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Disclaimer:

Portable Neutron Dose Rate Instrument Evaluation

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1.0 Introduction

The purpose of this document is to summarize the results of the evaluation of Portable Neutron Dose Rate Equipment (DOSE) coordinated by Health Physics Services (HPS) in the continuing effort to provide the most versatile and cost effective radiological monitoring instrumentation for the Savannah River Site (SRS). This evaluation will select the Neutron Dose Rate Instrument for the Mobile Plutonium Facility (MPF) project as well as the next site approved DOSE.

Instrument manufacturers were asked to submit one operational instrument for formal technical and field evaluation. This evaluation defines the requirements for acceptable DOSEs that can be calibrated with neutron radiation sources. In a continuing effort to increase cost effectiveness, and provide radiation monitoring equipment that incorporates the latest advancements in technology, a set of Minimum Technical and Operational Specifications (MTOS) and an evaluation protocol were developed by HPS. The MTOS includes the desired functionality and technical requirements for RME used for radiological control at SRS.

It was mandatory for a vendor to meet all the MTOS requirements for Savannah River Nuclear Solutions (SRNS) to consider their products for testing. Each vendor was expected to provide documentation to support compliance with MTOS requirements. The DOSE that will ultimately be procured must satisfy all the MTOS minimal technical and operational specifications in this document.

1.1 Scope

This evaluation covers the desired performance requirements for Portable Neutron Dose Rate Equipment (DOSE). This evaluation selects a neutron instrument that best meets the desired functionality and requirements.

1.2 Applicable Documents

The standards applicable to this evaluation are identified below. To the extent that these documents apply, the latest revision shall be used.

WSRC-IM-2006-00003	RME Technical Basis Manual, Revision 6, 2/24/2017
ANSI N42.17A	Performance Specifications for Health Physics Instrumentation – Portable Instrumentation for use in Normal Environmental Conditions.
WSRC-IM-2005-00001	RME Technical Specifications Manual, Revision 4, 9/30/2014.
SRNS-J6700-2018-00054	Evaluation of Portable Neutron Instrumentation Test Plan, Revision 2, 5/16/2018.

1.3 Terminology

MTOS	Minimum Technical and Operational Specifications.
Functionality:	Operational functions or capabilities of DOSEs in addition to the MTOS.
Technical Evaluation:	Physical documentation and design review of equipment by qualified technical expert's familiar with the technical and operational needs for DOSEs at SRS.
Maintenance/Calibration Evaluation:	A graded evaluation by Maintenance and Calibration Personnel to assess on the features, serviceability, calibration, maintenance, and operation of DOSEs while performing normal task requirements.

1.4 Requirements

The following specifications were developed by the Health Physics Services Radiological Instrumentation Section to establish the minimum technical and operational specifications required for inclusion in the evaluation process for initial instrument procurement. Instrument manufacturers were to examine these specifications to determine the adequacy of candidate instruments.

1.4.1 Each vendor submitted one instrument and a technical manual for each model submitted for this evaluation process. The instruments were to be delivered with all standard and optional accessories required by this specification. The instrument(s) were to arrive at the Site on or before the date determined by the procurement buyer. The instruments shall be returned to the vendor after completion of the evaluation process.

1.4.2 The instrument of choice was the one that satisfied all criteria in Section 3.1.1; best met the criteria in Section 3.1.2 and has the highest graded score for the evaluation criteria in Section 3. The results of the technical, field, and maintenance/calibration evaluations were used as justification for standardization of a DOSE and justification for future purchases of this instrument type for a minimum of 5 years and a maximum of 10 years.

1.4.3 Section 3.1.1 established the MTOS Requirements for the proposal. MTOS Requirements were considered mandatory and therefore the grading method for this area was pass/fail. Tests were conducted to confirm vendor compliance with MTOS requirements.

1.4.4 Section 3.1.2 established the Desired Functionalities. The Desired Functionalities were not mandatory and therefore were graded on subjective criteria.

1.4.5 Section 3.2 established the Technical, Field, and Maintenance/Calibration Evaluation criteria. The evaluation criteria were considered aids in determining the most appropriate instrument on a competitive basis. Examples of the evaluation criteria were given for each subsection. The criteria checks were completed using a graded approach.

2.0 Summary

The vendors that submitted instruments for this evaluation were Thermo Scientific, Ludlum Measurements, and Fuji Electric. Health Physics Services Radiological Instrumentation led the evaluation of the Portable Neutron Dose Rate Instruments. The instruments were rated on Instrument Design and Workmanship, Maintenance and Repair, Calibration, Source Checks, Operation, and Set-up. Each instrument was rated on each of the five criteria on a scale of 1 to 5, with 5 being the highest rating possible. See Appendices A and B for full details on the individual instrument ratings and comments.

The results of the evaluation ratings are listed below:

INSTRUMENT	**RATING**
Thermo Scientific RadEye NL/Moderator	4.1
Ludlum Model 30-7	4.6
Fuji Electric NSN3	3.3

The evaluation process was very lengthy and time consuming. After the evaluations were completed the evaluators stated, in discussions, that the Ludlum 42-49 with Model 30, when combined known as Model 30-7, was preferred over any other unit evaluated.

The Ludlum Model 30-7 neutron dose rate instrument was preferred as the first choice and best meets the criteria in Section 3.1 of this document. The Thermo RadEye NL/Moderator and the Fuji NSN3 both failed the MTOS requirements. It is recommended that the Ludlum Model 30-7 be procured as the standard DOSE for future use.

3.0 Discussion

Health Physics Services (HPS) compiled a list of potential radiation instrumentation manufacturers and suppliers. The vendors were asked to provide a technical response for any DOSE that they felt would meet the requirements

Three vendors choose to participate and sent instruments to be evaluated. Site Procurement issued three no cost purchase orders for this on-site evaluation. The vendors were also informed that the unit they supplied would be evaluated head to head with other vendor units based on the criteria provided in the original request for a technical response. Procurement also set a deadline for the delivery of equipment to be evaluated. DOSEs were evaluated in no particular order.

From the onset, it was the goal of the evaluation team to have little to no contact with each of the vendors. In our opinion, the requirements and desired functions were clearly outlined and having to contact the vendor was a negative. Having said this, Ludlum and Fuji Electric did their homework and provided good documentation and directions. On the other end of the spectrum, Thermo Scientific's documentation and directions were poor.

The Neutron Dose Rate Evaluation Protocol was developed and approved for the evaluation. The protocol laid the foundation and methodology for the evaluation process.

The evaluation included three major areas: a technical evaluation, a maintenance/calibration evaluation, and a field evaluation. The technical and maintenance evaluation was completed by HPS calibration personnel, and field evaluations by Radiological Protection staff members. All evaluations were performed in 735-2B to expedite the process and reduce the possibility of contaminating the vendor's equipment.

3.1 Minimum Technical and Operational Specifications / Desired Functionalities

3.1.1 Requirements

3.1.1.1 The detector shall be capable of assessing the dose equivalent from fast and intermediate neutrons.

3.1.1.2 Analog meter with selectable ranges or digital readout with auto-ranging.

3.1.1.3 Operating Temperature Range – 0 to 40 degrees C and humidity range 20% to 90% non-condensing.

3.1.1.4 The instrument is not sensitive to gamma radiation below 10 R/hr.

3.1.1.5 The equipment shall have a method to verify adequate battery power.

3.1.1.6 Calibration can be performed with little or no disassembly.

3.1.1.7 Display Units – mrem/hr.

3.1.2 Desired Functionalities

3.1.2.1 Quantify the exposure rate from neutron radiation.

3.1.2.2 Capable of operation in environmental conditions typical for operations at SRS (ANSI N42.17A).

3.1.2.3 The instrument shall be battery operated.

3.1.2.4 The instrument weighs less than 20 lbs (including batteries).

3.1.2.5 The battery lasts for more than 24 hours.

3.1.2.6 Display has a bright backlight.

3.1.2.7 The instrument is easy to calibrate.

3.1.2.8 The screen is easily readable.

3.1.2.9 The instrument is compact.

3.2 Instrument Evaluation Ratings Criteria

Instrument Evaluation Ratings Forms were completed by all evaluators; the Technical Lead Evaluator and HPS Calibration Staff. The MTOS criteria in Section 3.1 were broken down into the following categories: Instrument Design and Workmanship, Maintenance and Repair, Calibration, Source Checks, and Operation. An abbreviated version of this form containing Set-up, Source Checks, and Ease of Operation categories was used for field and maintenance/calibration evaluations. All evaluations were weighted equally.

3.2.1 Instrument Design and Workmanship

The design, workmanship quality, and construction materials of the instrument shall incorporate modular components. Design shall support mobility of equipment.

Evaluation Method: Equipment design and construction will be evaluated to determine the suitability of the instrument. Evaluator will obtain their opinion of the instrument.

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3.2.2 Maintenance and Repair

Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides shall be included with the instruments for evaluation. This shall include customer service and parts availability.

Evaluation Method: A spare parts list with pricing should be provided to allow determination of maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment which includes past product support.

3.2.3 Calibration

Calibration of the proposed instrument should require minimum disassembly. The technical manual shall include the vendor calibration and troubleshooting procedures.

Evaluation Method: The calibration procedures will be evaluated to determine maximum efficiency and effectiveness. Complete calibration shall be performed by SRNS HPS to verify calibration methodology.

3.2.4 Source Checks

Source checks of the proposed instrument should require no disassembly. The technical manual shall include the quality control procedures.

Evaluation Method: The procedures will be evaluated to determine maximum efficiency and effectiveness. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

3.2.5 Operation

Operation of the proposed instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but is not limited to, ease of handling characteristics, display and alarm clarity, function switch accessibility and parts replacement. A reference list of customers using the proposed instrument should be included.

Evaluation Method: Operational history may be verified through the reference list provided. Walk-through evaluations will be performed on operational characteristics of the equipment.

3.3 Technical, Maintenance/Calibration and Field Evaluation Criteria

At the end of each evaluation, the evaluator was asked to give each instrument a rating. This was based on a scale of 0 to 5 with 5 being the highest rating possible. If no overall rating was provided by an evaluator for an instrument then the average of all ratings indicated on the form was used. In these cases, attempts were made to obtain an overall evaluation rating from the evaluator prior to using the calculated average.

The initial calibration and testing were performed by the Technical Lead Evaluator. HPS and Field Radiological Protection personnel then conducted instrument evaluations. Prior to the evaluation of an instrument, the Lead Evaluator conducted a brief introduction on the functions and controls of the instrument. The Lead Evaluator answered any question concerning the calibration, testing, functions, and operations of the instrument.

3.3.1 Technical Evaluation

A total of 7 required minimum functional and design criteria and 9 desired functionalities were included in the specifications submitted to vendors. The vendors that submitted instruments for this evaluation were Thermo Scientific, Ludlum Measurements, and Fuji Electric. The technical evaluation process was completed over the entire period. The priority for the technical evaluation was to determine whether the DOSEs met the MTOS requirements in Section 3.1.1. Per the documentation provided to potential vendors, the ability of the DOSE to meet these requirements was mandatory. Therefore, the grading criterion was Pass/Fail. Evaluator results for these MTOS requirements are provided in Appendix A.

It was determined that only the Ludlum DOSE met the MTOS requirements (all passed). The ability to meet Desired Functionality specifications provided in Section 3.1.2 was not mandatory, but provided an advantage for DOSEs possessing these. The criteria utilized during evaluation of these specifications were subjective, based on a rating of 1 to 5. The Thermo RadEye NL/Moderator and Ludlum Model 30-7 rated highest for the desired functionality criteria with 41 total points, followed by the Fuji Electric NSN3 with 33 points. Full details are listed in Appendix A.

The technical evaluation showed that the Thermo RadEye's overall strengths were the durability of the instrument and light weight (6.5 lbs). Weaknesses of this instrument included having to open the moderator to turn on/off the instrument, gamma sensitivity at 5,000 mR/hr, a change in instrument response of greater than 15% based on the angle of incidence. The Ludlum 30-7 strengths were durability, no gamma sensitivity in fields up to 10,000 mR/hr, and instrument readings were within 10% at all angles of incidence to the source. This instrument's weakness was the weight at 9.2 lbs, but this is still less than what the current instrument weighs (~18 lbs). The Fuji NSN3 strengths were its light weight (7.5 lbs) and that it did not require disassembly for source checks. This instrument's weakness was that it must be returned to the vendor for all repairs, the batteries died within 24 hours, and a change in instrument response of greater than 30% when the angle of incidence to the source changed.

Average instrument ratings are provided below, with full details given in Appendix B.

INSTRUMENT	**RATING**
Thermo Radeye NL/Moderator	3.4
Ludlum Model 30-7	4.8
Fuji ElectricNSN3	3.4

3.3.2 Field Evaluation

The field evaluation process was completed over separate one day periods. A total of two (2) Radiological Protection Inspectors performed evaluations on the DOSEs in the 735-2B Calibration Laboratory. Source checks were performed using an Am-Be source, and were satisfactory on each DOSE that was evaluated.

Each of evaluators stated that the Ludlum Model 30-7 was similar to the current NRDs used in the field and the Thermo RadEye NL/Moderator and Fuji Electric were lightweight. Each evaluator also stated that the Thermo Radeye NL/Moderator and Fuji Electric NSN3 were directionally dependent on the Am-Be source. Average instrument ratings follow, and full details are provided in Appendix B.

INSTRUMENT	**RATING**
Thermo RadEye NL/Moderator	3.5
Ludlum Model 30-7	4.5
Fuji Electric NSN3	3.5

3.3.3 Maintenance/Calibration Evaluation

The maintenance/calibration evaluation was conducted by Calibration Laboratory personnel who were experienced in calibrations. From a maintenance standpoint, it was documented that for repair the Ludlum 30-7 and Thermo Radeye NL/Moderator had one board that could be replaced with no component replacement and that the Fuji Electric NSN3 would have to go back to the vendor for all repairs.

Calibration of the all three instruments was rated as easy. The Thermo RadEye NL would have to be removed from the moderator to be calibrated. Also noted, the Ludlum Model 30-7 would need to have the back removed with a screwdriver for calibration adjustments. Average instrument ratings are given below, and full details are provided in Appendix B.

INSTRUMENT	**RATING**
Thermo RadEye NL/Moderator	4.0
Ludlum Model 30-7	5.0
Fuji Electric NSN3	2.0

3.3.4 Calibration

3.3.4.1 Neutron Calibration

All of the DOSE manuals provided similar instructions on performing a neutron dose rate calibration.

For consistency in documentation and expediency, calibration data sheets were created in SRNS-J6700-2018-00054 for this evaluation.

4.0 Conclusion and Recommendations

Two of the DOSE instruments did not meet the MTOS requirements based on pass or fail ratings criteria. Instrument selection was based on the overall numeric rating results from the various technical, maintenance/calibration, and field evaluations that were performed over the course of this project. Based on all evaluations, the average numeric ratings were 4.6 for the Ludlum Model 30-7, 4.1 for the Thermo RadEye NL/Moderator, and 3.3 for the Fuji Electric NNS3.

The Ludlum Model 30-7 proved to be the most versatile of all the DOSEs evaluated. It is recommended that the Ludlum Model 30-7 be procured as the standard DOSE for future use.

DOSE Selected

Ludlum Model 30-7

5.0 References

1. User Manual for Ludlum Model 30, Ludlum Measurements, Inc., March 2017.
2. Instruction Manual, Neutron Survey Meter Model: NSN3, Fuji Electric, Co., April 2015.
3. RadEye NL Operating Instructions, Thermo Scientific, July 2014.
4. WSRC-IM-2005-0001, RME Technical Specifications Manual, Revision 4, September 30, 2014.
5. Procedure Manual Q3, Procedure 260, Special and Non-Routine Calibrations.
6. SRNS-J6700-2018-00054, Evaluation of Portable Neutron Instrumentation Test Plan, Revision 2, May 16, 2018.
7. ANSI N42.17A, Performance Specifications for Health Physics Instrumentation – Portable Instrumentation for use in Normal Environmental Conditions.
8. WSRC-IM-2006-00003, RME Technical Basis Manual, Revision 4, February 24, 2017.

APPENDICES

A – MTOS and Desired Functionalities Evaluation Results

B – Instrument Evaluations

C – Calibration and Test Results

D – Portable Neutron Dose Rate Instruments Evaluated

APPENDIX A

Minimum Technical and Operational Specifications Evaluation Results

Requirement	Thermo (RadEye NL Moderator)	Ludlum (30-7)	Fuji (NSN3)
3.1.1.1 The detector shall be capable of assessing the dose equivalent from fast and intermediate neutrons.	Pass	Pass	Pass
3.1.1.2 Analog meter with selectable ranges or digital readout with auto-ranging.	Pass	Pass	Pass
3.1.1.3 Operating Temperature Range – 0 to 40 degrees C and humidity range 20% to 90% non-condensing.	Pass	Pass	Fail
3.1.1.4 The instrument is not sensitive to gamma radiation below 10 R/hr.	Fail	Pass	Fail
3.1.1.5 The equipment shall have a method to verify adequate battery power.	Pass	Pass	Fail
3.1.1.6 Calibration can be performed with little or no disassembly.	Pass	Pass	Pass
3.1.1.7 Display Units – mrem/hr.	Pass	Pass	Pass

APPENDIX A, cont'd.

Desired Functionalities Evaluation Summary Score

Desired Function (Scale of 5)	**Thermo (RadEye NL/ Moderator)**	**Ludlum (30-7)**	**Fuji (NSN3)**
3.1.2.1 Quantify the exposure rate from neutron radiation.	5	5	5
3.1.2.2 Capable of operation in environmental conditions typical for operations at SRS (ANSI N42.17A).	5	5	2
3.1.2.3 The instrument shall be battery operated.	5	5	5
3.1.2.4 The instrument weighs less than 20 lbs (including batteries).	4	3	4
3.1.2.5 The battery lasts for more than 24 hours.	5	5	1
3.1.2.6 Display has a bright backlight.	5	5	5
3.1.2.7 The instrument is easy to calibrate.	3	4	4
3.1.2.8 The screen is easily readable.	4	5	3
3.1.2.9 The instrument is compact.	5	4	4
Total Score	41	41	33

Note: Desired functionalities ratings are subjective and shall be scored using a graded approach (1 to 5).

APPENDIX A, cont'd.

Desired Functionalities Evaluation Summary
(This table contains information that support Summary Score table)

Desired Function	**Thermo (RadEye NL/ Moderator)**	**Ludlum (30-7)**	**Fuji (NSN3)**
3.1.2.1 Quantify the exposure rate from neutron radiation.	Yes	Yes	Yes
3.1.2.2 Capable of operation in environmental conditions typical for operations at SRS (ANSI N42.17A).	Yes	Yes	No/Outside Range
3.1.2.3 The instrument shall be battery operated.	Yes	Yes	Yes
3.1.2.4 The instrument weighs less than 20 lbs (including batteries).	Yes/6.5 lbs	Yes/9.2 lbs	Yes/7.5 lbs
3.1.2.5 Does the battery last more than 24 hours?	Yes	Yes	No
3.1.2.6 Display has a bright backlight.	Yes	Yes	Yes
3.1.2.7 The instrument is easy to calibrate.	Yes/Open Moderator	Yes/Unscrew back of meter	Yes
3.1.2.8 The screen is easily readable.	Yes/Hard to view during calibration	Yes	Yes/Small screen/Refresh makes hard during calibration
3.1.2.9 The instrument is compact.	Yes	Yes	Yes

APPENDIX B

Technical Evaluation

Instrument: Thermo Radeye NL/Moderator
Evaluated By: Michelle Holman-Abbott
Date: 5/16/2018

Overall Rating 3.4

Technical Criteria	Rating Level (1 to 5)

1. Instrument Design and Workmanship — Rating: 4

   The design, workmanship quality, and construction materials of the instrument shall incorporate modular components, allow for easy location and placement and have a proven record in an industrial environment.

   Strengths: The RadEye NL/Moderator is robust and component lay out is suitable. All adjustments are made through software on the computer.

   Weaknesses: The instrument moderator must be opened to turn on/off the instrument and replace batteries.

2. Maintenance and Repair — Rating: 3

   Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides should be included with the instrument for evaluation. A spare parts list with pricing should be provided to aid in determining maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment.

   Strengths: The instrument would be cheaper to replace than repair.

   Weaknesses: The instrument moderator must be opened to turn on/off the instrument and replace batteries.

APPENDIX B, cont'd.

Thermo Radeye NL/Moderator Evaluation, cont'd

3. Calibration — Rating: 3

Calibration of the proposed instrument should require minimum disassembly. The technical manual should include the calibration procedures for neutron calibration methods. The calibration procedures will be evaluated to determine maximum efficiency and effectiveness with regard to applications. Complete calibration shall be performed by SRS HPS to verify calibration methodology

Strengths: Calibration requires a computer, software and instrument dock. The instrument did calibrate within 10% with the moderator facing the source.

Weaknesses: Calibration does require removal of the RadEye NL from the moderator. The instrument was gamma sensitive at 5000 mR/hr for a Cesium 137 source. When exposed to the Cs-137 source at 5000 mR/hr it jumped to 100 uR/hr. The instrument took over 8 minutes to step down to 2 uR/hr with no exposed source. At -45 degrees on the Cs-137 source at 5000 mR/hr the meter continued to step-up; after 1 minute it was at 336 uR/hr. This time the instrument immediately went to 0 mR/hr when the source was removed. The instrument is directional dependent per manufacturer and testing data.

4. Source Checks — Rating: 4

Source Checks of the proposed instrument should require minimum disassembly. The source check procedures will be evaluated to determine maximum efficiency and effectiveness. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

Strengths: Easy to complete source checks due to light weight of instrument.

Weaknesses: Will have to make a new source jig to be used with current neutron sources in the field.

5. Operation — Rating: 3

Operation of the proposed instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but is not limited to, ease of handling, display and alarm clarity, function switch accessibility and parts replacement. A reference list of customers using the proposed instrument should be included. Contact may be made to verify operational history through reference list provided. Walk-through evaluations will be performed on operational characteristics of the equipment

Strengths: Most of the controls were easily understood and manipulated. Instrument is light weight. Weighs 6.5 pounds.

Weaknesses: Instrument is gamma sensitive and directionally dependent. To turn on/off instrument you must remove moderator top.

APPENDIX B, cont'd.

Technical Evaluation

Instrument: Ludlum Model 30-7
Evaluated By: Michelle Holman-Abbott
Date: 5/16/2018

Overall Rating 4.8

Technical Criteria	Rating Level (1 to 5)

1. Instrument Design and Workmanship — Rating: 5

   The design, workmanship quality, and construction materials of the instrument shall incorporate modular components, allow for easy location and placement and have a proven record in an industrial environment.

   Strengths: The Ludlum Model 30-7 is robust and component lay out is suitable. All adjustments are made through software on the computer. Easy to read display during calibration and operation

   Weaknesses: Special cable used on the instrument, purchased separately.

2. Maintenance and Repair — Rating: 5

   Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides should be included with the instrument for evaluation. A spare parts list with pricing should be provided to aid in determining maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment.

   Strengths: The detector on this instrument is easy to change out. The meter is separate from the detector and can be replaced when damaged.

   Weaknesses: N/A.

APPENDIX B, cont'd.

Ludlum Model 30-7 Evaluation, cont'd

3. Calibration Rating: 4

Calibration of the proposed instrument should require minimum disassembly. The technical manual should include the calibration procedures for neutron calibration methods. The calibration procedures will be evaluated to determine maximum efficiency and effectiveness with regard to applications. Complete calibration shall be performed by SRS HPS to verify calibration methodology

Strengths: One point calibration. The instrument did calibrate within 10%. The instrument was not gamma sensitive at 10,000 mR/hr. The instrument is not directionally dependent.

Weaknesses: The back of the meter must be removed to connect the instrument to a computer for calibration. The center line for the detector is not identified on the instrument.

4. Source Checks Rating: 5

Source Checks of the proposed instrument should require minimum disassembly. The source check procedures will be evaluated to determine maximum efficiency and effectiveness. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

Strengths: Can use current source check jigs in the field.

Weaknesses: N/A.

5. Operation Rating: 5

Operation of the proposed instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but is not limited to, ease of handling, display and alarm clarity, function switch accessibility and parts replacement. A reference list of customers using the proposed instrument should be included. Contact may be made to verify operational history through reference list provided. Walk-through evaluations will be performed on operational characteristics of the equipment

Strengths: The Model 30-7 is easy to operate and has a large digital display. The instrument is rugged and can with-stand environmental conditions.

Weaknesses: Weighs 9.2 pounds.

APPENDIX B, cont'd.

Technical Evaluation

Instrument: Fuji Electric NSN3
Evaluated By: Michelle Holman-Abbott
Date: 5/16/2018

Overall Rating 3.4

Technical Criteria	Rating Level (1 to 5)

1. Instrument Design and Workmanship — Rating: 3

   The design, workmanship quality, and construction materials of the instrument shall incorporate modular components, allow for easy location and placement and have a proven record in an industrial environment.

   Strengths: The NSN3 is lightweight.

   Weaknesses: The display unit is thin and will be damaged during use or transportation.

2. Maintenance and Repair — Rating: 1

   Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides should be included with the instrument for evaluation. A spare parts list with pricing should be provided to aid in determining maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment.

   Strengths: All repairs must go to the vendor except the battery and the packing seal.

   Weaknesses: Strict storage conditions outside the typical range found at SRS.

APPENDIX B, cont'd.

Fuji Electric NSN3 Evaluation, cont'd

3. Calibration — Rating: 4

Calibration of the proposed instrument should require minimum disassembly. The technical manual should include the calibration procedures for neutron calibration methods. The calibration procedures will be evaluated to determine maximum efficiency and effectiveness with regard to applications. Complete calibration shall be performed by SRS HPS to verify calibration methodology

Strengths: Calibration requires a computer, software and instrument dock. The instrument did calibrate within 10% facing the source.

Weaknesses: Instrument is very directionally dependent. Gamma sensitivity was 990 mrem/hr at 10 R/hr. Screen flashes on monitor during calibration (at LSI) due to refresh, which made it harder to read during calibration.

4. Source Checks — Rating: 5

Source checks of the proposed instrument should require minimum disassembly. The Source Check procedures will be evaluated to determine maximum efficiency and effectiveness. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

Strengths: No disassembly needed to source check this instrument. Light weight instrument, weighs 7.5 pounds.

Weaknesses: Will have to make a new source jig to be used with current neutron sources in the field.

5. Operation — Rating: 4

Operation of the proposed instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but is not limited to, ease of handling, display and alarm clarity, function switch accessibility and parts replacement. A reference list of customers using the proposed instrument should be included. Contact may be made to verify operational history through reference list provided. Walk-through evaluations will be performed to determine operational characteristics of the equipment

Strengths: Easy to change out batteries in the field. Instrument is light weight.

Weaknesses: This instrument is directionally dependent. This instrument requires six AA batteries that last less than 24 hours in laboratory conditions.

APPENDIX B, cont'd.

Maintenance/Calibration Evaluation Rating Form

Instrument: Thermo RadEye NL/Moderator

Name	Date	Rating Level
Alan Boone	5/16/2018	4

Overall Rating 4

Maintenance/Calibration Criteria

1. Maintenance and Repair Rating: 5

Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides should be included with the instrument for evaluation. A spare parts list with pricing should be provided so that SRS can determine maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment.

Basis for Rating One board on meter to replace.
Strengths N/A
Weaknesses N/A
Exceptions N/A

2. Calibration Rating: 3

Calibration of the proposed instrument should require minimum disassembly. The technical manual should include the calibration procedures for neutron calibrations. The calibration procedures will be evaluated to determine maximum efficiency and effectiveness. Complete calibration shall be performed by SRS HPS to verify calibration methodology

Basis for Rating Difficult to read meter during calibration.
Strengths One point calibration. Easily adjusted. Currently calibrate RadEyes onsite.
Weaknesses Must be plugged into computer to be adjusted and needs new jig for calibration.
Exceptions N/A

APPENDIX B, cont'd.

Maintenance/Calibration Evaluation Rating Form

Instrument: Ludlum Model 30-7

Name	Date	Rating Level
Alan Boone	5/16/2018	5

Overall Rating 5

Maintenance/Calibration Criteria

1. Maintenance and Repair Rating: 5

Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides should be included with the instrument for evaluation. A spare parts list with pricing should be provided to allow determination of maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment.

Basis for Rating Detector easily changeable. One board on meter to replace.
Strengths Similar to current ASPs.
Weaknesses N/A
Exceptions N/A

2. Calibration Rating: 5

Calibration of the proposed instrument should require minimum disassembly. The technical manual should include the calibration procedures for neutron calibrations. The calibration procedures will be evaluated to determine maximum efficiency and effectiveness. Complete calibration shall be performed by SRS HPS to verify calibration methodology

Basis for Rating Calibration is easy.
Strengths One point calibration. Easily adjust HV and calibration constants.
Weaknesses Must be plugged into computer to be adjusted.
Exceptions N/A

APPENDIX B, cont'd.

Maintenance/Calibration Evaluation Rating Form

Instrument: Fuji Electric NSN3

Name	Date	Rating Level
Alan Boone	5/16/2018	2

Overall Rating 2.0

Maintenance/Calibration Criteria

1. Maintenance and Repair Rating: 1

Maintenance and repair of the instrument should facilitate rapid return to operation. Easy access to and removal of internal components is desired and should not require specialized tools. Maintenance procedures and troubleshooting guides should be included with the instrument for evaluation. A spare parts list with pricing should be provided to allow determination of maintenance life cycle cost estimates. A visual inspection will be performed to determine repair factors of equipment.

Basis for Rating All repairs must go to manufacturer except for the battery and the packing seal.
Strengths Easy to change batteries.
Weaknesses Strict storage requirements.
Exceptions N/A

2. Calibration Rating: 3

Calibration of the proposed instrument should require minimum disassembly. The technical manual should include the calibration procedures for neutron calibrations. The calibration procedures will be evaluated to determine maximum efficiency and effectiveness. Complete calibration shall be performed by SRS HPS to verify calibration methodology

Basis for Rating Calibration is easy.
Strengths Easy to carry.
Weaknesses Display flashes on LSI monitor during calibrations making it hard to read. Large instrument for instrument platform.
Exceptions N/A

APPENDIX B, cont'd.

Thermo RadEye NL/Moderator Field Evaluations

Field Evaluation Rating Form

Instrument: Thermo RadEye NL/Moderator

Name	Date	Rating Level
Virginia Childers (1)	3/27/2018	3
Eddie Pruett (2)	4/30/2018	4

Field Evaluation Criteria

1. Set-up

Set-up of the instrument should facilitate prompt readiness for operation. Set-up procedures and troubleshooting guides shall be included with the instrument for evaluation. Set-up of the instrument will be evaluated to determine the suitability of the instrument.

2. Source Checks

Source checks of the proposed instrument should require minimum disassembly. Repeatability of readings will be evaluated to gauge instrument source response. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

Field Comments:
(1) Readings from different angles were not consistent.

(2) Instrument readings at the same angle were accurate.

3. Ease of Operation

Operation of the instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but not limited to, ease of handling, display and alarm clarity and function switch accessibility.

Field Comments:
(1) Light weight but slide cap over RadEye was inconvenient. Nice size and weight, but not good for field use.

(2) Small and easy to transport. A weakness is directionally dependenence. Requires manipulation of the moderator device.

APPENDIX B, cont'd.

Ludlum Model 30-7 Field Evaluations

Field Evaluation Rating Form

Instrument: Ludlum Model 30-7

Name	Date	Rating Level
Virginia Childers (1)	3/27/2018	4
Eddie Pruett (2)	4/30/2018	5

Field Evaluation Criteria

1. Set-up

Set-up of the instrument should facilitate prompt readiness for operation. Set-up procedures and troubleshooting guides shall be included with the instrument for evaluation. Set-up of the instrument will be evaluated to determine the suitability of the instrument.

2. Source Checks

Source checks of the proposed instrument should require minimum disassembly. Repeatability of readings will be evaluated to gauge instrument source response. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

Field Comments:
(1) Easy readout, accurate from all angles. Weakness was that the instrument took a little longer for reading to go back to zero.

(2) Instrument readings were repeatable and can be used on existing source check device.

3. Ease of Operation

Operation of the instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but not limited to, ease of handling, display and alarm clarity and function switch accessibility.

Field Comments:
(1) Easy to operate and read the display. One weakness is that it was heavier than other instruments tested. Would like to use in the field.

(2) Instrument is relatively light and little menu navigation required. Worried about meter mount being damaged in the field. Overall like that the carry handle is attached to the ball and not the meter. Not directionally dependent for dose rates.

APPENDIX B, cont'd.

Fuji Electric NSN3 Field Evaluations

Field Evaluation Rating Form

Instrument: Fuji Electric NSN3

Name	Date	Rating Level
Virginia Childers (1)	3/27/2018	3
Eddie Pruett (2)	4/30/2018	4

Field Evaluation Criteria

1. Set-up

Set-up of the instrument should facilitate prompt readiness for operation. Set-up procedures and troubleshooting guides shall be included with the instrument for evaluation. Set-up of the instrument will be evaluated to determine the suitability of the instrument.

2. Source Checks

Source checks of the proposed instrument should require minimum disassembly. Repeatability of readings will be evaluated to gauge instrument source response. Multiple source checks will be performed to determine stability and reproducibility of the equipment and to verify data storage functions if so equipped.

Field Comments:
(1) Readings from different angles were not consistent and the instrument is awkward to handle.

(2) Will need a new jig for source checking. Instrument readings at the same angle were accurate.

3. Ease of Operation

Operation of the instrument should be simple and require minimal user interaction. The instrument must be ergonomically suitable to instrument users. This includes, but not limited to, ease of handling, display and alarm clarity and function switch accessibility.

Field Comments:
(1) Easy to operate and read the display. One is the set-up functions. Harder to maneuver. Additional comment, that this instrument would not be good for field use.

(2) Menus and functions are easy to operate, light instrument and the display tilts. Additional comment, this instrument would be useful for environmental surveys where directional dependence limitations do not exist.

APPENDIX C
Portable Neutron Dose Rate Instruments Calibration and Test Results

Before Calibration (3/20/2018) readings Cf-252

Irradiator Reading	Instrument Reading Cal Factor 3	Instrument Reading Cal Factor 4.62	Instrument Reading Cal Factor 3.93
50.0 mrem/hr	13.5 mrem/hr	**114.0 mrem/hr**	68.0 mrem/hr
100.0 mrem/hr	70.0 mrem/hr	**135.0 mrem/hr**	113.0 mrem/hr
200.0 mrem/hr	130.0 mrem/hr	235.0 mrem/hr	205.0 mrem/hr
500.0 mrem/hr	312.0mrem/hr	550.0 mrem/hr	496.0 mrem/hr
800.0 mrem/hr	529.0 mrem/hr	926.0 mrem/hr	805.0 mrem/hr
1000.0mrem/hr	644.0 mrem/hr	1014.0 mrem/hr	1000.0 mrem/hr

Vendor: Thermo Fisher

Model: Radeye NL/Moderator Calibration: C_0: Original Calibration Factor = 3

$$C_1 = C_0 \times \frac{R_0}{R_1}$$

C_1=3x(200/130) C_1=4.62x(200/235)

C_1=4.62 C_1=3.93

Offset: 15.2cm
Z-Axis: 7.7cm on side
M&TE used: ______________
R007
R007N

Results of Tests: Cal Factor 3.93

Background 3/21/2018 0.0 mrem/hr and 3/22/2018 0.0 mrem/hr.

	Instrument Angle to the Source Degrees	3125 ug Cf-252 Rate: 500 mrem/hr	3125 ug Cf-252 Rate:300 mrem/hr	3125 ug Cf-252 Rate:200 mrem/hr	3125 ug Cf-252 Rate:100 mrem/hr	3125 ug Cf-252 Rate: 50 mrem/hr	2 Ci Cs-137 Rate: 900 mR/hr	2 Ci Cs-137 Rate:100 mR/hr	100 Ci Cs-137 Rate: 5000mR/hr	50 Ci Cs-137 Rate: 5 mR/hr
3/21/18	0	496.0	304.0	205.0	113.0	68.0	0.0	0.0	100.0	0.0
3/21/18	-45	508.0	306.0	210.0	120.0	68.0	0.004	0.003	336.0	0.0
3/21/18	-90	462.0	275.0	195.0	115.0	69.0	0.011	0.0	275.0	0.0
3/22/18	45	509.0	306.0	213.0	120.0	73.0	0.015	0.0	700.0	0.0
3/22/18	90	469.0	287.0	193.0	105.0	69.5	0.018	0.0	723.0	0.0
	180	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX C
Portable Neutron Dose Rate Instruments Calibration and Test Results

Before Calibration (3/20/2018) readings Cf-252

Irradiator Reading	Instrument Reading ICRP 21	Instrument Reading ICRP 74 Bare/ 1100 V	Instrument Reading ICRP 74 Bare/ 1000 V	Instrument Reading ICRP 74 Bare/ 1025 V
50.0 mrem/hr	68.1 mrem/hr	78.0 mrem/hr		52.0 mrem/hr
100.0 mrem/hr	140 mrem/hr	149.0 mrem/hr		105.0 mrem/hr
500.0 mrem/hr	705 mrem/hr	720.0 mrem/hr	312.0 mrem/hr	492.0 mrem/hr
700.0 mrem/hr	970.0 mrem/hr	1060.0 mrem/hr		705.0 mrem/hr
800.0 mrem/hr	1014.0 mrem/hr	1020.0 mrem/hr	516.0 mrem/hr	812.0 mrem/hr

Vendor: Ludlum

Model: 42-49/Model 30

Offset: 15.2cm
Z-Axis: 9.6 cm on side
M&TE used: R007
R007N

Results of Tests: Voltage 1025V

Background 3/22/2018 0.0 mrem/hr.

	Instrument Angle to the Source Degrees	3125 ug Cf-252 Rate: 500 mrem/hr	3125 ug Cf-252 Rate: 300 mrem/hr	3125 ug Cf-252 Rate: 200 mrem/hr	3125 ug Cf-252 Rate: 100 mrem/hr	3125 ug Cf-252 Rate: 50 mrem/hr	2 Ci Cs-137 Rate: 900 mR/hr	2 Ci Cs-137 Rate: 100 mR/hr	100 Ci Cs-137 Rate: 5000 mR/hr	50 Ci Cs-137 Rate: 5 mR/hr
3/22/18	0	492.0	298.0	194.0	105.0	52.0	0.0	0.0	0.0	0.0
3/22/18	-45	500.0	298.0	196.0	100.0	64.0	0.0	0.0	0.0	0.0
3/22/18	-90	497.0	291.0	192.0	104.0	55.0	0.0	0.0	0.0	0.0
3/22/18	45	500.0	295.0	198.0	95.0	54.0	0.0	0.0	0.0	0.0
3/22/18	90	501.0	302.0	206.0	99.0	50.0	0.0	0.0	0.0	0.0
3/22/18	180	500.0	304.0	201.00	96.0	53	0.0	0.0	0.0	0.0
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX C
Portable Neutron Dose Rate Instruments Calibration and Test Results

Before Calibration (3/14/2018) readings Cf-252

Irradiator Reading	Instrument Reading
50.0 mrem/hr	32.9 mrem/hr
100.0 mrem/hr	70.4 mrem/hr
200.0 mrem/hr	143.0 mrem/hr
300.0 mrem/hr	222.7 mrem/hr
500.0 mrem/hr	383.0 mrem/hr
800.0 mrem/hr	652.0 mrem/hr

Vendor: Fuji Electric

Model: NSN3

Calibration: C_0: Original Calibration Factor = 80

$$C_1 = C_0 \times \frac{R_0}{R_1}$$

C_1=80x(500/383)

C_1=104.0

Offset: 15.2 cm
Z-Axis: 8.1 cm
M&TE used:
R007
R007N

Results of Tests: Cal Factor 104.0

Background 3/19/2018 0.019 mrem/hr and 3/20/2018 0.038 mrem/hr.

	Instrument Angle to the Source Degrees	3125 ug Cf-252 Rate: 500 mrem/hr	3125 ug Cf-252 Rate:300 mrem/hr	3125 ug Cf-252 Rate:200 mrem/hr	3125 ug Cf-252 Rate:100 mrem/hr	3125 ug Cf-252 Rate: 50 mrem/hr	2 Ci Cs-137 Rate: 900 mR/hr	2 Ci Cs-137 Rate:100 mR/hr	100 Ci Cs-137 Rate: 5000 mR/hr	50 Ci Cs-137 Rate: 5 mR/hr
3/19/18	0	514.2	297.4	195.5	90.0	43.0	0.019	0.019	65.0	0.01
3/20/18	-45	580.0	335.0	215.0	105.0	48.0	0.03	0.03	153.00	0.026
3/20/18	-90	638.0	369.0	232.0	118.0	51.0	0.036	0.032	110.0	0.039
3/20/18	45	551.0	314.0	212.0	100.0	49.0	0.02	0.02	89.0	0.02
3/20/18	90	646.0	367.0	239.0	110.0	53.0	0.04	0.031	110.0	0.032
3/20/18	180	458.0	263.0	169.0	86.0	40.0	0.04	0.041	28.6	0.028
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX D
Portable Neutron Dose Rate Instruments Evaluated

Ludlum Model 30-7

Thermo RadEye NL/Moderator

Fuji Electric NSN3

Portable Neutron Dose Rate Instrument Evaluation

Distribution

HPS Memo Distribution

Fredrick R. Abbott

Sabrina Faircloth – RPD Records

EDWS

May 17, 2018

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Portable Neutron Dose Rate Instrument Evaluation