @ 28-29	0.50
Porosity	US @ 37	0.12
LOP	Center @ 38-39	0.30
Porosity Cluster	US - DS @ 41-42	0.75
Lack of fusion	US @ 40-41	0.13
Lack of fusion	US @ 41-42	0.50
Porosity cluster	US - DS @ 49-50	0.75
LOP	Center @ 48-49	0.20

The double wall isotopic radiographs were taken as a standard, normal field inspection technique and the reports of defects found in the five pipe welds are given in Tables 3-1 to 3-5.

Table 3-1

Double Wall/Single View Isotopic Radiography Data 4-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Slag	Center @ 0-1	0.13
Slag	US @ 0-1	0.13
Slag	DS @ 0-1	0.13
LOP	DS @ 0-1	0.13
LOP	Center @ 1-2	0.13
LOP	Center @ 1-2	0.13
POR	Center @ 1-2	0.08
Lack of fill	US to DS @ 2-3	0.25
Lack of fill	US @ 4-5	0.25
LOP	Center@ 6-11	4.00
LOP	Center@ 11-0	1.50
Lack of fill	US to DS @ 10-11	0.40

Table 3-2

Double Wall/Single View Isotopic Radiography Data 6-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Slag	US @ 2	1.25
Porosity	Center @ 2	0.10
LOP	Center @ 2-3	0.26
Slag	US @ 3-4	0.07
Porosity Clusters - 3 each	US - DS @ 7, 8-9 & 11-12	0.3 Each
Porosity	Center @ 12	0.08
LOP	US - DS @ 12	0.50
LOP	Center @ 12-13	0.25
Porosity - 2 each	Center @ 14 & 15	.06 Each
Lack of fill	US - DS @ 14-15	0.60
Porosity	Center @ 15	0.08
Lack of fusion	Center @ 15-0	5.50

Table 3-3

Double Wall/Single View Isotopic Radiography Data 10-Inch-Diameter Pipe Weld:		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Scattered Porosity	US - DS @ 0-4	Range: 0.04 -0.08
LOP	Center @ 5-6	0.75
LOP	Center @ 11-12	0.60
Porosity	Center @ 11-12	0.08
Porosity cluster	US - DS @ 14-15	0.50
Lack of fusion	Center @ 15-17	1.30
Lack of fusion	Center @ 17-21	3.40
Porosity cluster	US - DS @ 22-23	0.75
Slag - 4 each	US @ 23-24	Total 0.5
Lack of fill	US @ 25-26	0.25
Scattered Porosity	US - DS @ 26-29	Range: 0.04 -0.1

Table 3-4

Double Wall/Single View Isotopic Radiography Data 14-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
LOP	Center @ 43-1	2.00
LOP	Center @ 1-3	1.90
LOP - 2 each	Center @ 7	0.13 & 0.10
LOP	Center @ 12	0.13
Lack of fill - intermittent	US - DS @ 14-16	Total 1.0
Lack of fill	US @ 14-17	0.60
Porosity cluster	DS @ 17-18	0.50
Slag	US @ 19-20	0.20
Lack of fusion	Center @ 22	0.50
LOP	Center @ 26	0.30
Scattered Porosity	US @ 35-37	Range: 0.03-0.05
LOP	US @ 26	0.30
Porosity Cluster	US @ 28-29	0.40
LOP	DS @ 35-37	1.00
Scattered Porosity	US @ 35-37	Range: 0.03-0.05
LOP	Center @ 37-39	2.00
Scattered Slag	US @ 39-40	Total 0.75
Slag	US @ 41-42	0.13
Lack of fusion - intermittent	Center @ 41-43	Total 1.0
Porosity cluster	US @ 43-0	0.60

Table 3-5

Double Wall/Single View Isotopic Radiography Data 16-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Porosity Cluster	US - Center @ 0	0.60
Lack of Fusion	Center @ 0-18	18.00
Scattered Porosity	US - DS @ 7-11	Range: 0.03-0.08
Lack of fill - scattered	US @ 13-15	Total 1.0
Scattered Porosity	US - DS @ 14-18	Range: 0.03-0.07
Porosity	Center @ 21-22	0.10
Porosity	Center @ 24	0.10
Scattered Porosity	US - DS @ 26-34	Range: 0.03-0.14
Scattered Slag	US - Center @ 26-35	Total 1.5
Porosity	US @ 37	0.12
LOP	Center @ 38-39	0.30
Porosity Cluster	US - DS @ 41-42	0.75
Lack of fusion	US @ 40-41	0.13
Lack of fusion	US @ 41-42	0.50
Porosity cluster	US - DS @ 49-50	0.75
LOP	Center @ 48-49	0.20

An example of the double wall isotopic radiograph is shown in Figure 10. Then, double wall radiographs were taken using the pulsed 270KV XRS-3 source with a Vidisco real-time imaging system. The image obtained using this approach is shown in Figure 11. The reports of defects detected are given in Tables 4-1 to 4-5.

The inspection procedures used to produce the double wall, isotopic radiographs required approximately 10 seconds exposure for each radiograph and 30 minutes for film development. For the pulsed x-ray source, real-time imaging system, each image required approximately 2 seconds of exposure and the image was observed in about 10 seconds. Looking at the images shown in Figures 9, 10, and 11, it is obvious that the pulsed x-ray source, real-time imaging images are very similar in sharpness and clarity to the isotopic radiography.

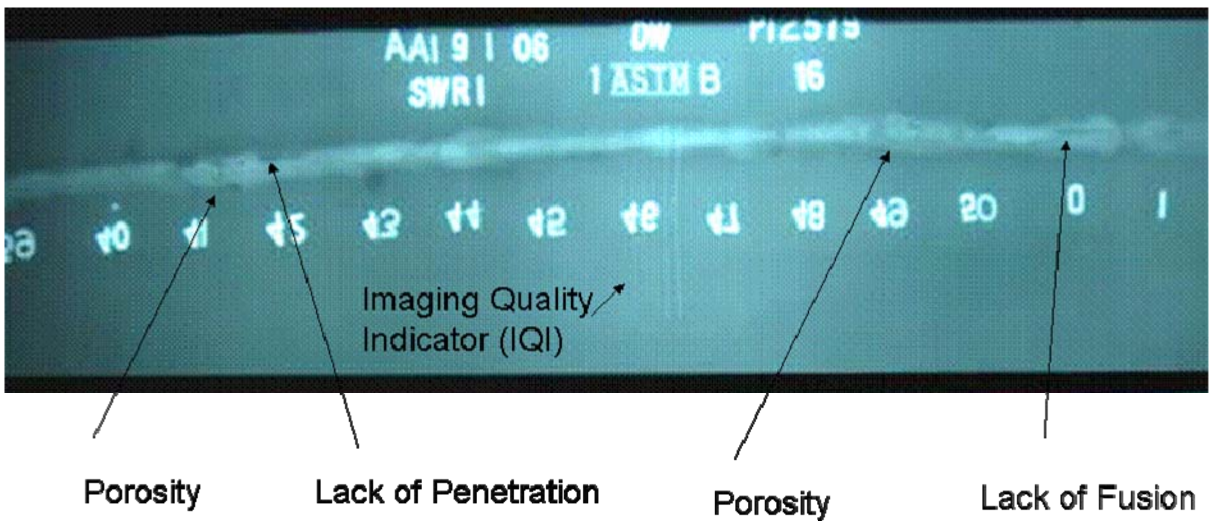


Figure 10. Double wall isotopic radiograph on 16-inch-diameter pipe

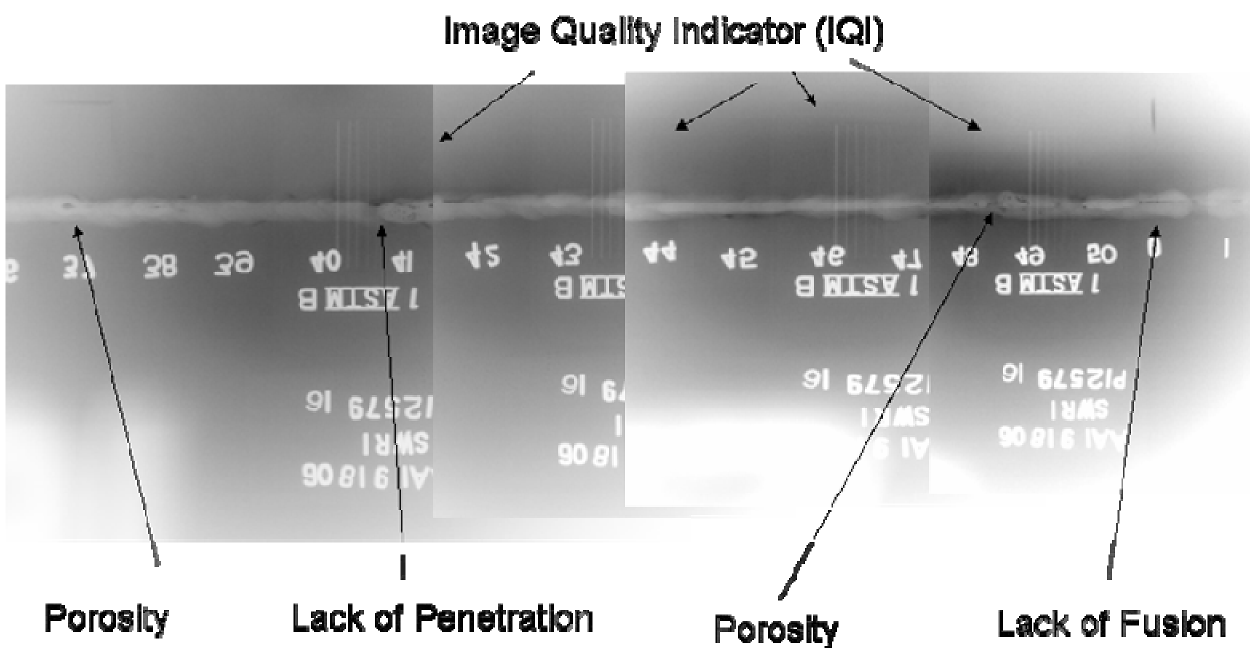


Figure 11. Composite real-time images obtained using the XRS-3 pulsed x-ray source and the Vidisco imaging system

Table 4-1

Double Wall/Double View Digital Radiography Data 4-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Slag	Center @ 0-1	0.30
Slag	US @ 0-1	0.13
Slag	DS @ 0-1	0.13
Lack of penetration (LOP)	Center @ 1-2	0.10
Porosity cluster	Center @ 3	Total 0.3
LOP	Center @ 4	0.25
LOP	Center @ 6	0.25
Lack of Fusion (LOF)	Center @ 7-10	3.00
Lack of Fusion (LOF)	Center @ 11-12	1.20

Table 4-2

Double Wall/Double View Digital Radiography Data 6-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Slag	US @ 1-2	0.25
Slag	Center @ 2	0.14
Slag	US @ 2	0.14
Porosity	DS @ 2-3	0.12
Lack of fill - 2 each	DS @ 3-4	0.25 & 0.14
Porosity	US @ 5-6	0.10
Porosity Cluster	DS @ 7	Total 0.3
LOF	US @ 7-9	2.00
Porosity cluster	US - DS @ 11-12	Total 0.3
Slag	US @ 12	0.15
LOP	Center @ 12-13	0.15
Slag	US @ 13	0.27
Porosity	Center @ 13	0.13
Porosity	US @ 13-14	0.11
LOF	Center @ 15-0	4.50
Porosity cluster	DS - Center @ 19	0.40

Table 4-3

Double Wall/Double View Digital Radiography Data 10-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Scattered Porosity	US - DS @ 0-3	Average size 0.08
Porosity	US @ 4-5	0.15
LOP	DS @ 3-9	5.00
Porosity - 3 each	US @ 7-8	Average size 0.15
Porosity - 3 each	US @ 8-9	Average size 0.10
LOP	DS @ 11-12	0.60
LOP	DS @ 16-20	4.00
Scattered Porosity	US - DS @ 15-20	Average size 0.10
Porosity cluster	DS - Center @ 22-23	Total 0.70
Scattered Porosity	US - DS @ 26-29	Average size 0.08
Porosity	US @ 29-30	0.10
Slag	US @ 29-31	0.80

Table 4-4

Double Wall/Single View Digital Radiography Data 14-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Slag	US @ 0	0.27
LOP	Center @ 0-1	0.40
Porosity	Center @ 1	0.10
LOP	Center @ 1-2	0.25
LOP	Center @ 1-2	0.27
LOP	Center @ 2	0.15
LOP	Center @ 2-4	1.10
LOP	DS @ 7-8	0.25
LOP	Center @ 7-11	3.40
Lack of fill	Center @ 12-13	0.25
Slag	DS @ 14-15	0.40
Scattered Slag	US @ 14-18	Total 3.45
Porosity Cluster	DS @ 17-18	Total 0.3
Slag	US @ 19-20	0.24
LOP	US - DS @ 22	0.40
Crater Crack	DS @ 23-24	0.20
Slag, 2 each	US @ 23-24	0.4 Each
Lack of fill	US - DS @ 25-26, 27-28, 29-30, 31-33, 33-34 & 40-41	Total 4.22
Porosity Cluster	US @ 28-29	Total 0.3
LOP	Center @ 39-43	2.70
Porosity	US @ 41-42	0.13
Lack of fusion	Center @ 43-1	1.60

Table 4-5

Double Wall/Single View Digital Radiography Data 16-Inch-Diameter Pipe Weld		
Defect Type	**Defect Location (Weld Center, Upstream (US) side of weld or Downstream (DS) side of weld @ Designated inches)**	**Defect Size in Inches**
Lack of fusion	Center @ 0-11	11.00
Porosity - 4 each	Center @ 0	.05 each
Porosity Cluster	US - DS @ 6	Total 0.5
Scattered Porosity	Center @ 7-11	.03 to 0.7
Lack of fill	US - DS @ 7-8	0.70
Lack of fusion	Center 11-12	0.70
Porosity Cluster	US - DS @ 13	Total 0.4
Lack of fusion	Center @ 13-15	0.75
Scattered Porosity	US - DS @ 14-17	.03 to 0.8
Lack of fusion	Center @ 17-18	0.60
Porosity	DS @ 21-22	0.11
Porosity	Center @ 24	0.10
Slag	US @ 25-28	0.75
Porosity	Center @ 27	0.10
Scattered Porosity	US-DS @ 28-33	.03 to .08
Slag	US-DS @ 34-35	Total 0.4
Porosity Cluster	US-DS @ 40-42	Total 0.4
LOP	Center @ 41-42	0.43
Porosity	DS @ 45	0.13
Slag	DS @ 45-47	1.65
Porosity - 2 each	DS & Center @ 47-48	.15 & .07
LOP	Center @ 48-49	0.20

Most industrial radiographic testing requires an image quality indicator (IQI) in each radiograph to assure radiographic quality. Notice that in Figures 9, 10, and 11, the IQI is observed and in both isotopic radiographs, five wires can be seen. The diameters of the five wires are 0.032 inch, 0.026 inch, 0.020 inch, 0.016 inch, and 0.013 inch, respectively. However, when the film is actually viewed with a magnifying glass on a viewer, the sixth wire which is 0.010 inch in diameter can also be seen. This means that the film has the resolution to resolve a defect that is 0.01 inch in diameter.

In Figure 11, the same five wires can also be seen. However, by enhancing the digital images to brighten or darken or increase or decrease contrast, the image can be sufficiently changed so that the sixth wire is also easy to detect as illustrated in Figure 12. Magnification can also help, but the pixel size becomes an issue. The pixel size is certainly larger than the film grain, so inherently, the film has better optical resolution. However, the real-time imager may have sufficient resolution for pipeline weld inspection.

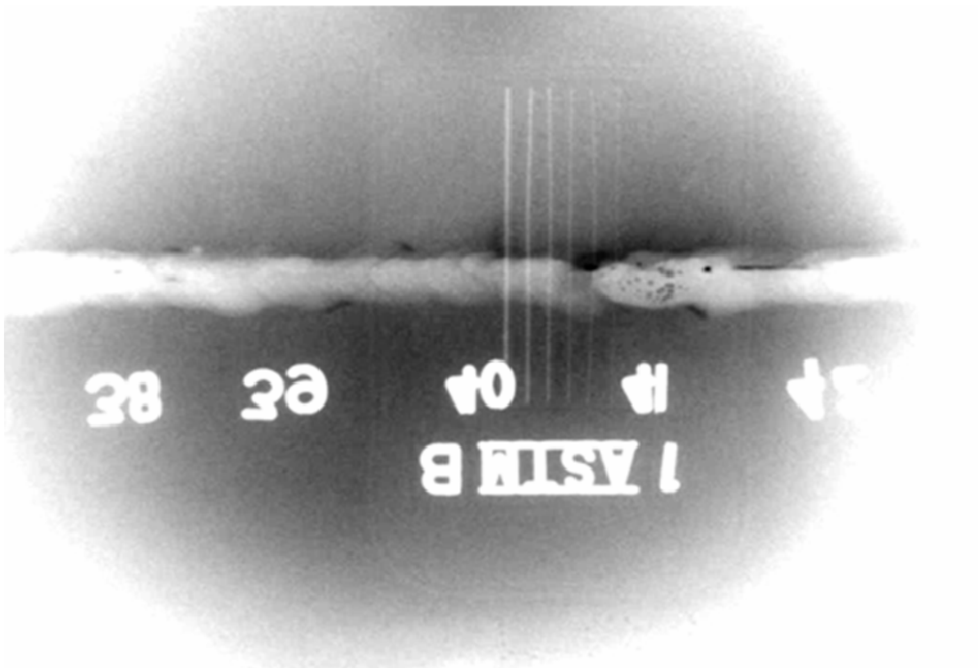


Figure 12. Digital image on pipe showing six detectable wires on the IQI

A comparison of defects detected for the isotopic source/film radiographs and the pulsed x-ray/digital radiographs are displayed on pseudo weld plans for 4-, 6-, and 10-inch-diameter pipe are shown in Figures 13, 14, and 15, respectively. Similar data were obtained for the 14- and 16-inch-diameter pipe welds. There are small differences between the defects detected and the size of the recorded defects, but these differences are minor.

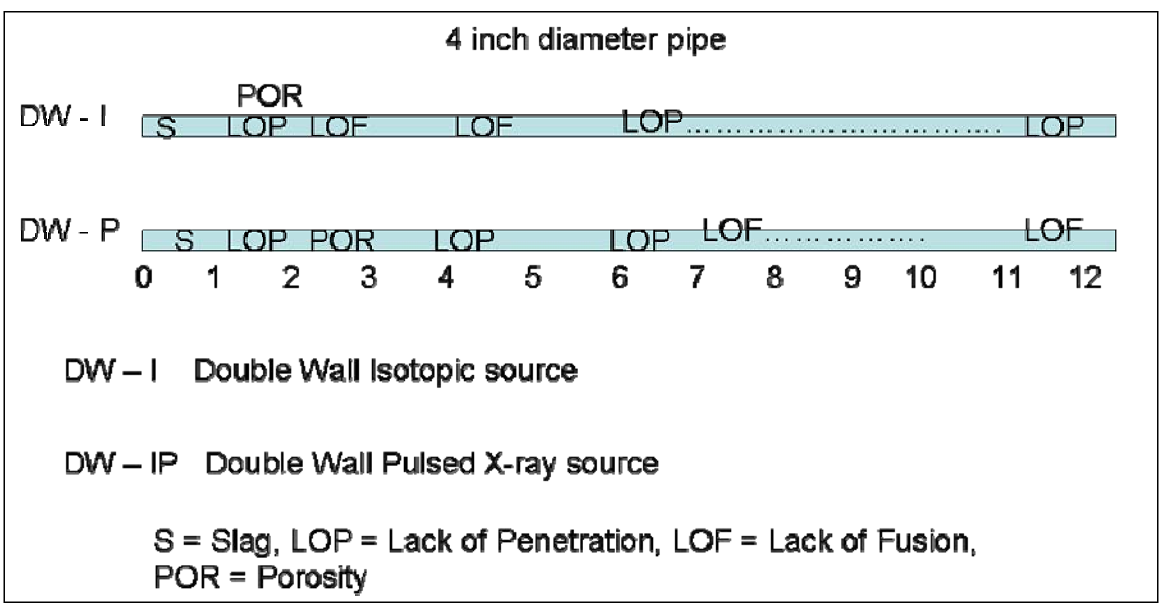


Figure 13. Illustration of defects reported in the 4-inch-diameter pipe weld for both isotopic and pulsed x-ray radiography

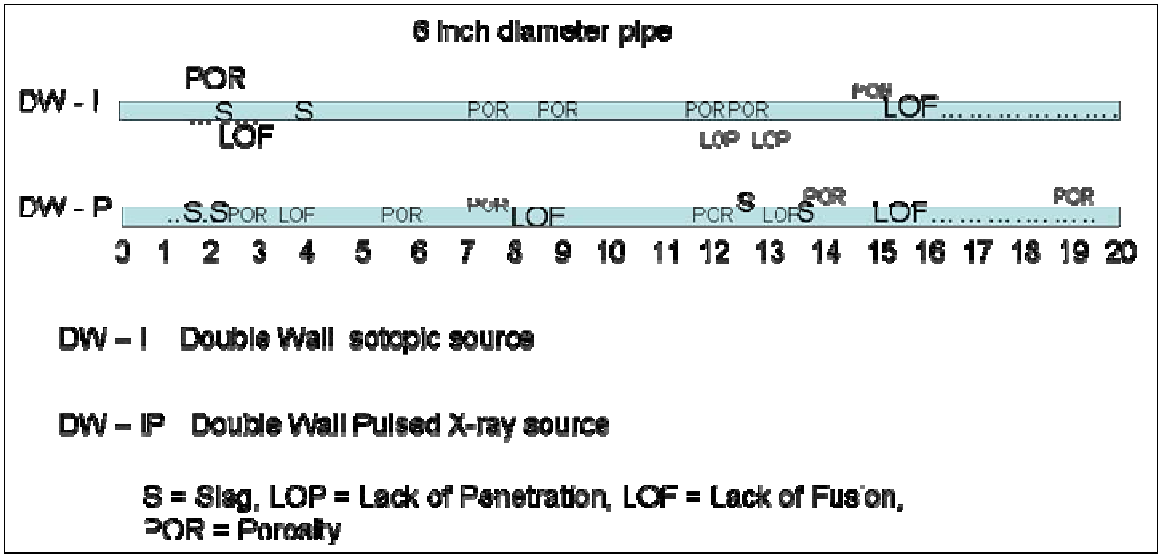


Figure 14. Illustration of defects reported in the 6-inch-diameter pipe weld for both isotopic and pulsed x-ray radiography

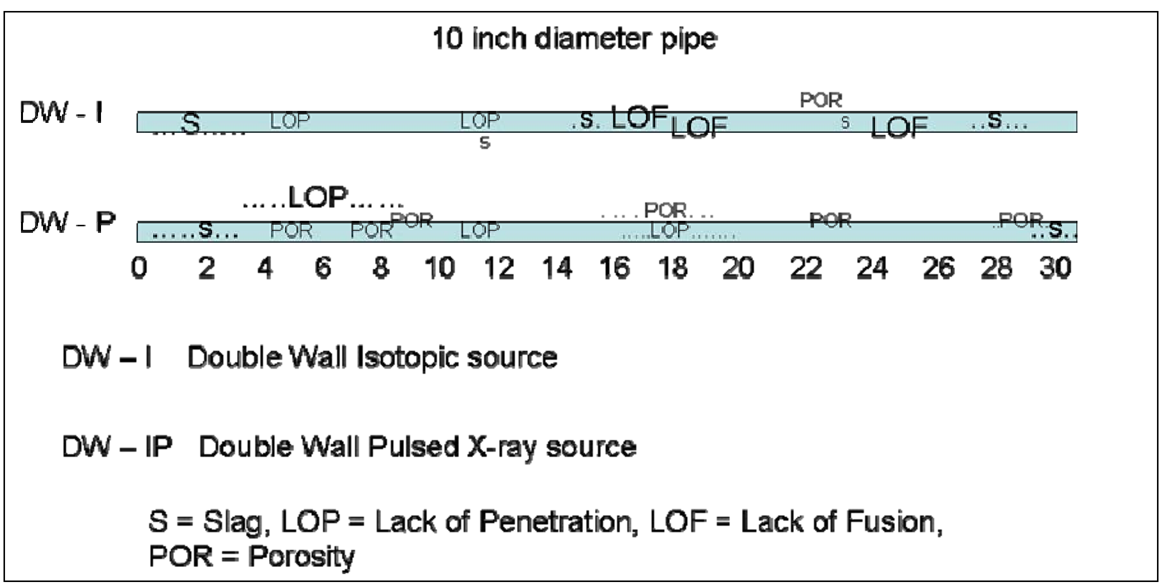
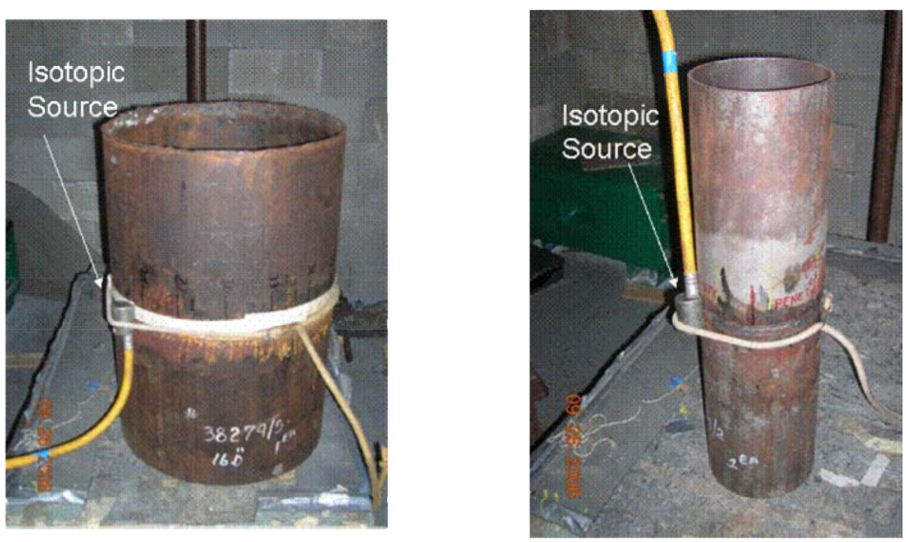


Figure 15. Illustration of defects reported in the 10-inch-diameter pipe weld for both isotopic and pulsed x-ray radiography

3.4 Impact to End-Users

Issues to be addressed included differences in the procedures in terms of time, set up, personnel required, source cost and labor/cost associated with following regulations, ease of use, and a discussion of the likelihood of successfully transferring this technology to industry.

In terms of information obtained from the isotopic radiograph and the pulsed x-ray source used in conjunction with the Vidisco real-time imaging system for this pipe diameter and thickness range, the two were basically identical. In terms of procedure development, the pulsed x-ray/Vidisco procedure development was faster because images could be obtained within a few minutes of the actual exposure as compared to at least 30 minutes needed for film development time to develop the isotopic procedure. In terms of geometrical issues, the vendor still preferred the isotopic source because it is very small and can be taped directly onto the pipe (as illustrated in Figure 16).



16" Double Wall 6" Double Wall

Figure 16. Photograph of isotopic source on pipe during radiography

In terms of actual radiation exposure time, for the isotopic source (depending on wall thickness) the exposure time was on the order of 60 seconds per shot and for the pulsed x-ray source, the exposure time for the same weld was approximately 3 seconds. Labor cost using the isotopic source is approximately double the cost associated with using the pulsed x-ray source because regulations require that two radiographers must be present when using an isotopic source while only one radiographer is required when using an x-ray machine. In terms of ease of use, the pulsed x-ray source/real-time imager is very similar to the isotopic source radiography. In terms of the cost of using the isotopic source film technology versus pulsed x-ray source/real-time imaging technology, the information contained in Table 5 provides comparisons between the two technologies by the vendor used in the pilot demonstration.

Table 5.
Comparison of Radiography Technologies

Characteristics	Isotopic source/film	Pulsed x-ray source/real-time imager
Cost of the source	$5,000	$5,000
Cost of portable film developing unit	$20,000	Not required
Cost of imaging device	$1/piece of film	$60,000 for real-time imaging screen
Cost of film processing chemicals for each job (consider a job being 50 radiographic films)	3 hours of labor and $200 in chemicals	Not required
Time required to get images from a 16-inch pipe	10 minutes for x-raying and 30 minutes for film development	10 minutes for x-raying and 6-10 minutes for reviewing real-time data
Cost of Chemicals	$200/week	None
Cost of Source Disposal	TBD	NA
Cost of Chemical Disposal	TBD	NA
Requirements for electrical power	None	Pulsed x-ray source is operated using 14.4V battery, imaging device requires XX battery, computer has its own battery….all of these batteries require AC power to recharge. A sufficient number of batteries can be used and recharged at the hotel or other home base facilities that are usually used on a daily basis
Image quality	Can detect all wires of an ASME B wire IQI	Can detect all wires of an ASME B wire IQI
Number of shots to cover 10 inches of weld	1 shot	Approximately 4 shots
Acceptance of technology	Isotopic radiography has been a standard for more than 50 years.	Pulsed X-ray source with real-time imager has been in the field on the order of a few years

4. COMMERCIALIZATION PLAN

To effectively commercialize this technology, an inspection company that performs pipeline weld inspections, such as All American Inspections, must be convinced that this technology is useful. To that end, All American is an integral part of the team.

Secondly, SwRI and All American will present the results obtained from this pilot demonstration at an ASNT (American Society of Nondestructive Testing) conference and an API (American Petroleum Institute) meeting. These presentations will provide a good opportunity to showcase the technology and to share information with companies that usually conduct pipeline inspections using isotopic sources. These presentations will most likely occur at the 2007 ASNT Fall Conference and the 2007 API Conference.

Aerospace application involved in the maintenance and repair of aerospace structures could be a viable commercial area. Perhaps evaluating the system at the FAA NDI validation center would provide some credibility to the system and its capabilities.

As a provider of services, All American would be able to market the system easily. Durability of the system and duty cycle would need to be evaluated, but the potential is there.

5. CONCLUSIONS

Based upon the work conducted to date on this project, the following conclusions have been reached.

(1) For double wall pipe radiography (which is the requirement for field pipeline weld joint inspection), isotopic radiography and pulsed x-ray with real-time imaging capability provide results that meet the code requirements. The nominal code requires that ASME IQI B wire (all wires) can be detected.

(2) This system is excellent for the intended DOT pipeline inspection, providing the adequate sensitivities are achieved. Because of its portability and reduced exposure time this seems to be a “great fit”.

(3) Contacting ASTM and approaching their radiographic committee in an effort to address this type of system specifically would be a vehicle to encourage its use industry wide.

APPENDIX 1

X-ray Radiographic Procedures for
Isotopic Double Wall Radiography

Isotopic Radiography Report for 3.5” diameter, 0.225” wall

SOURCE	Radiation Type: ☐ X-Ray ☒ Gamma Ray Method: ☐ Internal ☒ External Manufacturer: Amersham Ir^{192} MA: N/A KV: N/A Curies: 44 Focal Spot Size: .130"
INTENSIFICATION SCREENS	Type: LEAD Thickness (Front): .010 In. (Back): .010 In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 4 in. Object to Film Distance: ..375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	No. Exp: 3 (per item) Film Size: 4.5 In. Wide X 10 In. length Diagnostic Readable Length: 3.66 In. Film Overlap: 3.00 In. Film Type: D4 Class: 1 Manufacturer: Agfa No. Film in Cassette: 1 Unexposed Base Density: .02 Cassette Separation 120 Deg Exposed density of: Parental Material: Weld Metal: 2.5 Equipment Used To Determine Density: McBETH TD-52 Method: ☒ Multiple Film ☐ Single Film Film Position: 120 DEG.
FILM PROCESSING	Drying Detail: FORCED AIR ☒ Manual / ☐ Automatic Developing Time: 5.5 MIN Manufacture: Agfa Rinse Time: .5 MIN Manufacture Agfa Fix Time: 4 MIN Manufacture: Agfa Final Rinse: 10 MIN Temp: 68°
EXPOSURE TIMES	Single Exposure: 12 Sec Total Exposure Time: 36 SEC Curie Seconds: 528
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
LETTER/NO. BELT	Orientation of Markers PARALLEL TO WELD Manner of Location 1" incriments
MATERIAL DATA	Diameter: 3.5 in. W.T. .225 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Carl Martinez Approved By: B. Lancon

Isotopic Radiography Report for 6” diameter, 0.20” wall

SOURCE	Radiation Type: ☐ X-Ray ☒ Gamma Ray Method: ☐ Internal ☒ External Manufacturer: Amersham Ir^{192} MA: N/A KV: N/A Curies: 44 Focal Spot Size: .130"
INTENSIFICATION SCREENS	Type: LEAD Thickness (Front): .010 In. (Back): .010 In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 6.00 in. Object to Film Distance: ..325 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	No. Exp: 3 (per item) Film Size: 4.5 In. Wide X 10 In. length Diagnostic Readable Length: 6.28 In. Film Overlap: 1.86 In. Film Type: D4 Class: 1 Manufacturer: Agfa No. Film in Cassette: 1 Unexposed Base Density: .02 Cassette Separation 120 Deg Exposed density of: Parental Material: Weld Metal: 2.4-2.5 Equipment Used To Determine Density: McBETH TD-52 Method: ☒ Multiple Film ☐ Single Film Film Position: 120 DEG.
FILM PROCESSING	Drying Detail: FORCED AIR ☒ Manual / ☐ Automatic Developing Time: 5 MIN Manufacture: Agfa Rinse Time: .5 MIN Manufacture Agfa Fix Time: 4 MIN Manufacture: Agfa Final Rinse: 10 MIN Temp: 68°
EXPOSURE TIMES	Single Exposure: 30 Sec Total Exposure Time: 90 SEC Curie Seconds: 1320
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
LETTER/NO. BELT	Orientation of Markers PARALLEL TO WELD Manner of Location 1" incriments
MATERIAL DATA	Diameter: 6.0 in. W.T. .200 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Carl Martinez Approved By: B. Lancon

Isotopic Radiography Report for 10” diameter, 0.25” wall

SOURCE	Radiation Type: ☐ X-Ray ☒ Gamma Ray Method: ☐ Internal ☒ External Manufacturer: Amersham Ir^{192} MA: N/A KV: N/A Curies: 100 Focal Spot Size: .160"
INTENSIFICATION SCREENS	Type: LEAD Thickness (Front): .010 In. (Back): .010 In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 10.00 in. Object to Film Distance: .375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	No. Exp: 3 (per item) Film Size: 4.5 In. Wide X 17 In. length Diagnostic Readable Length: 10.46 In. Film Overlap: 3.26 In. Film Type: D4 Class: 1 Manufacturer: Agfa No. Film in Cassette: 1 Unexposed Base Density: .02 Cassette Separation 120 Deg Exposed density of: Parental Material: Weld Metal: 2.5-3.0 Equipment Used To Determine Density: McBETH TD-52 Method: ☒ Multiple Film ☐ Single Film Film Position: 120 DEG.
FILM PROCESSING	Drying Detail: FORCED AIR ☒ Manual / ☐ Automatic Developing Time: 5 MIN Manufacture: Agfa Rinse Time: .5 MIN Manufacture Agfa Fix Time: 4 MIN Manufacture: Agfa Final Rinse: 10 MIN Temp: 68°
EXPOSURE TIMES	Single Exposure: 40 Sec Total Exposure Time: 120 SEC Curie Seconds: 400
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
LETTER/NO. BELT	Orientation of Markers PARALLEL TO WELD Manner of Location 1" incriments
MATERIAL DATA	Diameter: 10.0 in. W.T. .250 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Carl Martinez Approved By: B. Lancon

Isotopic Radiography Report for 14” diameter, 0.35” wall

SOURCE	Radiation Type: ☐ X-Ray ☒ Gamma Ray Method: ☐ Internal ☒ External Manufacturer: Amersham Ir^{192} MA: N/A KV: N/A Curies: 100 Focal Spot Size: .160"
INTENSIFICATION SCREENS	Type: LEAD Thickness (Front): .010 In. (Back): .010 In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 14.00 in. Object to Film Distance: .425 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	No. Exp: 3 (per item) Film Size: 4.5 In. Wide X 17 In. length Diagnostic Readable Length: 14.65 In. Film Overlap: 1.17 In. Film Type: D4 Class: 1 Manufacturer: Agfa No. Film in Cassette: 1 Unexposed Base Density: .02 Cassette Separation 120 Deg Exposed density of: Parental Material: Weld Metal: 2.5-3.0 Equipment Used To Determine Density: McBETH TD-52 Method: ☒ Multiple Film ☐ Single Film Film Position: 120 DEG.
FILM PROCESSING	Drying Detail: FORCED AIR ☒ Manual / ☐ Automatic Developing Time: 5 MIN Manufacture: Agfa Rinse Time: .5 MIN Manufacture Agfa Fix Time: 4 MIN Manufacture: Agfa Final Rinse: 10 MIN Temp: 68°
EXPOSURE TIMES	Single Exposure: 80 Sec Total Exposure Time: 240 SEC Curie Seconds: 800
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
LETTER/NO. BELT	Orientation of Markers PARALLEL TO WELD Manner of Location 1" incriments
MATERIAL DATA	Diameter: 14.0 in. W.T. .350 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Carl Martinez Approved By: B. Lancon

Isotopic Radiography Report for 16" diameter, 0.20" wall

SOURCE	Radiation Type: ☐ X-Ray ☒ Gamma Ray Method: ☐ Internal ☒ External Manufacturer: Amersham Ir^{192} MA: N/A KV: N/A Curies: 100 Focal Spot Size: .160"
INTENSIFICATION SCREENS	Type: LEAD Thickness (Front): .010 In. (Back): .010 In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 16.00 in. Object to Film Distance: .325 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	No. Exp: 4 (per item) Film Size: 4.5 In. Wide X 17 In. length Diagnostic Readable Length: 12.56 In. Film Overlap: 2.22 In. Film Type: D4 Class: 1 Manufacturer: Agfa No. Film in Cassette: 1 Unexposed Base Density: .02 Cassette Separation 120 Deg Exposed density of: Parental Material: Weld Metal: 2.5-2.7 Equipment Used To Determine Density: McBETH TD-52 Method: ☒ Multiple Film ☐ Single Film Film Position: 120 DEG.
FILM PROCESSING	Drying Detail: FORCED AIR ☒ Manual / ☐ Automatic Developing Time: 5 MIN Manufacture: Agfa Rinse Time: .5 MIN Manufacture Agfa Fix Time: 4 MIN Manufacture: Agfa Final Rinse: 10 MIN Temp: 68°
EXPOSURE TIMES	Single Exposure: 70 Sec Total Exposure Time: 280 SEC Curie Seconds: 700
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
LETTER/NO. BELT	Orientation of Markers PARALLEL TO WELD Manner of Location 1" incriments
MATERIAL DATA	Diameter: 16.0 in. W.T. .200 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Carl Martinez Approved By: B. Lancon

APPENDIX 2

X-ray Radiographic Procedures for Pulsed X-ray Double Wall Radiography

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Pulsed X-ray Radiography Report for 3.5" diameter, 0.225" wall

SOURCE	Radiation Type: Pulsed X-Ray Method: ☐ Internal ☒ External Manufacturer: Golden XRS-3 MA: N/A KV: N/A Curies:NA 4 mR/pulse @ 12" from Source Focal Spot Size: 0.125"
REAL TIME IMAGING PLATE	Vidisco
INTENSIFICATION SCREENS	Type: NA Thickness (Front): NA In. (Back): NA In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 4 in. Object to Film Distance: ..375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	NA
FILM PROCESSING	NA
EXPOSURE TIMES	Single Exposure: approximately 2 sec
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
LETTER/NO. BELT	Orientation of Markers PARALLEL TO WELD Manner of Location 1" incriments
MATERIAL DATA	Diameter: 3.5 in. W.T. .225 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Steve Winterberg Approved By: G. Light

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Pulsed X-ray Radiography Report for 6" diameter, 0.20" wall

SOURCE	Radiation Type: Pulsed X-Ray Method: ☐ Internal ☒ External Manufacturer: Golden XRS-3 MA: N/A KV: N/A Curies:NA 4 mR/pulse @ 12" from Source Focal Spot Size: 0.125"
REAL TIME IMAGING PLATE	Vidisco
INTENSIFICATION SCREENS	Type: NA Thickness (Front): NA In. (Back): NA In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 4 in. Object to Film Distance: ..375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	NA
FILM PROCESSING	NA
EXPOSURE TIMES	Single Exposure: approximately 2 sec
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
MATERIAL DATA	Diameter: 6.0 in. W.T. .200 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Steve Winterberg Approved By: G.Light

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Pulsed X-ray Radiography Report for 10” diameter, 0.25” wall

SOURCE	Radiation Type: Pulsed X-Ray Method: ☐ Internal ☒ External Manufacturer: Golden XRS-3 MA: N/A KV: N/A Curies:NA 4 mR/pulse @ 12” from Source Focal Spot Size: 0.125”
REAL TIME IMAGING PLATE	Vidisco
INTENSIFICATION SCREENS	Type: NA Thickness (Front): NA In. (Back): NA In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 4 in. Object to Film Distance: ..375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	NA
FILM PROCESSING	NA
EXPOSURE TIMES	Single Exposure: approximately 2 sec
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
MATERIAL DATA	Diameter: 10.0 in. W.T. .250 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Steve Winterberg Approved By: G. Light

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Pulsed X-ray Radiography Report for 14” diameter, 0.35” wall

SOURCE	Radiation Type: Pulsed X-Ray Method: ☐ Internal ☒ External Manufacturer: Golden XRS-3 MA: N/A KV: N/A Curies:NA 4 mR/pulse @ 12” from Source Focal Spot Size: 0.125”
REAL TIME IMAGING PLATE	Vidisco
INTENSIFICATION SCREENS	Type: NA Thickness (Front): NA In. (Back): NA In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 4 in. Object to Film Distance: ..375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	NA
FILM PROCESSING	NA
EXPOSURE TIMES	Single Exposure: approximately 2 sec
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
MATERIAL DATA	Diameter: 14.0 in. W.T. .350 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Steve Winterberg Approved By: G. Light

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Pulsed X-ray Radiography Report for 16” diameter, 0.20” wall

SOURCE	Radiation Type: Pulsed X-Ray Method: ☐ Internal ☒ External Manufacturer: Golden XRS-3 MA: N/A KV: N/A Curies:NA 4 mR/pulse @ 12” from Source Focal Spot Size: 0.125”
REAL TIME IMAGING PLATE	Vidisco
INTENSIFICATION SCREENS	Type: NA Thickness (Front): NA In. (Back): NA In.
GEOMETRIC ARRANGEMENT	Viewing: ☐ SWE/SWV ☐ DWE/DWV ☒ DWE/SWV Source to Film Distance: 4 in. Object to Film Distance: ..375 in. Source Position: Offset 0 in. Offset Angle: 0°
FILM DATA	NA
FILM PROCESSING	NA
EXPOSURE TIMES	Single Exposure: approximately 2 sec
PENETRAMETER	Penetrameter Material SS I.D. No. ASTM B Shim Thickness: N/A Type: Wire ☒ Film Side: ☐ Source Side: Penetrameter Position: IN WELD No. per Film: 1 Sensitivity Required: 2T
MATERIAL DATA	Diameter: 16.0 in. W.T. .200 in. Grade Material: Joint Design: BUTT
WELDING PROCESS	☐ SMAW ☐ GMAW ☐ Automatic ☐ Other: GTAW

Remarks:

Prepared By: Steve Winterberg Approved By: G. Light