

# Radiological Assessment of General Steel Industries (GSI)—Granite City, Illinois

Robert Anigstein

S. Cohen & Associates  
1608 Spring Hill Road  
Suite 400  
Vienna, Virginia 22182

June 20, 2012

## HISTORY OF SITE OPERATIONS

- 1940: General Steel begins casting tank armor for U.S. Army
- U.S. Army Corp of Engineers builds betatron facilities at two General Steel foundries:
  - November 1951: Eddystone, PA
  - January 1952: Granite City, IL
- ca. 1953: Mallinckrodt Chemical Works (MCW), St. Louis, under AEC contract, starts shipping uranium to General Steel-Granite City for betatron radiography
- January 1, 1953: Start of covered operations under EEOICPA
- Late 1963: Eddystone foundry shuts down, 2nd betatron moved to Granite City plant
- June 30, 1966: End date of last MCW purchase order—beginning of residual period
- 1989–1993: FUSRAP surveys of betatron buildings—contamination found only in Old Betatron Building
- 1993: Cleanup of Old Betatron Building completed—end of residual period



Aerial View of General Steel Castings Division in Granite City



Enlarged Aerial View Showing Two Betatron Buildings



Aerial View of New Betatron Building



Betatron Radiography of the Axle of a Power Shovel Cast at GSI

## SOURCES OF RADIATION EXPOSURE AT GSI

- External exposure to direct penetrating radiation (photons) from betatron operations
  - Stray radiation during betatron operation
  - Delayed radiation from activated metals
- External exposure to sealed radiography sources
  - $^{226}\text{Ra}$ —2 sources, 500 mCi ea: –May 1962
  - $^{60}\text{Co}$ —260 & 280 mCi (initial activities): May 1962–
- External exposure of skin to non-penetrating (beta) radiation
  - Natural uranium and photoactivated uranium isotopes
  - Activated steel
- Internal exposure
  - Intakes of uranium oxide
  - Intakes of activated metal dust

# BOUNDING EXTERNAL EXPOSURE SCENARIOS, APPLIED TO ALL WORKERS

## Annual Exposure to Penetrating (Photon) Radiation

| Years     | Bounding scenario         | Dose/exposure       |
|-----------|---------------------------|---------------------|
| 1953–1954 | Radiographer using Ra-226 | 15 rem <sup>†</sup> |
| 1955–1962 |                           | 12 rem <sup>†</sup> |
| 1963–1966 | Layout man                | 9.2 R <sup>‡</sup>  |

<sup>†</sup> A.E.C. annual occupational dose limits

<sup>‡</sup> MCNPX simulations

## Bounding Scenario for Neutron and Beta Exposures Annual Doses to Betatron Operators—(based on MCNPX simulations)

| Year      | Neutron dose<br>(rem) | Beta dose to skin (rads) |            |
|-----------|-----------------------|--------------------------|------------|
|           |                       | Hands & forearms         | Other skin |
| 1953-1957 | 0.48                  | 33.4                     | 6.27       |
| 1958      | 0.48                  | 32.1                     | 6.22       |
| 1959-1960 | 0.48                  | 30.9                     | 6.18       |
| 1961      | 0.48                  | 34.2                     | 6.30       |
| 1962      | 0.48                  | 27.2                     | 6.04       |
| 1963      | 0.47                  | 13.9                     | 5.56       |
| 1964      | 0.46                  | 10.7                     | 5.45       |
| 1965      | 0.46                  | 10.2                     | 5.43       |
| 1966      | 0.23                  | 4.8                      | 2.71       |

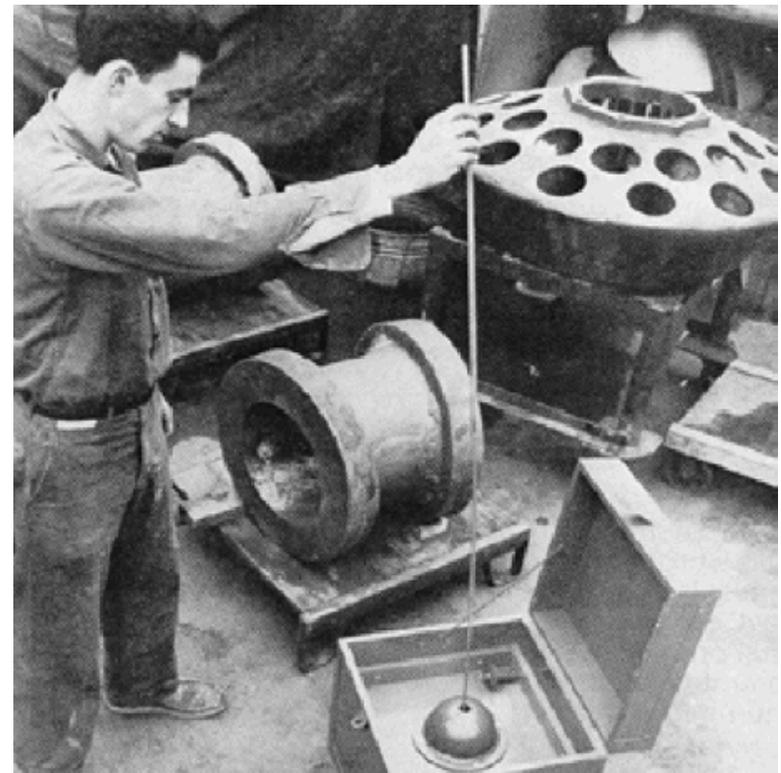
## Radium Used for Radiography at GSI: 1953–1962



Radium Industrial Radiography Source (ca. 1940s)



The "Fishpole" Technique



Source Being Removed from its Shield ("pig")

## Radiographer: 1953-1962

- “During this period [1953–1962] the exposure limits published by the A.E.C. at the applicable time were followed. They were never exceeded and averaged under 25%.” (GSI AEC license application)
- AEC Form 4: Occupational External Exposure History of GSI worker
  - 18 quarters (July 1, 1957–December 31, 1961)
  - 9.1 rem total, ~2 rem/y
  - Worker performed radiography on weekends
    - 1–2 shifts, 80%–90% of the time
    - 40–90 shifts/y: 22–50 mrem/shift
  - Extrapolate dose to full-time radiographer, 65 h/wk: 9–20 rem/y
  - Worker testified he wore film badge while performing radiography
- MCNPX and exposure rate analysis, based on worker's account of radiographic practices: ~10 R/y

## Photos Suggest Film Badges Used as Early as 1953

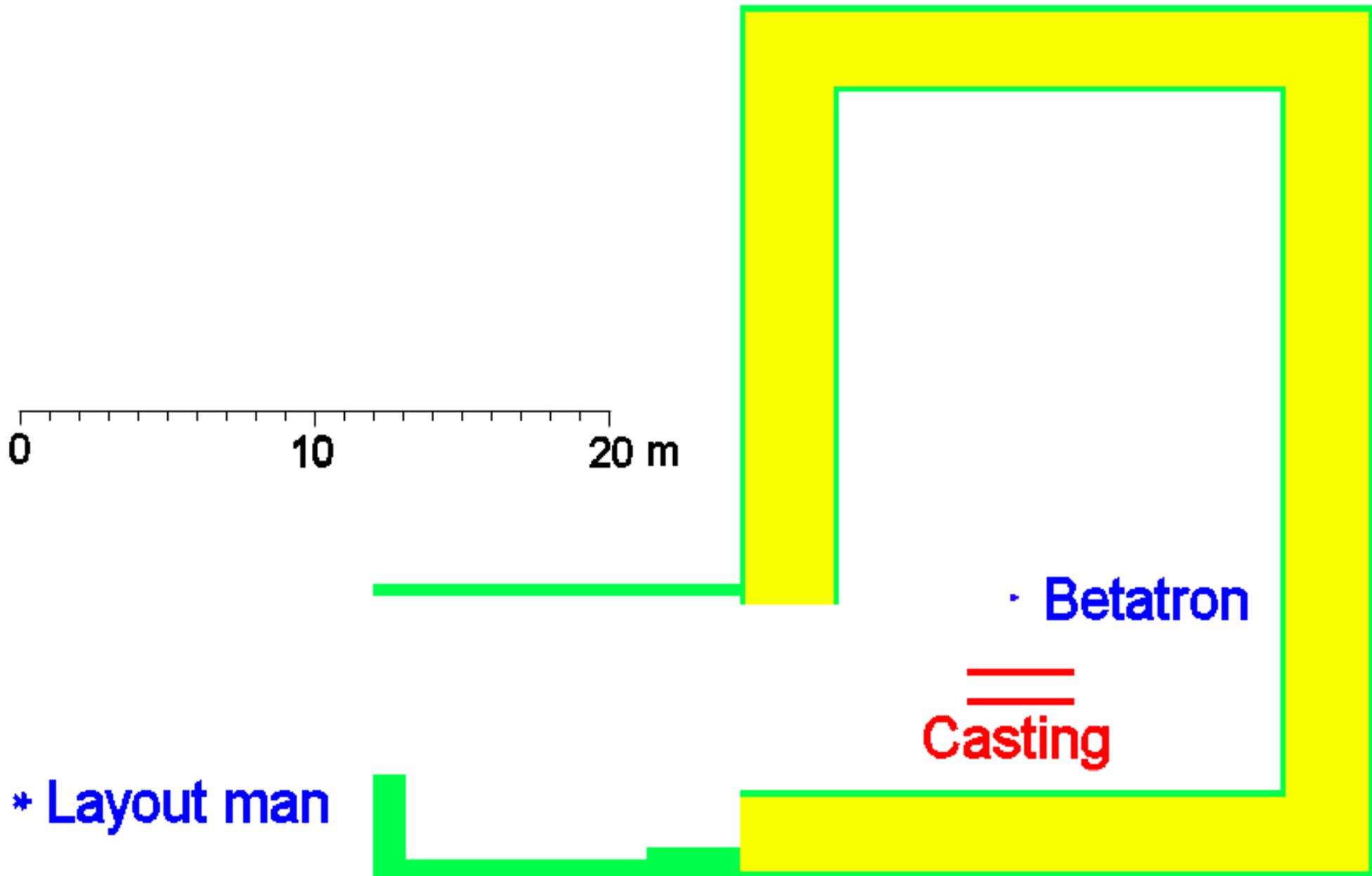


William Greer at the Control Board in the Betatron Building (GSI magazine)



Tracerlab Film Badge (late 1940s, 1950s)





\* Layout man

MCNPX Model of Exposure Geometry of Layout Man

## INTERNAL EXPOSURES

- Inhalation of fission and activation products in uranium dust during 24 h post radiography
  - Dose from natural uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ) = 20 mrem per mg inhaled
  - Dose from fission and activation products =  $9 \times 10^{-5}$  mrem per mg inhaled
  - Conclusion: additional dose from fission and activation products insignificant
- Inhalation of activation products in steel castings: annual dose = 0.09 mrem (insignificant)
- Inadvertent ingestion doses insignificant compared to inhalation ( $\leq 1\%$ )
- Annual doses from inhalation of natural uranium dust
  - SC&A review of NIOSH calculations of uranium intakes and doses—conclusions:
    - NIOSH correctly implemented model, assuming parameters listed in GSI site profile
    - Some NIOSH parameter values found to be questionable
      - Exposure duration
      - Work practices
      - Resuspension factors
  - NIOSH based uranium dust concentrations during uranium handling operations at GSI on slug production and canning facility described in Battelle-TBD-6000
- SC&A expects to help the Work Group review the appropriateness of the use of the TBD-6000 model of a uranium slug facility as a surrogate for the handling of uranium at GSI

## EXPOSURES DURING RESIDUAL PERIOD

- SC&A reviewed NIOSH model of internal doses during residual period—conclusion:
  - Consistent with model of uranium intakes during operational period
  - Used questionable parameter values
- SC&A reviewed external exposure during residual period:
  - Concur with NIOSH assessment