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Annual Report for the Research Reactor Infrastructure Program

November 2020

Prepared by
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RRI Project Manager

Idaho National Laboratory

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SUMMARY

Idaho National Laboratory (INL) manages and provides project management, technical support, quality engineering, quality inspection and nuclear material support for the Department of Energy (DOE) Research Reactor Infrastructure (RRI) program. This program provides nuclear reactor fuel for United States domestic University Test and Research and Training Reactor programs. Currently, the RRI program supports 24 domestic universities that operate a total of 25 nuclear reactors at their on-campus reactor facilities. These on-campus reactors serve a vital national role in both educating and providing experience to nuclear engineers, nuclear scientists, and other professionals critical to our national laboratories, Department of Energy, Department of Defense, Nuclear Regulatory Commission, nuclear power, nuclear medicine, related industries, and Homeland Security. This Annual Report covers university reactor information, including the licensed power rating of the reactor facility, the fuel type of the reactor facility, and operational data. Data include energy generated in 2019, average hours per week that the reactor is operated, and grams of U-235 consumed in 2019 which is the most recent year that data are available.

During FY-20, the world was impacted by a global pandemic, the Novel Coronavirus 2019 (COVID-19). The response to COVID-19 was different, yet similar at each university reactor facility. This Annual Report includes a description of the impact that COVID-19 had on the reactor facilities. Impact statements were provided by the reactor management teams at each facility.

The Annual Report also identifies RRI project accomplishments completed during FY-20. Accomplishments are discussed for fuel fabrication and delivery to university reactor facilities, spent fuel shipments from reactor facilities, project management and technical support provided by the RRI program, and issues and opportunities.

The mission of the RRI program was met for FY-20. Enough fuel elements were delivered to the university research reactors to maintain sustained operability of all supported reactor facilities. Spent fuel elements were returned to the DOE-owned receipt and storage facility at Savannah River Site, thus maintaining a minimal supply of Special Nuclear Material (SNM) at university facilities.

Regardless of pervasive funding constraints at each reactor facility, nuclear education and research programs continue to operate, and many are seeing expansion of their programs.

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ACRONYMS

AEC	Atomic Energy Commission
AGN	Aerojet General Nucleonics
BEA	Battelle Energy Alliance
BWXT	BWX Technologies, Inc.
CNS	Consolidated Nuclear Services
COVID-19	coronavirus disease 2019
DOD	Department of Defense
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Operations Office
ERDA	Energy Research and Development Administration
HEU	Highly Enriched Uranium
HP	Health Physicist
INL	Idaho National Laboratory
LEU	Low Enriched Uranium
MIT	Massachusetts Institute of Technology
MURR	University of Missouri Research Reactor (Columbia)
NASA	National Aeronautics and Space Administration
NEUP	Nuclear Energy University Program
NRC	Nuclear Regulatory Commission
RINSC	Rhode Island Nuclear Science Center
RO	Reactor Operator
RPI	Rensselaer Polytechnic Institute
RRI	Research Reactor Infrastructure
SNM	Special Nuclear Material
SRO	Senior Reactor Operators
S&T	Science & Technology
TI	TRIGA International
TRIGA	Training, Research, Isotope production, General Atomics
TRTR	Test, Research and Training Reactors
UCI	University of California–Irvine

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Annual Report for the Research Reactor Infrastructure Program

1. PURPOSE OF THE PROGRAM

Idaho National Laboratory (INL) manages and provides project management, technical support, quality engineering, quality inspection and nuclear material support for the Department of Energy (DOE) Research Reactor Infrastructure program (RRI). This program provides nuclear reactor fuel for United States domestic University Test and Research and Training Reactor programs. The two fuel types fabricated for the program, plate fuel and Training, Research, Isotope Production, General Atomics (TRIGA) fuel are obtained through subcontracts with two fuel fabricators, BWX Technologies, Inc. (BWXT) and TRIGA International (TI). Respectively, these subcontractors fabricate high and low enriched uranium aluminide, silicide and TRIGA fuel on a recurring basis. The program is also responsible for funding, coordinating, and scheduling the return of the DOE-owned, irradiated nuclear fuel over the life of the program.

2. DESCRIPTION

2.1 Background and History

The background and history of the RRI program is contained in Appendix A.

2.2 National Value of University Reactor Programs

In 1980, there were 63 nuclear research and test reactors, which provided critical hands-on experience and enabled multidisciplinary research. Currently, the RRI program supports 24 domestic universities that operate a total of 25 nuclear reactors at their on-campus reactor facilities. On-site reactors, clearly, enhance the educational and research missions of a university. Properly equipped and managed on-campus reactors offer unique advantages in terms of hands-on education and research experience in running small scale experiments which would not be practical at larger off-campus reactors. These on-campus reactors serve a vital national role in both educating and providing experience to nuclear engineers, nuclear scientists, and other professionals critical to our national laboratories, DOE, Department of Defense (DOD), Nuclear Regulatory Commission (NRC), nuclear power, nuclear medicine, related industries, and Homeland Security. Additionally, the reactor facilities offer tours and information about the reactor facilities and the uses of nuclear energy. In a report from the University Research Reactor Task Force to the DOE Nuclear Energy Research Advisory Committee published in April 2001, the finding was that on-campus reactors have "become a valuable asset as an educational outreach tool for promoting and educating the public about nuclear technologies. These on-campus research reactors contribute to academic values through research, and education and through service to off-campus user constituencies."

2.2.1 Research

University research reactors are the focus of multidisciplinary research with contributions to physics, chemistry, biology, medicine, epidemiology, environmental sciences, material sciences, fluid mechanics, geology, archaeology, paleontology, forensic sciences, and other fields in addition to nuclear engineering research and reactor physics. The three principal reactor research techniques are neutron activation analysis, neutron scattering, and neutron radiography. The latter two are largely confined to reactors of one megawatt and higher power. Research reactors in the United States constitute unique and essential research tools in several aspects: structural determinations of materials including superconductors and biologicals, ultra-sensitive analysis for traces of elements, radiological display of physical phenomena, and introduction of radioisotopes for medical diagnostics and research.

2.2.2 Education

On-campus reactors have been a traditional focus of educational programs for nuclear engineers. Educational uses are made of even the smallest fractional watt on-campus reactors. Beneficiaries include graduate and undergraduate students, as well as nuclear power plant operators, secondary schools and the general public through outreach programs.

2.2.3 Service

University reactors, particularly those of one megawatt and larger, serve a range of off-campus constituencies: the medical community, industrial organizations, and government agencies. These clients use irradiated materials, materials analysis, trace element detection, and radiographic analysis of objects and processes. By providing such services, managers of university research reactors establish beneficial links to off-campus users, expose faculty and students to commercial applications of the nuclear sciences, and earn revenue to help support reactor programs.

2.3 Mission

The mission of the RRI program is to provide nuclear reactor fuel to domestic universities at no, or low, cost to the university. The title of the fuel remains with the U.S. government and, when universities are finished with the fuel, the fuel is returned to the U.S. government. The authority for this program is established under Section 31, Atomic Energy Act of 1954, as amended, 42 U.S.C. 2051.

2.4 University Reactor Information

The RRI program requested input from all supported facilities in order to quantify the capabilities at each facility. Many variations of reactor technology exist within the university operated reactor facilities. The RRI program subcontracts with 24 university facilities to supply government owned nuclear fuel for operations. Facilities include 12 TRIGA facilities, eight plate fuel facilities, three Aerojet General Nucleonics (AGN) facilities; one Pulstar fueled facility, and one critical facility.

Two types of plate fuel are fabricated and used at the reactor facilities, aluminide, and silicide. All but two reactors have been converted from highly enriched uranium (HEU) to low enriched uranium (LEU) to conform to the objective of the Global Threat Reduction Initiative.

Reactors are licensed and operate at a wide range of powers. The reactor operating at the highest power level and supported by the RRI program is the University of Missouri–Columbia research reactor (MURR), which is licensed to operate at 10 mega-watts. New York's Rensselaer Polytechnic Institute (RPI) operates the reactor with the lowest power level at 1 watt. A wide variety of capabilities exist within the university reactor community.

Table 1 contains information for university reactor facilities that are supported by the RRI program. Information contained in the table includes the licensed power rating of the reactor facility, the fuel type of the reactor facility, and whether the reactor fuel type is HEU or LEU.

Table 1. Research reactor facility details.

University	Reactor Licensed Power Level	Fuel Type	Fuel Details
University of Missouri–Columbia (MURR)	10 MW	Aluminide Plate Fuel	HEU
Massachusetts Institute of Technology (MIT)	4.9 MW	Aluminide Plate Fuel	HEU
Univ. of California–Davis	2 MW	TRIGA	LEU
Rhode Island Nuclear Science Center	2 MW	Silicide Plate Fuel	LEU

Kansas State	1.25 MW	TRIGA	LEU
Oregon State University	1 MW	TRIGA	LEU
University of Texas at Austin	1 MW	TRIGA	LEU
North Carolina State University	1 MW	PULSTAR	LEU
Penn State University	1 MW	TRIGA	LEU
Texas A&M University	1 MW	TRIGA & AGN	LEU
University of Massachusetts at Lowell	1 MW	Silicide Plate Fuel	LEU
University of Wisconsin	1 MW	TRIGA	LEU
Washington State University	1 MW	TRIGA	LEU
Ohio State University	500 KW	Silicide Plate Fuel	LEU
Reed College	250 KW	TRIGA	LEU
University of California at Irvine	250 KW	TRIGA	LEU
University of Maryland	250 KW	TRIGA	LEU
University of Missouri S&T	200 KW	Silicide Plate Fuel	LEU
University of Florida	100 KW	Silicide Plate Fuel	LEU
University of Utah	100 KW	TRIGA	LEU
Purdue University	10 KW	Aluminide Plate Fuel	LEU
Idaho State University	5 W	AGN	LEU
University of New Mexico	5 W	AGN	LEU
Rensselaer Polytechnic Institute	1 W	Critical Facility	LEU

The primary mission of each university reactor facility is to educate and perform university research. Depending on the capabilities, experimentation activities, and additional missions of each reactor facility, operations may be performed around the clock, or only a couple hours per week.

Table 2 contains operational data for each of the reactor facilities for calendar year 2019 (most recent year end data available). Data include energy generated in 2019, average hours per week that the reactor is operated, and grams of U-235 consumed in 2019.

Table 2. Research reactor facility operational data (calendar year 2019).

University	Energy Generated	Average Hours Per Week	U-235 Consumed
University of Missouri–Columbia (MURR)	78,485 MWH	150.88	4.12 kg
Massachusetts Institute of Technology (MIT)	31,092 MWH	110	1.645 kg
Univ. of California–Davis	1,435 MWH	27.6	68 g
Rhode Island Nuclear Science Center	432.42 MWH	7.03	22.52 g
Kansas State	21.96 MWH	4.7	1.15 g
Oregon State University	1,187 MWH	25.1	69 g
University of Texas at Austin	867 MWH	16.67	37.80 g
North Carolina State University	1,549.8 MWH	33.2	75.77 g

Penn State University	240.4 MWH	14.5	12.3 g
Texas A&M University	1,184.9 MWH	22.8	52.95 g
University of Massachusetts at Lowell	105 MWH	5.3	5.46 g
University of Wisconsin	91.81 MWH	3.0	4.8 g
Washington State University	1154 MWH	31	60 g
Ohio State University	57.12 MWH	8.0	3.0 g
Reed College	14.50 MWH	1	1 g
University of California at Irvine	18.60 MWH	3.07	0.969 g
University of Maryland	6.1 MWH	3	0.27 g
University of Missouri S&T	10.7 MWH	2.93	0.553 g
University of Florida	22.785 MWH	6.7	1.234 g
University of Utah	5.6 MWH	3	0.252 g
Purdue University	24.67 kWH	1.66	1.03 g
Idaho State University	0.0284 kWH	1.434	1.25 micrograms
University of New Mexico	0.244 kWH	2.7	10.7 micrograms
Rensselaer Polytechnic	0.01107 kWH	1.2	0.49 micrograms

Although the major focus of all university reactor facilities is to educate and perform university research, many also provide commercial services such as isotope production for medical and industrial use. All missions are executed concurrently, and no reactor facilities are operated solely to perform commercial work. Most on-site university research reactors offset operating costs by charging industrial users and commercial industry for neutrons and products provided. All funding derived from these sources are used to subsidize and maintain operability of the reactor facilities and, if these additional funding sources were not available to the reactor facilities, the reactor directors indicated that the reactors face a high risk of being shut down due to lack of operational funding provided by their respective universities.

Table 3 contains reactor usage data for each of the reactor facilities for calendar year 2019 (most recent year end data available). Data include percentage of fuel usage for five categories of operations. These include instruction and training, university research, academic and industrial research for facilities other than the sponsoring university, calibration and maintenance activities, and isotope or other products generated and sold to outside industry.

Table 3. Research reactor facility usage data.

University	Instruction and Training	University Research	Academic and Industrial Research	Calibration and Maintenance	Commercial Industry
University of Missouri–Columbia (MURR)	Information not Provided	Information not Provided	Information not Provided	Information not Provided	Information not Provided
Massachusetts Institute of Technology (MIT)	10%	40%	15%	20%	15%

Univ. of California–Davis	0%	50%	50%	0%	0%
Rhode Island Nuclear Science Center	40%	30%	30%	5%	0%
Kansas State	34%	43%	0%	23%	0%
Oregon State University	2%	18%	51%	19%	10%
University of Texas at Austin	25%	55%	20%	0%	0%
North Carolina State University	56%	<2%	40%	2%	0%
Penn State University	18%	20%	44%	18%	0%
Texas A&M University	27%	15%	15%	5%	38%
University of Massachusetts at Lowell	37%	44%	16%	3%	0%
University of Wisconsin	90%	2%	3%	5%	0%
Washington State University	50%	25%	10%	10%	5%
Ohio State University	20%	35%	43%	3%	0%
Reed College	60%	30%	0%	10%	0%
University of California at Irvine	27%	54%	11%	8%	0%
University of Maryland	20%	70%	0%	10%	0%
University of Missouri S&T	95%	5%	0%	0%	0%
University of Florida	100%	0%	0%	0%	0%
University of Utah	60%	30%	0%	10%	0%
Purdue University	83%	17%	0%	0%	0%
Idaho State University	90%	10%	0%	0%	0%
University of New Mexico	100%	0%	0%	0%	0%
Rensselaer Polytechnic	80%	0%	0%	20%	0%

Appendix B contains information provided by the universities affiliated with the RRI program. Each university overview contains a brief history of the reactor facility, the mission of the reactor, products provided, and customers supported by the reactor facility, and any special capabilities that make the facility unique or different from the other university reactor facilities.

3. IMPACT OF COVID-19 ON THE UNIVERSITY REACTOR FACILITIES

During FY-20, the world was impacted by a global pandemic, the Novel Coronavirus 2019 (COVID-19). The response to COVID-19 was different, yet similar at each university reactor facility. Below is a description of the impact that COVID-19 had on the reactor facilities. Impact statements were provided by the reactor management teams at each facility.

3.1 University of Missouri–Columbia (MURR)

The MURR reactor continued to operate during the pandemic. There was no disruption to their operating schedule. For the first three to four months after the start of the pandemic, they minimized the physical presence needed at MURR for maintaining only critical functions – safe and reliable operation of the reactor and producing and shipping MURR's life-saving isotope which patients rely on each and every week. This aligned with the U.S. president's guidance statement: "if you work in a critical infrastructure industry, as defined by the Department of Homeland Security, such as healthcare services and pharmaceutical and food supply, you have a special responsibility to maintain your normal work schedule." Additionally, they instituted all the University of Missouri COVID-19 policies such as social distancing, wearing masks, constant cleaning/sanitization, etc.

As of November 1, 2020, nearly the entire MURR staff have now returned to the facility, and research and education have begun again.

3.2 Massachusetts Institute of Technology (MIT)

The MIT reactor was in lockdown from March 18, 2020 until June 15, 2020, with reactor staff entering about once a week for checks such as those required for Tech Specs and security. Other than that, all staff worked from home to the extent possible. This included communicating closely with the NRC on deferrals for installation of the new nuclear safety system, on-the-job training requirements, medical examinations, and a small number of required surveillance procedures. Staff were able to avoid needing to use most of the deferrals that were considered; for instance, a Tech-Spec-required Independent Audit was completed entirely remotely, with staff arranging remote access, or scanning all necessary documents and emailing them to the auditor.

MIT's training program for new operator license candidates continuing online only, so there was no way to complete the practical hands-on aspects, resulting in cancellation of the planned September 2020 NRC licensing examination. Additionally, many of the candidates are MIT students who are not allowed by MIT to return to campus even as of November 1, 2020, creating uncertainty as to whether an exam could be administered in February 2021. These impedances may result in a shortage of student operators to support continuous 24/7 operation down the road.

3.3 University of California–Davis

The University of California–Davis reactor facility has been closed to all non-essential visitors, which has suspended all outreach and educational programs. Irradiation services (primarily neutron radiography) have continued without pause to support the Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and their subcontractors.

3.4 Rhode Island Nuclear Science Center

The Rhode Island Nuclear Science Center (RINSC) stopped giving tours and stopped allowing classes to come to the facility in March 2020. Since many of the groups that visit the facility on an annual basis come toward the end of the academic year, this had a significant impact on the number of tourists and classes that visited the facility.

RINSC is used for neutron activation analysis by a company that does analytical work for biomedical researchers from universities and hospitals from around the world. Unfortunately, since many universities shutdown and scaled back their operations due to COVID-19, the number of samples that the reactor irradiated for the company was significantly lower than it has been for previous years.

3.5 Kansas State University

The Kansas State University reactor outreach activities (tours, workshops, demonstrations) have been

suspended since March 2020. April is when they typically see the most visitors, so this had a major impact on tours.

The reactor did not have any requests for operations for the first few months because research labs on campus were hibernated. Campus research was opened in phases which resulted in a couple of experiment requests. Overall, operations for experimenters were drastically reduced.

Reactor staff availability was limited due to campus shutdown. Full-time staff-maintained license requirements. Part-time student staff had minimal participation in facility activities.

Activities were halted for training new operators until the fall 2020 semester.

Operator medical exams were delayed due to medical services being focused on COVID-19 response. Completion of medical exams was accomplished in the later phases of campus reopening.

Academic use of the facility has been limited to remote instruction. Class laboratory sessions are being held through video/tele-conference.

3.6 Oregon State University

The Oregon State University reactor was minimally operated from the middle of March 2020 to the middle of May due to the campus shutting down most of the laboratories. Most researchers that perform irradiations were unable to work at their laboratories (on and off campus), so their inability to operate did not affect the reactor as much as it could have. There is potential for a future facility shutdown if COVID-19 levels escalate on campus.

3.7 University of Texas

The University of Texas reactor facility was determined to be an essential operation due to several essential missions that it supports. Thus, the reactor continued to operate during normal working hours throughout the pandemic, though with significantly decreased staffing. Most graduate and undergraduate research and service activities were secured through most of the summer. A minimal essential staff for safe and secure operation was maintained at the facility, with additional staff working from home and available as backups in case of an infection of essential staff from March 16, 2020 to June 1, 2020. Following June 1, 2020, staffing was increased at measured paces; however, the reactor still operates with a reduced staff presence (especially due to internal requirements to disallow the vast majority undergraduate student workers in campus research facilities). Overall, the number of runs decreased significantly due to reduction in students and faculty on campus to run experiments and normal service work companies reducing their workload.

3.8 North Carolina State University

The North Carolina State University reactor was shut down for a brief period in late March 2020 due to the impacts of COVID-19, but quickly resumed operation after about a week. An exception to operate the reactor was granted by the university to support “Defense Industrial Base Essential Critical Infrastructure” and “Department of the Air Force Mission Essential Activities.” For several months, reactor operations staff worked in fully separate shifts to assure the ability to continue operations if members of one shift were to become ill with COVID-19 or be required to quarantine. Student reactor operators were not allowed to work on campus from late March until early August. To date, no reactor staff or student operators have reported becoming infected or ill with COVID-19.

3.9 Penn State University

In response to the COVID-19 pandemic and ensuing shutdown of most activities at Penn State University, the reactor facility restricted operations to:

- Surveillances and maintenance required to comply with the license and technical specifications

- Operations required to maintain licensed staff proficiency
- Supporting research projects that were judged to be "critical infrastructure" work.

Some of the normal research workload performed at Penn State is in support of nuclear utilities and defense contractors and is categorized as critical infrastructure support. The facility was able to complete all this work (which was reduced due to shutdowns or restricted staffing at some of the manufacturers of the test components) and all license requirements while limiting staffing to an appropriate minimum. Support of faculty research projects, outreach events, and non-critical work was postponed. While outreach events are still generally not allowed, the reactor is again supporting research work beyond that which is considered critical infrastructure. The overall effect of the COVID-19 pandemic has been to cut the operating (critical) hours of the facility between April 1st and September 1st by approximately 33% versus the same time in 2019. A longer-term effect will be felt in the operator training program. The facility had scheduled a training exam for the week of March 16, 2020. This was cancelled by the NRC, and, with restricted student access to campus, it is not possible to adequately train for a new exam date before March 2021. Due to the short time between licensing student operators and their graduation, this will result in at least four months of having no student interns licensed to operate the facility, from January–April 2021, and a licensed student workforce below our historical average for the rest of 2021.

3.10 Texas A&M

In March 2020, the Texas A&M reactor was shut down and a skeleton crew was established to maintain regular monitoring and other requirements. Isotope production and training were stopped, and classroom demonstrations were recorded for nuclear engineering lab classes. The reactor was re-opened with a slightly bigger skeleton crew in May 2020, and isotope production began on a limited scale. The reactor customers were also in COVID-limited operations. By late summer, the reactor was back to full operations, but the facility was still limited in occupancy. Support personnel continue to work from home but come onsite as needed. Texas A&M reactor operations are effectively in a new normal, with regular operations and training and reduced production due to customer limitations. The demand continues to rise. Lab classes were offered with recorded demonstrations in Fall 2020.

3.11 University of Massachusetts at Lowell

The University of Massachusetts at Lowell reactor was shut down for six weeks during March through April 2020. The reactor restarted operations in May 2020 and is now fully operational, although staff schedules are staggered to minimize the number of personnel on site at any given time. This results in approximately one-half of the staff at any given time, making operations difficult, but manageable.

3.12 University of Wisconsin

COVID-19 significantly impacted the University of Wisconsin's effort to pivot to more research utilization of the reactor facility. The reactor facility was completely shut down from March 13, 2020 to June 15, 2020, apart from one two-hour entry per week to maintain pool water inventory and conduct necessary surveillance. As a result, all student staff graduated and left before new students could be hired and trained. All effort from June 15, 2020 forward has been directed towards training new students to successfully pass the NRC licensing exams as well as completing all deferred technical specification surveillance. As of November 1, 2020, resumption of routine full power operations for research utilization irradiations is still pending.

3.13 Washington State University

The ongoing COVID-19 national pandemic has impacted the Washington State Nuclear Science Center. Washington State Governor, Jay Inslee, issued a Stay Home Stay Healthy emergency order in March 2020 which resulted in the reactor staff working remotely from home for about a month, only

coming to the facility physically to ensure the required maintenance and operation were being completed. During this time, the reactor staff developed a written return to work plan, detailing the steps and procedures that would allow the reactor to reopen utilizing a phased or staged approach. Initial precautions included installing hand sanitizing units throughout the building, supplying masks and personal protection equipment to personnel, developing an enhanced cleaning schedule, and ensuring that the six-feet social distancing guidance was being maintained as much as possible. The safe return to work plan also has the flexibility to revert to previous stages should the pandemic escalate locally or in case a staff member contracts COVID-19. Once approved by Washington State University, the reactor staff gradually transitioned back to on-site work over a three-week period.

Going into 2020, the reactor management team was extremely excited to collaborate with multiple national labs on the development of both new and existing projects as well as working with Washington State University professors to expand research capabilities throughout the facility. While some of the projects for which the reactor provides products were able to move forward as scheduled, many projects were either cancelled or postponed until 2021. Site visits were also postponed due to the travel restrictions, except those visits that were necessary or required, such as regulatory inspections and operator licensing exam administration. Plans regarding establishing a reactor user facility were also delayed while the reactor and university worked to develop procedures to help minimize the spread of COVID-19.

The student reactor operator training program has also been significantly impacted by the COVID-19 pandemic. The student reactor operator training program has been a facet of the reactor's core mission since 2008. The program is intended to span the course of two semesters allowing university students the time to learn reactor physics, technical specifications, and regulatory requirements in addition to hands-on experience in operations and preventative maintenance in a professional work environment. This year, the facility had a colloquium planned with INL in May that was also postponed due to COVID-19. The colloquium would have allowed the student trainees to tour different labs at INL as well as present posters about the Washington State University reactor.

Normally, the reactor would be able to have multiple student trainees at the facility for hands-on training. However, after Washington State University announced students would not be returning to campus following spring break, the training program had to make the transition to an online format. This proved challenging as the reactor had six students just months out from their scheduled U.S. NRC reactor operator licensing exam in May 2020, and the last few months of training are crucial as they consist of mostly hands-on operation and maintenance of the reactor. The exam was postponed until mid-November. When the fall semester began in September, the nuclear science center had already planned for a virtual format to welcome in the new cohort of trainees and, at that time, could allow one previous trainee in for hands-on experience at a time in compliance with the departmental staged return to work plan. Since Washington State University students are unable to return to campus for spring semester, the reactor will continue with a hybrid virtual and socially distanced training program.

While COVID-19 has presented many challenges this year, it has also allowed the reactor staff to develop new and creative ways to support our clients, teach and connect with students, and fine tune facility safety procedures and policies.

3.14 Ohio State University

The Ohio State University research reactor was impacted by the COVID-19 pandemic. Reactor operations were postponed for several months, aside from service work for the nuclear industry that was considered essential. The annual maintenance activities were postponed multiple months but were able to be completed within the required technical specification timeframe.

All tours of the reactor facility have been cancelled for the foreseeable future. As of November 1, 2020, the number of visitors allowed in the building is still restricted. Finally, the number of students

allowed in any given student lab section is limited, so the number of sections for hands-on student laboratories has been increased to accommodate all the students.

3.15 Reed College

Reed College in Oregon sent all their students' home on March 16, 2020 due to the COVID-19 pandemic and conducted all classes online. The remaining reactor staff maintained the required surveillance requirements and only operated the reactor to fulfill surveillance and requalification requirements. In July, the reactor resumed nonessential operations. In August, when the students returned to campus, the Reed Reactor resumed normal operations with two major exceptions: (1) The new COVID-19 requirements mean that Reed College no longer offers any reactor facility tours. (2) Facility access is scheduled to limit the number of people in the facility at any time. This includes routine checklists, maintenance, operations, paperwork, etc. Occupancy is limited to two, or at most three, people in any room at any time. Wearing masks, social distancing, disinfecting, etc. are all required regardless of the number of people present.

3.16 University of California–Irvine

In mid-March 2020, the University of California, Irvine (UCI) suspended all operations on campus and asked everyone to work from home. Exceptions were made for research activities directly related to solving issues with the COVID-19 virus and essential maintenance. This was classified as a Phase 1 situation. Anyone returning to campus was asked to follow strict distancing and masking requirements. The Reactor Supervisor carried out minimal required monthly and other surveillance of the reactor for this period, and all security provisions remained in place including 24-hour police dispatch manning.

Science and Engineering departments subsequently set up procedures for applying for Phase 2 research and support operations. The reactor submitted plans for minimal occupancy that included:

- Limiting number of individuals present in each space based on square feet of room
- Masks to be worn at all times
- Additional face shields required if persons needed to be closer than 6 feet for greater than 15 minutes
- Use of isopropanol spray and/or wipe between each use of any instrument, including the control console.

This plan was approved, and the facility has continued both activation analysis functions and reactor operator training functions under these requirements since the end of April 2020. Owing to similar restrictions on other research groups, limited use is being made of the reactor by UCI (one graduate student only) other than for operator training during this period. The laboratory class in radiochemistry that uses the reactor and should have been offered in October–December 2020 was postponed. However, UCI Chancellor Gilman has recently announced that all UCI undergraduate instruction will be remotely conducted through June of 2021, so the class will not be offered in 2020–2021. Operator training is being conducted by Zoom, with individuals practicing in the facility one at a time. All reactor operations are being carried out or supervised by one of two licensed senior operators; no other licensed operators are active.

As a result of curtailment by other universities and by business users, a significant reduction in reactor use has occurred.

We have had one NRC inspection, conducted "live" by a single inspector, and anticipate operator licensing examinations shortly while meeting all distancing and masking requirements.

3.17 University of Maryland

The impacts that COVID-19 had on the University of Maryland research reactor included limiting the access to the facility for the student operators. It also disrupted the training program for new reactor operators. The reactor facility is not allowing tours for their educational and outreach programs. One of the staff members retired, and they have not been able to hire a replacement for the position. The reactor received a 2017 Nuclear Energy University Program (NEUP) Grant for the installation of a new fission chamber; the installation of the fission chamber has been delayed. Finally, the reactor staff has been working with the NRC to amend the operating license to increase the size of the core; the license amendment process has been delayed.

3.18 University of Missouri S&T

Initial impacts to the University of Missouri S&T reactor facility were relatively minor, with operations far less restricted than at other research test reactor facilities. On-site laboratory classes were suspended as of mid-March 2020 (and resumed August 2020), although experiments were able to be conducted by faculty and reactor management in a limited capacity during the interim. Student employees (who form most of the staff at the Missouri S&T reactor) were prohibited from campus until the July timeframe, which delayed some scheduled maintenance and calibration items.

Ongoing effects have been far more severe. The postponement of maintenance requiring additional staff support pushed many surveillance requirements very close to their limits (including day of, in some cases). Ongoing issues with the startup channel have effectively prevented operations in the second half of the year, with repairs still underway, but hampered by personnel lack of availability and a lack of financial resources. These delays precipitated the need for a license amendment to delay control rod visual inspections up to one year.

Budgets have been repeatedly cut over the last several years, with this year's cuts in response to COVID-19 and the Missouri state legislature's withholding of fourth quarter spending resulting in the cut of a dedicated campus Health Physicist (HP). Consequently, duties previously assigned to this HP have had to be combined into the responsibilities of an already over-burdened Radiation Safety Officer (the Director of Environmental Health and Safety). The initiation of a search/hiring process for a second full-time staff member (reactor maintenance engineer/electronics technician) at the facility was delayed approximately six months, at least partially by COVID-19's impact throughout the University of Missouri System. This has also directly contributed to the observed reactor downtime.

Despite aggressive social distancing and self-checking, all facility personnel are currently in a two-week quarantine due to an operator testing positive for COVID-19. While masks are worn at all times, it is not always possible to maintain physical separation due to a confined control room configuration (although time in close contact is minimized) and activities requiring more than one person in close proximity (e.g., unloading an instrument tube from the reactor pool). This has led to the campus administration-directed precautionary move to quarantine.

A sharp increase in state and local cases is currently being observed. This may provide cause for Missouri S&T to suspend in-person classes, with impacts expected to be similar to the spring 2020 suspension. However, this may also pose some severe challenges for operator requalification depending on implementation.

3.19 University of Florida

The University of Florida campus was closed from March 2020 through August 2020. During this period of campus closure, the reactor facility had minimal staffing to perform operations. The reactor staff consists of a total of five persons. Of this staff, two accelerated their retirement dates partly due to the pandemic. This loss of an electrical engineer and senior reactor operator has left the reactor understaffed.

All experiments and graduate research were also postponed starting in March until August.

3.20 University of Utah

While COVID-19 caused disruptions to the University of Utah planned research activities, and they had to forego irradiation services for a period as well as enduring a local earthquake, the reactor and facilities remain sound. During the shutdown period after March, reactor staff focused on improving computational models and preparing for a new control system and other upgrades, in addition to writing new research grant proposals.

3.21 Purdue University

The COVID-19 Pandemic caused a shutdown of Indiana's Purdue University classes and all research on campus from mid-March through August 2020. This caused several delays in research and receipt of materials for sponsored irradiation activities. Additionally, and most impactful, it has prevented Purdue from continuing the operator training and licensure by the US NRC. This will have ramifications into mid-2021, as the reactor will be understaffed for that period.

3.22 Idaho State University

Idaho State University had to postpone their NRC operator exams scheduled for April. They are now scheduled to take place in November. They have been forced to change operator requalification from hands-on to remote and from quarterly to monthly. There are no actual operations performed for the requalification process. The reactor has limited access to conduct class laboratories and research during the COVID-19 pandemic. The pandemic has also resulted in delays in the completion of the console changeover.

3.23 University of New Mexico

COVID-19 pandemic controls adopted by the University of New Mexico in the second quarter of 2020 impacted the use of the reactor; during the period of 3/19/20–6/7/20, no operation occurred. In typical years, the reactor logs extensive teaching laboratory use during this period. Student reactor operator (RO) candidates studying for RO licensure in the fall of 2019 had been expected to sit for NRC examinations in the spring of 2020, but this was postponed. Although reactor use was impacted by the COVID-19 pandemic, reactor staffing, security, and surveillances were unaffected, as well as licensed staff-maintained currency in operating hours during the reporting period. Two RO candidates completed their NRC exams in the fall of 2020 after the spring postponement. Had the exams occurred in the spring, it is likely that the candidates would be licensed reactor operators assisting with the use of the reactor at this point, and it is likely that an additional 1-2 trainees would have felt comfortable sitting for the exam.

3.24 Rensselaer Polytechnic Institute

The RPI research reactor in New York has only operated three times since March. Two of the four senior reactor operators (SRO) lost proficiency for at least one-quarter of the year. All the SROs are now proficient. Several of the surveillances were past due, but these are not required to be current unless the reactor is operating. The surveillance and maintenance schedule has been significantly affected, but with no results having implications to the operating license.

4. RRI PROJECT ACCOMPLISHMENTS DURING FISCAL YEAR 2020

This section of the report identifies project accomplishments completed during FY-20. These accomplishments are divided into the following sub-sections:

1. Fuel fabrication and delivery to universities

2. Spent fuel shipments
3. Project management and technical support
4. Issues and opportunities
5. Other activities.

4.1 Fuel Fabrication and Delivery to Universities

The following fresh fuel fabrication activities and deliveries were made to universities during FY-20.

- Twenty fresh fuel elements were delivered to the MURR facility. All but one planned shipment was completed as scheduled during FY-20. MURR requested that the April shipment be cancelled due to the impacts of the COVID-19 on the operations of the reactor staff.

- Nine fresh fuel elements were delivered to the MIT facility. All but one planned shipment was completed as scheduled during FY-20. MIT requested that the April shipment be cancelled due to the impacts of the COVID-19 which caused the reactor facility to shut down for a period of time.

4.2 Spent Fuel Shipments

The following spent fuel shipment activities were completed during FY-20.

- Twenty-Four spent fuel elements were shipped from MURR to the DOE Receipt Facility located at the Savannah River Site.

- Eight spent fuel elements were shipped from RINSC to the DOE Receipt Facility located at the Savannah River Site.

4.3 Project Management and Technical Support

The following project management and technical support activities were completed during FY-20.

- The RRI project manager updated the comprehensive fuel tracking system to support fuel acquisition and dispositioning planning. The tracking system includes all domestic university reactors and is updated and maintained on a regular basis. Additional information gathered included fresh fuel and spent fuel anticipated needs for the next five years. This information is important to DOE and the RRI program as it will be used to prioritize fresh fuel procurement activities and spent fuel shipment support.

- INL maintained current and updated fuel support contracts with the 24 domestic universities that operate reactor facilities. These contracts document government ownership of reactor fuel, usage, and reporting requirements. Maintenance of these contracts is important to DOE and the RRI program as these are the contractual agreements that implement the Atomic Energy Act Sections 31 and 53 for the receipt and use of DOE-owned reactor fuel.

- MURR was invoiced for 20 fresh fuel elements delivered during FY-19 in accordance with a contractual agreement between DOE-ID and the University of Missouri, (Contract # DE-SC07-78D01723). This subcontract was put in place to address potential perceptions of government assistance to a university competing with commercial industry in the production and distribution of medical isotopes. INL invoices MURR on an annual basis for the fuel elements delivered and accepted during the previous fiscal year. These funds are then used to support program activities as agreed upon between the RRI program and DOE, either through fiscal year planning activities or implementation of the baseline change proposal process. During FY-15, the cost share agreement was renegotiated with MURR. The cost share amount was increased to $10,000 for all fuel elements delivered after July 2017.

4.4 Issues and Opportunities

The following Issues and Opportunities for project improvements were addressed during FY-19.

- The TRIGA fuel fabrication line in Romans, France is currently scheduled to restart operations in 2021. The Battelle Energy Alliance (BEA) and TI are currently working on the award of the Blanket Master Contract that identifies the terms and conditions for future contract releases for fuel fabrication. To procure reactor fuel, TI must be placed on the Qualified Supplier List at the INL. A quality audit must be performed as part of the approval process. Due to the COVID-19 pandemic, the auditors are unable to travel to France to perform audit functions. The decision has been made to complete a tabletop audit followed up by an on-site visit once international travel is approved. TI will be placed on the Qualified Supplier List, but fuel will not be delivered to reactor facilities until the on-site visit has been completed. This is important to DOE and the RRI program because TI is currently the only international source for new TRIGA fuel fabrication. The twelve university operated TRIGA reactor facilities have estimated a need of approximately 801 additional fuel elements for the lifetime of their respective reactor cores. Of these, approximately 668 will be fabricated by TI. The remainder will come from the inventory of lightly irradiated fuel elements currently stored at INL.

4.5 Other Activities

The following other activities are project management tasks completed to support the RRI program and ensure success in meeting the mission of the program.

- The RRI project manager presented the Program Status Report at the annual Test, Research and Training Reactor (TRTR) Conference. Due to the COVID-19 pandemic, the annual conference was held virtually. Attendees included representatives from the university reactor facilities, national laboratories, DOE, and the NRC. Attendance and presentation at the annual TRTR conference is important to DOE and the RRI program as this is an opportunity to meet with reactor facilities representatives to address concerns and to update the reactor community as a whole on the status and future plans for the RRI program.

5. BUDGET SUMMARY

The INL RRI program budgeted cost of work scheduled for FY-20 was $8,291,455. At year-end, the budgeted cost of work performed was $7,351,085. The actual cost of work performed was $7,398,625. This resulted in a schedule variance of -$940,370 (-11.3%) and a cost variance of -$47,540 (-0.6%).

5.1 Schedule Variance Analysis

Eighty-six percent ($804.6K) of the variance is associated with two activities. 1) Framatome is behind schedule on the completion of several milestones associated with the restart of the TRIGA fuel fabrication line. The milestone delays were caused by the delays of the French Regulatory agency in reviewing and approving the Safety Analysis Report (Article 26). This has resulted in sixty-four percent ($603.6K) of the schedule variance. 2) Due to the COVID-19 pandemic, HEU metal procurement from Consolidated Nuclear Services (CNS) Y-12 at Oak Ridge, Tennessee has been delayed until FY-21. This has resulted in twenty-two percent ($201K) of the schedule variance.

6. CONCLUSIONS

The mission of the RRI program was met for FY-20. Enough fuel elements were delivered to the university research reactors to maintain sustained operability of all supported reactor facilities. Spent fuel elements were returned to the DOE-owned receipt and storage facility at Savannah River Site, thus maintaining a minimal supply of Special Nuclear Material (SNM) at university facilities.

Regardless of pervasive funding constraints at each reactor facility, nuclear education and research programs continue to operate, and many are seeing expansion of their programs.

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Appendix A

Research Reactor Infrastructure Program History

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The Atomic Energy Commission (AEC) initiated the Research Reactor Infrastructure program (formerly known as the University Reactor Fuel Assistance Program) by issuing grants to universities to assist in the procurement of reactor fuel. Because the federal government funds this program and owns the uranium, title of the fuel is retained by the government. Beginning in 1974, increased physical security requirements for safeguarding SNM required fuel manufacturing licensees to upgrade their facilities at significant costs, which caused many fuel manufacturers to discontinue operations.

On October 11, 1974, in wake of the 1973 oil crisis, the AEC was split as part of the Energy Reorganization Act of 1974. Two new agencies were formed: the NRC which would regulate the commercial nuclear power industry, while the Energy Research and Development Administration (ERDA) would manage the energy research and development, nuclear weapons, and naval reactors programs. The ERDA agency became active on January 19, 1975.

Because possible foreign fuel suppliers were not allowed to possess U.S. government-owned HEU needed to fabricate the fuel in the mid-1970s only Texas Instruments and Atomics International were manufacturing plate-type fuel for ERDA (Texas Instruments was manufacturing oxide fuel, and Atomics International was manufacturing aluminide fuel). Both Texas Instruments and Atomics International were only accepting cost plus fixed fee contracts, which were very difficult for universities to handle and manage. Seven plate-type reactors had to sharply reduce reactor operations and faced the inability to operate because of lack of fuel. In 1977, an organized university consortium requested ERDA assistance in providing plate-type fuel through use of existing government subcontracts using government owned equipment at Atomics International, where ERDA had a contract to manufacture aluminide plate-fuel.

In 1977, the ERDA Idaho Operations Office was assigned responsibility for the fuel assistance program which was managed by EG&G Idaho, Idaho National Engineering Laboratory's prime subcontractor. In late 1977, the ERDA became the DOE. Fuel deliveries under this program began in 1978.

In 1985, the aluminide plate-type fuel subcontract was transferred from Atomics International to BWXT located in Lynchburg, Virginia. Currently, all plate fuel for the RRI program is fabricated by BWXT.

In 1958, General Atomics in San Diego, California started manufacturing TRIGA fuel which was used to operate their newly designed TRIGA reactors. In 1996, General Atomics entered a joint venture with CERCA in France to form TI, and the fabrication line was moved from California to Romans, France.