



Unlicensed/Aluminum Fuel Event
at The University of Texas
Nuclear Engineering Teaching Laboratory

Overview

- Historic Context
- Discovery of Aluminum Element Utilization & Investigation
- Discovery of Procedure Deficiencies
- USNRC Special Inspection
- Cause analysis & Corrective Actions
- Resumption of Normal Operations & Subsequent Activities



Historic Context

Nuclear Engineering Teaching Laboratory

- Construction 1998-1992
- Replaced TRIGA I on main campus with a TRIGA II on Pickle Research Campus



NETL Reactor Manager 1999-2016

- Operator at TRIGA I & TRIGA II
- Participated in construction activities



1999 B159.xls File for Fuel Inventory & Management (updated annually)

- Fuel serial numbers
- Type of fuel
- Other fuel & core information

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P ^{100%}
1	IDNumber	Type	Drawing	Uranium	U-235	% 235	SRC	Original	Taylor Burn	Ice-hours	Me-days	burn-up	u-tons	u-235	U bal.	% E
33	2938	SFE		201	40.1	20	NA	0.73	-	2,291,887	1,029	1,080	1,188	38.30	198.56	19.3%
34	2939	SFE		187	37.4	20	NA	0.68	-	2,895,940	1,210	1,271	1,388	35.45	184.85	19.2%
35	2940	SFE		197	39.4	20	NA	0.72	-	2,895,940	1,210	1,271	1,388	37.42	194.86	19.2%
36	2941	SFE		184	36.8	20	NA	0.67	0.015	2,895,940	1,210	1,271	1,388	34.82	181.75	19.2%
37	2943	SFE		189	37.8	20	NA	0.69	0.015	1,601,914	0,719	0,755	0,831	36.33	187.34	19.4%
38	2944	SFE		183	36.6	20	NA	0.67	0.015	2,895,940	1,210	1,271	1,388	34.62	180.75	19.2%
39	2945	SFE		194	38.8	20	NA	0.71	-	-	-	-	-	38.13	193.42	19.7%
40	2946	SFE		194	38.8	20	NA	0.71	-	2,895,940	1,210	1,271	1,388	36.81	191.77	19.2%
41	2947	SFE		197	39.4	20	NA	0.72	-	2,895,940	1,210	1,271	1,388	37.38	194.66	19.2%
42	2948	SFE		203	40.6	20	NA	0.74	-	2,895,940	1,210	1,271	1,388	38.56	200.64	19.2%
43	2950	SFE		192	38.3	20	NA	0.70	-	2,895,940	1,210	1,271	1,388	36.37	189.53	19.2%
44	2951	SFE		199	39.8	20	NA	0.73	-	2,348,482	1,054	1,107	1,218	37.93	196.83	19.3%
45	2952	SFE		212	42.4	20	NA	0.77	-	2,547,265	1,144	1,201	1,321	40.46	209.98	19.3%
46	2954	SFE		200	40.0	20	NA	0.73	-	2,895,940	1,210	1,271	1,388	38.04	198.00	19.2%
47	2955	SFE		192	38.4	20	NA	0.70	0.015	2,895,940	1,210	1,271	1,388	36.41	189.82	19.2%

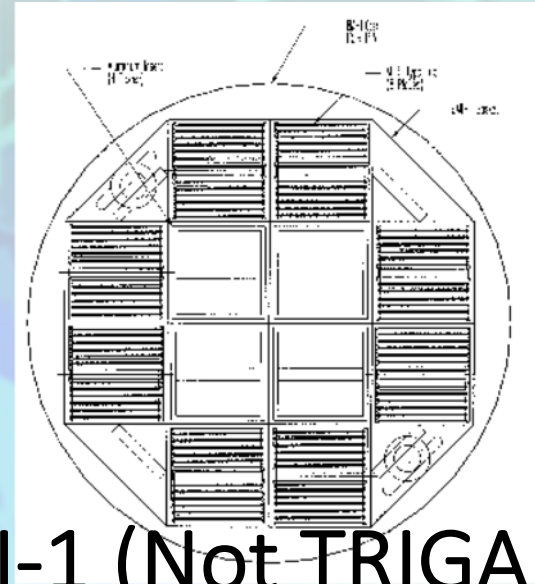
2004 Fuel Shipments (2 Sets) from UICU



NAC-LWT

**Waste Shipment
basket)**

**(235 mass limit in
TRIGA elements)**

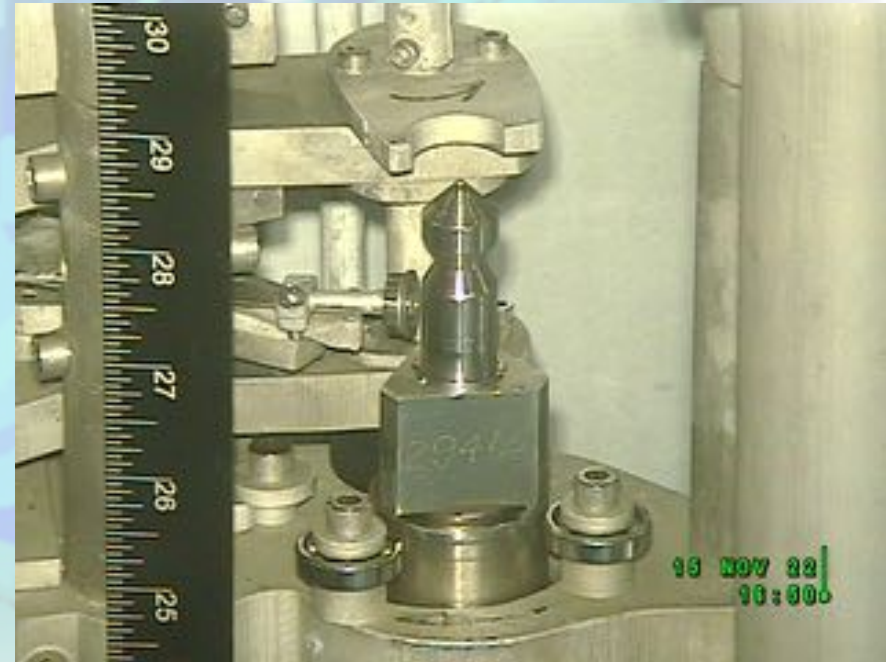


BMI-1 (Not TRIGA

**to other TRIGA facilities
(Recycled Elements)**

2018 Biennial Fuel Inspection

- Obsolete & failure prone strain-gage system used for older TRIGA I fuel
- IFEs, FFCRs & streamlined elements used a different method
- Precision of Optical measurements tested as possible replacement for strain gage system



January 2022 Annual Maintenance

- Biennial Fuel Inspection
- Campaign to increase excess reactivity for planned 2022 experiment

B159 File used to identify elements with greatest impact on reactivity

September 2022

- 3rd NETL Reactor Manager retired
- Staff SRO appointed 4th Reactor Manager



Discovery of Aluminum Fuel Utilization & Investigation

Oct 2022 Discovery of Aluminum Fuel Utilization

- DOE Fuels Assistance request for info
- Reactor Manager:
 - Deep dive on fuel inventory
 - Discovered records of Al clad fuel in core
 - Removed, visually verified, inspected
 - Notified Associate Director

NETL Associate Director 1/2

- Suspended routine operations
- Reviewed reportability criteria,
 - Criteria for LCOs & LSSS states “as specified in Technical Specifications”
 - LCOs & LSSS specified in Technical Specifications were not challenged

NETL Associate Director 2/2

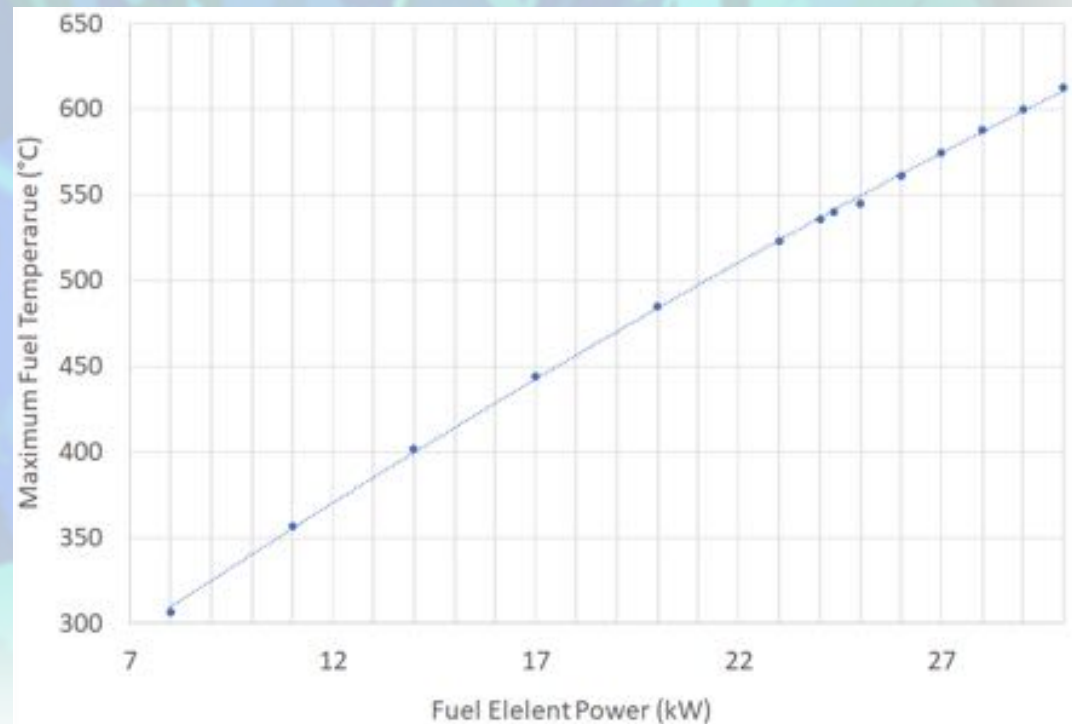
- “An observed inadequacy in the implementation of administrative or procedural controls ... that ... causes or could have caused ... existence or development of an unsafe condition”
- “Unsafe condition”: exceed temperature safety limit

NETL Associate Director

- 245 IFE readings 382°C to 391°C at 900 kW
- Highest Al-clad fuel 86% of IFE power
- Steady-state within safety limit
- Pulsing & SS potential assessed by way of Neutronics & Thermal Hydraulic Analysis
 - Accepted for technical review in USNRC Audit
 - Steady State temperature at element power
 - Max pulsing temperature at max IFE reading

Steady-State Temperature Analysis

- 500°C occurs at 21 kW
- 113 elements 900 kW, average 7.96 kW
- Peaking factor of 2.6 yields 20.7 kW
- Not feasible

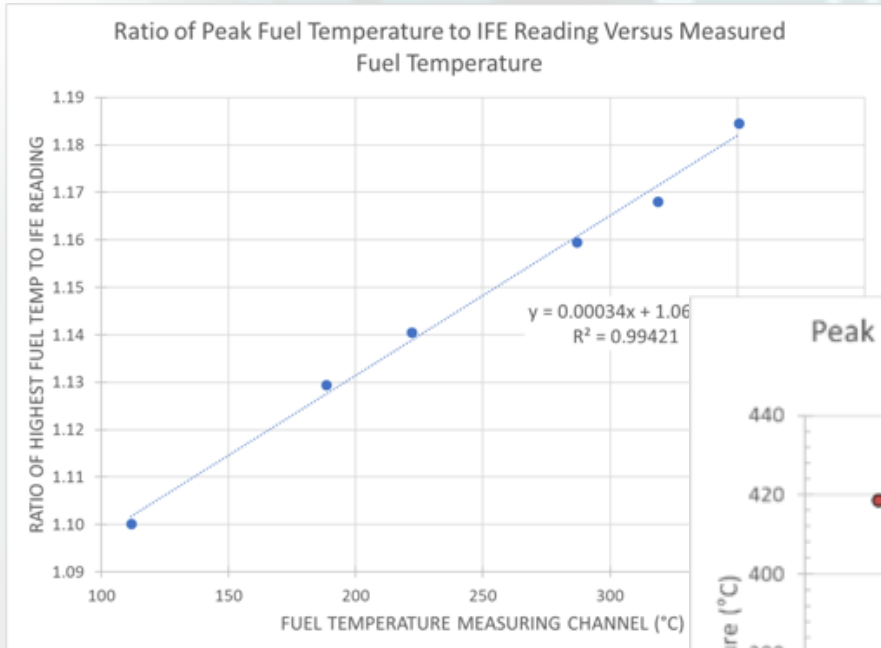


Pulsing Analysis

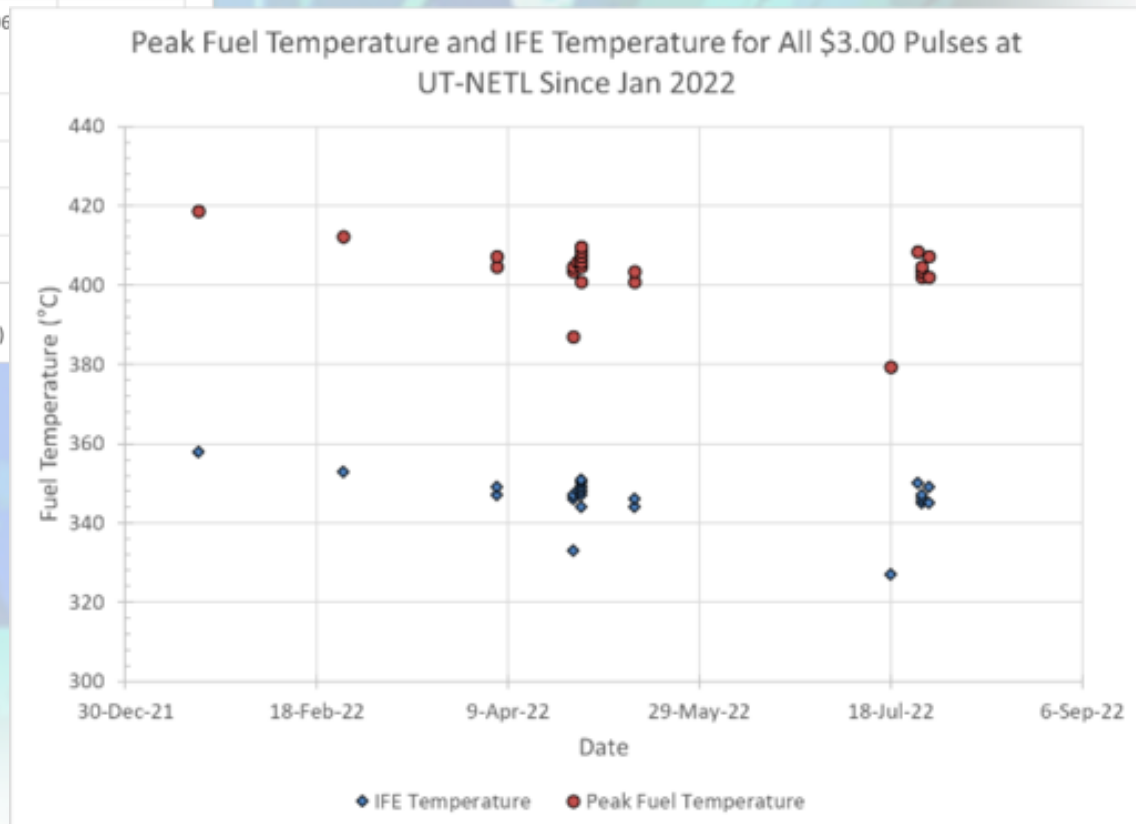
- TRACE correlation between FT channel & maximum temp
 - Peak temp. occurs near surface
 - IFE measures near center
- TRACE hot channel analysis:
 - Average fuel channel for physics
 - Hot channel as Ave. times Peaking-Factor
 - Allows only a single material
- Stainless-steel neutronics assumed to limit pulse characteristics

MCNP/TRACE Pulsing Analysis

Peak pulse IFE Reading & Peak pulse fuel temperature



Peak pulse temp versus IFE Reading (TRACE)



Recommendation to Director

- Analysis showed temperatures
 - Below safety limit in actual conditions
 - Below safety limit in possible conditions
- Not technically reportable under Technical Specifications language *although it that would likely not be well-received*
- NRC should be notified of operating in unlicensed and unanalyzed condition

NETL Management

- Associate Director
 - Informed NRC Program Manager
 - Informed inspector assigned to NETL
 - Began investigation
- Director
 - Notified Reactor Oversight Committee (ROC)
 - Developed and communicated a running Event Summary to ROC and NRC

Initial Investigation

- Al-clad fuel elements loaded in Jan 22
- Fuel inspected prior to installation
- Reactor operations:
 - 24 MWD from Jan-Nov
 - 37 Pulses performed with 24 @ \$3
- No evidence of fuel failure
 - Off-gas and bay air particulate detector
 - Pool water sample assay
 - Visual inspection



Discovery of Procedure Deficiencies

Investigation Continued

- Fuel Inspection Surveillance records:
 - *No elongation values for 2020 and 2022*
 - *Missing initial length for 2022 fuel installed*
- Reactor Manager from Jan 2022 verified
 - Inspections performed
 - Elongation values acceptable
- *Camera was used in 2020 and 2022, but was not approved as a revised procedure*

Immediate Response

- Assess all TS surveillance procedures for any other potential issues
- Prior to restart:
 - Correct any inadequate surveillance performance issues
 - Revise fuel inspection procedure
 - Perform fuel inspection
 - Remove any fuel lacking initial values

Assessment Results

- One calibration procedure:
 - Could not be performed as written
 - Corrected with minor change & performed
- A 'Minor change' deleted recording data
- Many minor changes improperly processed
- Only fuel inspection required for restart

NOTE: Many procedures are confusing or hard to understand - to be addressed post-restart

A Note on NETL Procedures & Safety Culture

- *Leadership Safety Values & Actions*: procedures available & adequate to support safety
- *Work Processes*: control by comprehensive, high-quality programs, processes and procedures.
- *Questioning attitude* includes
 - all individual's responsible assess procedures
 - If a procedure or work document is unclear or cannot be performed as written, stop & resolve
- Multiple safety culture lapses at every level

Fuel Element Inspection

- Fuel Element Inspection procedure
 - Revised to use IFE/FFCR/streamlined technique
 - Developed over about 2 weeks
 - Reviewed and approved by ROC over ~10 days
- Initial lengths located during ROC review:
 - Some elements in shipping documents
 - A legacy file for the remainder
- Fuel inspection performed over ~3 weeks

Epiphany: During inspection understanding crystallized that the inspection method

- Compared fuel length to a standard
- Did not compare length to initial length – *hence the difficulty locating initial lengths*
- This was more than a record-keeping issue
- *The method did not measure elongation*

Significance

- *The explicit basis for the elongation limit is limiting potential fuel failure*
- Aluminum-clad fuel use
 - lack of controls over unqualified fuel
 - Lead to discovery of LTA surveillance
- Fuel element with unacceptable elongation is unambiguously unsafe
- Potential for unsafe conditions was reported under the umbrella of AI fuel use



USNRC Special Inspection

NRC Special Inspection

- Special inspection scheduled for:
 - 1 week off-site
 - 1 week on-site
 - Remainder off-site
- NRC on-site:
 - During & at completion of fuel inspection
 - Requested to view an aluminum element

Bubbles 1/3

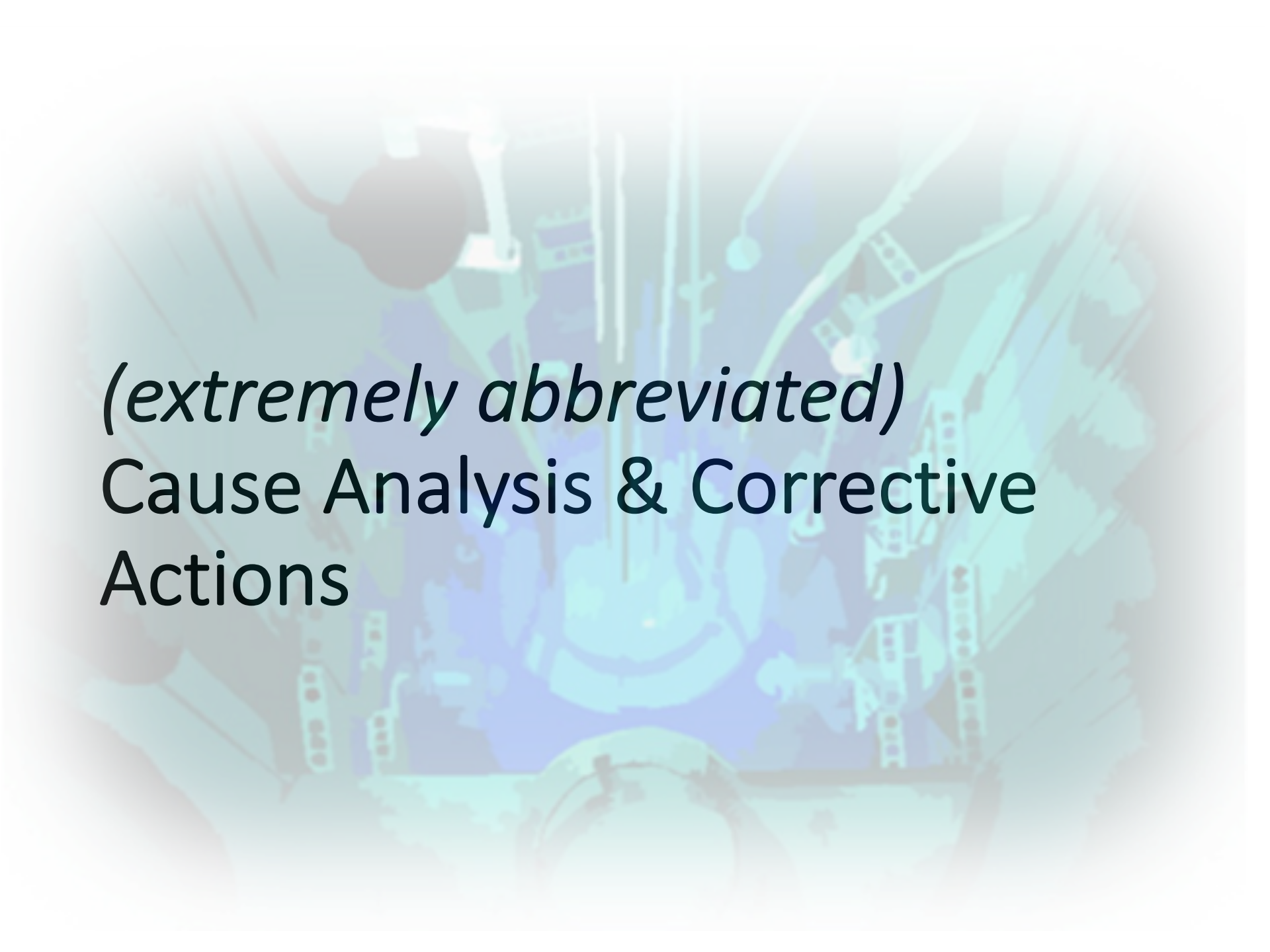
- Transferring to inspection stand:
 - Bubbles were observed
 - In the stand, the bubbles stopped
 - Observed trapped gas underneath element
- No evidence of fission product release
 - No off-gas or air particulate detector elevation
 - No abnormal radioisotopes in pool sample
- Stable conditions, inspection continued

Bubbles 2/3



Bubbles 3/3

- Most probable source, hydrogen evolution through the weld/cladding interface
- Intended to try capturing gas for analysis
- Bubble gone at conclusion of inspection



(extremely abbreviated)
Cause Analysis & Corrective
Actions

Casual Analysis: LTA Attention to Detail

Multiple observations, the most important:

- Missing the 'AI SFE' label in the B159 file

	A	B	C	D	E	F	G
1	IDNumber	Type	Drawing	Uranium	U-235	% 235	SRC
192	2903	SFE		200	40.1	20	NA
193	2902	SFE		195	39.0	20	NA
194	2901	SFE	ZrH1.7	194	38.7	20	IL
195	2899	SFE		181	36.2	20	NA
196	2587	AI SFE	ZrH1.7	218	42.9	20	IL
197	2466	AI SFE	ZrH1.7	206	41.1	20	IL
198	2457	SFE		178	35.0	19.7	GA
199	2430	SFE		183	36.0	19.7	GA
200	2414	SFE		183	36.0	19.7	GA
201	2406	SFE		183	36.0	19.7	GA
202	9849	SFE		191	37.9	19.8	Ger

- Fuel inspection method not capable of measuring elongation

Other Personnel Errors

- **Strong Rule Incorrectly Chosen**
 - Selection of elements based on 235 mass
 - Processing and use of minor changes
 - Feasibility for approval
- **Check of Work in Progress LTA**



Casual Analysis: Written Communications LTA

- Procedures less than adequate for:
 - Control of fuel
 - Core planning
 - 50.59 Process
- Procedure management less than adequate

Casual Analysis: Lack of Management Oversight

- LTA procedures not addressed
- No oversight for planning core loads
- Failure to detect safety culture issues
 - Lack of self-critical attitude
 - Inadequate procedure management
 - Inadequate understanding of safety basis

Corrective Actions for Restart 1/2

- Aluminum fuel elements removed, placed in segregated and labeled storage
- Fuel inspected
- Fuel handling procedure revised
 - To control disqualified fuel
 - Require load reviewed by management
- B159 file revised to support control

Corrective Actions for Restart 2/2

- Complete reactivity surveillances
- Comprehensive training on
 - Safety Culture
 - Safety Culture Work Environment
 - Root cause analysis
 - Collected a set of CA not related to event

Restart Readiness Review

- ROC approved
 - Restart corrective actions
 - Minor revision to FUEL-1
- NRC Inspectors on-site for ROC meeting
- NRC requested opportunity for management review prior to restart

NRC couldn't technically prevent restart since they didn't order shutdown, but there are no conceivable circumstances where we wouldn't cooperate - and as it turned out the ROC meeting was Friday before Thanksgiving.



Return to Normal Operations & Subsequent Activities

Restart

- Restart and return to normal operations occurred on December 1, 2022

10CR50.59 Discrepancies

- NETL Event Summary listed 50.59 failures:
 - Use of aluminum elements
 - Fuel inspection surveillance procedure
- NRC SIT identified 50.59 w/o ROC review
 - Forms marked '50.59 not required' BUT
 - Determination questions marked "NO"
 - *SAR Design bases not affected by activities*
 - *We did not have adequate 50.59 instructions*

Post-Startup Corrective Actions

- Implemented corrective action documentation & tracking using:
 - Tool developed by Reactor Manager
 - Bi-weekly staff meeting review
- Developed (*final draft in staff review*)
 - Administrative procedure for process-based procedures using consensus guidance
 - Procedure writer's guide
 - 50.59 instructions based on NEI 21-06



Supplemental Information

2018 Spent Fuel Shipping Inspection

- Spent fuel inspection requested by Idaho Fuel Storage Facility Manager
 - Prep for resumption of shipping (any day now)
 - Training for receipt facility
- 1st time al. element inspection at NETL
- Aluminum elements identified in report

Reactor Manager Experience Base 1999-2023

- 2nd Reactor Manager 1999-2016
 - Licensed at TRIGA I
 - Participated in construction
 - Licensed at NETL TRIGA II
 - UT Mechanical Engineering degree
- 3rd NETL Reactor Manager 2016-2022
 - Enlisted nuclear electrician's mate
 - Entered Navy education program
 - Commissioned & retired as EOD Officer
- 4th Reactor Manager 10/2022-present
 - Retired Navy EOD Chief
 - UT Electrical Engineering degree

A Note on NETL Procedures

- Adequate for experience base of:
 - 1982-1999, 1st reactor manager
 - 1999-2016, 2nd manager UT TRIGA & NETL SRO
- NETL procedures are:
 - Organized structurally like CFRs
 - Mostly rule based, not describing processes
 - Not adequate for the lowest experience
 - Verbose
 - Not conducive/useful for verbatim compliance
- Loss of corporate knowledge in 2016
- 3rd & 4th (current) manager's nuclear procedure experience base was only NETL

What are we going to do about it?

- Procedures really need to be updated
 - This is not a quick fix
 - Procedure management addressed first
- Safety culture needs attention
 - No finger pointing, blame or punishment
 - Explaining Nuclear Safety Culture
 - Enlisting & encouraging participation
 - Routinely checking the pulse

Revision to Procedure Control Procedure

P3Format.doc		Date: 4/8/10
Number - Rev.:	ADMN-1: 3.0	
Procedure Title:	NETL Procedure Control	

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3. Procedure Control

There should be a limited number of Verified Procedure copies in use at the NETL to ease the maintaining of updates and reviews. A Master procedure copy will be maintained by the Reactor Supervisor which has a red "Original" stamp. A Working copy with a blue "Copy" stamp will be available for use at the Control Console. All other procedure copies should be verified and maintained current by the individuals holding copies in their office or work area. Copies that are not stamped with a red "Original" or blue "Copy" stamp will not be routinely verified and should not be assumed current. Electronic copies of procedures should not be considered current unless so verified by comparison to a current controlled copy.



NETL Procedure Control (DRAFT)	ADMN-1	Rev. 4.00
	Approved: Jul 4, 1776	Page 10 of 29

5.4 Document Control

5.4.1 General


1. Prepare and review procedures using common software such as Microsoft Word.
2. Send documents to the ROC for final approval by using a locked file format such as Adobe PDF.
3. Avoid emailing copies of draft procedures for review; reference a shared storage location when possible.
4. Send procedures to the ROC for review and approval by enclosing and referencing the following documents in a single folder:
 - a. proposed draft procedure (including appendixes)
 - b. previously approved procedure (required for revisions)
 - c. attachment(s) (if used)
 - d. applicable records from Appendix A: 50.59 Process records (Screening and/or Evaluation)
 - e. a document outlining changes between the original and revised procedure, or describing a new procedure
 - f. if the 50.59 Process is not required, a document providing the reason
5. Perform procedures only from the master copy or the reactor control room copy.

Casual Analysis: Written Communications

1
2 **II. PROCEDURE**

3
4 **A. TRIGA Fuel Movement**

- 5
6 1. A senior reactor operator shall supervise all movements of
7 fuel, including movements to or from the reactor core grid
8 structure and movements between storage locations. At
9 least one person should assist with the handling of the
10 fuel elements.
11
12 2. Restrict all fuel element arrays except the reactor core to
13 an array limit of less than 20 elements.
14
15 a. Store fuel elements in the fuel storage wells or
16 in the reactor pool. Use the 19 element
17 hexagonal array racks (these may be stacked two
18 deep per well) or the 6 or staggered 12 element
19 linear array racks.
20
21 b. Elements not in storage racks or shipment casks
22 should be in groups of three or less.



activities so as to minimize the number required to achieve the desired result.

28 ... the reactor core, storage racks,
29 shipment casks or other locations with special fuel
30 handling tool.

- 31 5. Maintain access control or restrict use of fuel handling
32 tool by lock if fuel movements are not in progress.
33
34 6. Test fuel handling tool on non-fuel element prior to use.
35
36 7. Approve by inspection and test any device other than the
37 fuel handling tool prior to use for movement of fuel.
38 Handle the instrument elements with the extension tubes.
39 Handle control followers with the extension rods.
40
41 8. Handle fuel elements carefully. Care should be taken not
42 to bump or scrape elements. Minimize the possibility and
43 potential consequences of an accidental drop of an element.

History of 10CFR50.59 at NETL

- 2010 Reactor Oversight Committee review
- Procedure revision approved
- No mention of USQD or 50.59 review
- After the review, Reactor Manager:
*“That’s not a modification, it’s a procedure,
50.59 doesn’t apply to procedures”*
- Briefed NETL Director & NRC
- Reactor Manager given a form
 - Simplified, deleting specific questions
 - Attached form to admin procedure w/o instructions or guidance