Draft Regulatory Issue Summary (RIS)

CONSIDERATIONS IN LICENSING HIGH BURNUP SPENT FUEL (HBF) IN DRY STORAGE AND TRANSPORTATION

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HBF Taskforce

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United States Nuclear Regulatory Commission
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Overview

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- HBF Taskforce path forward
- RIS
  - Addressees
  - Intent
  - Background
  - Summary of Issue (Licensing Approaches)
    - Storage
    - Transportation
- Questions and Comments

HBF Taskforce Path Forward

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- Past
  - Presented approaches at 1/24/14 NEI public meeting
  - 2014 RIC in March (poster)
- Future
  - Issue RIS via FRN for public comment (February 2015)
  - Issue final RIS (May 2015)
  - In parallel, beginning draft NUREG that expands on RIS with greater technical detail

RIS - Addressees

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- Holders of and applicants for:
  - Part 71 CoC
  - Part 72 CoC
  - Part 72 General License
  - Part 72 Specific License

RIS - Intent

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- Provide high level information on **some** approaches acceptable to the NRC for applications containing HBF

RIS - Background

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- License low burnup fuel using the basis in Interim Staff Guidance (ISG) – 11, Rev. 3 and confirmation from Idaho Cask Demonstration

- License HBF up to 20 years using basis in ISG-11, Rev. 3

RIS – Background cont.

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- ISG-11, Rev. 3 in relation to HBF
  - Originally developed to limit formation of radial hydrides and to limit creep deformation to less than 1%
  - However, later research shows that radial hydrides may still form even if temperatures and stresses in ISG-11, Rev. 3 are not exceeded
    - Radial hydrides, due to hydride reorientation, need to be considered for beyond 20 years in dry storage for HBF

RIS – Background cont.

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- Licensing HBF beyond 20 years
  - Issue of hydride reorientation
    - Occurs when hydrides in cladding go above a certain temperature and then cool below another temperature – ductile-to-brittle transition temperature (DBTT)
    - Affects temperature-dependent fuel cladding mechanical properties
    - Limited data availability
  - Additional factors need to be considered to meet regulations

RIS – Background cont.

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- Associated regulations:
  - Storage:
    - 72.122(h) – protect fuel against gross rupture
    - 72.122(l) – ready retrieval of spent fuel
  - Transportation:
    - 71.33(b)(3) – chemical and physical form for approval
    - 71.89 – package opening instructions
    - 71.55(d)(2) – during normal conditions of transport, geometric form of content is not substantially altered

RIS – Background cont.

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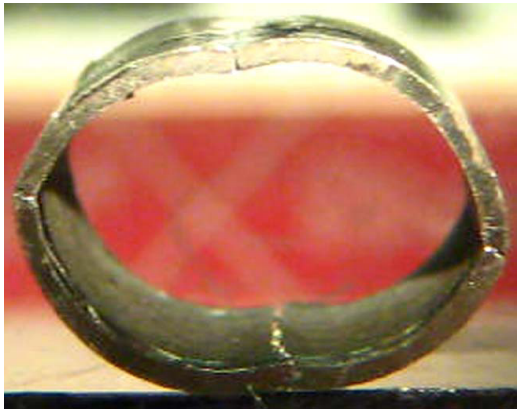
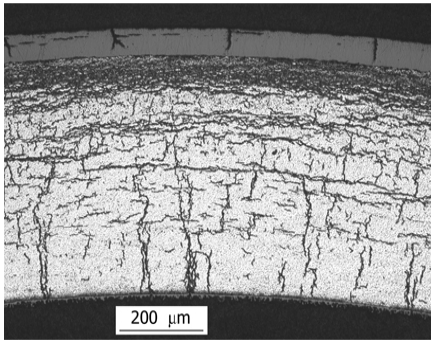
- Hydride reorientation would only affect cladding integrity if there is a “pinch mode”:
  - Pinch mode occurs when inertia loads which result in a large tensile stress are perpendicular to the radial hydrides
  - Seen during the hypothetical accident condition 30 foot side drop in transportation regulations, which may challenge cladding integrity





Source: Argonne National Laboratory, “Radial-Hydride-Induced Embrittlement of High-Burnup ZIRLO Cladding Exposed to Simulated Drying Conditions” T.A. Burtseva, Y. Yan, and M.C. Billone, June 30 2010 (ML101620301)

RIS – Background cont.

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Theme of licensing approaches: we do not expect fuel to reconfigure due to hydride reorientation during storage or normal conditions of transport – we expect to get confirmation of this belief through current and future research results

RIS – Summary of Issue

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- Licensing Approaches
  - Based on LBF but modified to account for limited data availability. As we get more data, we expect these approaches to evolve closer to that of LBF
  - Main difference between HBF approach and LBF approach: if there is limited data, applicant can demonstrate a “defense-in-depth approach”
  - Structure of approaches consider whether or not the fuel has been placed in damaged fuel cans and the length of time it has been in dry storage

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Licensing Approaches

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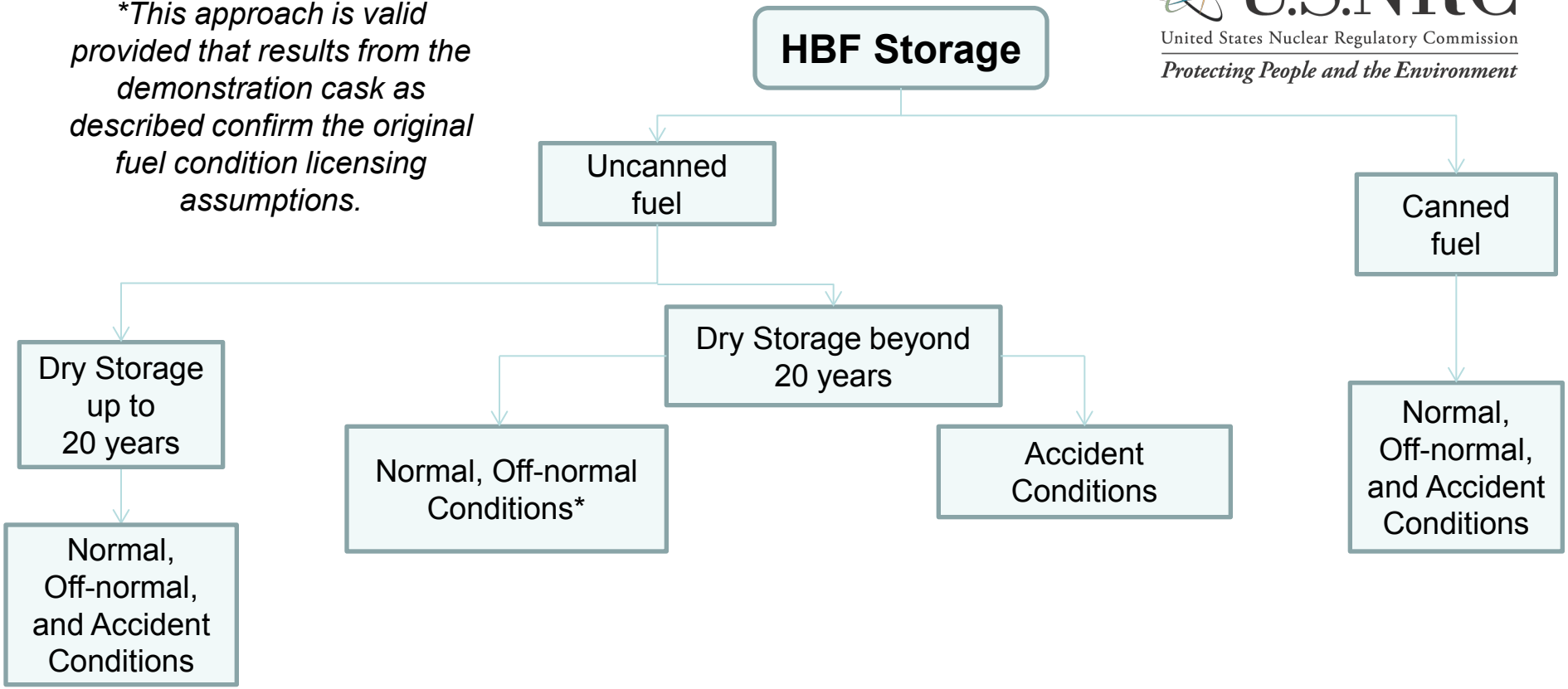
Storage

**This approach is valid provided that results from the demonstration cask as described confirm the original fuel condition licensing assumptions.*



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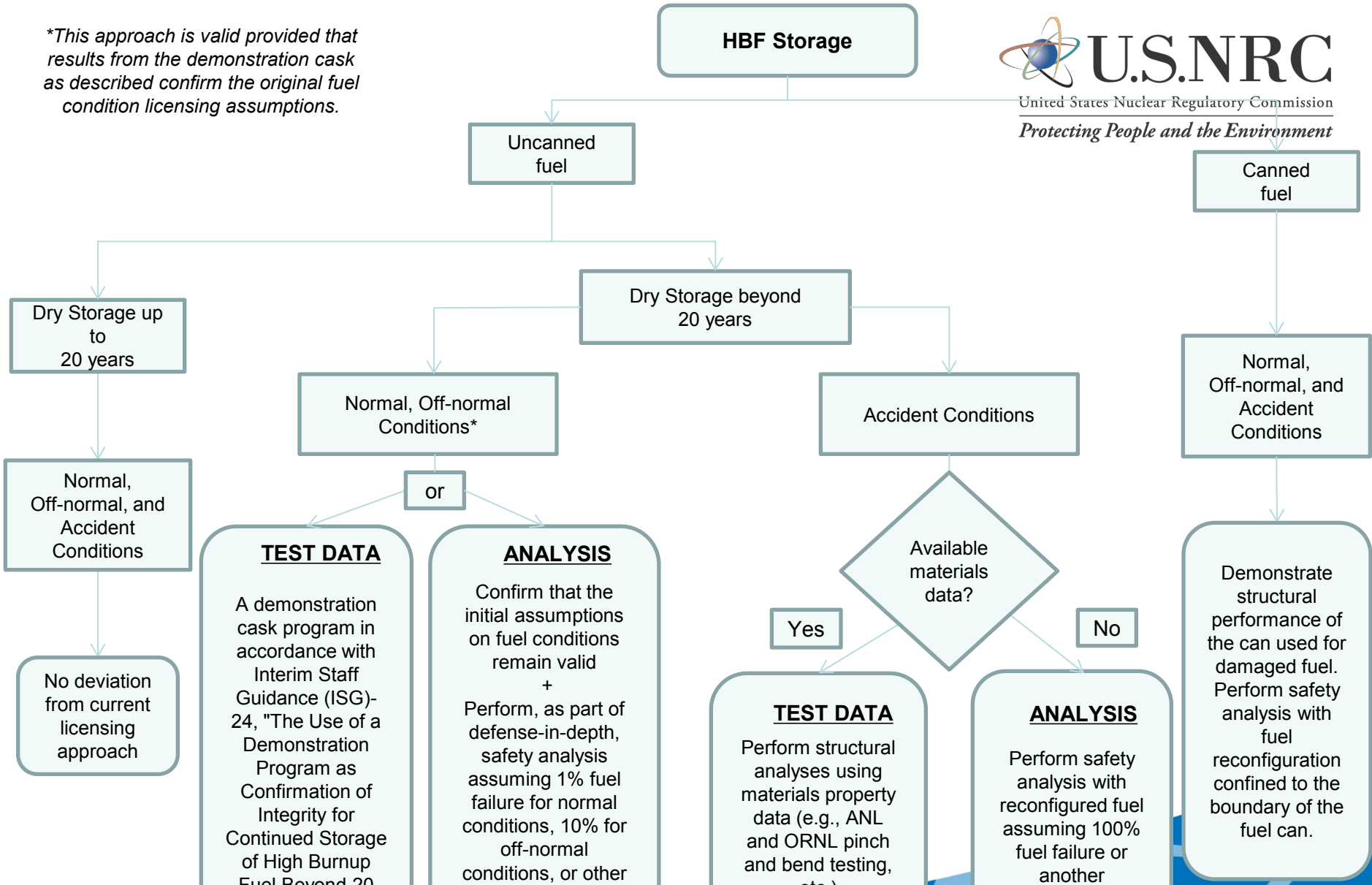

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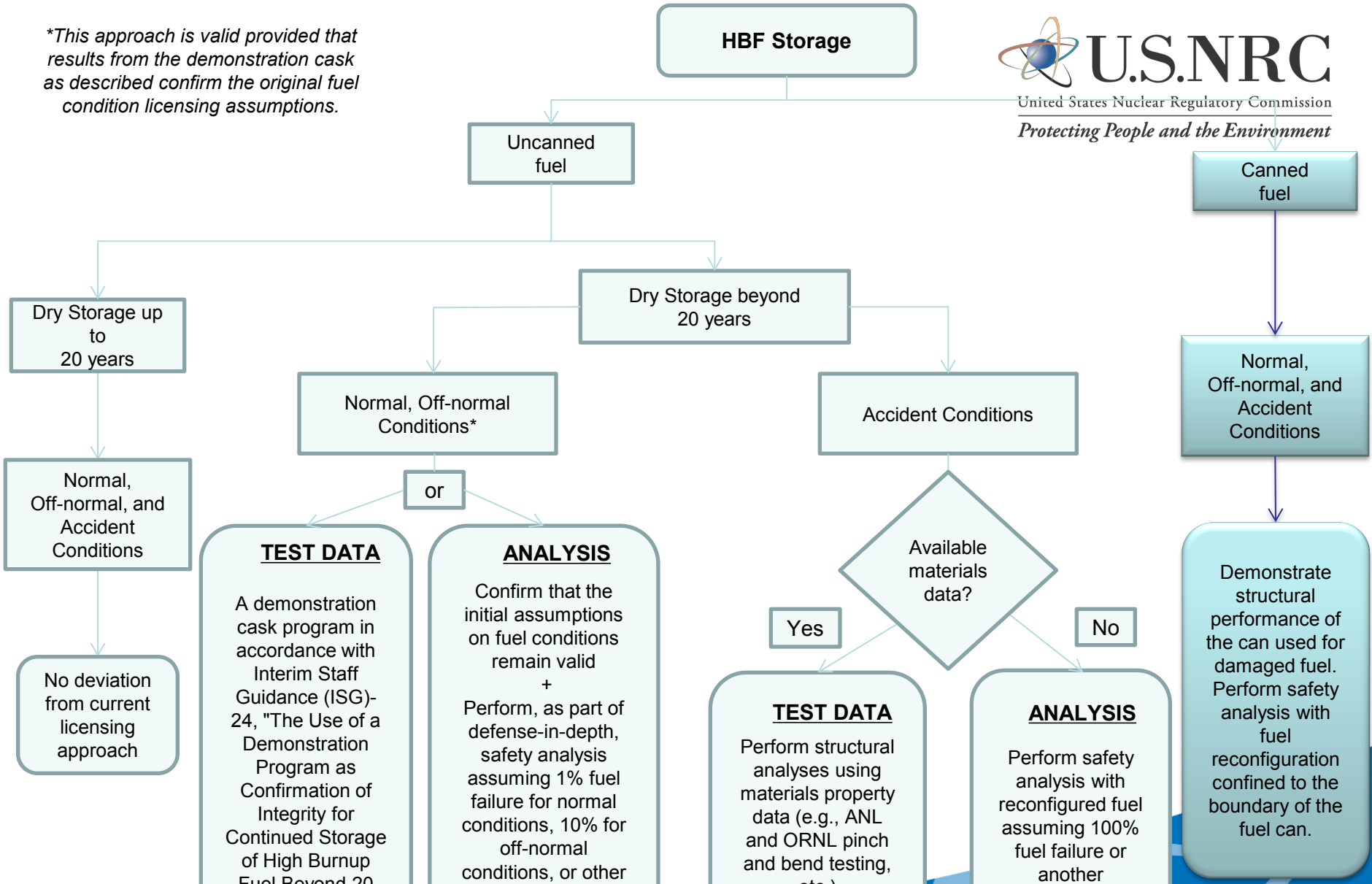
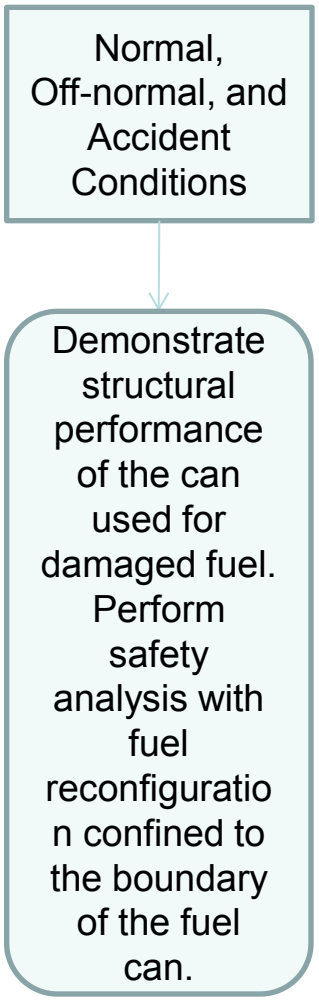


Canned Fuel



- Canned fuel does not depend on time in dry storage.
- Structural performance of the can must be demonstrated, then perform normal safety analysis with the fuel reconfiguration confined to the boundary of the fuel can

**This approach is valid provided that results from the demonstration cask as described confirm the original fuel condition licensing assumptions.*

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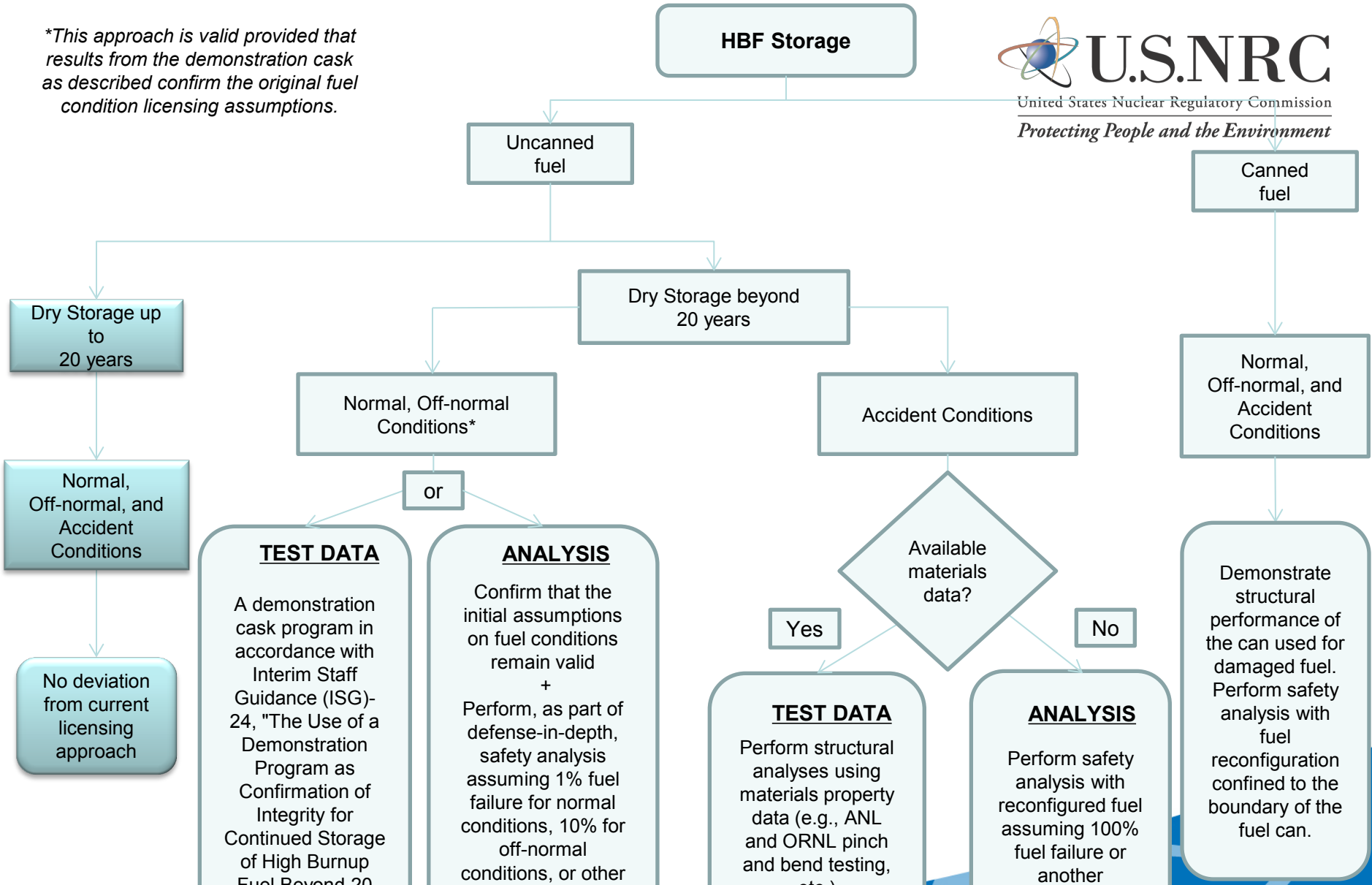
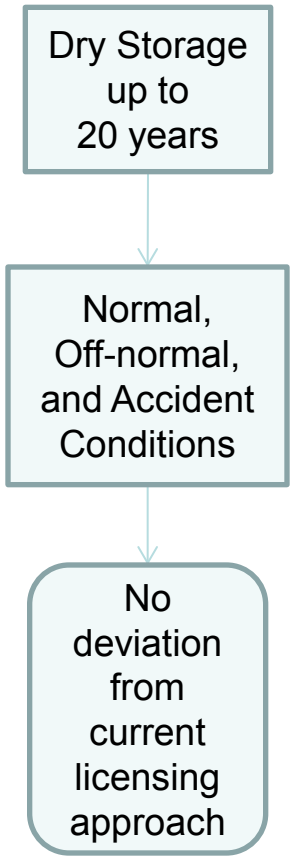


Uncanned Fuel



- Fuel that is not canned and will be in dry storage for a period up to 20 years will follow the current licensing approach

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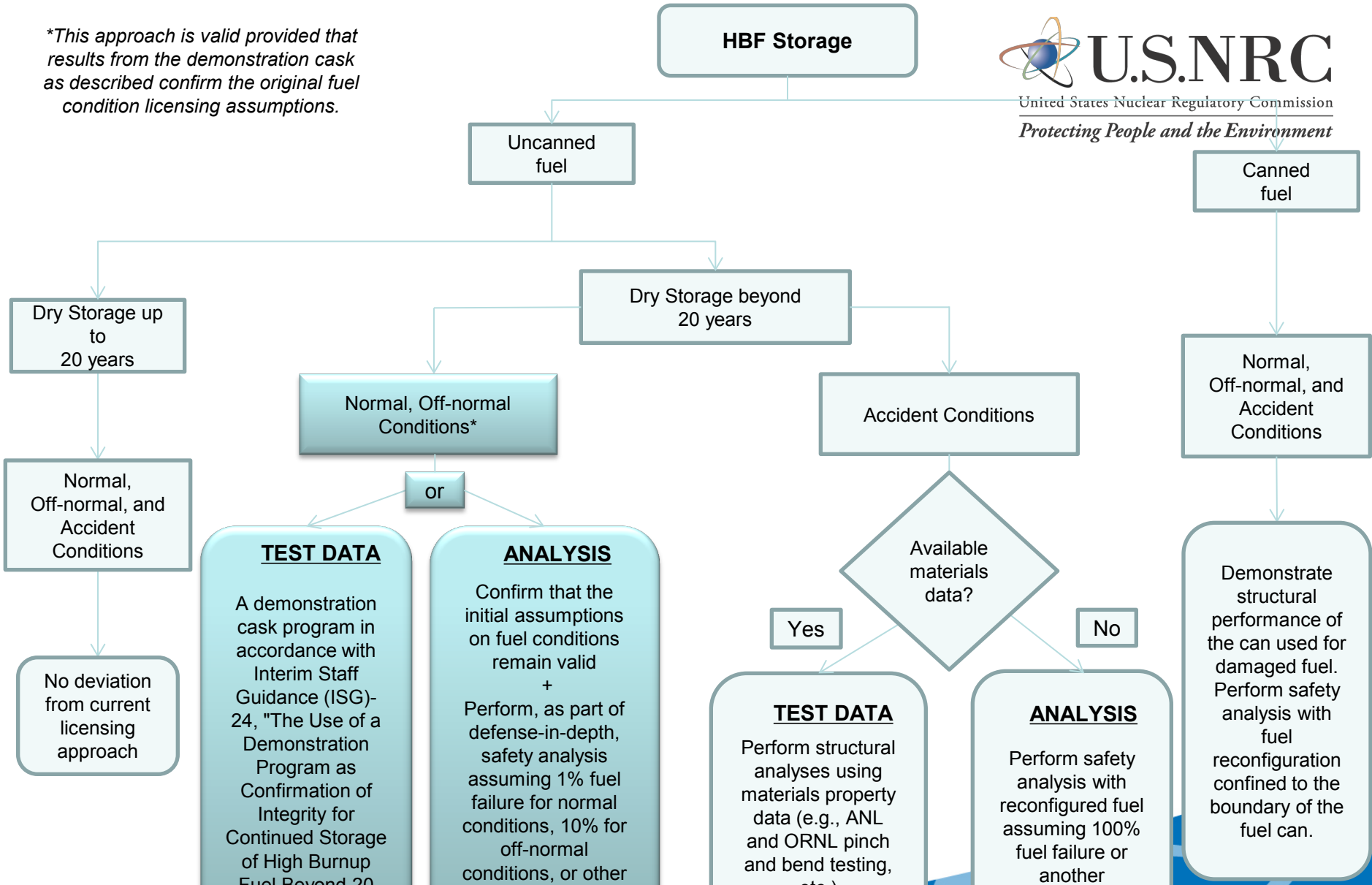
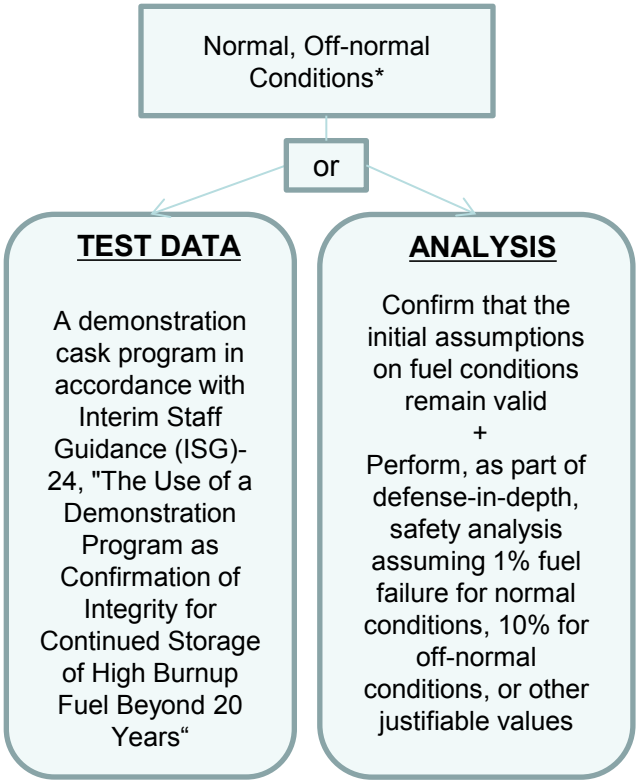
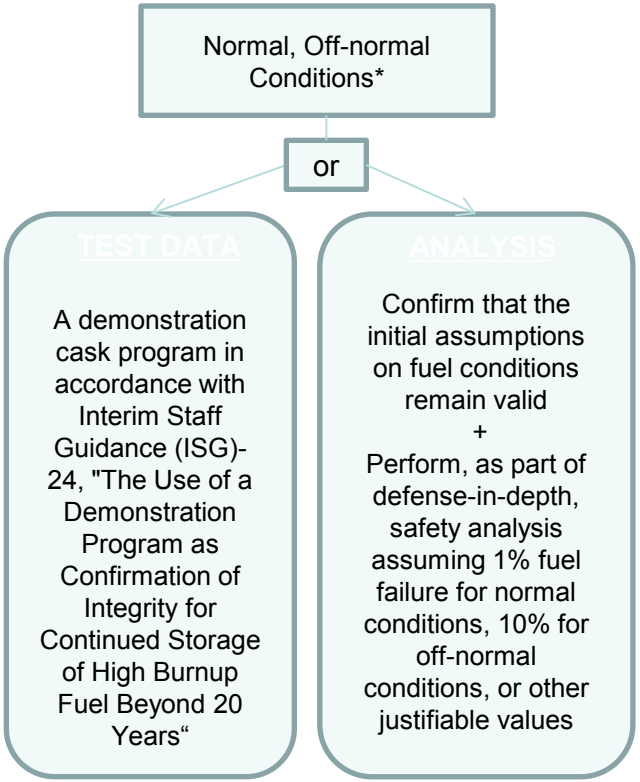


Beyond 20 years, Normal and Off-normal Conditions



- Test Data
  - Relies on ISG-24 guidance to use a cask demonstration as confirmation of integrity for continued dry storage of HBF beyond 20 years
- Analysis
  - Confirmation that initial assumptions on the fuel condition are still valid – can be done lead system examination
  - Safety analyses assuming 1% and 10% fuel failure for thermal, containment, shielding, and criticality (defense in depth)
    - Values taken from confinement analysis
    - Previous studies completed regarding fuel failures of all fuel types consider 1% to be a bounding value
  - Or other justifiable value

Beyond 20 years, Normal and Off-normal Conditions



**This approach is valid provided that results from the demonstration cask as described confirm the original fuel condition licensing assumptions.*

- The * highlights that this licensing approach is valid provided that results from the demonstration cask as described confirm the original fuel condition licensing assumptions

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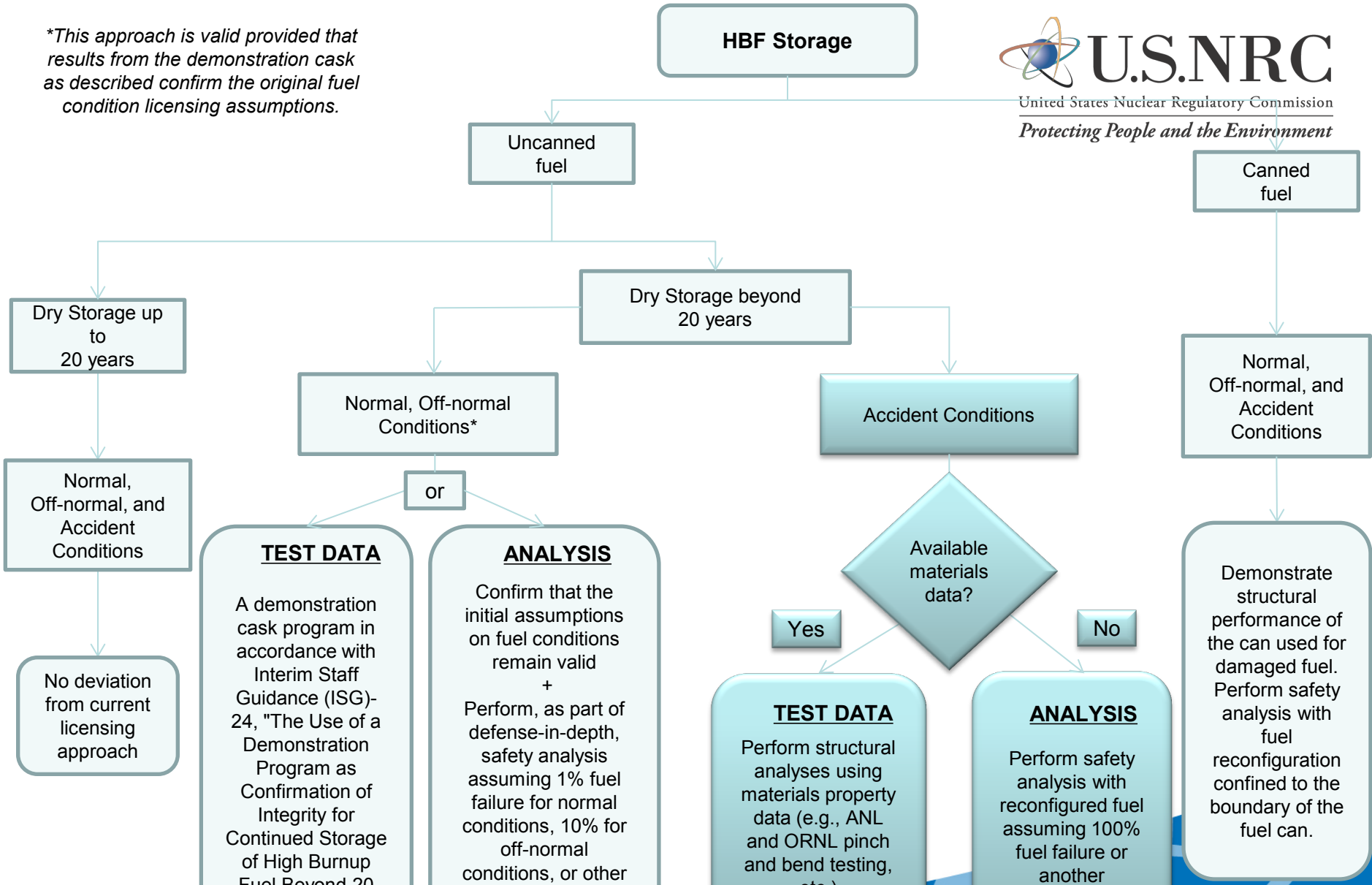
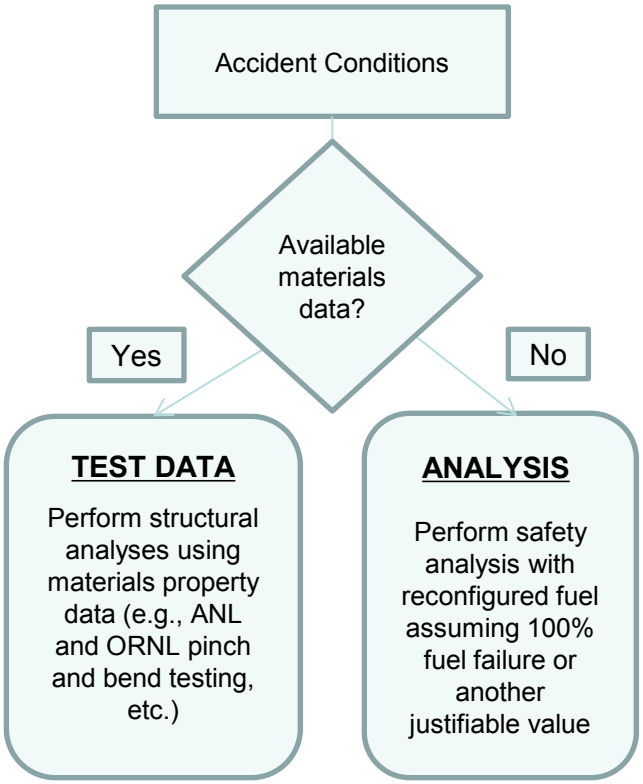


Beyond 20 years, Accident Conditions



- Test Data
  - Relies on available and applicable cladding materials data
  - Possible data that can be used are results from ANL and ORNL pinch and bend tests, or applicant provides own data
- Analysis
  - Perform safety analysis assuming 100% fuel failure for all disciplines (thermal, confinement, shielding, and criticality)
  - Or other justifiable value

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Transportation

*If minimum fuel temperature is above the ductile-to-brittle transition temperature (DBTT), then fuel can be treated as directly shipped from pool

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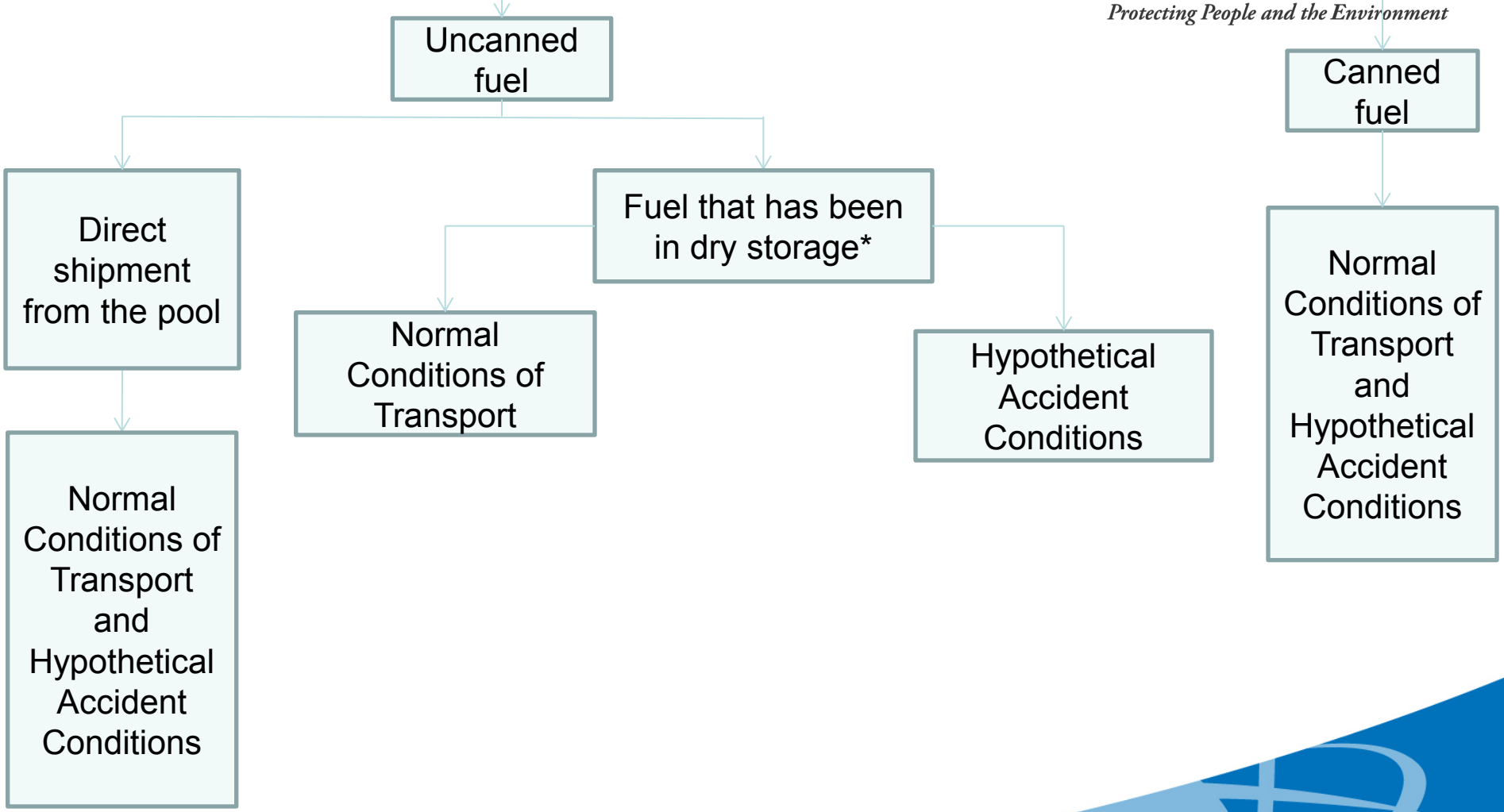

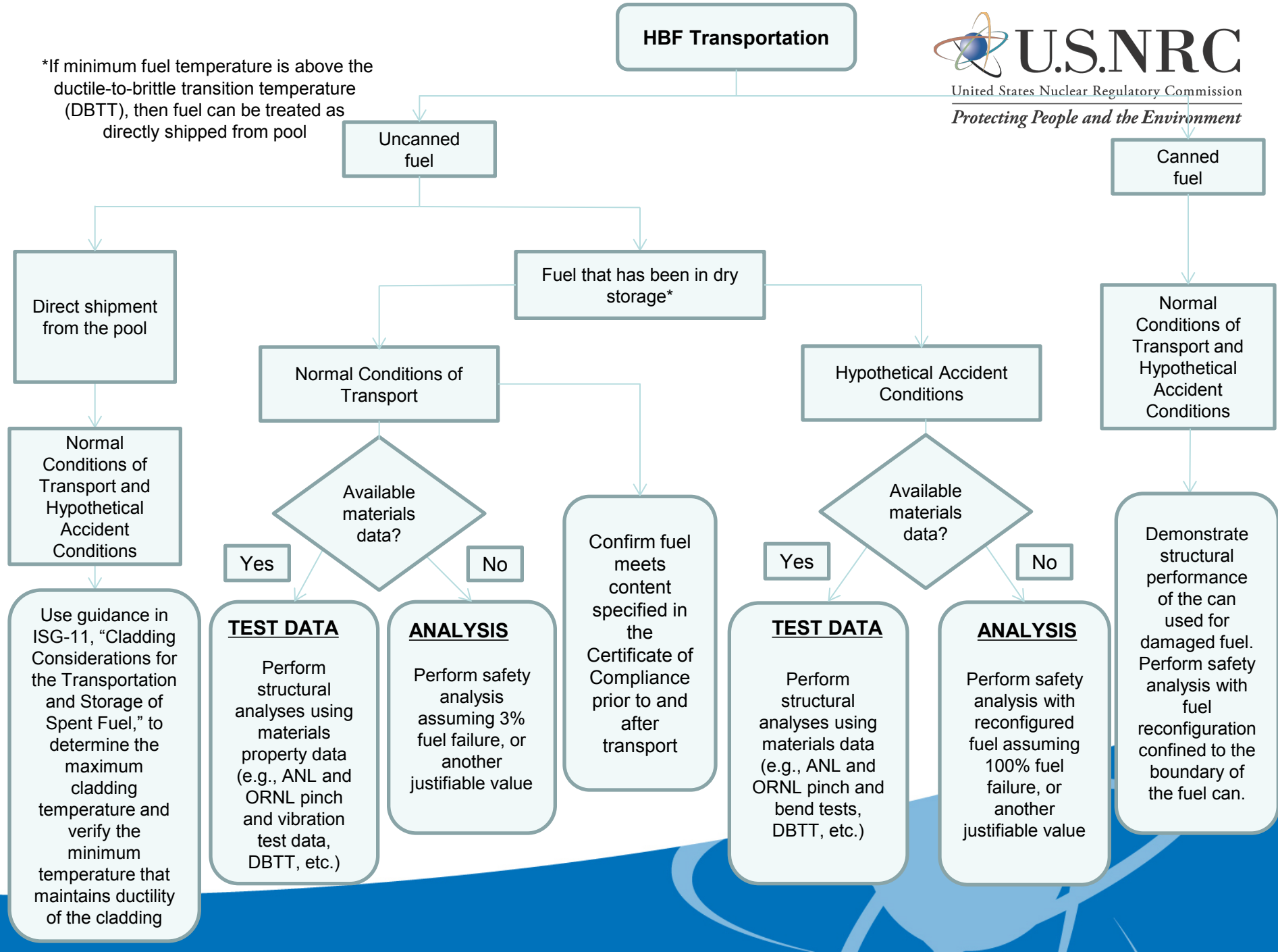
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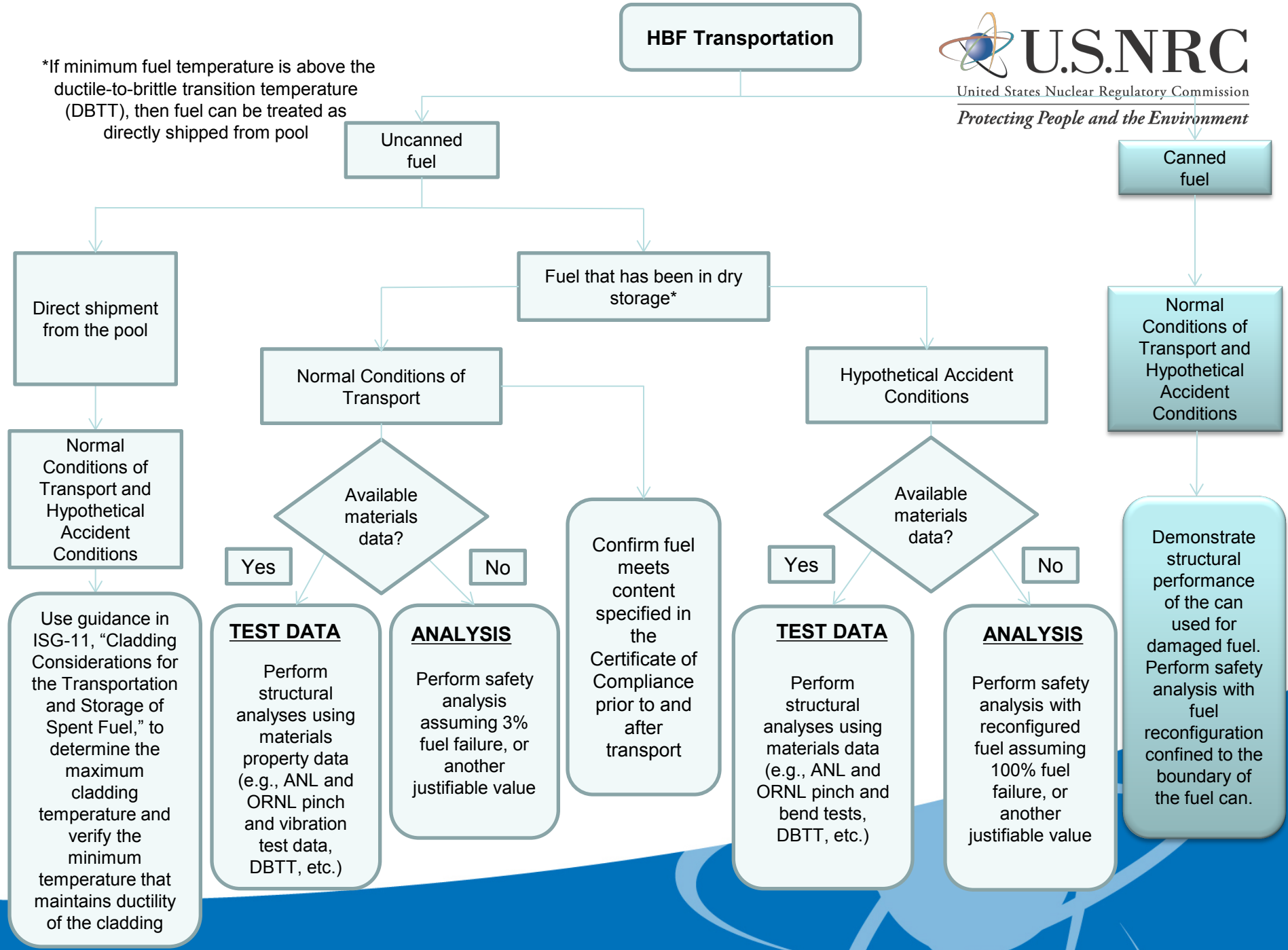
*If minimum fuel temperature is above the ductile-to-brittle transition temperature (DBTT), then fuel can be treated as directly shipped from pool
Uncanned fuel
Canned fuel
Direct shipment from the pool
Fuel that has been in dry storage*
Normal Conditions of Transport and Hypothetical Accident Conditions
Normal Conditions of Transport
Hypothetical Accident Conditions
Use guidance in ISG-11, "Cladding Considerations for the Transportation and Storage of Spent Fuel," to determine the maximum cladding temperature and verify the minimum temperature that maintains ductility of the cladding
Available materials data?
Yes
No
TEST DATA
Perform structural analyses using materials property data (e.g., ANL and ORNL pinch and vibration test data, DBTT, etc.)
ANALYSIS
Perform safety analysis assuming 3% fuel failure, or another justifiable value
Confirm fuel meets content specified in the Certificate of Compliance prior to and after transport
Available materials data?
Yes
No
TEST DATA
Perform structural analyses using materials data (e.g., ANL and ORNL pinch and bend tests, DBTT, etc.)
ANALYSIS
Perform safety analysis with reconfigured fuel assuming 100% fuel failure, or another justifiable value
Normal Conditions of Transport and Hypothetical Accident Conditions
Demonstrate structural performance of the can used for damaged fuel. Perform safety analysis with fuel reconfiguration confined to the boundary of the fuel can.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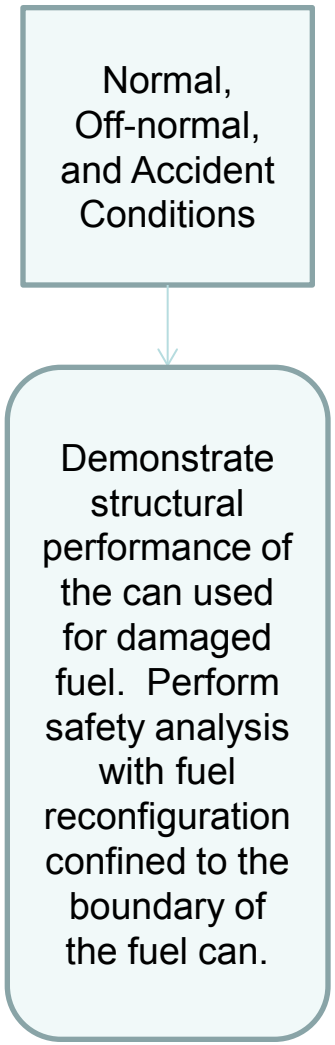
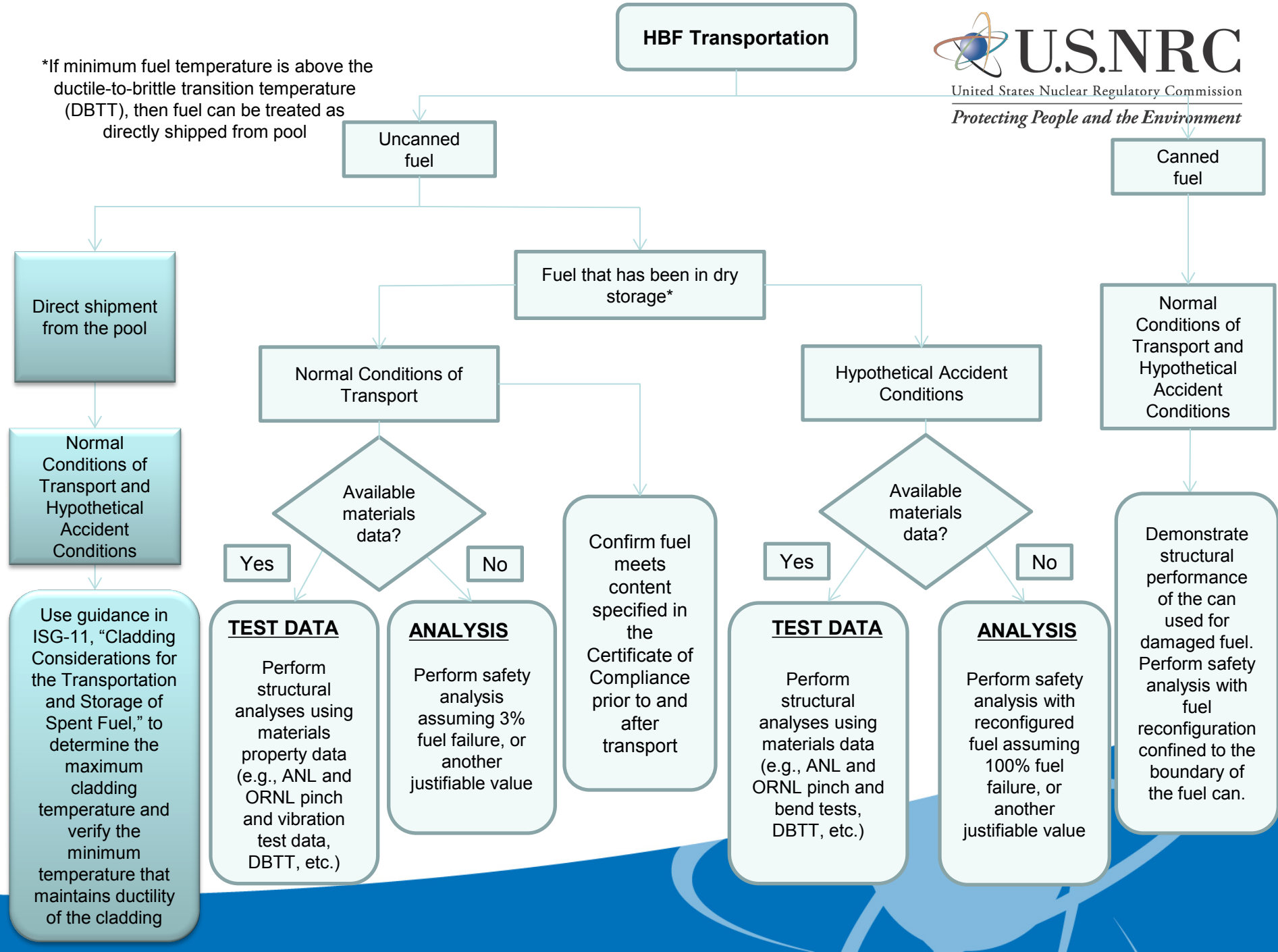
Canned Fuel



- Canned fuel does not depend on time in dry storage. Structural performance of the can must be demonstrated, then perform normal safety analysis with the fuel reconfiguration confined to the boundary of the fuel can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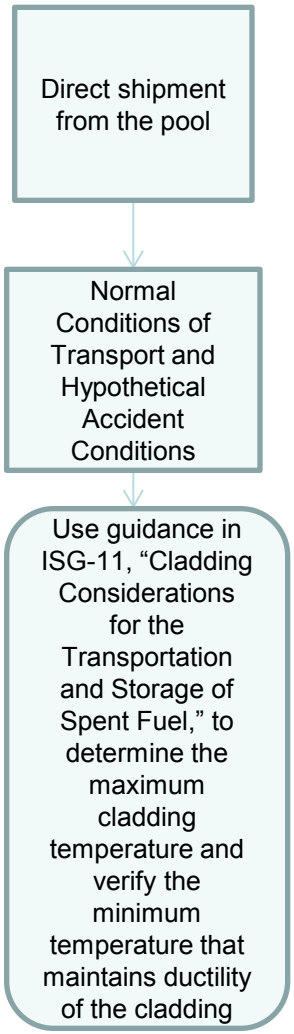
Uncanned fuel
Canned fuel
Direct shipment from the pool
Fuel that has been in dry storage*
Normal Conditions of Transport and Hypothetical Accident Conditions
Normal Conditions of Transport
Hypothetical Accident Conditions
Available materials data?
Yes
No
Available materials data?
Yes
No
Use guidance in ISG-11, "Cladding Considerations for the Transportation and Storage of Spent Fuel," to determine the maximum cladding temperature and verify the minimum temperature that maintains ductility of the cladding
TEST DATA
Perform structural analyses using materials property data (e.g., ANL and ORNL pinch and vibration test data, DBTT, etc.)
ANALYSIS
Perform safety analysis assuming 3% fuel failure, or another justifiable value
Confirm fuel meets content specified in the Certificate of Compliance prior to and after transport
TEST DATA
Perform structural analyses using materials data (e.g., ANL and ORNL pinch and bend tests, DBTT, etc.)
ANALYSIS
Perform safety analysis with reconfigured fuel assuming 100% fuel failure, or another justifiable value
Normal Conditions of Transport and Hypothetical Accident Conditions
Demonstrate structural performance of the can used for damaged fuel. Perform safety analysis with fuel reconfiguration confined to the boundary of the fuel can.

Directly Shipped from pool



- Fuel shipped from the pool
  - Determine the maximum and minimum cladding temperature to verify the ductility of the cladding:
    - Data to defend the DBTT values – has hydride reorientation occurred?
    - Temperature computational fluid dynamic code that is conservative on the low temperature side

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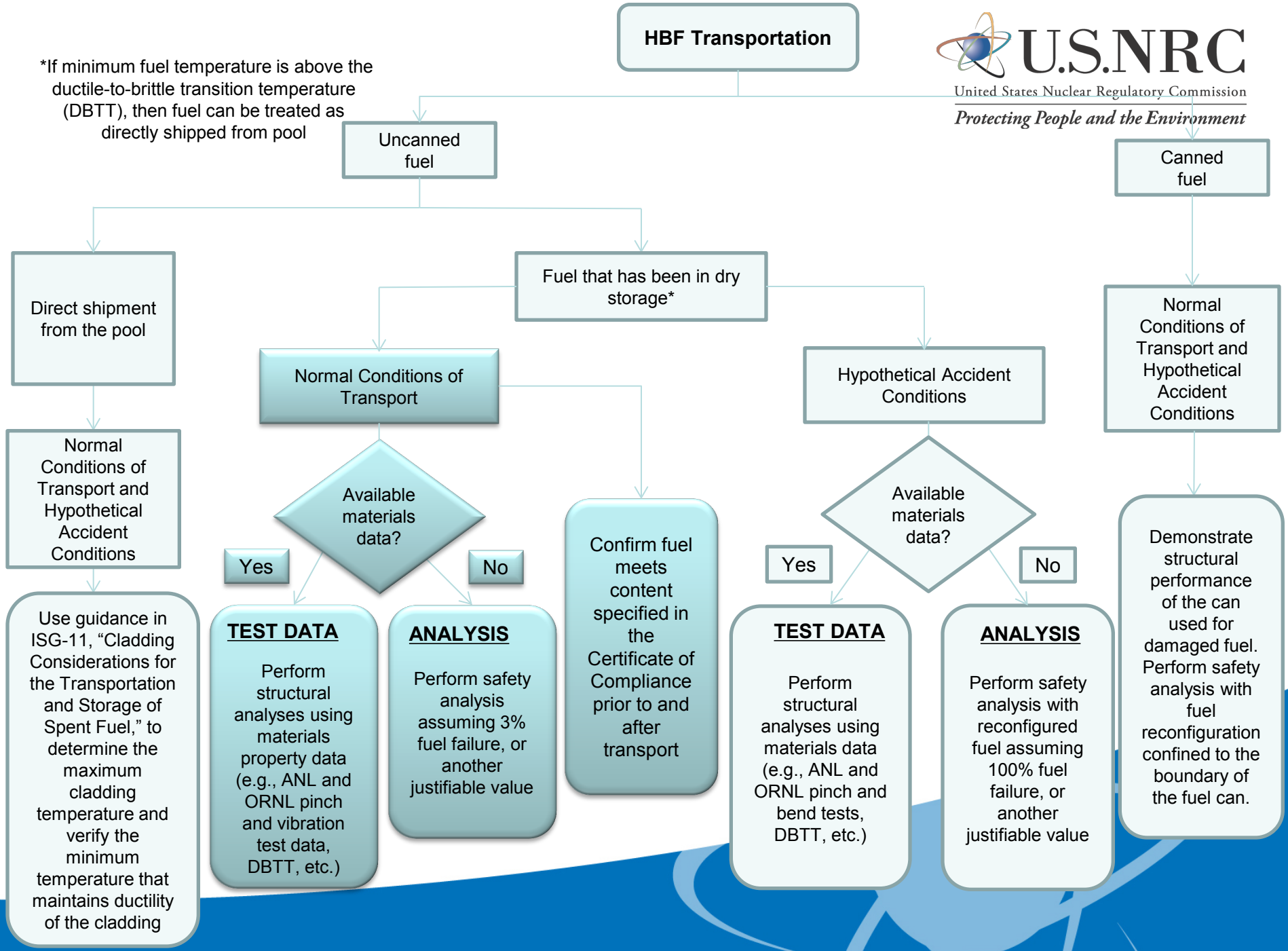
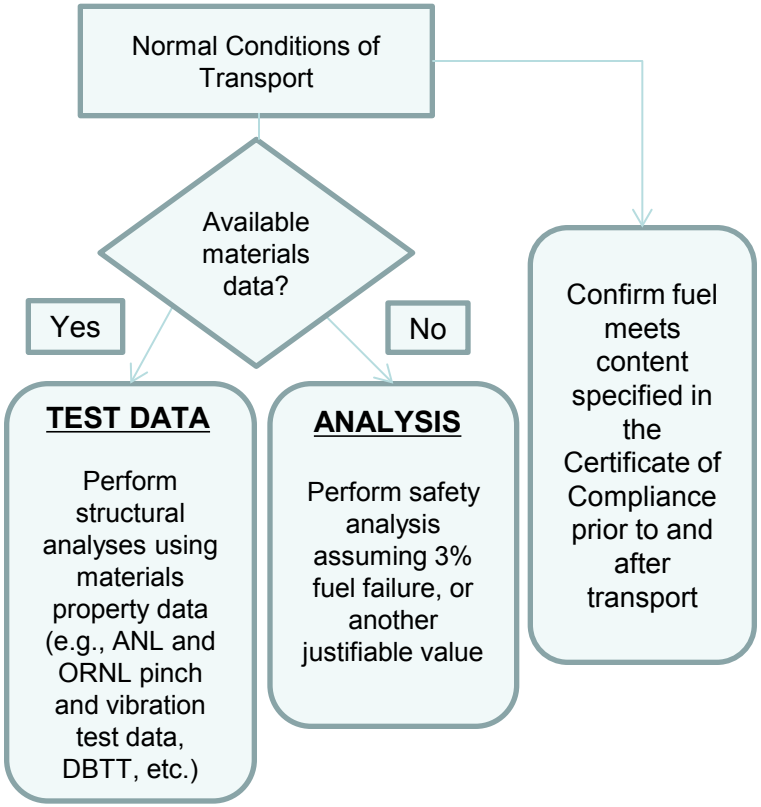
*If minimum fuel temperature is above the ductile-to-brittle transition temperature (DBTT), then fuel can be treated as directly shipped from pool



From Storage – Normal Conditions of Transport



- Test Data
  - Structural analysis relies on available cladding materials data
  - Possible data that can be used are results from ANL and ORNL pinch and vibration tests, or applicant provides own data
- Analysis
  - Safety analyses assuming 3% fuel failure for criticality, shielding, thermal, and containment
  - Or other justifiable value
- Fuel condition must be confirmed before and after shipment. This confirmation can be done in multiple ways (i.e., demo, gas sampling, etc.)

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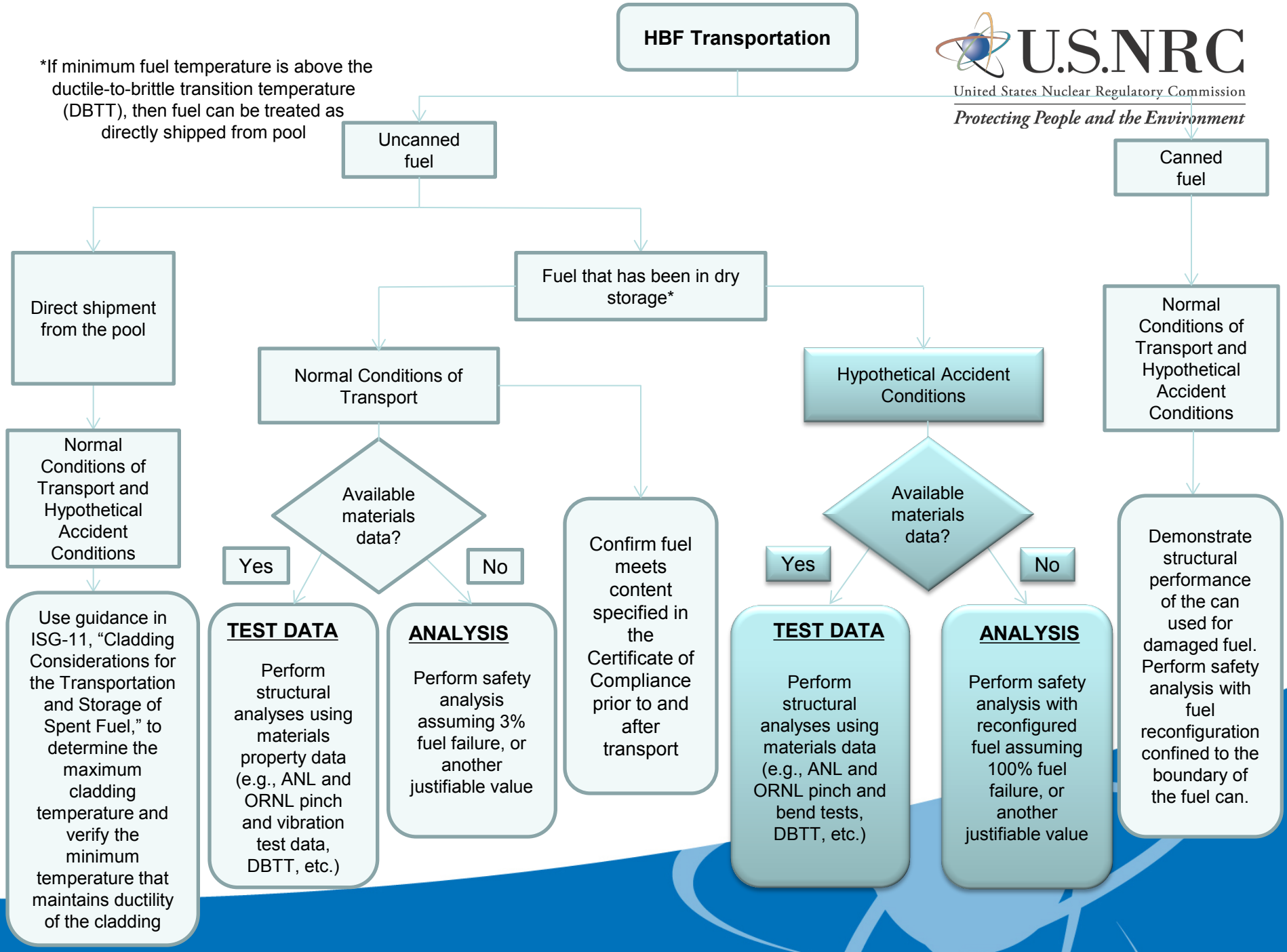
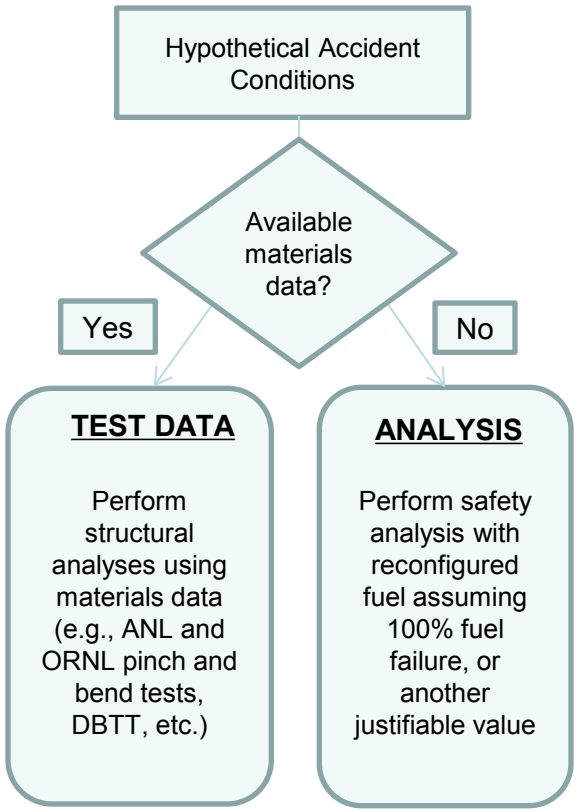
*If minimum fuel temperature is above the ductile-to-brittle transition temperature (DBTT), then fuel can be treated as directly shipped from pool



From Storage – Hypothetical Accident Conditions



- Test Data
  - Relies on available cladding materials data
  - Possible data that can be used are results from ANL and ORNL pinch and bend tests, or applicant provides own data
  - If fuel can reasonably be expected to reconfigure, perform safety consequence analysis
- Analysis
  - Safety analyses assuming 100% fuel failure in thermal, containment, shielding, and criticality
  - Or other justifiable value

Fuel from Dry Storage

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Fuel that has been in dry storage*

*If minimum fuel temperature is above the ductile-to-brittle transition temperature (DBTT), then fuel can be treated as directly shipped from pool

- This asterisk is giving the option to the applicant to show that even if the fuel has been in dry storage, they can demonstrate that the hydrides have not reoriented by arguing the temperatures have not decreased below the DBTT.

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RIS Questions and Comments?

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Backup Slides

Research related to ISG-11, Rev. 3

1. M.C. Billone, T.A. Burtseva, and R.E. Einziger, Ductile-to-brittle transition temperature for high-burnup cladding alloys exposed to simulated drying-storage conditions, Journal of Nuclear Materials 433 (2013) 431–448.
2. K. Kamimura, Integrity Criteria for Spent Fuel Dry Storage in Japan, Proc Int Seminar on Interim Storage of Spent Fuel, ISSF 2010 Tokyo, Japan, p VI-3-1.
3. M. Aomi, Evaluation of Hydride Reorientation Behavior and Mechanical Property for High Burnup Fuel Cladding Tube in Interim Dry Storage, 15th Int Symposium on Zirconium in the Nuclear Industry, June 2007, also J of ASTM International, 5, No 9.

Lead System Examination

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- Provides basic data on cask and cask internals
- Not equivalent to a full demonstration cask program as specified in ISG-24

Retrievability

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- Demonstration cask program and any lead system examinations provide assurance of retrievability