Nuclear Renaissance = Nuclear Proliferation

a presentation by
Gordon Edwards Ph.D.
and Robert Del Tredici

featuring the photographs of Robert Del Tredici

Canadian Coalition for Nuclear Responsibility
www.ccnr.org
Part 1.
The Nuclear Renaissance
Fuel Pellet in hand
“Given costs relative to other supply options, nuclear power, which accounted for 16% of the electricity supply in 2005,
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IPCC: Working Group III report

“Given costs relative to other supply options, nuclear power, which accounted for 16% of the electricity supply in 2005, can have an 18% share of the total electricity supply in 2030.
IPCC: Working Group III report

“Given costs relative to other supply options, nuclear power, which accounted for 16% of the electricity supply in 2005, can have an 18% share of the total electricity supply in 2030 but safety, weapons proliferation and waste remain as constraints”
The world-wide renaissance of nuclear power that has so often been predicted will not take place in the next few decades. Nuclear energy will be on the decline till the year 2030, and will continue to decline in importance globally.

WIEN INTERNATIONAL, January 10, 2010
The new chairman of the Federal Energy Regulatory Commission (FERC) said the U.S. doesn’t need to build any new nuclear or coal-fired plants. It could make do with renewable energy and natural gas.

Wall Street Journal, April 27, 2009
Don't expect more than three new nuclear plants to be built in the next 10 years, experts at a session on nukes at Fortune's *Brainstorm: Green* conference agree.
Key Points

1. Nuclear Power cannot solve the problem of greenhouse gas emissions.

2. Nuclear expansion exacerbates the problem of weapons proliferation.

LESSON 1

The problems posed by a nuclear renaissance far exceed its benefits.
Part 2. The Spread of Nuclear Weapons
Conventional chemical explosive
Sub-critical pieces of uranium-235 combined

Gun-type assembly method

High-explosive lenses

Implosion assembly method

Plutonium core compressed
**Fuel bundle graphic**

- Conventional chemical explosive
- Sub-critical pieces of uranium-235 combined

**Uses**

- Highly Enriched Uranium

**Uses**

- Any Kind of Plutonium

**Gun-type assembly method**

- High-explosive lenses
- Plutonium core compressed

**Implosion assembly method**
When an atom of uranium-238 absorbs a neutron...
When an atom of uranium-238 absorbs a neutron... 

... it is transformed into an atom of plutonium-239
On 15 November 1945 the U.S., U.K. and Canada issued a Joint Declaration with 3 prophetic insights.
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1. nuclear weapons provide "a means of destruction hitherto unknown, against which there can be no adequate military defence";

2. "no system of safeguards will of itself provide an effective guarantee against the production of atomic weapons";
On 15 November 1945 the U.S., U.K. and Canada issued a Joint Declaration with 3 prophetic insights.

1. nuclear weapons provide "a means of destruction hitherto unknown, against which there can be no adequate military defence";

2. "no system of safeguards will of itself provide an effective guarantee against the production of atomic weapons";

3. atom bombs are weapons "in the employment of which no single nation can, in fact, have a monopoly."
The 1945 Joint Declaration urged the United Nations to find a way of "entirely eliminating the use of atomic energy for destructive purposes and promoting its use for industrial and humanitarian purposes."
the development of atomic energy for peaceful purposes and . . . for bombs are, in much of their course, interchangeable and interdependent.

We have concluded unanimously that there is no prospect for security against atomic warfare in a system of international agreements to outlaw such weapons controlled only by a system which relies on inspection and similar police-like methods.
Non-Proliferation Treaty (1968)

Preamble

Affirming the principle that the benefits of peaceful applications of nuclear technology, including . . . nuclear explosive devices should be available for peaceful purposes to all Parties of the Treaty, whether nuclear-weapon or non-nuclear weapon States . . .
Non-Proliferation Treaty (1968)
Article V

Each party to the Treaty undertakes . . . to ensure that . . . peaceful applications of nuclear explosions will be made available to non-nuclear-weapon States . . . and that the charge to such Parties for the explosive devices used will be as low as possible . . .
Key Points

1. All nuclear weapons need a HEU (highly enriched uranium) or plutonium explosive.

2. All nuclear reactors need EU (enriched uranium) or plutonium as a fuel.

3. PNE (peaceful nuclear explosives) are allowed under the NPT but not accepted.

4. Safeguards alone are not enough.
A nuclear weapons free world is incompatible with stockpiles of peaceful nuclear explosives.
Part 2.
Nuclear Weapons
Proliferation
Paths to Proliferation . . .

(a) Highly Enriched Uranium (HEU)
Conventional chemical explosive

Sub-critical pieces of uranium-235 combined

Gun-type assembly method
Key Points

1. Gun-Type atomic bombs are relatively low-tech, but HEU is needed.

2. Obama’s April summit focused on HEU: “locking down” & eliminating civilian use.

3. Medical isotopes are made at Chalk River (NRU reactor) from HEU targets.

4. HEU can be denatured (just blend in DU).
A nuclear weapons free world is incompatible with stockpiles of highly enriched uranium (HEU).
Paths to Proliferation . . .

(b) Depleted Uranium
DU = depleted uranium
Fission schematic
Key Points

1. Depleted uranium (DU) has no significant commercial use – it is nuclear waste.

2. DU is mainly uranium-238; it is the raw material from which plutonium is made.

3. Metallic components of H-bombs are made from DU and contribute most of the radioactive fallout and most of the blast.

4. DU is not adequately safeguarded.
A nuclear weapons free world is incompatible with stockpiles of depleted uranium (DU) . . .
A nuclear weapons free world is incompatible with stockpiles of depleted uranium (DU) . . . as long as nuclear reactors exist.
Paths to Proliferation . . .

(c) Plutonium
Implosion assembly method

- High-explosive lenses
- Plutonium core compressed
X-Ray motion picture frames of implosion experiment
Key Points

1. All kinds of reactor-produced plutonium can be used to make powerful bombs.

2. Plutonium cannot be denatured by any method known to science.

3. Thorium is not a nuclear fuel; it must be blended with plutonium to be used at all.

4. Thorium-232 is transformed into U-233 (uranium-233) -- excellent bomb material.
A nuclear weapons free world is incompatible with stockpiles of separated plutonium . . .
A nuclear weapons free world is incompatible with stockpiles of separated plutonium . . .

. . . even as reactor fuel (MOX).
Final Thoughts

1. The NPT can be read to mean that producing HEU and plutonium are not peaceful uses of nuclear energy . . .
Final Thoughts

1. The NPT can be read to mean that producing HEU and plutonium are not peaceful uses of nuclear energy . . .

. . . as we have done with PNEs.
Final Conclusion

A nuclear weapons free world is not sustainable in the context of a nuclear power renaissance . . .
Final Conclusion

A nuclear weapons free world is not sustainable in the context of a nuclear power renaissance . . .

. . . for without HEU, DU or MOX, there is no future for nuclear power.
The End

Canadian Coalition for Nuclear Responsibility

www.ccnr.org
un char de combat endommagé par des munitions à U.A.
Uranium and its Dangers

featuring the photographs of Robert Del Tredici

Canadian Coalition for Nuclear Responsibility
www.ccnr.org
THE ZEEP REACTOR

A nuclear chain reaction was first initiated in Canada on September 5, 1943, when the ZEEP reactor went into operation here at Chalk River. Originally part of an effort to produce plutonium for nuclear weapons, the reactor was designed by a team of Canadian, British, and French scientists and engineers assembled in Montreal and in Ottawa in 1942-43 under the administration of the National Research Council. Named Zero Energy Experimental Pile, because it was developed to produce only one watt of heat, the ZEEP reactor was used to provide data for the design of the powerful NRX (National Research Experimental) reactor. In 1952, the project was transferred from NRC to Atomic Energy of Canada Limited.

Engraved by the
Archaeological and Historical Board of Directors
Ministry of Culture and Entertainment

LE REACTEUR ZEEP

La diffusion des armements nucléaires

les États-Unis

le Canada

l’Angleterre

(la France)

[la Russie]

l’Inde

le Pakistan

le Taiwan

l’Argentine

la Corée du Sud

[l’Israël]
THE ZEEP REACTOR

A nuclear chain reaction was first initiated in Canada on September 5, 1945, when the ZEEP reactor went into operation here at Chalk River. Originally part of an effort to produce plutonium for nuclear weapons, the reactor was designed by a team of Canadian, British and French scientists and engineers assembled in Montreal and in Ottawa in 1942-43 under the administration of the National Research Council. Named Zero Energy Experimental Pile because it was developed to produce only one watt of heat, the ZEEP reactor was used to provide data for the design of the powerful NRX (National Research Experimental) reactor. In 1952 the project was transferred from NRC to Atomic Energy of Canada Limited.
IONIZING RADIATION

THYROID
- iodine-131: 8 days
- cobalt-60
- krypton-85: 10 years
- zine-65: 246 days
- barium-140: 13 days
- potassium-42: 12 hours
- cesium-137: 30 years
- plutonium-239: 24,000 years

SKIN
- sulphur-35: 87 days
- cobalt-60
- krypton-85

LIVER
- cobalt-60: 5 years

OVARIES
- iodine-131: 8 days
- cobalt-60: 5 years

LUNGS
- radon-222 (and whole body)
  - alpha: 3.8 days
- uranium-233 (et al)
  - alpha: 162,000 years
- plutonium-239 (and bone)
  - alpha: 24,000 years

SPLEEN
- polonium-210 (and whole
  - alpha: 138 days

KIDNEYS
- uranium-238 (and bone)
  - alpha: 4,500,000 years
- ruthenium-106
  - gamma: 1 year

BONE
- radium-226
  - alpha: 1,620 years
- zine-65
  - gamma: 246 days
- strontium-90
  - beta: 28 years
- yttrium-90
  - beta: 64 hours
- promethium-147
  - beta: 2 years
- barium-140
  - beta (gamma): 13 days
- thorium-234
  - beta: 24.1 days
- phosphorus-32
  - beta: 14 days
- carbon-14 (and fat)
  - beta: 5,600 years
Four Types of Atomic Radiation

- Alpha
- Beta
- Gamma
- Neutron
Four Types of Atomic Radiation

- **Alpha**: 2 protons + 2 neutrons
  
  (stopped by paper)
  
  (pos. charge)

- **Beta**

- **Gamma**

- **Neutron**
Four Types of Atomic Radiation

- **Alpha**
  - 2 protons + 2 neutrons
  - heavy particle
  - (stopped by paper)
  - (pos. charge)

- **Beta**
  - 1 high-energy electron
  - lightest particle
  - (stopped by aluminum)
  - (neg. charge)

- **Gamma**

- **Neutron**
Four Types of Atomic Radiation

- **Alpha**
  2 protons + 2 neutrons
  (stopped by paper)
  heavy particle
  (pos. charge)

- **Beta**
  1 high-energy electron
  (stopped by aluminum)
  lightest particle
  (neg. charge)

- **Gamma**
  1 high-frequency photon
  (stopped by lead)
  E-M wave
  (no charge)

- **Neutron**
Four Types of Atomic Radiation

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Stopped By</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>2 protons + 2 neutrons</td>
<td>paper</td>
<td>pos. charge</td>
</tr>
<tr>
<td></td>
<td>(<em>stopped by paper</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta</td>
<td>1 high-energy electron</td>
<td>aluminum</td>
<td>neg. charge</td>
</tr>
<tr>
<td></td>
<td>(<em>stopped by aluminum</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma</td>
<td>1 high-frequency photon</td>
<td>lead</td>
<td>E-M wave</td>
</tr>
<tr>
<td></td>
<td>(<em>stopped by lead</em>)</td>
<td></td>
<td>(no charge)</td>
</tr>
<tr>
<td>Neutron</td>
<td>1 high-energy particle</td>
<td>water</td>
<td>medium particle</td>
</tr>
<tr>
<td></td>
<td>(<em>stopped by water</em>)</td>
<td></td>
<td>(no charge)</td>
</tr>
</tbody>
</table>
Four Types of Atomic Radiation

- **Alpha**
  - 2 protons + 2 neutrons
  - (stopped by paper)
  - heavy particle
  - (pos. charge)

- **Beta**
  - 1 high-energy electron
  - (stopped by aluminum)
  - lightest particle
  - (neg. charge)

- **Gamma**
  - 1 high-frequency photon
  - (stopped by lead)
  - E-M wave
  - (no charge)

- **Neutron**
  - 1 high-energy particle
  - (stopped by water)
  - medium particle
  - (no charge)

(Note: X-Rays are similar to gamma rays but are less energetic)
l’uranium appauvri est utilisé aussi pour des bombes nucléaires
on fabrique des cylindres creux d'uranium appauvri
Summary of doubling dose estimates for lung cancer in uranium miners:

- Archer (1967)  120 WLM
- Hewitt (1980)  Newfoundland  50 WLM
- Sevc (1976)  ~50 WLM
- US EPA (1980)  ~40 WLM
- Ellett (1980)  40 WLM
- BEIR-II (1972)  34 WLM
- BCMA (1980)  NIOSH & Sevc  19-20 WLM
- BEIR-III (1980)  12-17 WLM
- Axelson (1980)  2 WLM

The lifetime incidence of lung cancer in males is 52.5 per thousand. The doubling dose from exposure to radon would be 40 WLM or less.

Thus, there is a risk of 12.5 lung cancers per 1000 workers per WLM. The risk would be 4 times as high at today’s permissible exposures.

Compare this with the risk of accidental death in “safe” industries of 0.1 accidental deaths per million workers per year!
Although radon is a gas . . .
Although radon is a gas . . .

its byproducts are solids and lodge in the lungs . . .
Although radon is a gas . . .
its byproducts are solids and lodge in the lungs . . .

. . . in fact 85% of the lung dose is from alpha-emitting polonium
une usine d’enrichissement
Uranium 238
Alpha ⇄
Thorium 234
Beta ⇄ Gamma
Protactinium 234
Beta ⇄ Gamma
Uranium 234
Alpha ⇄ Gamma
Thorium 230
Alpha ⇄ Gamma
Radium 226
Alpha ⇄ Gamma
Radon 222
Alpha ⇄
Polonium 218
Alpha ⇄
Lead 214
Beta ⇄ Gamma
Bismuth 214
Beta ⇄ Gamma
Polonium 214
Alpha ⇄
Lead 210
Beta ⇄ Gamma
Bismuth 210
Beta ⇄ Gamma
Polonium 210
Alpha ⇄
Lead 206

Half-life

<table>
<thead>
<tr>
<th>Decay Chain</th>
<th>Microsec*</th>
<th>Millisec**</th>
<th>Second</th>
<th>Hour</th>
<th>Day</th>
<th>Week</th>
<th>Thousand</th>
<th>Million</th>
<th>Billion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium 238</td>
<td>4.5 billion years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorium 234</td>
<td>245,000 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protactinium 234</td>
<td>1,600 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uranium 234</td>
<td>76,000 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorium 230</td>
<td>1,600 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium 226</td>
<td>245,000 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon 222</td>
<td>3.8 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polonium 218</td>
<td>3.0 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lead 214</td>
<td>27 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth 214</td>
<td>20 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polonium 214</td>
<td>160 microseconds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead 210</td>
<td>21 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth 210</td>
<td>5 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polonium 210</td>
<td>138 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>stable</td>
<td>stable</td>
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<td></td>
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</tr>
</tbody>
</table>

*Microsec; 1/1,000,000 of a second  **Millisec; 1/1,000 of a second
The Yellowcake Road (Canada)
# Uses of Canadian Uranium

<table>
<thead>
<tr>
<th>Mill Site</th>
<th>Uranium Use</th>
<th>Mill Site</th>
<th>Uranium Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Radium, NWT</td>
<td></td>
<td>Elliot Lake, Ont.</td>
<td></td>
</tr>
<tr>
<td>Rayrock, NWT</td>
<td></td>
<td>Lacnor</td>
<td></td>
</tr>
<tr>
<td>Uranium City, Sask.</td>
<td></td>
<td>Nordic</td>
<td></td>
</tr>
<tr>
<td>Beaverlodge</td>
<td></td>
<td>Stanrock</td>
<td></td>
</tr>
<tr>
<td>Gunnar</td>
<td></td>
<td>Spanish-American</td>
<td></td>
</tr>
<tr>
<td>Larado</td>
<td></td>
<td>Milliken</td>
<td></td>
</tr>
<tr>
<td><strong>Other Saskatchewan</strong></td>
<td></td>
<td>Stanleigh</td>
<td></td>
</tr>
<tr>
<td>Cluff Lake</td>
<td>OHEX</td>
<td>Quirke</td>
<td>OHEX</td>
</tr>
<tr>
<td>Rabbit Lake</td>
<td>OHEX</td>
<td>Panel</td>
<td>OHEX</td>
</tr>
<tr>
<td>Key Lake</td>
<td>OHEX</td>
<td>Denison</td>
<td>OHEX</td>
</tr>
<tr>
<td>McClean Lake</td>
<td>OHEX</td>
<td>Bancroft, Ont.</td>
<td></td>
</tr>
<tr>
<td><strong>Other Ontario</strong></td>
<td></td>
<td>Dyno</td>
<td></td>
</tr>
<tr>
<td>Agnew Lake, Espanola</td>
<td>OHEX</td>
<td>Bicoft</td>
<td></td>
</tr>
<tr>
<td>Pronto, Blind River</td>
<td></td>
<td>Faraday</td>
<td></td>
</tr>
<tr>
<td><strong>Other Uses</strong></td>
<td></td>
<td>Madawaska</td>
<td></td>
</tr>
</tbody>
</table>

- **uranium for bombs** (1941-1968)
- ... for export (from 1968)
- ... for CANDU (from 1968)
Thermal Pulse

70 years

4,400 years

8,800 years
## Radioactive Inventory

### Main Components: Radioactive Tailings

<table>
<thead>
<tr>
<th>Region</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest Territories</td>
<td>2.7 million tonnes</td>
</tr>
<tr>
<td>Ontario</td>
<td></td>
</tr>
<tr>
<td>Elliot Lake</td>
<td>145.3 million tonnes</td>
</tr>
<tr>
<td>Bancroft</td>
<td>6.2 million tonnes</td>
</tr>
<tr>
<td>Other</td>
<td>5.0 million tonnes</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td></td>
</tr>
<tr>
<td>Uranium City</td>
<td>14.8 million tonnes</td>
</tr>
<tr>
<td>Cluff Lake</td>
<td>2.2 million tonnes</td>
</tr>
<tr>
<td>Rabbit Lake</td>
<td>10.1 million tonnes</td>
</tr>
<tr>
<td>Key Lake</td>
<td>3.9 million tonnes</td>
</tr>
<tr>
<td>Other / Canada</td>
<td>3.0 million tonnes</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>193.2 million tonnes</strong></td>
</tr>
</tbody>
</table>

### High Level Radioactive Waste

<table>
<thead>
<tr>
<th>Site</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce</td>
<td>11.1 million kilograms</td>
</tr>
<tr>
<td>Darlington</td>
<td>1.8 million kilograms</td>
</tr>
<tr>
<td>Pickering</td>
<td>8.4 million kilograms</td>
</tr>
<tr>
<td>Gentilly</td>
<td>1.1 million kilograms</td>
</tr>
<tr>
<td>Pt. Lepreau</td>
<td>1.3 million kilograms</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23.7 million kilograms</strong></td>
</tr>
</tbody>
</table>
The toxicity of irradiated CANDU fuel over a period of ten million years.
The toxicity of irradiated CANDU fuel over a period of ten million years.

This graph represents the irradiated fuel produced in a single year by one CANDU.

The minimum amount of water needed to dilute this waste is about the same as the amount of water in Lake Superior.
Tritium (Hydrogen-3)

• Radioactive isotope of hydrogen (with 2 extra neutrons)
• Produced in large amounts from heavy water in CANDUs
• Released in the form of liquid water or water vapour
• Levels of tritium in Great Lakes is measurably growing
• Intake by inhalation, ingestion, and through the skin
• Crosses the placenta, can cause teratogenic effects
• DNA especially sensitive, can cause genetic damage
• Permissible levels in Canada highest in the world
Carbon-14

- Radioactive isotope of carbon (2 extra neutrons)
- Released in the form of CO$_2$ and radioactive dust
- Produced in large amounts by activation of nitrogen
- Six thousand year half-life means global accumulation
- Enters into all organic molecules (organically bound)
- DNA especially sensitive, may cause genetic damage
- Permissible levels in Canada highest in the world
Tritium (Hydrogen-3) and Carbon-14

- Prodigious amounts produced by CANDUs
- Both pure beta emitters (no gamma at all)
- Both very low energy (short track radiation)
- Do not bio-concentrate in the food chain
- Long half-lives leads to environmental build-up
- Essential constituents of organic molecules
- Reproductive risks exceed cancer risks
Nuclear waste generated in kilograms per thousand people.

Source: OECD environmental data 1999
... it takes 70,000 years for temperatures to return to normal
Exhibit 4: Some Radionuclides with Relatively Short Half Lives Decay into Radioactive Decay Products with Half Lives Measured in Geologic Time
The Nuclear Fuel Cycle? or The Nuclear Fuel Chain?
when a neutron
strikes a non-fissile
atom of uranium-238
two beta particles
are given off
and an atom of
plutonium-239 is
created
PLUTONIUM LIFE SPAN

500,000 YEARS

- 2000 AD
- START OF RECORDED HISTORY
- END OF LAST ICE AGE
- NEANDERTHAL MAN
A nuclear chain reaction was first started in Canada on September 5, 1942, when the ZEEP reactor went into operation here at Chalk River. Originally part of an effort to produce plutonium for nuclear weapons, the reactor was designed by a team of Canadian, British, and French scientists and engineers assembled in Montreal and in Ottawa in 1942-43 under the administration of the National Research Council. Named Zero Energy Experimental File because it was developed to produce only one watt of heat, the ZEEP reactor was used to provide data for the design of the powerful NRX (National Research Experimental) reactor. In 1958 the project was transferred from NRCC to Atomic Energy of Canada Limited.
THE ZEEP REACTOR

A nuclear chain reaction was first initiated in Canada on September 5, 1945, when the ZEEP reactor went into operation here at Chalk River. Originally part of an effort to produce plutonium for nuclear weapons, the reactor was designed by a team of Canadian, British and French scientists and engineers assembled in Montreal and in Ottawa in 1942-43 under the administration of the National Research Council. Named Zero Energy Experimental Pile because it was developed to produce only one watt of heat, the ZEEP reactor was used to provide data for the design of the powerful NRX (National Research Experimental) reactor. In 1952 the project was transferred from NRC to Atomic Energy of Canada Limited.
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CANADA
DEPARTMENT OF MINES

INVESTIGATIONS IN ORE DRESSING AND METALLURGY

1931
OTTAWA

PRECAUTIONS FOR WORKERS IN THE TREATING OF RADIUM ORE

W.R. McClelland

The hazards involved in the handling of high-grade radioactive materials make necessary the adoption of certain precautions. Recent investigations in the field of radium poisoning have led to the conclusion that precautions are necessary even in the handling of substances of low radioactivity. The ingestion of small amounts of radioactive dust or emanation over a long period of time will cause a building up of radioactive material in the body, which eventually may have serious consequences. Lung cancer, bone necrosis, and rapid anaemia are possible diseases due to the deposition of radioactive substances in the cell tissue or bone structure of the body.
When a neutron strikes a fissile uranium atom, the results are fission products and more neutrons.

Figure 6. Nuclear fission using U-235 as fissile material.
CANDU Nuclear Power Plant

Heat applied to ordinary water produces steam

Steam

Steam pressure drives turbine

Turbine drives generator producing electricity

Electricity

Heavy water 'coolant' transfers heat from uranium fuel to ordinary water in boiler (steam generator)

Heat produced by fissioning uranium

Fuel (Uranium)

Reactor

Boiler
When a neutron strikes a fissile uranium atom, U-235.
When a neutron strikes a fissile uranium atom, the results are fission products.
A neutron striking a fissile uranium atom results in fission products and more neutrons.
Radioactivity and Human Health

featuring the photographs of Robert Del Tredici

Canadian Coalition for Nuclear Responsibility
www.ccnr.org
Alpha Radiation