GSI-191 RESOLUTION OPTIONS

June 22, 2010

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GSI-191 RESOLUTION OPTIONS

- Meeting Purpose:
  - Identify and discuss factors affecting viability of various options to close GSI-191
- Objective: For all options identify
  - Precursor actions
    - Rule changes
    - Application guidance
    - Implementation guidance
  - Plant actions
  - NRC actions
  - Timeframe for closure
  - Considerations for operational margin

Discussion Topics

Time	Topic	Presenter
8:30-8:45	Introduction and Meeting Purpose	NRC/Mel Arey
8:45-9:00	Update on PWROG Activities	Mo Dingler
9:00-9:30	Insights on Risk Significance of GSI-191 Sequences	Rick Grantom
9:30-10:00	Considerations on use of GDC-4	John Butler
10:00-10:30	Considerations on use of 50.46a	Wayne Harrison
10:30-10:45	Break	
10:45-11:15	Considerations on use of 50.46	John Butler
11:15-11:30	Plant Impacts of Closure Options	Tim Bowman
11:30-12:00	Discussion	All
12:00	Adjourn	

Update on PWROG Activities

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Zones of Influence Update

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Zones of Influence Update

- Background:
  - Several licensees commissioned Westinghouse to perform testing to reduce Zones of Influence (ZOIs)
    - Materials tested included thermal and electrical insulation
    - Testing documented in several topical reports (WCAPs)
  - Unified PWROG effort undertaken to address NRC RAIs
  - NRC identified seven major issues
    - Five resolved
    - Two remain open
      - Application of ANSI/ANS 58.2-1988 jet expansion model to data
      - Scaling data from smaller test articles to plant components
  - Impasse with NRC necessitates further work if ZOI reductions are to be achieved

Zones of Influence Update

- **Approved ZOI Reduction project**
  - Computational Fluid Dynamics (CFD)
    - Establish a predictive tool to calculate jet pressure field
    - Provide for determination of isobar volumes to calculate ZOIs
    - Replaces previous use of ANSI model
  - Additional jet impingement testing:
    - Instrumented tests
      - Data to benchmark CFD model
      - Establish pressures for further testing of insulation targets
    - Insulation target tests
      - Use larger targets to reduce “scaling” penalty from BWROG URG
      - Establish destruction distances for various insulation system
  - Project programmatic features for success
    - Close NRC staff involvement included in plan
    - Project plan calls for project “evaluation points” following key meetings with NRC

Long-Term Core Cooling (LTCC) Update

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Long-Term Core Cooling (LTCC) Update

- BACKGROUND
  - PWROG program goal is to develop limits for debris entering the core that will not challenge LTCC.
  - Testing has shown that acceptable fiber limit is dependent on particulate-to-fiber ratio (p:f).
    - At higher p:f, Westinghouse and AREVA fuel exhibit similar behavior.
    - At lower p:f, pronounced differences exist between the two fuel vendors.

Long-Term Core Cooling (LTCC) Update

- RECENT AND CURRENT ACTIVITIES
  - Resolution of mixed-core questions and methodology
  - Discussion of guidance to licensees on calculation of available driving head
  - Discussion of actions to resolve fuel-vendor related questions at low p:f
  - Discussion related to applicability of debris limits to untested flow rates

Insights on Risk Significance of GSI-191 Sequences

C. R. Grantom P.E.
S.S. Rodgers
W. E. Schulz
STP Nuclear Operating Company
June 22, 2010

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Outline

- Background
- Risk Characterization of Sequences needing the Recirculation Function
- Relationship to other risk contributors
- Risk Informed Approach for Addressing GSI-191

Background

- Deterministic approaches have been pursued up until now with limited risk characterization applied ("compliance" position as basis to omit risk participation)
- NRC PRA Policy statement states risk should be used in all regulatory matters supported by the state-of-the-art
- Experiments and empirical data have been performed that has provided substantial information
- No experiment could capture the full scope of the recirculation function in an integrated fashion
- Plant Modifications have been installed to improved sump design and function (margins increased)

Background

- 50.46 Design Basis LOCA is a theoretical event and does not reflect realistic mechanisms for pipe breaks
- Risk analyses used for PRA is best estimate by definition and practice
- PRA can quantify margins and demonstrate confidence in safety functions being capable of mitigating events requiring the recirculation function (e.g., NRC 50.46a and GDC 4 expert elicitations)
- From an industry perspective, even if probability of sump blockage is 1.0 for the largest LOCAs, the increase in CDF would be ~2E-07 per year or ~3%
- Thus, Large LOCAs are not significant contributors to nuclear safety risk

GSI 191 Risk Perspective for STP Background

- In terms of largest pipe size STP has 12”, 16” and 27” to 31” for loop piping. The 16” is unique for the pressurizer surge line.
- Given the existing NRC approved guidance regarding debris generation, transportation, and strainer blockage, the STP strainers are adequate for all but the largest breaks, i.e., up to and including 12” and the 16” surge line but not 31” loop lines.
  - The 16” surge line is bounded by the worst break location for the 12” line; the debris generation analysis calculation was performed for a 7D ZOI for a 29” pipe which was the same sphere as a 12” pipe break using a 17D ZOI.
- *The total CDF for STP is estimated at 6.4 E-06 (LLOCA is 0.15% of total CDF).*

Risk Characterization & Considerations of Recirculation Function (Our Current State-of-Knowledge)

- PRA best estimate indications are that fracture mechanics (i.e., LBB) are mechanistically the best phenomenological representation of how LOCA initiating events would manifest themselves
  - NUREG 1829, Expert Elicitation, considered LBB as part of the determination of pipe break frequencies
- Recirculation Function is modeled for long term cooling
- Modeling of each phase of recirculation is not generally included in PRA models (already low and dominated by other risk contributors)

Establishing the Risk Significance of Sequences with Recirculation Function

- The risk strategy is to estimate:
  - the change in risk from assuming different values of sump failure rates and,
  - the risk reduction we obtained by the installed new strainer design, and then quantitatively compare that with what risk reductions remain to be gained by further modifications (further margin increases).

Establishing the Risk Significance of Sequences with Recirculation Function

Sensitivity Study Varying Sump Failure Rates

Risk Significance of Sequences with Recirculation Function

- Sump Failure Rates
  - The core damage frequency from a Large LOCA at STP is estimated at 9.4E-09 events per reactor-year.
  - This is based on a Large LOCA initiating event frequency of 2.67 E-06 per reactor-year. This value is taken from NUREG/CR-5750, Table D-11.
  - An event that causes the plugging of all the sumps and fails recirculation is estimated at 1.0E-05. Typical failure rate for what are considered to be passive components.

Risk Significance of Sequences with Recirculation Function

- Sump Failure Rates
  - With a CDF value at 9.4E-09 and sump plugging at 1.0E-05, sequences where the recirculation function as a result of large LOCAs are not significant contributors to core damage.
  - A plant specific sensitivity case was run where the probability of a total sump plugging event was raised to 1.0E-03 (a factor of 100) and to 1.0E-02 (a factor of 1000).
  - The CDF due to large LOCA increased from 9.4E-09 to 1.1 E-08, and 3.3E-08, respectively (still not a significant contributor to station risk).

Establishing the Risk Significance of Sequences with Recirculation Function

Comparison of new strainer design and additional safety benefit with further modifications

Risk Significance of Sequences with Recirculation Function

- Risk Basis 1 (Current Plant Specific Base Case)
  - The conditional core damage probability for a large LOCA (>6”) according to the present STP model (little or no sump blockage) is 3.51E-03.
  - That means that, given a large LOCA, there is a probability of 3.51×10^{-3} that core damage results.
  - If the large LOCA initiating event frequency is 2.67E-06, then the core damage frequency due to large LOCA is 2.67E-06 x 3.51E-03 = 9.37E-09.
  - Other sensitivity studies performed by industry also indicate the LLOCA contribution to total CDF is very small

Risk Significance of Sequences with Recirculation Function

- Risk Basis 2 (Generic)
  - NUREG-1829 lists the following mean annual frequencies for these particular size breaks:
    - 7 inch and larger 1.6E-06 LLOCA initiating event frequency
    - 14 inch and larger 2.0E-07 LLOCA initiating event frequency
    - 31 inch 2.9E-08 LLOCA initiating event frequency
- Risk Basis 3 (Plant Specific)
  - STP has one 12 inch Reactor Coolant System piping line, one 16 inch PZR surge line, and then 27 to 31 inch RCS Loop piping (nothing in between).

Risk Significance of Sequences with Recirculation Function

- Risk Basis 4 (Plant Specific)
  - STP can demonstrate the debris generation and sump blockage is not a concern for piping up to 12 inches. This is in the context of the latest NRC approved guidance for the new strainers and assuming the very conservative 17D ZOI.

Risk Significance of Sequences with Recirculation Function

- Risk Assumption 1 (Current Configuration)
  - Assume that the new strainer design (using the conservative NRC guidance) is effective up to but not including the 27 to 31 inch main loop lines.
  - Under that assumption, the CDF estimates are
    - 7 inch and larger 1.6E-06 initiating event frequency yields 5.6E-09 CDF
    - 14 inch and larger 2.0E-07 initiating event frequency yields 7.3E-10 CDF
    - 31 inch 2.9E-08 initiating event frequency yields 2.9E-08 CDF
  - Thus, total LLOCA CDF under Assumption 1 is 3.53E-08

Risk Significance of Sequences with Recirculation Function

- Risk Assumption 2 (Proposed Configuration)
  - Assume that plant modifications are made such that NRC guidance is met.
  - Under that assumption the CDF estimates are:
    - 7 inch and larger 1.6E-06 initiating event frequency yields 5.6E-09 CDF
    - 14 inch and larger 2.0E-07 initiating event frequency yields 7.3E-10 CDF
    - 31 inch 2.9E-08 initiating event frequency yields 2.1E-10 CDF
  - Thus, total LLOCA CDF under Assumption 2 is 6.44E-09

Risk Significance of Sequences with Recirculation Function

- Risk Reductions:
  - Assumption 1 to Assumption 2 (3.53E-08 – 6.44E-09) = 2.9E-08
  - Even if more bounding cases were evaluated (i.e., guaranteed sump failure), the change in CDF would still be within RG 1.174 guidelines

Risk Significance of Sequences with Recirculation Function

- The risk reductions demonstrate further modifications are not warranted.
  - Are well within Region 3 of RG 1.174
  - Demonstrate a high confidence of substantial margin of the capability to mitigate accidents where the recirculation function is required

Conclusions for GSI-191 Closure

- The PRA model shows that risk / safety is insensitive to the remaining uncertainties
- Additional plant modifications to address uncertainties will not improve risk / safety as predicted by the PRA model
- Additional defense in depth is provided by contingency procedures that are not credited in the PRA model used in these assessments

Consideration of GDC-4 Resolution Option

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GDC-4
Overview of Approach

- GDC-4 States:

"… dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping."

- In layman's terms:

Local dynamic effects associated with postulated ruptures in Leak-Before-Break piping can be excluded from the design basis.

GDC-4
Overview of Approach

- Current rule does:
  - Allow exclusion of local dynamic effects from LBB qualified piping
    - Local dynamic effects include missiles, pipe whipping, pipe break reaction forces, and discharging fluids [1]
    - Exclusion of dynamic effects permits removal (avoidance) of jet impingement barriers and shields; removal (avoidance) of pipe whip restraints; redesign of pipe connected components, and disregard jet impingement forces on adjacent components [1]

GDC-4
Overview of Approach

- Current rule does not:
  - Specify for which design basis analyses, which components, or which local impacts the specified dynamic effects can be excluded (i.e., no exclusionary application beyond applicable piping systems and specified local dynamic effects)

GDC-4
Application to GSI-191

- Current PWR situation
  - Each PWR licensee's design and supporting analyses for GSI-191 account for the impacts of local dynamic effects (debris generation) for the full break spectrum
  - Analyses have been performed in manner that compounds known conservatisms
  - "Closure" has been reached for approximately 56% of PWRs
  - Resolution for remainder held up by difficulties demonstrating to NRC staff satisfaction the conservatism in key aspects (e.g., ZOI, credit for debris settling)

GDC-4
Application to GSI-191

- In applying GDC-4
  - Licensee would perform a reevaluation to demonstrate that strainer qualification addresses limiting debris generation using methods accepted by NRC
    - Limiting debris generation determined for non-LBB piping systems
  - Results provided as revision to supplemental response to GL 2004-02
    - Identification of LBB qualified piping
    - Determination of limiting debris generation
    - Discussion of defense-in-depth measures and actions to maintain defense-in-depth

GDC-4
Timeframe for Closure

- Application provides clearly defined closure path
  - Minimal need for application guidance
  - No need for additional testing to support application
  - Straightforward NRC review

GDC-4
Considerations for Operational Margin

- Provides needed operational margin to address emergent issues
  - Applies to all plants
- Licensee commitment to control problematic insulations going forward
- Plans for ZOI testing expected to further demonstrate defense-in-depth and increase operational margins

GDC-4
Key References

1. Memorandum, Evans to Grobe, Leak-Before-Break Knowledge Management Document, May 29, 2007
2. Letter, Marion to Holahan, Application of Leak-Before-Break Technology to Pipe Break Debris Generation and Request for Public Comment Opportunity, October 4, 2002
3. Memorandum, Grobe to J. E. Dyer, Differing Professional Opinion Panel Response to DPO-2006-002, November 13, 2006
4. Letter, Pietrangelo to Leeds, Reconsideration of GDC-4 Application to GSI-191, April 7, 2010
5. Letter, Pietrangelo to Jaczko, Additional Information in Support of April 15 Commission Briefing on GSI-191, April 27, 2010

Consideration of 50.46a Resolution Option

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50.46a
Overview of Approach

- Proposed 50.46a states [1]:

"… LOCAs involving breaks at or below the transition break size (TBS) are design-basis accidents. LOCAs involving breaks larger than the TBS are beyond design-basis accidents.."

- Evaluation Model for Breaks smaller than TBS

"…The evaluation model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system during a LOCA."

"…Comparisons to applicable experimental data must be made and uncertainties in the analysis method and inputs must be identified and assessed so that the uncertainty in the calculated results can be estimated."

"…This uncertainty must be accounted for, so that when the calculated ECCS cooling performance is compared to the criteria set forth in paragraph (e)(3) of this section, there is a high level of probability that the criteria would not be exceeded."

50.46a
Overview of Approach

- Proposed 50.46a states:
- Evaluation Model for Breaks larger than TBS
  - Rule requirements are identical to "Evaluation Model for Break smaller than TBS", except:

"…These calculations may take credit for the availability of offsite power and do not require the assumption of a single failure. Realistic initial conditions and availability of safety-related or non safety-related equipment may be assumed if supported by plant-specific data or analysis, and provided that onsite power can be readily provided through simple manual actions to equipment that is credited in the analysis."

- Acceptance Criteria
  - Acceptance criteria applicable to GSI-191 for "Breaks smaller than TBS" and "Breaks larger than TBS" are identical

50.46a
Overview of Approach

- Current rule does:
  - Allow consideration of likelihood of breaks in treatment of break spectrum
  - Provides considerable potential relief for “LOCA blowdown analysis” of breaks greater than TBS
  - Calls for significant changes to supporting infrastructure
    - Analysis to show assumptions forming the technical bases for the rule apply
    - ECCS analysis methodology with more realistic assumptions, including GSI-191
    - Revised change control process
    - Possible enhancement to leak detection capability
    - New configuration control requirement for situations where the plant is outside the assumptions in the new analysis
    - PRA revisions for internal and external initiators and all modes, including shutdown

50.46a
Overview of Approach

- Proposed rule does not:
  - Provide language applicable to GSI-191 allowing relaxed treatment of breaks larger than TBS
  - Provide implementation guidance for rule (in general)
  - Provide implementation guidance for application specific to GSI-191

50.46a
Application to GSI-191

- Current PWR situation
  - Each PWR licensee's design and supporting analyses for GSI-191 account for the impacts of local dynamic effects (debris generation) for the full break spectrum
  - Analyses have been performed in manner that compounds known conservatisms
  - "Closure" has been reached for approximately 56% of PWRs
  - Resolution for remainder held up by difficulties demonstrating to NRC staff satisfaction the conservatism in key aspects (e.g., ZOI, credit for debris settling)

50.46a
Application to GSI-191

- Necessary First Steps
  - Revisions to rule language necessary to provide clear line of sight to GSI-191 evaluation
  - Development of Rule implementation guidance
    - Guidance for determining TBS applicability
    - Change control process
    - Configuration control requirements
  - Development of GSI-191 application guidance
    - Criteria for determining acceptable assumptions and models for breaks larger than TBS
    - Identification of candidate lists of realistic initial conditions suitable for a “beyond design basis” event
      - Clear guidance on application to plant specific resolution

50.46a
Application to GSI-191

- Viability of 50.46a application to GSI-191 is uncertain
  - Significant time and effort will be needed to provide necessary guidance on rule implementation and application to GSI-191
  - Pilot applications needed to develop/refine guidance and reduce uncertainties
- Licensee decisions to implement 50.46a will need to factor in plans for future application beyond GSI-191

50.46a Timeframe for Closure

- Final NRC approval in 3Q12 or 4Q12

1Q 2011	Final Rule (rule changes to address GSI-191 applicability could result in additional comment period
3Q 2011	Develop implementation guidance (+ 6 months or greater)
3Q 2011	Develop application guidance (+ 6 months or greater)
1Q 2012	Pilot LAR submittal for GSI-191 only (+ 6 months or greater)
3Q-4Q 2012	NRC Review (+ 6-9 months)
~ 2014	Non-pilot LAR submittal and NRC review

- Extensive Licensee analysis activities are required in this schedule
  - Substantial PRA model or assessment to account for all modes, internal and external initiators
  - Thermal-hydraulic analysis
  - NUREG-1829 and NUREG-1903 applicability

50.46a
Key References

1. § 50.46a Draft Final Rule Language, April 30, 2010 ((ADAMS Accession no. ML101250271)

Consideration of 50.46 Alternative Evaluation Option

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50.46 Alternative Evaluation Overview of Approach

- 50.46 States:

"… evaluation model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor coolant system during a LOCA accident. Comparisons to applicable experimental data must be made and uncertainties … accounted for so that … there is a high level of probability that the criteria would not be exceeded."

50.46 Alternative Evaluation Overview of Approach

- Current rule does:
  - Allow consideration of likelihood of breaks in treatment of uncertainties
  - Section 6 of NEI 04-07 [1] and associated safety evaluation report [2] provide framework for risk-informed treatment of break spectrum
  - Section 6 treatment similar to proposed 50.46a:
    - Region I (Breaks $\leq$ 14") – No change in treatment (customary design basis)
    - Region II (Breaks > 14") – More realistic design basis analysis methods and assumptions

50.46 Alternative Evaluation Overview of Approach

- Current rule and associated guidance do not:
  - Provide practical application guidance on the identification and acceptability of “realistic” methods and assumptions
- Multiple revisions of methods and assumptions proposed in Section 6 of NEI 04-07 were rejected in NRC safety evaluation report

50.46 Alternative Evaluation Application to GSI-191

- Current PWR situation
  - Each PWR licensee's design and supporting analyses for GSI-191 account for the impacts of local dynamic effects (debris generation) for the full break spectrum
  - Analyses have been performed in manner that compounds known conservatisms
  - "Closure" has been reached for approximately 56% of PWRs
  - Resolution for remainder held up by difficulties demonstrating to NRC staff satisfaction the conservatism in key aspects (e.g., ZOI, credit for debris settling)

50.46 Alternative Evaluation Application to GSI-191

- Necessary First Steps
  - Development of criteria for determining acceptable inputs, models and assumptions for Region II analysis
  - Identification of candidate lists of inputs, models and assumptions for Region II analysis
  - NRC review of Region II application guidance
- Viability of 50.46 Alternative Evaluation is dependent on degree of separation between treatment of Region I and Region II

50.46 Alternative Evaluation Application to GSI-191

- In applying 50.46 Alternative Evaluation
  - Licensee would perform a reevaluation to demonstrate that strainer qualification addresses limiting debris generation using methods accepted by NRC
  - Results provided as revision to supplemental response to GL 2004-02
    - Identification of Region II treatments applied
    - Additional information as called for in Section 6 of NEI 04-07

50.46 Alternative Evaluation Timeframe for Closure

- Application dependent on timely identification and approval of viable separation between Region I and Region II assumptions
  - Upfront need for application guidance
  - Need for additional testing, design modification dependent on degree of separation (plant specific)
  - Once criteria established and agreed to, NRC review of plant application should be relatively straightforward

50.46 Alternative Evaluation Considerations for Operational Margin

- Has potential to provide needed operational margin to address emergent issues
  - Applies to all plants
- Licensee commitment to control problematic insulations going forward
- Plans for ZOI testing expected to further demonstrate defense-in-depth and increase operational margins

50.46 Alternative Evaluation Key References

1. NEI 04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology, Revision 0, December 2004
2. Letter, Black to Pietrangelo, Pressurized Water Reactor Containment Sump Evaluation Methodology (Safety Evaluation), December 6, 2004

Plant Impacts of Closure Options

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NEI
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Industry Perspective

- PWRs have done modifications, analysis, and testing to resolve this issue.
- The changes have made a measurable improvement in Core Damage Frequency.
- New questions and issues continue to arise during the efforts to close out GSI-191.

Industry Perspective

- Possible actions to close GSI-191 under the current regulatory process are resource and radiation dose intensive.
- The additional change in CDF from these actions are negligible.
- Resources would be better spent on other projects that have a more positive impact on CDF and station reliability.
- A more realistic regulatory approach to address GSI-191 would be a better holistic approach to safety.

STP Example

- To comply with the current regulatory process, STP must
  - Perform a combination of the following activities:
    - Remove SG insulation and replace with reflective metal insulation (RMI)
    - Place sure hold bands on pipe insulation
    - Add more sump strainers
  - Support additional ZOI, sump strainer, and fuel testing

STP Impact

- The estimated dose per unit for the modifications is:
  - RMI on RCS components — 70 – 300 Rem
  - Sure-hold bands — 20 – 80 Rem
  - Strainers — 0.1 Rem
- The estimated cost per unit is:
  - RMI — $10 million
  - Sure-hold bands — $6 million
  - Strainers — $4 million

STP Impact

- STP is committed to the safe and reliable operation of our units.
- STP has a Plant Investment Plan that funds projects that upgrade systems and components to improve safety and reliability.
- Upgrades that satisfy new regulatory requirements are part of this investment plan.

STP Impact

- Based on this cost and dose, STP would have to delay reliability and safety improvements from its Plant Investment Plan to fund the modifications to close GSI-191.
- Here are examples of the projects that might be delayed:
  - Secondary plant changes that protect Steam Generator health
  - Primary system instrumentation upgrades
  - Permanent shielding to reduce outage dose
  - Procedure upgrades
  - Communication equipment upgrades
  - Essential Cooling Water pump upgrades

STP Impact

- What is the impact of delaying these upgrades?
  - Additional outage dose of 20 Rem in 2014
  - An estimated increase in CDF of 2.78E-08
  - An increase of 1% in initiating events due to reactor trips

GSI-191 Resolution

- Continuing on the current closure process will provide negligible improvements in CDF.
- A better use of resources to improve safety is through a more realistic regulatory approach.

Conclusion

- ✓ GDC-4 is only option that provides appropriate level of safety in a timely manner with minimal uncertainty
- ✓ For other options considered there is significant effort and time needed to develop implementation guidance and significant uncertainties on outcome

Discussion

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