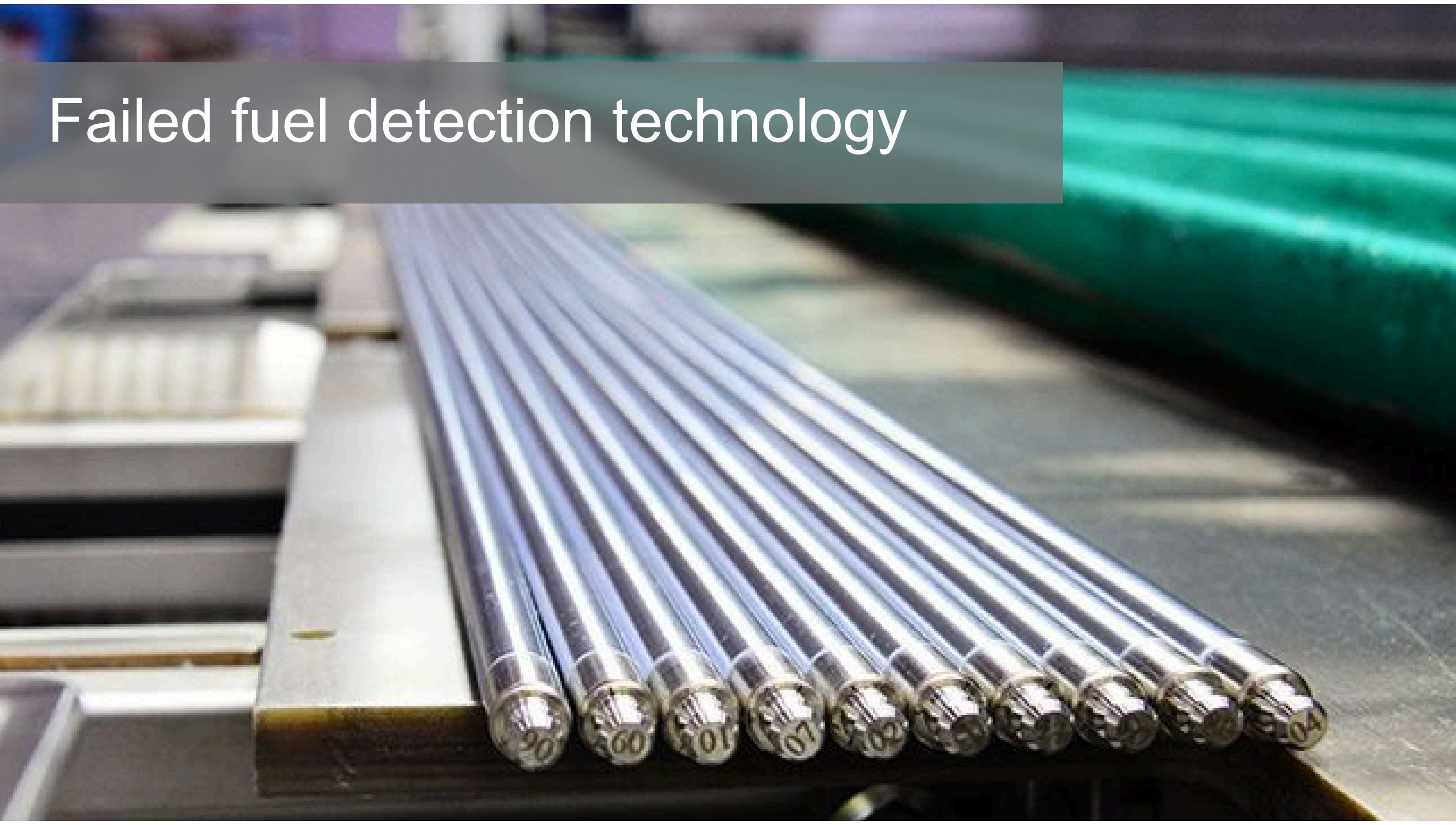
Failed fuel detection technology



Overview

Over the last few decades, Curtiss-Wright has supplied precipitator and scintillator-based detection technology to both generations of the UK's carbon dioxide gas-cooled reactors as well as internationally to HTGR and sodium pool reactors (in the latter type, the cover gas has been sampled). Our technology is deployed for real-time early detection of traditional failed fuel canisters and can detect Noble gases released from microcracking of TRISO and other types of fuel pellet. It achieves that by measuring beta decay from the noble gases present as result of fission product escape. Curtiss-Wright can provide the precipitator as part of a complete failed fuel detection system.

Key features

- Real-time detection of failed fuel canisters or pellets: uses precipitator/scintillator technology to detect failed fuel canisters or fuel pellets by measuring beta decay from noble gases released during fission product escape
- Electrostatic precipitation mechanism: gases from leaking fuel decay into solid daughters within a shielded chamber, these solid particles are trapped on a grounded wire by electrostatic attraction
- Sensitive and optimized detection: highly sensitive, with optimized sample transit and soak times to maximize solid form collection on the wire
- Discrimination and adaptability: discriminates against radionuclides that remain gaseous or have very long/short half-lives - can be adapted to include gamma spectrometry for measuring and identifying gamma-emitting daughters, enhancing sensitivity and reducing background noise
- Ruggedized: precipitator rated at 45 bar working gas pressure and can be used to directly sample primary coolant gas as well as sodium and salt reactor cover gas

Technical specifications

The working principle is that gas is fed into a shielded chamber with a grounded collection wire at the center and a high voltage applied at the chamber perimeter. Gases typically present from leaking fuel decay while in the chamber to form solid daughters, e.g. Xe decaying to Cs and Kr to Rb, which are trapped on the wire by electrostatic precipitation. The wire is then automatically moved to a position within a plastic scintillator-based detector where the beta emissions are transformed into electrical pulses and counted. The system naturally discriminates against any radionuclides that remain gaseous, or with a very long or very short half-life in the gaseous state, and against gamma and alpha decays due to the plastic scintillator form.

The wire transport system is arranged to ensure the section of the wire that is exposed to the gas must travel twice the length of the 60 feet long wire before it is exposed again. This minimizes residual background on the sampling wire.

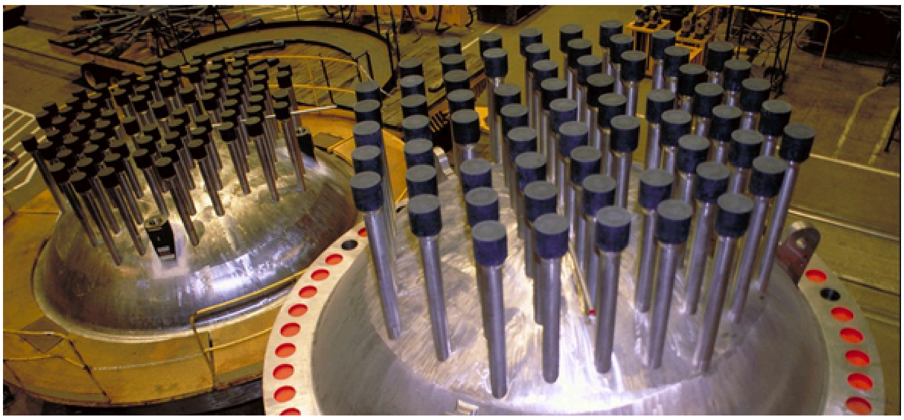
A number of the noble gases transmute several times through solid daughters and the daughters further decay in sensible (measurable) timescales to their stable end form – the technique depends on "intercepting" them at the optimum point in time. For example, typical chains that practically can be monitored are:

- ^{138}I gas beta-decays ($T_1/_2$ = 5.9 s) to ^{138}Xe gas which beta-decays ($T_1/_2$ = 14 m) to ^{138}Cs solid. That then further beta-decays ($T_1/_2$ = 32 m) to stable ^{138}Ba
- ^{88}Br gas beta-decays ($T_1/_2$ = 15.8 s) to ^{88}Kr gas which beta-decays ($T_1/_2$ = 2.84 h) to ^{88}Rb solid. That then further beta-decays ($T_1/_2$ = 17.8 m) to stable ^{88}Sr

This technique is very sensitive provided the sample transit time to the precipitator and the "soak" time in the precipitation chamber are optimized to maximise the solid form on the wire for counting purposes. Typical timings on gas reactors are of order a minute soaking the wire and then counting windows of order tens of seconds but this has to be optimized for the reactor installation and type of fuel arrangement.

Measurement time windows set to cover two or more bands on the decay curves allow discrimination between short and longer lived nuclides and can therefore determine, to a degree, whether there is a low level of degradation (eg porosity, minor crazing due to age) or a high level (significant cracking and release of fission products) that might be representative of a fuel overheating event.

The system can be adapted to add gamma spectrometry at the back end – this allows gamma-emitting daughters to be both measured and identified. This technique is considerably more sensitive than measuring the gamma emitters in the cover gas directly since only the solid forms that attach to the wire are present so the background and spectrum complexity are much lower.

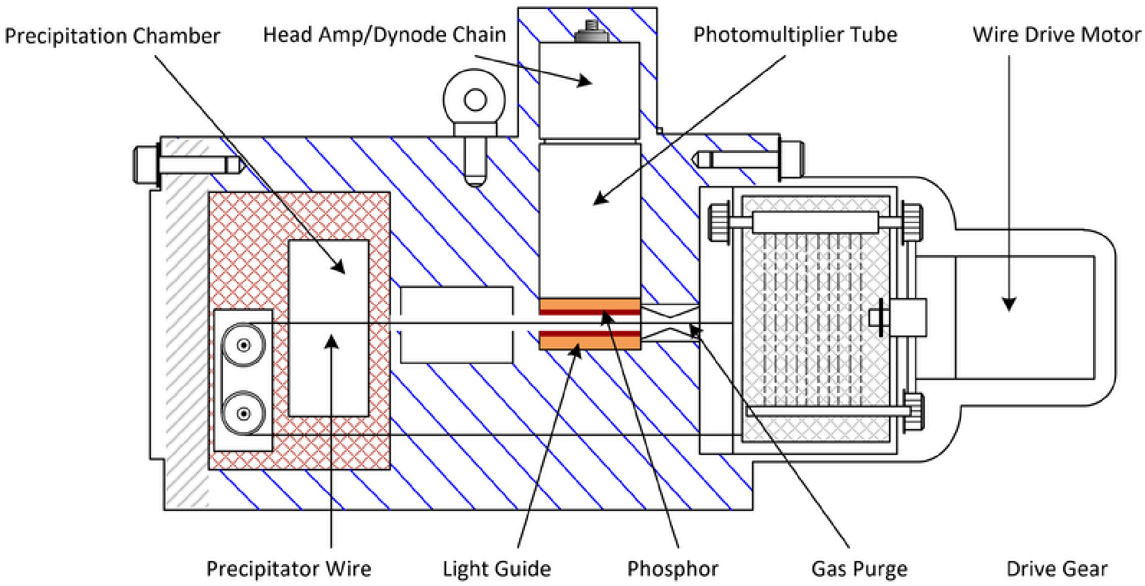


Technical specifications

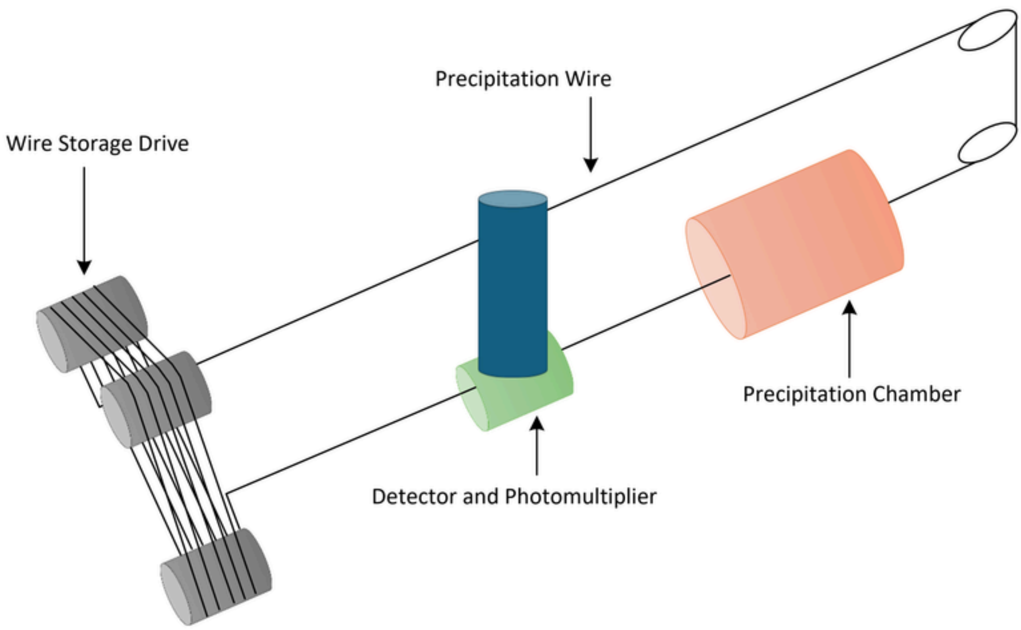
Failed fuel detection precipitator

- Beta emitting solid radionuclides are trapped on the wire by electrostatic attraction in the precipitation chamber
- The wire is moved and the exposed section of wire is stopped inside the cylindrical phosphor
- Beta particles are converted to light flashes and transmitted through the plastic light guide to the end face of the photomultiplier tube where they are converted to electrons and multiplied to form an electrical pulse
- Working gas pressure 45 bar

Precipitator (Mark XI)



Wire drive mechanism



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