From:	dobos@infrotonfusion.com
To:	Edward Harvey
Cc:	andras.pungor@gmail.com
Subject:	[External_Sender] Re: FW: Fwd: Request for Pre-Application Meeting and Submission of Regulatory Engagement Plan – Infroton Fusion Microreactor
Date:	Thursday, May 8, 2025 12:01:19 AM

Subject: Re: Follow-up on Our Conversation

Dear Ed,

It was a pleasure speaking with you and your colleagues today.
Thank you very much for the constructive and engaging discussion.

I would like to confirm that the information and attachments provided in our original request are **not sensitive** and **do not constitute business secrets**.
This field is **protected by patents**, and the shared materials are considered **public**.
I fully endorse this clarification.

We look forward to receiving your summary email and to continuing our collaboration.

Thank you
Andras
www.infrotonfusion.com

2025-05-07 20:53 időpontban Edward Harvey ezt írta:

> Mr. Pungor,
>
> It was a pleasure speaking with you today. We are working on an email to summarize the references in our discussion that we will send to you soon.
>
> In the meantime, can you please confirm that the information and attachments you sent in your initial request are not sensitive or proprietary?
>
> Thank you,
> Ed
>
> ---
>
> **From:** dobos@infrotonfusion.com <dobos@infrotonfusion.com>
> **Sent:** Sunday, April 27, 2025 12:56 PM
> **To:** MSHD Resource <Meta_System_Help_Desk.Resource@nrc.gov>
> **Subject:** [External_Sender] Fwd: Request for Pre-Application Meeting and Submission of Regulatory Engagement Plan – Infroton Fusion Microreactor

Subject: Request for Pre-Application Meeting and Submission of Regulatory Engagement Plan – Infroton Fusion Microreactor

To: nrc.projectmanager@nrc.gov

Dear John P. Segala, Chief Advanced Reactor Licensing Branch 2
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

I hope this message finds you well.

On behalf of **Infroton Fusion Inc.**, I am pleased to submit our **Regulatory Engagement Plan** regarding the licensing approach for our **Infroton Fusion Microreactor**.

We respectfully request to initiate a **pre-application engagement process** with the U.S. Nuclear Regulatory Commission (NRC), in accordance with the guidance outlined in **ML21145A106** (Draft Pre-application Engagement to Optimize Advanced Reactors Application Reviews).
We seek feedback on our proposed licensing path, regulatory framework interpretations, and the technical topics described in the attached document.

Project Overview:

- The Infroton fusion microreactor will be **manufactured in Hungary**, in collaboration with the **Wigner Research Centre for Physics**.
- The first unit is planned for **deployment and commissioning in the United States** between **2027 and 2028**, at a site to be selected in the future.

In addition, we kindly propose that the NRC consider further steps to stimulate the growth of the fusion energy industry, based on the following regulatory innovations:

Proposal for Design-Specific Licensing (DSL) for Fusion Energy Systems:

- A **single, nationwide type license** for a certified fusion machine, allowing streamlined deployment across multiple sites without requiring repetitive site-specific evaluations.
- Pre-approval of design and environmental review, ensuring consistent safety and environmental standards.
- Rigorous manufacturing and operational oversight, with regular inspections and compliance reporting.

Key Elements of DSL Approach:

- **Design Registration:** Submission of comprehensive design, safety, environmental, and manufacturing documentation.
- **Simplified Licensing:** Site operators can reference the approved design without undergoing full individual licensing processes.
- **Ongoing Oversight:** Periodic inspections and required operational reports maintain safety and regulatory compliance.

The rapid evolution of fusion technology opens a unique opportunity to revolutionize the energy sector.
Infroton anticipates that the first commercial fusion power plants based on **deuterium-only fuel** could begin operation around **2030**, potentially reaching over **30 GW of installed capacity**.
A DSL framework could significantly accelerate the widespread, safe, and cost-effective deployment of fusion energy solutions, similarly to the way that type certifications enable

efficient production and regulation in the aviation sector.

Attached to this message, you will find:

- **Infroton Fusion Inc. – Regulatory Engagement Plan (Version 1.0, 2025-01-10)**

We would greatly appreciate the opportunity to schedule an initial pre-application meeting to discuss these proposals in more detail and to establish a constructive dialogue moving forward.

Please feel free to contact me directly to coordinate the meeting or to request any further information.

Thank you very much for your time and consideration. We look forward to working together toward the next generation of clean energy.

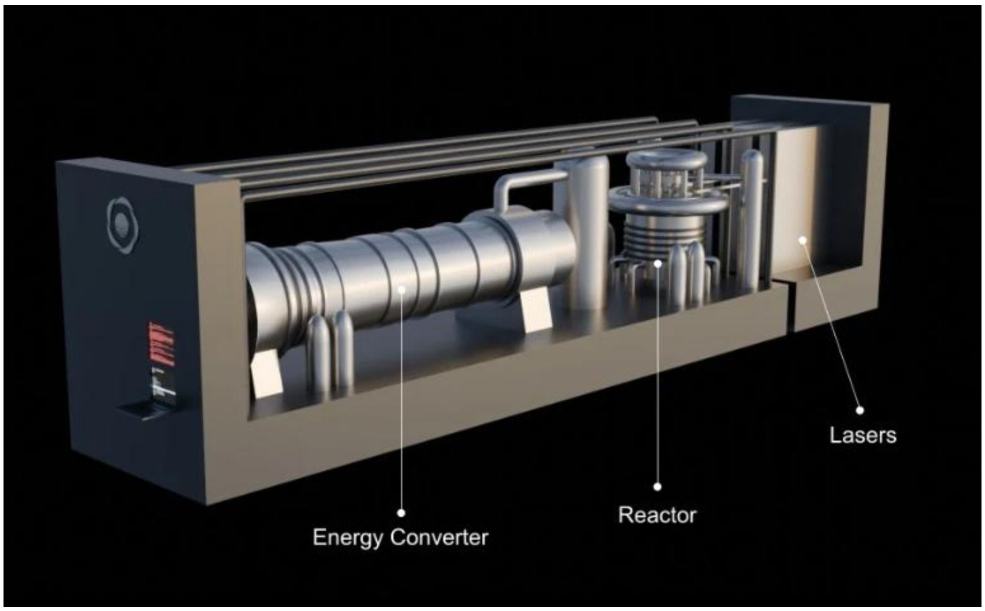
Sincerely,
János Dobos
CEO – Infroton Fusion Inc.
320 Post Road, Suite 150, Darien, CT 06820
dobos@infrotonfusion.com
www.infrotonfusion.com

Infroton Reactor Operator's Manual

WGM MIF 20-40-60-80 (+2) MW 01-01-2025

Our Vision: Clean, sustainable fusion energy everywhere, for everyone

We base our sustainable future on the inexhaustible deuterium reserves found in the oceans.



The equipment of **Infroton Fusion Inc.** operates with easily accessible deuterium fuel and is capable of producing **clean, sustainable electrical energy at a cost of 6.5 USD/MWh**.

Infroton fusion microreactors integrate into an operational fleet upon activation. Centralized remote monitoring allows for **emergency shutdowns, data collection, and trend analysis**, resulting in **enhanced safety**.

Recommended Applications: Infroton fusion microreactors are suitable for: **Data centers, Industrial facilities, Seawater desalination plants, Green hydrogen production plants, Backup energy supply for renewable sources like solar and wind power, Communities seeking independence from large electrical grids, Remote regions without traditional energy infrastructure, Temporary energy solutions in regions with failing infrastructure.**

Approval Date: 01-01-2025
www.infrotonfusion.com

WARNING

The equipment may only be operated by individuals officially certified and trained by INFROTON®, possessing a valid training certificate issued by INFROTON.

Before using the INFROTON equipment, read the **entire updated manual**, including the attached **laser and energy converter handbook**.
Improper use of the equipment may result in hazardous radiation exposure or malfunction.

AVOID DIRECT CONTACT WITH THE EQUIPMENT.

Compliance with safety regulations and standards for fusion reactors, lasers, and energy converters is **crucial**.

WARNING: The technical content of this document is subject to change without prior notice due to product modifications. INFROTON assumes no responsibility for the use of equipment without an officially signed commissioning protocol.

Table of Contents

1 INTRODUCTION

1.1 Purpose of the Manual

This document provides a **comprehensive technical and operational description** of the **20 (+2) MW Whispering Gallery Mode (WGM) spin-polarized magnetic inertial fusion (MIF) power plant**, developed by **Infroton Fusion Inc.**. The manual serves as a detailed **guide for installation, operation, maintenance, and safe usage** of the system.

1.2 Overview of the Power Plant

The **Infroton Modular Fusion Power Plant** is a **pioneering technology** utilizing **laser beams and liquid lead cooling** to sustain fusion reactions.

Key Components:

- **Whispering Gallery Mode Lasers:** Laser beams circulate tangentially inside the capsule fusion targets, **optimizing plasma compression and temperature**.
- **Liquid Lead-Cooled Reactor:** Ensures effective **heat dissipation** using liquid lead, known for its excellent thermal conductivity.
- **Capsule Targets:** Fusion deuterium fuel is encapsulated and automatically fed into the reactor.
- **Energy Converter (typically a steam turbine generator):** Converts thermal energy from fusion reactions into **electrical power**.

1.3 Applications

The **Infroton Fusion Power Plant** is an **ideal solution** for:

- **Industrial facilities**
- **Utility networks**
- **Remote regions**
- **Weather-independent backup for solar and wind energy systems**

Its **compact design and modular structure** allow for **rapid deployment and scalable capacity expansion**.

1.4 Target Audience, This document is primarily intended for:

- **Operations Engineers**
- **Maintenance Technicians**
- **Nuclear Safety Experts**
- **Laser Technology and Energy Conversion Specialists**

1.5 Related Documents and Resources

- Official Infroton Fusion Website: www.infrotonfusion.com
- Technical Attachments and Specifications
- Steam Turbine Documentation
- Laser System Documentation

1.6 Receipt of Equipment

Upon receipt of the equipment, **carefully inspect it for any damages**.

2 SAFETY REGULATIONS

2.1 General Safety Regulations

During the operation of **Infroton reactors**, **nuclear, laser, and mechanical safety** is of utmost importance. All operation and maintenance activities must comply with **international standards** and **local regulations**.

2.2 Radiation Protection Rules

- **Radiation levels must be continuously monitored.**
- Workers must wear **appropriate radiation protection equipment**.
- Immediate action must be taken if **radiation safety limits are exceeded**.

Maximum Radiation Values:

- **Gamma Radiation:** 1 mSv/hour
- **Neutron Flux:** 10^6 n/cm²/s

2.3 Laser Safety Regulations

- Only **qualified personnel** may operate laser equipment.
- **Protective eyewear** is mandatory during laser operation.
- **Hazardous laser zones** must be clearly marked.

2.4 Mechanical Safety

- **Protective covers** on rotating parts must not be removed.
- Maintenance on **pressurized systems** can only be performed when the system is shut down.

Failure Handling Steps:

1. Activate the **emergency shutdown button**.
2. **Evacuate** the work area immediately.
3. Notify **technical staff and Infroton support**.

2.5 Emergency Protocols

- Emergency shutdown protocols must be **activated immediately** during system failures.
- **Regular emergency drills** must be conducted.

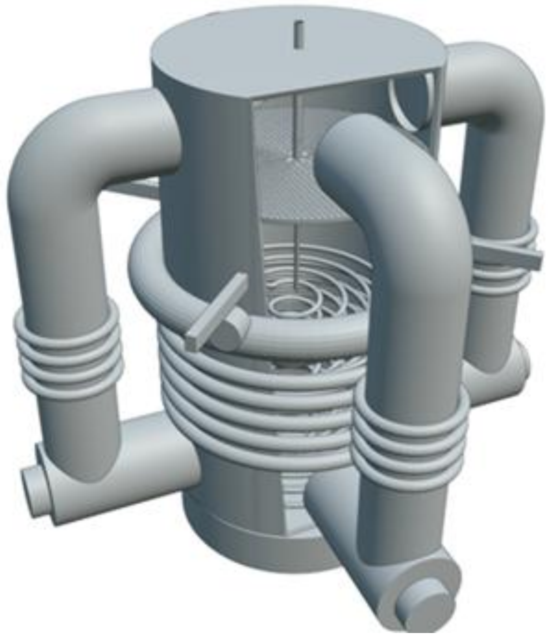
3 TECHNICAL DATA

3.1 General Technical Specifications

Parameter	Value
Power Output	20 – 40 – 60 – 80 MWe (+2 MWe internal use)
Dimensions	2.4 m wide × 3.3 m high × 12 m long (reactor with lasers) + energy converter: 2.4 × 3.3 m / 12 m
Annual Production per Plant	160,000 MWh + 16,000 MWh for internal use
Lifetime	25 years
Firing Frequency	1 Hz (1 shot/sec) – 2 Hz – 3 Hz – 4 Hz (Repetition Rate)
Fusion Energy Output	100 MWh (1 Hz), 200 MWh (2 Hz), 300 MWh (3 Hz), 400 MWh (4 Hz)
Conversion Efficiency	22%
Material Requirement per Target	1 mg cryogenic deuterium
Hourly Material Requirement (22 MWe)	3,600 targets/hour
Annual Material Requirement (22 MWe)	32 kg/year deuterium (32 million targets/year)
Cost per MWh	6.5 USD/MWh (Material: 70,000 USD/160,000 MWh = 0.44 USD/MWh, Energy: 0 (self-sustained), Other: 6.06 USD/MWh)

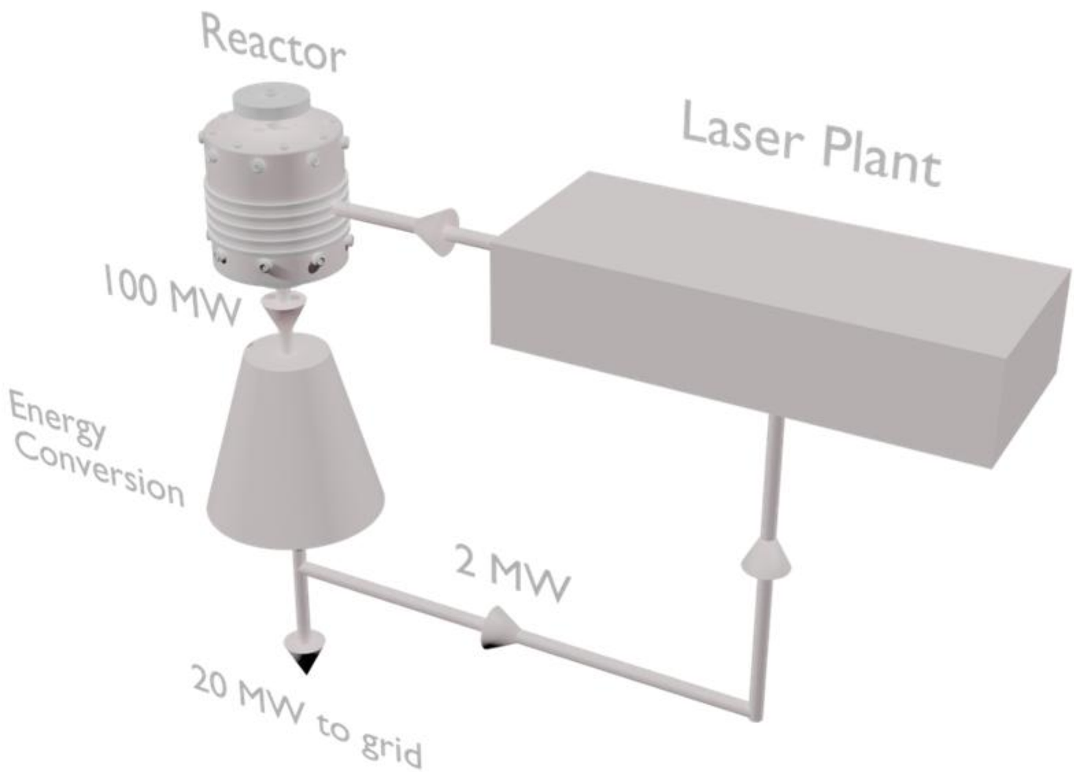
3.2 Reactor Thermal Specifications

- **Reactor Type:** WGM Magnetic Inertial Fusion Reactor (MIF)
- **Maximum Liquid Lead Temperature:** 350°C – 650°C
- **Maximum Steam Pressure and Temperature:** 150 bar, 550°C
- **Return Steam Pressure:** 10 bar, 200°C



Main Fusion Reactor Body Parameters

1. **Reactor Size:** Diameter: 1.5 m, Height: 1.8 m, Wall Thickness: 10 mm
2. **Reactor Material:** Corrosion-resistant steel, resistant to heat and lead.
3. **Bottom Tank Plate:** Fixed welded structure with a lead drain nozzle (300 mm diameter).
4. **Tank Cover:** Bolt-fastened, removable (with vacuum insulation) and equipped with a feed nozzle.
5. **Lead Shower Tray:** A circular plate (20 mm thick, 1.5 m diameter) with densely spaced holes (20 mm diameter, 17.5 mm spacing). Above it is a 40 cm thick lead layer.
6. **Spiral Tube Heat Exchanger:** Diameter: 0.9 m, Height: 0.8 m, 60 m of 20 mm diameter spiral tubes with 2 mm wall thickness, supported vertically to prevent deformation.
7. **Lead Propeller Pump (4 units):** Pumps extract 650°C liquid lead from the bottom, pass it through the heat exchanger, cool it to 350°C, and return it to the reactor through four transport tubes. **Pump Capacity:** 4 × 75 liters/s = 600 liters/s.
8. **Lead Transport Pipes (4 units):** Diameter: 300 mm, Height: 1.8 m.
9. **Electric Heaters:** 14 kW electric heaters installed on the tank wall and bottom for lead temperature maintenance (used during annual maintenance).
10. **Laser Input and Camera Windows:** Four windows (50 mm × 50 mm) installed on the reactor wall. The window material (e.g., glass or quartz) must transmit laser light at the correct wavelength and withstand laser intensity.
11. **Vacuum Ports (4 units):** Diameter: 100 mm, connected to a 100 mm circular vacuum ring. **Pre-Vacuum Pump Speed:** 10-20 m^3/h.
12. **Safety and Monitoring Elements:** Temperature sensors and X-ray diagnostics for structural monitoring.



Visualization of Infroton fusion microreactor operating status

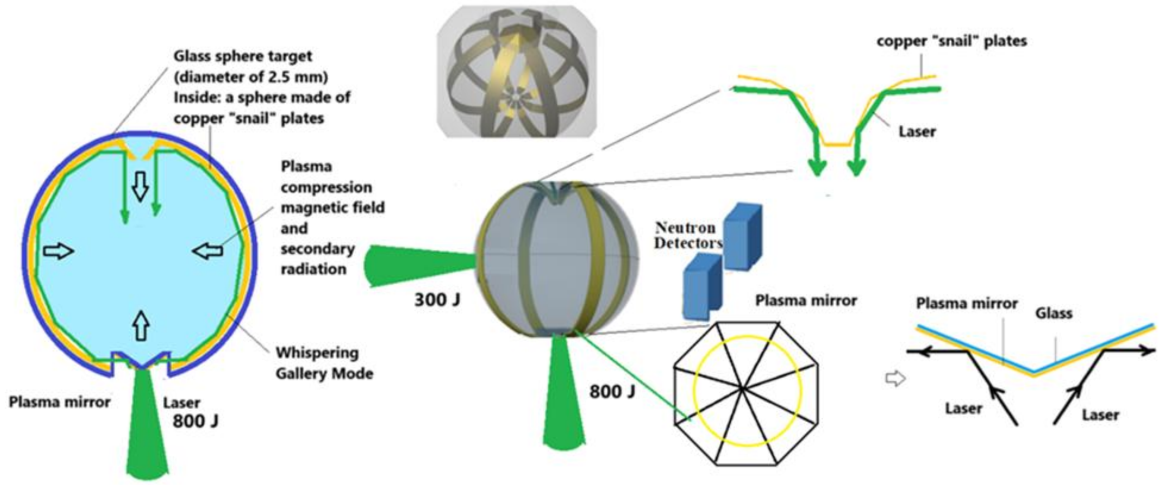
3.3 Target Design (Manufactured by General Atomics)

Target Structure:

- **Material:** Quartz glass capsule with a **300-micron wall thickness**.
- **Internal Diameter: 2.5 mm**.
- **Fuel: 1 mg of spin-polarized deuterium gas**.

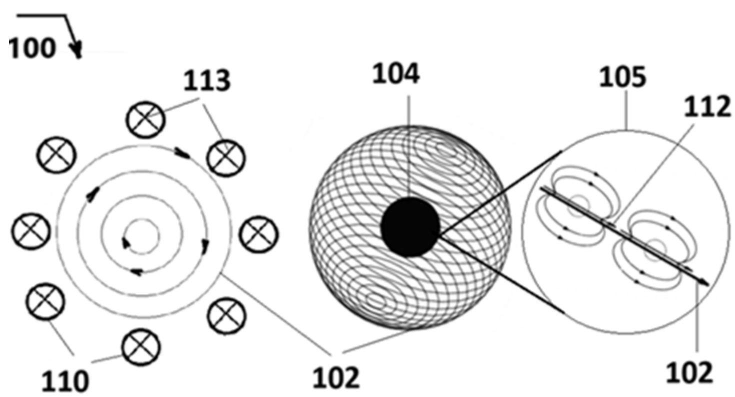
Internal Configuration:

- **Eight Copper Half-Snail Plates:**
  - **Thickness:** 30 microns
  - **Width:** 200 microns
- These copper half-snails serve as **waveguides for laser beams**, enabling **Whispering Gallery Mode (WGM)** propagation.



Whispering Gallery Mode (WGM)

- **Laser Beam Propagation:** Laser beams circulate tangentially along the **copper half-snail surfaces**, forming a **Whispering Gallery Mode pattern**.
- **Magnetic Field Generation:** The laser interaction generates an **intense magnetic field (100–250 Tesla)** within the spherical capsule.
- **Spin-Polarized Fuel Advantage:** The **spin-polarized deuterium gas** enhances the probability of fusion reactions, even at lower laser intensities.



Fusion Mechanism in Whispering Gallery Mode (WGM)

1. **Spherical Configuration of Half-Snail Targets:**
   - Eight **half-snail copper targets (110)** are arranged in a **spherical configuration** inside the quartz capsule.
2. **Laser Interaction:**
   - Eight **whispering gallery mode photon beams (101)** are directed at the **upper edges** of the half-snail targets.
   - The lasers circulate along the **copper snail surfaces**, propagating in **Whispering Gallery Mode**.
3. **Energy Transfer:**

   - Heated **electrons** in the copper snail structures transfer energy to **surrounding cooler particles**, generating **spin currents (113)**.
4. **Magnetic Field Formation:**
   - These spin currents induce a **strong, spherical magnetic field (102)**, which remains interconnected throughout the capsule.
5. **Plasma Compression:**
   - The magnetic field compresses the **plasma (104)**, containing **spin-polarized deuterium, tritium, and helium-3 ions (105)**.
6. **Spin Alignment:**
   - The **spin orientation (112)** of the fuel ions aligns with the lines of the **magnetic field (102)**, becoming increasingly concentrated toward the **center of the sphere**.
7. **Dynamic Magnetic Interaction:**
   - The ions' spins continuously align and adjust to the **circular magnetic field pattern**, undergoing **Larmor precession** around the magnetic lines.
8. **Increased Fusion Cross-Section:**
   - The collective spin precession enhances the **fusion cross-section**, maintaining **spin polarization** even under extreme conditions of **high temperature and collisions**.
   - This reduces the **Coulomb barrier**, facilitating **effective particle interactions and sustained fusion reactions**.

4 SYSTEM DESCRIPTION

4.1 Main Components

- **Reactor Module:** Includes the fusion reactor, lead cooling circuit, and control systems.
- **Laser System:** Plasma-generating and magnetic field-generating lasers.
- **Energy Conversion System:** Steam turbine and generator.
- **Target Feeding System:** Automated capsule feeding mechanism.

4.2 System Configuration

Infroton fusion reactors are built, delivered, and operated as **complete energy production facilities**. This eliminates most of the traditional construction tasks associated with reactor deployment, offering several advantages:

- **Pre-Testing:** Reactors are tested in the factory before delivery to ensure compliance with all specifications.
- **Reduced Site Preparation:** No on-site assembly is required upon delivery.
- **Enhanced Monitoring:** Shipment records ensure no unexpected stress occurred during transportation.

Compact Size Advantages:

- Avoids large industrial buildings for housing reactors.
- Simplifies fuel refueling using **automated target capsules**.
- Enhances **remote maintenance and control** via a centralized command center.

Safety Features:

- The system defaults to a **safe shutdown state** in case of failures.
- Backup heating for liquid lead is provided by a **diesel generator** until a service vehicle arrives.
- Real-time data analysis using **machine learning algorithms** quickly identifies anomalies.

Operational Philosophy:
Infroton reactors can be **remotely monitored and controlled**, significantly minimizing on-site personnel requirements. This setup ensures efficient and secure operation, even in the most isolated environments.

5 INSTALLATION AND COMMISSIONING

5.1 Installation Requirements

- **Site Preparation:** Ensure adequate space and necessary utilities are available.
- **Mechanical Installation Procedures:** Follow detailed guidelines for mechanical setup.
- **Electrical Connections:** Properly establish power connections and verify all electrical systems.

5.2 Commissioning Steps

1. **System Inspections:** Perform regular inspections and verify all components.
2. **Startup Protocols:** Follow documented startup procedures.
3. **Calibration Procedures:** Ensure all instruments are accurately calibrated.

Scalability and Flexibility: Infroton expects to manufacture thousands of fusion reactors annually, addressing both permanent and temporary energy solutions. Each reactor is built to the **same specifications**, ensuring compatibility across various deployment sites.

Site Selection: Reactors are designed for flexibility and can be **temporarily stored** until deployment. Regulatory compliance is managed with local authorities before final site activation.

Fuel and Plasma Management:

- **Deuterium Fuel Capsules:** Each capsule undergoes **extreme pressure and temperature conditions** to initiate fusion. Deuterium is **non-radioactive**.
- **Plasma Safety:** Plasma (40 microns in diameter) dissipates quickly in the vacuum, cooling the lead bath to 650°C.

Neutron Production:

- Neutrons are slowed and absorbed by the **liquid lead bath**, converting kinetic energy into heat.
- **Reaction Pathways:**
    - D + D → T (1.01 MeV) + proton (3.02 MeV)
    - D + D → He3 (0.82 MeV) + neutron (2.45 MeV)

Secondary Reactions:

- D + T → He4 (3.5 MeV) + neutron (14.1 MeV)
- D + He3 → He4 (3.6 MeV) + proton (14.7 MeV)

The **magnetic field spin polarization** ensures **precise neutron emission control**.

6 OPERATING INSTRUCTIONS

6.1 Normal Operating Procedures

1. **Startup Process:**
    - Ensure all systems are in standby mode.
    - Verify liquid lead is at the correct operating temperature (350°C – 650°C).
    - Start the laser and diagnostic systems.
    - Initiate capsule feeding system.
2. **Performance Monitoring:**
    - Continuously monitor power output and reactor status.
    - Check temperature, pressure, and radiation levels in real-time.
    - Ensure proper synchronization between laser and capsule delivery systems.
3. **Routine Inspections:**
    - Regularly check cooling circuits, lasers, and diagnostic equipment.
    - Verify vacuum pressure and capsule alignment.

Remote Operations:
Infroton fusion reactors are designed to be operated remotely from a **centralized control center**. This approach ensures minimal on-site presence while maintaining high operational efficiency.

Control Philosophy:

- **Automatic Fail-Safes:** Immediate shutdown in case of anomalies.
- **Real-Time Data Analysis:** Machine learning algorithms optimize reactor performance and predict maintenance needs.

6.2 Performance Optimization

- **Parameter Adjustments:** Optimize laser pulse timing, energy levels, and capsule delivery intervals.
- **Cooling System Monitoring:** Ensure lead temperature remains stable.
- **Resource Management:** Monitor fuel and consumable supplies.

6.3 Handling Abnormal Operations

- **Sudden Power Drops:** Identify and resolve root causes using diagnostic systems.
- **Unexpected System Failures:** Follow troubleshooting protocols and notify technical support.
- **Emergency Shutdown Procedures:** Follow predefined emergency shutdown steps.

6.4 Shutdown Protocols

Planned Shutdown:

1. Stop the **capsule feeder system**.
2. Shut down the **laser systems**.
3. Deactivate the **energy converter system**.
4. Activate the **diesel generator** for lead heating.
5. Maintain liquid lead circulation.
6. Drain liquid lead using the **service vehicle**.

Emergency Shutdown:

1. Trigger the **emergency shutdown button**.
2. Stop capsule feeding and laser systems immediately.
3. Switch to backup power using the diesel generator.
4. Maintain liquid lead temperature and circulation.
5. Drain lead with the service vehicle if necessary.

6.5 Routine Maintenance Tasks

- Conduct **X-ray inspections** on reactor structures.
- Clean **cooling systems**.
- Calibrate and clean **laser systems**.
- Inspect and maintain the **capsule feeder system**.
- Service the **energy conversion system**.

6.6 Documentation and Reporting

- Maintain **operational logs**.
- Record **fault reports and maintenance activities**.
- Regularly update **performance metrics and safety audits**

7 MAINTENANCE PROCEDURES

- **Scheduled Maintenance:** Daily, weekly, monthly, and annual tasks.
- **Structural Inspections:** Routine X-ray monitoring of the reactor structure.
- **Cooling System Maintenance:** Ensure lead circulation and heat exchanger efficiency.
- **Laser System Calibration and Cleaning:** Maintain optimal beam alignment and power output.
- **Steam Turbine Service:** Regular turbine inspections and maintenance.
- **Capsule Feeder System Checks:** Ensure smooth capsule delivery and alignment.

8 TROUBLESHOOTING

- Data Analysis: Analyze real-time data from the central monitoring center.
- Automated Alerts: Address issues flagged by automatic fault detection systems.
- Emergency Shutdown: If a critical failure occurs, initiate the emergency shutdown protocol immediately.

9 FUEL HANDLING

- Deuterium Capsules: Non-radioactive and stable.
- Pressure Checks: Monitor capsule storage pressure daily.
- Fuel Delivery Rate: Adjustable between 1-4 Hz based on energy requirements.
- Spent Material Management: Annually remove approximately 200 kg of copper-glass slag.
- Tritium and Helium-3 Extraction Protocols: Follow strict guidelines for safe extraction and storage

10 SAFETY SYSTEMS

10.1 Key Safety Mechanisms

- **Automatic Shutdown Systems:** Immediate reactor shutdown during anomalies.
- **Overheat Protection:** Prevents damage caused by excessive temperatures.
- **Pressure Relief Mechanisms:** Prevents over-pressurization of critical components.
- **Radiation Monitoring:** Continuous neutron and gamma radiation monitoring.
- **Structural Integrity Checks:** Routine X-ray inspections of critical reactor components.

10.2 Safety Mechanisms

- **Lead Shielding:** Lead’s natural radiation shielding properties minimize the risk of radioactive contamination.

- **Passive Cooling Systems:** Ensures continuous safe cooling in emergency situations without operator intervention.

10.3 Fuel Cycle Management

- **Automated Fuel Feeding:** Deuterium-tritium capsules are automatically fed into the reactor core.
- **Residual Material Management:** Combustion byproducts remain as slag in the lead. Being lighter than lead, the slag can be easily removed from the surface using a slag removal system.
- **Radiation Stability of Lead:** Lead does not become radioactive during the fusion process.
- **Vacuum Environment:** The entire fusion process occurs in a vacuum, with steam separators installed before vacuum pumps to remove and recycle gaseous combustion byproducts.

10.4 No Radioactive Waste

- The system operates with **zero radioactive waste**, providing an **environmentally sustainable fusion energy solution**.

The **Infroton fusion reactor** stands out for its **unique installation and operational approach**. Its size and transportability enable highly flexible deployment options, combining modular construction, remote operation, and adaptable site selection.

- **Fuel Utilization:** The reactor uses deuterium fuel, with secondary D-T reactions increasing fusion efficiency.
- **Tritium Management:** Not all tritium participates in fusion immediately, requiring extraction and processing from the vacuum chamber.

10.5 Tritium Extraction from the Vacuum Chamber

- Gaseous combustion byproducts, including tritium, are extracted from the reactor's vacuum chamber using **vacuum pumps**.
- **Steam Separators:** Positioned before the vacuum pumps to remove contaminants and water vapor.

- **Isotope Separation System:** Extracted gas mixtures are processed in an isotope separation system that physically or chemically separates tritium from other gases (e.g., deuterium and helium).

Separation Methods:

- **Cryogenic Distillation:** Separates gases based on their boiling points.

- **Palladium Membrane Technology:** Only hydrogen-based gases pass through, allowing for effective tritium isolation.

10.6 Tritium Storage

- The separated tritium is stored in **special storage tanks** designed for long-term safe containment.
- **Tank Material:** Typically stainless steel or other tritium-resistant materials to minimize gas diffusion and corrosion.
- **Utilization of Isolated Tritium:**
    - Sold for **industrial or research purposes**.
    - Safely disposed of if unnecessary, often oxidized into **tritiated water (HTO)** and securely stored.

10.7 Continuous Monitoring

- **Leak Prevention:** Specialized sensors continuously monitor the storage and handling systems for even the smallest tritium leaks.
- **Real-Time Monitoring:** Data from monitoring systems are transmitted to a **remote control center** for immediate analysis and intervention if needed.

10.8 Safety and Environmental Measures

- **Atmospheric Emission Prevention:** Isotope separation systems operate in a **closed-loop configuration**, ensuring tritium does not escape into the environment.

Conclusion: With this **comprehensive tritium management process**, Infroton reactors ensure **safe and reliable operation**, minimizing environmental risks while adhering to **strict safety standards**.

11 DIAGNOSTIC SYSTEMS

- Real-Time Data Collection and Analysis: Continuous monitoring of key reactor parameters.
- Sensor Networks: Provide comprehensive data on temperature, pressure, radiation, and fuel usage.
- Performance Monitoring Tools: Enable predictive maintenance and optimization.

12 ENVIRONMENTAL IMPACT ASSESSMENT

- Radiation Emissions: Continuously monitored and managed within regulatory limits.
- Closed-Loop Cooling System: Prevents harmful lead vapor emissions.
- Waste Management Protocols: Safe handling and disposal of byproducts.

13 DECOMMISSIONING GUIDE

- Safe Equipment Dismantling: Performed by qualified Infroton personnel,
- Waste Management: All waste is handled and stored in compliance with regulations.

14 ENERGY PERFORMANCE DATA

Infroton guarantees the operational efficiency and energy performance parameters stated in this manual throughout the equipment's lifetime.

15 SPECIAL OPERATING MODES

- Energy Conversion Optimization: Adjustable energy conversion rates,
- Frequency Adjustment: Operates between 1 Hz (20 MW) and 4 Hz (80 MW) while maintaining self-sustainability.
- Scalable Power Output: Adaptable to changing energy requirements

.

Prepared by: János Dobos, CEO
Infroton Fusion Inc.
Version: 1.0
Date: 01-01-2025

Website: www.infrotonfusion.com

INFROTON FUSION Inc

Infroton

Title:	**Pre-Application Regulatory Engagement Plan for Infroton Fusion Microreactor**
Subject:	**Infroton Document**
Number:	**DOC-0A3E**
Revision:	**1.0**
Author:	**Janos Dobos**
Checked By:	**-**
Technical Reviewer:	**-**
Manufacturing Reviewer:	**-**
Nuclear Reviewer:	**-**
Approved By:	**-**
Approval Date:	**2025-01-10**

REVISION LOG

Rev.	Change Summary
1.0	Initial Release

CONTENTS

FIGURES

REFERENCES

[1] https://lasers.llnl.gov/news/fusion-ignition-and-the-path-to-inertial-fusion-energy

[2] T Pisarczyk, Strongly magnetized plasma produced by interaction of nanosecond kJ-class laser with snail targets, 2023, Plasma Physics and Controlled Fusion

[3] NRC SECY-23-0001 (Fusion regulation under 10 CFR Part 30)
ADVANCE Act of 2024 (US fusion policy update)
10 CFR Part 30 mint fő szabályozási alap (melléktermék anyagokra)
ML21145A106 (Guidance for pre-application engagement for advanced reactors

1 INTRODUCTION

Infroton Fusion, Inc. is seeking a commercial license for the Infroton fusion microreactor. This Regulatory Engagement Plan details Infroton's pre-application process by identifying:

- Unique design features
- Potential regulatory challenges
- Topics for technical discussions
- The anticipated licensing path
- A schedule of proposed activities

Infroton seeks input, feedback, and guidance in response to the information outlined in this plan in order to inform decisions and actions during the pre-application process, culminating in the submissions of a license application. Infroton understands the value of regulation and seeks to build a strong relationship. The Infroton Fusion Microreactor is classified under the "byproduct material" category per 10 CFR Part 30, and thus falls outside the scope of 10 CFR Part 50 licensing requirements for fission reactors.

For the first unit, Infroton plans to complete all the analysis, testing, documentation, and communications required within the existing framework. During this initial license application, we expect to identify areas for modernization in the process that would be beneficial in future applications and will share these observations with the NRC. Especially valuable will be guidance on the interpretation of regulations that were written for existing design and how those regulations should be applied to advanced reactors to achieve safer or more robust systems.

1.1 Communication

To establish accountability and facilitate communication, the main point of contact will be:

Janos Dobos

dobos@Infrotonfusion.com

320 Post Road, Suite 150 Darien, CT 06820

While the point of contact should be cognizant of all correspondence related to licensing, it is not a requirement that communication to or from Infroton go through the point of contact. Additional points of contact will be provided directly to the regulatory project manager.

2 BUSINESS MODEL

Details of Infroton's business model are provided to communicate the motivation behind design and operational decisions; each of these decisions are carefully formulated to meet an important customer requirement while complying with the intent of the regulation.

2.1 Size and Packaging

Infroton is a ~22 MWe fusion microreactor designed to fit within the physical envelope of a single shipping container, making it road, rail, air and sea transportable; by using a conventional shipping container, the need for specialized equipment or handling procedures is eliminated.

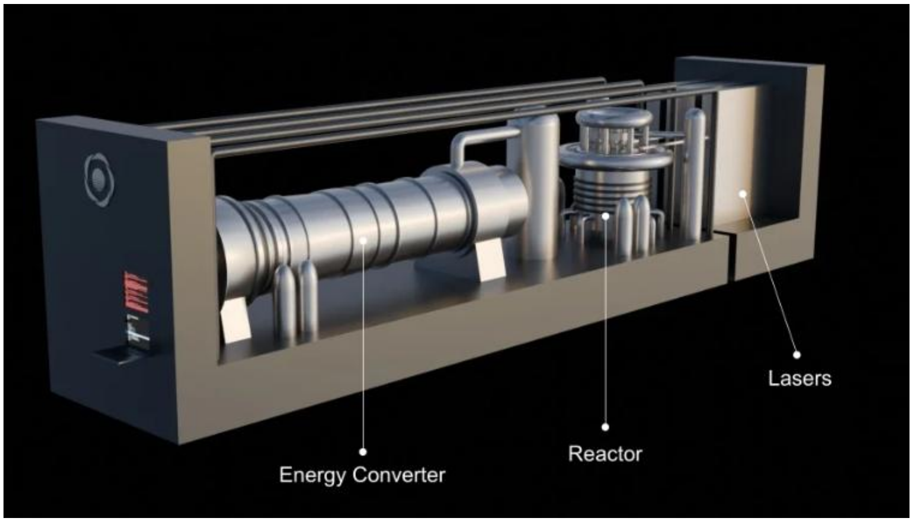


Figure 1 Graphical representation of a Infroton fusion microreactor

2.2 Production

Infroton fusion microreactors will be produced on an assembly line in a centralized manufacturing facility, eliminating the variation and defects associated with one-off projects while lowering unit cost and lead time. Microreactors will be built to meet a target production rate and will be insulated from changes in demand; this reduces staff and supply chain fluctuations which in turn reduces the associated defects, cost, and schedule impacts. This model may result in the temporary storage of completed microreactors. Deuterium fueling and Zero Power Critical (ZPC) testing will occur at the factory. This allows for the demonstration of functionality and defect screening in a controlled environment prior to deployment at a site. Note: Deuterium not a fissile material and, in its natural isotopic form, does not emit ionizing radiation. Screening for defects before shipping enhances system safety during transportation, upon arrival at the customer site, and prior to on-site ITAAC (Inspections, Tests, Analyses, and Acceptance Criteria) completion. A ZPC test conducted during factory acceptance eliminates uncertainty regarding the multiplication factor of the as-built product.

2.3 Operations

Infroton fusion microreactors will enter the operational fleet upon activation; remote monitoring of all microreactors from a central control room will allow data collection and trend analysis, yielding improved levels of safety. By operating numerous units of the same design, data across multiple microreactors will be collected and allow for design/operating limits to be validated against a broad and diverse sample, yielding tighter control and greater confidence in operating limits. Live monitoring during operations is an improvement that could both improve safety and meet the intent of modernization efforts. Observations that result in a software update or process change can be immediately pushed out to the entire fleet.

2.4 Potential Applications

Infroton Fusion Microreactors Proposal

We propose Infroton fusion microreactors for a wide range of applications, including: Data centers, Industrial facilities, Seawater desalination plants, Green hydrogen production, Backup power for weather-dependent solar panels and wind farms, Consumer communities seeking independence from large electrical grids, Power supply for remote regions not served by traditional grids.

Additionally, they can serve as temporary power solutions in regions where existing infrastructure has failed.

Fuel Supply and Remote Operation

The annual supply of deuterium fuel capsules required for an Infroton microreactor can fit on a single pallet, enabling continuous operation in remote locations.

Startup requires the expertise and equipment of the manufacturer, as the reactors are filled with liquid lead and initialized using specialized laser systems by the manufacturer.

In case of a shutdown, the circulation of liquid lead is ensured by a backup power system powered by either batteries or a diesel generator.

Remote Monitoring and Operational Efficiency

Remote monitoring capabilities allow for rapid response to observations, minimizing reliance on on-site personnel.

This setup ensures efficient operation and enhances safety, even in the most isolated environments.

Infroton fusion microreactors represent a reliable, sustainable, and scalable energy solution for both permanent and temporary applications in diverse environments.

3 DESIGN/UNIQUE FEATURES

Infroton Fusion Inc, building on the successful fusion experiments of the National Ignition Facility (US) (link), Professor Pisarcyk (1), and the Wigner Research Centre (2), as well as its own patented innovations, has developed a validated whispering gallery mode magneto-inertial fusion technology, powered by easily obtainable deuterium fusion fuel.

Infroton Fusion Reactor Overview

The Infroton fusion reactor is a whispering gallery mode laser-driven spin-polarized magnetic inertial fusion system that uses liquid lead coolant to extract thermal energy while moderating protons, alpha particles, gamma rays, and neutrons. Due to spin polarization, the direction of neutron emission can be controlled and designed.

Fusion Fuel: The reactor uses deuterium fuel capsules, which are exposed to extremely high pressure and temperature via lasers to initiate the fusion reaction. Deuterium is not a radioactive material by itself.

Plasma Handling: The magnetic inertial fusion plasma has a 40-micrometer diameter, and as such, the plasma itself does not pose a safety risk.

Neutron Production: When two deuterons fuse, two possible reaction channels occur:

- D + D → T (1.01 MeV) + p (3.02 MeV)
- D + D → He3 (0.82 MeV) + n (2.45 MeV)

These are followed by secondary reactions:

- D + T → He4 (3.5 MeV) + n (14.1 MeV)
- D + He3 → He4 (3.6 MeV) + p (14.7 MeV)
- Alpha particles and protons are confined within the plasma by the magnetic field.
- Neutrons transfer their energy in a 300 mm thick lead shower, preventing them from reaching the reactor walls.

The spin polarization enables precise control over the neutron emission direction.

Liquid Lead Cooling and Energy Collection:

- Fast neutrons transfer their energy to lead atoms through collisions, heating the lead.
- Lead efficiently absorbs neutrons and transfers heat to heat exchangers.

Conversion of Thermal Energy into Electrical Energy:

- The hot liquid lead generates steam through a heat exchanger.
- The steam drives a steam turbine generator, producing electrical energy.

Safety Mechanism:

- Lead possesses natural radiation shielding properties, minimizing the risk of radioactive contamination.
- The system includes passive cooling mechanisms for emergency scenarios.

Fuel Cycle:

- Deuterium-tritium capsules are automatically fed into the reactor core.
- Burn residues remain as slag in the lead, which, being lighter than lead, can be easily skimmed off the surface with a slag remover.
- The lead does not become radioactive during the process.
- The entire process occurs in a vacuum, with steam separators installed before vacuum pumps to remove and recycle gaseous combustion residues.

No Radioactive Waste:

The system produces no long-lived radioactive waste, enhancing environmental sustainability., making it an environmentally sustainable fusion energy solution.

The Infroton fusion microreactor is unique in how it will be deployed and operated; the proposed size and transportability of the microreactor are objectively ordinary but unlock unique considerations when taken in combination, such as unitconstruction packaging, remote operations, and flexible site selection.

In addition to these unique physical and operational considerations, Infroton's goal to deliver an inherently safe and robust product led us to invest heavily in our simulation and test infrastructure. As we progress through test campaigns, we will utilize internally developed software known as SimEngine that hosts our digital twin, which can be configured to represent any combination of physical and virtual hardware; these products will be used to qualify our controls software in accordance with NQA-1. Through continuous integration testing, the uncertainty of the inputs can be reduced significantly; furthermore, changes to either those inputs or the digital twin itself will automatically queue and re-run tests to identify any variation in the outputs and results.

Central to the setup of SimEngine and the creation of the digital twin has been a focus to ensure consistency and reproducibility, so that a given test configuration with the same inputs and initial conditions will produce the same outputs on different hosts. In doing so, our goal was to minimize the noise contributed by the operator or test hardware, which will allow increased regulatory efficiency as tools can be shared more readily between Infroton and the NRC.

Handling of Tritium Waste

Infroton microreactors use deuterium fuel, where tritium produced during D-D fusion reactions can undergo secondary reactions with deuterium. The D-T reaction is more likely to occur than the D-D reaction due to its lower thermal energy requirement. However, not all tritium may immediately participate in fusion reactions, so the tritium extracted from the reactor vacuum chamber must be treated to ensure safe and efficient operation.

Extraction of Tritium from the Vacuum Chamber

- Gaseous combustion byproducts, including tritium, are extracted from the reactor vacuum chamber using vacuum pumps.
- Steam separators are installed before the vacuum pumps to remove other impurities and water vapor.
- The extracted gas mixture is fed into an isotope separation system, which physically or chemically separates tritium from other gases (e.g., deuterium and helium).

Separation Methods:

- Cryogenic Distillation: Gases are separated based on their different boiling points.
- Palladium-Based Membrane Technology: Only hydrogen-based gases are allowed to pass through, enabling tritium isolation.

Tritium Storage

- The separated tritium is stored in special storage tanks designed for long-term safe containment.
- These storage tanks are typically made of stainless steel or other tritium-resistant materials to minimize gas diffusion and corrosion.
- The isolated tritium may either be:
    - Sold for industrial or research purposes.
    - Safely disposed of if not needed, often by oxidizing it into tritiated water (HTO) and storing it securely.

Continuous Monitoring

- To prevent tritium leakage, the storage and handling systems are continuously monitored using specialized sensors capable of detecting even the smallest leaks.
- Monitoring system data is transmitted in real-time to a remote supervision center for immediate response and intervention if necessary.

Safety and Environmental Measures

- Prevention of Atmospheric Release: The isotope separation systems operate in a closed-loop configuration, ensuring that no tritium escapes into the environment.

Conclusion: Through this comprehensive tritium management process, Infroton microreactors ensure safe operation while minimizing environmental risks and maintaining compliance with strict safety

3.1 Unit Construction

Infroton fusion microreactor will be built, shipped and operated as complete utilization facilities. This will eliminate the majority of the construction work typically associated with reactor builds and take further advantage of the benefits of manufacturing in a production facility. Site activation will also be greatly simplified: prior to shipping, an acceptance test can be performed at the factory and no further assembly or construction will be required when the microreactors arrive at their operating site. Post shipment, transportation vibration records can be reviewed to ensure that the unit experienced only expected and analyzed loads during transport.

3.2 Remote Operations

The reduced size of Infroton fusion microreactor eliminates many of the traditional operations associated with nuclear reactors, such as changes in power setpoint, refueling and on-line maintenance; these operations are either automated, performed at a central manufacturing facility, or made obsolete. This change requires a new model of operations, one in which numerous microreactors at multiple sites are managed remotely. Infroton is planning a concept in which microreactors are remotely monitored, utilizing increased connectivity and safety-automation to augment the capacity of a centralized control room. To support this approach, emphasis was placed on inherent safety wherever possible, designing a component or system that defaults to a safe condition and does not rely on instrumentation or controls that may fail. The table below summarizes the common safety concerns and the type of control implemented in comparison to traditional reactor designs.

If connectivity to a microreactor is lost or any unsafe condition occurs, safety-automation ensures that the system shuts down without the need for any external intervention. Infroton believes that increasing the amount and portability of reactor telemetry at this scale will dramatically modernize operations and increase safety in ways that were previously not possible, such as through the use of machine learning on incoming data to quickly identify outliers and by providing real-time access to a greater number of NRC users. Integral to this approach will be the use of software to create an inherently safe design by automating decisions based on test data and analysis, with trained operators supervising and intervening in the event of unexpected scenarios.

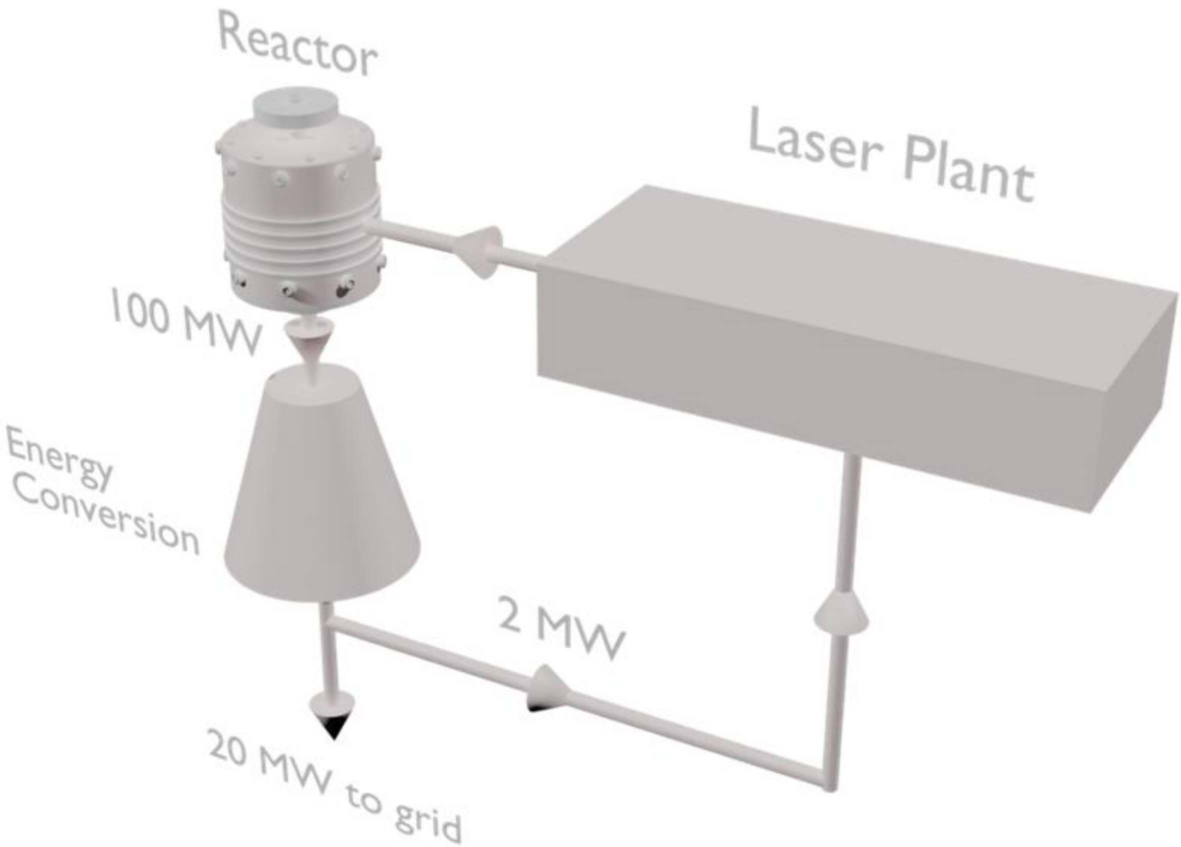


Figure 3 Visualization of Infroton fusion microreactor operating status

3.3 Site Selection

Infroton expects to produce on the order of thousand/year of Infroton fusion microreactors; these quantities—along with temporary installations and rapid response applications—require an efficient approach to addressing the environmental requirements and concerns regarding site selection. Each microreactor is built to the same specification while the unique characteristics for the final site are not known and cannot be considered ahead of time; therefore, Infroton is designing Infroton fusion microreactor to be tolerant of and compatible with a wide variety of potential sites.

4 REGULATORY CHALLENGES

Select topics with potential regulatory hurdles are highlighted in the sections below; Infroton expects to seek guidance from the NRC on these topics and will provide more detail and potential solutions in future exchanges.

Factory zero power functionality and safety verification tests.

Testing must occur at the factory to characterize the reactor, determine control drum angles, and validate that the build conforms with requirements; any nonconformances that do occur can be identified and rectified prior to shipping, avoiding risk in transport and operation. Infroton anticipates challenges with the lead time for advanced notifications ahead of fuel loading and reactor testing.

Infroton anticipates unique licensing approaches to support the building, fueling and testing of multiple microreactors at the manufacturing facility, potentially seeking additional, separate licenses for specific portions of the process.

4.1 Fueling and transportation

Fueling: Deuterium is loaded at the factory, which is not a radioactive material, so there is no transportation of fissile material. Infroton does not anticipate challenges with 10 CFR Chapter I, Part 71, which specifies the testing requirements for containers used in the transport of radioactive materials, as Infroton does not transport radioactive material.

4.2 Site Selection

Infroton proposes to pursue a standardized site evaluation envelope that addresses the bounding environmental and seismic conditions, thereby allowing streamlined future site approvals via simplified environmental assessments As noted in section 2.2, microreactors will be built at a steady rate and may be temporarily stored in inventory until ordered by a customer, therefore, the lead time between site selection and deployment will be truncated from a period of years to weeks or even days. Infroton anticipates challenges with the standard review time associated with licensing events (early site permitting, construction license, combined operating license).

Infroton plans to discuss with the NRC the feasibility of obtaining a construction permit for a "theoretical site" that encompasses the worst-case conditions of all expected future sites; to streamline the process, future applications for construction permits would be compared to the existing permit to verify that all parameters fall within the values of the originally issued permit.

4.3 Onsite Personnel

Infroton fusion microreactors are designed to be monitored and controlled by operators who are located at a geographically distinct and separate location from the installation site; while onsite security will be present to control physical access, no control or operation support buildings will be erected alongside the deployed microreactor. Infroton anticipates challenges with 10 CFR Chapter I Part 50 which requires a minimum number of operators at an onsite control room.

Infroton believes the intent of the requirement is to provide a specific level of oversight and monitoring, which will be achieved by redundant and secure connectivity between microreactors and numerous operators at a central control room. Additionally, given the fact that operator mistakes have been a large contributor to past accidents, Infroton envisions inherent software safety features beyond what is required by the regulation to provide safety beyond the level intended by the requirements in Part 50.

5 LICENSING PATH

Infroton Fusion Inc. is building a comprehensive, green deuterium-based fusion energy ecosystem that enables its partners to achieve their business objectives while contributing to the decarbonization of the economy.

As an initial step, Infroton will construct two state-of-the-art Gigafactories in North America and Europe, which will:

Assemble Infroton small modular fusion power plants,

Produce deuterium-based fusion fuel,

Manufacture up to 32 billion fuel capsules annually, each containing 1 mg of deuterium, ensuring a continuous fuel supply for Infroton Fusion Power Plants.

Gigafactory Capabilities:

Annual Capacity: 1,000 units of 20 MW Infroton modular fusion power plants.

Deuterium Production: 40,000 kg/year of clean, green fuel.

Modularity: The factories can be rapidly deployed near water sources anywhere in the world.

Infroton's Gigafactories represent a scalable and sustainable approach to delivering reliable fusion energy solutions on a global scale.Infroton is considering multiple licensing pathways, driven by the following key considerations:

- Work that must be repeated for each microreactor should be standardized and minimized
- Fueling and testing must occur at the manufacturing facility
- Approval should cover as many geographical sites as practicable

Multiple licensing paths are illustrated below and will be explored further to determine which path will best fit Infroton’s particular use case.

Infroton embraces an incremental validation approach that relies heavily on building and testing hardware; frequent test campaigns that verify engineering designs at component and subassembly levels help buy down risk long before a complete microreactor is manufactured. This results in a shortened schedule with high confidence.

Below are the test events planned to support Demonstration of Microreactor Experiments reactor DOME; data generated from these events may also contribute content to our license application..

- Jan 2026 – Reactor Pressure Vessel Hydrostatic Test. Validation of the pressure vessel design and build process, occurring prior to reactor assembly, gating the electrically heated passive cooling demonstration test and safeguards against a potential issue being passed along and affecting schedule.
- Apr 2026 – Electrically Heated Passive Cooling Demonstration Test. Test of the assembled, as-built reactor to validate the models and simulations used in designing the reactor. This also serves as an opportunity to gather data which is used to check assumptions and refine analysis tools.
- Oct 2026 – Assembly Validation Testing for Demonstration Unit. Build of the demo unit will be a pathfinder to improve work instructions and procedures and inform changes for production to improve quality and increase efficiency. Interactions across all assemblies and subsystems can be observed with physical hardware.
- Oct 2026 – Transportation of Assembled Unit. Transportation loads and concepts of operation are verified and modified as needed. Special tooling or handling fixtures are tested or designed if needed.
- Oct 2026 to Nov 2026 – Fueling. Material handling procedures are executed in a controlled environment.
- Jan 2026 – DOME Testing a: Proof of design and high-fidelity data collection, expected reactivity insertion for criticality, Reactor heatup , Power increase , Validates controls, software and procedures prior to certification of a commercial unit. Simulated failure demonstrates, cooling, shutdown modeling.

6 SCHEDULE

A Infroton fusion microreactor demonstration unit will be built and tested as part of the Demonstration of Microreactor Experiments (DOME), currently targeted for 2026. Infroton anticipates using this experiment and the data gathered from it to both inform and validate the design of the microreactor. As a result of this early demonstration and verification, Infroton anticipates completing the license application on an accelerated timeline; below is a graphical representation of test milestones and a sampling of topics for further discussion. A notional schedule with greater detail will be delivered in conjunction with future meetings to inform staffing plans and align support expectations; when selecting topics to include in this schedule, Infroton will take guidance from ML21145A106 (DRAFT Pre-application Engagement to Optimize Advanced Reactors Application Reviews).

Instrumentation and Control: Instrumentation must be provided to monitor variables and systems during normal operation, anticipated operational occurrences, and accident conditions to ensure adequate safety is maintained.

Monitoring Radioactive Releases: Measures must be in place to monitor radioactivity in the airspace of the reactor building, effluent discharge pathways, and the plant surroundings during normal operation, anticipated operational occurrences, and postulated accidents.

7 TECHNICAL EXCHANGES

The following items cover the technical information that Infroton plans to discuss during the pre-application phase to facilitate understanding with the NRC prior to submission of a formal application.

7.1 Meetings

Infroton anticipates engaging with the NRC on a number of topics to support the license application. The following is a list of potential areas for discussion:

- Application Schedule
- Licensing Path
- Code Interpretation and Compliance
- Gap Analysis
- Test Plans
- Digital Twin
- Risk/Technology
- Analysis Methods

Infroton will also conduct a series of proprietary, internal reviews to coincide with the design maturity and build schedule of the Infroton fusion microreactor demonstration unit. Where helpful in demonstrating compliance to regulatory requirements or otherwise beneficial in communicating information, Infroton will coordinate with NRC staff to attend these reviews.

7.2 White Papers

Due to the novel features utilized by the Infroton fusion microreactor to improve safety and increase operational efficiency, Infroton may submit white papers to explain how these features achieve the underlying intent of the regulatory framework. The list of potential topics for white papers include:

- Reactor Design. Primary and secondary coolant loops o Reactivity control and redundancy
- Operational Plans . Zero power factory testing. Remote monitoring and control
- Analysis and Assumptions o Worst-case siting conditions. Digital twin and simulation
- Regulatory Compliance. Principal design criteria. Consolidation of multiple licenses . Exceptions

The above list is not exhaustive and topics may be added, removed or revised throughout the preapplication phase.

Infroton Fusion Inc