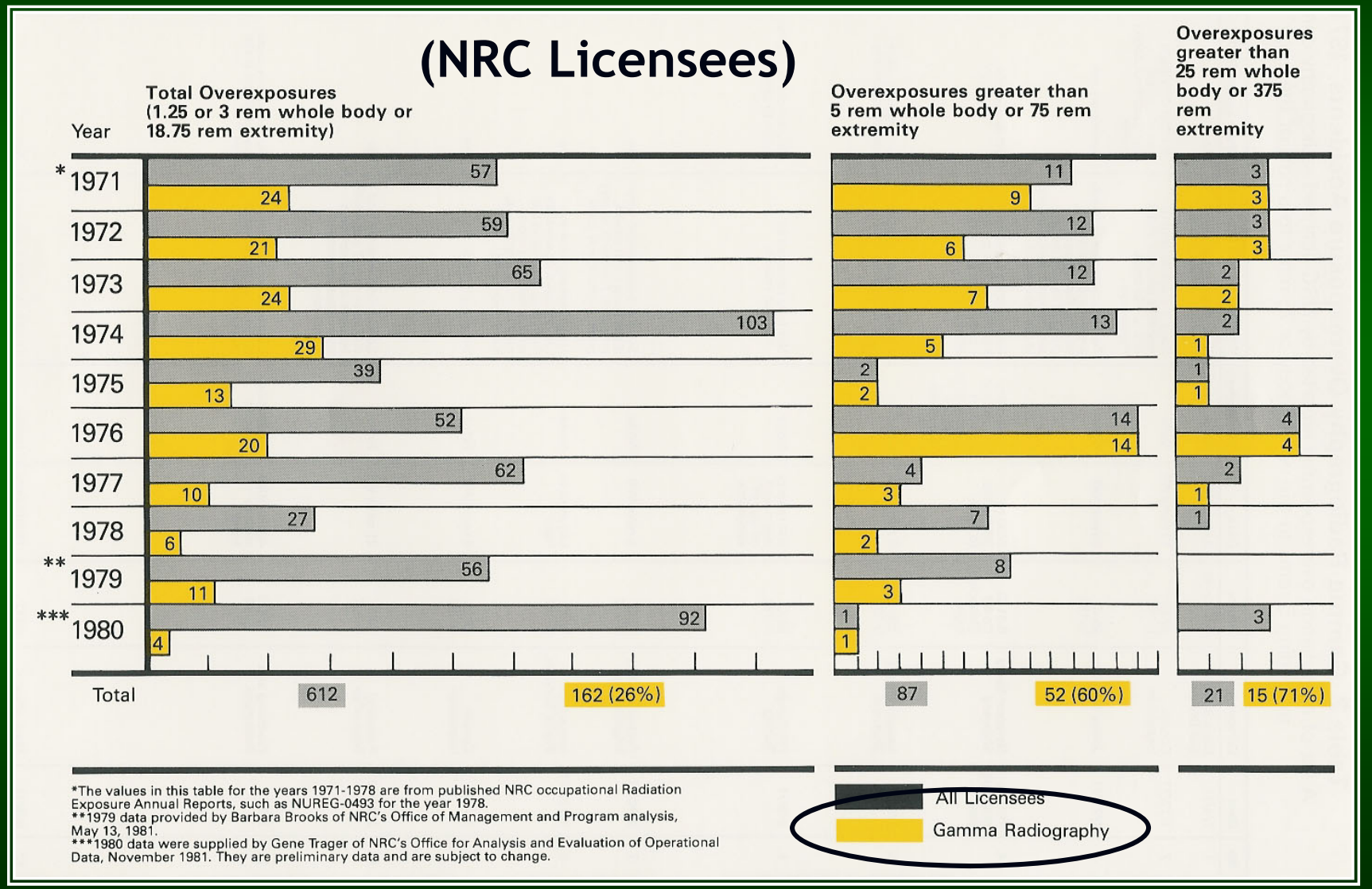
Industrial Radiography Incident Case Histories

Radiography Incidents

Learning Objectives

- Understand different types of radiography incidents
- Understand causes of ind. radiography incidents
- Understand potential significance of overexposures
- Understand techniques used to investigate & resolve radiography incidents

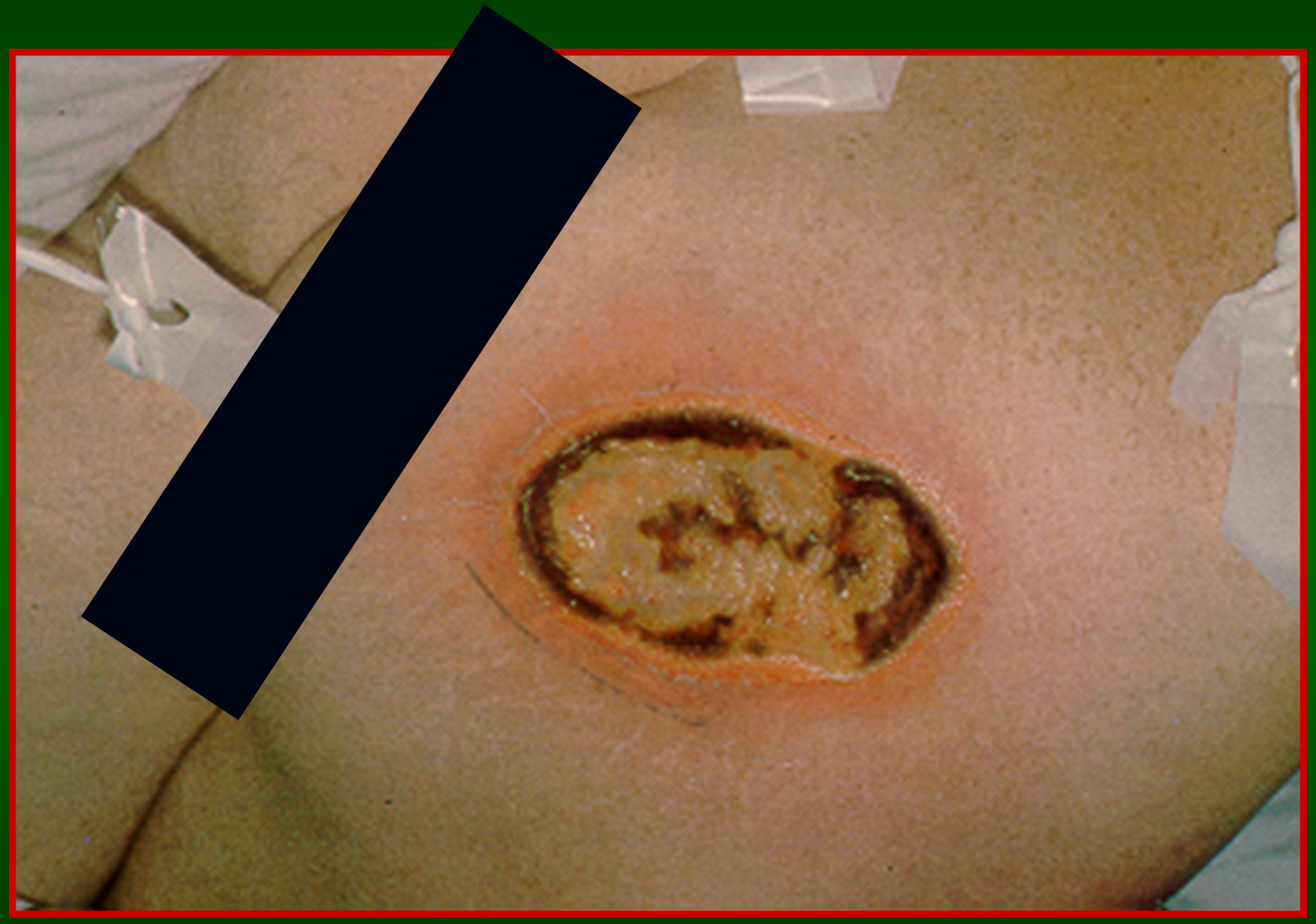
IR Overexposures: 1971 – 1980



*The values in this table for the years 1971-1978 are from published NRC occupational Radiation Exposure Annual Reports, such as NUREG-0493 for the year 1978.
**1979 data provided by Barbara Brooks of NRC's Office of Management and Program analysis, May 13, 1981.
***1980 data were supplied by Gene Trager of NRC's Office for Analysis and Evaluation of Operational Data, November 1981. They are preliminary data and are subject to change.

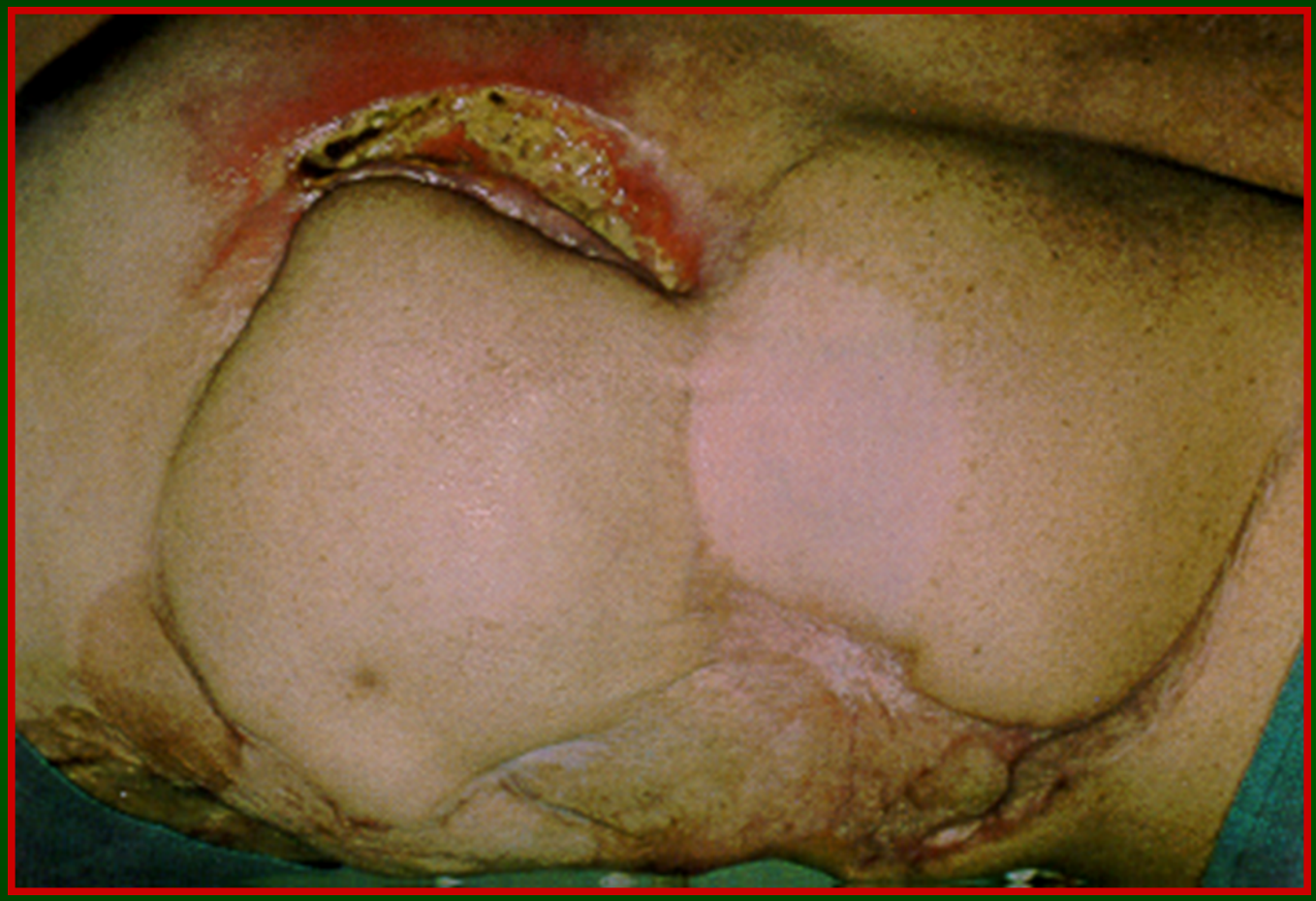
Ref.: NUREG/BR-0024, Table 1 (Sept. 1982)

1979 IR Overexposure Victim



31 days after accident

1979 IR Overexposure Victim



19 months after accident

Source: U.S. NRC NUREG/BR-0024 (Sept. 1982)

IR Hand Overexposure

Burns & blisters from direct handling of Ir-192 source

IR Hand Overexposure — 5 Years Later

Hands remained very sensitive to heat/cold; more amputations possible

Persistent pain led to multiple amputations

Source: NUREG/BR-000, Vol. 1 (Sept. 1980)

IAEA Safety Series Report No. 7

Lessons Learned From Accidents in Industrial Radiography

(1998)

- Inadequate regulatory control
- Failure to follow operational procedures
- Inadequate training
- Inadequate maintenance
- Human error
- Equipment malfunction or defect
- Design flaws
- Willful violation

Risk Ranking of Licensed Activities

Relative Risk Ranking	Activity
	Industrial radiography (field)
High	Medical – therapy
	Medical – brachytherapy (manual loading)
	Medical – teletherapy (single source)
	Industrial radiography (shielded room)

Industrial radiography holds the no. 1 & no. 5 spots on the NRC risk ranking list

Source: U.S. NRC NUREG/CR-6642, Vol. 2 (2/00)

Questions Posed by the NRC in 1978

- Is the nature of industrial radiography such that a certain no. of overexposures are unavoidable?
- Are job requirements so demanding that the average radiographer can't be adequately trained to make the right decisions when confronted with either routine or unusual occurrences?
- Is it impossible for mgmt. to exercise sufficient admin. control, since most of the violations of safety procedures are committed by radiographers when mgmt. isn't around?
- Are regulators failing to pinpoint problem areas?
- Would increasing penalties significantly reduce the number of overexposures?

Overexposure Analysis

Overexposures generally happen in two parts:

First, the source is left exposed when it shouldn't be

Second, a required radiation survey is omitted or inadequately done

Both conditions must be met for an overexposure to occur

Overexposure Analysis

Two Basic Levels of Defense Against Overexposures

1. Prevent inadvertent exposure of the source
2. Detect sources that are exposed before they result in an unnecessary exposure

- No. 1 depends largely on equipment performance & is more amenable to direct improvement than No. 2, which depends on consistent performance of safety procedures

Overexposure Analysis

Common Causes of Source Becoming Exposed

- Radiographer forget to retract source
- Source stuck in guide tube
- Source disconnected from control cable
- Radiographer did not fully retract source into fully shielded position
- Source moved out of shielded position after survey
- Radiographer confused "in" & "out"

Overexposure Analysis

Common Causes of Failure to Discover Exposed Source

- No survey performed
- Incomplete survey
- Failure to lock camera before moving
- Radiographer recognized problem but failed to respond properly
- Broken survey meter

Radiography Incidents

IR Overexposures: 1985 – 2005

- Radiography overexposures have been reported every year from 1985 – 2005 (2004 was the only exception)
- Highest TEDE dose was 93 rem (1989)
- Highest SDE dose was 6000 rad skin dose (1990)

Ref.: NUREG-0713, Vol. 27, Tables 6.1 - 6.2 (Dec. 2006)

Conclusions from NRC Public Meeting

How can mgmt. do its job more effectively & reduce the frequency & severity of overexposures?

1. Emphasize that main purpose of training is to ensure safety, not compliance
2. Workers must know requirements & why they matter
3. Strong internal audit program
4. Offer incentives (+/−) to work safely, follow procedures

Conclusions from NRC Public Meeting

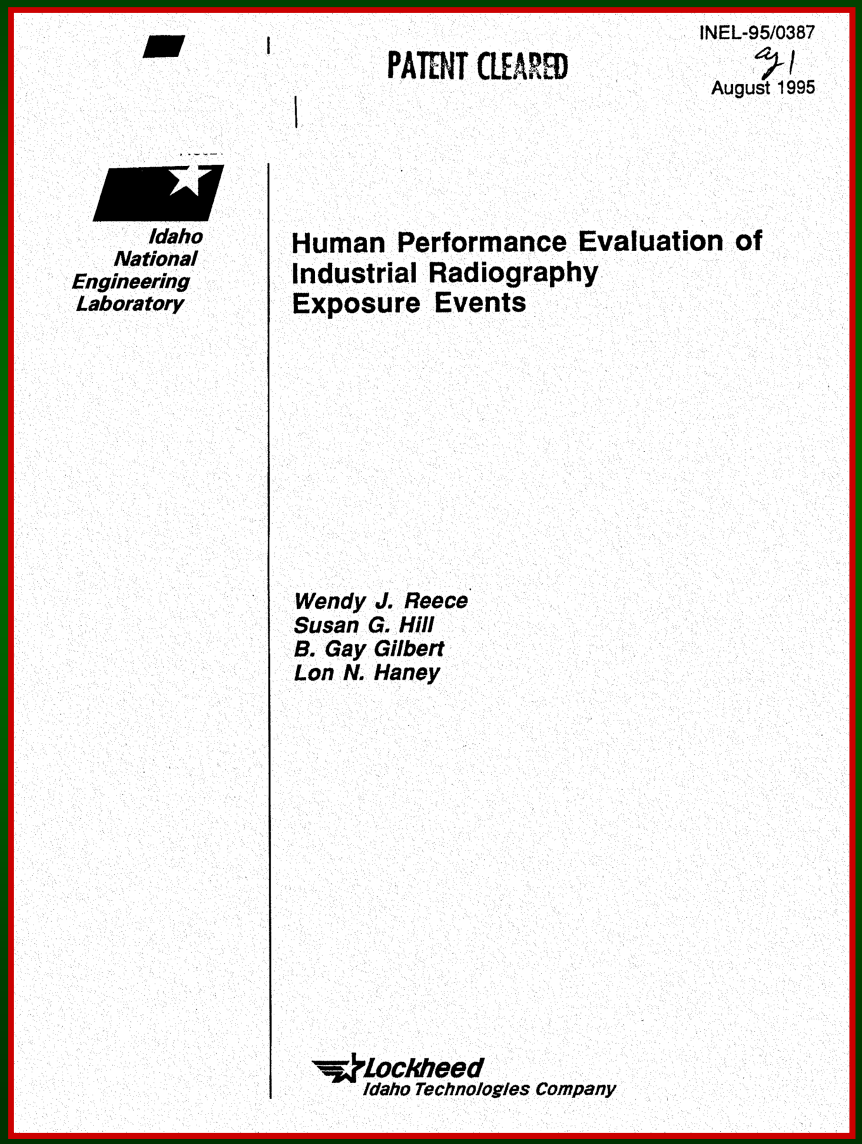
How can management do its job more effectively & reduce the frequency & severity of overexposures?

5. Audit workers' records
6. Periodic training
7. Use qualified instructors
8. Investigate incidents promptly & thoroughly

Pipeliner Incident – 1995 (location unknown)

- Screw retaining 12 Ci Ir-192 source in pipeline crawler fell out, allowing source to fall out of shielded position
- Source saturated the crawler's onboard rad. detector, so it didn't respond to signals from the operator with his control source & failed to operate
- Radiographer never did any surveys, so exposed source wasn't discovered until crawler was taken apart
- Radiographer's whole body dose = 8.7 rem

1995 INEL Study of IR Overexposures



PATENT CLEARED

INEL-95/0387

August 1995

Idaho National Engineering Laboratory

Human Performance Evaluation of Industrial Radiography Exposure Events

Wendy J. Reece
Susan G. Hill
B. Gay Gilbert
Lon N. Haney

Lockheed Idaho Technologies Company

1995 INEL Study

INEL categorized 95 IR events:

17	Survey not performed or not properly
16	Source not properly retracted
13	Badge tampered with or accidentally overexposed (not necessarily true exposures)
30	Insufficient information for categorization

Data analysis suggested two primary types of errors

1. Errors related to proper use of survey meters
2. Errors involving equipment set-up

NRC IN 99-04

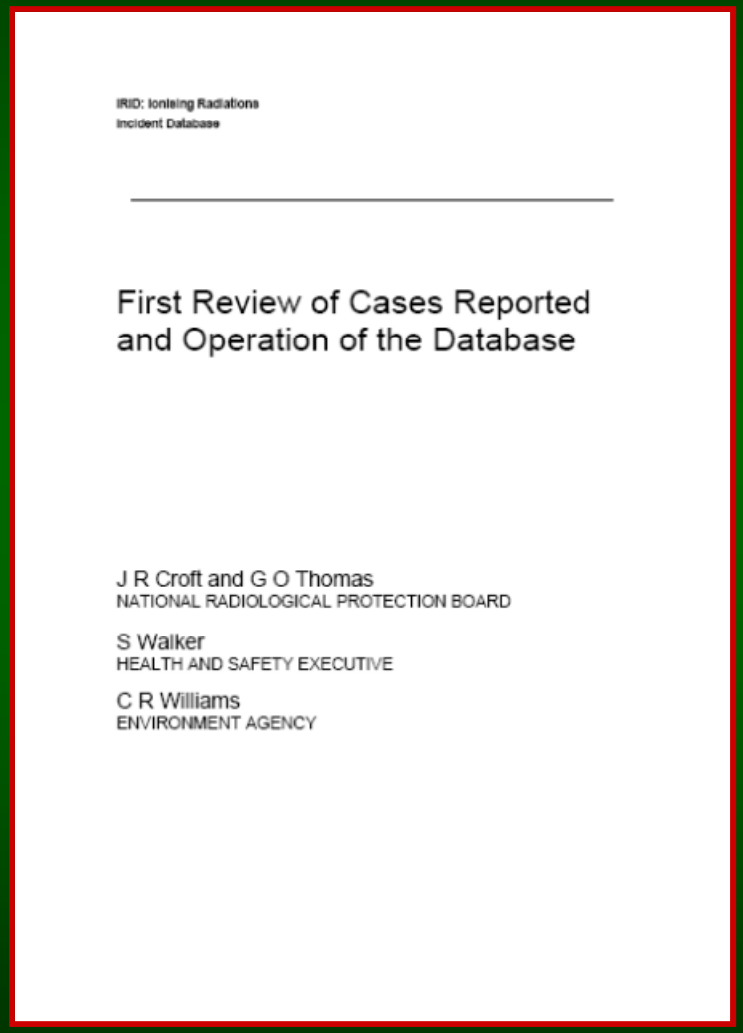
Unplanned Radiation Exposures to Radiographers, Resulting From Failures to Follow Proper Radiation Safety Procedures

Incidents

1998 Radiographer walked into controlled area during a shot; wasn't wearing an alarm ratemeter & didn't carry a survey meter; received 350 mrem whole body & 7 rem to right hand

1998 Rad. asst. entered large pipe after a shot to reposition camera & guide tube without wearing alarm ratemeter & didn't carry a survey meter; discovered lock wasn't engaged; radiographer retracted source

1999 Study of Ind. Rad. Overexposures



IRID: Ionising Radiations
Incident Database

First Review of Cases Reported
and Operation of the Database

J R Croft and G O Thomas
NATIONAL RADIOLOGICAL PROTECTION BOARD

S Walker
HEALTH AND SAFETY EXECUTIVE

C R Williams
ENVIRONMENT AGENCY

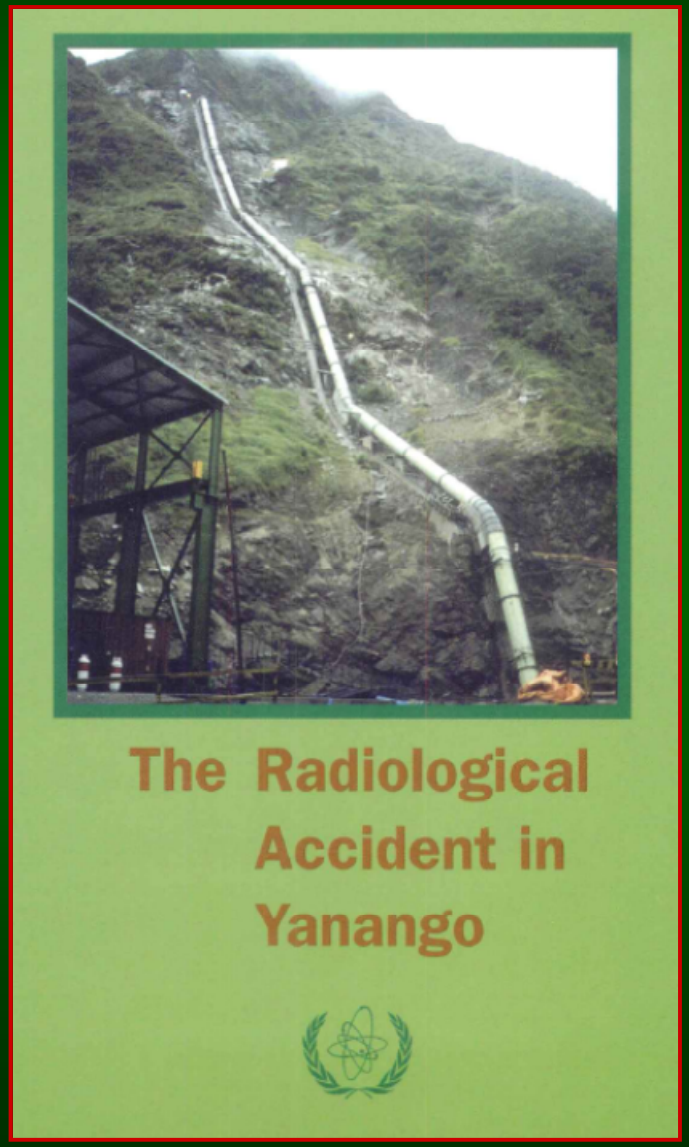
UK Natl. Rad. Protection Board

Ionising Radiations Incident Database (IRID)

Annex A – Incident Case Histories
A4 – X & Gamma Radiography

Radiography Incidents

IAEA Report on 1999 Radiography Incident in Peru



Peru Overexposure Incident

Estimated dose to welder

Skin	1 Mrad
Soft Tissue	0.25 Mrad
Femur	14.3 krad
Gonads	2.3 krad
Bladder	1.8 krad
Rectum	1.8 krad

Peru Overexposure Incident

Peru Overexposure Incident — Feb. 1999

Source: IAEA

Peru Overexposure Incident

Violations

- Procedures were not effectively implemented by mgmt.
- Lack of safety culture
- Inadequate security & supervision of the source
- Responsible person was not a fully trained & qualified radiographer

Ind. Radiographer Radiation Burn

NRC PNO-III-02-019 May 1, 2002

Possible Radiation Injury to Radiographer

X-Ray Overexposure Incident

Feb. 24, 1999 Miami International Airport

- While x-raying a Boeing 727, radiographer inadvertently started the unit's warm-up mode
- Without verifying that the exposure had terminated, he entered the aircraft & moved the tube head while the asst. placed film on plane's exterior
- Upon return to the control, he saw machine was on warm-up cycle; exposure time was estimated as 2–3 min.
- Neither worker was wearing an alarm ratemeter & neither used their survey meters; radiographer claimed he lost his ratemeter earlier in the shift

X-Ray Overexposure Incident

- No work report filed for job, so no dosimeter readings initially recorded; after incident, reported dose to asst. was 90 mrem; badge read 105 mrem
- On 3/15 radiographer sought medical attention for his hand; told doc it was a steam burn, but location of burns was consistent with hands' position by beam port
- Having lost most feeling in his hand, radiographer informed mgmt. on 3/18, who got him medical treatment

X-Ray Overexposure Incident

- Investigators found no internal audits performed
- Company's dose reconstruction & corrective actions were inadequate; ordered to redo dose estimate, conduct internal audits & monitor field reports
- Revised dose est.: 576 rads to extremities,2.5 rem TEDE; state est.: 1–2,000 rads to extremities, 10-20 rem TEDE
- State concluded radiographer exceeded annual dose limit, so banned him from radiography for rest of year; company was fined $5K
- Cause: failure to follow procedures, wear & use safety equipment
- Lessons learned: X-ray RT also hazardous; backscatter can contribute greatly to dose

Misconnect Incident

Orlando, FL - June 2004

Misconnect & Retrieval Incident

Orlando, FL - June 2004

Cause: Asst. radiographer failed to properly connect drive cable to source assembly (failed to follow O&E pro.)

Root cause: Failure to properly inspect & maintain equipment, including failure to perform misconnect tests

Misconnect & Retrieval Incident

Asst. RSO's Source Retrieval Technique

Misconnect & Retrieval Incident

Asst. RSO's Source Retrieval Technique

Incident Investigation

Information to Collect/Questions to Ask

- Obtain a "blow-by-blow" chronological account of the incident from the start of the job (routine radiographic operations) - what they were shooting (ex: 3 inch piping, contact shots), what the original set-up was when the source became disconnected, how many shots had been taken, what accessory equipment was being used (bungee cords, stand, magnet, clamp, collimator, etc.); have them draw a diagram of the setup in place when the problem occurred.
- Have each witness provide a detailed description of every step taken to recover the source, and have them make diagrams showing everything. Diagrams need to show exact body position during each step.

Incident Investigation

Information to Collect/Questions to Ask

- Names, titles of the radiography crew, the manager, any witnesses at the scene
- Qualifications of the personnel involved in the incident
- Description of the equipment problem
- Cause of incident (if known)
- Mfr. name & model number of the equipment involved
- Place, time, and date of the incident
- Actions taken to establish normal operations
- Corrective actions taken or planned

Incident Investigation

Information to Collect/Questions to Ask

- Obtain “blow-by-blow” chronological account of incident
- Have licensee provide diagrams of the setups
- Have each witness provide a detailed description of every step taken.
- Try to get explicit details on how the source was returned to the camera
- Ask ARSO if he did any planning and if he practiced before the retrieval
- Have workers perform a re-enactment
- Ask how ARSO’s dose was determined
- Don’t ask accusatory questions; be empathic
- Urge them to ship equipment to mfr. for analysis
- Determine if it was a disconnect or a misconnect
- Get pictures of everything

Equipment Incidents

Crushed Camera

- Camera was crushed when a pipe fell off of a platform during radiography
- Source was shielded with sand until the vendor arrived to retrieve the source

Equipment Incidents

Incinerated Camera

Camera damaged during vehicle fire; integrity of source & shielding was not compromised

Equipment Incidents

Incinerated Source Changer

- Source changer burned in fire; shielding integrity was not compromised but source could not be removed

Equipment Incidents

Stripped Hand Crank Gear

- Teeth of gear from hand crank was stripped; could impair either the extension or retraction of the source

Equipment Incidents

Stuck Source Incident – May 2005

- During field RT, crew couldn't retract source
- RSO was able to free source & retract it into camera
- Cause: dent in guide tube under 'bend restrictor'
- Minimal exposures to crew & RSO
- Corrective action: remove guide tube from service
- Root cause: bent guide tube
- Lesson learned: better daily equipment inspections needed; visual inspection may miss the problem, but testing with a dummy source would catch it

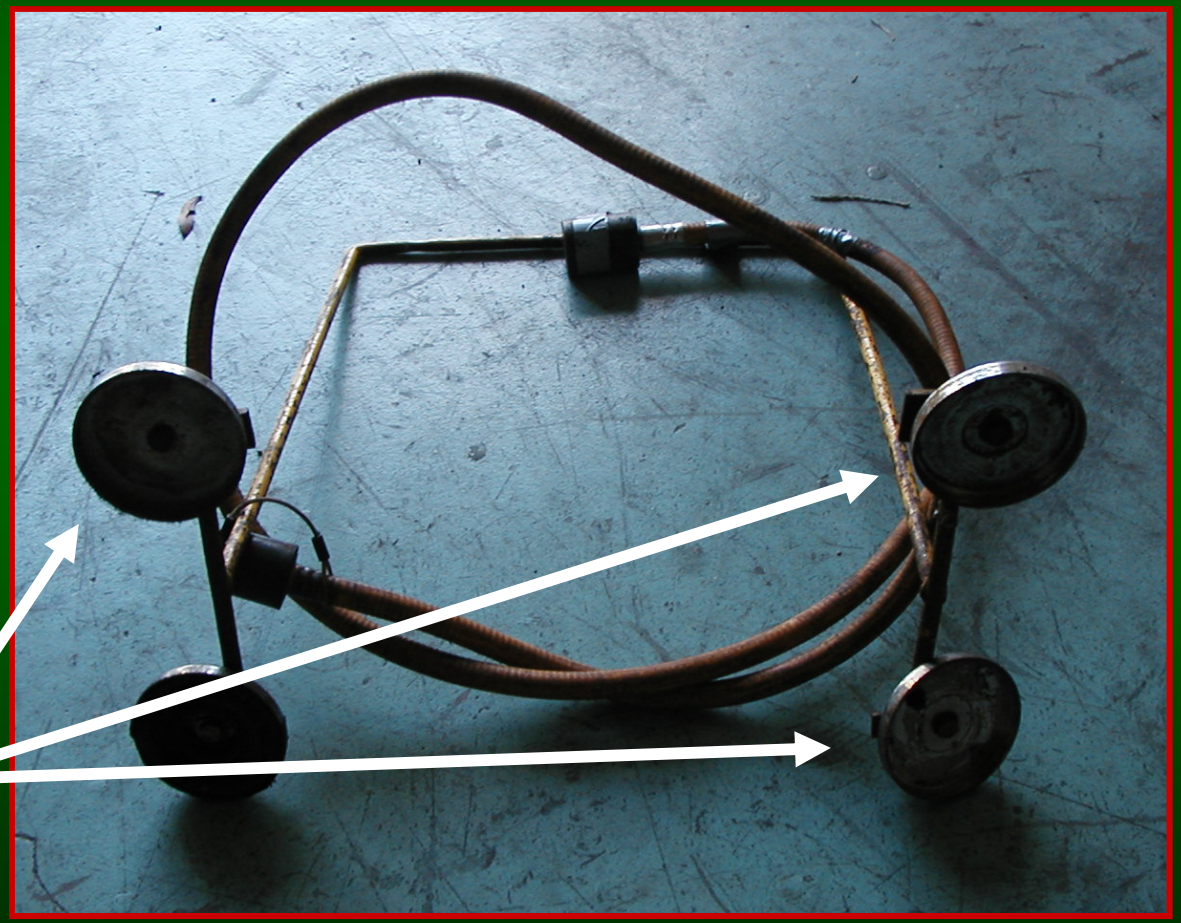
Equipment Incidents

Crimped Guide Tube Incident – July 2006

- During RT on a tank in CT, magnetic stand fell on the guide tube & crimped it, preventing the 62-Ci Ir-192 source from being retracted
- Crew controlled area until camera mfr. personnel arrived to retrieve the source
- Root cause: bent guide tube; unclear if condition of magnetic jig was a contributing factor
- Lesson learned: accessory equipment plays an important role; must be properly maintained, inspected, & used to ensure safe operations

Equipment Incidents

Magnetic Jig – Possible Culprit in Incident?



Broken/missing magnets

Radiography Incidents

- Burns to an individual's hand from touching a source

Radiography Incidents

- Burn to an individual who accidentally stood between the radiation beam & the film

Radiography Incidents

- Burn to driver's back after being exposed for 12 min. to a 20 Ci source in a shutter-type camera stored inside truck; driver didn't know the shutter was open

Stolen Radiography Camera

Miami, FL

- After completing night shift, crew went to a residence to shower before another job; camera (with keys in it) was stolen from rig parked in front of house
- Feds assumed authority over investigation, brought in search team that flew over Miami area with detectors trying to locate the device
- FBI also investigated possibility that camera was sold to a Panamanian co. that had been trying to buy a used camera (the one stolen was same model the co. was seeking to purchase); camera was never recovered
- Root Cause/Lessons Learned: Failure to follow security procedures & FL regs for control of radiation sources

Recent Incidents

Source Incident - July 2007

- Camera loaded with 97-Ci Ir-192 source was perched on an I-beam when the collimator fell, creating a sharp bend in the guide tube
- Licensee built a tool using a 15' section of conduit with a vice grip taped to the end, which was used to push the collimator up level with the camera & straighten the bend in the guide tube, which enabled them to crank the source back into the camera
- Cause: bent guide tube
- Lesson learned: Don't have to damage equipment to create a problem; a bad set-up will do the trick

Recent Incidents

Radiography Overexposure Incident - Sept. 2006

Theft of a radioactive camera from Indo-Gulf Fertilizers has sent alarm bells ringing. Scientists and the police believe that as the gadget contains radioactive material, its improper handling may generate harmful emissions. Used for detecting cracks in huge steel structures, the 20-kg stolen gadget contains Iridium, a radioactive material.

The theft came to light on April 24. The manner in which proper entries are made and gate passes are issued, it is highly unlikely that the theft would have taken place without the involvement of some insider.

Iridium-192 is the isotope of most concern based on general availability. It is used in a number of industrial and medical applications.

Recent Incidents

Stolen Camera Causes Panic – June, 2007

Four accidentally irradiated Africans have arrived for treatment in France following the discovery that an Ir-192 source used for industrial X-ray examinations had in July irradiated a yet-unknown number of people.

The Ir-192 source had slipped undetected out of its shielding and was then flown by DHL to BV's office in Abidjan, Cote d'Ivoire. Experts from IRSN are working to estimate the level and distribution of their doses. Clinical symptoms indicated that one BV employee in Abidjan had received a dose of several Gray (several hundred rads).

If necessary, he said, the man could be treated with a revolutionary stem cell therapy applied successfully this year to victims of two other irradiation accidents, in cooperation with the French Army's health service at the Percy Military Hospital outside of Paris. IRSN experts will also help BV evaluate the doses received by all other people who came in contact with the source, he said.

NRC Event Reports

Event No. 43769 Event Date: Nov. 3, 2007

Radiography Source Fails to Fully Retract Into Camera

Event No. 43761 Event Date: Oct. 29, 2007

Radiography Source Left Unattended for 6 Hours

Event No. 43751 Event Date: Oct. 23, 2007

Improperly Connected Camera Source

Event No. 43669 Event Date: Sept. 27, 2007

Radiography Source Will Not Retract Into Camera

Rule Changes

- Equipment performance requirements, including posilock mechanism (made many camera models obsolete)
- Two-member crew requirement
- Refinement of supervision rule: direct, personal supervision of assistant required
- Radiographer certification
- In some states (e.g., TX, LA, FL), additional requirements

Warning Signs Used in Radiography

5 mR/hr isodose line

Trefoil +
"Caution – Radiation Area"

100 mR/hr isodose line

Trefoil + "Caution – High Radiation Area" or "Danger – High Radiation Area"

Warning Signs Used in Radiography

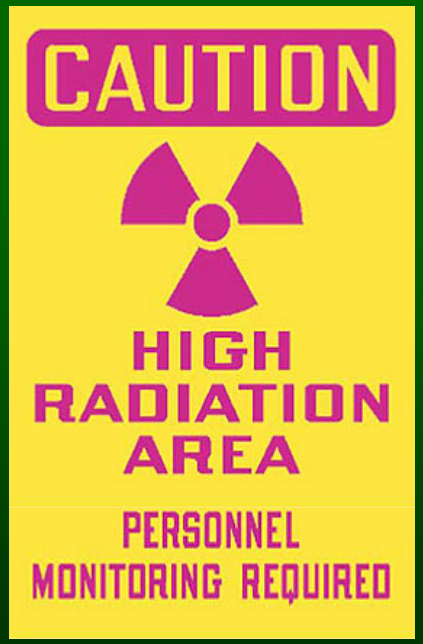
Problem:

Yellow color & "Caution" warning translation:
"Proceed With Caution"

Warning Signs Used in Radiography

Solution:

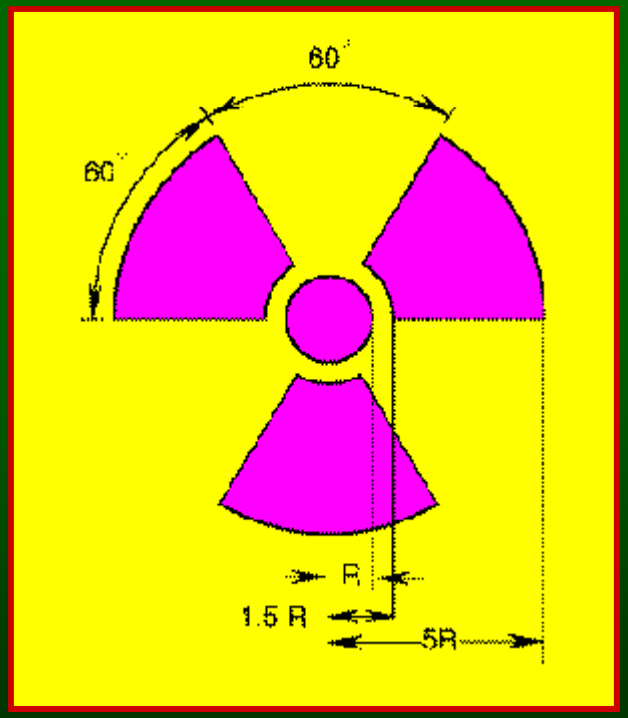
Regs allow use of additional warnings as appropriate



Warning Signs Used in Radiography

Problem:

Many people don't know what the trefoil stands for



Warning Signs Used in Radiography

Solution:

Regs allow use of additional warnings as appropriate

KEEP OUT

RESTRICTED AREA

AUTHORIZED PERSONNEL ONLY

RADIOGRAPHY IN PROGRESS

PERSONNEL
MONITORING REQUIRED

X-RAY MACHINE IN USE

Warning Signs Used in Radiography

Solution:

- Many people don't know what the trefoil stands for

Radiography Incidents

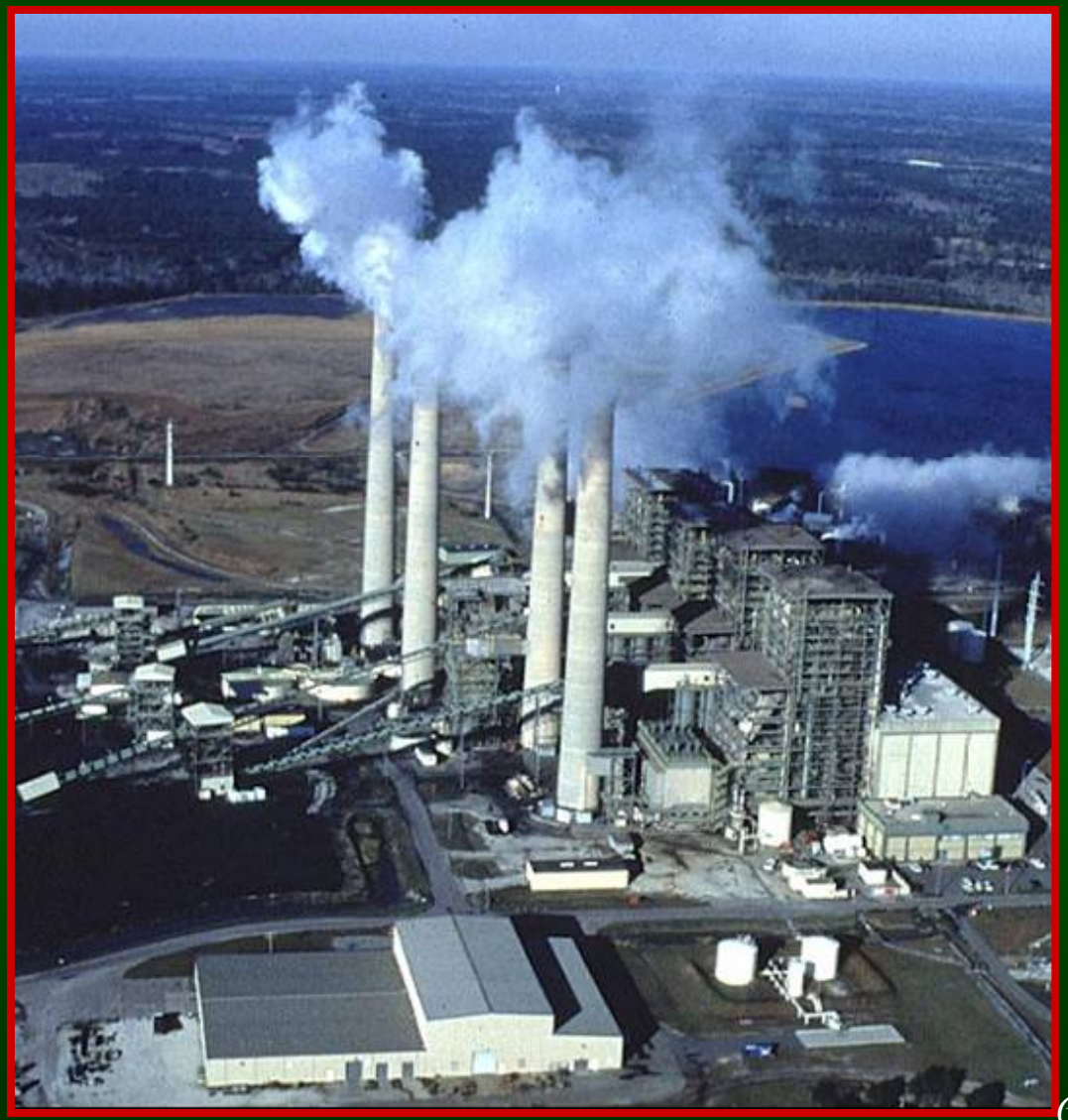
1995 Power Plant Incident & Investigation

Santee Cooper Power & Light Winyah Generating Station in Georgetown, SC

Incident & Investigation – 1995

Winyah Generating Station

Georgetown, SC



1995 Incident

Cause

- Bent guide tube, failure to follow emer. procedures

Root Cause

- Lack of mgmt. commitment to safety, compliance

Lesson Learned

1995 Incident

Cause

- Bent guide tube, failure to follow emer. procedures, inadequate procedures, lack of source retrieval training

Root Cause

- Lack of mgmt. commitment to safety
- Lack of adequate regulatory oversight*

* Licensee had been inspected less than 6 months before the incident; only violation noted: late leak test; a competent inspection would have identified their problems.

1995 Incident

Lesson Learned

- Even if an allegation sounds unbelievable, keep an open mind, because the unbelievable can happen
- The worker least likely to lie is always the asst. rad.
- Radiographers need to be held responsible for their actions
- Regulators need to be properly trained to conduct investigations

Final Thoughts

When we talk about accidents, are they really accidents?

Industrial Radiography Incident Case Histories

Questions?