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Developing Effective Inspection Plans for Fixed Equipment Programs

by Lynne Kaley & John Conway

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Lynne Kaley, PE

- Materials/Corrosion and Risk Management Engineer
- 30+ Years Refining, Petrochemical and Midstream Gas Processing Experience
- 10 years owner/user plant metallurgist/corrosion and corporate engineer
- 20+ years consulting with plant management, engineering and inspection departments:
  - Risk-Based technology (RBI) development leader
  - Development of implementation work process for plant application
  - Member of API committees for development of API 580 and API 581 recommended practices
- Project Manager of API RBI Project from 1996-2009

John Conway

- 33 years Inspection/Reliability Experience
  - Owner/User
  - Inspection/Reliability Management
  - Inspection and RBI Consulting
- Certifications/Training/Education
  - National Board
  - API 510 with 571 endorsement API 570, API 653
  - NACE-Senior Corrosion Technologist
  - BS- University of Texas at Austin
- Affiliations
  - API Codes and Standards Participant
  - Development of recommended practices for Corrosion Under Insulation (CUI) and Integrity Operating Windows (IOW)

Purpose

- **Purpose of Presentation**
  - Development of effective inspection programs with or without RBI
  - Proper documentation of inspection to achieve full credit for inspection performed
  - Development of acceptance/rejection criteria prior to conducting inspection
  - Show examples to demonstrate potential challenges and how to handle exceptions during inspection
- **Sources/References**
  - API 510, 570, 653
  - API 580, 581
  - API 571

Outline

- Introduction
- Inspection Program Goals
- Inspection Planning Process
- Fixed Interval vs. Risk-Based
- Cost Benefit for Risk-Based
- Today’s Inspection Responsibilities
- Future Inspection Programs
- Industry Examples (4)
- Conclusions

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Introduction

- Flood of technology and regulatory requirements since 1990 has changed inspection program management work flow
- Outsourcing inspection and engineering services has provided additional resources and expertise but has created a fractured work flow and introduced multiple hand-offs
  - Can introduce errors at each hand-off point
  - May not achieve the same level of ownership by each party
  - May not take advantage of synergy potential between parties
- Inspection data analysis required to:
  - Develop, evaluate and interpret inspection findings
  - Provide recommendation for next inspection required
- Multiple software products add complexity as well as time consuming manual methods for combining results

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Inspection Program Goals

- Assure regulatory and corporate compliance
- Identify program improvements by streamlining the workflow and eliminating, to the extent possible, time-consuming manual activities or duplicate efforts
  - Provide improved inspection data quality by being more involved and aware of the working process
  - Provide suggestions for improvements as well as better analysis and information from the field
  - Help define/design the streamlined workflow including procedure, decision-making points, analysis and reporting
- Provide added-value services for budgeted inspection program
- Develop multi-year inspection plan for scheduling and budgeting
- Provide data management and analysis, scorecard metrics and dashboard reporting

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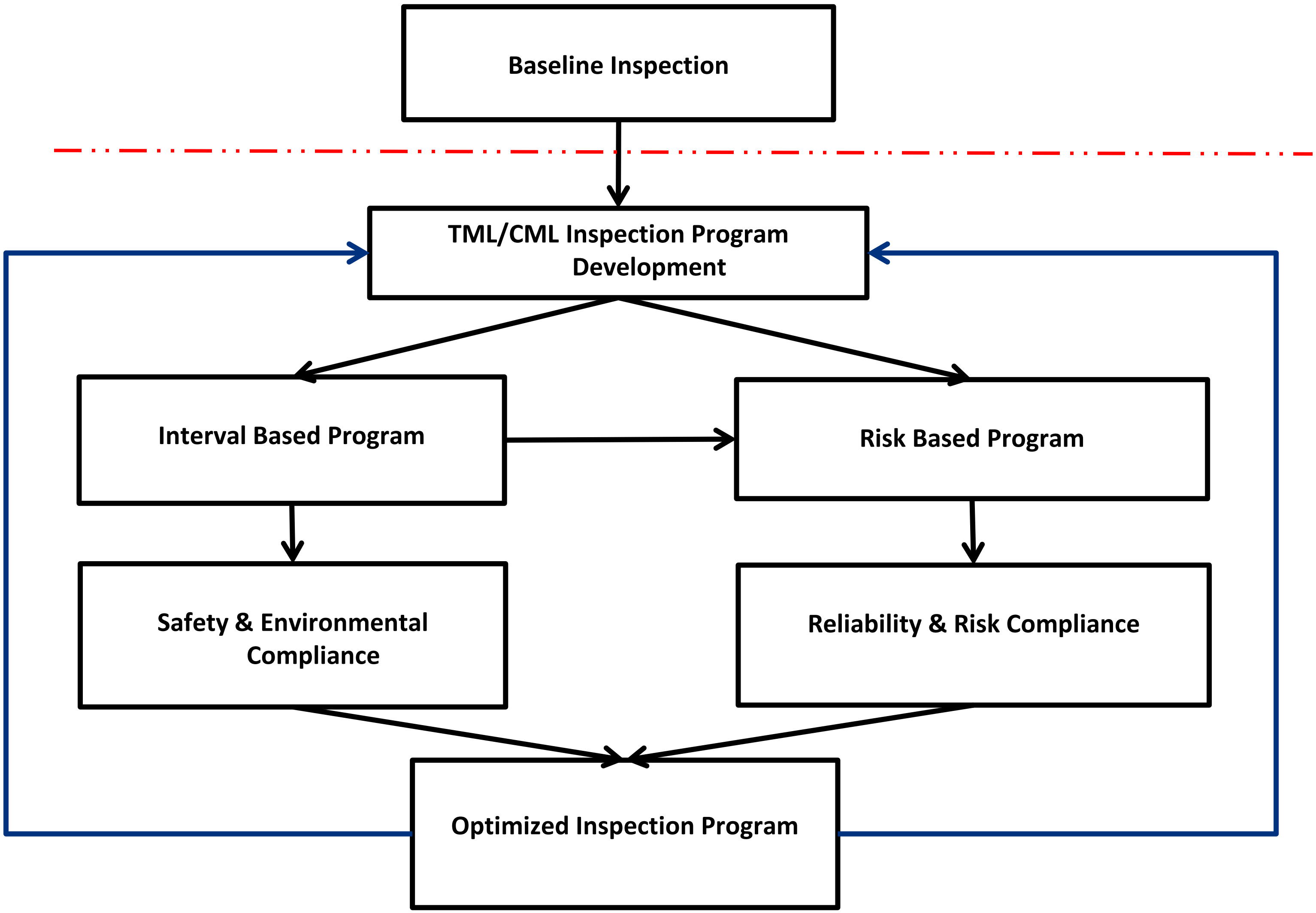
Inspection Plan Development



Inspection Plan Development

- Critical to develop credible inspection plan
  - Collect quality data, evaluate, validate and manage fixed equipment data
  - Historical inspection and maintenance records
  - Damage assessment, damage rate and key operating variable driving damage (integrity operating window, IOW)
  - Develop specific inspection requirements based on operation of plant and complexity of operation
- Prioritize Equipment inspection
  - Inspection due dates versus internal accessibility and expected damage
- Define criteria for inspection
  - Acceptable damage for continued operation
  - Fitness for service assessments, as required
  - Repair/Replacement criteria

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Analysis and Review

- Materials/corrosion review with assignment of active damage mechanisms
  - Critical to the success of any equipment reliability program
  - Critical to success of any fixed interval or RBI program
  - Required by codes & standards and regulations
  - Should include special emphasis mechanisms (e.g., Stress Corrosion Cracking, Creep, Wet H_2S)
- Inspection history and effectiveness
  - RBI has introduced a way to quantify and use inspection effectiveness (eg. A, B, C levels)
  - Interval based inspections nominally target B level inspections
  - Can be subjective and lead to less consistency

Inspection Recommendations

- Analysis produces specific equipment inspection recommendations
  - Recommendations from engineering study typically general guidance
  - Recommendation should include expected results of inspection, type and location of damage as well as damage rate
  - May include an acceptance/rejection criteria
- More detailed planning required before on-stream or turnaround inspection is performed
  - P&ID and equipment design drawing level mark-up
  - P&ID and piping isometric review and mark-up
- Inspector must be prepared in the event of unexpected findings and know how to handle them if encountered

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Fixed Interval vs. Risk Based Programs

Fixed Interval-Based

- T_{min} & ½-life determination
- Set fixed maximum interval
- No consequence analysis
- Probability based on damage rate only
- Nominally B-Level effective inspection

Risk-Based

- Optimize intervals based on risk
  - Reduced inspections for low consequence equipment
  - Credit for probability assessment
- Multiple levels of inspection effectiveness

API Codes & Standards

- API 510 Fixed interval internal inspection
  - The period between internal or on-stream inspections shall not exceed ½ the remaining life of the vessel or 10 years, whichever is less
  - If remaining life is < 4 years, the inspection interval may be the full remaining life up to a maximum of 2 years
- API 510 allows of on-stream inspection as a substituted for the internal inspection in the following situations:
  - Vessel entry for internal inspection is physically impossible
  - When entry is physically possible and all of the following conditions are met:
    - General Corrosion Rate < 5 mpy
    - Remaining Life > 10 yrs
    - Corrosive character and trace components known at least 5 years in same or similar service
    - No questionable condition is discovered during the External inspection
    - Operating temperature < lower limit of creep-rupture range
    - No susceptibility to environmental cracking or H_2 damage
    - No non-integrally bonded liner, e.g. strip or plate

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API Codes & Standards

- API 570 interval between piping inspections shall be established and maintained using the following criteria:
  - Corrosion rate and remaining life calculations
  - Piping service classification
  - Applicable jurisdictional requirement
- API 653 Inspection Intervals
  - Inspection shall be set to ensure the bottom plate is not below the minimum thickness in Table 6.1
  - In no case shall the internal inspection exceed 20 years
  - Unknown corrosion rates, internal interval shall not exceed 10 years

Transition to Risk-Based Program?

- Is there cost benefit and added value to move from Fixed Interval to Risk based interval approach
  - Cost of RBI implementation
  - Cost of annual maintenance, periodic reviews and resources to manage program
- Added Value of RBI
  - Set interval for Risk (from fixed interval matrix) and allows intervals up to and beyond > 10 years
  - Allows various levels of inspection effectiveness based on risk reduction requirements
  - Cost benefit is determined prior to implementation, based on optimized interval basis comparison
- Ultimately, it's the users decision and both Interval based and Risk based comply with API codes and regulatory requirements

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Cost Benefit & Metrics

- Cost benefit comparison of costs for previous program versus cost of optimized program
- Metrics:
  - Compliance to API 510, 570 and 653
  - Overdue inspections
  - Inspection deferrals
  - On-stream availability
  - Elimination of work effort duplication
  - Redirected inspection effort

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Today's Inspection Responsibilities

- Manage, gather and analyze fixed equipment design and operating data to support engineering activities (operating windows, damage assessments)
- Manage, gather and analyze inspection data to support engineering activities (RBI, FFS)
- Align and execute inspections to make the best use of RBI, FFS and other new technologies
- Monitor inspection data quality, analyze results and assess impact on equipment safety environment and reliability
- Coordinate and manage technical and administrative functions
- Develop and maintain scorecards to measure programs value to mitigate risk, increase reliability, and assess cost effectiveness

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Today's Inspection Responsibilities

- Conduct Inspection as recommended from Fixed Interval or RBI program includes Inspection methods, coverage, effectiveness
- Provide information for field inspector such as expected corrosion rate, past thickness information and other damage mechanisms possible
- Compare findings of reported damage to expected damage and consider
  - Quality of inspection
  - If damage is worse than expected, why?
  - If damage is less than expected, why?
  - What needs to change in the risk analysis to reflect this new information?
  - Are adjustments in damage rates needed?
- Following examples to demonstrate inspection planning requirements

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Future Inspection Program Management

- Inspection accessible through one software user interface
- Inspection strategies centered around equipment damage mechanism circuits
- Inspection Program Management workflow will be streamlined and driven by priorities set by business metrics
- Notifications of operating variability outside of IOW's will be provided in real time through process monitoring software communicating PSM program
- MOC process will be incorporated into the day-to-day workflow
- Scorecard metrics and automated dashboard reporting
- Virtual Reality based on 3D Laser models

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Industry Examples - Essentials for Inspection Work Flow

- Case Study 1 – Specific Equipment Inspection Plans
- Case Study 2 – Detailed Inspection Planning
- Case Study 3 – Field Execution
- Case Study 4 – Final Inspection Recommendations

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Case Study 1 – Specific Equipment Inspection Plans

- Review identified damage mechanisms for vessels and piping
  - Include mechanical damage, corrosion and cracking mechanisms
  - Review design, operating data, materials of construction
  - Review inspection history to identify possible internal issues
  - Use API 571 or other applicable Codes & Standards and/or Recommended Practices
- Review inspection effectiveness by RBI analysis, if available (examples provided in API 581)
- Prepare specific equipment inspection plan details with inspection requirements, coverage and associated drawings identifying location for inspection
- Review all documentation to avoid potential discovery issues

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Case Study 1

347 SS strip lining of Hydrotreater Reactor with dye penetrate test

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Case Study 1

- Mechanism identified: Polythionic Acid Cracking (PTA) on 347 SS Weld Overlay.
- Inspection Recommendation: Angle beam inspection for cracking
- History record review during turnaround revealed mechanical and thermal cracking to a 347 SS strip liner installed on past outages
- Changes to planned inspection:
  - Mechanism changed to include mechanical and thermally induced cracking on strip liner repairs
  - PT used for detection of surface cracking
  - Sections of strip liner removed to inspect base material
- Returned to service after inspection and required repairs

Case Study 2 – Detailed Inspection Planning

- Successful inspection planning requires applying the results of the damage mechanism assessment into the planning process to accurately provide the following tasks :
  - Assist developing critical path inspection schedule
  - Prioritize equipment inspections with likelihood of requiring repairs; Plan and estimate resources to execute repairs
  - Assure plan complies with inspection effectiveness requirements (doing correct inspection in the right area)
  - Assess manpower and resources required to execute inspection plan
  - Assist planning to determine manpower and resources required to plan for maintenance and discovery repairs
  - Provide cost assessments to repair or replace
  - Reliability
  - What if's and contingency plans

Case Study 2

- Spreadsheet Example

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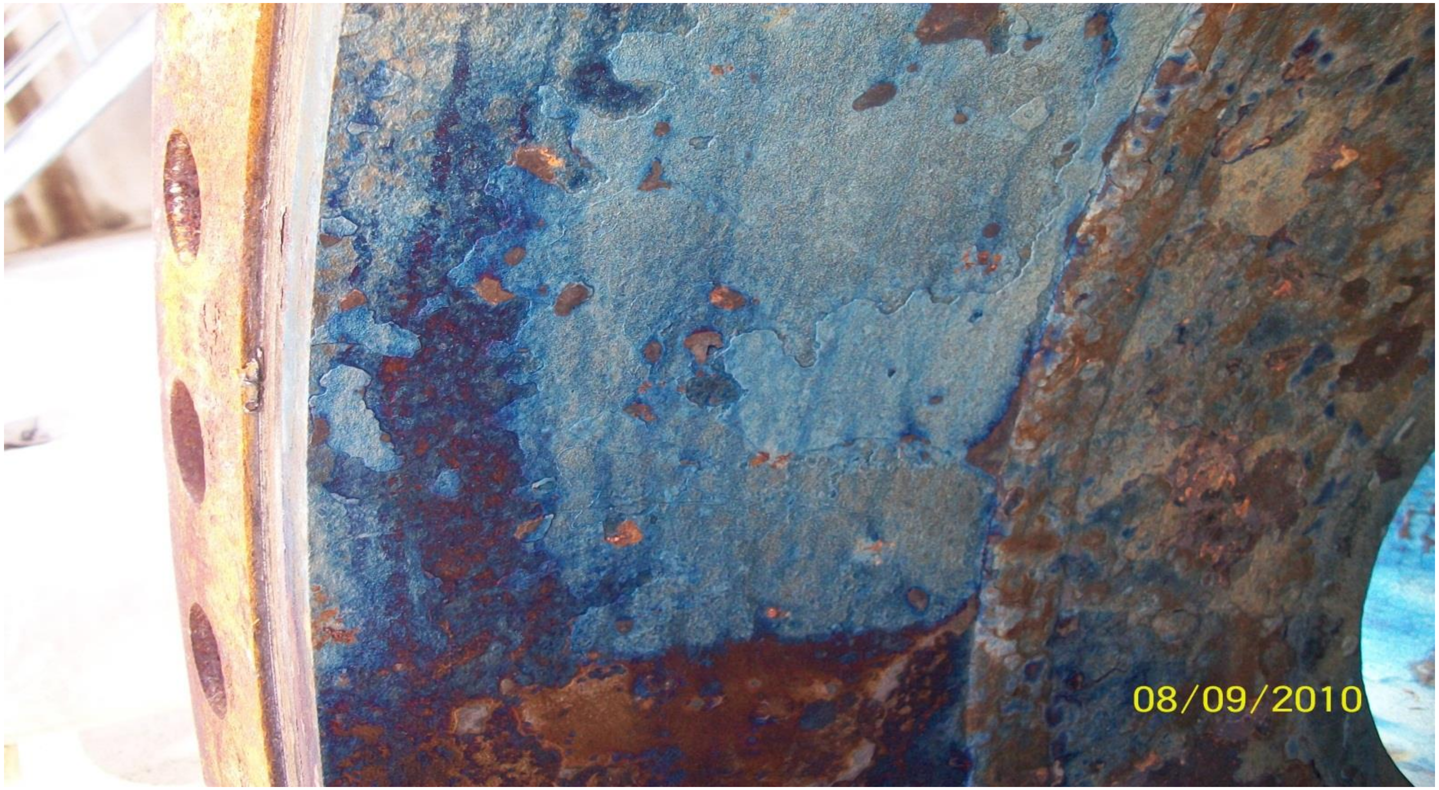
Case Study 3 – Field Execution

- Assure equipment /piping are inspected per applicable mechanical damage, corrosion and/or cracking mechanism
- Assess if inspections are performed in accordance with industry best practices
- Assess if inspections comply with owners inspection effectiveness requirements
- Facilitate the inspection and corrective action repair recommendations for the client’s approval.
- Coordinate/facilitate inspection recommendations requiring engineering support (including coordinating or facilitating RCFA’s, FFS analysis and critical path inspection engineering activities)
- Reassess risk for equipment requiring repairs not anticipated prior to turnaround
- Coordinate with inspection planning to reassess turnaround critical path activities impacted by inspection to expedite completion

Case Study 3



Prussian Blue in Hydrotreater Effluent Exchanger Channel Head

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Case Study 3

- Ammonium chloride and Ammonium Bisulfide corrosion mechanism identified (localized thinning)
- Significant nitrogen or cyanides not expected in system
- Exchanger opened for inspection and cleaning, Prussian Blue observed when opened for inspection indicating the presence of cyanides
- Investigation revealed naphtha feed contained cyanides
- Inspection plan modified during turnaround for presence of H_2S and cyanide
- Consider possible plan changes to other equipment in relevant systems

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Case Study 4 – Final Inspection Recommendations

- Update inspection records
- Provide conceptual scope recommendations for client upon completion of turnaround
- Provide pertinent details to assess equipment during ensuing run and plan next outage
- Detail inspection effectiveness in reports for inspection grading
- Provide lessons learned assessment to improve inspection performance

Case Study 4

- Plant plans to increase TAN and sour crude feedstock
- Primary Concerns:
  - Monel Liner transition to Carbon Steel sections of crude column/High Temperature Corrosion
  - Significant localized weld repairs during prior two turnarounds outages
  - Aqueous phase HCl/Ammonium Chloride Corrosion
  - 410 SS Liner in high temperature corrosive environment
- Plans to upgrade unit metallurgy during next turnaround
- Inspection and repairs anticipated and performed on the crude/vacuum unit equipment during recent outage
- Objective to assure that equipment would operate effectively until planned upgrades at next turnaround

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Case Study 4 - Recommendations

- Short Term:
  - Develop inspection strategy with Inspection Department to inspect vessel for aqueous and high temperature localized corrosion with existing metallurgy
  - Support inspection and engineering effort to prepare detailed design scope for the outage
  - Review on-stream inspection and turnaround inspection data and establish CML's and establish inspection interval based on crude corrosivity
  - Establish estimated corrosion rate for vessel and associated piping range based on planned crude feed composition and blending strategy for run
  - Implement inspection integrity operating window (IOW) with the Chemical Vendor/ Process Engineering to stay appraised of any issues that would require increased inspections (example : increased salts to Crude Overhead)
    - Support impending RBI effort to establish the risk profile for this vessel
    - Coordinate and provide Fitness for Service Support as required

Case Study 4 - Recommendations

- Long Term:
  - Provide engineering with inspection data required to design project
  - Prepare detailed inspection scope of work to repair and upgrade vessel based on results analyzed from proposed short term inspection strategy
  - Provide planning and scheduling support
  - Provide off-site vendor support

Conclusions

- Flood of technology to the industry in recent years, leading to significant changes in the inspection planning work flow
- Either interval basis used needs to be optimized for effectiveness in detecting damage and location of damage
- Damage reviews are critical step, as well as review of equipment history, in effective inspection plan development
- Whether using interval or risk-based interval setting is used, inspection must:
  - Review the damage potential and inspection methods/coverage recommended
  - Thoroughly review histories in order minimize discovery during inspection
  - Work with Planning to prioritize and schedule inspection
  - Provide API 571 endorsed inspector for critical equipment inspections to identify possible unexpected results or presence of potential damage mechanisms during discovery
  - Provide recommendations for short and longer term actions, as required

Questions?

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