

Development of a Compact Electron Accelerator for Livestock Odor Treatment

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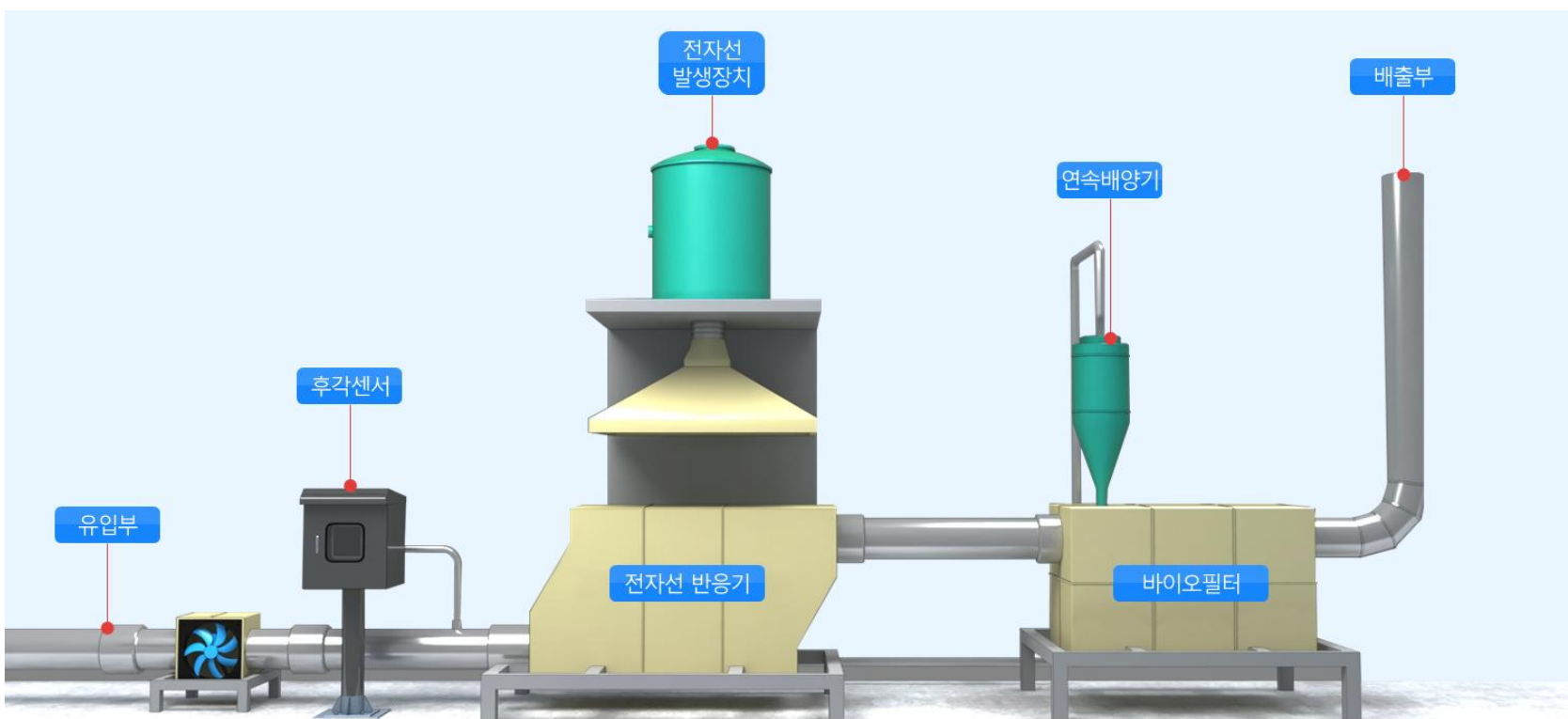
Abstract

Electron accelerators are utilized in various industrial fields, including medical applications. Industrial electron accelerators of this kind typically generate electron beams with energies within 10 MeV and powers ranging from tens to hundreds of kW. Currently, KAERI is developing a compact electron accelerator system to reduce livestock odor using an electron beam. Generally, Direct Current (DC) type electron accelerators are used for industrial gas treatment. However, since DC accelerators are large and heavy, they are primarily used in fixed facilities, which poses significant limitations for use in diverse user conditions. To address this issue, a pulsed electron accelerator was introduced to miniaturize the accelerator system. The developed system generates an electron beam with a beam energy of 500 keV and a beam current of 1 mA, driven by radiofrequency (RF) power. The entire system, including the gas reactor, radiation shielding, and auxiliary devices, is installed in a space of approximately 2.5 m (H) × 2.5 m (W) × 4 m (L) and weighs about 8 tons. This paper describes the details of the electron accelerator system under development.

* Kewword: Compact Electron Accelerator, Livestock Odor Treatment, Radiation Equipment Fab.

Livestock odor treatment system

Integrated system for odor treatment



Configuration of the integrated livestock odor treatment system

✓ The integrated livestock odor treatment system is designed to reduce and eliminate a variety of high-concentration odors produced in livestock facilities. It consists of an **electron accelerator** of which power is controlled by an odor sensor, a **gas reactor**, and a **biofilter** based on a porous carrier containing radiation-resistant microorganisms.

Electron accelerator module installed in a vehicle



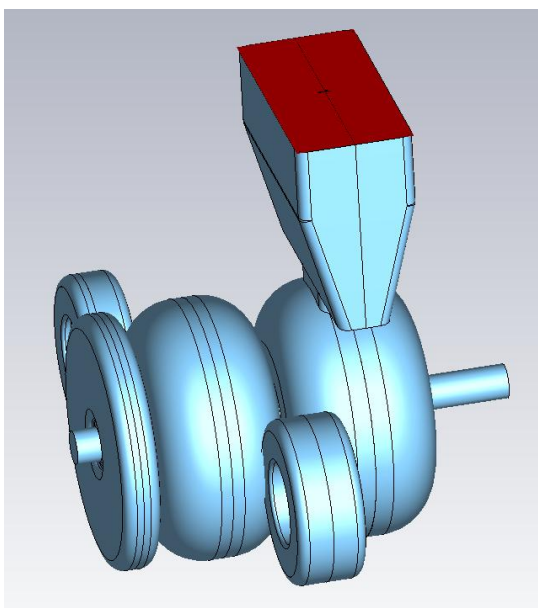
Accelerator mounted vehicle

Main parameters of accelerator and vehicle	
Parameter	Value
Electron beam energy	500 keV
Beam current (average)	1 mA (3 mA max)
Beam dose rate	1 kGy/s max
Module size	2.5 m x 2.5 m x 4 m (H x W x L)
Module weight	8 ton

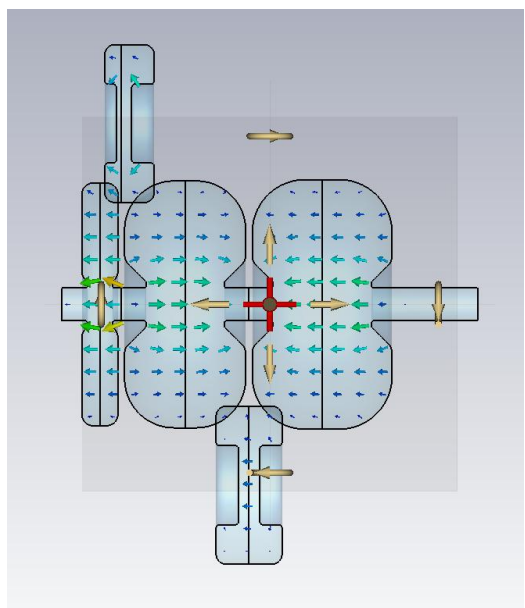
✓ The system's key components, the electron accelerator and the gas reactor, including their shielding, are modularized and designed to be mounted on a vehicle. This makes the system mobile and adaptable for use in various locations.

Electron Accelerator

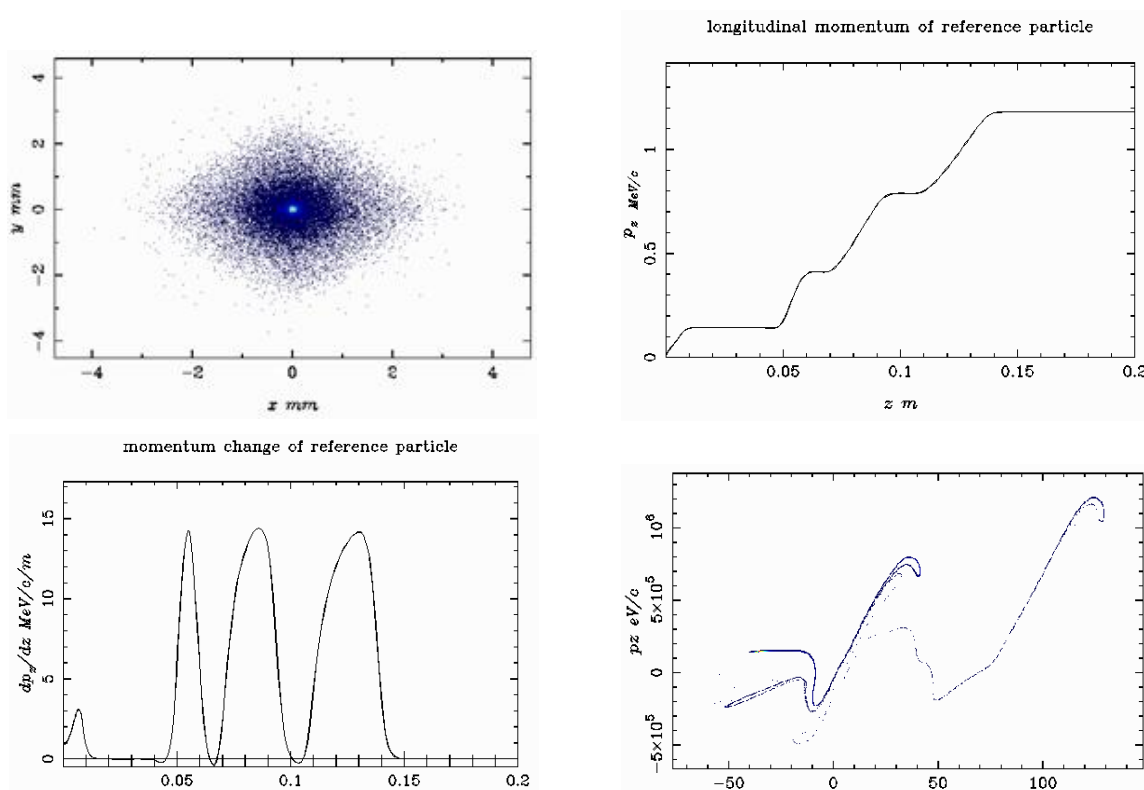
Pulsed electron accelerator



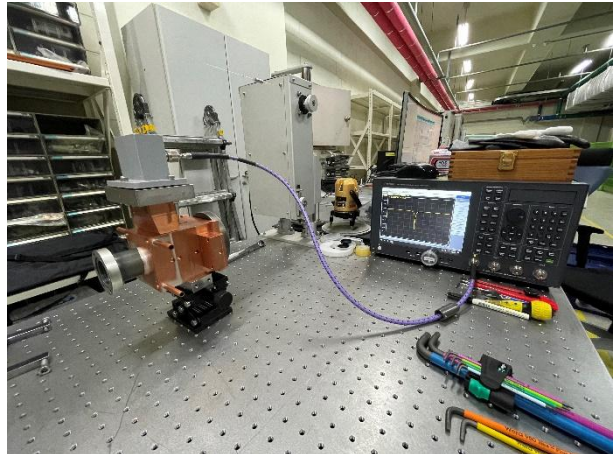
3D modeling of the RF cavity



CST simulation result



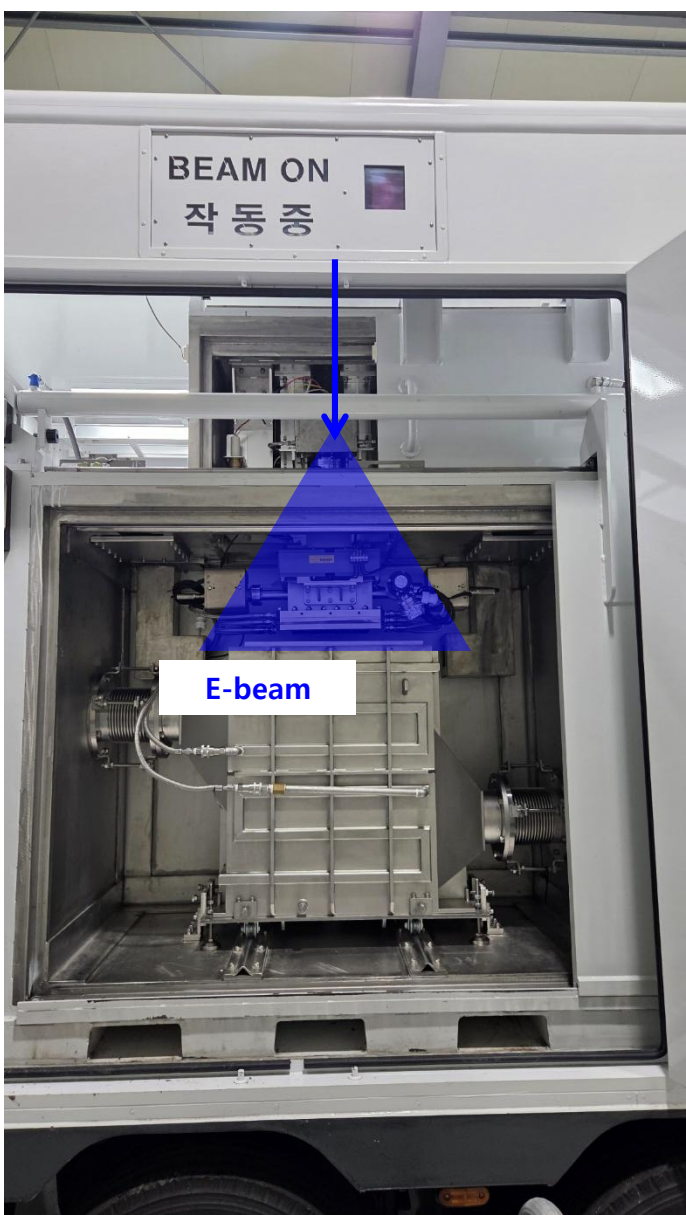
Beam dynamics simulation result



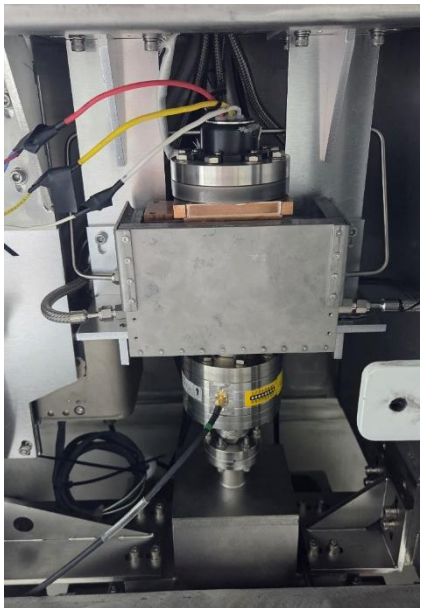
Fabricated RF cavity and RF performance test

✓ The electron accelerator uses a widely-used industrial S-band RF accelerating cavity, allowing for research into odor decomposition using a pulsed electron beam. It is designed with a 2.5-cell standing-wave structure to ensure stable electron beam acceleration even with a possibility of RF power shortage. The accelerator generates a 500 keV electron beam at 1 mA (with a maximum of 3 mA).

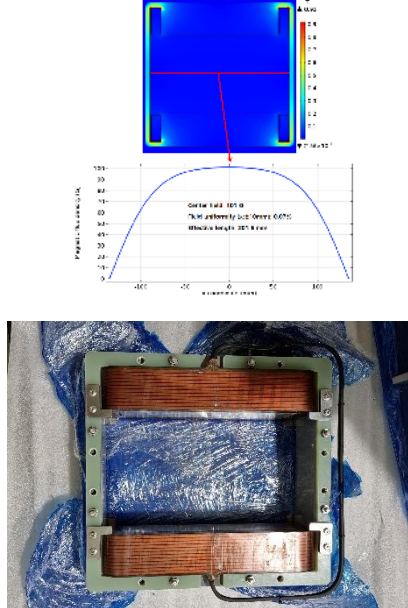
Accelerator module



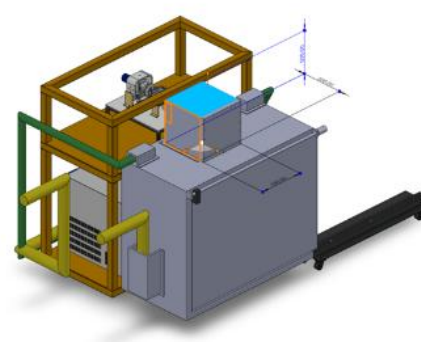
Modularized accelerator and gas reactor with shieldings



Electron gun and cavity



Beam scanning magnet

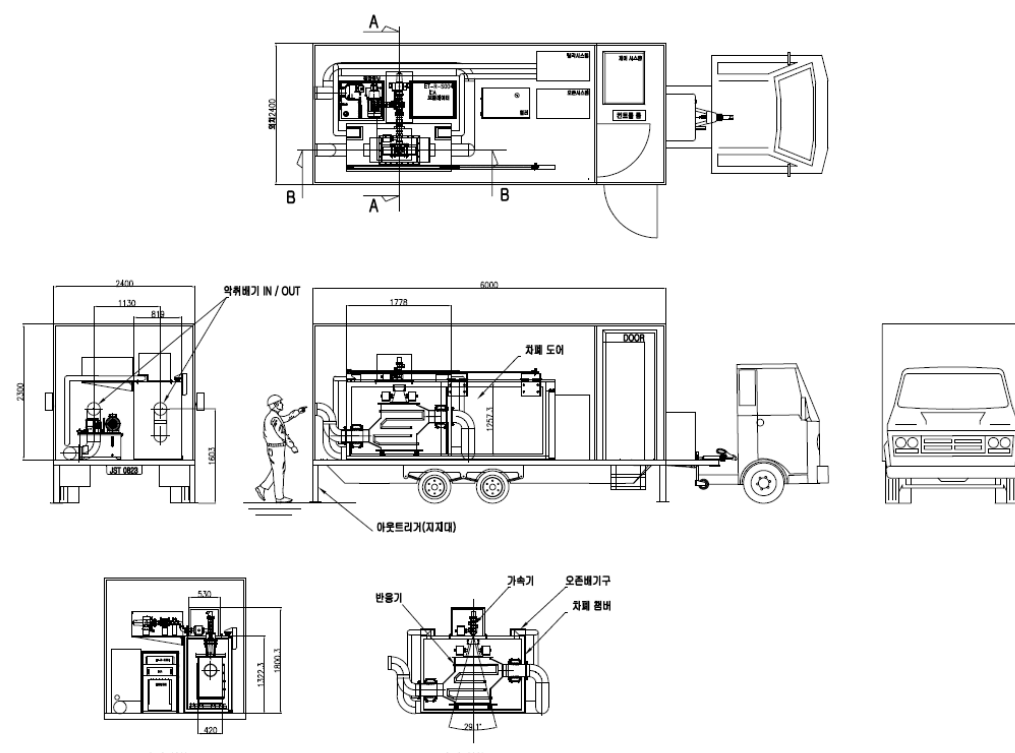


Radiation shielding modeling

✓ The **shielding** for the electron accelerator is designed to completely enclose the electron gun, accelerating cavity, scanning horn, and gas reactor surrounding in all six directions. To minimize the weight of the self-shielding accelerator module, different shield thicknesses were adopted depending on the location. Additionally, a special shielding structure was applied to all parts that penetrate the shield, from the inside to the outside due to cooling channels and power cables.

Vehicle with accelerator module

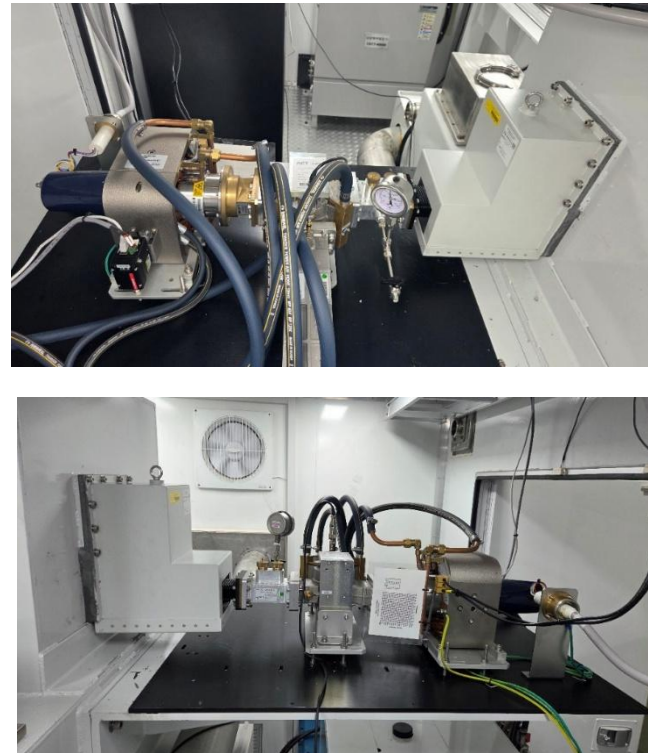
System integration



Layout of the accelerator system mounted on a vehicle



Inner view inside vehicle



RF power source

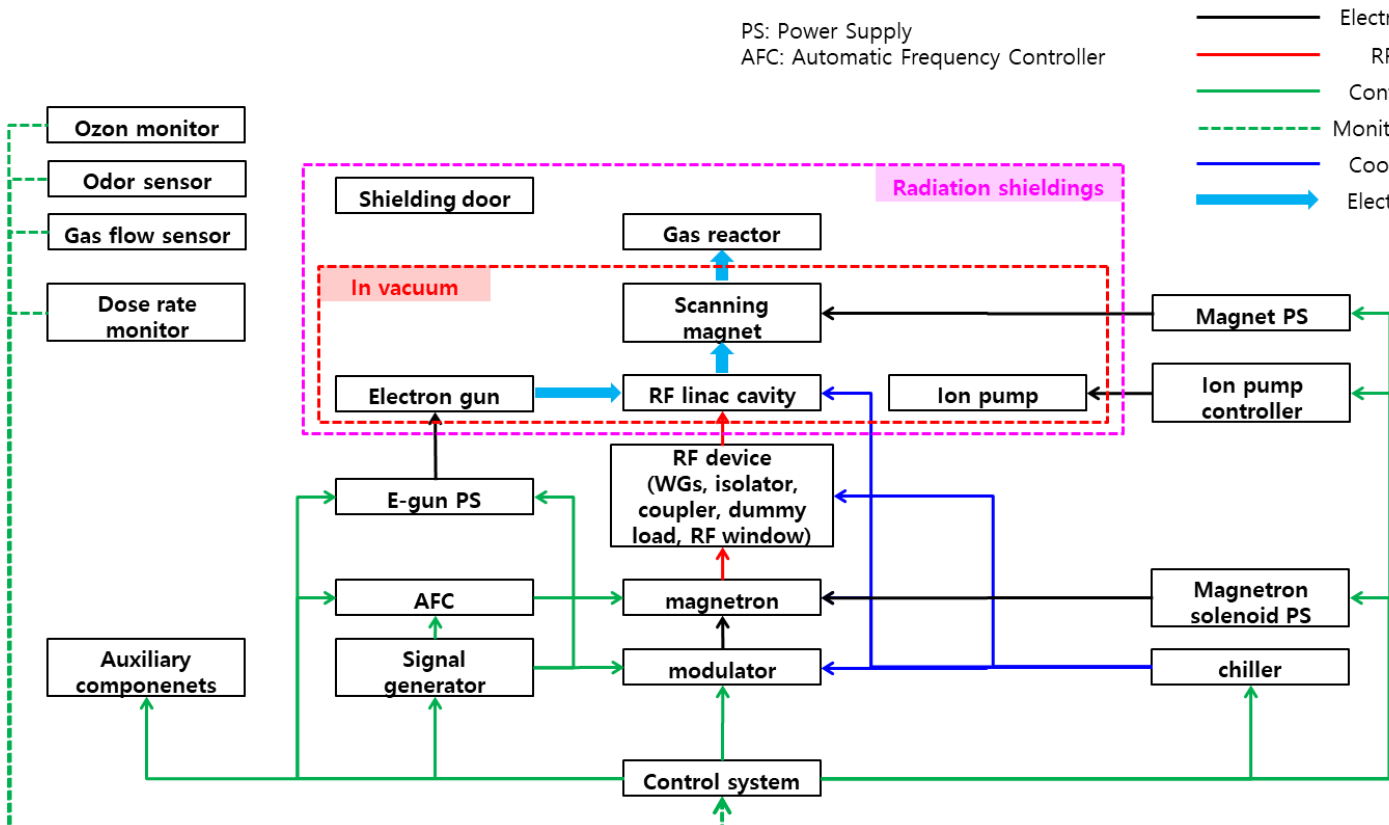


Control rack

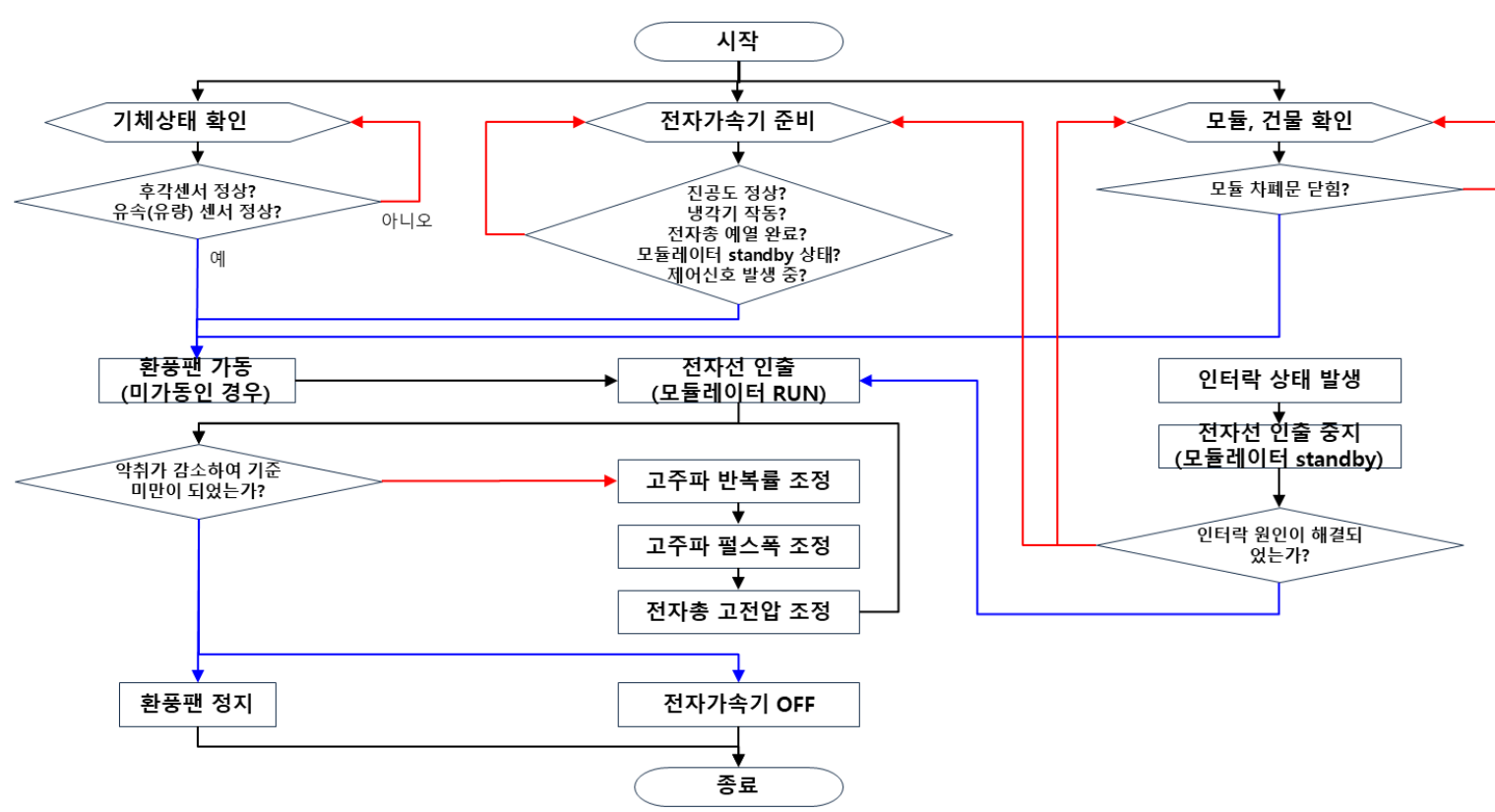
✓ To enable immediate mounting onto a vehicle, the system was designed as a **modular unit**. It integrates the core components—including the RF power source (modulator, magnetron), electron gun, accelerating cavity, and RF transmission components—with auxiliary systems like vacuum, cooling, electric power, signal generation, and controls.

✓ The vehicle designed to transport the electron accelerator module offers a protective environment for the equipment while ensuring easy maintenance for the user through a thoughtful internal layout and multiple access points. It also includes an air conditioning system to prevent malfunctions and premature aging of the accelerator, which is sensitive to environmental changes. An interlock system is built in to protect both users and the equipment during operation.

Control system



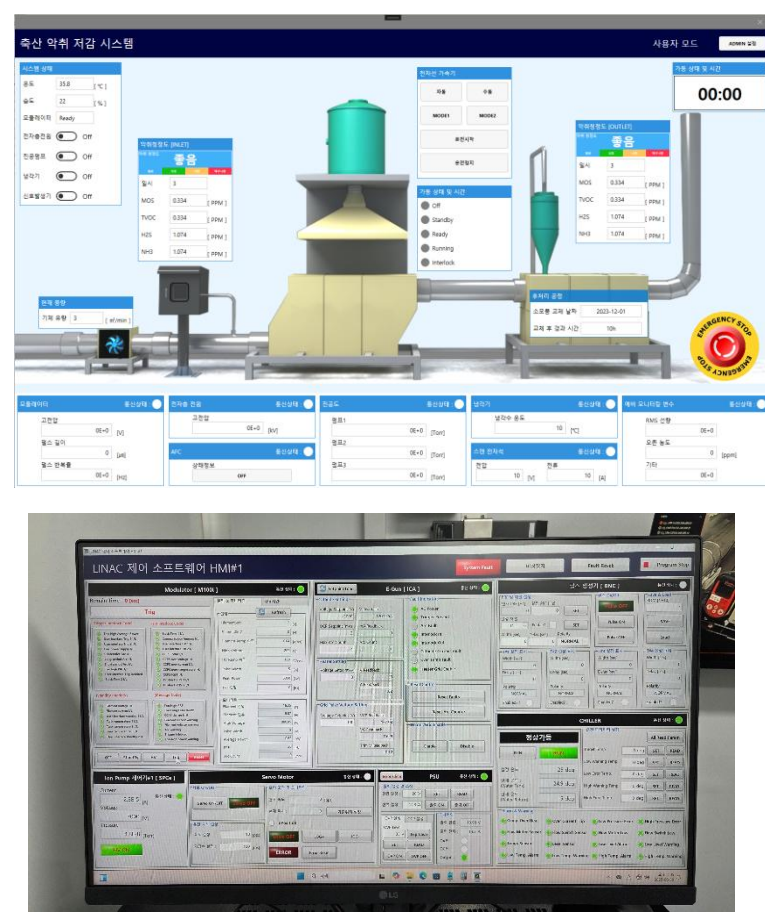
Configuration of the control system



Operation flow chart



Control room



Control software

✓ Control system of the accelerator is configured to increase operational efficiency **by providing real-time feedback on odor volume and concentration, which in turn controls the electron beam output.**

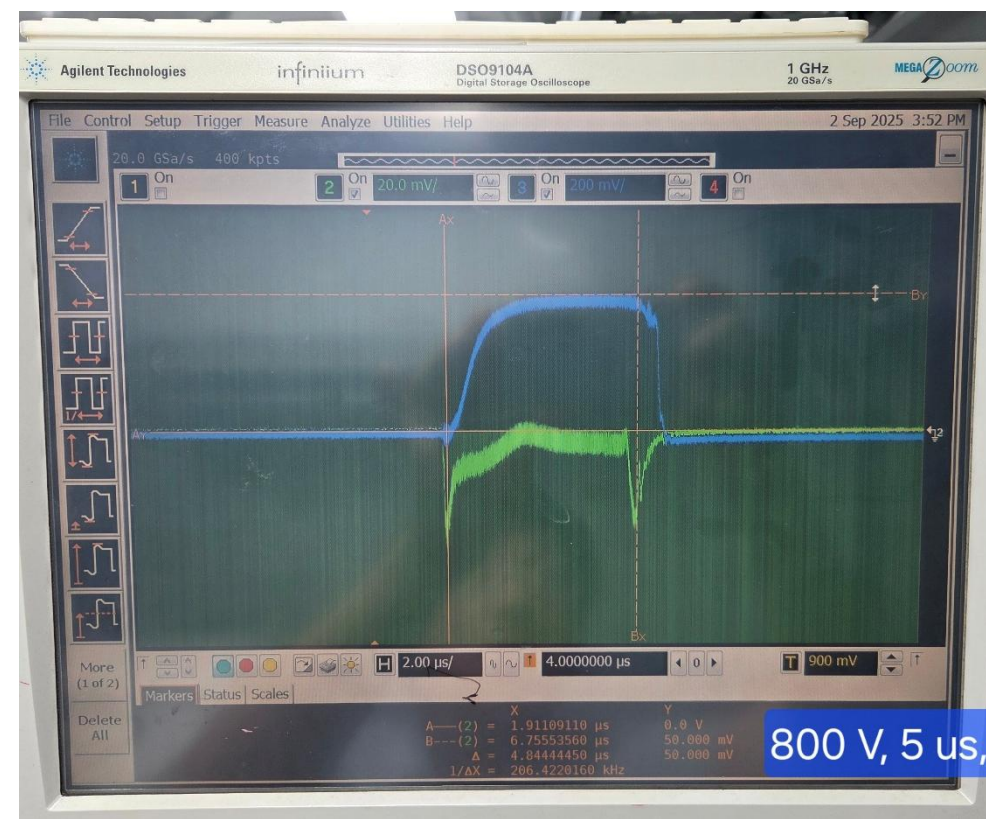
✓ Control room is located right next to the accelerator module on the vehicle and control PC and monitoring CCTVs are installed.

✓ Control software is consist of main page and sub-parameter control pages. They show real-time status of the control parameters and interlock signals.

Beam acceleration test

✓ When RF power is first applied to an electron accelerator, RF conditioning is performed. Once this process is complete, the RF power is not reflected from the cavity and is stably injected into the accelerating structure (or accelerating tube), thereby allowing electrons to be effectively accelerated.

✓ The current of the accelerated electron beam from the accelerating structure is measured by an ICT (Integrated Current Transformer) installed beneath the accelerating structure (the principle being to measure the current from the induced magnetic field formed around it when the current flows).



Reflected RF signal (green) and electron beam pulse signal measured by ICT (blue)

Summary

✓ To facilitate the direct use of electron accelerators at sites where electron beams are applied, a **mobile, compact electron accelerator system** was built. This device is scheduled to be deployed to a livestock facility in the second half of 2025 for a demonstration study on its effectiveness in reducing odors.

✓ This compact accelerator was developed based on existing research at the Radiation Equipment Fabrication Center. It is planned to be optimized and improved for broader **application in environmental and military defense fields.**

✓ This work has been carried out under the KAERI R&D program 'Management of Radiation Equipment FAB. (No. 2710007334).