QSA GLOBAL.

Quality and Safety Assurance (QSA)

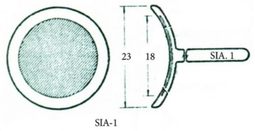
Products For Medical Therapy, Petrochemicals, Nuclear Power and Process Industries

Radioisotopes and Alternatives – an Industry Perspective on Gamma Radiography

QSA GLOBAL.

RADIATION SOURCE APPLICATIONS

	ANNUAL ACTIVITY	ANNUAL UNITS	ANNUAL SALES Pre C19
• **Radiation Processing (COMMODITIES)**			
Co-60	MCi's /y	100's units /y	$10's M/y
• **Fire Prevention (SAFETY SECTOR)**			
Am-241	10s Ci's /y)	10M's/y	$100's M/
• **Gas Detection (SECURITY SECTOR)**			
Ni-63, H-3	10's Ci's /y	1000's /y	$1's M/y
• **Effluent Monitoring (ENVIRONMENTAL SECTOR)**			
C-14, H-3	10's Ci's /y	1000's /y	$1's M/y
• **Instrument Calibration (HEALTHCARE & INDUSTRY SECTORS)**			
Co-57, Ge-68, Na-22, + many more	Ci's /y	10k's /y	$10's M/y
• **Medical Therapy (HEALTHCARE SECTOR)**			
Ir-192, I-125, Pd-103, Y-90, P-32, Ra-223, Ac-225 + many more	100k Ci's /y	100,000's /y	$100's M/y
• **Nuclear Power (ENERGY SECTOR)**			
Cf-252, SbBe	Ci's /y	100's units /y	$10's M/y
• **Gauging and Control (PROCESS INDUSTRY SECTOR)**			
Co-60, Cs-137, Sr-90, Kr-85, Pm-147, Am-241, AmBe, Cf-252 +	1000's Ci's /y	10,000's /y	$100's M/y
• **Gamma Radiography (SAFETY SECTOR)**			
Co-60, Ir-192, Se-75, Yb-169	10's MCi's /y	10,000's /y	$100's M/y
• **Oil Exploration, Well Logging (ENERGY SECTOR)**			
Cs-137, Am-241/Be, Cf-252, Ir-192, Kr-85, H-3, KUTh	1,000's Ci's /y	100's /y	$10's M/y
TOTAL			**$Bns/y**



SIA-1

QSA Global.

LEADING GLOBAL PROVIDER OF GAMMA RADIOGRAPHY EQUIPMENT AND RADIOISOTOPE PRODUCTS

History and Experience

1940s – 1990s

QSA's businesses began in the 1940s. Tech Ops in Boston became part of Amersham International in the 1980s and together they became QSA Global in the 1990s,

2000s

QSA transferred its UK operations to the USA in 2004. Since then QSA installed state-of-the-art AmBe, SbBe, Cf-252, Cs-137, Ir-192 and Se-75 manufacturing in Boston, Baton Rouge, Houston and Dobrany.

TODAY

QSA Global is a Division of ITW (Illinois Tool Works) a fortune 200 company. We manufacture and distribute radioisotope products globally via over 30 international distributors and trading partners.

QSA has remained a premier supplier of high energy radiation source products, technologies and services since the 1940s.

Boston Massachusetts

Baton Rouge Louisianna


Houston Texas


Dobrany Czech Republic

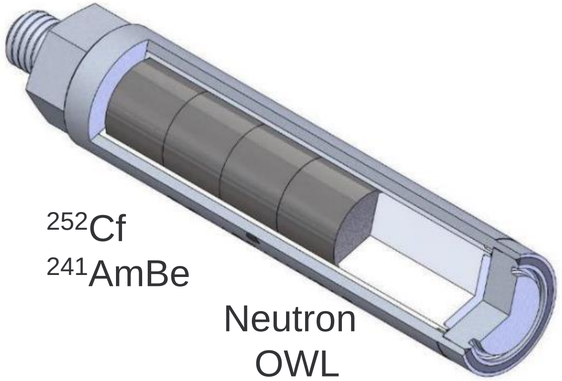
Radiation Sources and Devices

- Gamma Radiography ^{60}Co ^{192}Ir ^{75}Se
- Oil Well Logging ^{137}Cs $^{241}AmBe$
- Industrial Gauging ^{137}Cs $^{241}AmBe$
- Reactor Start-Up ^{252}Cf SbBe
- Medical Therapy ^{90}Sr ^{192}Ir

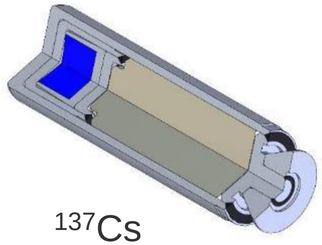
Gamma Ray Exposure Devices

Guide-Tube & Collimator Accessories

Real-Time
Portable
X- Ray
Inspection



^{252}Cf
$^{241}AmBe$
Neutron
OWL



^{137}Cs
Gamma
OWL

^{60}Co ^{192}Ir ^{75}Se
Gamma
Radiography

Industrial Radiography Testing Market

Gamma and X-Ray

Main Gamma Radiography Segments

Vertical	2013	2014	2015	2016	2017	2018	2020	CAGR% (2014 - 2020)
Power Generation	74.49	80.41	86.79	93.64	101.01	108.94	126.63	7.86
Petrochemical and Gas	81.63	89.09	97.21	106.03	115.62	126.04	149.64	9.03
Automotive	33.63	36.19	38.94	41.88	45.04	48.42	55.93	7.52
Infrastructure	29.09	31.08	33.19	35.43	37.81	40.33	45.83	6.68
Manufacturing	48.68	52.28	56.13	60.24	64.64	69.34	79.72	7.28
Aerospace	60.50	66.07	72.12	78.71	85.87	93.66	111.31	9.08
Others	9.70	10.36	11.06	11.81	12.60	13.44	15.27	6.68
Total	**337.72**	**365.48**	**395.45**	**427.75**	**462.59**	**500.17**	**584.32**	**8.13**

X-Ray Segments

Source: Investor Presentations, Expert Interviews, and MarketsandMarkets Analysis.

Gamma radiography is predominantly used in outdoor field locations to inspect pipe welds, tanks, oil rigs, refineries and off-shore

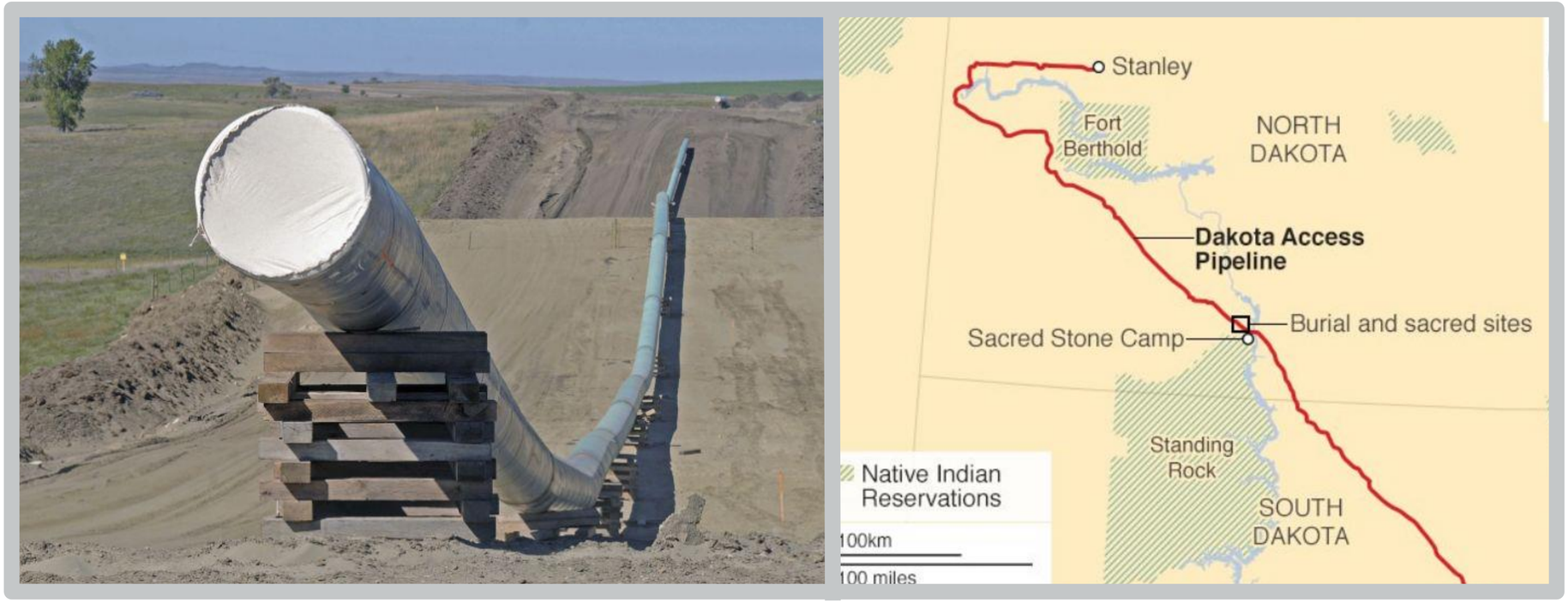
Industrial Radiography Testing
People and Units

~40,000 technicians performing NDT work in the USA

NRC or state qualified radiographers	>10,000 in USA
Industrial radiography licensees	>1,000 in USA
Number of sources sold in the USA	> 4,000 annually
Number of sources sold globally	>10,000 annually

Pipeline Safety - Politically Sensitive

Gamma Radiography Assures Pipeline Weld Integrity



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Pipeline Incidents

Since 1965, Safety Regulations Were Introduced That Demanded Routine Inspection of Critical Welds in Pipeline and Petrochemical Process Infrastructure

LaSalle Heights – Quebec 1965

- At approximately 8:05am a six-inch fissure emerged in a natural gas supply line in the cellar of 367 rue Bergevin, destroying units in it along with those in buildings 365, 363 and 361.
- Approximately 36 units were affected. The explosion left a twenty-foot deep crater where the three-story apartment building had once stood.
- In all, 28 people lost their lives, 39 were injured and 200 left homeless. Most of the casualties were women and children because many men had left for work.
- Since 1965, gamma radiography has been an important technique to detect pipeline flaws and prevent a recurrence of such disasters

Pipeline Incidents

The 30-inch pipeline exploded around 5:30 a.m. Saturday, and left a crater about 86 feet long, 46 feet wide and 20 feet deep. Police say the resulting fire probably lasted 30 to 40 minutes. It reportedly was visible about 20 miles to the north in Carlsbad, N.M.

Serious Consequences of Pipe Weld Rupture

Pipeline Explosion Kills 10 Campers in New Mexico in 2000

Blast Zone

Louisiana 2017 - Pipeline Explosion

Accidents Happen

13

Serious Pipeline Incidents 1994 - 2013

- **The U.S. had 745 serious incidents with gas distribution, causing 278 fatalities and 1059 injuries, with $110,658,083 in property damage.**

- There were an additional **110 serious incidents** with gas transmission, resulting in 41 fatalities, 195 injuries, and $448,900,333 in property damage.

- There were an additional **941 serious incidents** with gas all system type, resulting in 363 fatalities, 1392 injuries, and $823,970,000 in property damage.

- A recent Wall Street Journal review found that there were **1,400 pipeline spills and accidents in the U.S. 2010-2013**

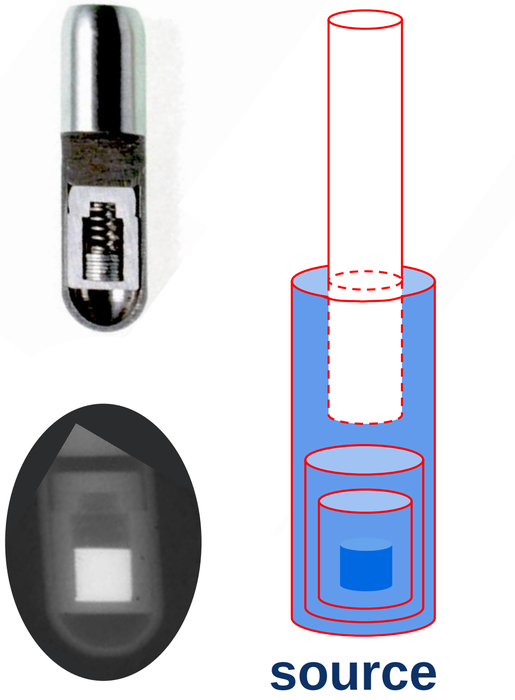
Source - Wikipedia

Gamma Radiography Prevents Catastrophic Explosions of Vital Energy Infrastructure

Saves Lives and $$$Bns

Gamma Radiography Devices

Gamma Radiography Sources



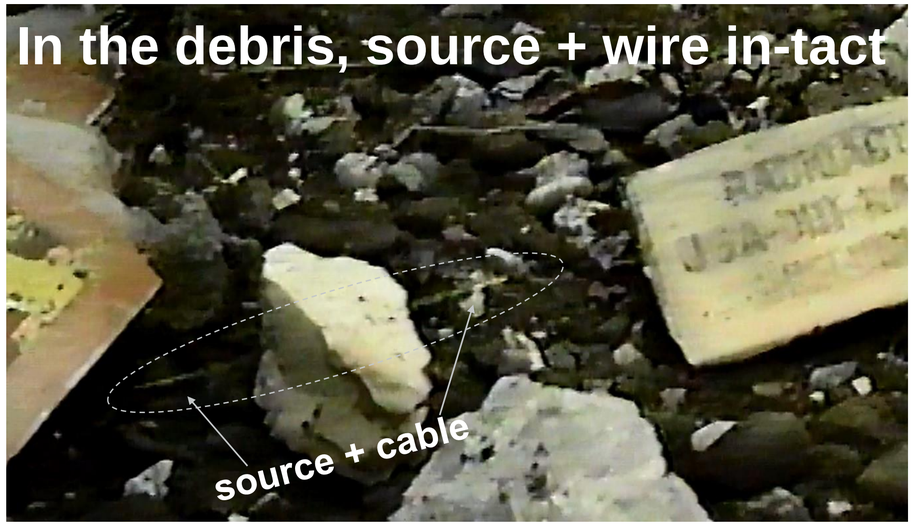
	Average Emission Energy	Half-life
^{60}Co (cobalt)	1,250 keV	5.27y
^{192}Ir (iridium)	375 keV	74d
^{75}Se (selenium)	225 keV	119d
^{169}Yb (ytterbium)	120 keV	32d

Higher Energy Sources Radiograph Thick/Denser Materials

1996 Explosion (Dirty Bomb) Test

Naval Weapons, Argentia, Newfoundland

^{192}Ir 660 Projector

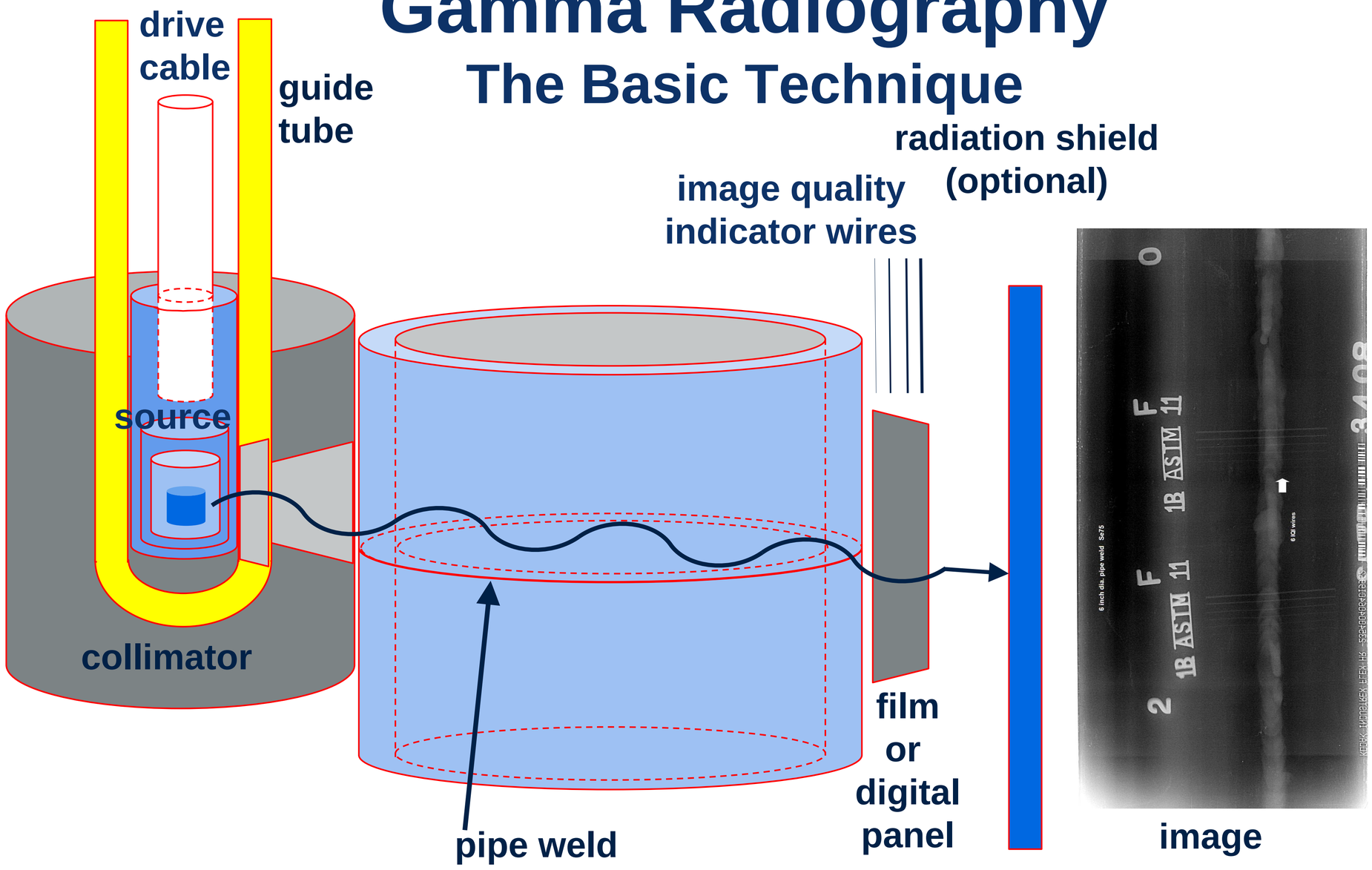


The explosion test was carried out with the source in the guide tube in the exposed position

35 lbs of C4 (Cemtex)

Gamma Radiography

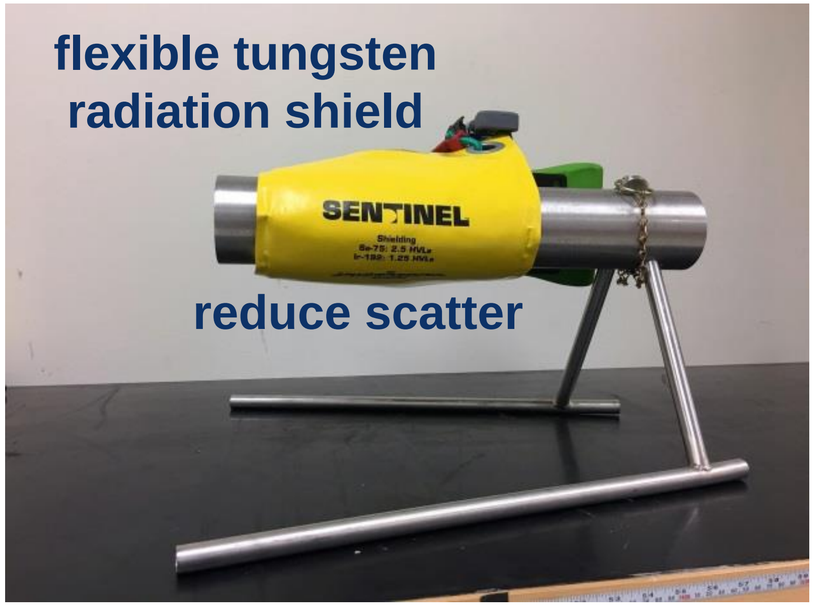
The Basic Technique

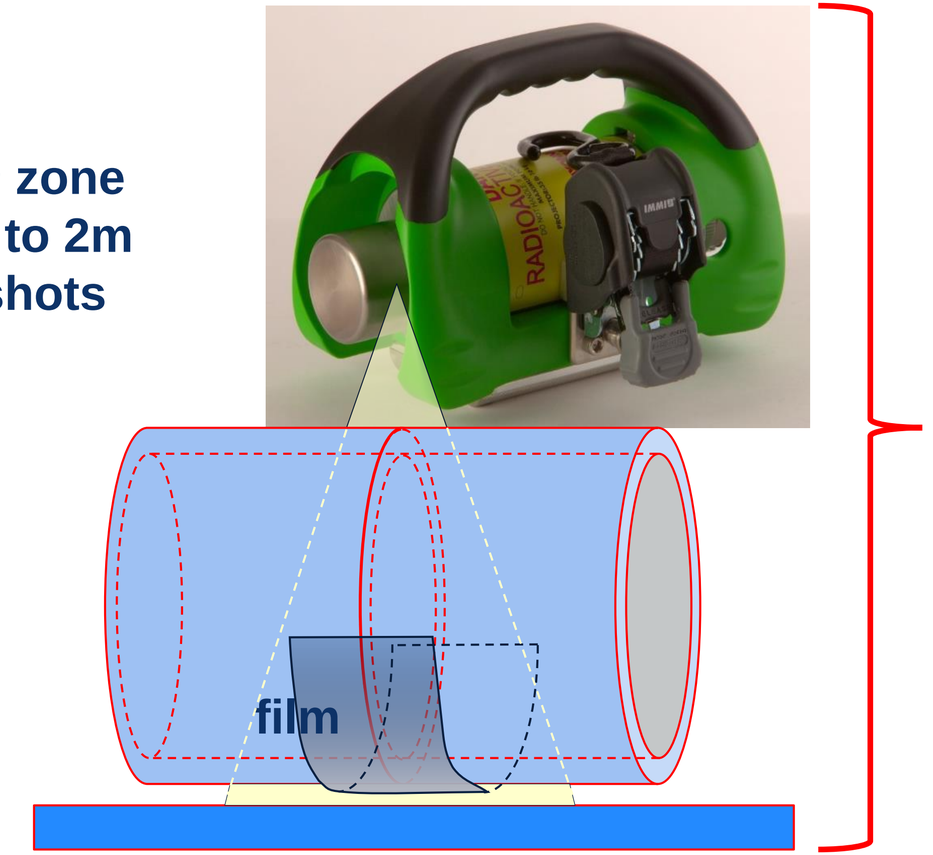


SCAR Technique

Small Controlled Area Radiography with ^{75}Se

Collimator Included
Source never leaves the device
Small radiation safety exclusion zone
100m safe zone can be reduced to 2m
Sites can keep working during shots
SAFETY FIRST





The SCAR technique is more popular outside of the USA

Alternative Technologies – X-Rays

Portable Low-Energy Real-Time X-Ray Scanner <120keV

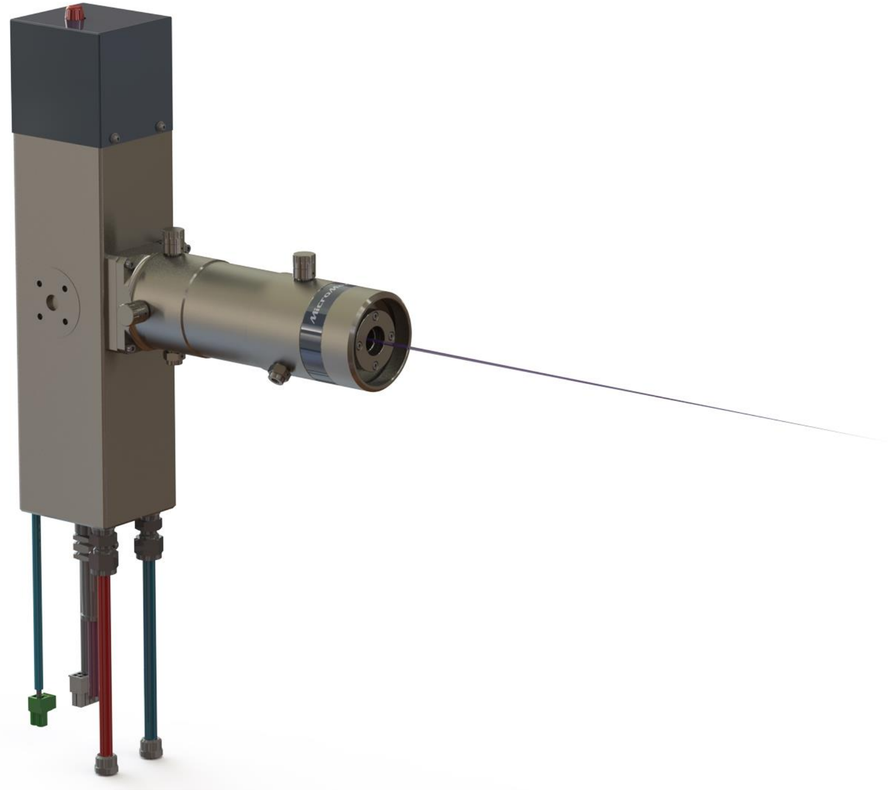
OpenVision

Finding Corrosion under insulation without removing the Insulation

Checking Luggage/Vehicles for Contraband & Weapons

Field Injuries / Veterinary

Alternative Technologies
Microfocal X-Ray Systems



Gamma Radiography has Already been Replaced in Factories by Benchtop and Shop-floor X-Ray Systems

Portable and Semi-Portable X-Ray Generators

Not Suitable for all Field Locations – Large, Heavy, Need External Power

X-Ray Unit

Power Supplies

X-Ray Tube

Challenging Field Site Locations

X-Ray units and power supplies cannot be used everywhere

Gamma Radiography Pipe Weld Examination

300 Feet Up Sub-zero ºF or down in the mud and grime

Alternative Technologies - X-Ray Crawlers

Pipeline Crawlers Used on New or Empty Pipelines

X-Ray Crawler Train

Power Pack

X-Ray Generator

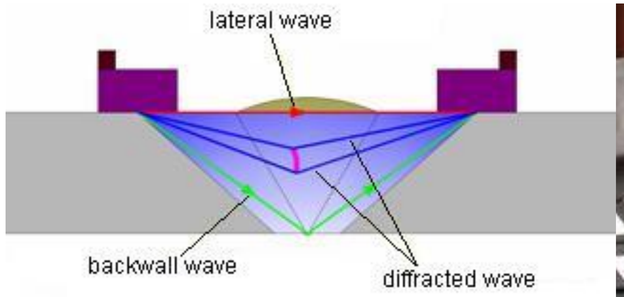
Gamma Ray Crawler Train

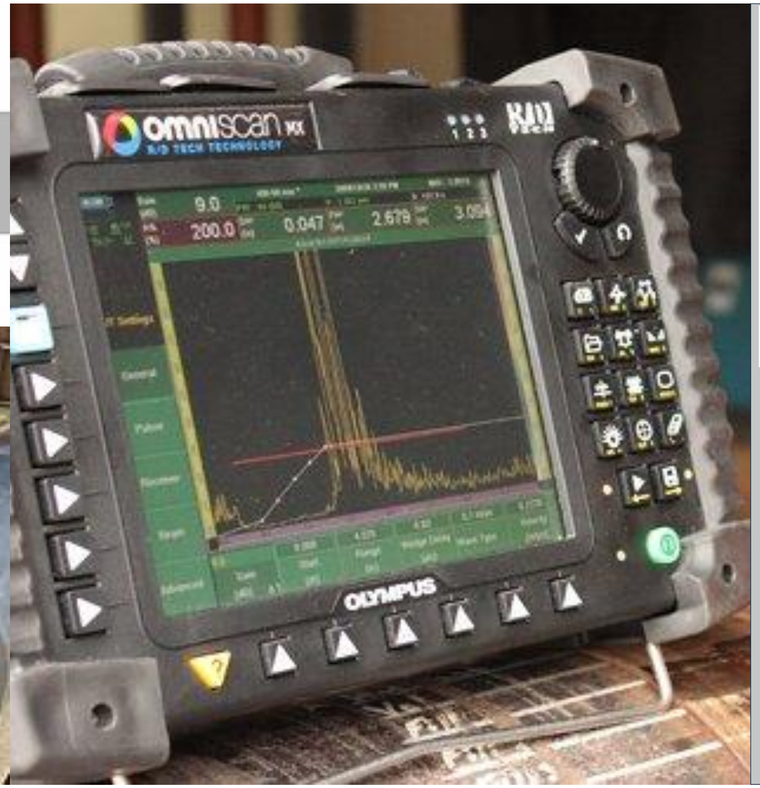
Crawlers Can’t Go Everywhere

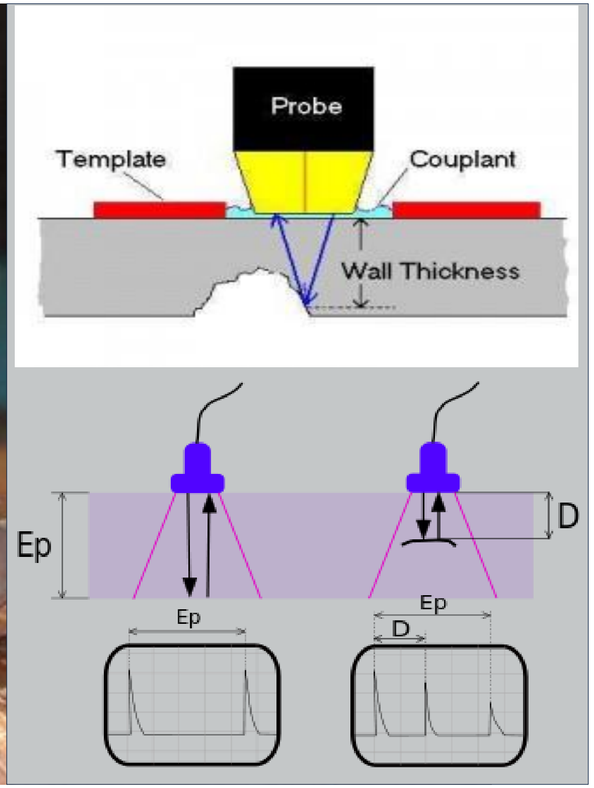
Ultrasonic Testing

The Basic Technique

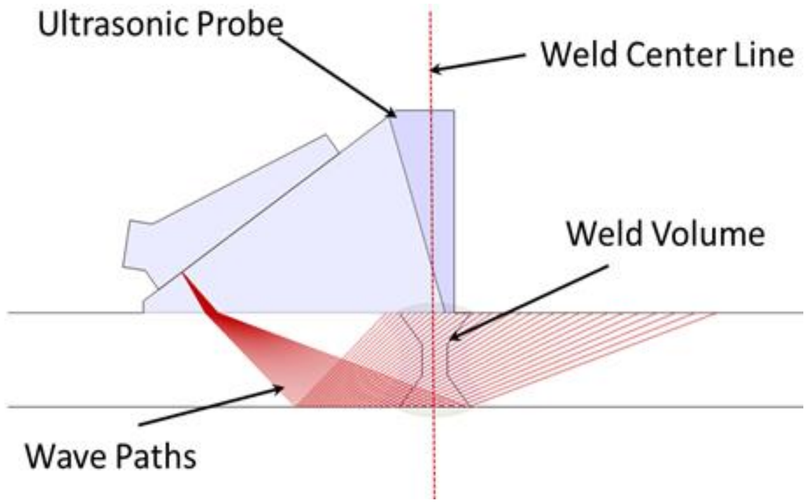
Pulse and Echo







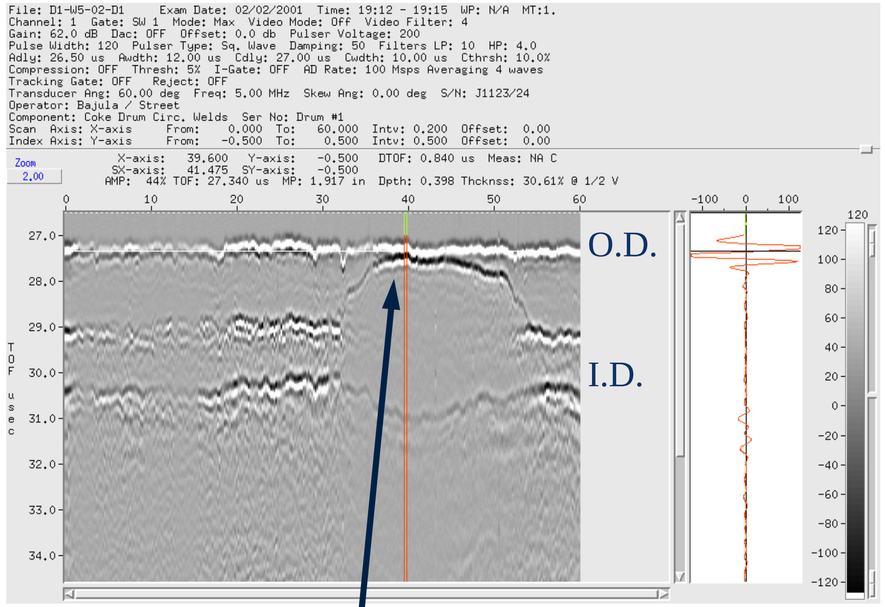
Automated Ultrasonic Testing (AUT)

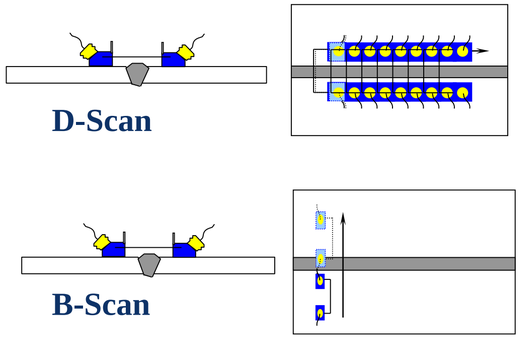


Phased Array Ultrasonic Testing (PAUT)

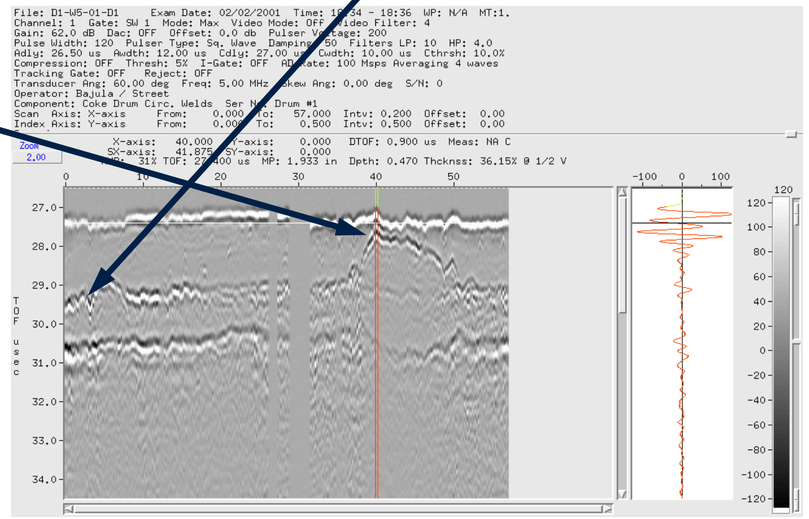
Coke Drum Scan Using Automated Ultrasonic Testing

Ultrasonic test scans produce wiggly lines on a trace representing sound echoes from discontinuities in the test material





This trace is interpreted as indicating moderate cracking



Scans need skillful examination and interpretation by trained graduate technicians

Gamma radiography is often used to validate uncertain interpretations

Ultrasound vs. Gamma Radiography

UT Measures Sonic Discontinuities

RT Measures Mass / Density

Type of Defect	Measurement Response	
	UT	RT
• Narrow Crack Aligned with Sound Wave	Weak	Strong
• Narrow Vertical Crack	Strong	Strong
• Narrow Horizontal Crack (Delamination)	Strong	Weak
• Shallow Surface Defect	Weak	Strong
• Wall thickness	Strong	Weak
• Porosity	Weak	Strong

Difficult Climatic Conditions

Ultrasound imaging doesn’t work if the sonic couplant fluid freezes

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

NUREG/CR-7204
PNNL-24232

Applying Ultrasonic Testing in Lieu of Radiography for Volumetric Examination of Carbon Steel Piping

Is it Ultrasonic or is it Radiography inspection?

(Case Study- Difficult Pipe weld comparing AUT to RT)

Title Is it Ultrasonic or is it Radiography inspection?
Author I J Roux, M Eng. (SA) RAE Engineering & Inspection Ltd.
111 4808 87 Street, Edmonton, Alberta, Canada
Paper delivered at the 2005 National Pressure Equipment Conference, February 2005, Banff, Alberta, Canada 37

Abstract
Risk is always part of the engineering effort and change as we progress though the life cycle of a project, from design to construction to in service and eventual phased-out. The risk engineering effort of the one phase has a direct influence on the next phase of the project. This paper report on an investigation of the risk associated with the welding of a 600mm steam-line using a new material for this application, and a welding procedure with out post weld heat treatment. The quality aspects of the risks were investigated and the using of both radiography and automated ultrasonic testing to verify the weld quality. **Can we inspect the weld by only Radiography or only AUT (TOFD)? Or do you need both?**
TOFD - Time Of Flight Diffraction Technique an alternative to Radiography

The answer is a definite YES **you have to do AUT and RT** if you want to reduce the risk of missing possible unacceptable defects. The one technique is complimentary to the other.

Ultrasound vs. Gamma Radiography Comparison

Pro

Ultrasound Testing

- Measures residual wall thickness
- Linear defects normal to the sound beam are well detected (delamination)
- There is no radiation safety hazard
- Instantaneous real-time results
- Requires access to only one side of a pipe
- Automatable (PAUT, AUT)

Gamma Radiography

- Lower level technician training needed
- Minimal surface preparation
- Works at low temperature
- Sources may be easier to use in highly inaccessible places
- Simple interpretation of data – not technician dependent
- No calibration standards are needed
- Generally less expensive than UT
- Generally faster than UT
- Generally higher resolution than UT

Con

Ultrasound Testing

- Requires higher level technician training
- Requires surface preparation / sonic coupling
- Does not work at very low temperature
- Less sensitive to detecting porosity
- Transducers may not be locatable in highly inaccessible places
- Interpretation of data is technician dependent
- Calibration standards are needed

Gamma Radiography

- Doesn’t Measure residual wall thickness
- Linear defects normal to the radiation beam may go undetected (delamination)
- Requires access to both sides of a pipe
- Radiation safety hazard / security risk
- Delayed results
- Regulatory / transportation constraints
- Criminal background checks for technicians

Conclusions

Ultrasound Testing (UT) and Radiography Testing (RT) are Complementary

Radiography images density/mass changes, Ultrasound echoes detect discontinuities

- **UT and RT cannot individually detect all types of weld defect, but using both techniques, all defects can be detected**
- **It is not possible to use X-Ray units or UT systems in all remote field locations or climatic conditions**
- **Gamma ray exposure devices are extremely tough and can detect pipeline and tank flaws in the toughest places and in extreme climatic of conditions**
- **The SCAR technique can be used to enhance safety, security and efficacity of gamma radiography**
- **Use of lower activity gamma sources could mitigate safety / security risks**

The Bottom Line Is

All NDT Techniques are Complementary and Vital

RT + UT/AUT/PAUT + X-Ray + Magnetic-Particle + Die-Penetrant + Eddy-Current + others - **ALL** needed to avoid this