Oak Ridge - Early Controls Retrospective

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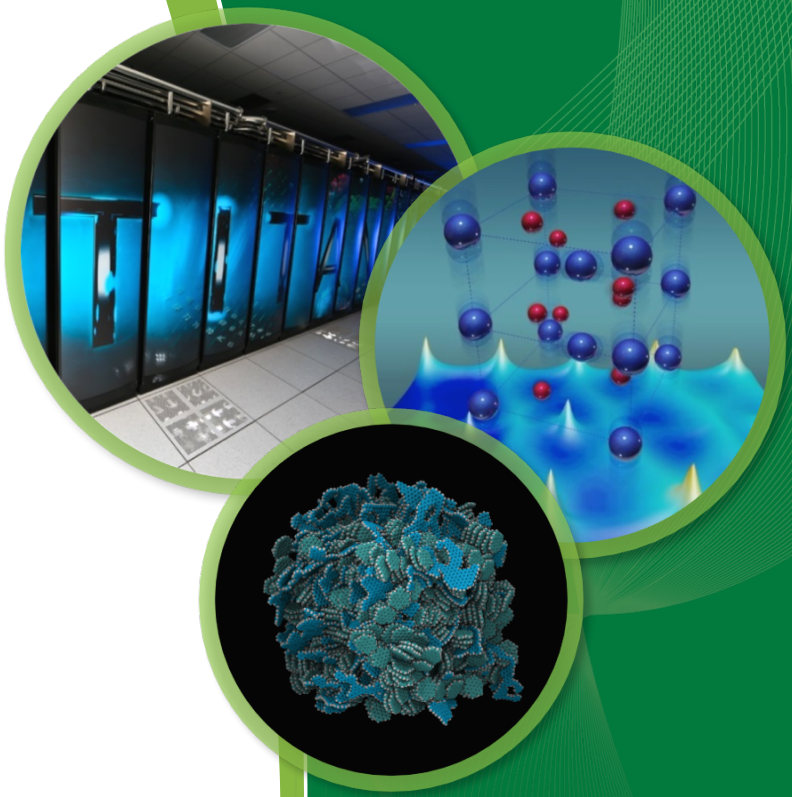

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OAK RIDGE National Laboratory

The Prophet of Oak Ridge

- John Hendrix, a “mystic” living on Black Oak Ridge, was know for recounting his “visions” to family and friends
- In 1900 he retreated to the woods for 40 nights, as instructed by a “voice” then returned and reported:

“And I tell you, Bear Creek Valley someday will be filled with great buildings and factories, and they will help toward winning the greatest war that ever will be. And there will be a city on Black Oak Ridge and the center of authority will be on a spot middle-way between Sevier Tadlock's farm and Joe Pyatt's Place. A railroad spur will branch off the main L&N line, run down toward Robertsville and then branch off and turn toward Scarborough. Big engines will dig big ditches, and thousands of people will be running to and fro. They will be building things, and there will be great noise and confusion and the earth will shake. I’ve seen it. It’s coming.”

The Dawn of the Atomic Age

- December 2, 1942, at the University of Chicago, Enrico Fermi demonstrated a controlled nuclear reaction for visiting dignitaries on a nearby balcony; the pile went critical at 3:20 pm
- He controlled the reaction by slowly withdrawing a cadmium coated rod while “carefully monitoring the neutron flux within the pile” (no radiation shielding was used)
- According to Richard Fox, who provided the rod controls

  “The manual speed control was nothing more elaborate than a variable resistor with a piece of cotton clothesline over a pulley and two lead weights to make it ‘fail-safe’ and return to its zero position when released”

- Richard Fox and Ernest Wollan monitored and recorded the radiation emitted by the reaction

The Secret City

- In 1942 the US Army designated 59,000 acres of land (~92 square miles) between Black Oak Ridge and the Clinch River to serve as a one of three sites for the development of the atomic bomb
- About 3000 people were given a few weeks and ~$47/acre to relocate as construction began and thousands of scientists, engineers, and other workers converged on the “secret city”
- The site was selected for the small population, isolated location and access to water, rail and affordable electricity
- The remote location helped the project stay secret and Oak Ridge did not appear on maps until 1949
- The population of the town grew from ~3,000 in 1942 to ~75,000 by 1945


WHAT YOU SEE HERE
WHAT YOU DO HERE
WHAT YOU HEAR HERE
WHEN YOU LEAVE HERE
LET IT STAY HERE
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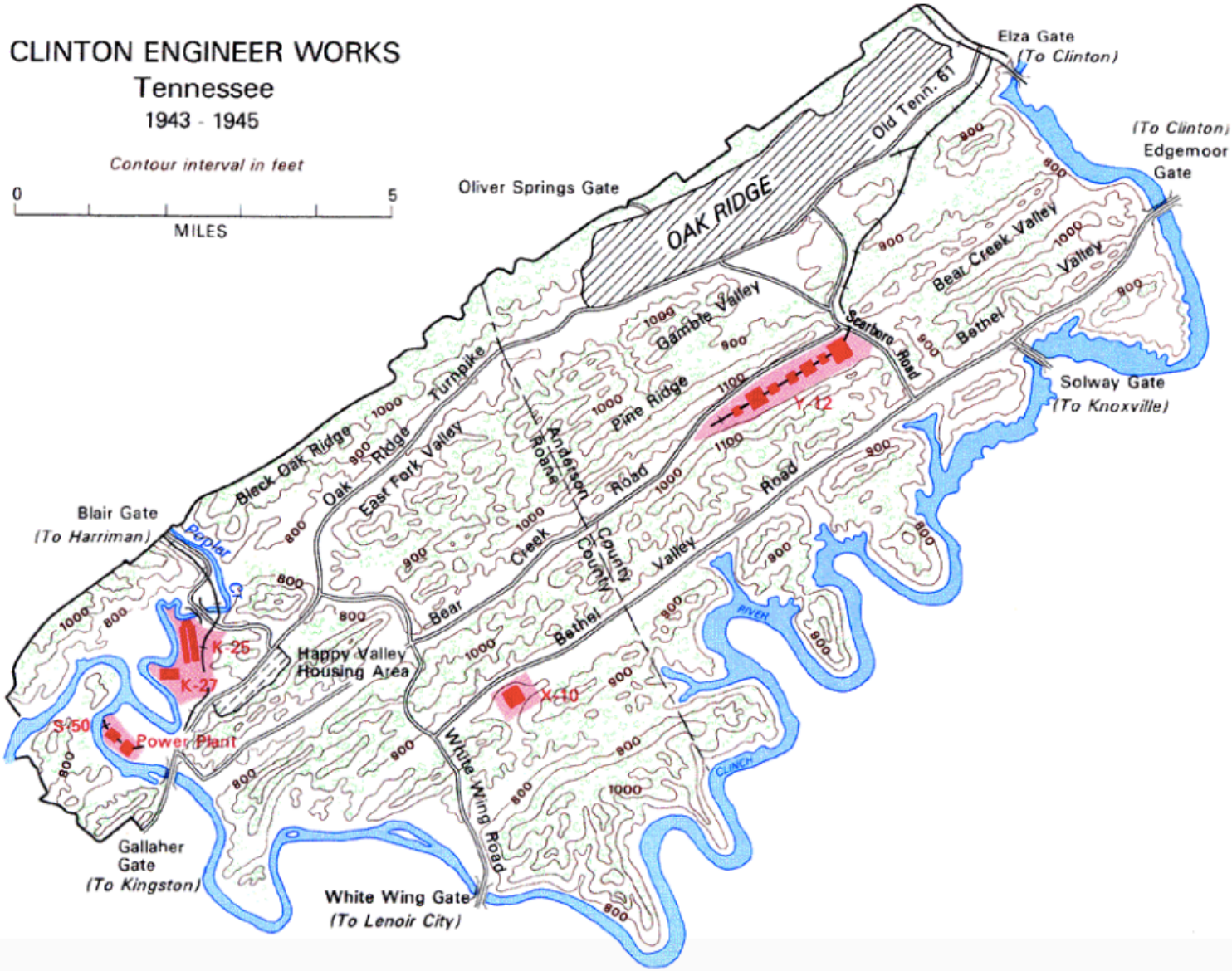
Clinton Engineering Works

- After land was acquired, the US Army moved quickly to build three isolated plants to refine materials for the first atomic bomb
- K-25
  - cost ~$500M, built in 18 months, employed ~12,000 workers
  - began production ~12 months after construction began and while construction continued
  - separated uranium-235 from uranium-238 using gaseous diffusion
- Y-12
  - cost ~$673M, built in ~10 months, employed ~22,000 workers
  - used calutrons to perform electromagnetic isotope separation
- X-10
  - Cost ~$27M, built in 10 months, employed ~1500 workers
  - Pilot for a larger plutonium plant to be built in Hanford, WA


CLINTON ENGINEER WORKS
Tennessee
1943 - 1945
Contour interval in feet
0
5
MILES
Elza Gate
(To Clinton)
Old Tenn. 61
(To Clinton)
Edgemoor
Gate
Oliver Springs Gate
OAK RIDGE
Bear Creek Valley
Bethel Valley
Scarboro Road
Solway Gate
(To Knoxville)
Y-12
Gamble Valley
Pine Ridge
Turnpike
Black Oak Ridge
Oak Ridge
East Fork Valley
Anderson
Robins
Road
Blair Gate
(To Harriman)
Poplar Ck
K-25
K-27
S-50
Power Plant
Happy Valley
Housing Area
Bear Creek
County Line
Bethel Valley
Road
X-10
White Wing Road
Gallaher
Gate
(To Kingston)
White Wing Gate
(To Lenoir City)
CLINCH RIVER

K-25 Building

- The K-25 plant was housed in the largest building in the world (1943)
  - 4 stories, 44 acres, ~2 million ft^2
  - Dedicated power plant, also the largest in the world

- It took 5 years to demolish (2008-2013)

K-25 Controls

- The fourth floor of the K-25 was the operating floor and featured the control room including hundreds of instrument panels and control devices where operators monitored the the process
- “The K-25 plant was the first large-scale fully automated factory in history. Because of the complexity and size of the plant, 9,000 employees working in three shifts were needed to monitor its operations.”

The main control room at the K-25

Y-12 Calutron Operations and Control

- ~2500 operators were hired; most were recent female graduates from local high schools
- The operators were trained to watch meters and turn knobs to make adjustments when specific thresholds were reached
- Calutrons were first operated by Berkley scientists to work out the “bugs”
- When the local operators took over, it was noted that

  “…the young ‘hillbilly’ girl operators were out producing the Berkley PhDs”

- A challenge was issued by the Berkley supervisor, competition ensued and still the local operators prevailed

Y-12 Calutron Controls

X-10 - Graphite Reactor

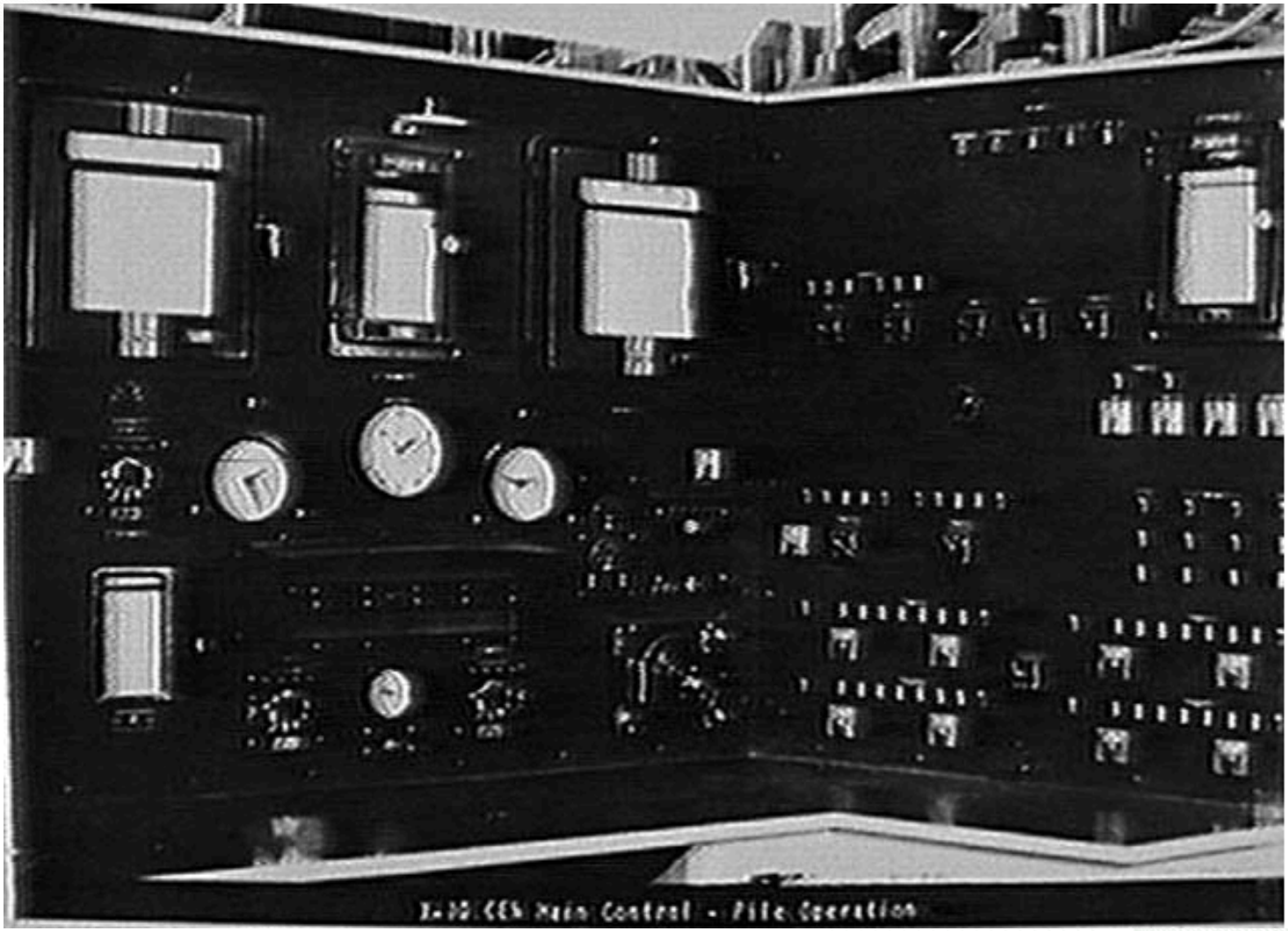
- World's first permanent nuclear reactor
- Used neutrons emitted in the fission of uranium-235 to convert uranium-238 into plutonium-239
- Challenged engineers to design and build systems to remotely transfer and evaporate liquids, dissolve and separate solids and handle toxic gases
- Instrumentation was developed for remote measurements of volumes, densities, and temperatures in a hazardous (radiation) environment
- Microscopic amounts of radioactive elements were separated from volumes of liquid thousands of times larger

Graphite Reactor Control System

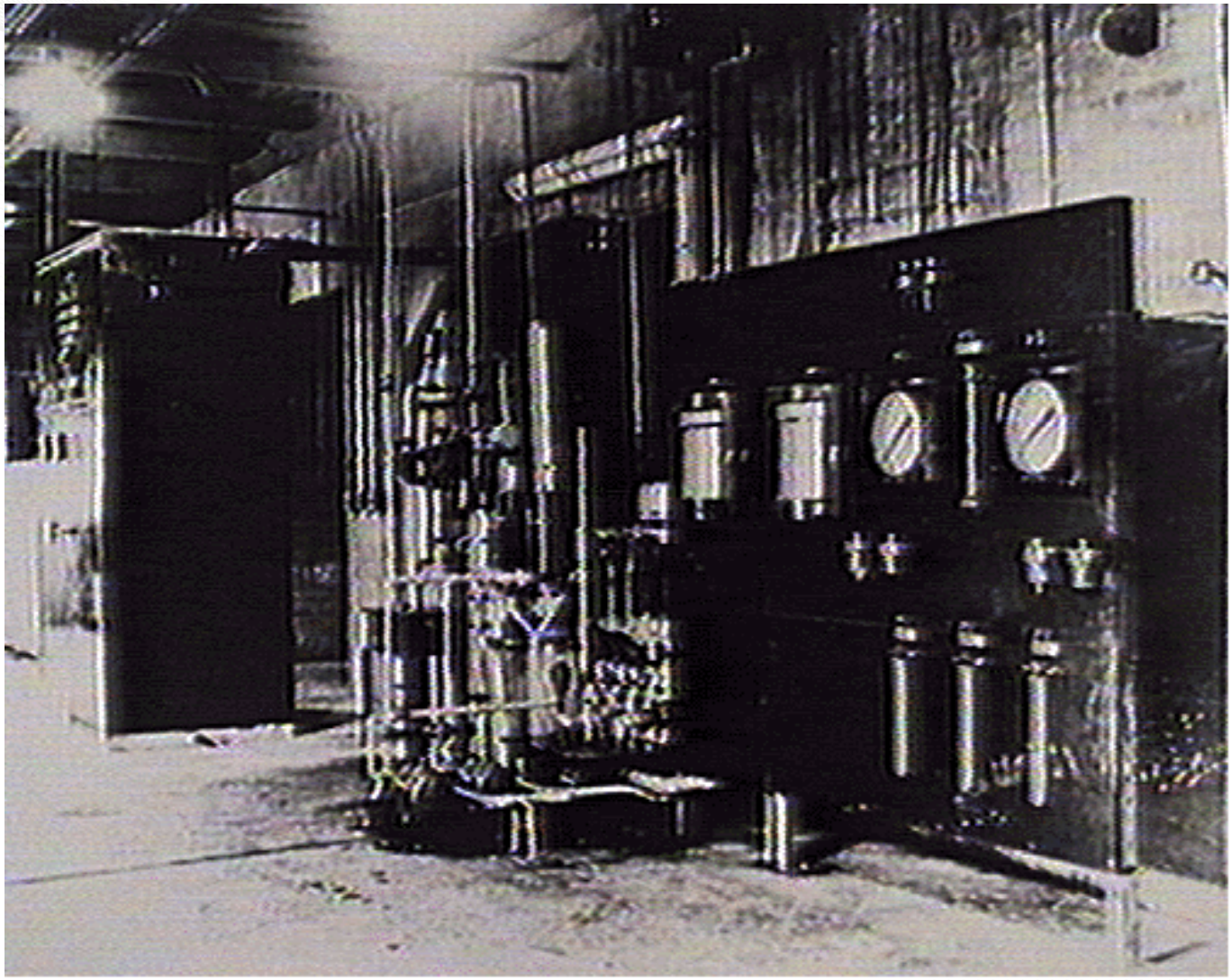
CONTROL SYSTEM

When the amount of uranium required for operation is in the reactor, the start of the chain reaction is spontaneous. For this reason, the reactor must have enough neutron absorbers in its safety and control system to engage neutrons much faster than they can be produced by the reactor. The safety system consists of three rods of cadmium encased in steel and two steel rods containing $1\frac{1}{2}$ per cent boron. The three 8-foot cadmium rods are suspended in shafts in the top shielding, and can be dropped by gravity through their shafts into the central part of the reactor in the event of emergency or normal shutdown. These three rods are attached to cables that, in operating positions, are wound up on the drums of electric-driven windlasses and are held in that position by electric brakes. If an electric power failure should occur, the rods automatically fall into the reactor when the power to the brakes goes off. For normal shutdowns, the power to the brakes is turned off by a switch at the control console, causing the rods to be released. There were originally four of these rods, but one has been removed to allow its shaft to be used for research and various experiments. This fourth rod can be safely removed because experience and tests indicate that the remaining rods can handle all possible control problems.

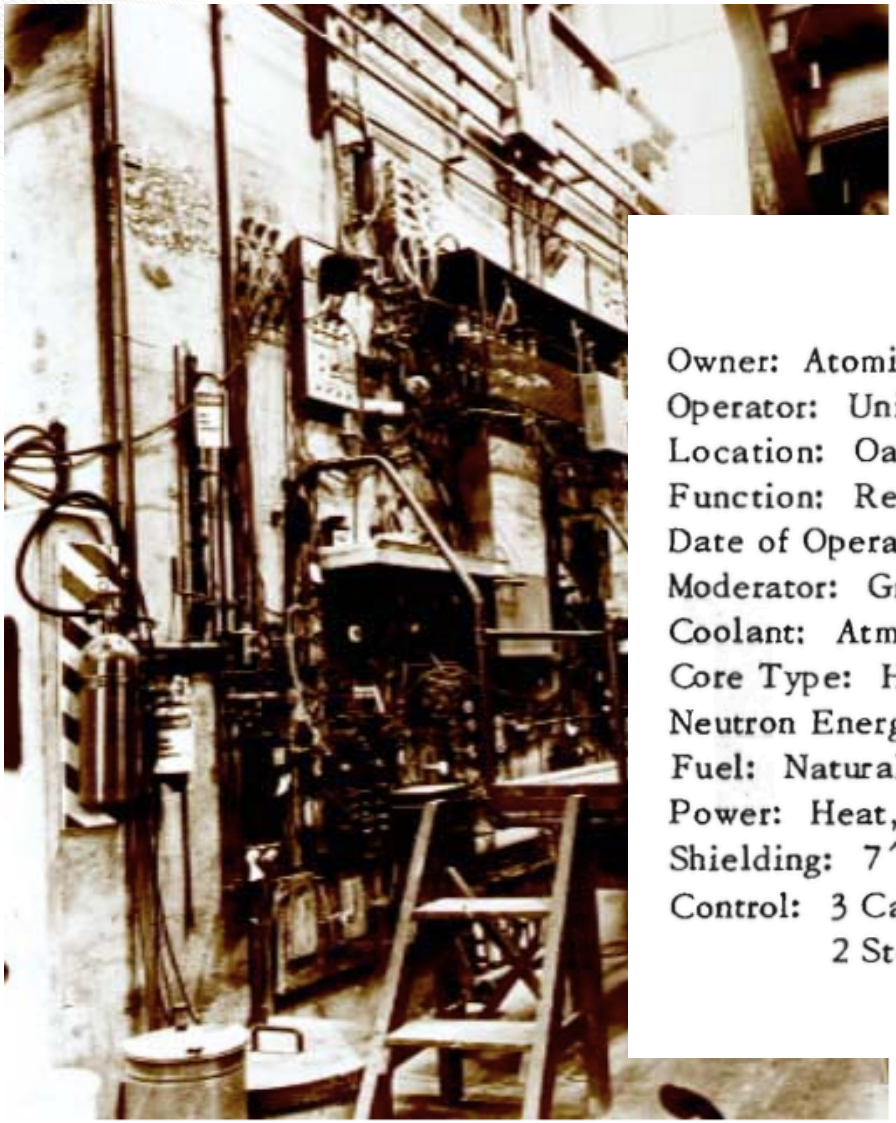
X-10 Graphite Reactor Main Control, Pile Operation



X-10 Control for Pile Fan



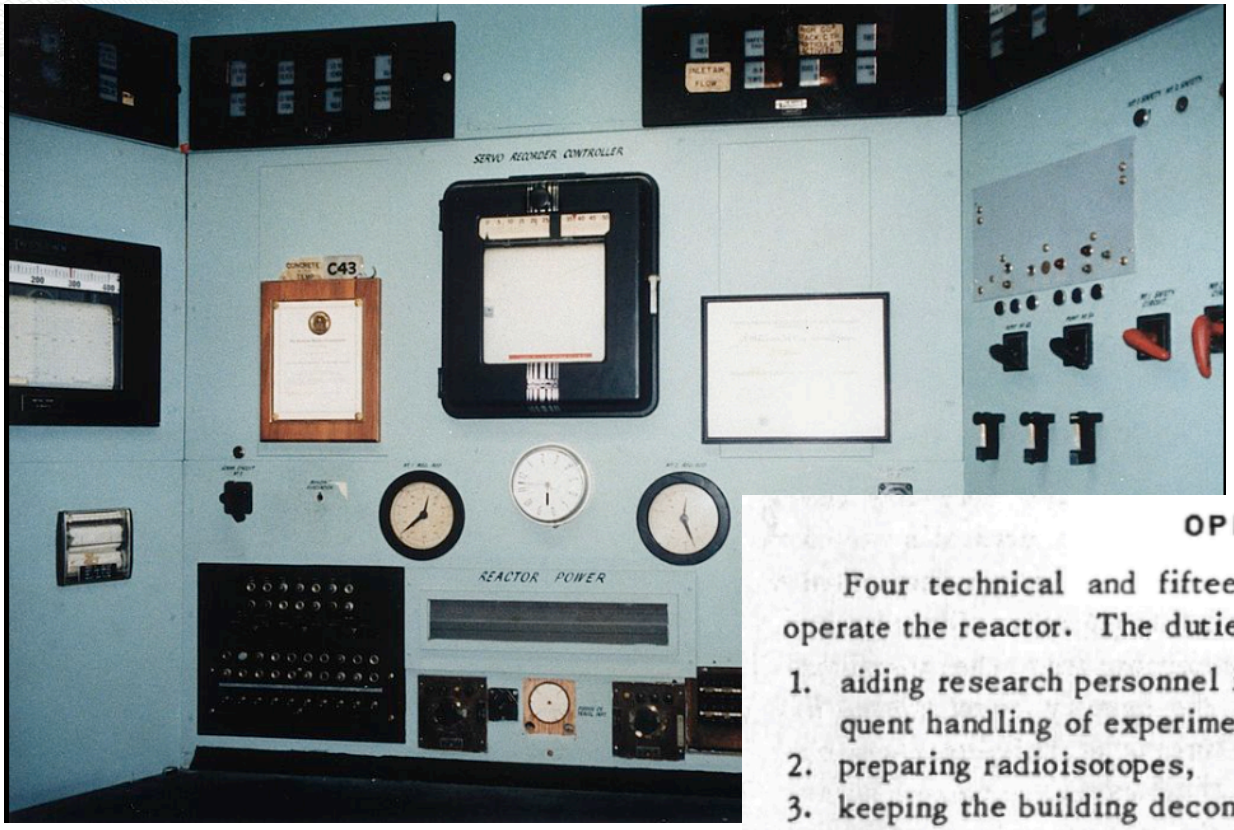
X-10 Hot Laboratory Remote Control



REACTOR DATA

Owner: Atomic Energy Commission, Oak Ridge National Laboratory
Operator: Union Carbide Nuclear Company
Location: Oak Ridge National Laboratory, Oak Ridge, Tennessee
Function: Research; Radioisotope Production
Date of Operation: 1943
Moderator: Graphite
Coolant: Atmospheric Air
Core Type: Heterogeneous
Neutron Energy: Thermal
Fuel: Natural Uranium
Power: Heat, 3.5 Mw; Electricity, 0
Shielding: 7′ Concrete
Control: 3 Cadmium Encased Steel Rods (Penetrate top shielding)
2 Steel Rods 1½% Boron (Enter horizontally)

X-10 Graphite Reactor Control Room



OPERATION

Four technical and fifteen nontechnical men are needed to operate the reactor. The duties of these men include:

1. aiding research personnel in charging, discharging, and subsequent handling of experimental equipment,
2. preparing radioisotopes,
3. keeping the building decontaminated and otherwise safe,
4. operating a water-demineralization plant and a hydrogen liquefier.

While the reactor is in operation, it normally involves only moving the regulating rods to keep the automatic controls within predetermined limits. Meter readings are taken every hour. The reactor is shut down each Monday for maintenance work. Experimental equipment and radioisotopes are moved in and out of the reactor, and fuel channels are inspected for failure of aluminum fuel jackets.

Oak Ridge National Laboratory

- Having provided critical research and materials for the two atomic bombs that were used to end WWII, the Oak Ridge plants were converted to peacetime uses
- K-25 continued to enrich uranium until 1964
- The K-25 area demolition and clean-up was recently completed and the area is now the East Tennessee Technology Park
- Y-12 is the Y-12 National Security Complex and we try not to know what they do but it is related to ”stockpile stewardship”
- The graphite reactor at X-10 transitioned to produce radioactive isotopes for medical, industrial and research purposes and the site became Oak Ridge National Laboratory in 1948

Thank You!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SPALLATION NEUTRON SOURCE
OAK RIDGE NATIONAL LABORATORY
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Books

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City Behind a Fence by Charles W. Johnson and Charles O. Jackson

Oak Ridge (Images of America) by Ed Wescott