



# CHARACTERIZATION VIA THE RADHAND DEVICE INTEGRATED INTO THE REACH™ SYSTEM FOR A LOW-COST IN-SITU WASTE CHARACTERIZATION OF NUCLEAR WASTE

**A. Pepperosa**, E. Fanchini, M. Morichi, S. Kelly Jr, K. Tuite, M. Locatelli

a.pepperosa@caen.it



Andrea Peperosa  
CAEN s.p.a.



Sean Kelly Jr.  
WMG Inc.

# CHARACTERIZATION VIA THE RADHAND DEVICE INTEGRATED INTO THE REACH™ SYSTEM FOR A LOW-COST IN-SITU WASTE CHARACTERIZATION OF NUCLEAR WASTE

A. Peperosa<sup>1,a</sup>, E. Fanchini<sup>1</sup>, M. Morichi<sup>1</sup>, S. Kelly Jr<sup>2,b</sup>, K. Tuite<sup>2</sup>, M. Locatelli<sup>3</sup>

<sup>1</sup>CAEN s.p.a – Via Vetrina N.11, 55049 Viareggio, Italy

<sup>2</sup>WMG Inc. - 16 Bank Street, 10566 Peekskill, NY, USA

<sup>3</sup>CAEN Technologies, Inc. – 1140 Bay Street, 10305, Staten Island, NY, USA [a.peperosa@caen.it](mailto:a.peperosa@caen.it) [skelly@wmginc.com](mailto:skelly@wmginc.com)

**ABSTRACT:** A key aspect involving both operational activities as well as radioprotection in NPP is the management of nuclear waste. Providing efficient and reliable real-time radionuclide concentrations contributes invaluable information while processing nuclear waste as it can in turn reduce costs with packaging, transportation, and disposition for NPPs. Typical NPPs procedures involve characterizing nuclear waste by using HPGc-based systems to determine the radionuclide concentrations and the individual isotope abundances. Often, this requires NPPs to be equipped with a laboratory on site as well as radiological experts and immense amounts of time and effort to obtain the results for well-defined gamma-emitting radionuclides which are easily detectable. Current characterization practices involve obtaining waste stream specific distributions which are then applied to all waste packages of the same waste stream type. This type of analysis is typically performed by HPGc detectors whom the main drawbacks are the typical long measurement times, the time for post process analysis, and the typical high entry cost (around 100kEuro). Due to the integration of software and hardware technologies in the smart era, CAEN SpA and WMG Inc. developed a faster and more user-friendly waste package characterization toolkit, named the REACH™ Detector System, which represents a step change in the way LLRW is characterized and classified. It is intended for all waste packages for open geometry measurements by providing a low-cost detection technology with an easily transportable device. The REACH™ Detector System directly measures gamma dose rates and gamma emitting activity by radionuclide for packaged radioactive material. It is equipped with the RadHAND device used for the gamma measurement and data digitalization via RFID technology and a software database for data storage and management. The system can track in every moment the uniquely identified WP using the attached RFID tag and restore the WP characterization history using the developed database. This presentation will show some results for tests made with the RadHAND device which measured real package radioactive waste from NA commercial power plants to evaluate its performances in fixed geometry configuration. The feasibility to substitute the old typical procedure based on HPGc characterization with this new system will be analyzed.

### The Challenge

Current methods of characterizing LLRW are gross approximations which tend to yield overly conservative results which can significantly increase packaging, transport, and disposal costs. The inaccuracies of these methods involve the underestimation of short-lived radionuclides typically found in LLRW. When dose-to-cure conversion techniques are used and hard-to-detect radionuclides are estimated using scaling factors relative to Co-60 and/or Cs-137, underestimating the short-lived gamma emitters results in overestimating the hard-to-detect nuclides as well as Co-60 and Cs-137 since most of the dose rate is attributed to these two radionuclides. Providing efficient and reliable real-time radionuclide concentrations provides invaluable information while processing nuclear waste at NPP. More accurate results can be achieved by directly measuring the gamma emitting activity in the packaged LLRW. However, this is typically done using HPGc detectors, which are not easily portable, require significant data processing, and a subject matter expert to interpret the detector results.

### The Solution: The REACH™ Detector System

The REACH™ Detector System is a two-part system: part hardware and part software.

The **part hardware** is composed by an innovative handheld, the **RadHAND**, designed to perform both spectroscopic radiation measurements and UHF RFID tagging of radiological objects. It embeds a 2"x2" NaI(Tl) crystal inside which is integrated with electronics to provide both measured dose rates and identified gamma emitting radionuclides on the detector's onboard display. The radionuclide identification process is completed by an automated pulse processing algorithm. The RadHAND utilizes RFID technology to digitize all info acquired during the characterization process. RFID tags can be attached to packages and have their package-specific information such as spectral acquisition data (e.g., identified radionuclides and measured dose rate) and "logistics" data (e.g., date, time and location where the measurement was taken, a picture of the container configuration/type, and reading distance) saved to the tag memory.

The **part software** performs peak processing by use of the **GAMON™ algorithm**. This algorithm uses the automated radionuclide information obtained from the RadHAND to perform isotope-specific dose rate evaluations to calculate the identified radionuclides' concentrations. The REACH™ software incorporates self-shielding correction factors as a function of energy, geometry, material type, and reading distances.



### Test and Results

The in-field testing consisted of performing gamma scans for twenty-nine real packages of radioactive waste varying in size from 55-gallon drums, B-25 Metal boxes, and 20' intermodal containers. Waste forms included ion exchange resin, routine dry active waste (DAW), contaminated and activated metals, and Fly Ash. Comparative results for Fly Ash Drums are presented hereinafter.

### Fly Ash Drum 20' Intermodal Experimental Setup



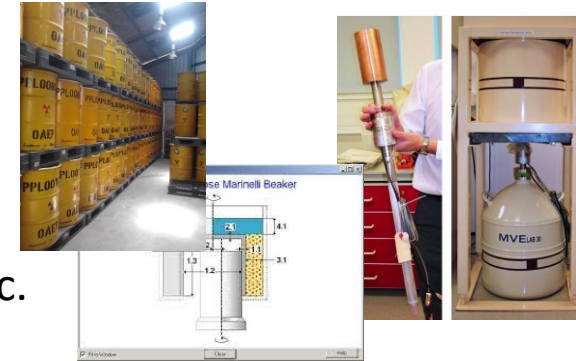
**Fly Ash Drum Comparison Summary**

Measurement	Method	Activity	Time	Count	Standard Deviation	Relative Error
FA-170a	HPGc	1.20E+02	1:00:00	10000	100	1.0%
FA-170a	REACH	1.20E+02	0:10:00	10000	100	1.0%
FA-201	HPGc	1.50E+02	1:00:00	15000	150	1.0%
FA-201	REACH	1.50E+02	0:10:00	15000	150	1.0%
FA-202	HPGc	1.80E+02	1:00:00	18000	180	1.0%
FA-202	REACH	1.80E+02	0:10:00	18000	180	1.0%
FA-203	HPGc	2.10E+02	1:00:00	21000	210	1.0%
FA-203	REACH	2.10E+02	0:10:00	21000	210	1.0%
FA-204	HPGc	2.40E+02	1:00:00	24000	240	1.0%
FA-204	REACH	2.40E+02	0:10:00	24000	240	1.0%
FA-205	HPGc	2.70E+02	1:00:00	27000	270	1.0%
FA-205	REACH	2.70E+02	0:10:00	27000	270	1.0%
FA-206	HPGc	3.00E+02	1:00:00	30000	300	1.0%
FA-206	REACH	3.00E+02	0:10:00	30000	300	1.0%
FA-207	HPGc	3.30E+02	1:00:00	33000	330	1.0%
FA-207	REACH	3.30E+02	0:10:00	33000	330	1.0%
FA-208	HPGc	3.60E+02	1:00:00	36000	360	1.0%
FA-208	REACH	3.60E+02	0:10:00	36000	360	1.0%
FA-209	HPGc	3.90E+02	1:00:00	39000	390	1.0%
FA-209	REACH	3.90E+02	0:10:00	39000	390	1.0%
FA-210	HPGc	4.20E+02	1:00:00	42000	420	1.0%
FA-210	REACH	4.20E+02	0:10:00	42000	420	1.0%
FA-211	HPGc	4.50E+02	1:00:00	45000	450	1.0%
FA-211	REACH	4.50E+02	0:10:00	45000	450	1.0%
FA-212	HPGc	4.80E+02	1:00:00	48000	480	1.0%
FA-212	REACH	4.80E+02	0:10:00	48000	480	1.0%
FA-213	HPGc	5.10E+02	1:00:00	51000	510	1.0%
FA-213	REACH	5.10E+02	0:10:00	51000	510	1.0%
FA-214	HPGc	5.40E+02	1:00:00	54000	540	1.0%
FA-214	REACH	5.40E+02	0:10:00	54000	540	1.0%
FA-215	HPGc	5.70E+02	1:00:00	57000	570	1.0%
FA-215	REACH	5.70E+02	0:10:00	57000	570	1.0%
FA-216	HPGc	6.00E+02	1:00:00	60000	600	1.0%
FA-216	REACH	6.00E+02	0:10:00	60000	600	1.0%
FA-217	HPGc	6.30E+02	1:00:00	63000	630	1.0%
FA-217	REACH	6.30E+02	0:10:00	63000	630	1.0%
FA-218	HPGc	6.60E+02	1:00:00	66000	660	1.0%
FA-218	REACH	6.60E+02	0:10:00	66000	660	1.0%
FA-219	HPGc	6.90E+02	1:00:00	69000	690	1.0%
FA-219	REACH	6.90E+02	0:10:00	69000	690	1.0%
FA-220	HPGc	7.20E+02	1:00:00	72000	720	1.0%
FA-220	REACH	7.20E+02	0:10:00	72000	720	1.0%
FA-221	HPGc	7.50E+02	1:00:00	75000	750	1.0%
FA-221	REACH	7.50E+02	0:10:00	75000	750	1.0%
FA-222	HPGc	7.80E+02	1:00:00	78000	780	1.0%
FA-222	REACH	7.80E+02	0:10:00	78000	780	1.0%
FA-223	HPGc	8.10E+02	1:00:00	81000	810	1.0%
FA-223	REACH	8.10E+02	0:10:00	81000	810	1.0%
FA-224	HPGc	8.40E+02	1:00:00	84000	840	1.0%
FA-224	REACH	8.40E+02	0:10:00	84000	840	1.0%
FA-225	HPGc	8.70E+02	1:00:00	87000	870	1.0%
FA-225	REACH	8.70E+02	0:10:00	87000	870	1.0%
FA-226	HPGc	9.00E+02	1:00:00	90000	900	1.0%
FA-226	REACH	9.00E+02	0:10:00	90000	900	1.0%
FA-227	HPGc	9.30E+02	1:00:00	93000	930	1.0%
FA-227	REACH	9.30E+02	0:10:00	93000	930	1.0%
FA-228	HPGc	9.60E+02	1:00:00	96000	960	1.0%
FA-228	REACH	9.60E+02	0:10:00	96000	960	1.0%
FA-229	HPGc	9.90E+02	1:00:00	99000	990	1.0%
FA-229	REACH	9.90E+02	0:10:00	99000	990	1.0%
FA-230	HPGc	1.02E+03	1:00:00	102000	1020	1.0%
FA-230	REACH	1.02E+03	0:10:00	102000	1020	1.0%
FA-231	HPGc	1.05E+03	1:00:00	105000	1050	1.0%
FA-231	REACH	1.05E+03	0:10:00	105000	1050	1.0%
FA-232	HPGc	1.08E+03	1:00:00	108000	1080	1.0%
FA-232	REACH	1.08E+03	0:10:00	108000	1080	1.0%
FA-233	HPGc	1.11E+03	1:00:00	111000	1110	1.0%
FA-233	REACH	1.11E+03	0:10:00	111000	1110	1.0%
FA-234	HPGc	1.14E+03	1:00:00	114000	1140	1.0%
FA-234	REACH	1.14E+03	0:10:00	114000	1140	1.0%
FA-235	HPGc	1.17E+03	1:00:00	117000	1170	1.0%
FA-235	REACH	1.17E+03	0:10:00	117000	1170	1.0%
FA-236	HPGc	1.20E+03	1:00:00	120000	1200	1.0%
FA-236	REACH	1.20E+03	0:10:00	120000	1200	1.0%
FA-237	HPGc	1.23E+03	1:00:00	123000	1230	1.0%
FA-237	REACH	1.23E+03	0:10:00	123000	1230	1.0%
FA-238	HPGc	1.26E+03	1:00:00	126000	1260	1.0%
FA-238	REACH	1.26E+03	0:10:00	126000	1260	1.0%
FA-239	HPGc	1.29E+03	1:00:00	129000	1290	1.0%
FA-239	REACH	1.29E+03	0:10:00	129000	1290	1.0%
FA-240	HPGc	1.32E+03	1:00:00	132000	1320	1.0%
FA-240	REACH	1.32E+03	0:10:00	132000	1320	1.0%
FA-241	HPGc	1.35E+03	1:00:00	135000	1350	1.0%
FA-241	REACH	1.35E+03	0:10:00	135000	1350	1.0%
FA-242	HPGc	1.38E+03	1:00:00	138000	1380	1.0%
FA-242	REACH	1.38E+03	0:10:00	138000	1380	1.0%
FA-243	HPGc	1.41E+03	1:00:00	141000	1410	1.0%
FA-243	REACH	1.41E+03	0:10:00	141000	1410	1.0%
FA-244	HPGc	1.44E+03	1:00:00	144000	1440	1.0%
FA-244	REACH	1.44E+03	0:10:00	144000	1440	1.0%
FA-245	HPGc	1.47E+03	1:00:00	147000	1470	1.0%
FA-245	REACH	1.47E+03	0:10:00	147000	1470	1.0%
FA-246	HPGc	1.50E+03	1:00:00	150000	1500	1.0%
FA-246	REACH	1.50E+03	0:10:00	150000	1500	1.0%
FA-247	HPGc	1.53E+03	1:00:00	153000	1530	1.0%
FA-247	REACH	1.53E+03	0:10:00	153000	1530	1.0%
FA-248	HPGc	1.56E+03	1:00:00	156000	1560	1.0%
FA-248	REACH	1.56E+03	0:10:00	156000	1560	1.0%
FA-249	HPGc	1.59E+03	1:00:00	159000	1590	1.0%
FA-249	REACH	1.59E+03	0:10:00	159000	1590	1.0%
FA-250	HPGc	1.62E+03	1:00:00	162000	1620	1.0%
FA-250	REACH	1.62E+03	0:10:00	162000	1620	1.0%
FA-251	HPGc	1.65E+03	1:00:00	165000	1650	1.0%
FA-251	REACH	1.65E+03	0:10:00	165000	1650	1.0%
FA-252	HPGc	1.68E+03	1:00:00	168000	1680	1.0%
FA-252	REACH	1.68E+03	0:10:00	168000	1680	1.0%
FA-253	HPGc	1.71E+03	1:00:00	171000	1710	1.0%
FA-253	REACH	1.71E+03	0:10:00	171000	1710	1.0%
FA-254	HPGc	1.74E+03	1:00:00	174000	1740	1.0%
FA-254	REACH	1.74E+03	0:10:00	174000	1740	1.0%
FA-255	HPGc	1.77E+03	1:00:00	177000	1770	1.0%
FA-255	REACH	1.77E+03	0:10:00	177000	1770	1.0%
FA-256	HPGc	1.80E+03	1:00:00	180000	1800	1.0%
FA-256	REACH	1.80E+03	0:10:00	180000	1800	1.0%
FA-257	HPGc	1.83E+03	1:00:00	183000	1830	1.0%
FA-257	REACH	1.83E+03	0:10:00	183000	1830	1.0%
FA-258	HPGc	1.86E+03	1:00:00	186000	1860	1.0%
FA-258	REACH	1.86E+03	0:10:00	186000	1860	1.0%

# The Challenge..

## Current characterization methods for LLRW

- Gross approximations which tend to yield overly conservative results
  - E.g., Periodic swipe sampling of DAW every two years (10 CFR Part 61, USA regulation)
- Compositing swipes over time underestimates short-lived radionuclides which results in overestimating hard-to-detect nuclides as well as Co-60 and Cs-137
- Estimating package specific gamma-emitting activity is typically done via HPGe detectors
  - Not easily portable, significant data processing, liquid nitrogen cooled, cost prohibitive, etc.



## ..and the Solution

- REACH™ system allows a technician to directly measure gamma emitting activity for LLRW, via RadHAND with quick on-the-fly results
- The REACH™ Software uses package specific radionuclide information with package specific dose rates to perform waste characterization and classification



# Test Results & Conclusion

## Fly Ash Drum Comparison Summary

Radionuclides of Interest	REACH uCi	Percent Abundance	HPGe	GCD	REACH/HPGe	REACH/GCD
Ag-108m	0.00E+00	0.00%	7.25E+01	0.00E+00	0.00	
Ag-110m	7.06E+01	0.32%	1.36E+02	6.36E+02	0.52	0.11
Am-241	3.91E+01	0.18%	0.00E+00	3.71E+01		1.05
Ba-133	5.92E+00	0.03%	0.00E+00	6.97E+00		0.85
C-14	3.11E+01	0.14%	0.00E+00	3.83E+01		0.81
Ce-141	0.00E+00	0.00%	8.33E+00	0.00E+00	0.00	
Cm-243	2.30E+01	0.10%	1.08E+02	2.18E+01	0.21	1.05
Cm-244	2.30E+01	0.10%	0.00E+00	2.16E+01		1.06
Co-57	5.40E+01	0.24%	1.16E+02	2.89E+02	0.47	0.19
Co-58	0.00E+00	0.00%	9.38E-01	2.31E+00	0.00	0.00
<b>Co-60</b>	<b>1.82E+03</b>	<b>8.23%</b>	<b>1.92E+03</b>	<b>2.09E+03</b>	<b>0.94</b>	<b>0.87</b>
Cr-51	0.00E+00	0.00%	0.00E+00	4.14E-02		0.00
Cs-134	7.04E+00	0.03%	4.25E+00	9.01E+00	1.66	0.78
<b>Cs-137</b>	<b>4.69E+03</b>	<b>21.25%</b>	<b>4.01E+03</b>	<b>4.45E+03</b>	<b>1.17</b>	<b>1.05</b>
Fe-55	1.50E+03	6.79%	0.00E+00	1.61E+03		0.93
Ge-68	3.83E+03	17.33%	5.31E+03	8.33E+03	0.72	0.46
Lu-177m	0.00E+00	0.00%	2.99E+01	6.98E+01	0.00	0.00
Mn-54	3.69E+01	0.17%	3.82E+00	3.29E+01	9.66	1.12
Nb-94	1.20E+01	0.05%	0.00E+00	1.46E+01		0.83
Nb-95	1.69E+02	0.77%	6.70E-01	7.67E+00	**	22.06
Ni-63	4.85E+03	21.96%	0.00E+00	5.97E+03		0.81
Pu-238	1.26E+01	0.06%	0.00E+00	1.20E+01		1.05
Pu-239	5.40E+01	0.24%	0.00E+00	5.19E+01		1.04
Pu-240	5.40E+01	0.24%	0.00E+00	5.19E+01		1.04
Pu-241	0.00E+00	0.00%	0.00E+00	4.54E-01		0.00
Pu-242	7.89E+00	0.04%	0.00E+00	7.14E+00		1.10
Rh-101	3.47E+01	0.16%	0.00E+00	3.84E+01		0.90
Sb-124	0.00E+00	0.00%	0.00E+00	6.29E+00		0.00
Sb-125	4.60E+02	2.08%	7.51E+01	1.08E+02	**	4.24
Sn-113	0.00E+00	0.00%	0.00E+00	1.23E+00		0.00
Sr-90	1.30E+03	5.89%	0.00E+00	1.23E+03		1.05
Tc-99	2.92E+03	13.20%	0.00E+00	2.81E+03		1.04
Th-227	0.00E+00	0.00%	0.00E+00	4.34E-03		0.00
Zn-65	6.22E+00	0.03%	6.24E+01	6.85E+01	**	0.09
Zr-95	8.07E+01	0.37%	0.00E+00	2.30E+01		3.51
Totals	2.21E+04			2.81E+04		0.787
Total gammas	1.12E+04		1.19E+04	1.60E+04	0.941	



- Good agreement between REACH and HPGe detector (the total gamma emitters found were within 10%).
- The final characterization results were over 20% lower than the results provided by the waste generators on the average
- One final test which was completed was a “walk-around” scan of a 20’ intermodal container. It was completed in roughly 1 minute and the results were within 4% of those obtained using fixed detector locations and count times totaling over 20 minutes
- Next in-field test are coming soon