



# Auto Q2™

## Low Level Waste Assay System



### KEY FEATURES

- Complete quantitative gamma analysis for fission/activation products or TRU (alpha) radionuclides
- Multiple large coaxial or broad energy detectors for optimal performance
- NDA-2000™ Non-Destructive Assay Software provides extensive setup analysis, calibration, and QA capabilities
- <sup>239</sup>Pu detection levels <1 mg
- Container sizes up to 210 L (55 gal)
- MGA™/MGAU™ U/Pu isotopics software
- 10 cm (4 in.) low background steel shield
- PLC-based electromechanical control system
- Many optional capabilities available including:
  - Automatic weighing system
  - Automatic attenuators
  - Automated conveyor system
  - Larger sample sizes (e.g., 400 liter drums)

### INTRODUCTION

The Auto Q2 (AQ2) system is Mirion's second generation Automated Low Level Waste Assay System. Based on the successful Canberra™ IQ3™ system, the system is designed to quantify plutonium and uranium in 200 L drums at levels below 10 nCi/g and at the same time perform plutonium isotopics measurements on drums containing less than 10 mg of plutonium.

At this level, low level waste drums can easily be segregated from TRU drums. For TRU drums the AQ2 system utilizes several techniques to provide accurate quantification of the fissile content of the drum. These include transmission correction to determine the drum matrix density, and lump detection using multi-energy assays.

For TRU waste, the AQ2 system utilizes the MGA Multi-Group Analysis software to determine the plutonium isotopics as well as the U/Pu ratio and the Pu/<sup>241</sup>Am ratio. MGAU software provides uranium isotopics values for materials which do not contain plutonium. The MGA analysis allows the gamma system to quantify the otherwise difficult to assay isotopes of plutonium.

The system is designed to be operated as an automated counting system which can process batches of drums, or can be incorporated into a complete NDA process line.

The following sections describe the system hardware and software as well as the typical system performance.

## DESCRIPTION

### AQ2 SHIELD

The AQ2 shield provides a 4π, 10 cm thick, low background steel shield as a measurement chamber for the drums. The shield is one of the key features in enabling the low detection limits to be achieved. Special steel is used to eliminate the typical <sup>60</sup>Co contamination which is found in most steels, and other construction materials are carefully selected to minimize those which might contain naturally occurring gamma emitters. This provides an assay chamber which eliminates outside radiation levels, and does not contribute radiation from contamination in the construction materials.

Inside the shield, the drum is placed on a rotator minimizing the effects of source and matrix non uniformities. An automated absorber can be provided to extend the dynamic range of the assay system so that high fissile gram content drums can be assayed.

### DETECTION SYSTEM

The standard system uses a vertical array of three high purity germanium detectors oriented for maximum sensitivity. The use of three detectors minimizes the spatial distribution effects within the drum in much the same fashion as a segmented gamma scanner.

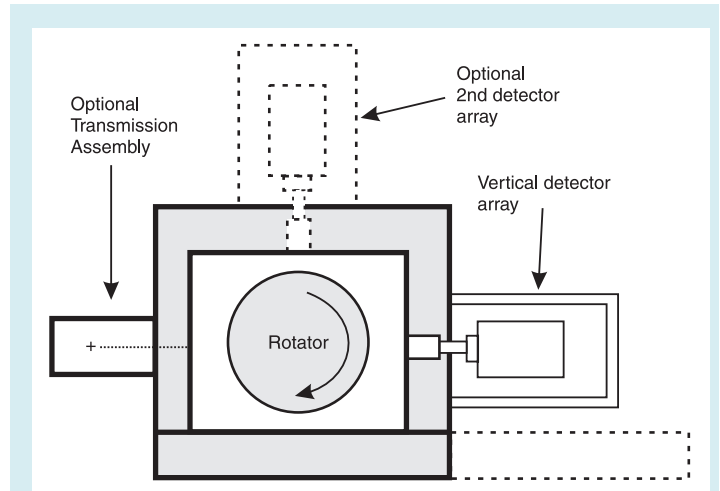


Figure 1 – Diagram of the Auto Q2 system showing the relative positions of detector arrays and transmission source.

The standard AQ2 system is provided with three 30% relative efficiency coaxial detectors. These detectors are suited for routine assay of power plant wastes, uranium, and plutonium bearing wastes where the relative isotopic abundances are known. Detection levels for the standard configuration, as low as 2 mg <sup>239</sup>Pu, are achievable for low density waste drums. Detection limits for the system are shown in Table 1.

Table 1 – Auto Q2 Lower Limit of Detection – Typical and Worst Case.

Nuclide	Daughter Measured	Energy (keV)	Typical LLD (pCi/g) Density (g/cc)				Typical LLD (pCi/g) Density (g/cc)			
			0.1	0.3	0.8	1.8	0.1	0.3	0.8	1.8
<sup>137</sup> Cs	<sup>137m</sup> Ba	662	0.09	0.04	0.03	0.02	0.13	0.07	0.08	0.23
<sup>134</sup> Cs		800	0.08	0.04	0.02	0.02	0.11	0.06	0.06	0.14
<sup>60</sup> Co		1173	0.08	0.03	0.02	0.02	0.10	0.05	0.05	0.08
<sup>58</sup> Co		810	0.08	0.04	0.02	0.02	0.11	0.06	0.06	0.14
<sup>144</sup> Ce		134	1.03	0.49	0.35	0.34	1.50	0.88	2.32	17.0
<sup>232</sup> Th	<sup>228</sup> Ac	911	0.28	0.12	0.08	0.06	0.38	0.20	0.20	0.41
<sup>228</sup> Th	<sup>212</sup> Pb	239	0.18	0.08	0.06	0.05	0.26	0.15	0.31	1.76
<sup>228</sup> Th	<sup>208</sup> Tl	583	0.24	0.10	0.07	0.06	0.33	0.17	0.22	0.88
<sup>228</sup> Th	<sup>208</sup> Tl	2614	0.11	0.05	0.02	0.02	0.15	0.07	0.05	0.05
<sup>238</sup> U	<sup>234m</sup> Pa	1001	13.8	5.7	3.6	3.0	18.6	8.8	8.9	20.0
<sup>238</sup> U	<sup>214</sup> Bi	609	0.17	0.07	0.05	0.04	0.24	0.12	0.14	0.41
<sup>235</sup> U		185	0.17	0.08	0.06	0.05	0.24	0.14	0.33	2.22
<sup>239</sup> Pu		414	6.0	2.7	2.0	1.6	8.6	4.7	7.2	35.7
			(nCi/g for <sup>239</sup> Pu)				(nCi/g for <sup>239</sup> Pu)			

CONDITIONS – Uniform source calibration at appropriate density; three each 30% Ge detectors; 30 minute sample count time; full sample container at stated density. LLD (Lower Limit of Detection) – 5% Type I error, 5% Type II error. WORST CASE LLD – Maximum activity present if all activity is in a 1 cm diameter sphere which is at the worst location in a homogeneous density sample.

Options are available for up to six HPGe detectors, more efficient detectors, or alternate detector types such as LEGe™ or BEGe™ detectors.

The detectors are mounted in Model 7935-7 multi-attitude cryostats. These cryostats are configured with Mirion's exclusive Remote Detector Chamber (RDC) which permits back shielding to be placed around the detector end cap. This helps to further improve the low background counting capability of the system.

The cryostats are filled with liquid nitrogen and typically have a five day holding time. Because of the number of detectors and the frequent filling required, the AQ2 system comes with an automatic liquid nitrogen filling system. This permits the detectors to be filled on a scheduled basis after hours when the system is not in use. The autofill system must be interfaced to either a 240 L portable storage Dewar or a fixed facility storage Dewar as an LN<sub>2</sub> supply.

## **BROAD ENERGY GERMANIUM (BEGE) DETECTORS**

The BEGe detectors are optimized to provide the necessary high resolution required for the MGA analysis while providing high efficiency for the quantitative analysis. The use of BEGe detectors allows the system both quantitative and isotopic analysis of uranium and plutonium wastes with a single set of detectors.

## **TRANSMISSION SOURCE MECHANISM (OPTION)**

To the left side of the shield opposite the primary detector array, is the transmission source shield and actuator mechanism. This mechanism houses three sources which are located at the same heights as the germanium detectors. This provides an accurate determination of the average density of the matrix material in the drum near the top, center, and bottom.

The source shutters are interconnected by a rod and sources exposed by pulling the shutter assembly vertically up into the collimator slots. This design ensures that the shutters will drop into the shielded position in the event of a power failure. Sensors verify the full-open and full-closed positions of the transmission sources and a red warning light indicates when the transmission source is open.

Sources typically used for this system are <sup>152</sup>Eu or <sup>133</sup>Ba. These have been chosen to provide a source with a reasonable half-life and gamma energies close to the key plutonium lines. Alternate transmission sources are also available (e.g., <sup>169</sup>Yb or <sup>75</sup>Se) for specialized applications.

## **LOADING SYSTEM**

The loading system is a powered roller conveyor mechanism. Once the drum is positioned, the door opens, the drum is moved into the assay chamber, and the door is closed. The loading mechanism is designed for a working weight of up to 545 kg (1200 lb). The mechanism can handle drum sizes up to 55 gallons (210 L). Special versions of the AQ2 system are available for larger drums.

For a stand-alone system, drums are loaded directly onto the conveyor. For at-line systems, the conveyor can be interfaced to the facility's conveyor.

## **MECHANISM CONTROL SYSTEM**

The mechanism control system is a PLC-based controller with associated contactors, stepper motor controllers, I/O modules, drivers, etc. The PLC utilized is a GE/Fanuc Series 90 PLC. The PLC interfaces to the application software through an RS-485 interface. The flexibility of this design permits it to be easily modified to interface to a customer's process line. The control system is mounted in a locking NEMA-12 enclosure to ensure security, safety, and environmental control.

## **WASTE ASSAY APPLICATION SOFTWARE**

The Mirion Genie™ 2000 based NDA-2000 Non-Destructive Assay Software is used for the Auto Q2 applications. The application software is designed to run under Windows NT/2000/XP and utilizes all of the standard Genie 2000 high resolution gamma spectroscopy techniques. In addition, some of the features included in the software are:

- A high level menu structure for ease of use.
- Multiple matrix correction techniques including:
  - Average Density.
  - Differential peak analysis.
  - Transmission Correction.
- Integrates measured plutonium isotopics (MGA analysis).
- Total Measurement Uncertainty (TMU) Analysis.
- Extensive QA and measurement control routines.
- Automated calibration routines.
- Archiving capabilities.
- User editable report templates.
- Compliant with NQA2 and ISO 9001.
- And much more.

A more detailed description is included in the NDA-2000 (S529) specification sheet.

## PERFORMANCE

A minimum detectable activity of 56 Bq (1.5 nCi) at 0.1 g/cc material to 222 Bq (6 nCi) at 1.7 g/cc material per drum can be achieved for nuclides with gamma energies from 300 to 1500 keV and 100% gamma abundance. (Detection levels are based on a uniform source and matrix sample of a clean waste drum under normal environmental background conditions. The typical assay is considered to require 30 minutes with three minutes allocated to transmission measurements.)

Worst case accuracy will typically be less than plus or minus a factor of three for point sources of radioactivity located anywhere in the sample chamber when the sample density is 1 g/cc or less. For a more detailed look at the performance of the Auto Q2 system for a variety of nuclides, refer to Table 1.

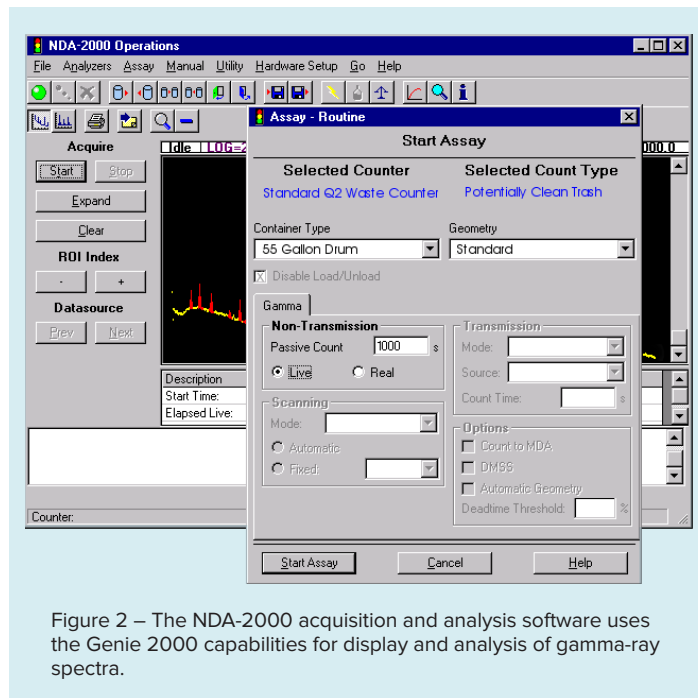


Figure 2 – The NDA-2000 acquisition and analysis software uses the Genie 2000 capabilities for display and analysis of gamma-ray spectra.

## SPECIFICATIONS

### PHYSICAL

#### SHIELD ASSEMBLY

- Total Weight – 6577 kg (14 500 lb).

#### DIMENSIONS

- Width – 2632.5 mm (103.64 in.) (front with door open including transmission source option); 2185 mm (86 in. without transmission source option).
- Depth – 1855 mm (73 in.) includes stub conveyor which is approximately 781 mm (30.75 in.).
- Height – 2100 mm (82.68 in.).

#### STANDARD SYSTEM LOAD CAPACITY

- Maximum Drum Diameter – 609.6 mm (24 in.).
- Maximum Drum Height – 889.0 mm (35 in.).
- Maximum Drum Gross Weight – 1200 lb (545 kg).

### RELATED SYSTEMS

- Segmented Can Scanner – SGS™ Segmented Gamma Assay System assay system optimized for waste and scrap materials in containers less than 30 cm in diameter.
- High Activity SGS – SGS assay of Intermediate Level Wastes in 200 liter and larger drums with surface exposure rates in excess of 100 R/hr (1 Sv/hr).
- High Throughput SGS – SGS assay of drums using multiple HPGe detectors for increased throughput.
- Shielded Multi-Detector SGS – Segmented Gamma Analysis system using multiple HPGe detectors and a 4π low background steel shield provides both the accuracy of the SGS analysis and low detection levels.
- TGS™ Tomographic Gamma Scanner – Provides improved accuracy over the standard SGS system along with images of the drum contents.



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