STATUS OF THE AUTOMATED RADIOXENON SAMPLER ANALYZER, AND THE INTERNATIONAL MONITORING SYSTEM INTERNATIONAL NOBLE GAS EXPERIMENT

David Penn, Steven Biegalski, and Kendra Biegalski

Veridian Systems Division

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ABSTRACT

As part of the US involvement in the development and deployment of an International Monitoring System (IMS) for monitoring nuclear explosions, the Automated Radioxenon Sampler Analyzer (ARSA) was developed. The ARSA system automatically and continuously samples the atmosphere to separate elemental xenon via selective adsorption. The collected xenon sample is transferred to a radiation counting device where the electron and photon radiation spectra are acquired. The radiation spectra data are then transmitted to the International Data Centre (IDC) in Vienna, Austria for archiving, analysis and distribution to state signatories. A combination of four radioactive xenon isotopes and isomers are of particular interest for nuclear explosion monitoring purposes: ^{131m}Xe, ^{133m}Xe, ^{133}Xe, and ^{135}Xe. Four xenon-sampling systems have been built to support the IMS and currently they are in a testing and validation program, the International Noble Gas Experiment (INGE). As part of the third Phase of the INGE, the ARSA will be installed in Guangzhou, China and operated by local technicians and scientists at the Guangdong Environmental Radiation Research and Monitoring Center (GERC). Veridian Systems Division is the prime contractor for the installation and maintenance for the ARSA with the support of the original developers, Pacific Northwest National Laboratory (PNNL). Once installed at the GERC, the ARSA is scheduled to remain in China for one year, with an option to extend the period for an additional year.

In the past year Veridian Systems Division, under contract with the Defense Threat Reduction Agency (DTRA), has been performing an independent operational test and evaluation of a commercially manufactured ARSA prototype. The manufactured prototype will be delivered to Guangzhou. The manufactured prototype operates in the same manner as the original ARSA, built by PNNL, but does have some mechanical differences. Therefore it was necessary to perform a month long performance test in Charlottesville, Virginia to provide evidence to the IDC that the prototype meets the minimum requirements for the IMS. Once the ARSA is installed at the GERC, the local operators will become responsible for the daily operation and maintenance of the system.

The data produced by the ARSA during Phase III includes the electron-photon coincidence spectra as well as various sensor and instrumentation signals that are used to determine the "State of Health" (SOH) of the system. The data is transmitted from the ARSA automatically at two-hour intervals and delivered via the Internet to the International Data Center (IDC). From the IDC, it is distributed to Phase III participants and state signatories.

OBJECTIVE

This paper discusses the performance of the ARSA prior to its installation in China, the challenges that arose during the site coordination meetings, and the issues observed during the operation to date.

RESEARCH AND ACCOMPLISHMENTS

The International Noble Gas Experiment (INGE), Phase III

The American Automated Radioxenon Sampler Analyzer (ARSA) is one of four devices participating in the INGE and will be installed at the GERC in Guangzhou, China during the summer of 2002. The other three systems, and their respective installation sites, are composed of the:

1. French SPALAX located in Papeete, Tahiti
2. Russian ARIX located in Rio de Janeiro, Brazil
3. Swedish SAUNA located in Spitsbergen, Norway

The ARSA is being installed by Veridian Systems Division (VSD) scientists with the support of scientists from the Pacific Northwest National Laboratory (PNNL). It is the responsibility of VSD to ensure the performance of the ARSA with respect to the IMS requirements both before and after the installation. It is also the responsibility of VSD to provide oversight to the Chinese operators regarding the infrastructure requirements of the ARSA. To facilitate the success of the ARSA in the INGE a site coordination meeting was held at the GERC to solidify the responsibilities for each of the parties involved. The site coordination meeting was held during April of 2002. During the site coordination meeting VSD was given the opportunity to inspect the site and provide the local operators with the infrastructure upgrade requirements for proper operation of the ARSA.

Site Coordination

Representatives attended the site coordination meeting from VSD, PNNL, GERC, and the IMS. The meeting itinerary included an in depth inspection of the facility where the ARSA will be installed, the method proposed to move it to its final location and the data and communications channels that will be required for operation of the system.

The GERC representatives were supplied with a list of infrastructure requirements, see Table 1, in advance of the meeting and many of the requirements had already been met.

Table 1. ARSA Facility Requirements for Guangzhou, China

Facility Area	Requirement	Comments
Building Structure	ARSA Size is 36”x72”x72”	The entryways at the site must allow for the ARSA to enter the building.
	Floor loading	The weight of the ARSA is 2000 lbs. This weight is distributed over eight 1-inch diameter feet.
	On-site receiving	The site must have a facility to receive the ARSA when it is shipped.
	On-site moving of ARSA	The site must have equipment to facilitate the movement of the ARSA from the receiving location to the ARSA lab.
Communications	Phone line or Network Drop	The facility must have a mechanism for ARSA communications. The specifics of the local communications must be conveyed to Veridian before installation so that the ARSA may be configured and so that the proper parts are brought to the installation.

Air intake/ventilation	Outside air is needed.	A 4" flex hose will run out the lab window to the roof of the building. A rain hood/cap/bend and screen will be placed at the end of the intake tube.
Noise	System noise is around 80 dB.	Noise abatement measures may be required.
Power	230 V, 50/60Hz, single phase	A 230 V line will need to be installed.
	25 Amps	The power for the ARSA will require at least a 40 Amp breaker.
Site Security	Lab window	Security will be placed on ARSA lab windows.
	Doors	Locks will be placed on ARSA lab doors and access limited to specified personnel.
Drainage	Drainage is required for ARSA (about one quart per day)	A line must be run to the nearest drain.
Air Conditioning	Power output of ARSA is about 5 kW.	A minimum of 2-tons of air conditions is required.
System Ground	ARSA should be grounded.	It is recommended that the ARSA have a specific ground.
Storage Space	Shipping containers need to be stored.	Additional space beyond the ARSA lab need for storage.
Tools	ARSA utilizes standard tools.	English based tools needed.
Support Gases	Nitrogen bottles needed for ARSA	The site should obtain 99.999% grade (or higher purity) nitrogen for the ARSA The ARSA consumes about 200 cubic feet of nitrogen each month under normal operations.

In general the facility was in good condition and the laboratory where the ARSA will be installed had been renovated recently. The laboratory is separated into three sections, one of which houses a particulate system, see Figure 1, which samples the atmosphere for aerosols as part of the IMS. In Figure 1 the particulate system is in the room on the left and the ARSA will be installed in the room on the right.

Figure 1 ARSA lab at CN22

Since much work had already been completed to the site, few upgrades were required; the most important of which are:

1. Converting the three phase 380 V power to single phase 220 V, 25 A
2. Increasing the air conditioning capacity from 4.2 kW to 7 kW
3. Changing the location of the air intake on the roof of the building.

The first two of the above upgrades are straightforward but the third was required because it was located approximately 1 meter downstream from a chemical lab fume hood exhaust system. (Figure 2) The air intake has been relocated upstream of the location approximately 10 meters from the vent.

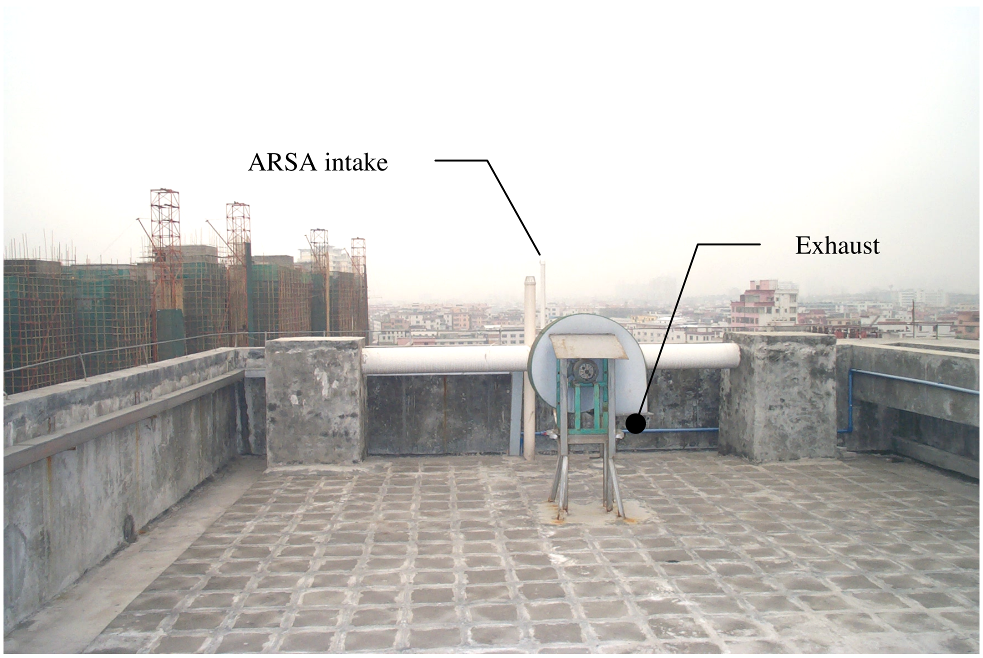

Figure 2. ARSA intake and fume hood vent location

The remainder of the coordination meeting involved discussions regarding the shipping procedures, customs, communications, and operation of the ARSA. The schedule put into place for the ARSA was to tune the system in the two to three weeks following the coordination meeting. Once the system was tuned it begin a pre-shipment performance testing period for one month in Charlottesville, Virginia. Once the baseline performance of the ARSA is determined and found acceptable by the IDC it would be ready for shipment. In parallel with the performance testing the Chinese were to complete the infrastructure upgrades and assist Veridian with determining the customs procedures. The ARSA was not to be shut down and disassembled until all of these issues were resolved. The customs issue was of particular importance because there is typically a deposit required for items temporarily imported into China. In the case of the ARSA, a representative from the Chinese Ministry of Defense was of great assistance and applied for the system to be brought in with no deposit required. At the time of writing this paper, the requirements for shipment were recently received and the ARSA is being prepared for shipment.

Once the ARSA is shipped, it will be stored temporarily by the shipping company in Guangzhou until the install team arrives. The ARSA will be tentatively scheduled for delivery at the site on the third day of the installation period. During the first two days of the installation period, the install team will perform a final inspection of the site and provide some limited training to the local operators so that they can assist with the installation. Since the lab is located on the 7th floor of the building and there is no elevator or external lifting mechanism, the GERC is responsible for coordinating with a local contractor to lift the ARSA from the ground floor to the laboratory on the 7th floor. Lifting the ARSA to the 7th floor will be accomplished through an open space in the stairwell, see Figures 3 and 4. The lifting will be done by constructing a frame above the 7th floor and using an electric winch to lift the

ARSA. A platform will be built at the 7th floor to extend under the ARSA and transfer it to the lab. Once the ARSA is in the lab, it will be installed on a vibration isolation pad to help decouple vibration from the compressor to the surrounding labs instrumentation, in particular the HPGe detector that is located approximately 2 meters away.

Figure 4. Stairwell at ground level

Figure 3. Stairwell opening

The last significant discussion during the site coordination meeting was electronic access to the machine and data transmission. At the time of the coordination meeting, the GERC did not have a LAN and connected to the Internet via an analog modem. It was originally agreed that the ARSA would be configured to do the same but after experiencing some difficulty with the analog service, it was agreed that an ADSL connection would be installed. Also, the ARSA will be configured to send data to the IDC at two-hour intervals that will then forward the data to Phase III participants and state signatories.

Pre-Shipment Testing

Since the ARSA being delivered for the INGE Phase III was not produced by PNNL, but by an independent manufacturer, the system was subjected to a month long pre-shipment test. This test was put into place to provide evidence to the IDC that the system complies with the minimum requirements for the IMS. Since the ARSA had been operating well and producing high quality data for some time before the site coordination meeting, there were few items that needed to be addressed before the test began.

The intrusion detection system on the ARSA was installed but needed to be configured for proper operation as well as two sensors for the room temperature and humidity needed to be integrated. The ARSA xenon quantification instrumentation (a cathetometer and infrared absorption meter) calibration was also checked and the format for transmitted data was modified to reflect the message format and protocols required by the International Data Center (IDC). The test was initiated on 13 May 2002 and ended on 10 June 2002. The data produced was transmitted to the Center for Basic and Applied Research and the IDC for analysis. The ARSA pre-shipment test report was generated based on this data and the performance was found to be acceptable by the IMS. The technical and data requirements for the period of performance are summarized in Tables 2 and 3. In addition to the technical requirements, it should be noted that the ARSA has provided a level of service where it was online for 97% of the test. It should also be noted that the time off-line was not due to a mechanical failure but was a safety mechanism protecting the machine during a severe weather condition.

Table 2. Data Requirements

Requirement	Type of Data	Recording and Saving	Transmission to IDC
1	Partial spectra	Every 2h	Every 2h
2	Full spectrum	Three times per day	Three times per day
3	State-of-Health data	Every 10 min and when it is switched on and off	Every 2h
4	UPS on/off	Every 10 min and when it is switched on and off	Every 2h
	Main power on/off	Every 10 min and when it is	Every 2h

5		switched on and off	
6	Auxiliary power	Every 10min and when it is switched on and off	Every 2 h
7	Meteorological data	Every 10min	Every 2 h
8	Indoor room temperature	Every 10min	Every 2 h
9	Indoor humidity	Every 10min	Every 2 h

Table 3. Technical Requirements

Requirement	**Characteristics**	**Minimum requirements**
1	Air flow	$0.4\ m^3\ h^{-1}$
2	Total volume of sample	$10\ m^3$
3	Collection time	≤ 24 h
4	Measurement time	≤ 24 h
5	Time before reporting	≤ 48 h
6	Reporting frequency	Daily
7	Isotopes measured	^{131m}Xe, ^{133m}Xe, ^{133}Xe, ^{135}Xe
8	Measurement mode	Beta-gamma coincidence or high resolution gamma spectroscopy
9	Minimum detectable concentration	$1\ mBq\ m^{-3}$ for ^{133}Xe

During the pre-shipment test the ARSA collected and measured atmospheric xenon continuously over the testing period with the exception of approximately 12 hours. This offline time was due to a severe storm (lightning, thunder, tornadoes) that tripped the manual main power circuit breaker. It was necessary to manually reset the breaker, located in the building fuse box, for the system to restart.

Data Performance

The data performance results are listed below and summarize the performance for the current configuration of the ARSA. The list numbers can be used as a reference to the requirements in Table 2. The data format for all transmitted messages is compliant with the specifications provided by the IDC in [IDC3.4.1r3] "Formats + Protocols for Messages".

1. The ARSA partial spectra functionality is provided on demand through a software menu item and when the system is stopped either manually or automatically.
2. Full spectra are recorded, saved, and transmitted by the ARSA three times per day. The data transmission frequency can be seen in Figure 1. Data was not sent on the 5th and 6th due to the power outage, partial spectra were recorded before the system automatically shut down on UPS power. Once the system is restarted, it must complete at least two collection cycles before a new sample is transferred to the radiation detector for counting. This produces a delay before new data is transmitted.
3. State-of-Health data were recorded at ten-minute intervals and transmitted to the IDC every two hours. The SOH refers to the readings from various sensors and systems on the ARSA that are used to monitor the performance and for diagnostics. The SOH data is structured as groups, or blocks, of data for organization. See [IDC 3.4.1r3] for more details.
4. The UPS status is recorded every ten minutes and is included in the #PowerSupply block of the State-of-Health messages.
5. The main power status is recorded at ten minute intervals and included in the #PowerSupply block of the State-of-Health messages.
6. Auxiliary power on the ARSA is only provided as battery power through the UPS. Once main power is lost, the system will operate for ten minutes before a command is sent to automatically shut the system down. The ARSA UPS battery is sufficient to power the system for three consecutive power losses without recharging, approximately 30 minutes.
7. Meteorological data is not provided by the ARSA system.

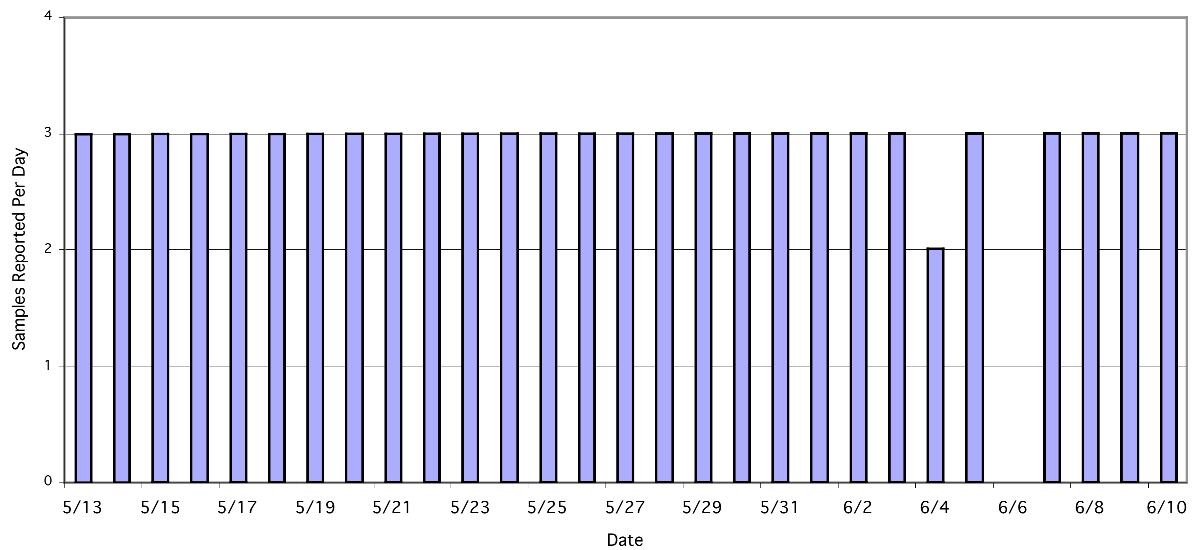

Figure 5 Complete sample measurement reporting frequency

8. The indoor room temperature sensor reading is recorded every ten minutes and reported every two hours in the #DetectorEnv block of the State-of-Health messages.
9. The indoor room humidity sensor reading is recorded every ten minutes and reported every two hours in the #DetectorEnv block of the State-of-Health messages.

Technical Performance

1. The total airflow produced by the system during the testing period can be seen in Figure 6. The mean value for the period is 5.94 m^3 h^{-1} with a standard deviation of 0.004 m^3 h^{-1}.

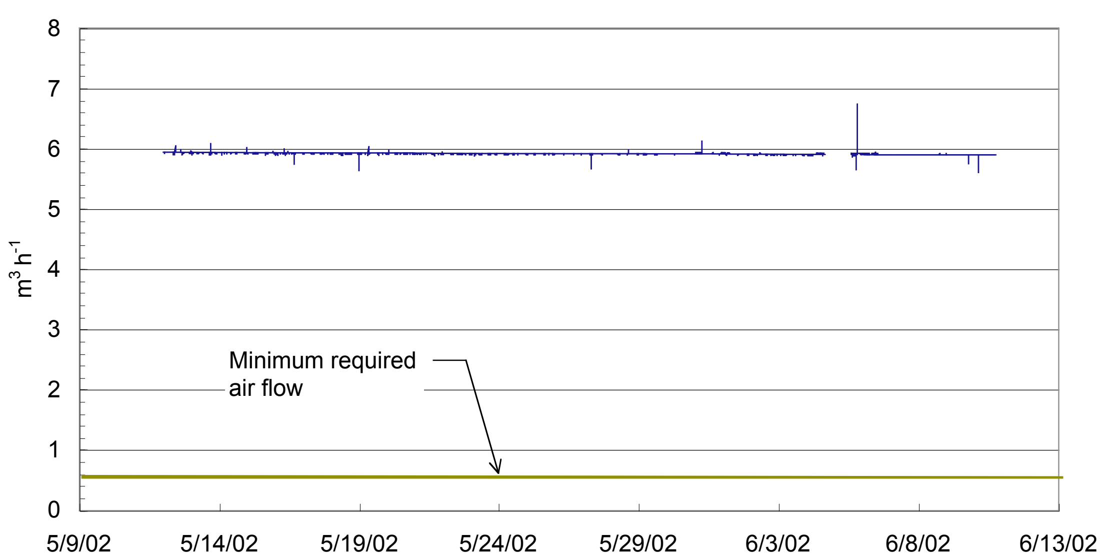

Figure 6. Total airflow through system

2. The total volume of each sample during the performance period is shown in Figure 7. The mean value is 17.63 m^3 with a standard deviation of 0.15 m^3.

3. The mean collection time for each sample is eight hours plus or minus ten minutes. The collection time was determined by calculating the amount of time a flow control valve was open for sample collection.
4. The mean measurement time for the gas samples during the performance test is 24.00 hours with a standard deviation of 0.01 hours. The mean measurement time for the gas background measurements is 7.36 hours with a standard deviation of 0.01 hours.
5. The time before reporting data was examined by comparing the dates a sample measurement acquisition stopped and the date the data was transmitted. In all cases the dates were the same indicating no more than 24 hours passed before the data was reported.
6. During the performance period, sample spectra were consistently reported three times per day with the exception of the 4^{th}, 5^{th}, and 6^{th} of June. On the 4^{th} of June two samples were reported before the system shut down. On the 5^{th} of June the three samples being measured at the time the system was shutdown on the 5^{th} were transmitted.
7. Figure 9 displays the spectra measured for a sample collected over the 7^{th} and 8^{th} of June. The abscissa and ordinate represent the beta and gamma measurement energy range that provides evidence of the beta-gamma coincidence measurement mode. The outlined boxes are indicative of the regions of interest for the four isotopes that are required to be measured (^{131m}Xe, ^{133m}Xe, ^{133}Xe, ^{135}Xe).
8. The minimum detectable concentration for the performance test period was consistently below the 1 mBq m^{-3} specification for ^{133}Xe. The mean values for each of the sample cells are reported in Table 4 with the data represented in Figure 8.

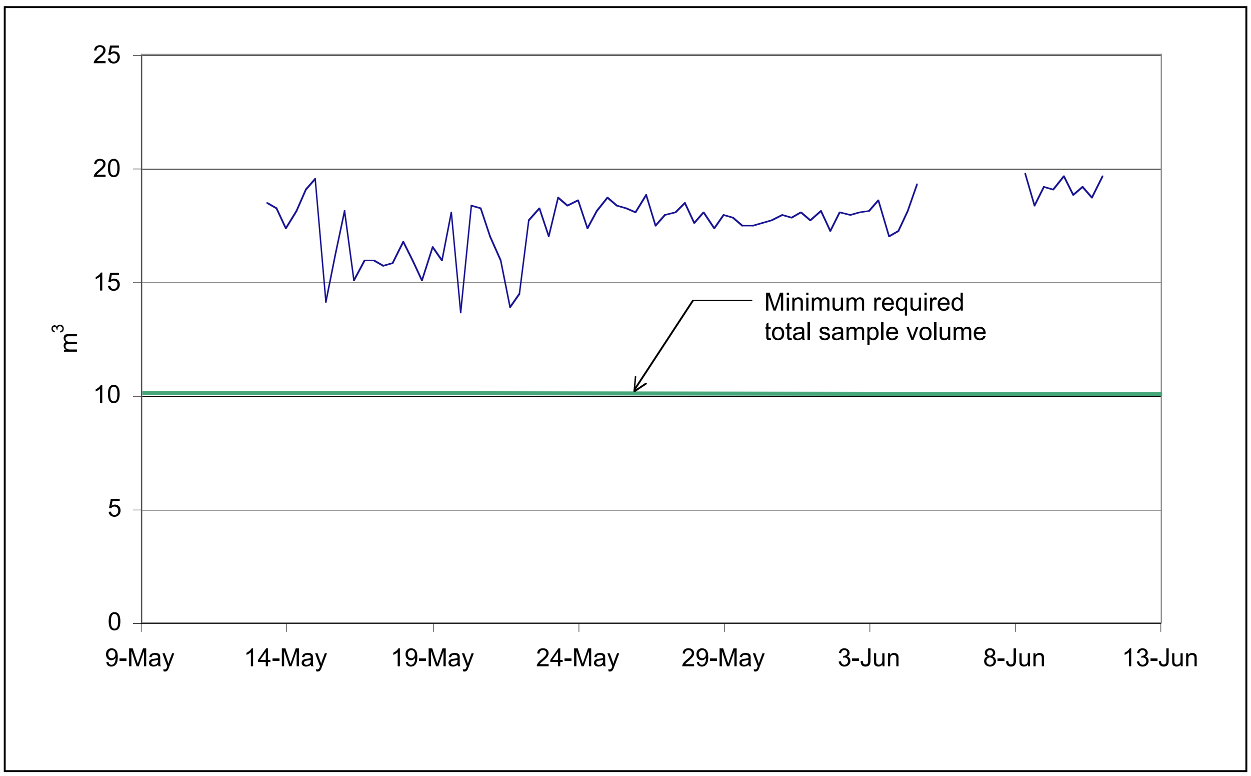

Figure 7. Total sampled air volume

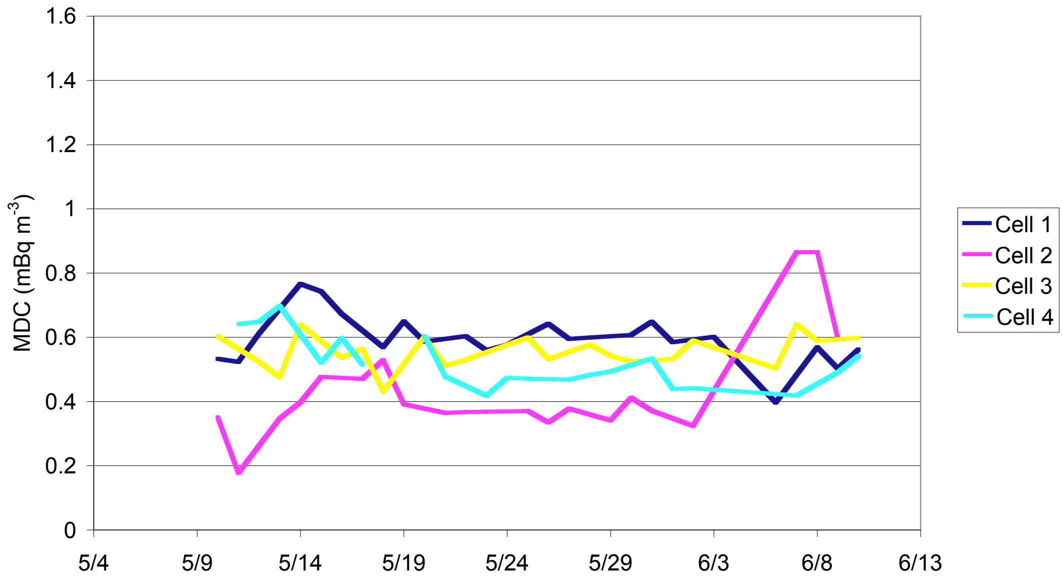

Figure 8. ^{133}**Xe MDC values for the individual detector cells**

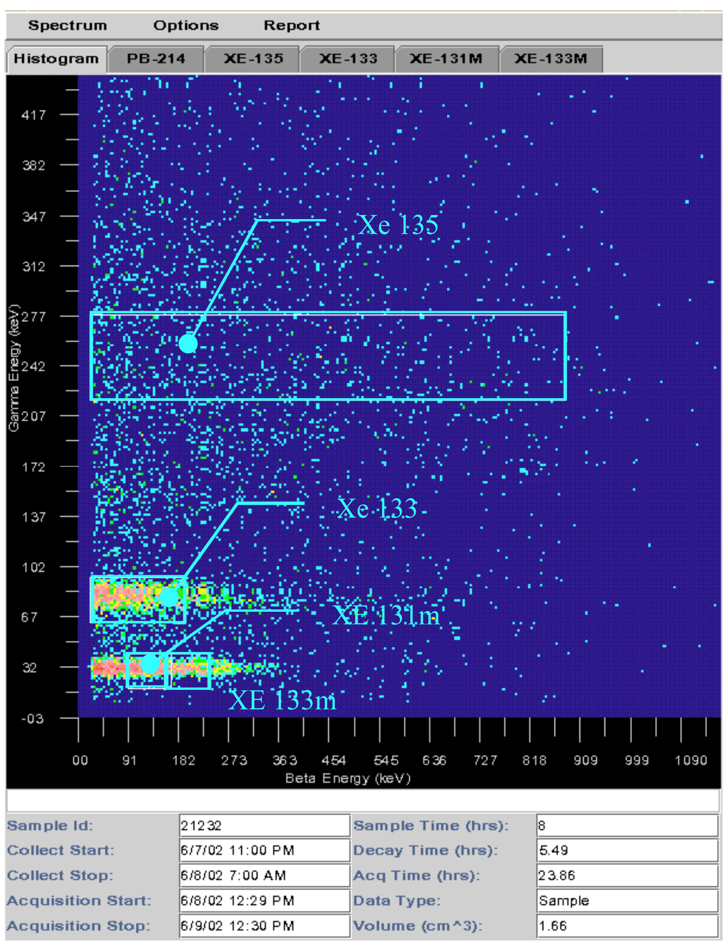

Figure 9. Sample beta-gamma coincidence data

Table 4. Mean MDC Values

Detector Cell	*Mean ^{133}Xe MDC mBq m^{-3}*	*Standard Deviation*
1	0.60	0.08
2	0.43	0.17
3	0.56	0.05
4	0.52	0.08

CONCLUSIONS AND RECOMENDATIONS

The status of the ARSA is that it is ready to be installed at the GERC; this should be accomplished by the end of the summer, 2002. At the time of writing this paper, a draft of the infrastructure upgrade report was received and the ARSA is being prepared for shipment to Guangzhou. Once the system arrives and is cleared by customs, the install team will leave for the site. The installation is scheduled for one month, which includes mechanically installing the system, setting up communications with the IDC, checking the calibration of the system, training the local operators, and preparing the system for a one month post installation performance test. After the post installation performance test is complete and the IDC approves the installation report, VSD will enter into a maintenance mode. The local operators will be required to perform the daily operation of the ARSA that includes inspection of the State-of-Health and spectral data as well as perform any required unscheduled maintenance. VSD will continue to support the ARSA by reviewing the data on an intermittent basis to ensure the proper performance of the machine and performing scheduled maintenance at six-month intervals.