

# The MSU Cyclotron Lab's Own Hidden Figure: Prof. Thelma Irene Arnette and "The Bomb"

Mary  
Ruth  
Arnette  
Age: 26



Thelma  
Irene  
Arnette  
Age: 20

University of Tennessee, Knoxville (Yearbook) "The Volunteer" 1941

Jaideep Taggart Singh (he/him/his)

Michigan State U./FRIB/NSCL

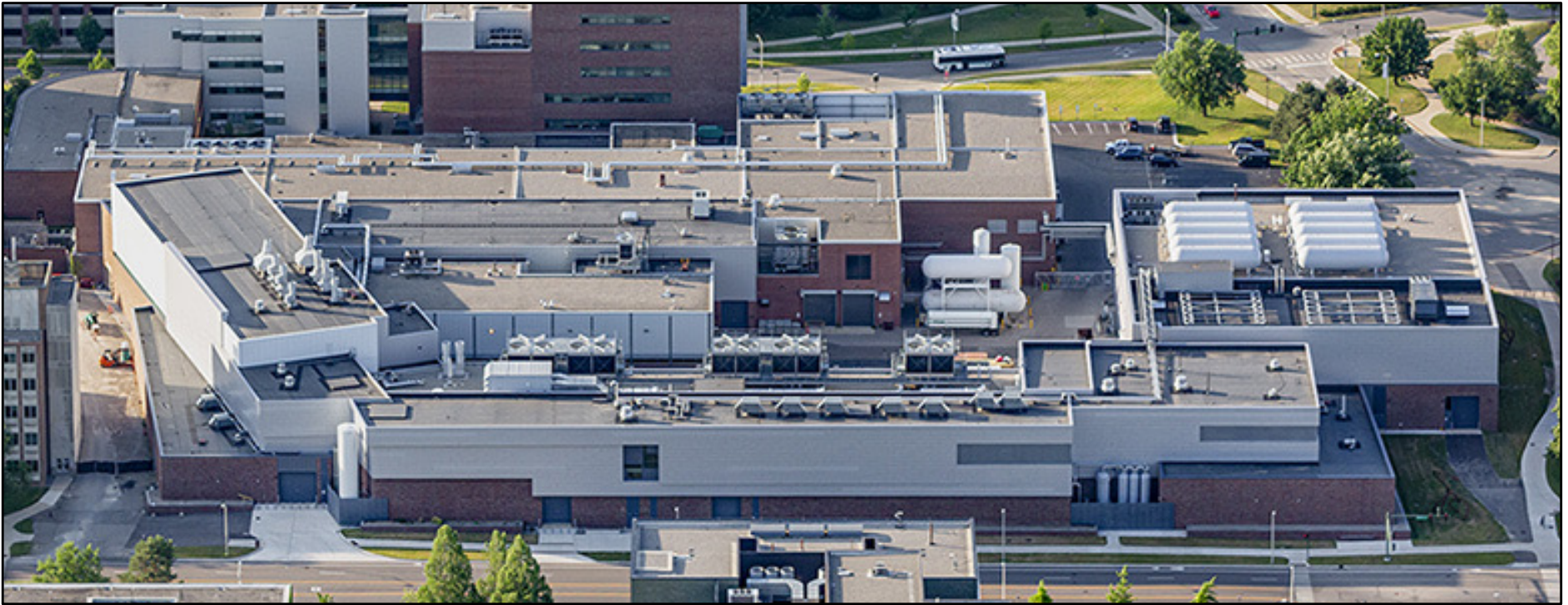
11:00-12:00 (EST) October 21, 2021 (Hybrid)

<https://msu.zoom.us/j/91227314695> (research)

FRIB/NSCL Research Discussion



# The Lab Today: Facility for Rare Isotope Beams [TIA: 100]



- Superconducting linear accelerator facility costing over \$700 million
- 627 Staff, students, & faculty as of 2021-10-19 (Melissa Garza, FRIB HR)
- Over 1500 scientific users from 30 countries worldwide
- Will double the known number of isotopes and enable cutting edge rare isotope science with first experiments expected in early 2022!
- Funded by U.S. Department of Energy

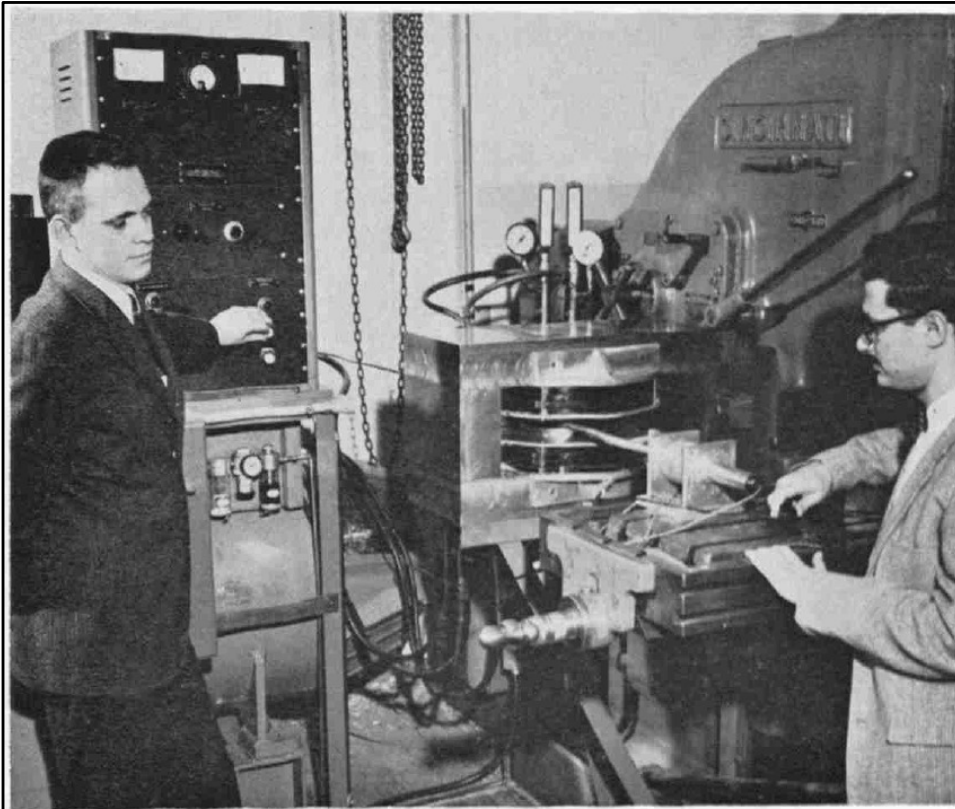
# The Lab 63 Years Ago: The MSU Cyclotron Project [37]

Proposal for a  
**Nuclear Research Facility**  
in the Medium Energy  
(50 Mev) Range Utilizing  
a Variable Energy  
Multi-Particle Cyclotron

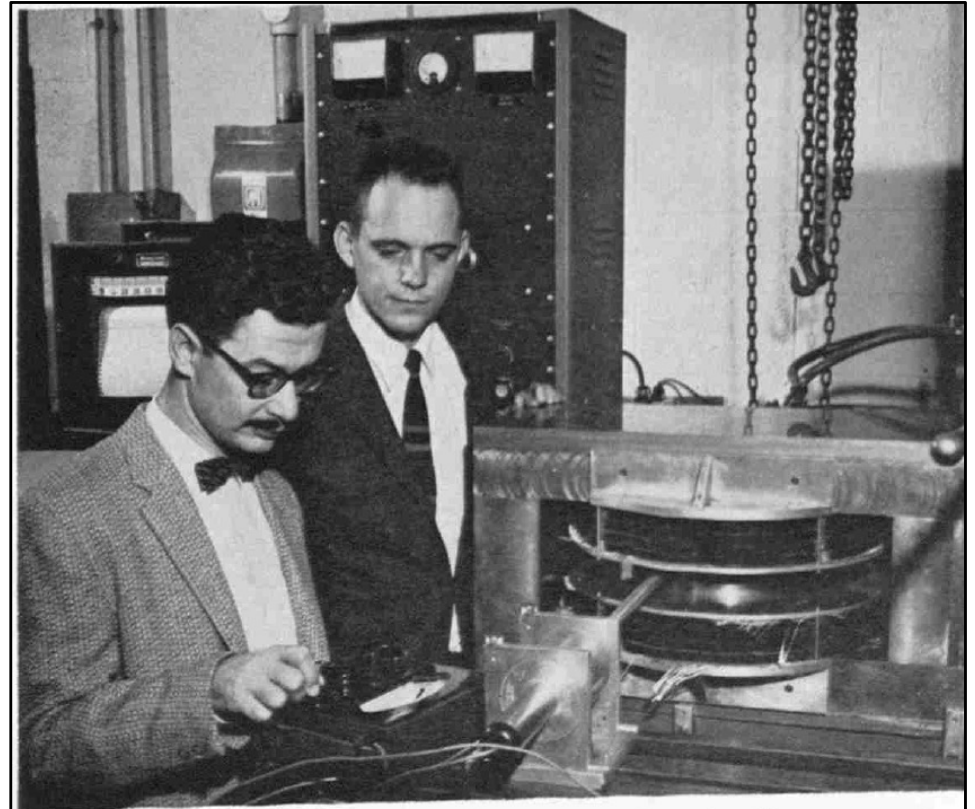
- Room temperature cyclotron facility costing over \$10 million (adjusted)
- 1 Staff, students, & faculty as of 1958-11 (Prof. Henry Blosser)
- No users lined up yet – internal or external
- Research with protons and stable heavy ions planned for 1962
- Unfunded proposal submitted to the U.S. Atomic Energy Commission (precursor to the U.S. Department of Energy)

# The Founders: Profs. Henry Blosser & Morton Gordon

## March 1961 [40]



*Dr. Henry G. Blosser (left) and Dr. Morton M. Gordon are shown with a 1/16th scale model of the magnet which will be used in the new type cyclotron. The model is mounted on a milling machine, which permits accurate movement and positioning of the probe.*



*A close-up view of the model magnet and probe. By inserting probes between the magnet's pole faces, the magnetic field may be measured at various points. This data will show how the atomic particles will move in the completed cyclotron.*

**Spartan Engineer, Volume 14, No. 3, p. 21 (March 1961)**

# The Third Person Hired: A Computer Programmer [38]

pleted in about a year. Assisting Drs. Gordon and Blosser are, Miss Arnette, a full time computer programmer, four graduate and three undergraduate students. Calculations

C.D. Church, E.E., Spartan Engineer,  
Volume 14, No. 3, p. 21 (March 1961)

Henry G. Blosser, *The Centennial Review*,  
Vol 25, No. 3 (Summer 1981)

of its day. The facility provided the capability for innovative studies of how cyclotrons work and, using this capability, Professors Blosser, Gordon and Arnette (the latter two also recruited from Oak Ridge) were able to develop a new “extraction” process which, according to the computer, would allow cyclotrons to produce much more precise beams than had previously been available from such accelerators. To set a context for this

1958). Morton M. Gordon, from the University of Florida, joined the cyclotron team on March 18, 1959, and was soon joined by Thelma Arnette. Gordon, who was losing his vision (Gordon 2007), completed the theoretical work, Arnette performed the computational analysis, and Blosser developed the hardware. Eventually this team developed a novel new design of a precision cyclotron.

*The CNS @ MSU 1855-2005* by Clarence Suelter (2008)

*“Up From Nothing”* by Sam Austin (MSU Press 2015)

theoretical research and teaching although he had become blind. Thelma Arnette came from ORNL and specialized in computer programming; this would be her emphasis at MSU. Hugh McManus was

# A Notable Promotion to Assistant Professor of Physics July 1, 1962 [41]

Minutes of the Meeting of the Board of Trustees: June 20, 1962

67. Thelma Arnette, Assistant Professor of Physics and Astronomy at a salary of \$11,300 per year on a 12-month basis effective July 1, 1962. **\$103k (adjusted)**
68. Martin Reiser, Assistant Professor (Res.) of Physics and Astronomy at a salary of \$10,000 per year on a 12-month basis effective September 1, 1962 to August 31, 1964.

- 87 total appointments on June 20, 1962 by MSU BOT
- 65 men – 75%
- 22 women – 25% (3 to 1 male/female ratio)
- male salary = \$9.0k +/- \$3.6k (\$82k +/- \$33k, adjusted)
- female salary = \$7.6k +/- 4.0k (\$69k +/- \$36k, adjusted)
- \$7.6k/\$9.0k = 85 cents to the dollar
- **TIA: 2<sup>nd</sup> highest salary out of 22 women**
- **TIA: 15<sup>th</sup> highest salary out of 87 appointments**

# BS in Education: University of Tennessee, Knoxville June 1, 1942 [21]



- **Phi Kappa Phi** – “an honor society established in 1897 to recognize and encourage superior scholarship without restriction as to area of study, and to promote the “unity and democracy of education””
- **Pi Lambda Theta** – “founded in 1910 for outstanding students who intend to pursue careers in education”
- At least two student trips to **Mexico**
- **Piano** accompanist in several public performances noted in the local newspapers

University of Tennessee, Knoxville (Yearbook) “The Volunteer” 1942

THELMA IRENE ARNETTE . . . . . Knoxville, Tennessee

Education; Phi Kappa Phi; Pi Lambda Theta.

# Home Economics or Education? UTK Seniors in Yearbook – 1942 [21]

Major	Number of Men	Number of Women
Engineering	41	0
Agriculture	31	0
Business Administration	28	11
Liberal Arts	26	25
Law	4	1
Education	2	15
Home Economics	0	87
Total	132	139

University of Tennessee, Knoxville (Yearbook) "The Volunteer" 1942 - Seniors

# Jane Halliburton Greer @ UTK

## An Anecdote from ~1940 [20]

ended up doing. Several years earlier, she had decided to become an engineer. And she had worked hard at Judson College in Alabama to take all the right courses that would allow her to study engineering once she'd transferred back home to attend the University of Tennessee. But come registration day, a university official rudely yanked her out of line where she stood waiting to register for the School of Engineering.

“We don’t matriculate engineering as a major for females,” he told her.

“The Girls of Atomic City” by Denise Kiernan (Simon & Schuster 2013)

# Pearl Harbor

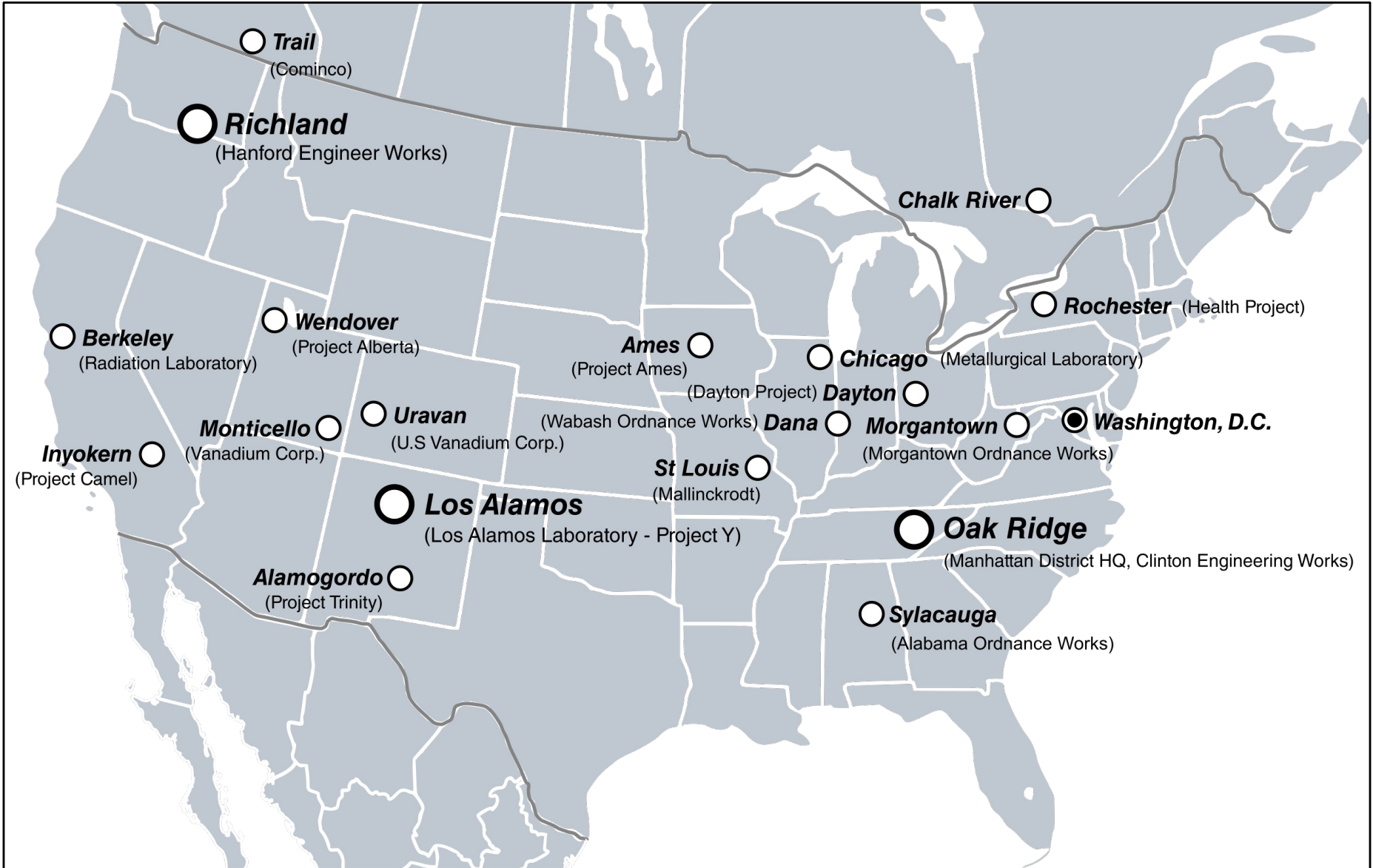
## December 7, 1941 [20]



[https://en.wikipedia.org/w/index.php?title=File:The\\_USS\\_Arizona\\_\(BB-39\)\\_burning\\_after\\_the\\_Japanese\\_attack\\_on\\_Pearl\\_Harbor\\_-\\_NARA\\_195617\\_-\\_Edit.jpg&oldid=808286040](https://en.wikipedia.org/w/index.php?title=File:The_USS_Arizona_(BB-39)_burning_after_the_Japanese_attack_on_Pearl_Harbor_-_NARA_195617_-_Edit.jpg&oldid=808286040)

# The Manhattan Project - Approved by President Roosevelt: June 1942 [21]

[https://en.wikipedia.org/wiki/File:Manhattan\\_Project\\_US\\_Canada\\_Map\\_2.svg](https://en.wikipedia.org/wiki/File:Manhattan_Project_US_Canada_Map_2.svg)

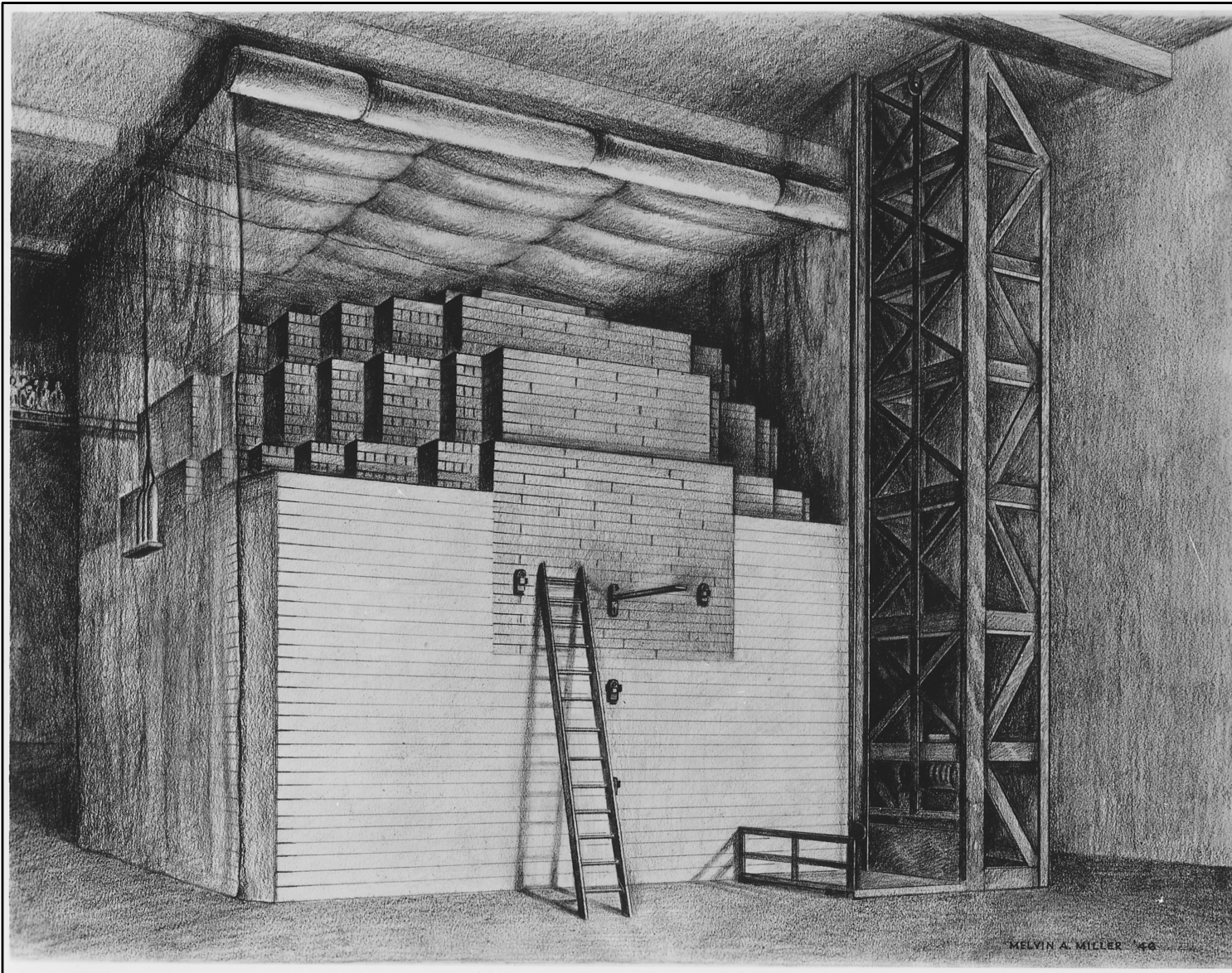




# CP1 @ Chicago: 1st Nuclear Reactor

## December 2, 1942 [21]

[https://commons.wikimedia.org/wiki/File:Stagg\\_Field\\_reactor.jpg](https://commons.wikimedia.org/wiki/File:Stagg_Field_reactor.jpg)



20 ft tall  
25 ft wide

56 tons of  
Uranium

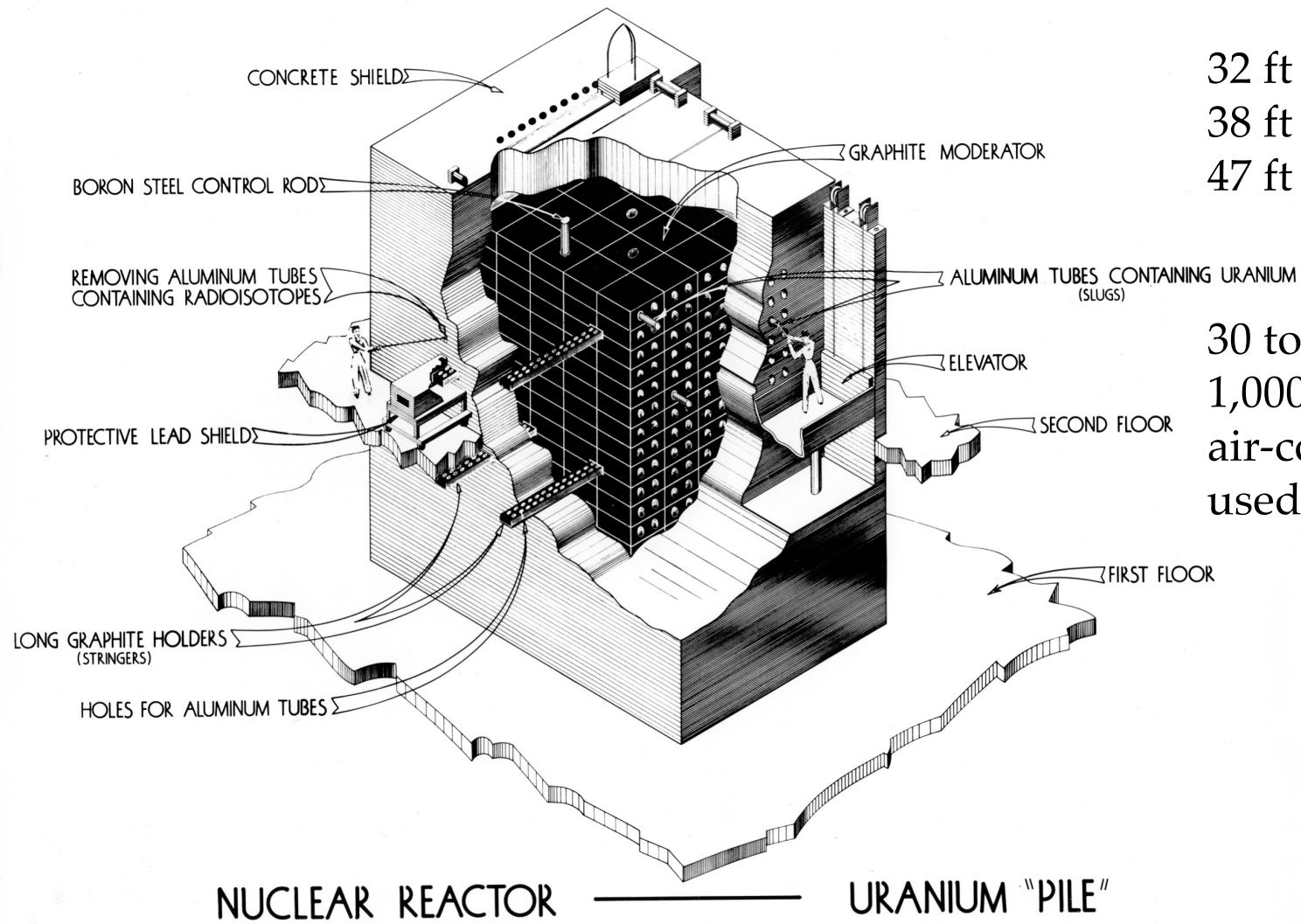
0.5 Watts

# X10 @ Clinton: 2nd Nuclear Reactor

## November 4, 1943 [22]

[https://commons.wikimedia.org/wiki/File:Nuclear\\_Reactor\\_Uranium\\_Pile\\_\(30502443888\).jpg](https://commons.wikimedia.org/wiki/File:Nuclear_Reactor_Uranium_Pile_(30502443888).jpg)

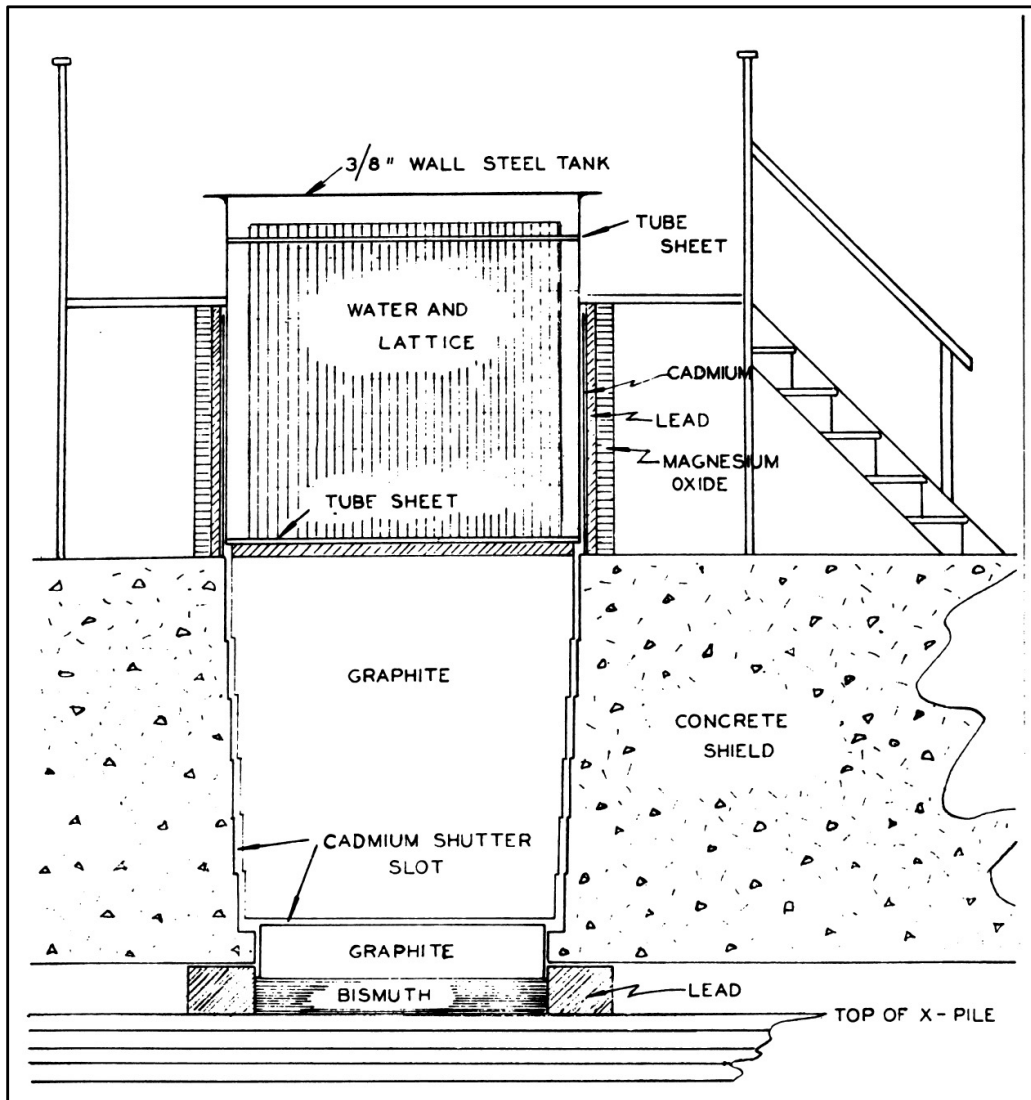
Courtesy of Oak Ridge National Laboratory, U.S. Dept. of Energy



32 ft high  
38 ft wide  
47 ft deep

30 tons of uranium  
1,000,000 Watts  
air-cooled  
used to make  $^{239}\text{Pu}$

# The Water Lattice Experiments June-October 1944 [23]



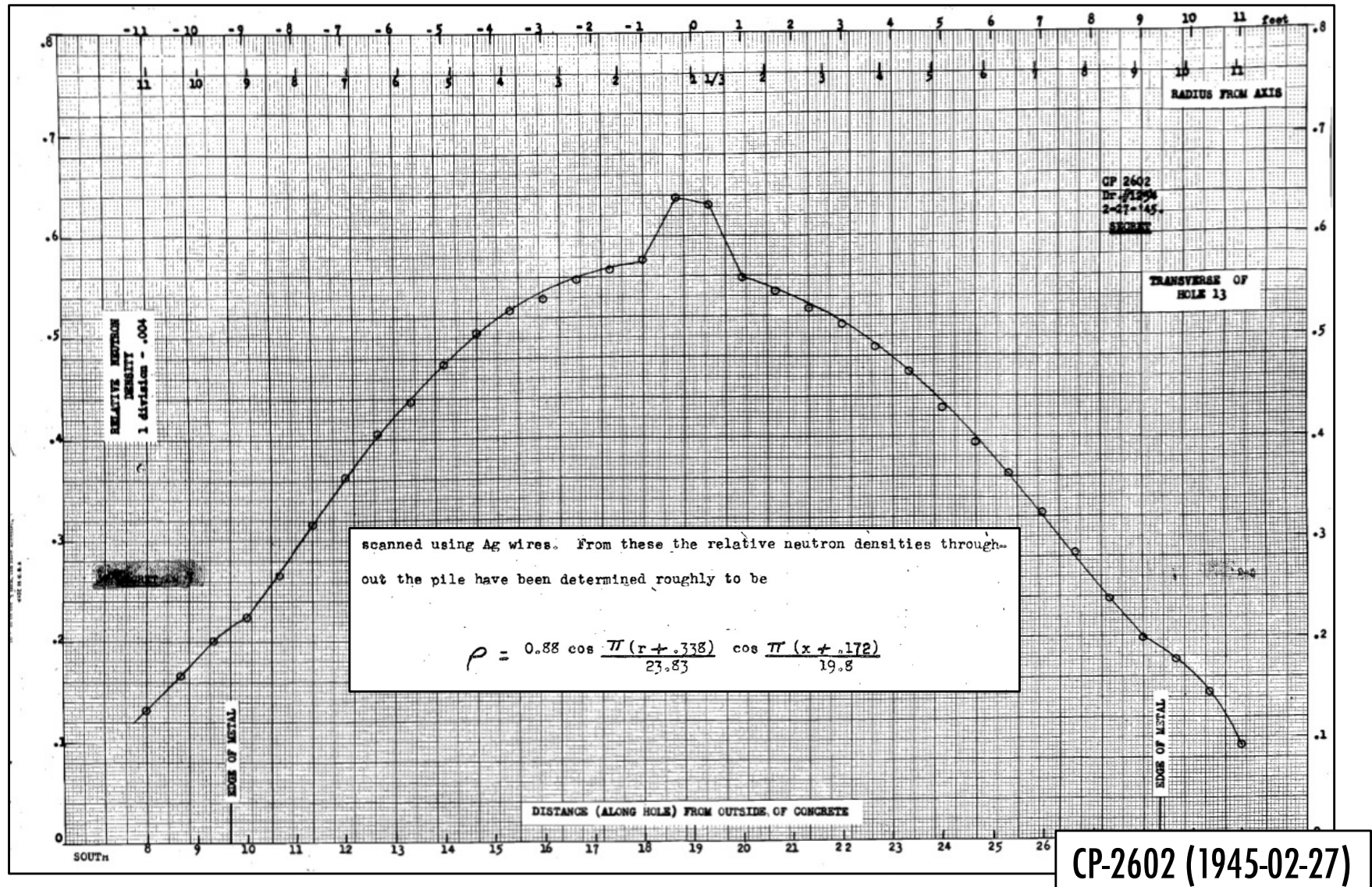
- These experiments showed that light water (normal water) was a good enough moderator for a nuclear reactor using low enriched Uranium.
- This observation formed the basis of **Pressurized Water Reactors** that currently produce **2/3 of all the nuclear energy** in the world.

CP-2048 (1944-10-03)

A.H. Snell, ORNL Review Vol 9 #4 Fall 1976

# Neutron Distribution in the Clinton Pile

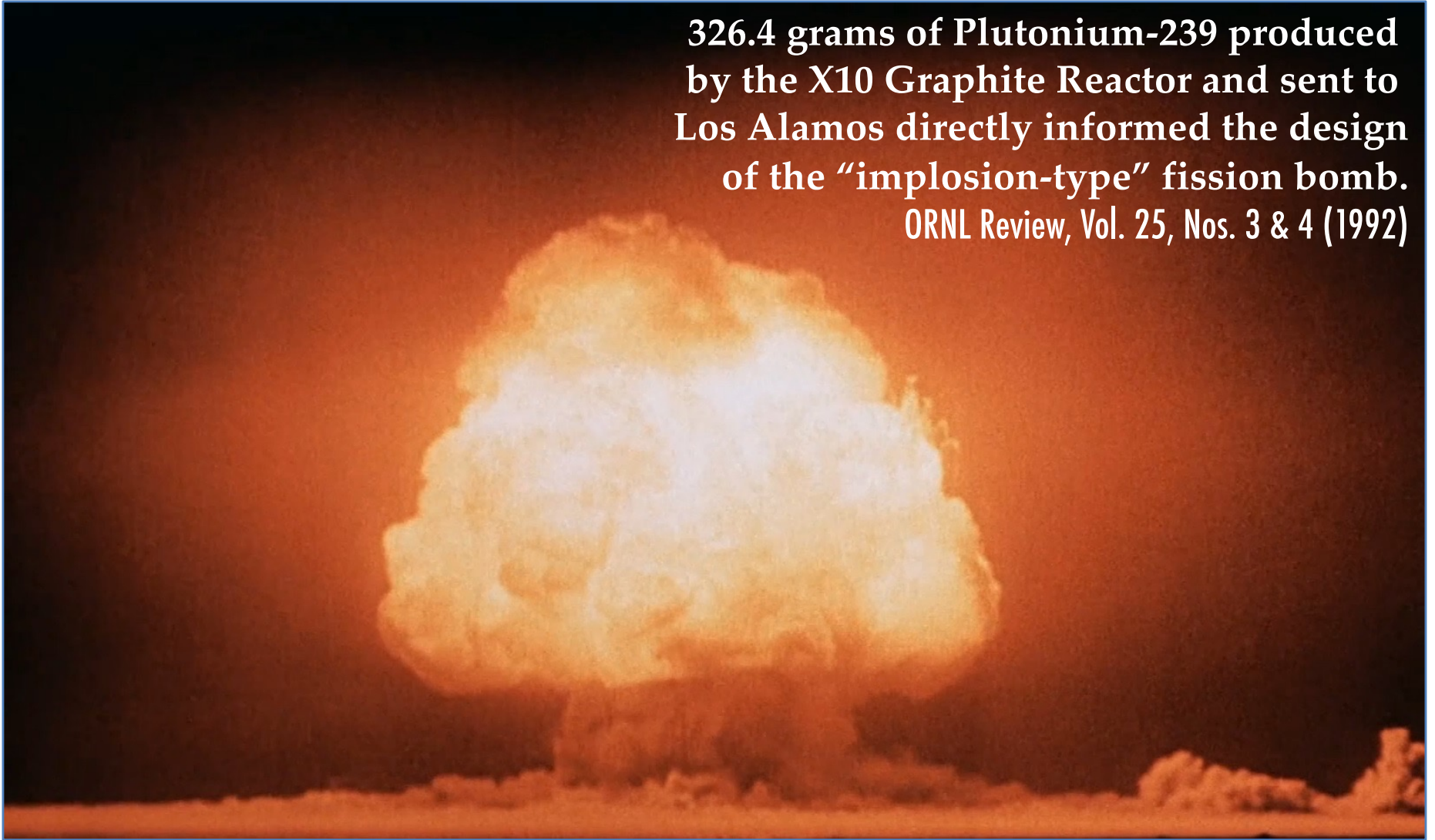
## February 1945 [24]



# Gadget (Trinity, NM) & Fat Man (Nagasaki) July 16 & August 9, 1945 [24]

[https://commons.wikimedia.org/wiki/File:Trinity\\_Detonation\\_T%26B.jpg](https://commons.wikimedia.org/wiki/File:Trinity_Detonation_T%26B.jpg)

326.4 grams of Plutonium-239 produced by the X10 Graphite Reactor and sent to Los Alamos directly informed the design of the “implosion-type” fission bomb.  
ORNL Review, Vol. 25, Nos. 3 & 4 (1992)



# Will Drums Filled With Enriched Uranium Hexafluoride Go Critical And Explode? - November 1945 [24]

We had been asked to make some measurements which would aid in arriving at an indication of the safety against criticality of certain vessels, called "Product Drums", containing enriched uranium hexafluoride in fairly large amounts. Theoretical estimates had been made by E. Teller and others<sup>1</sup>, which had been used (together with a generous safety factor) to set limits for the enrichment which could be tolerated in these vessels, but an accurate prediction was difficult to make particularly with regard to the influence of hydrogenous reflectors and the efficacy of cadmium coating on the drums. In view of the importance of the question from the engineering standpoint, it was desired to obtain measurements which would supplement the estimates and add new information about the reflection from surroundings.

MonP-47 (1945-11-30)

# A Slide Rule for Neutron Activation Calculations

## April 1946 [25]

The calculation of the strength of radioactive samples after neutron irradiation, followed perhaps by a period of decay, has become so much a matter of routine that it seems that a quick aid to calculation might be a time saver to those engaged in this type of work. The accompanying figures show how a slide rule could be constructed which would give answers to these calculations, including in most cases the correct power of 10, to an accuracy commensurate with the precision of most cross section and flux values. The expression to be evaluated is in general the product

$$nv \sigma M/A \times 6.06 \times 10^{23} (1 - e^{-\lambda t_1}) e^{-\lambda t_2}$$

in which  $nv$  is the neutron flux,  $\sigma$  the activation cross section,  $M$  the mass of the sample in grams,  $A$  its atomic weight,  $\lambda$  the decay constant of the induced activity,  $t_1$  the irradiation time and  $t_2$  the decay time subsequent to irradiation. This can be modified and condensed to the form

$$nv \Sigma M (1 - e^{-0.693 t_1'}) e^{-0.693 t_2'}$$

where  $\Sigma$  is the activation cross section per gram of normal element, and can be read from a table on the back of the slide rule for any of the one hundred and fifty or so activities usually encountered;  $t_1'$  and  $t_2'$  are respectively the activation and decay times, now expressed in units of the half-life of the activity concerned.

MDDC-734 (1946-04-01)

# Production of 88 mg of Carbon-14 for Use as a Radioactive Tracer: April 1947 [26]

## Carbon 14 Production From Ammonium Nitrate Solution in the Chain-reacting Pile<sup>1</sup>

L. D. NORRIS and ARTHUR H. SNELL<sup>2</sup>

*Clinton Laboratories, Oak Ridge, Tennessee*

<sup>1</sup> Work done under the auspices of the Manhattan District.

<sup>2</sup> The assistance of E. P. Meiners, Jr., Miss T. I. Arnette, and F. Schuler is gratefully acknowledged. We consider ourselves honored to have been associated with the late Dr. Louis Slotin in the early phases of the work.

“A great deal of credit is due **Miss Thelma Arnette** and Mrs. Ida Coveyou for assistance in the **preparation and counting of samples.**”

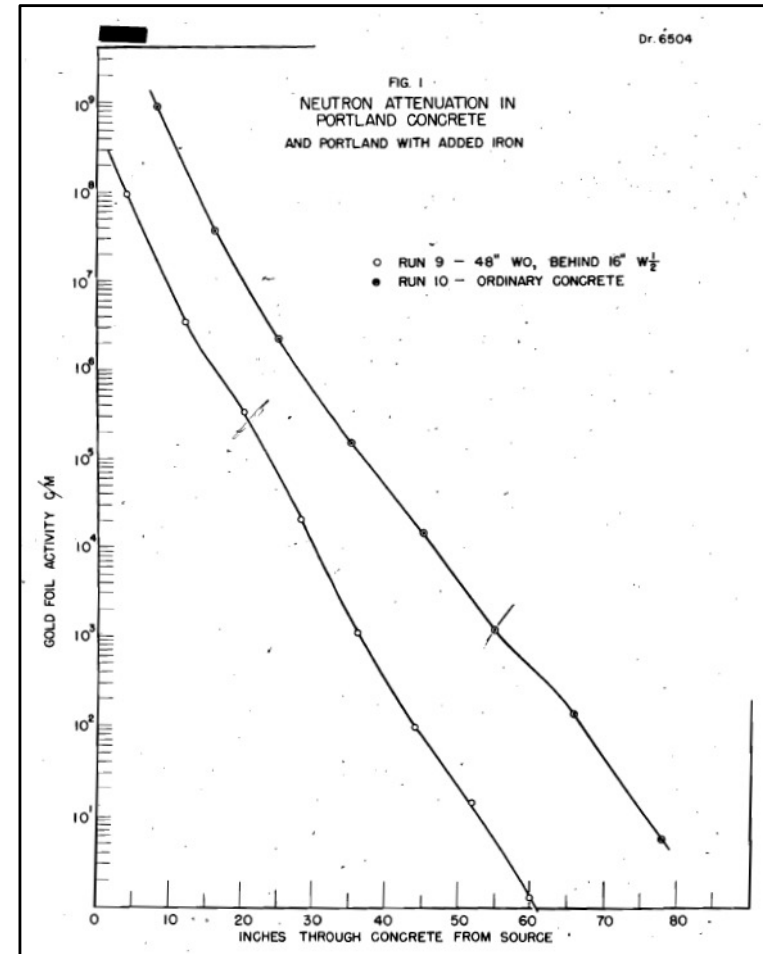
Science, 7 Mar 1947, Vol 105, Issue 2723, pp. 265-267  
ORNL-388 (1949-10-19)

# First Tests of Shielding for Nuclear Reactors

## November 1947 [26]



Everitt Blizard, an expert on radiation shielding.



Mon-P-437 (1947-11)

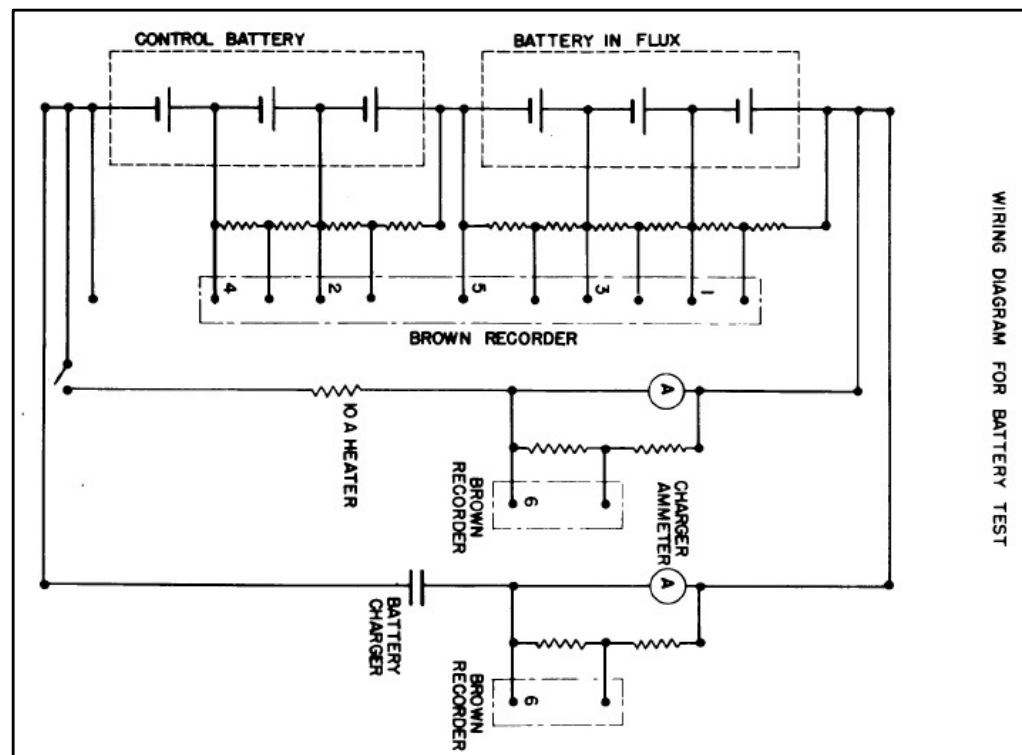
ORNL-209 (1949-03-16)

ORNL Review, Vol. 25, Nos. 3 & 4 (1992)

# Lead Storage Battery Radiation Damage Tests

## May 1948 [27]

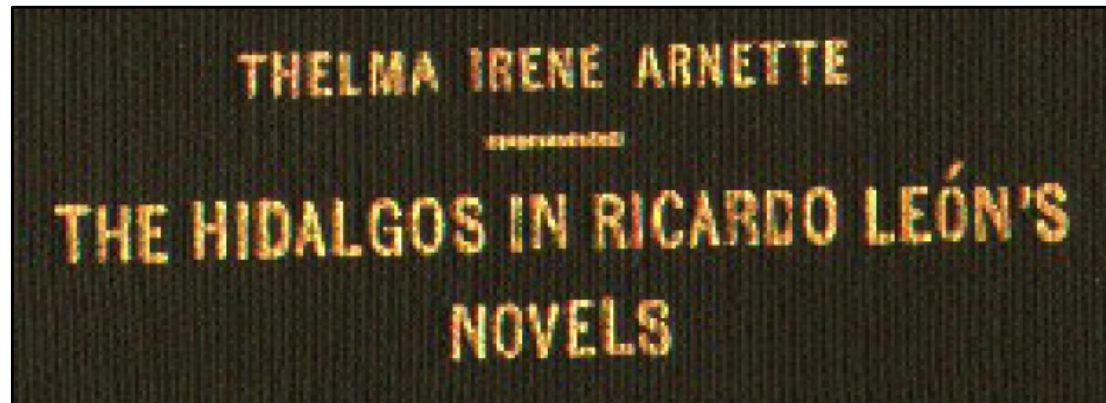
A lead-acid storage battery was placed at the inner edge of the X-10 shield in a neutron flux of  $10^{10}$ (nv) and a gamma flux of 8-10,000 r/hr. After being left there for two weeks, the battery was taken out. Comparisons were made of operating characteristics before, during, and after exposure. No trends indicating radiation damage were apparent in the data obtained.



ORNL-106 (1948-11-16)

# Masters of Arts in Spanish, UTK

## August 1948 [27]



DEFINITION OF HIDALGO

All types were not equally looked upon, even though an

According to the Velázquez Spanish Dictionary, an

hidalgo now means "a noble man or woman, a person of noble

descent; one who is enobled." Another authority defines

it thus: "una persona que por su sangre es de una clase

noble y distinguida."<sup>1</sup> Consequently, we gather that the

term is today almost synonymous with nobleman or aristocrat.

# An Early Study of Zirconium as a Reactor Material

## July 1950 [29]

Measurements have been made of the resonance integral for zirconium (~1% hafnium) and the slowing down distribution in zirconium (~1% hafnium) light water mixture containing 20.4% zirconium by volume. The resonance integral was measured in the energy range from Ra- $\alpha$ -Be neutrons to indium resonance. The slowing down distribution was measured to indium resonance using a fission source of neutrons. The value of the resonance integral is 23.9 cm<sup>2</sup>, the major part of which is probably due to the hafnium impurity. The mean square slowing down length  $\bar{r}^2 = 213.97$  cm<sup>2</sup> and  $\tau = 35.7$  cm<sup>2</sup>.

Zirconium is an important metal for reactors since it is “transparent” to neutrons. However, it has a hafnium impurity of 1% which is a strong neutron absorber and therefore needs to be removed to make reactor grade zirconium.

ORNL-641 (1950-07-27)

# The Total Cross Section of Holmium

## March 1950 [29]

### THE TOTAL CROSS SECTION OF HOLMIUM

T. E. Stephenson and T. Arnette

PHYSICAL REVIEW

VOLUME 87, NUMBER 3

AUGUST 1, 1952

Slow Neutron Crystal Spectrometry: The Total Cross Sections of Co, Er, Hf, Ni<sup>58</sup>, Ni<sup>60</sup>,  
Ho, and Fission Sm†

S. BERNSTEIN, L. B. BORST,\* C. P. STANFORD, T. E. STEPHENSON, AND J. B. DIAL  
*Oak Ridge National Laboratory, Oak Ridge, Tennessee*

(Received April 11, 1952)

water content. Miss T. Arnette assisted in taking much  
of the data. We are grateful to Dr. E. O. Wollan and

ORNL-694 (1950-06-13)  
ORNL-782 (1950-10-04)  
PR V87 N3 p. 487 (1952)

# Thermal Neutron Capture Cross Sections December 1950 [30]

## 7. STABLE-ISOTOPE CROSS SECTIONS

H. Pomerance and T. Arnette

PHYSICAL REVIEW

VOLUME 88, NUMBER 2

OCTOBER 15, 1952

### Thermal Neutron Capture Cross Sections

H. POMERANCE

*Oak Ridge National Laboratory, Oak Ridge, Tennessee*

(Received June 11, 1952)

The thermal neutron capture cross sections of more than one hundred isotopes, including all the isotopes of 24 elements, plus several others, have been measured with the Oak Ridge National Laboratory pile oscillator.

The author is indebted to Miss Thelma Arnette for her aid in this work.

ORNL-940 (1951-03-15)  
ORNL-1164 (1952-04-14)  
ORNL-1289 (1952-03-20)  
PR V88 N2 p. 412 (1952)

# Monoenergetic Thermal Neutrons from a Crystal Spectrometer - September 1951 [30]

## 7. A CRYSTAL SPECTROMETER AS A SOURCE OF MONOENERGETIC THERMAL NEUTRONS

R. G. Allen      T. E. Stephenson  
T. I. Arnette

PHYSICAL REVIEW

VOLUME 96, NUMBER 5

DECEMBER 1, 1954

### Slow Neutron Cross Sections of Gold, Silver, Indium, Nickel, and Nickel Oxide

R. G. ALLEN,\* T. E. STEPHENSON, C. P. STANFORD, AND SEYMOUR BERNSTEIN  
*Oak Ridge National Laboratory, Oak Ridge, Tennessee*

(Received March 1, 1954)

discussions on neutron scattering. We are indebted to Miss T. Arnette for help in taking the data, to R. M.

ORNL-1164 (1952-04-14)  
PR V96 N5 p. 1297 (1954)

# Experimentalists vs. Theorists!

## July 1952 [31]

editors relented—the term “pile” stands. The restandardization also brought out the differing attitudes of the experimentalist and the theorist. Thelma Arnette found a slope of the line on her graph of 3.34; the theorist found a slope from his least-squares fit of 3.35. He complimented her on coming so close to his computed value. She replied, “Of course. That was the only line I could draw through those points.”

ORNL-1340 (1952-07-30)  
AECD-3590 (1952-10-17)  
ORNL Review, Vol 8 No 3 (Summer 1975)

# Reactor Power Calibration for Livermore

## June 1954 [33]

LRL-149

POWER CALIBRATION OF THE WATER  
BOILER NUCLEAR REACTOR

The authors also wish to thank Dr. Thelma I. Arnette of Oak Ridge National Laboratory for exposing the CR&D Co. gold foils in the Standard Graphite Pile.

6. Private communication from Dr. Thelma Arnette, Oak Ridge, National Laboratory.

LRL-149 (1954-06)

# An Attempt to Measure the Neutrino Mass

## July 1955 [34]

PHYSICAL REVIEW

VOLUME 100, NUMBER 5

DECEMBER 1, 1955

### Spectrometry of the Neutrino Recoils of Argon-37

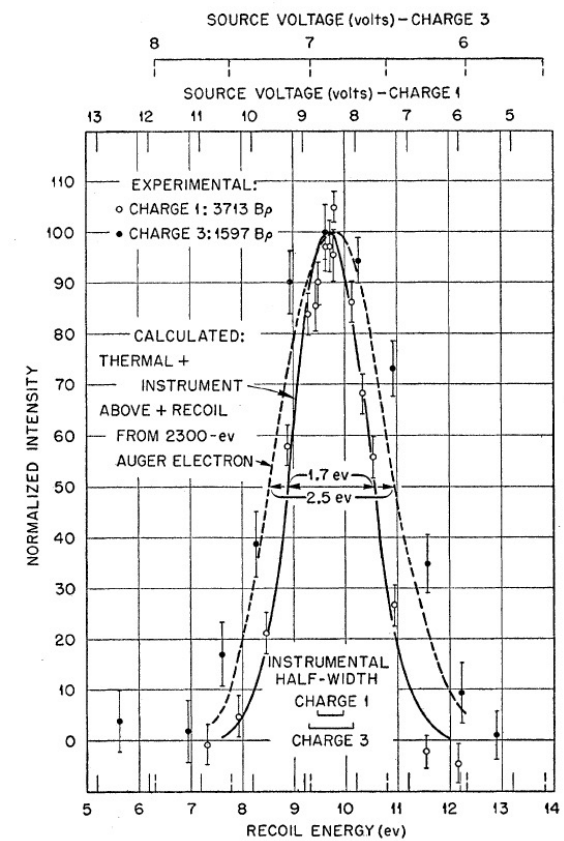
ARTHUR H. SNELL AND FRANCES PLEASANTON  
*Oak Ridge National Laboratory, Oak Ridge, Tennessee*

(Received July 28, 1955)

The theoretical line shapes have “folded into” them a small contribution (about 3%) from the appropriate finite instrumental resolution. We are indebted to Dr. J. M. Jauch for calculating the theoretical peak shapes, and to Miss Thelma Arnette who, under the guidance of Dr. T. A. Welton, was kind enough to compute the “folding in” effect.

They measured the neutrino rest mass upper limit of 5 keV from a line-shape analysis in an experiment ahead of its time.

PR V100 N5 p. 1396 (1955)



# Neutron Diffraction From Materials

## January 1957 [36]

*J. Phys. Chem. Solids.* Pergamon Press 1957. Vol. 2. pp. 289–300.

### THE MAGNETIC STRUCTURE OF $Mn_2Sb$

M. K. WILKINSON, N. S. GINGRICH,\* and C. G. SHULL†

Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Received 25 January 1957)

## 1994 Nobel Prize in Physics



Photo from the Nobel Foundation archive.

Clifford G. Shull  
The Nobel Prize in Physics 1994

Born: 23 September 1915, Pittsburgh, PA, USA

Died: 31 March 2001, Medford, MA, USA

Affiliation at the time of the award: Massachusetts Institute of Technology (MIT), Cambridge, MA, USA

Prize motivation: "for the development of the neutron diffraction technique."

Prize share: 1/2

*Acknowledgements*—The authors wish to express their appreciation to H. A. GERSCH, G. T. TRAMMELL, and L. HEATON for many interesting discussions of various phases of this investigation. They are also indebted to L. A. RAYBURN and Miss THELMA ARNETTE for assistance in collecting and analyzing much of the experimental data.

<https://www.nobelprize.org/prizes/physics/1994/shull/facts/>

# Studying the Properties of the "Fission Poison" Xe-135

## April 1959 [38]

PHYSICAL REVIEW

VOLUME 102, NUMBER 3

MAY 1, 1956

### Neutron Cross Section of Xenon-135 as a Function of Energy

S. BERNSTEIN, M. M. SHAPIRO,\* C. P. STANFORD,† T. E. STEPHENSON,‡ AND J. B. DIAL, *Physics Department,  
Oak Ridge National Laboratory, Oak Ridge, Tennessee*

AND

S. FREED,§ G. W. PARKER, A. R. BROSI, G. M. HEBERT,\* AND T. W. DEWITT,|| *Chemistry Department,  
Oak Ridge National Laboratory, Oak Ridge, Tennessee*

(Received June 27, 1955; revised manuscript received January 26, 1956)

PHYSICAL REVIEW

VOLUME 115, NUMBER 6

SEPTEMBER 15, 1959

### Total Neutron Cross Section of Xe<sup>135</sup> as a Function of Energy\*

E. C. SMITH,‡ G. S. PAWLICKI,§ P. E. F. THURLOW,|| G. W. PARKER, W. J. MARTIN, G. E. CREEK,  
P. M. LANTZ, AND S. BERNSTEIN,† *Oak Ridge National Laboratory, Oak Ridge, Tennessee*

(Received April 10, 1959)

#### ACKNOWLEDGMENTS

The computations of the least-squares fit to the Breit-Wigner equation were programmed for the ORACLE and carried through by N. M. Dismuke. Thelma Arnette assisted in obtaining the data and the programming. F. J. Muckenthaler and F. N. Watson assisted in taking the measurements. We are indebted to Dr. J. A. Harvey and Dr. L. Dresner for valuable discussion.

#### ACKNOWLEDGMENTS

We are much indebted to A. D. Bogard and H. Zeldes for aid in the radioactive assay of the samples, and to J. A. Ghormley for aid in the development of chemical procedures. In the processing we had the cooperation of C. E. Creek and J. Ruch. We are greatly indebted to the following people for their assistance during the very intense period of the taking of the data during the lifetime of the samples: T. Arnette, J. M. Cassidy, R. L. Clark, T. E. Cole, M. Davis, N. Kropoff, N. F. Lansing, R. H. Lewis, C. D. Moak, F. Pleasonton, J. Ruch, C. G. Shull, and D. I. Weinberg. We are grateful also for the help of R. Coveyou, R. Crook, A. Forbes, A. Householder, M. K. Hullings, K. Martin, L. Noderer, and N. M. Dismuke in the statistical analysis of the data.

# Transformations Between Lab Coordinate and Center of Mass Coordinates - April 1959 [38]

## TABLES FOR THE TRANSFORMATION BETWEEN THE LABORATORY AND CENTER-OF-MASS COORDINATE SYSTEMS AND FOR THE CALCULATION OF THE ENERGIES OF REACTION PRODUCTS

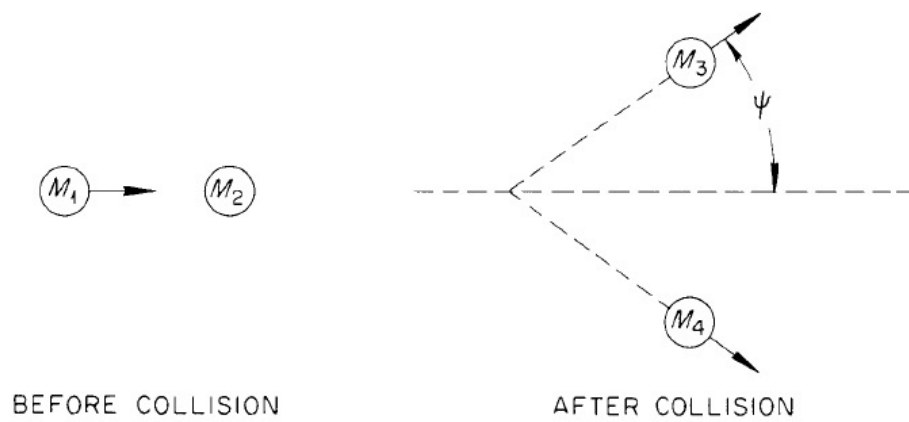
Jerry B. Marion\*

T. I. Arnette

H. C. Owens

From a theoretical standpoint the most meaningful representation of angular distribution data is in the center-of-mass coordinate system. The following tables have been prepared to facilitate the transformation of such data between the laboratory and center-of-mass systems. In this respect, these tables represent an extension of tables calculated previously<sup>1</sup> by making available more entries and thus reducing the necessity for interpolation. In addition, an associated table has been included which makes possible the calculation with relative ease of the energy of a nuclear reaction product as a function of the angle of observation in the laboratory system.

A nuclear reaction may be represented in the laboratory system in the following manner:



This technical note was cited near 20 times in PR journals up to 1989!

ORNL-2574 (1959-04-08)

# Programming the ORACLE Computer

## September 1954 [33]

### NUCLEAR STRUCTURE FROM HIGH-ENERGY ELECTRON SCATTERING

G. T. Trammell

The author would like to take this opportunity to acknowledge his debt to Thelma Arnette, who has done all the ORACLE coding that this problem entailed.

### ORBITS IN THE THOMAS CYCLOTRON<sup>1</sup>

D. S. Falk<sup>2</sup>

T. A. Welton

A systematic investigation, by the use of the ORACLE, has been undertaken of orbits in the *high-energy, fixed-frequency cyclotron* of the type suggested by L. H. Thomas and E. M. McMillan.

<sup>1</sup>This problem was coded for the ORACLE by T. Arnette.

ORNL-1798 (1954-11-26)

ORNL-1820 (1955-01-20)

# Cyclotron Studies with Blosser @ ORNL

## September 1956 [35]

### **NONLINEAR ACCELERATOR ORBIT CODES**

T. A. Welton and T. I. Arnette ..... 12

A set of Oracle codes of increasing flexibility and accuracy has been constructed for the purpose of carrying out calculations on linear and nonlinear orbit behavior in accelerators with constant orbital frequency as well as with constant momentum compaction.

### **ANALYTICAL TREATMENT OF ACCELERATION THROUGH RESONANCES**

M. M. Gordon and T. A. Welton ..... 14

Analytical and numerical studies of the phenomena encountered in passage through imperfection resonances have been largely completed.

### **CYCLOTRON MODEL DESIGN STUDY**

T. I. Arnette, H. G. Blosser, H. C. Owens, and G. T. Trammell ..... 15

Oracle calculations pertaining to the design of an electron model for a straight four-sector Thomas type of cyclotron are described.

ORNL-2204 (1957-01-29)

# Annual Meeting of the Association for Computing Machinery June 1958 [37]

## Interpolation Procedure for Closed Curves

T. I. Arnette

Oak Ridge National Laboratory  
Oak Ridge, Tennessee

It seemed desirable to devise a procedure for constructing a smooth, closed curve out of a relatively few calculated points on the curve. Available interpolation procedures either introduce discontinuities in slope at each data point (polynomial) or spurious fluctuations (Fourier series). By the following procedure it is possible, with relatively little calculation and the use of a flexible oscilloscope plotting routine, to produce automatically plotted curves which are easily as artistic as those drawn by a skilled draftsman.

# Blosser's RSI Paper for a New Cyclotron Design July 1958 [37]

## THE REVIEW OF SCIENTIFIC INSTRUMENTS

VOLUME 29, NUMBER 10

OCTOBER, 1958

### Four-Sector Azimuthally Varying Field Cyclotron

H. G. BLOSSER,\* R. E. WORSHAM, C. D. GOODMAN, R. S. LIVINGSTON,  
J. E. MANN, H. M. MOSELEY,† G. T. TRAMMEL, AND T. A. WELTON  
*Oak Ridge National Laboratory,‡ Oak Ridge, Tennessee*

(Received July 14, 1958)

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H. G. BLOSSER *et al.*

the first measurements. The results are shown in Fig. 18 and agree well with calculations.

In summary, the initial operation of the Cyclotron Analogue has been in accurate accordance with the predicted performance which confirms the methods used in the design computations and in the fabrication. From the standpoint of orbit dynamics the feasibility of large proton machines of this type is clearly demonstrated.

#### ACKNOWLEDGMENTS

It is a pleasure to acknowledge the important assistance of T. Arnette, H. Owens, and B. D. Williams in the coding

of the various computations for the computer; of R. G. Reinhardt and E. R. Wells in the mechanical engineering; and of B. P. Foster, A. W. Hanson, G. Hoy, D. L. Lafferty, H. F. Postma, and E. Rodgers in various phases of the planning and design. We are also indebted to the many technical personnel of the Laboratory who participated in the fabrication and assembly of the various components of the Analogue, and to A. H. Snell and A. M. Weinberg for their support and encouragement of the project. A number of discussions with M. M. Gordon and J. A. Martin have been most helpful.

# Studying Cyclotron Orbits with Gordon September 1958 [37]

## AN IBM 704 PROGRAM FOR COMPUTATION OF EQUILIBRIUM ORBIT PROPERTIES IN AVF CYCLOTRONS

M. M. Gordon    T. A. Welton    T. I. Arnette    H. C. Owens

Over the past four years considerable experience has been gained on a succession of Oracle codes for the computation of equilibrium orbit properties in AVF cyclotrons. The increasingly obvious limitations of these codes, combined with the acquisition of an IBM 704 computer at the K-25 plant, recently opened the possibility of a new family of codes of much greater speed and flexibility than are possible on the Oracle. The first code in this family is now complete. For input it requires the quantities  $B$  and  $\partial B / r \partial \theta$ , where  $B$  is the median plane field, stored on magnetic tape at uniform intervals of  $r$  and  $\theta$ .

ORNL-2610 (1959-02-26)

# IBM 704 Code for Cyclotron Orbits

## November 1959 [38]

AN IBM-704 CODE FOR  
DETERMINING EQUILIBRIUM  
ORBITS AND PROPERTIES OF  
SMALL-AMPLITUDE OSCILLATIONS  
IN CYCLOTRON FIELDS

### Abstract

An IBM-704 code for calculating properties of equilibrium orbits and small oscillations in general cyclotron magnetic fields is described in detail. The code is very flexible, accurate, and economical to operate.  
(auth)

### Authors:

[Arnette, T I](#); Owens, H C

### Publication Date:

1959-11-17

### Research Org.:

Oak Ridge National Lab., Tenn.

### OSTI Identifier:

4198701

### Report Number(s):

CF-59-11-2

# Masters of Science, Math, UTK December 1959 [38]

## AN INTERPOLATION METHOD FOR PERIODIC FUNCTIONS

This thesis is the development of a simple interpolation scheme for a periodic function. The interpolated function has continuous value, continuous  $k - 1$  order derivatives, and is free of spurious fluctuations. The coefficients are determined by a simple recursion relation, and a consistency condition must be satisfied to make the end of the curve join smoothly to the beginning.

This interpolation scheme, which has been programmed for a high-speed digital computer and used in connection with the automatic graphical display of the orbit dynamics in accelerators, was suggested by Dr. G. T. Trammell of the Oak Ridge National Laboratory Physics Division.

For their generous help and advice, my deepest gratitude is due to Dr. A. S. Householder, Dr. W. S. Snyder, and Dr. T. A. Welton.

# Thanks For Your Attention! [50]

- Versatile in Experience
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- Many Contributions to Important Work



Michigan State University Archives and Historical Collections

NSCL presents

# Women of the Manhattan Project

An open public lecture by Marquette University professor and author, Ruth Howes, Ph.D.

February 27, 2007  
11:30 a.m. – 12:30 p.m.

Room 1415  
Biomedical & Physical Sciences Building

Light refreshments will be served in Room 1400 before the lecture.

Women made a host of contributions to the Manhattan Project, the United States' massive 1940s effort to build an atomic bomb. Yet for most of the second half of the 20th century, descriptions of such contributions were limited to accounts of women lending their support as clerks, truck drivers, and dutiful spouses.

That changed in 1999 with the publication of *Their Day in the Sun: Women of the Manhattan Project*, co-authored by Ruth Howes, professor and chair of the Physics Department at Marquette University. In an open public lecture, Howes will highlight and extend some of the main themes from her book, notably, that women employed as physicists, chemists, mathematicians, life scientists, and technicians were critical to the success of the project that helped end World War II.

Dr. Howes earned her Ph.D. from Columbia University in 1971 and her subsequent career has included accomplishments in nuclear structure physics, undergraduate physics education, and the history of women in physics. Her appearance at MSU is sponsored by NSCL, a world-leading laboratory for rare isotope research and nuclear science education.

For more information, contact Geoff Koch at 517-333-6482 or [koch@nscl.msu.edu](mailto:koch@nscl.msu.edu).

Operation of NSCL as a national user facility is supported by the Experimental Nuclear Physics Program of the U.S. National Science Foundation.

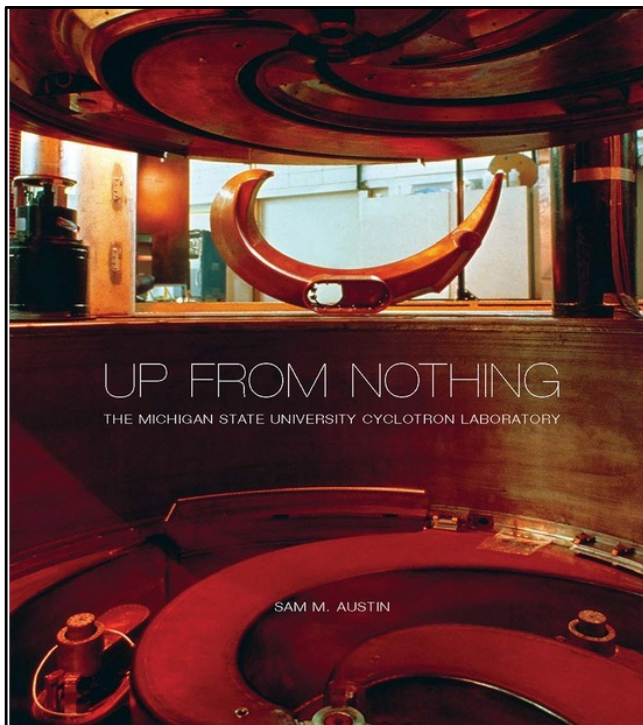
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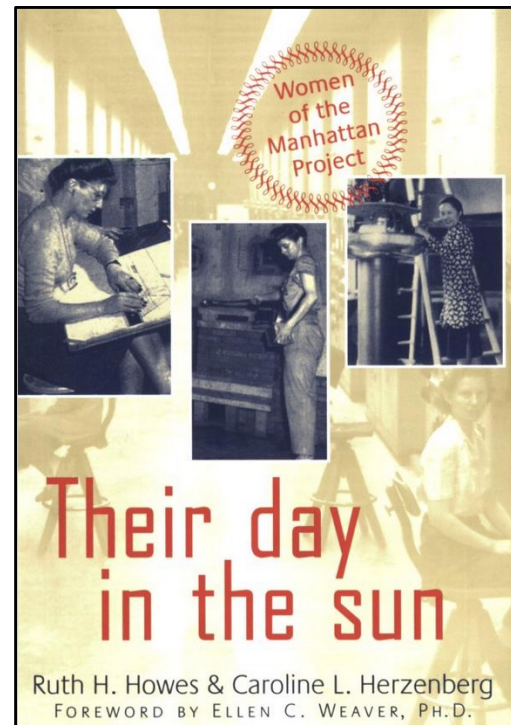
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# Acknowledgements

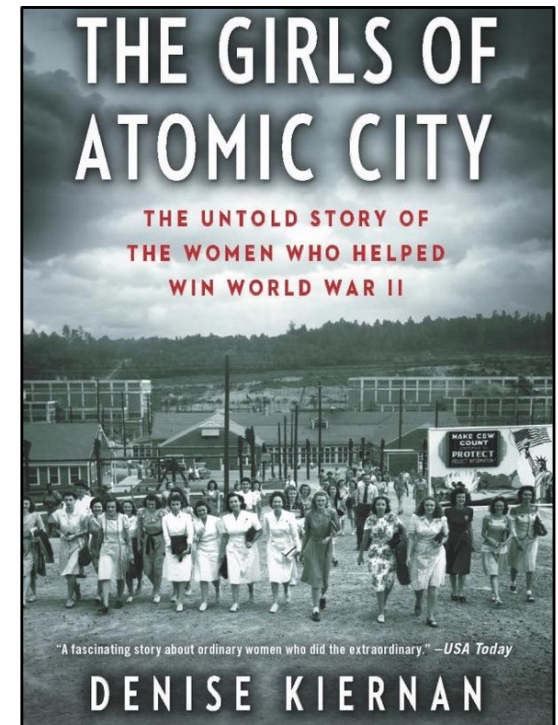
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- Sara Roberts – MSU Archives
- Danielle R. Hamilton – PHY 481 Honors Option Undergraduate Student
- Mark Dickey & David Whittaker – Oak Ridge National Laboratory Library
- Prof. Surjit Singh – my dad and future publisher



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FRIB/NSCL Research Discussion



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