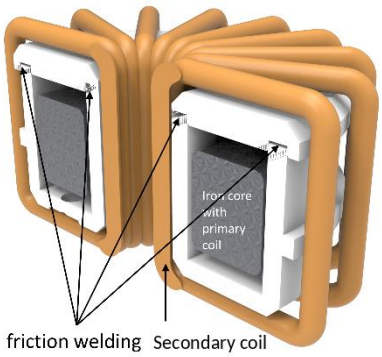
High Voltage Isolation Transformer Using Friction Welding

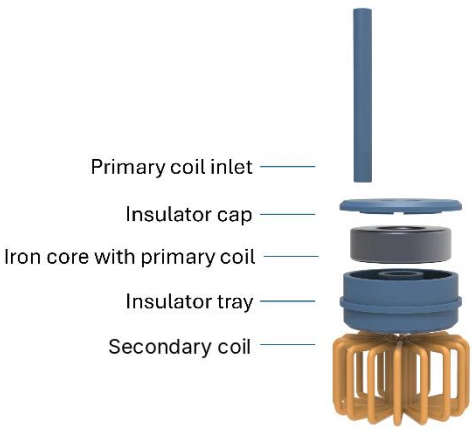
For fusion research (Wendelstein 7-X, ASDEX Upgrade), HUN-REN Centre for Energy Research has developed a new way to insulate high voltage isolation transformers. Instead of resin casting or oil, the iron core and the primary coil are enclosed in a polyethylene housing closed by rotary friction welding, so the parts fuse into one continuous insulation wall, without adhesive or filler. The result is a much lighter and more compact isolation transformer, made without casting or oil. Transformers have been successfully produced and tested with power ratings up to 10 kVA and insulation capabilities of up to 120 kV. 1 kVA transformer units, rated 100 kV DC, have been in service for years on fusion experiments. Applications include ion sources for accelerators and heater or filament supplies on high-voltage decks.

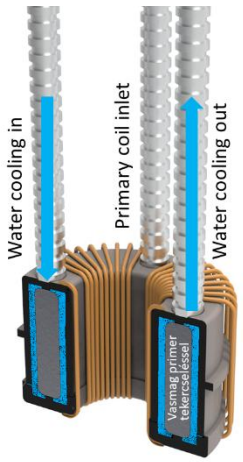
Description of the technology

High voltage isolation transformers supply mains power to equipment that floats at a high DC potential: ion sources, electron guns, and the high-voltage decks of accelerators and ion implanters. The critical part is the insulation between the windings, which must continuously withstand the full potential difference (typically 30–150 kV DC). Today this insulation is provided by vacuum-cast resin, oil or SF6 gas. All three add weight and volume, and casting also needs moulds, vacuum and a curing cycle.

The solution is a transformer case of three main parts: the primary coil inlet, insulator cap and insulator tray. These components are interconnected through rotary friction welding, effectively enclosing the toroidal iron core along with the primary coil. Additional inlet pipes can be applied for cooling the iron core and primary coil with distilled water or air. Various methods are available for cooling the secondary (outer) coil. Friction welding fuses the parts into one continuous polyethylene wall, without adhesive or filler, so the joints do not interrupt the insulation.







Weight and size: ~5 kg and ~5 litres for a 100 kV DC unit designed for 1 kVA, while commercial epoxy-cast isolation transformers of the same power typically weigh ~30 kg (~25 litres) at 100 kV DC and 25 kg even at 50 kV DC. Specifications:

- Primary coil voltage: 230 VAC (or other, on request)
- Secondary coil voltage: any, on request
- Isolation voltage: 100 kV DC rated, tested at 120 kV DC, higher voltage on request
- Power: up to 10 kVA, higher power on request

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Innovation and advantages of the offer

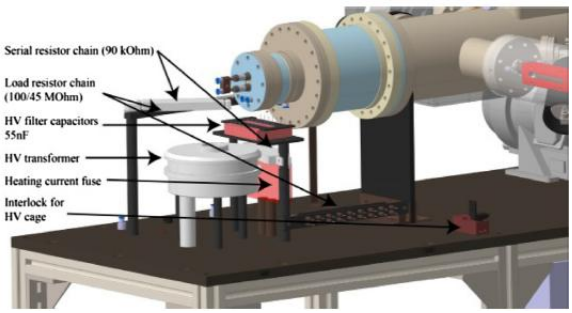
The major innovation is the use of friction welding to build the insulation: the housing parts fuse into one continuous polyethylene wall, without adhesive or filler. The key advantages are simpler manufacturing (no vacuum casting, curing cycle or oil filling), proven insulation (rated 100 kV DC, tested at 120 kV DC for 300 minutes across the 10 mm welded HDPE wall, average field 12 kV/mm, without breakdown), dual cooling (primary and secondary coils), space and weight savings (~5 kg and ~5 litres, against typically ~30 kg and ~25 litres for epoxy-cast units of the same rating) and a flexible secondary coil (wound outside the welded housing, so the output can be changed without touching the insulation). The technology is at TRL 7 and patented in Europe, the USA and Hungary.

Non-fusion Applications

The technology suits any equipment that needs mains power on a high-voltage deck (typically 30–150 kV DC): ion sources and accelerators, electron-beam welding machines, ion implanters, and heater or filament supplies at high potential. It can be licensed to manufacturers of high voltage isolation transformers.

EUROfusion Heritage

The technology has been used with success for years in fusion research: 1 kVA units have been in service at Wendelstein 7-X (~7 years) and ASDEX Upgrade (~5 years). At Wendelstein 7-X the transformer is a key component of the high-voltage system of the alkali beam diagnostic injector (see figure). This work received support within the framework of the EUROfusion Consortium (Grant Agreement No 101052200 — EUROfusion).



HV system of W7-X alkali beam injector

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Annex for internal use – Additional information

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Technology Readiness Level and collaboration opportunities

☐	☐	☐	☐	☒	☐	☒	☐	☐
TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9

1 kVA / 100 kV DC – TRL 7
10 kVA / 100 kV DC – TRL 5

Collaboration opportunities: R&D collaboration, licensing agreement, patent sale. Granted patents: EP 3928335 B1, US 12278035 B2, HU 231243 B1.

This technology/know-how is available for further adaptation and fine tuning to meet specific requirements. It can be used wherever mains power must be supplied to equipment at high DC potential.

IP Status

☐ Copyright

☐ Design Rights
☐ Exclusive Rights
☐ Granted patent or patent application essential
☐ Other (registered design, plant variety, etc.)

☐ Patent(s) applied for but not yet granted
☒ Patents granted
☒ Secret Know-how
☐ Trademarks

Other technical expertise's of the technology donor

The research area of the HUN-REN CER Fusion Plasma Physics Department is the advancement of controlled fusion energy production. It develops and builds plasma diagnostic and technology systems, performs and evaluates measurements on the world's largest fusion experiments. The major activities are cryogenic pellet production, acceleration and interaction with the plasma, plasma diagnostics using video cameras and Beam Emission Spectroscopy, modelling activities for beam-plasma interaction, 3D printing of fusion device models or development of a 35 keV proton source as the input beam to accelerator-driven compact neutron generators.

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