

# CRCPD White Paper on Fusion

(E-47 Committee on Commercial Nuclear Power)



CRCPD's Committee on Commercial Nuclear Power (E-47)

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Rapid Change

- Regulatory framework
- Technology readiness
- State direction



**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# White Paper Prepared and Reviewed by Experienced Personnel

- Members
  - Jeff Semancik, chair (CT)
  - Megan Shober (WI)
  - Szymon Mudrewicz (MA)
  - David Lafleur (PA)
- Advisors
  - Kim Steves (CRCPD)
  - Stefanie Blum (TX-DSHS)
  - Sarah Brodesser (OR)
  - Jill Wood (WA)
- Resource Individuals
  - Duncan White (US NRC)
  - Michael Wilt (US FEMA)
- Consultant
  - Michael Hua, PhD (Helion Energy)
- Peer Reviewers
  - Allyce Bolger (NRC)
  - Tyler Ellis (Commonwealth Fusion Systems)
  - James McCollough (NJ DEP)

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# *Supplements* NRC Guidance

- Reviews key regulatory issues
- Discusses available guidance
- Recommends radiation safety considerations
- Describes best practices

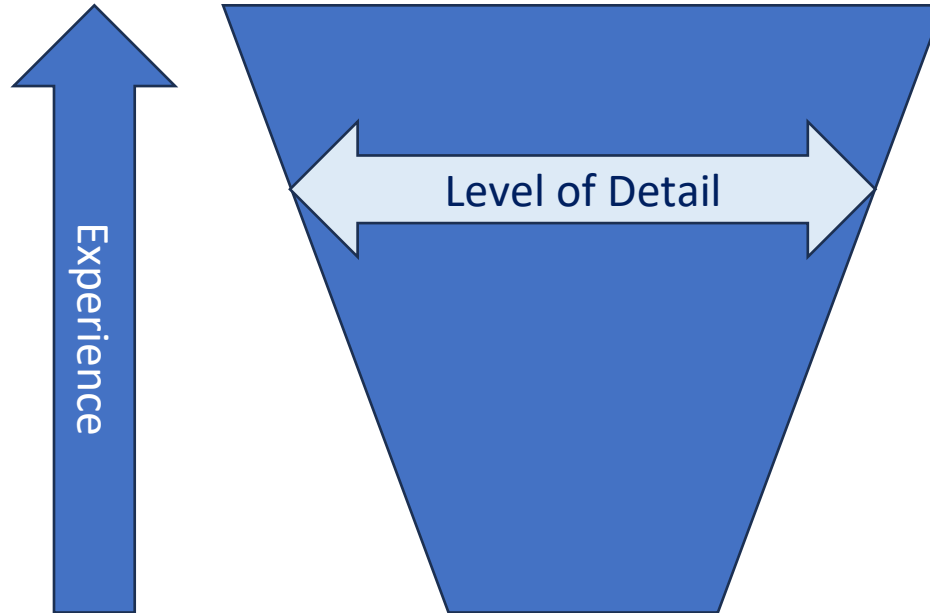
**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Key Areas

- Background of Fusion
- Licensing
- Inspections
- Emergency Planning
- Operator/User Training
- Cybersecurity
- Resources



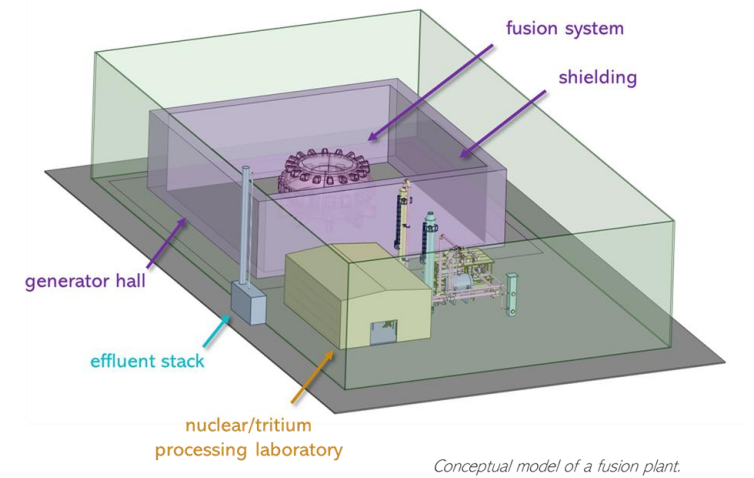
**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Licensing Challenges

- Staff training and knowledge
- Non-radiological hazards which could impact radiation safety
- Radioactive material inventory control
- Criteria for assessing evaluations of maximum dose to offsite persons
- Financial assurance and decommissioning planning
- Collaboration between states and the NRC



**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Licensing Best Practices

## Maintain Awareness

- Be aware of companies in your State that are pursuing fusion

## Engagement

- Meet with the applicant early and often.
- Perform site visits as construction milestones are reached

## Benchmark

- Coordinate with other states or the NRC who have issued fusion-related licenses or developed guidance
- Use advice, recommendations, and lessons learned

## Phased Approach

- Use where appropriate
- Ensure authorized activities are consistent with the facility's design and safety systems

## Review Codes & Modelling

- Ensure applicants make available for review necessary modeling data and the name of software/codes (including assumptions) as part of the licensing process
- Reference the list of common codes used by licensees
- Evaluate the plausibility and potential impact of industrial hazards (such as a hydrogen fire)
- Evaluate whether the facility considered other catastrophic environmental events

## Get Expert Help

- Consider hiring a third-party consultant for assistance in complex areas of licensing review is areas such as:
  - Neutron shielding
  - Tritium handling

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Licensing needs in phases of fusion licensing

Phase	Sample licensing needs
Calibration	<ul style="list-style-type: none"><li>• Californium-252 or Americium-Beryllium neutron source</li><li>• Portable neutron generator</li></ul>
Research and Development	<ul style="list-style-type: none"><li>• Multiple reviews for increased shielding as commissioning progresses</li><li>• Tritium, depleted uranium (Getter bed)</li><li>• Potential exemptions for air emissions in early stages</li><li>• Financial assurance for decommissioning</li></ul>
Demonstration/ Pilot	<ul style="list-style-type: none"><li>• Normal emissions of <math>3.7 \times 10^{12}</math> to <math>3.7 \times 10^{13}</math> Bq (100 to 100,000 Ci) of tritium</li><li>• Tritium monitoring and handling equipment</li><li>• Activation products</li><li>• Emergency planning (if/as needed)</li><li>• Environmental monitoring</li></ul>
Commercial	<ul style="list-style-type: none"><li>• Full-scope licensing</li></ul>

## CRCPD's Committee on Commercial Nuclear Power (E-47)




Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*




# Other Licensing Considerations

- Fuel
- Tritium
- Environmental Reviews
- Dose
- Monitoring
- Waste
- Neutrons and Charged Particles

## Standard ALARA

-  • Limit **time** around radiation.
-  • Increase **distance** from the source of radiation.
-  • Use **shielding** between the source of radiation and yourself.

## Tritium ALARA

-  • Limit **time** in tritium areas.
-  • Increase **ventilation** to reduce concentration and activity.
-  • Practice **decontamination** on surfaces and equipment.

CRCPD's Committee on Commercial Nuclear Power (E-47)

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

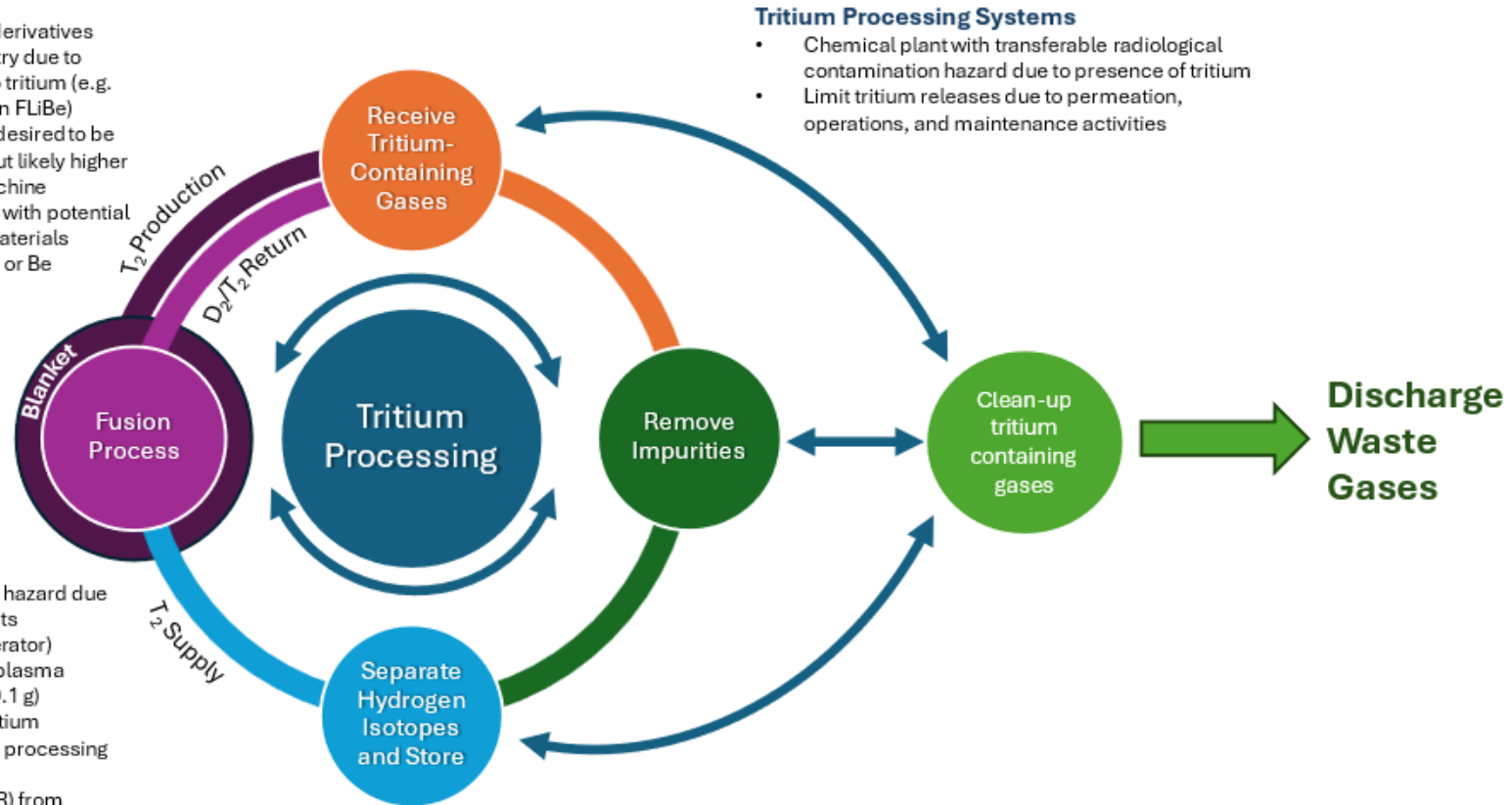
# Typical Tritium Fuel Cycle Considerations for a D-T Fusion Machine with Blanket Integration

## Breeding Blanket

- Proposed breeding technologies vary significantly
- Contains tritium derivatives based on chemistry due to conversion of Li to tritium (e.g. LiT in Pb-Li or TF in FLiBe)
- Tritium inventory desired to be maintained low but likely higher than in fusion machine
- High temperature with potential for air sensitive materials (eg Pb-Li, LiT), TF, or Be

## Fusion Machine

- Primarily a radiation hazard due to activation products (Similar to an accelerator)
- Tritium inventory in plasma likely to be small (<0.1 g)
- Minor amounts of tritium compared to tritium processing systems
- Material At Risk (MAR) from cryogenic pellets/gas for fueling, tritiated dust (e.g. W or Be) from first wall or other areas of tritium uptake



## Tritium Processing Systems

- Chemical plant with transferable radiological contamination hazard due to presence of tritium
- Limit tritium releases due to permeation, operations, and maintenance activities

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Activation Products...“elements 3-83”

- Absolute quantity of activation products difficult to predict a priori
  - Due to material impurities (e.g., trace cobalt concentration in steel)
  - Exacerbated by isotopes with short half-lives (< 5 min), where activities can be very high for very short periods of time
- Approaches vary by states:
  - License elements 3-83 as two line items:
    - half-lives less than or equal to 120 days
    - greater than 120 days
  - License “as needed” quantities of elements 3-83 due to activation
    - Revised as the number as impurities become known through operational experience
  - Beam time limit in lieu of a Becquerel/Curie limit
    - directly corresponds to how much activated material is created

**CRCPD’s Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Inspection Best Practices

- Develop a unified inspection strategy for assessing a fusion licensee's compliance with radiation control regulations.
- Perform smaller inspections more frequently by focusing on a different subset of program areas on each inspection.
- Rotate inspector responsibilities so that radiation control programs maintain depth of expertise for fusion licensees.
- Tailor early inspection of fusion machines to the phase of commissioning and operation of the facility.

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Emergency Planning

- Licensees must *consider* need for emergency plan when possession limits exceed:
  - $7.4 \times 10^{14}$  Becquerels (20,000 Ci) of tritium (assuming a 50% release fraction) per 10 CFR 30.32(i)
  - 10 CFR 30.72 Schedule C thresholds for other activation products
- Challenge - No commercial fusion machines for energy production currently in operation
  - Emergency planning for fusion machines is largely based on theoretical analyses and simulations
  - May not fully capture the complex and dynamic nature of a real-world emergency
- NRC Regulatory Guide 3.67 “Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities” provides guidance for Emergency Plans but...
  - No published guidance for performing or reviewing a dose evaluation
  - Case-by-case reviews to date
  - Third party assistance
- Other considerations
  - Who leads response?
  - What sampling capabilities are required offsite?

**CRCPD’s Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# User/Operator Training

- Department of Energy (DOE) guidance for
  - tritium handlers
  - operations and maintenance personnel
- Best practices:
  - Individuals that operate fusion machines should receive training in system operation as well as training for handling radioactive material used as fuel or produced by a fusion machine.
  - When a fusion machine uses radioactive fuel (e.g., tritium), at least one operator should be named on a radioactive materials license.

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Cyber Security

- Challenge to address
  - Uncertainty in authority to regulate
  - Beyond Knowledge-Skills-Abilities (KSA) of most inspectors
- Important to consider
  - Critical role in systems managing the magnetic fields, particle accelerators, cryogenic systems, vacuum system, tritium handling, radiation monitoring, and other essential operations
  - Facilities should continue to assess the impact of computer system failures
- Possible Solution - Voluntary compliance guidelines
  - not tied to a materials license
  - Verify program in place, not cybersecurity details

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Other details

- Resource list
- Access
- Future updates

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*

# Questions/Comments

- [Jeffrey.Semancik@ct.gov](mailto:Jeffrey.Semancik@ct.gov)
- 860-597-3628

**CRCPD's Committee on Commercial Nuclear Power (E-47)**

Conference of Radiation Control Program Directors, Inc.

*A Partnership Dedicated to Radiation Protection*