API RBI User Group Training

April 28-29, 2004
Houston, Texas

The Equity Engineering Group, Inc.

Course Outline

- Part 1: Introduction to RBI
- Part 2: Overview of API 580
- Part 3: Working Process
- Part 4: Software Introduction
- Part 5 Consequence Analysis
- Part 6: Likelihood Analysis
- Part 7: Inspection Planning
- Part 8: Cost Benefit Analysis
- Part 9: Overview of API 581
- Part 10: RBI Project Direction

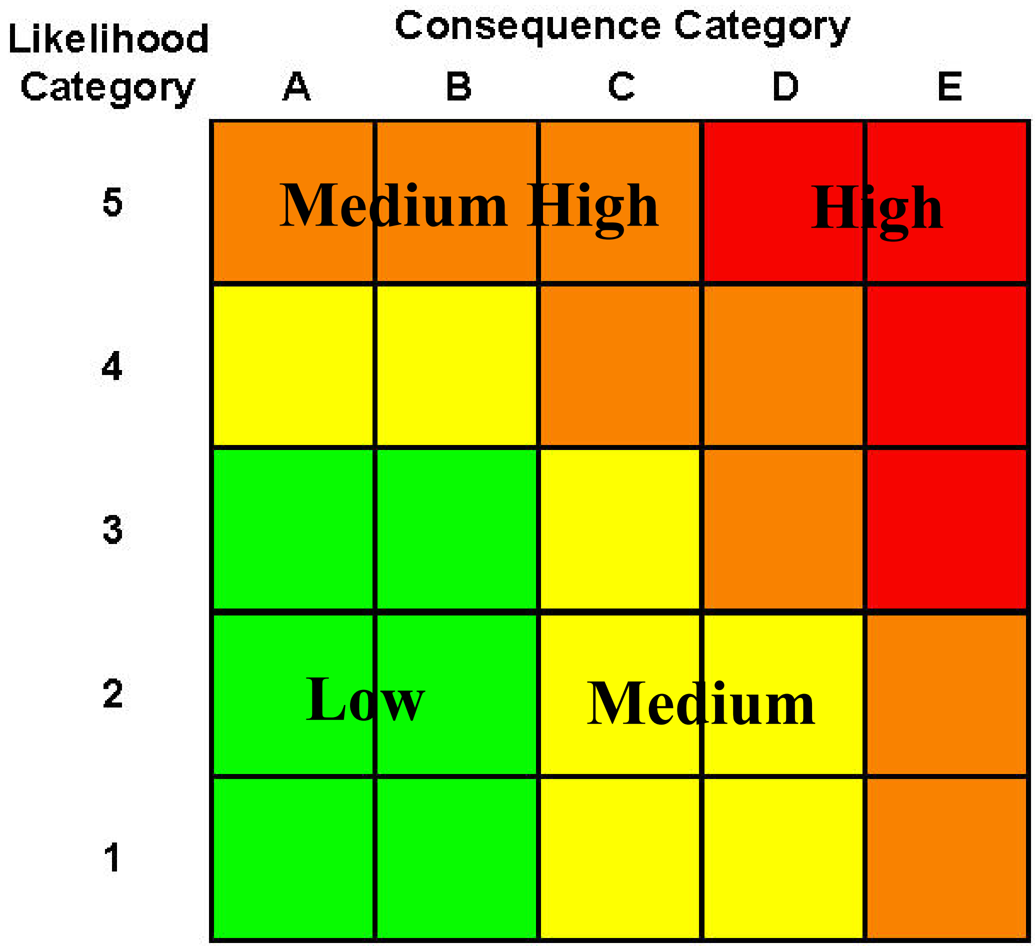
Introduction to Risk Based Inspection

Part 1

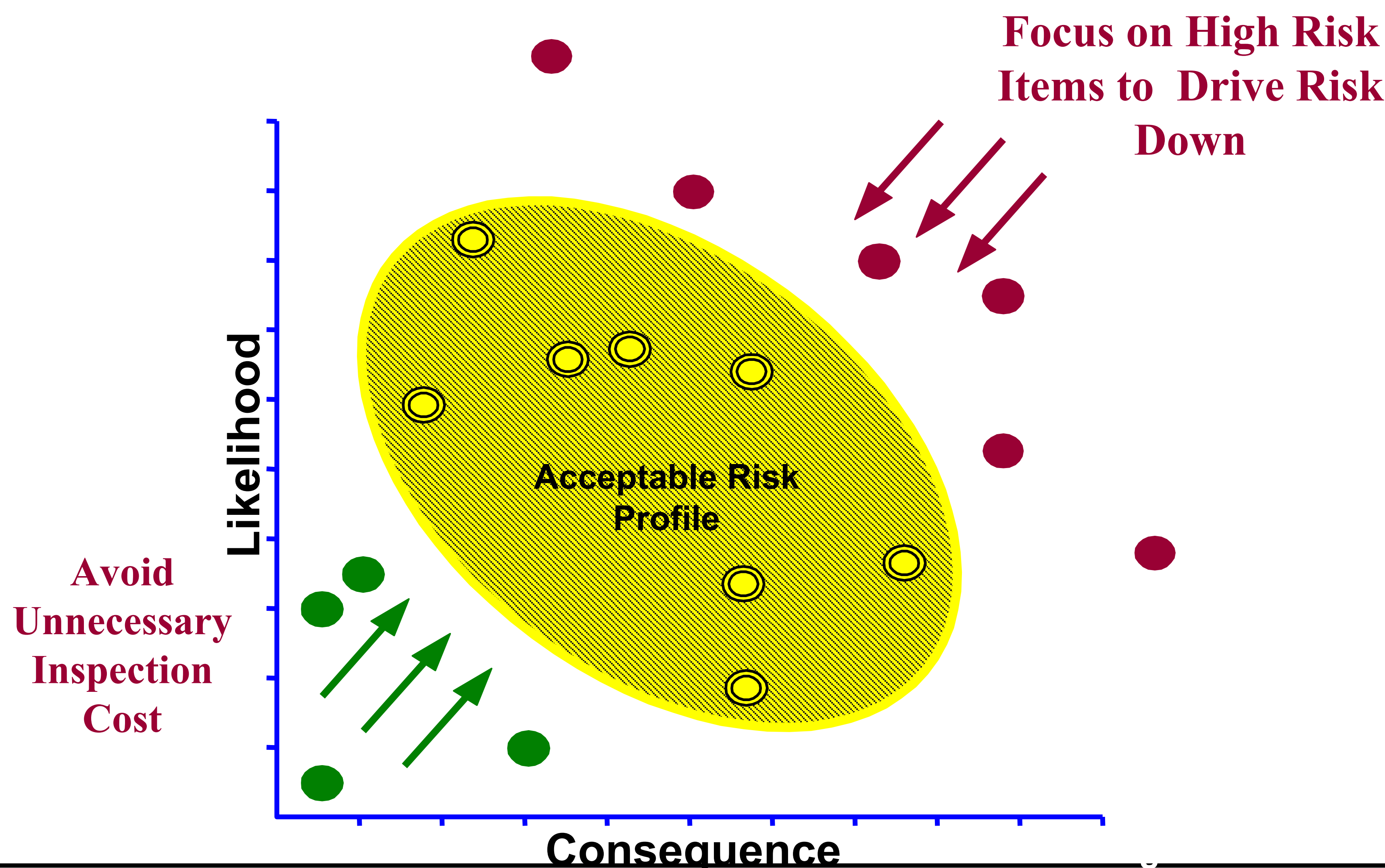
Types of API RBI Analysis / Software

- **Qualitative** Risk Analysis - simple, brief prioritization of equipment
- **Semi-Quantitative** Risk Analysis - more accurate, more detailed prioritization and planning
- **Quantitative** Risk Analysis - most in depth analysis including reliability and financial analysis

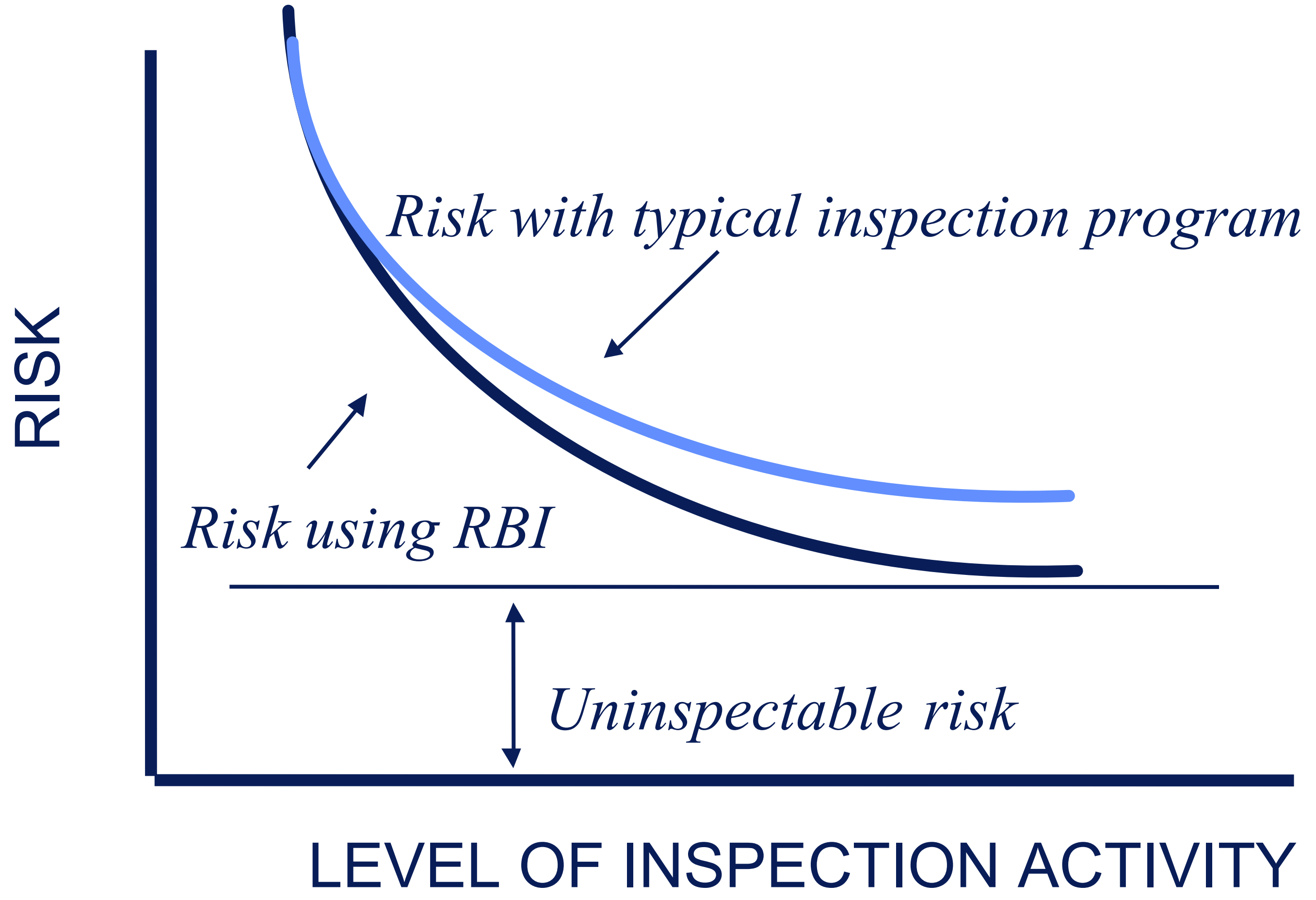
API RBI Risk Matrix



Managing Risk Acceptable Profile



Management of Risk Using RBI

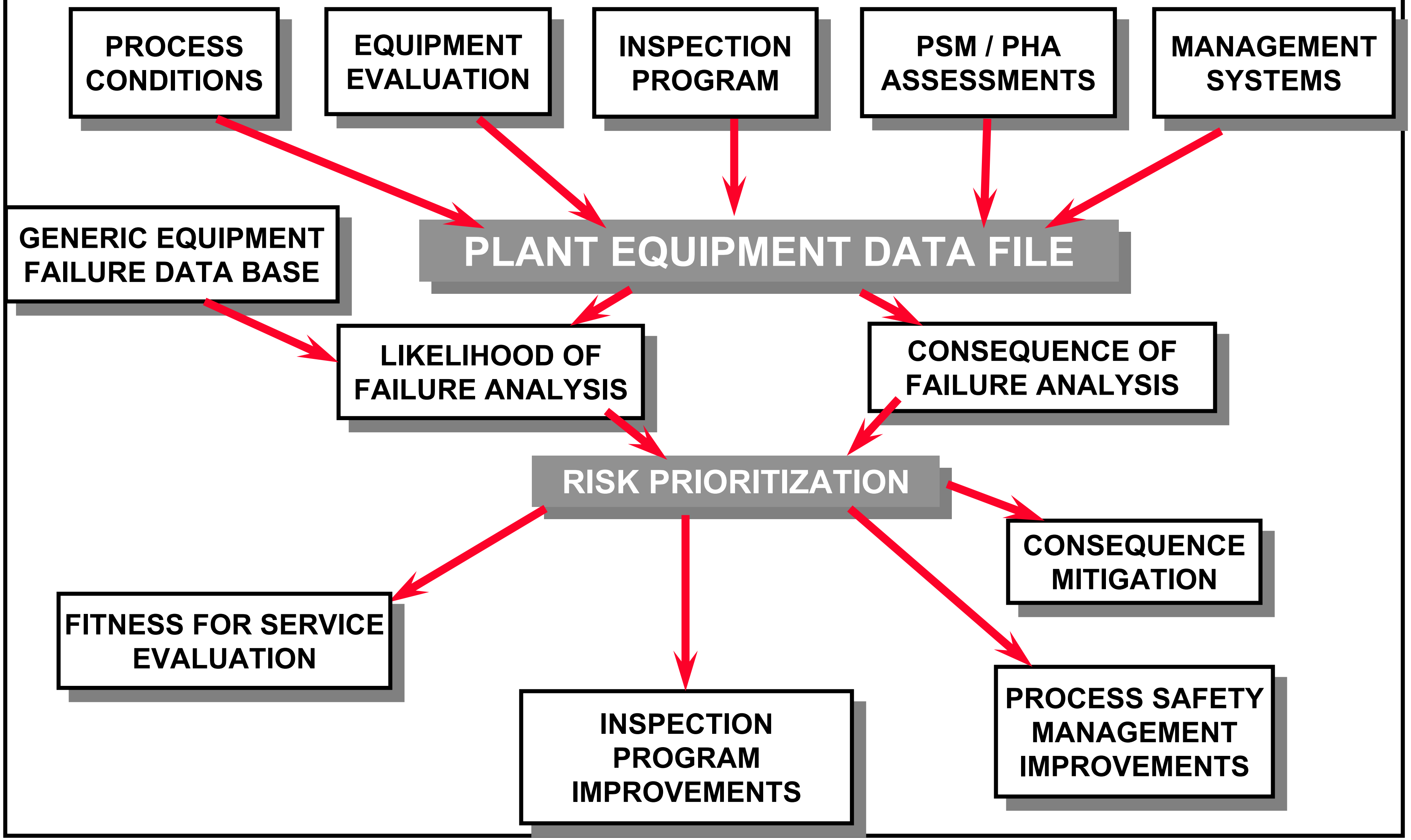


Risk is Relative:

"For the risk calculations associated with risk centered maintenance, accuracy is not as important as consistency.."

Jones, R.B., *Risk-Based Management, A Reliability-Centered Approach*

Quantitative Risk Based Inspection



Overview of API 580

<u>Part 2</u>

API RP Development Group

- Group Composition (1997-2002)
  - Owner/User representatives from 22+ refining, chemical and exploration companies
  - International representation
  - Disciplines represented:
    - Mechanical engineers
    - Materials/Corrosion engineers
    - NDE specialists
    - Inspection program and MI responsible professionals
  - Consultants
    - Consequence modeling expertise
    - Materials/Corrosion engineers
    - NDE specialists
    - MI expertise

Overview of API 580

Contents

- **Foreword**
- **Section 1 – Introduction, Purpose and Scope**
- Section 2 - References
- Section 3 – Definitions and Acronyms
- **Section 4 – Basic Concepts**
- **Section 5 – Introduction to Risk Based Inspection**
- **Section 6 – Planning the RBI Assessment**
- **Section 7 – Data and Information Collection for RBI Assessment**

Overview of API 580

Contents

- Section 8 – Identifying Deterioration Mechanisms and Failure Modes
- Section 9 – Assessing Probability of Failure
- Section 10 - Assessing Consequence of Failure
- Section 11 – Risk Determination, Assessment and Management
- Section 12 – Risk Management with Inspection Activities

Overview of API 580

Contents

- Section 13 – Other Risk Mitigation Activities
- **Section 14 – Reassessment and Updating RBI Assessments**
- **Section 15 – Roles, Responsibilities, Training and Qualifications**
- **Section 16 – RBI Documentation and Record Keeping**
- Appendix A – Deterioration Mechanisms

API RP 580 Foreword

- The assessment must:
  - **Systematically** evaluate **both** the probability of failure and the associated consequence of failure
  - The probability of failure assessment must be based on all forms of deterioration that could reasonably be expected to affect the piece of equipment in the particular service.
  - Refer to respective codes for specific requirements
  - **API RP 580 is a guide for users in properly performing such a RBI assessment**

Planning the RBI Assessment

- Clear Objectives and Goals must be defined and understood by the RBI Team and Management.
- The Goals should include:
  - A clear understanding of risk
  - A defined Risk Criteria
  - A plan to manage risk
  - Defined desired results, i.e. safety or environmental and/or cost impact

Planning the RBI Assessment

Considerations for Project Initiation:

- Establish Operating Boundaries
- Consider Start-up, Shut-down, Normal, Upset and Cyclic Operations
- Define Operating Time Period for consideration
- Determine Time and Resources Needed for the Study

Regulatory Response

- Few public or written endorsements
- Overall positive
  - Appreciate the systematic approach
  - Appreciate reproducibility
  - Appreciate depth of technology
  - US, Canada, and some others

API RP 580 Foreword

- Intended to provide guidance and includes:
  - What RBI is
  - What are the key elements of RBI
  - How to implement an RBI program
- Not intended to
  - supplant other practices that have proven satisfactory
  - discourage innovation and originality in the inspection of hydrocarbon and chemical facilities
  - substitute for the judgement of a responsible, qualified inspector or engineer
  - substitute for code of rules, regulations, or minimum safe practices

API RP 580 Foreword

- A supplement to API Codes and Standards
  - API 510 Pressure Vessel Inspection Code
  - API 570 Piping Inspection Code
  - API 653 Tank Inspection, Repair, Alteration and Reconstruction
- The Codes and Standards provide the latitude to:
  - Plan an inspection strategy
  - Increase or decrease the code designated inspection frequencies based on the results of a RBI assessment.

API RP 580 Foreword

- The assessment must:
  - **<u>Systematically</u>** evaluate **<u>both</u>** the probability of failure and the associated consequence of failure
  - The probability of failure assessment must be based on all forms of deterioration that could reasonably be expected to affect the piece of equipment in the particular service.
  - Refer to respective codes for specific requirements
  - **API RP 580 is a guide for users in properly performing such a RBI assessment**

Introduction, Purpose and Scope

- The purpose of API RP 580 is to provide users with the basic elements for developing and implementing a Risk Based Inspection (RBI) program.
- An introduction to the concepts and principles of risk based inspection for risk management
- Expected outcome should be linkage of risks with appropriate inspection or other risk mitigation activities to manage risk

Introduction, Purpose and Scope

- Key Elements of the RP:
  - a) Management systems for maintaining documentation, personnel qualifications, data requirements and analysis updates.
  - b) Documented method for probability of failure determination.
  - c) Documented method for consequence of failure determination.
  - d) Documented methodology for managing risk through inspection and other mitigation activities.

Introduction, Purpose and Scope

- RBI will not compensate for:
  - Inaccurate or missing information
  - Inadequate designs or faulty equipment installation
  - Operating outside the acceptable design envelope
  - Not effectively executing the plans
  - Lack of qualified personnel or teamwork
  - Lack of sound engineering or operational judgment

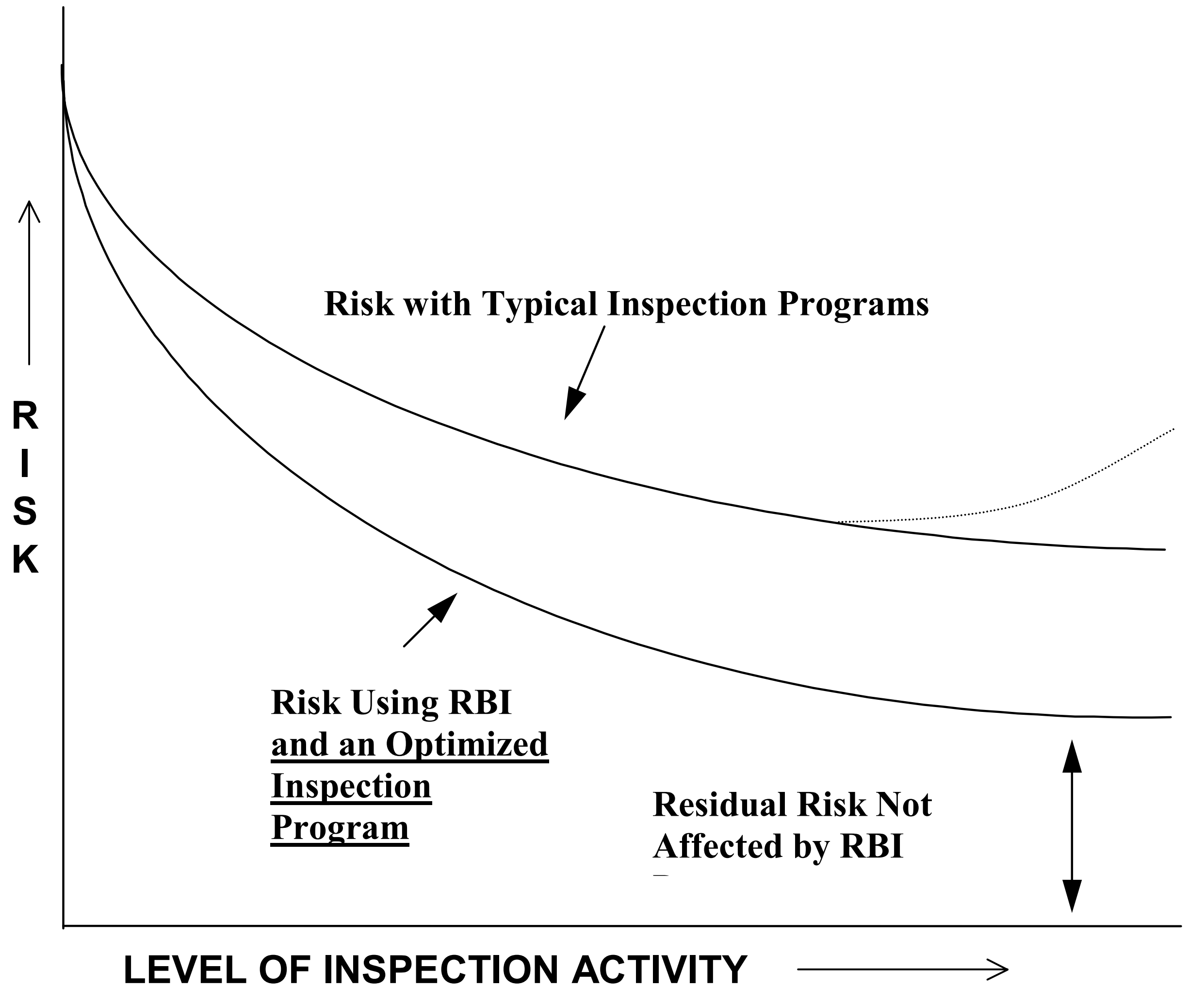
Basic Concepts

- Risk is something we live with each day

Risk = Probability x Consequence

- Risk reduction is only a part of risk management. It is a process to:
  - Assess risks
  - Determine if risk reduction is required
  - Develop a plan to maintain risks at an acceptable level

Basic Concepts



Basic Concepts

- Relative vs. Absolute Risk
  - Absolute risk is time consuming and difficult to determine due to uncertainties
  - RBI is focused on the systematic determination of relative risk
  - Serves as a focus of risk management efforts
  - Numeric risk values determined in quantitative assessments use appropriate sensitivity analysis methods

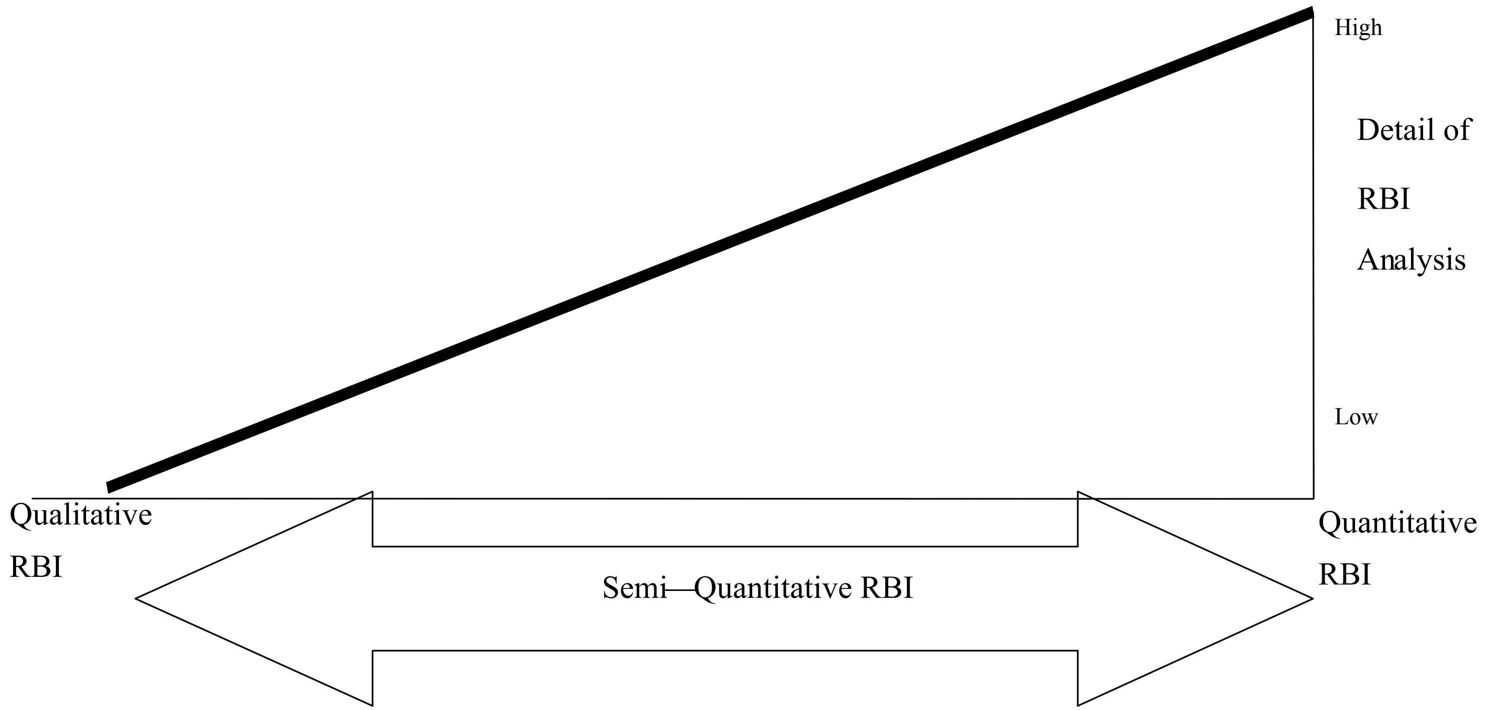
Introduction to Risk Based Inspection

- Traditional Focus on Likelihood
- **Probability x Consequence = Risk**
  - Multiple probable events/consequences considered
  - Various consequence factors
  - Risk expressed in various terms

Introduction to Risk Based Inspection

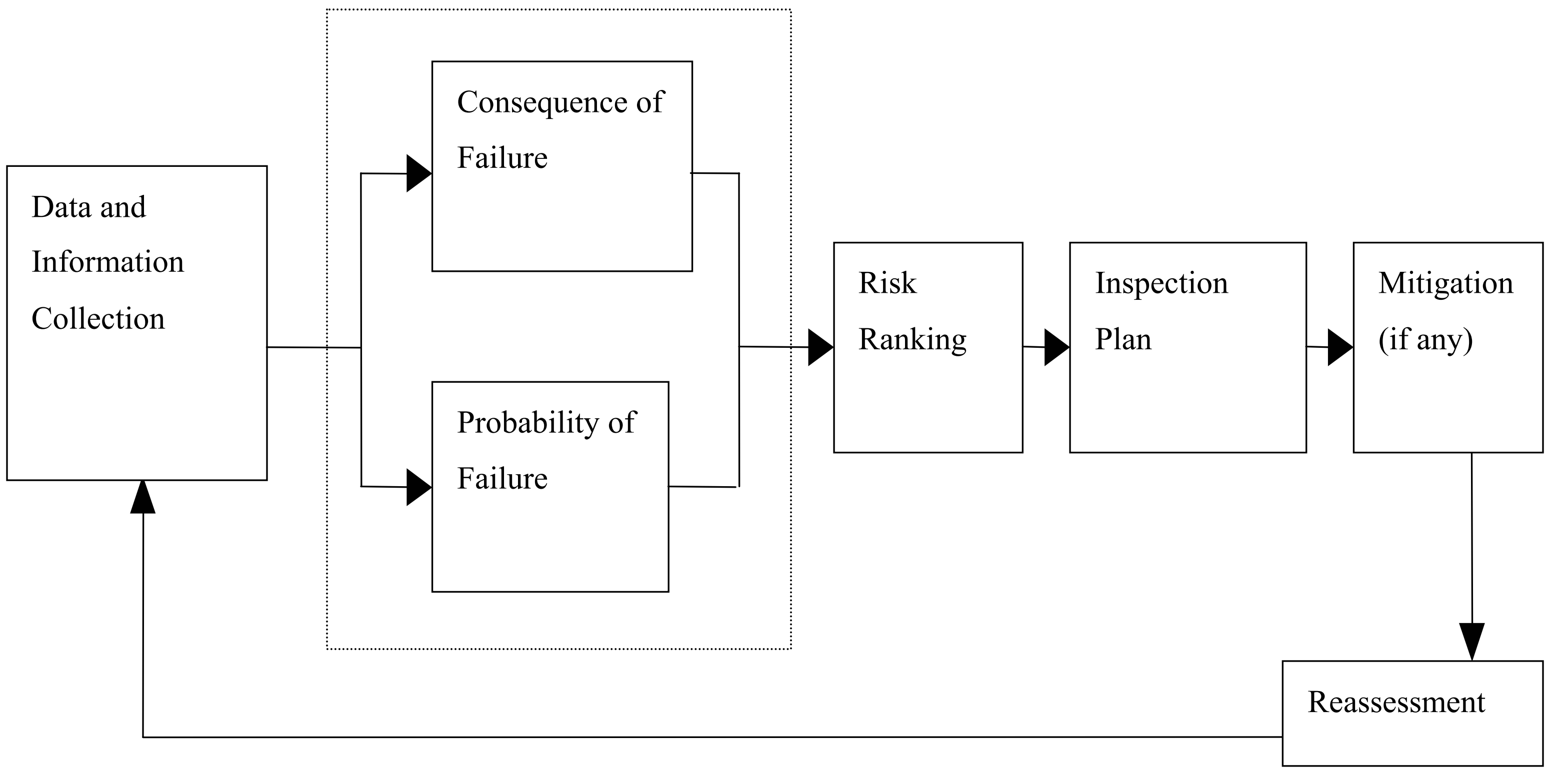
- Types of Assessment
  - Qualitative – uses engineering judgment and experience
  - Quantitative – uses logic models and evaluated probabilistically
  - Semi-quantitative
- Continuum of Approaches

Introduction to Risk Based Inspection



Introduction to Risk Based Inspection

Risk Assessment Process



Introduction to Risk Based Inspection

- Risk associated with equipment is influenced by current operating conditions, such as:
  - Process fluid or contaminants and aggressive components
  - Unit throughput
  - Desired unit run length between scheduled shutdowns
  - Operating conditions, including upset conditions: e.g. pressures, temperatures, flow rates, pressure and/or temperature cycling

Introduction to Risk Based Inspection

- Risk Management Through Inspection
  - Probability of failure
    - Deterioration type and mechanism
    - Rate of deterioration
    - Probability of identifying and detecting deterioration and predicting future deterioration states with inspection technique(s)
    - Tolerance of the equipment to the type of deterioration

Introduction to Risk Based Inspection

- **Using RBI to Establish Inspection Plans and Priorities**
  - Primary output is inspection plan
  - Risk ranking
  - Mitigation plans

Planning the RBI Assessment

- Clear Objectives and Goals must be defined and understood by the RBI Team and Management.
- The Goals should include:
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  – A defined Risk Criteria
  – A plan to manage risk
  – Defined desired results, i.e. safety or environmental and/or cost impact

Planning the RBI Assessment

Considerations for Project Initiation:

- Establish Operating Boundaries
- Consider Start-up, Shut-down, Normal, Upset and Cyclic Operations
- Define Operating Time Period for consideration
- Determine Time and Resources Needed for the Study

Planning the RBI Assessment

- Consider Mitigation Alternatives
  - Examples are remove unnecessary insulation or upgrade safety systems
- RBI of New Plant design
- End of Life Strategies
  - Focus inspection to predict actual failure time
  - May incorporate Fitness for Service evaluations for more quantitative analysis per API 579 as part of the strategy

Data and Information Collection for RBI

- General Data Required
  - Type of equipment
  - Materials of construction
  - Inspection, repair and replacement records
  - Process fluid compositions
  - Inventory of fluids
  - Operating conditions
  - Safety systems
  - Detection systems
  - Deterioration mechanisms, rates and severity
  - Personnel densities
  - Coating, cladding and insulation data
  - Business interruption cost
  - Equipment replacement costs
  - Environmental remediation costs

Data and Information Collection for RBI

Qualitative Study Needs:

- Rule Sets
  - Consistency is critical
- Ranges versus Discreet Values
- Higher Skill and Knowledge Levels in RBI Team
  - Must understand data sensitivities

Data and Information Collection for RBI

Quantitative Study Needs

- More Detailed Information Needed
  - Uses logic models
  - Depicts consequence scenarios
  - Calculates probabilities of events
- Models evaluated probabilistically
  - provide qualitative and quantitative insights
    - Level of risk
    - Identify the design, site, or operational characteristics that are the most important to risk

Data and Information Collection for RBI

- Data Quality
  - Good quality data is critical to the relative accuracy of an RBI study
  - Validation step is required to review data for errors
  - Experienced personnel are needed for this step
- The Codes & Standards specify data required to conduct an RBI study
- Many other Sources of information exist in an operating facility

Identifying Deterioration Mechanisms and Failure Modes

- Leads to Loss of Containment
- Critical to Success
  - Role of Corrosion/Materials engineer review
  - Understanding NDE and Damage Mechanisms
  - Impact of operating conditions
    - Normal, upset, start-up, shutdown, etc.
  - Understanding operation vs Chemical and Mechanical deterioration mechanism identification key to success

Identifying Deterioration Mechanisms and Failure Modes

- Categorized into Four (4) Types of Damage
  - Thinning (includes internal and external)
  - Stress Corrosion Cracking
  - Metallurgical and Environmental
  - Mechanical
- Refer to Appendix A in RP 580 for summary of damage causes
- API 571 development is in progress and will provide more detailed guidance in the future

Identifying Deterioration Mechanisms and Failure Modes

- Possible Other Equipment Failures and Modes
  - Pressure relief device failure – plugging, fouling, non-activation
  - Heat exchanger bundle failure – tube leak, plugging
  - Pump failure – seal failure, motor failure, rotating parts damage
  - Internal linings – hole, disbondment

Assessing Probability of Failure

- Probability of a specific adverse consequence
  - From a loss of containment due to a deterioration mechanism(s)
  - POF x Probability of scenario = Probability of specific consequence
  - Should address all possible failure mechanisms
  - Should address multiple mechanisms considering conditions
  - Must be credible, repeatable, well-documented
  - Units of measure should include frequency, quantitative or qualitative

Assessing Probability of Failure

- Should consider
  - Deterioration mechanisms
    - Potential, reasonably expected
    - Susceptibility and rate
  - Inspection effectiveness
    - Quantify the effectiveness of the past inspection and maintenance program and a proposed future inspection and maintenance program.
    - Determine the probability that with the current condition, continued deterioration at the predicted/expected rate will exceed the damage tolerance of the equipment and result in a failure.
    - The failure mode (e.g. small leak, large leak, equipment rupture) should also be determined based on the deterioration mechanism.
    - Determine the probability of more than one failure mode and combine the risks.

Assessing Consequences of Failure

- Discriminate items based on the significance of a potential failure
  - Loss of containment
    - Safety and health impact
    - Environmental impact
    - Production losses
    - Maintenance and reconstruction costs
  - Other functional failures can be included
- Units of Measure
  - Safety, cost, affected area, environmental, volume of fluid released, etc.

Risk Management with Inspection Activities

- RBI is reducing uncertainty through inspection
- Identifying Risk Management Opportunities from RBI and Probability of Failure Results
  - Identify the risk driver
  - Inspection opportunities through POF
- Establishing an Inspection Strategy Based on Risk Assessment
  - Mode of failure of the deterioration mechanism
  - Time interval between the onset of deterioration and failure, i.e. speed of deterioration
  - Detection capability of inspection technique
  - Scope of inspection
  - Frequency of inspection

Risk Management with Inspection Activities

- Managing Risk with Inspection Activities
  - Quantify current risk based on inspection results and past effectiveness (eg. Frequency, coverage, tools, internal/external inspections)
  - Use RBI to determine future risk based on various inspection options (What-If)
- Managing Inspection Costs – risk reduction/$
- Assessing Inspection Results and Determining Corrective Action
- Achieving Lowest Life Cycle Costs

Roles, Responsibilities, Training and Qualifications

- **Team Leader**
  - Full time, stakeholder
- **Equipment Inspector or Inspection Specialist**
  - Data gathering
  - Inspection effectiveness translation
  - Implementing the inspection plan
- **Materials and Corrosion Specialist**
- **Process Specialist**
- **Operations and Maintenance Personnel**

Roles, Responsibilities, Training and Qualifications

- Training
  - Leaders
    - Thorough understanding risk analysis and of the methodology via training, experience or education
  - Support staff
    - Basic RBI methodology training
      - Effective implementation
- Document Qualifications and Training
  - Procedure to document qualifications and training of practitioners

Documentation and Record Keeping

- Fully Document the Assessment
  - Type of assessment
  - Team members performing the assessment
  - Timeframe over which the assessment is applicable
  - The inputs and sources used to determine risk
  - Assumptions made during the assessment
  - The risk assessment results (including information on probability and consequence)
  - Follow-up mitigation strategy, if applicable, to manage risk
  - The mitigated risk levels (i.e. residual risk after mitigation is implemented)
  - References to codes or standards that have jurisdiction over extent or frequency of inspection

Documentation and Record Keeping

- Sufficient to:
  - Recreate the assessment if needed
  - Update the assessment

By those not involved in the original assessment!

The RBI Working Process

Part 3

RBI Work Process Steps

1. **Define the Scope**
2. Establish the Team
3. Create an Equipment List
4. Collect General Equipment Data
5. Collect Consequence Data
6. Collect Likelihood/Inspection Data
7. Develop an Inspection Plan and Risk Benefit

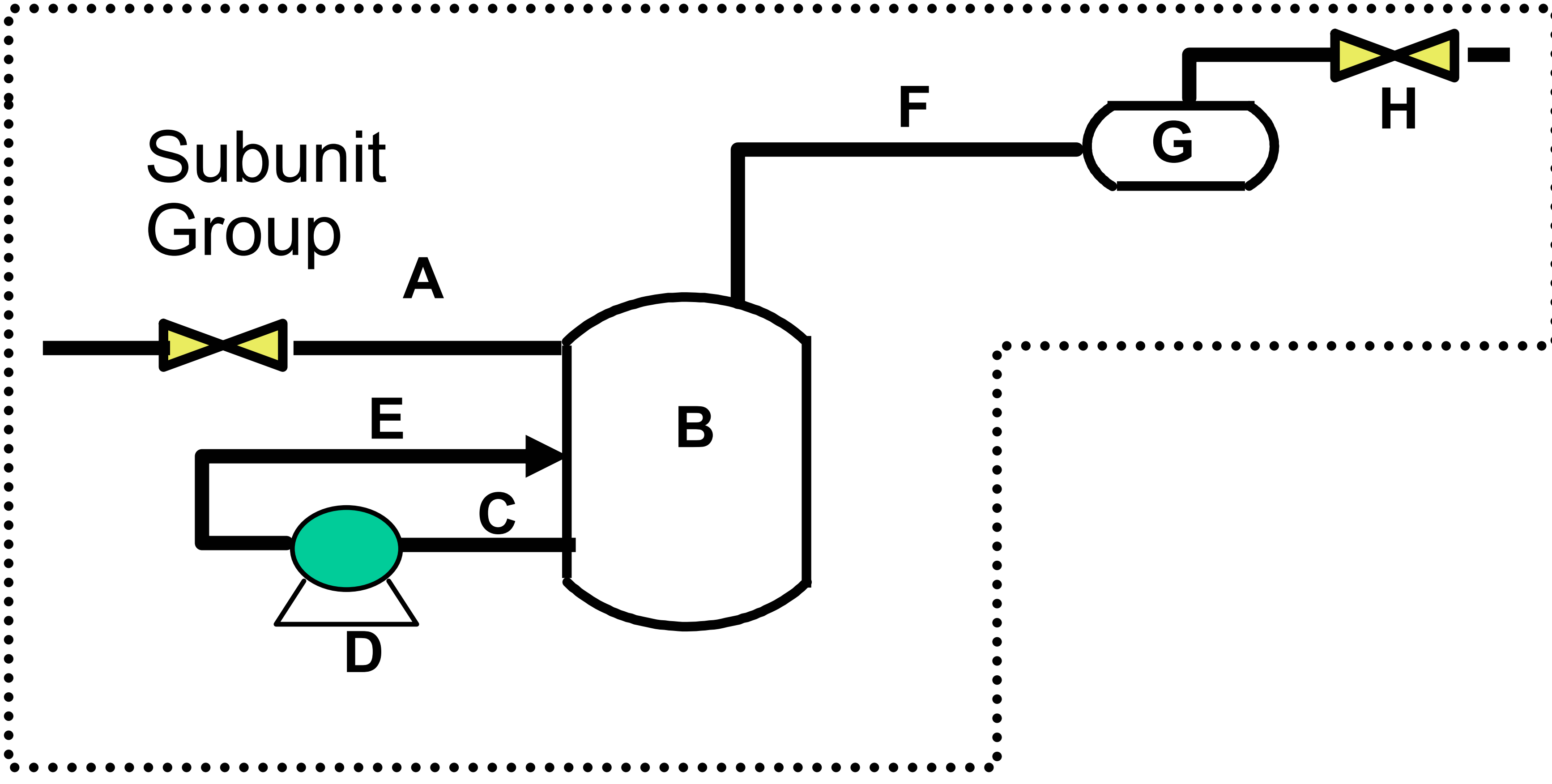
Step 1 - Define Scope

- Define, in the system, physical and operational boundaries.
- Do not break the system in the middle of an isolatable group.
  - Isolatable group is a group of equipment where inventory can be isolated by remotely operated valves.
  - Manual adjustment/estimate to inventory is required for individual equipment items for study

RBI Covers

- Reactors
- Pressure Vessels
- Piping
- Furnaces
- Pumps
- Compressors
- Heat Exchangers
- Storage Tanks

Defining the Equipment Included in the RBI Study



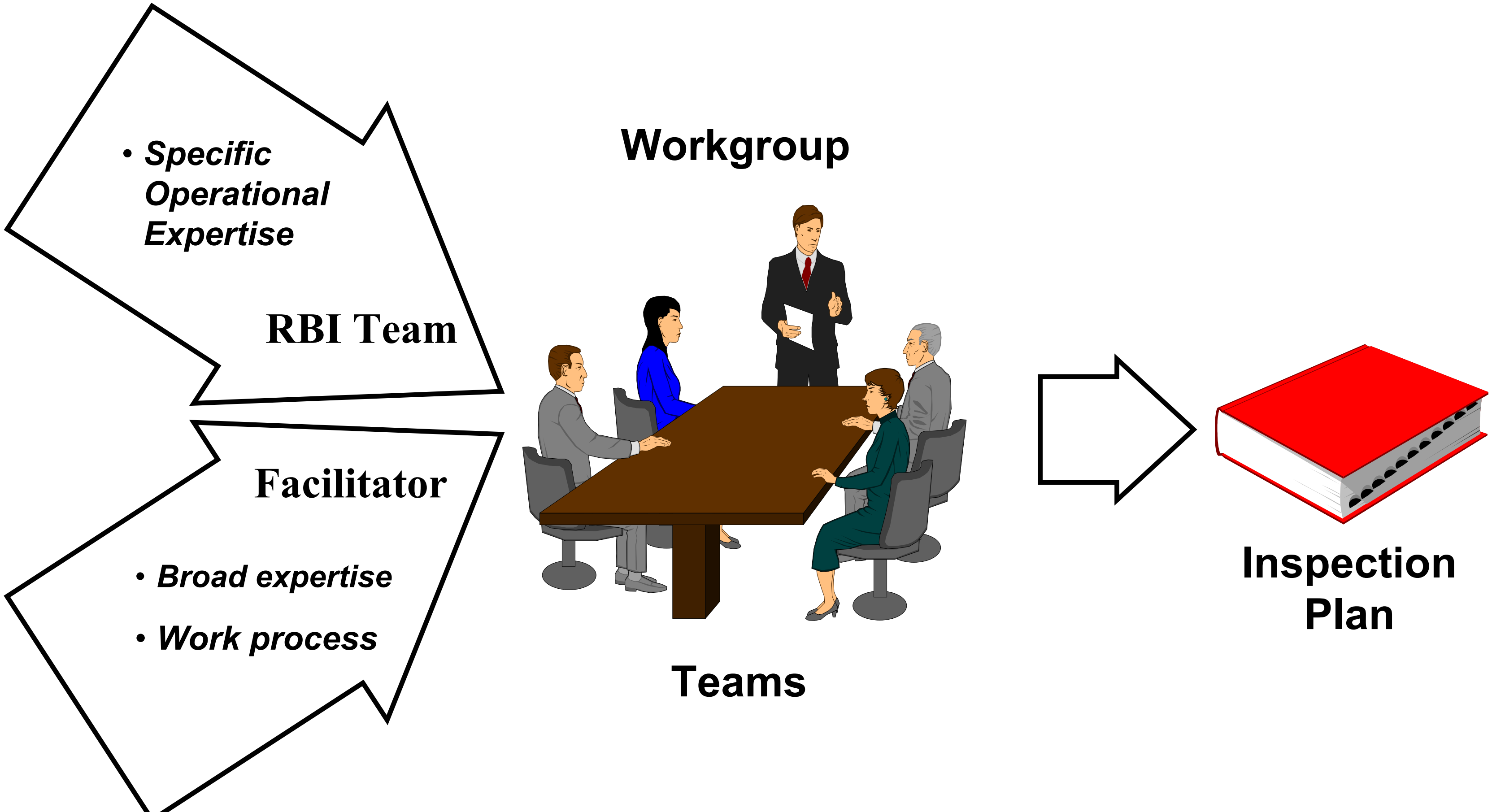
RBI Work Process Steps

1. Define the Scope
2. **Establish the Team**
3. Create an Equipment List
4. Collect General Equipment Data
5. Collect Consequence Data
6. Collect Likelihood/Inspection Data
7. Develop an Inspection Plan and Risk Benefit

Step 2 - Establish the RBI Team

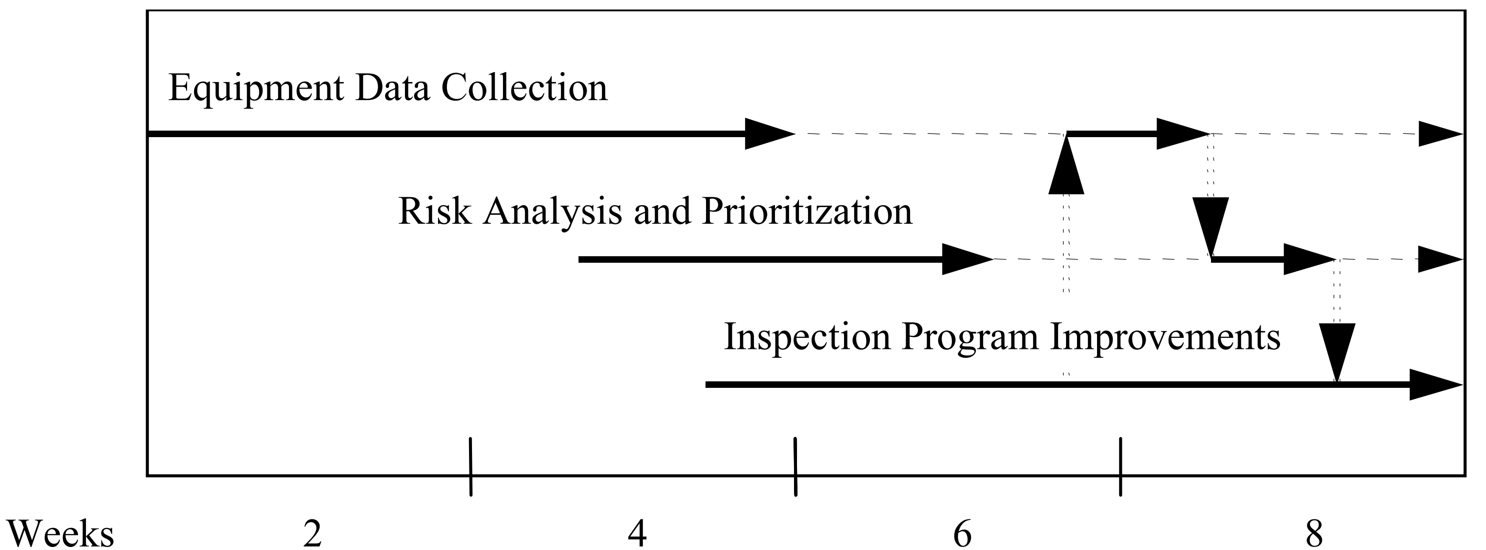
- Facilitator/ Project Manager
- Personnel with the following expertise:
  - Inspector
  - Metallurgy/Corrosion Engineer
  - Mechanical/Reliability Engineer
  - Process Engineer
  - Process Hazards
- Team can be a combination of plant and consulting expertise.

Inspection Management
RBI Work Process



RBI Schedule & Milestones

- The project manager must develop a timeline and outline the requirements for the study.
  - Typically, a three (3) month timeline is the minimum



RBI Time Frames & Schedules

- An RBI project can be easily divided into these main stages.
  - First Stage – data gathering and entry
  - Second Stage –interpreting results, performing checks and validation of data and assumptions.
  - Third Stage – prioritizing risks and inspection planning development

RBI Work Process Steps

1. Define the Scope
2. Establish the Team
3. **Create an Equipment List**
4. Collect General Equipment Data
5. Collect Consequence Data
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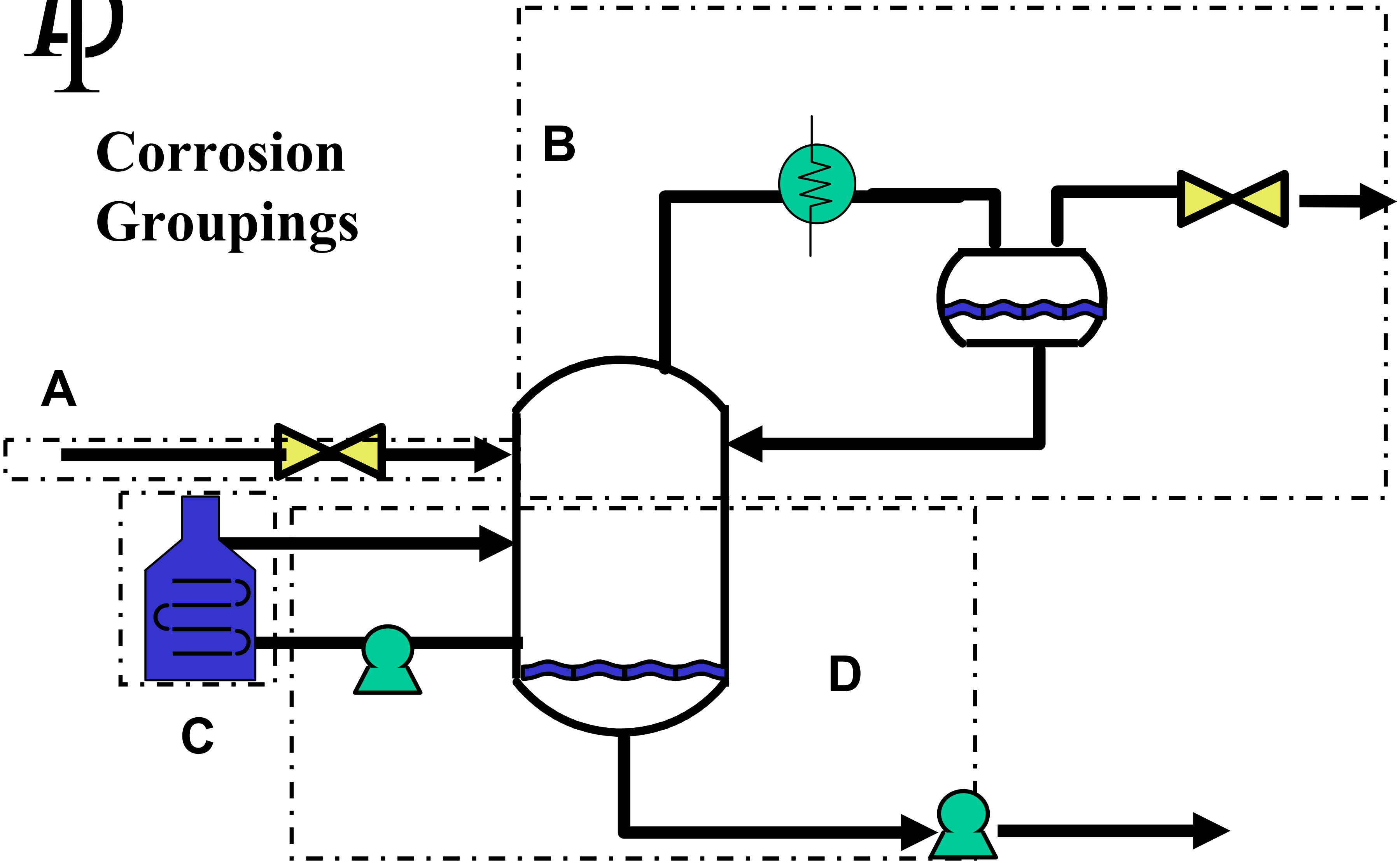
Step 3 - Create an Equipment List to be Included in the Study

- List equipment in unit by operating areas
  - Group equipment logically in corrosion groups by equipment in similar service
- Use a spreadsheet (Access of Excel)
- Identify the following:
  - Equipment ID
  - Equipment Description
  - Equipment Type

➭ This process familiarizes the team with the unit of study

Corrosion Groupings



Hints for a Successful Study

- Start by using a group facilitated approach
- Use simplified process flow diagrams
- Get people knowledgeable about the unit involved
- Group equipment logically, i.e. corrosion groups
- Use a spreadsheet format for data gathering
- Use existing electronic information whenever possible
- **And…..**

- ***Make conservative assumptions and Document them.***

  – Evaluate preliminary results and risk ranking
  – Identify variables driving risk
  – Update/Improve data, as necessary

RBI Work Process Steps

1. Define the Scope
2. Establish the Team
3. Create an Equipment List
4. **Collect General Equipment Data**
5. Collect Consequence Data
6. Collect Likelihood/Inspection Data
7. Develop an Inspection Plan and Risk Benefit

Step 4 - Collect General Data

- ✓ Unique Equipment ID
- ✓ Equipment Type
- ✓ Unit
- Material of Construction
- Service Start Date
- Operating Temperature
- Operating Pressure
- *Design Temperature*
- *Design Pressure*
- Diameter
- Length

RBI Work Process Steps

1. Define the Scope
2. Establish the Team
3. Create an Equipment List
4. Collect General Equipment Data
5. **Collect Consequence Data**
6. Collect Likelihood/Inspection Data
7. Develop an Inspection Plan and Risk Benefit

Step 5 - Collect Consequence Data

- Process stream characteristics (fluid characteristics representing behavior)
- Fluid phase (inside equipment)
- Toxic component of process stream
- Toxic concentration (typically % of total process stream composition)
- Inventory – calculated by program based on equipment dimensions and fluid density
- Detection, Isolation and Mitigation Systems

RBI Work Process Steps

1. Define the Scope
2. Establish the Team
3. Create an Equipment List
4. Collect General Equipment Data
5. Collect Consequence Data
6. **Collect Likelihood/Inspection Data**
7. Develop an Inspection Plan and Risk Benefit

Step 6 - Collect Likelihood Data

- Material of Construction
- Lining, if applicable
- Insulation (Y/N)
- Susceptibility Damage Mechanisms
- Expected Damage (rate or severity)
- *Concentration of contaminants*

Likelihood Data - Thinning

- Identify known in-service damage mechanisms
- Identify if General or Localized behavior of thinning corrosion (localized will affect < 10% of surface area)
- Measure and/or Estimate thinning rates
- **Service Start Date and Date of in current service**
- **Furnished Thickness**
- *Corrosion allowance*
- *On-line monitoring*

Determining Corrosion Rates

- Identify corrosion groups
  - Defined as same active damage mechanism and severity
- Determine damage rate based on:
  - Estimated - Solicit expert advice
  - Measured – From inspection history or equipment in similar service
  - Calculated - determine estimates from technical modules

*Rates for RBI generally range from 0 to 25 mpy

Likelihood Data - Cracking

- Identify known cracking mechanisms
- Susceptibility to cracking
  - Estimated - Solicit expert advice
  - Detected - Cracking history in this or equipment in similar service
  - Calculated - Determine estimates from other sources
- *On-line Monitoring*

Step 6 - Inspection Data

- Summarize inspection history from records
- **Enter date of inspection and inspection results by mechanism (e.g. thickness for thinning)**
- Grade effectiveness from Inspection Effectiveness Tables
- Start reviewing history with most recent inspection (most reliable information)
- Refer to Inspection Effectiveness tables for guidance

Effectiveness Categories

Effectiveness Category	Category Description
Highly Effective	Inspection methods correctly identify the anticipated in-service damage in nearly every case.
Usually Effective	The inspection methods will correctly identify the true damage state most of the time.
Fairly Effective	The inspection methods will correctly identify the true damage state about half of the time.
Poorly Effective	The inspection methods will provide little information to correctly identify the true damage state.
Ineffective	The inspection methods will provide almost no information that will correctly identify the true damage state.

The inspection effectiveness depends on the active mechanism. It is most effective if the active mechanisms are identified before determining the inspection effectiveness.

RBI Work Process Steps

1. Define the Scope
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RBI Work Process Steps

1. Define the Scope
2. Establish the Team
3. Create an Equipment List
4. Collect General Equipment Data
5. Collect Consequence Data
6. Collect Likelihood/Inspection Data
7. **Develop an Inspection Plan**

Step 7 – Inspection Planning

- Review damage types/mechanisms requiring inspection
- High Likelihood is reduced by activities capable of finding damage for corrective action before failure.
  - Review Inspection History and Effectiveness
  - Review CUI considerations
  - Investigate on-line monitoring activities, as appropriate.
  - Eliminate activities that are ineffective
  - Eliminate activities performed on low risk items
- Develop Plan and Financial Justification (Cost/Benefit)

Inspection Plan Summary Example

Description	Damage Mechanisms	Risk Ranking	Inspection Level	New Risk Ranking
4" Pipe from Overhead Knockout pump to Crude Column	Localized Thinning, CUI	5D	Highly Effective Inspection	4D
Overhead Knockout drum	Localized Thinning, HIC/SOHIC	3D	Usually Effective Inspection	2D
Air Cooler Inlet and Outlet Headers	Localized Thinning	4C	Usually Effective Inspection	3C
Crude Preheat piping (4", 6", 8" piping)	CUI	4C	Highly Effective Inspection	3C
Crude Column Feed piping (from Heater)	HT Sulfidation	2D* (5D if CS)	Positive Material Identification	2D

Cost Benefit Analysis Compare Traditional vs. RBI

- Inspection Costs and Risk Benefit
  - Effects of Plan Periods Changes
  - Effects of Non-intrusive Inspection vs. Intrusive
  - Inspection Technology Costs
  - Coverage or scope costs
  - Related Maintenance costs (big savings)
- Figures Reported in terms of Safety or Financial
  - Risk reduction in sq. ft./year/ite
  - Dollars/year/item
- Risk reduction per dollar spent

Application to Plant Special Emphasis Programs

- Corrosion Under Insulation
- Positive Materials Identification
- Corrosion Programs (HTHA, Wet H_2S, Chloride cracking, etc.)
- Increasing process operating envelopes
- Assess the risk and cost impact of process changes
- Opportunity Crudes
- Equipment in multiple services

Application to Other Programs

- Risk Based Approach Mechanical Integrity and PSM Programs
- Inspection Budget Optimization
- On-Stream Inspection Program
- Turn-around planning and scope optimization
- Plant Design/Revamp => Equipment Life Cycle Analysis

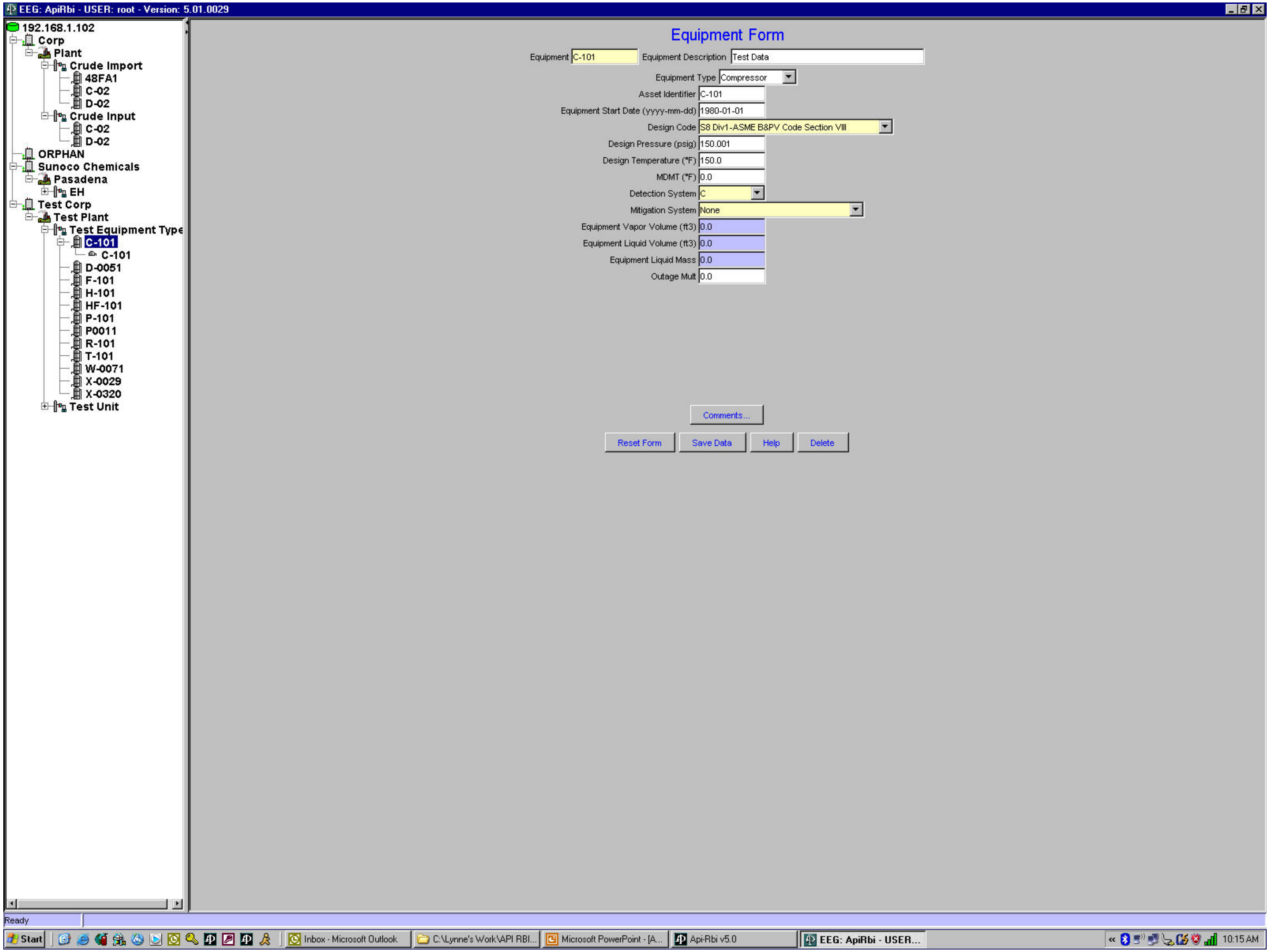
Version 5.01 Software Introduction

Part 4

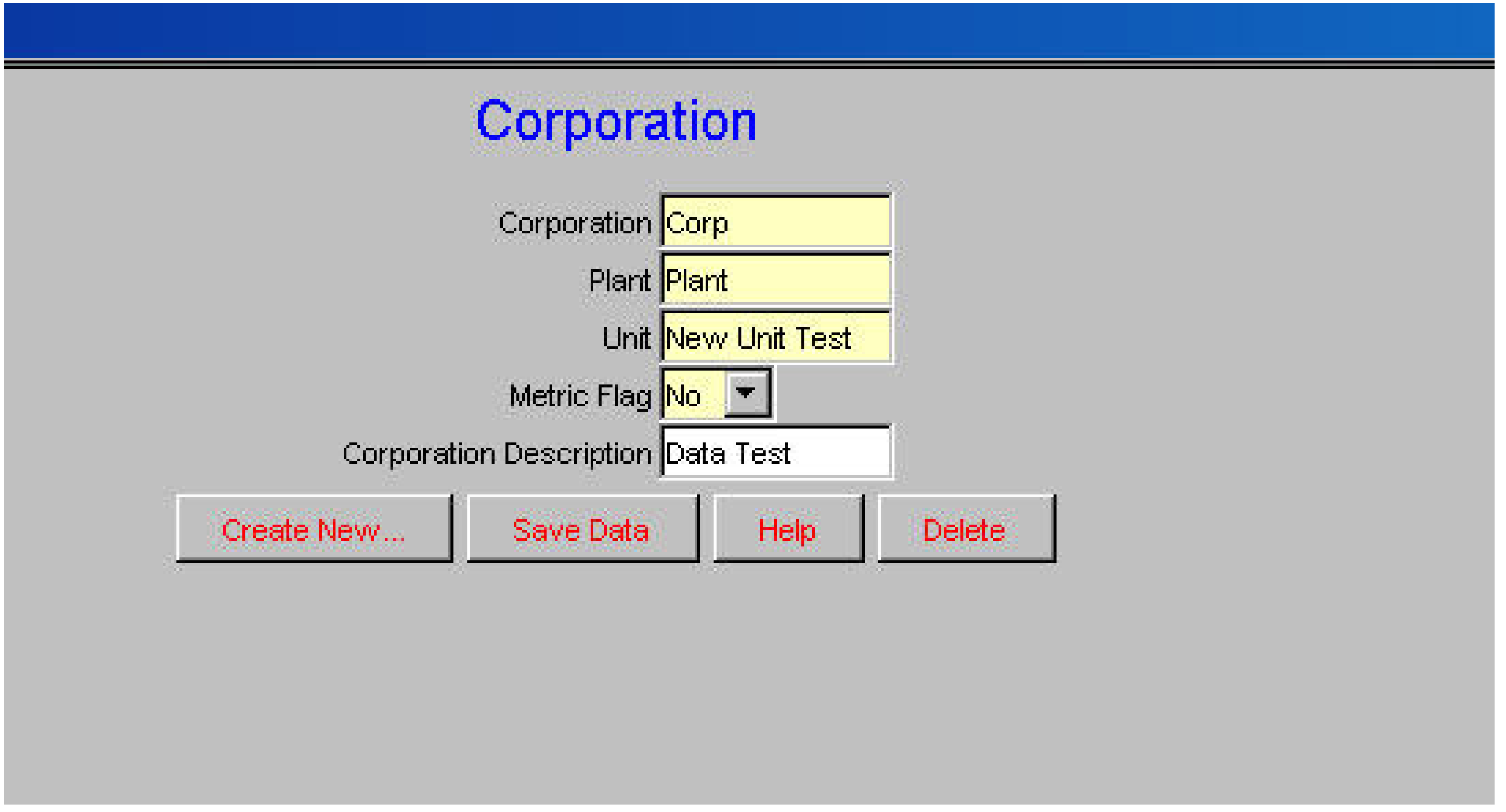
Highlight Differences

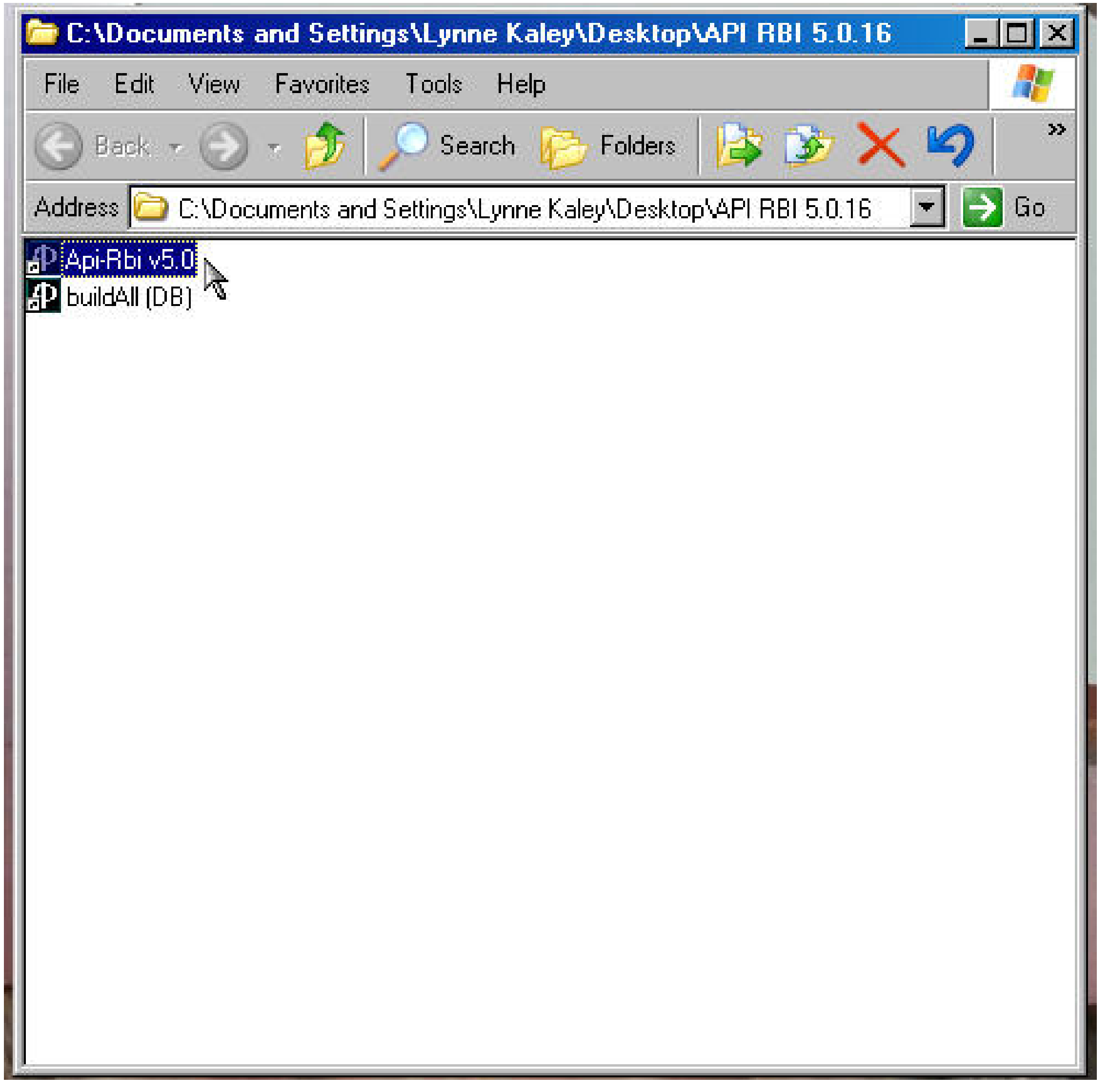
- J-Tree Navigation
- Corp-Plant-Unit Data entry
- Equipment/Component distinction
- Minor Calculation differences
- Data Entry differences

Version 5.0 J-Tree Navigation



Version 5.0 Corporation/Plant/Unit

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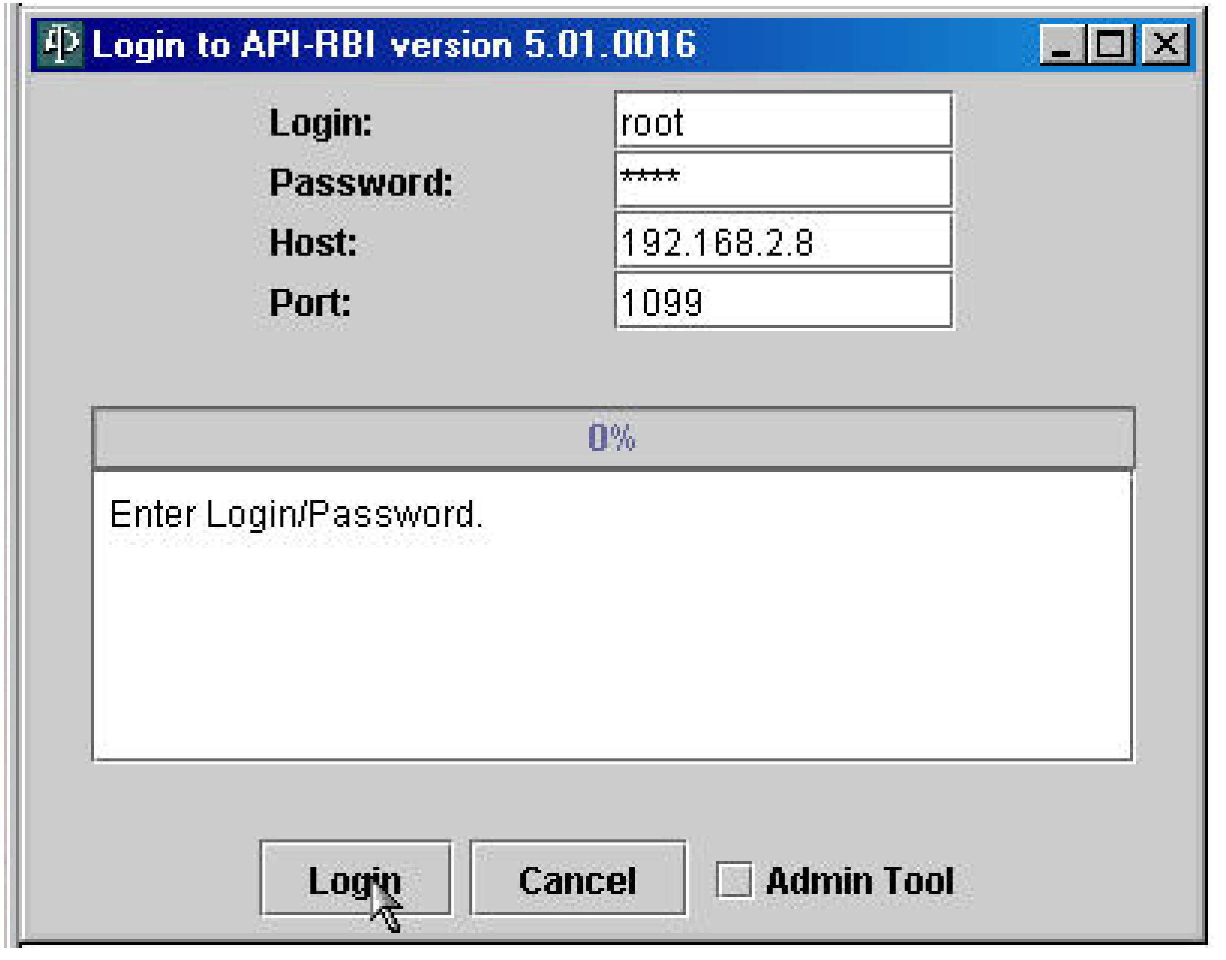
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root
Password:
****
Host:
192.168.2.8
Port:
1099
0%
Enter Login/Password.
Login
Cancel
Admin Tool

EEG: ApiRbi - USER: root - Version: 5.01.0029

- 192.168.1.102
  - Corp
  - ORPHAN
  - Sunoco Chemicals
  - Test Corp

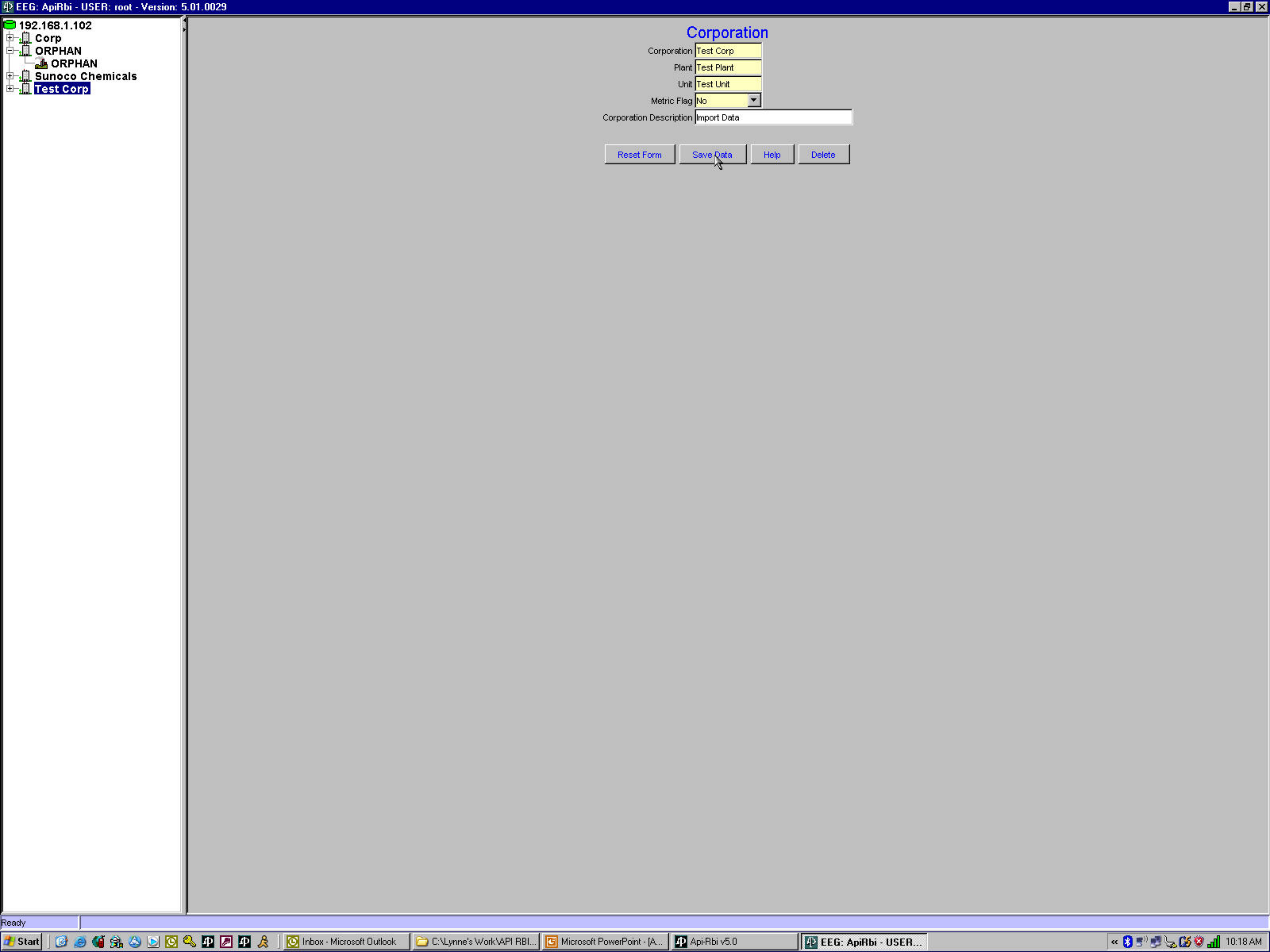
E2G The Equity Engineering Group, Inc.

American Petroleum Institute

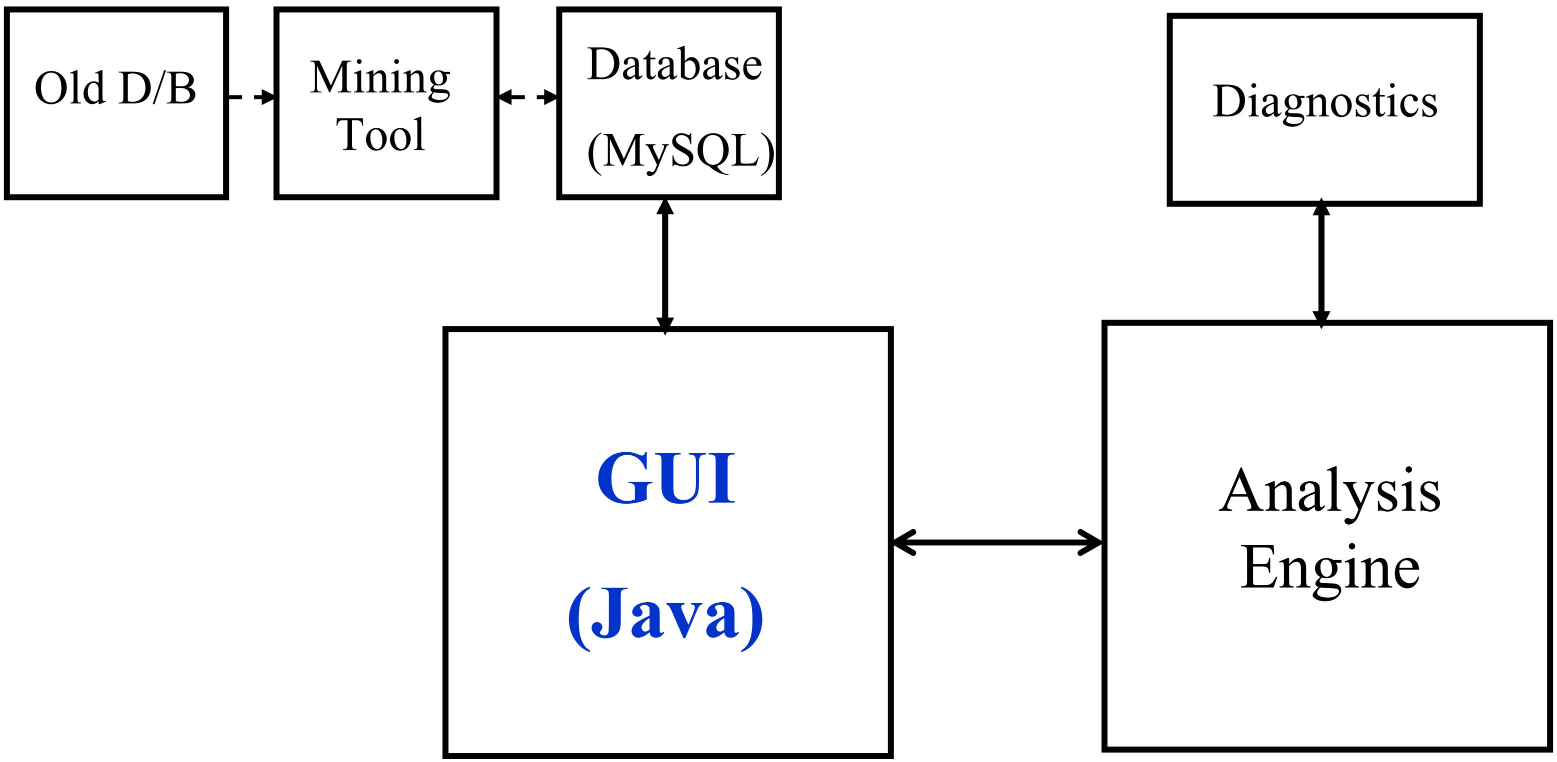
Version: 5.01.0029

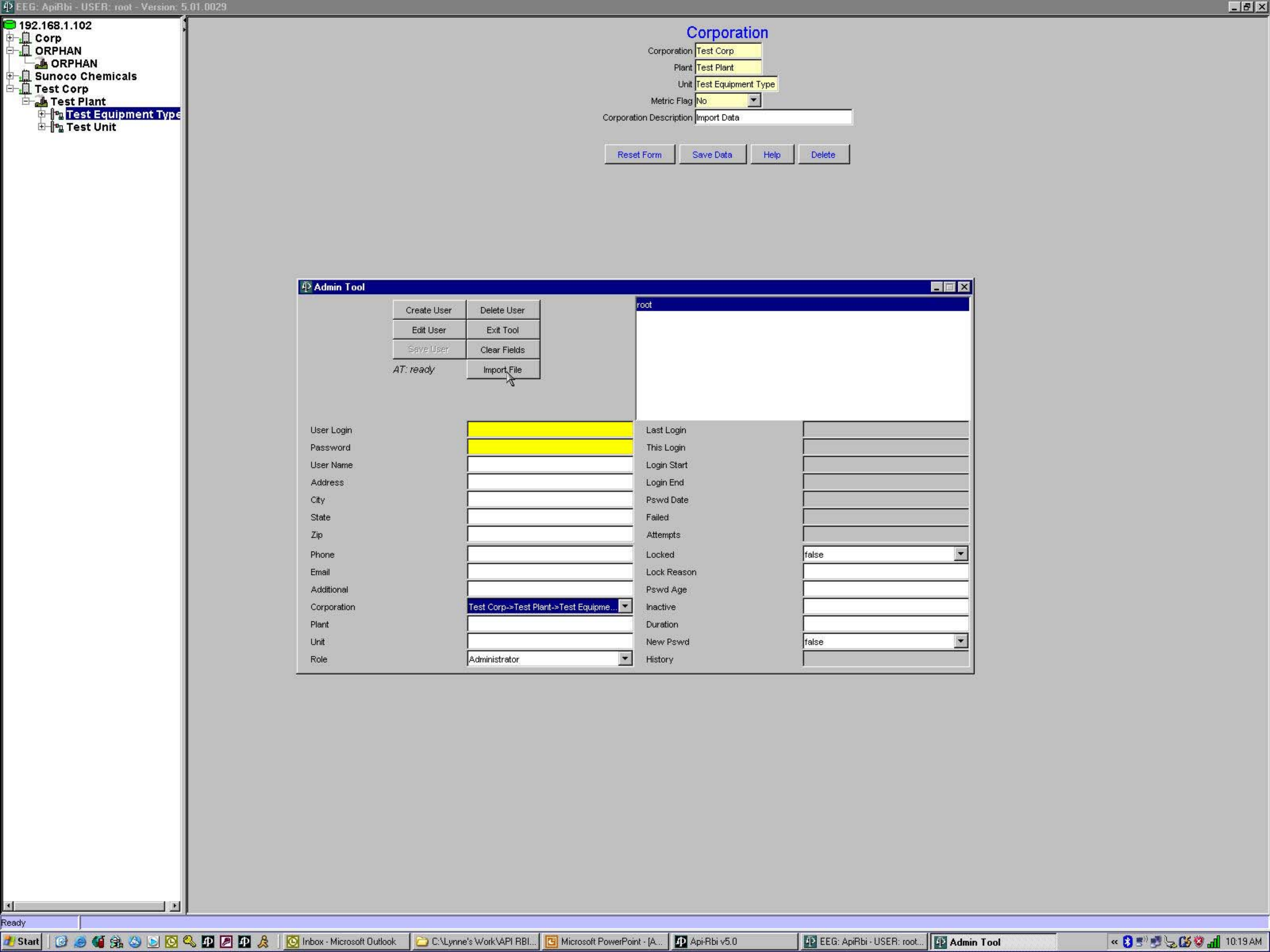
Ready

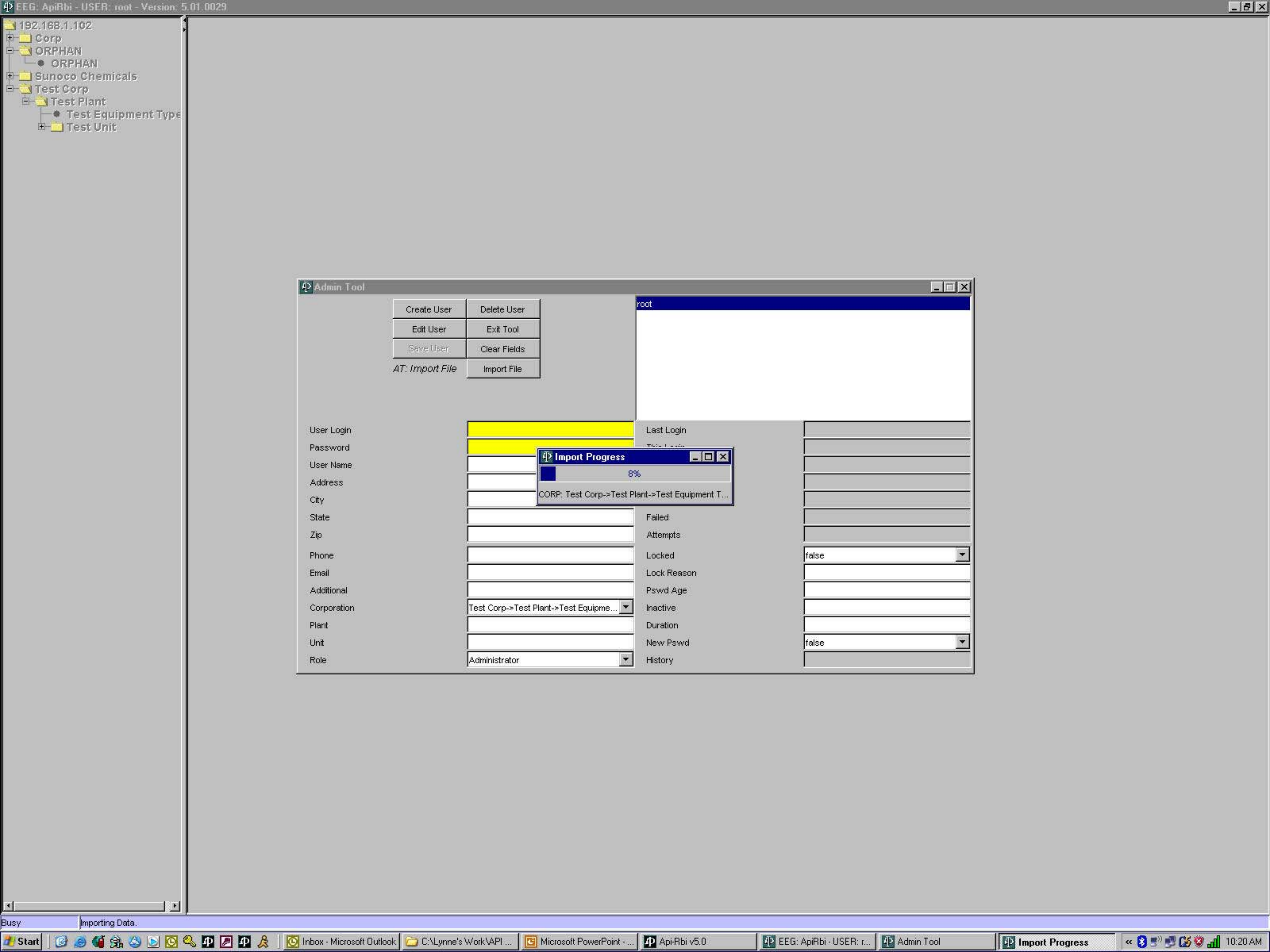
Start | Inbox - Microsoft Outlook | C:\Lynne's Work\API RBI... | Microsoft PowerPoint - [A... | Api-Rbi v5.0 | EEG: ApiRbi - USER... | 10:16 AM


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
ORPHAN
ORPHAN
Sunoco Chemicals
Test Corp
Corporation
Corporation
Test Corp
Plant
Test Plant
Unit
Test Unit
Metric Flag
No
Corporation Description
Import Data
Reset Form
Save Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
C:\Lynne's Work\API RBI...
Microsoft PowerPoint - [A...
Api-Rbi v5.0
EEG: ApiRbi - USER...
10:18 AM

Testing and Data Management




EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
ORPHAN
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
Test Unit
Corporation
Corporation Test Corp
Plant Test Plant
Unit Test Equipment Type
Metric Flag No
Corporation Description Import Data
Reset Form
Save Data
Help
Delete
Admin Tool
Create User
Delete User
Edit User
Exit Tool
Save User
Clear Fields
AT: ready
Import File
root
User Login
Password
User Name
Address
City
State
Zip
Phone
Email
Additional
Corporation Test Corp->Test Plant->Test Equipme...
Plant
Unit
Role Administrator
Last Login
This Login
Login Start
Login End
Pswd Date
Failed
Attempts
Locked false
Lock Reason
Pswd Age
Inactive
Duration
New Pswd false
History
Ready
Start
Inbox - Microsoft Outlook
C:\Lynne's Work\API RBI...
Microsoft PowerPoint - [A...
Api-Rbi v5.0
EEG: ApiRbi - USER: root...
Admin Tool
10:19 AM



EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
ORPHAN
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
Test Unit
Admin Tool
Create User
Delete User
Edit User
Exit Tool
Save User
Clear Fields
AT: Import File
Import File
root
User Login
Password
User Name
Address
City
State
Zip
Phone
Email
Additional
Corporation
Test Corp->Test Plant->Test Equipme...
Plant
Unit
Role
Administrator
Last Login
Failed
Attempts
Locked
false
Lock Reason
Pswd Age
Inactive
Duration
New Pswd
false
History
Import Progress
8%
CORP: Test Corp->Test Plant->Test Equipment T...
Busy
Importing Data.
Start
Inbox - Microsoft Outlook
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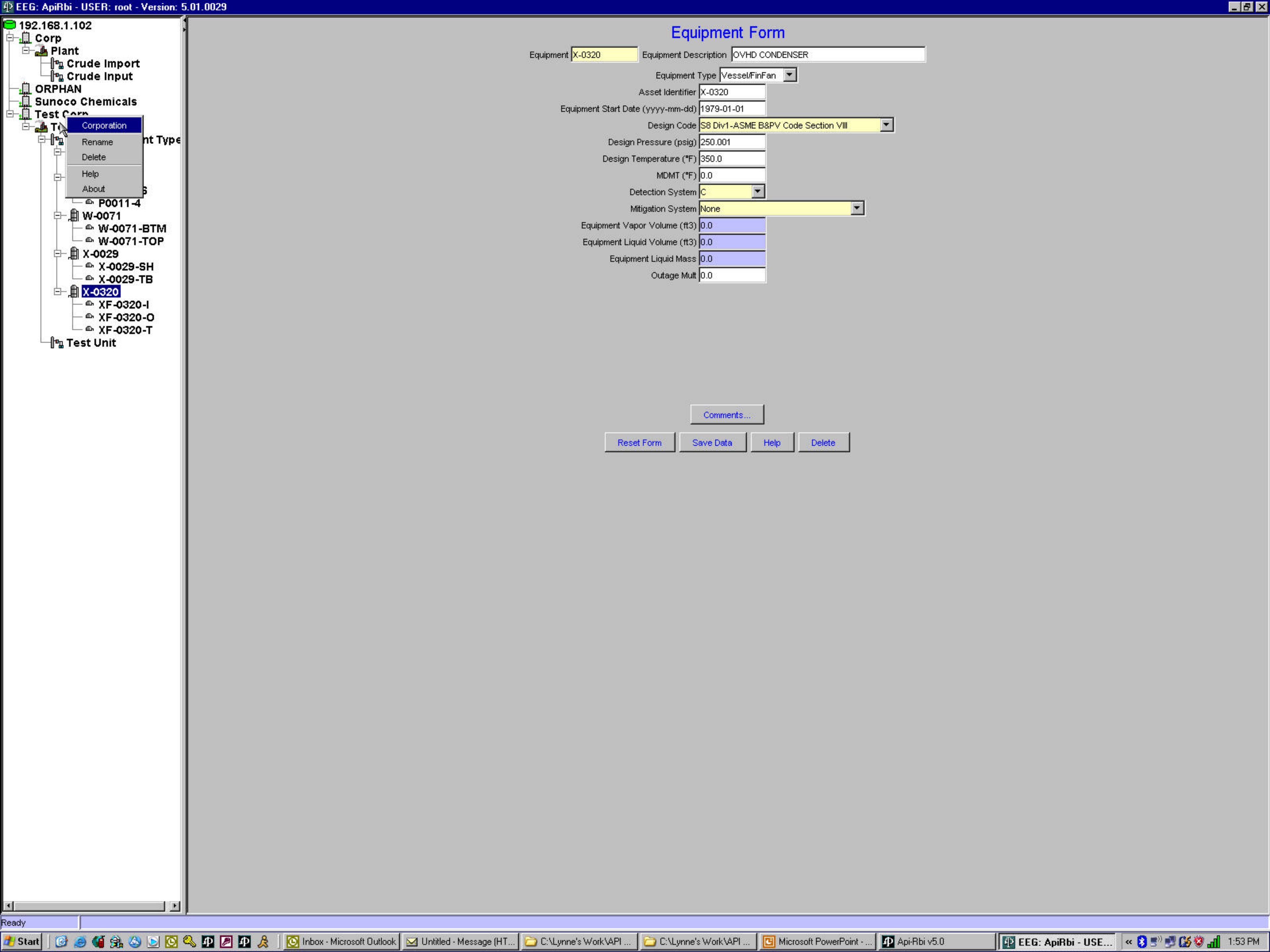
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USER: r...
Admin Tool
Import Progress
10:20 AM


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Corporation
Rename
Delete
Help
About
nt Type
P0011-4
W-0071
W-0071-BTM
W-0071-TOP
X-0029
X-0029-SH
X-0029-TB
X-0320
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Equipment Form
Equipment X-0320
Equipment Description OVHD CONDENSER
Equipment Type Vessel/FinFan
Asset Identifier X-0320
Equipment Start Date (yyyy-mm-dd) 1979-01-01
Design Code S8 Div1-ASME B&PV Code Section VIII
Design Pressure (psig) 250.001
Design Temperature (°F) 350.0
MDMT (°F) 0.0
Detection System C
Mitigation System None
Equipment Vapor Volume (ft3) 0.0
Equipment Liquid Volume (ft3) 0.0
Equipment Liquid Mass 0.0
Outage Mult 0.0
Comments...
Reset Form
Save Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
Untitled - Message (HT...
C:\Lynne's Work\API ...
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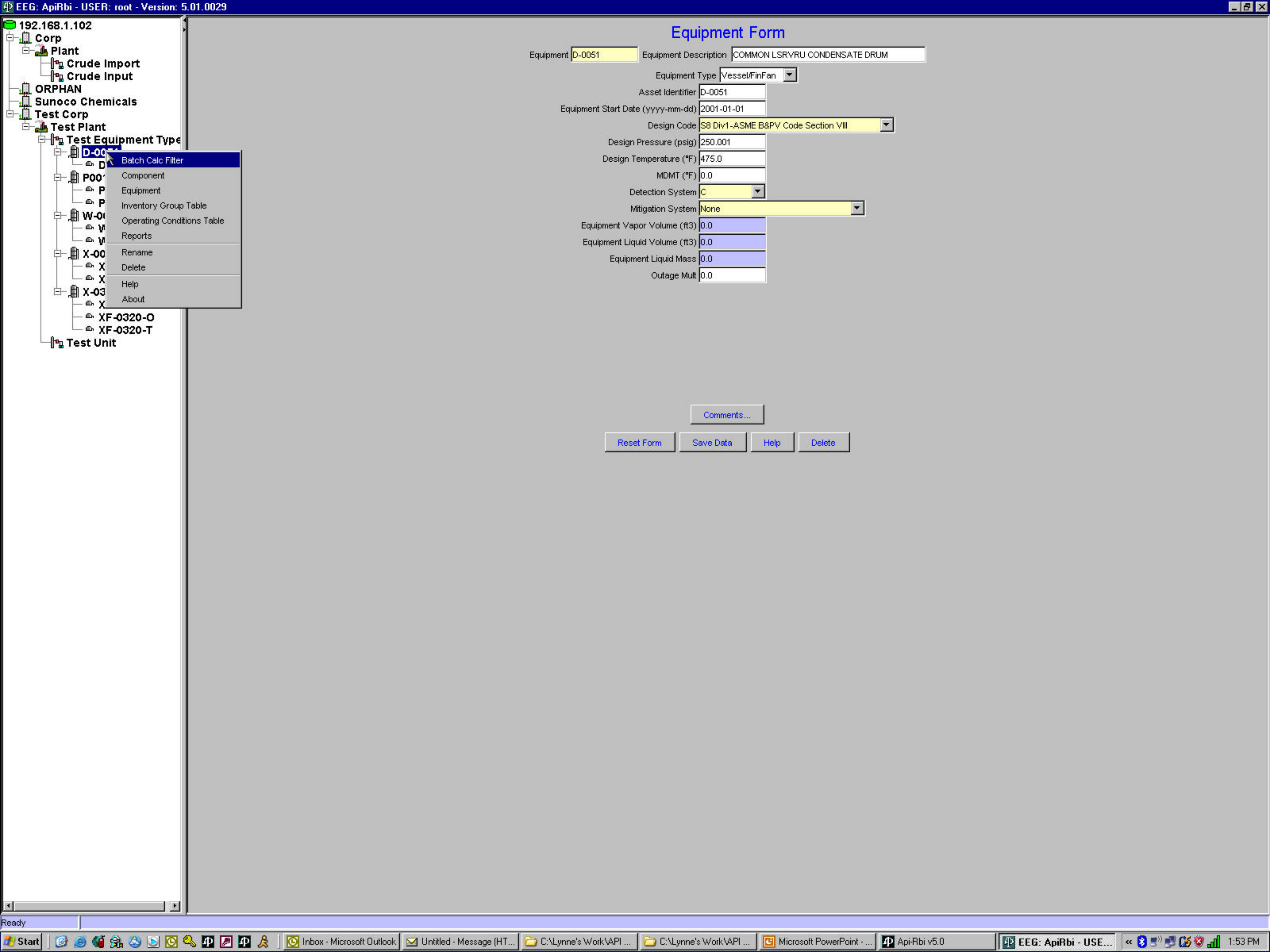
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USE...
1:53 PM


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
XF-0320-O
XF-0320-T
Test Unit
Batch Calc Filter
Component
Equipment
Inventory Group Table
Operating Conditions Table
Reports
Rename
Delete
Help
About
Equipment Form
Equipment D-0051
Equipment Description COMMON LSRVRU CONDENSATE DRUM
Equipment Type Vessel/FinFan
Asset Identifier D-0051
Equipment Start Date (yyyy-mm-dd) 2001-01-01
Design Code S8 Div1-ASME B&PV Code Section VIII
Design Pressure (psig) 250.001
Design Temperature (°F) 475.0
MDMT (°F) 0.0
Detection System C
Mitigation System None
Equipment Vapor Volume (ft3) 0.0
Equipment Liquid Volume (ft3) 0.0
Equipment Liquid Mass 0.0
Outage Mult 0.0
Comments...
Reset Form
Save Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
Untitled - Message (HT...
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Api-Rbi v5.0
EEG: ApiRbi - USE...
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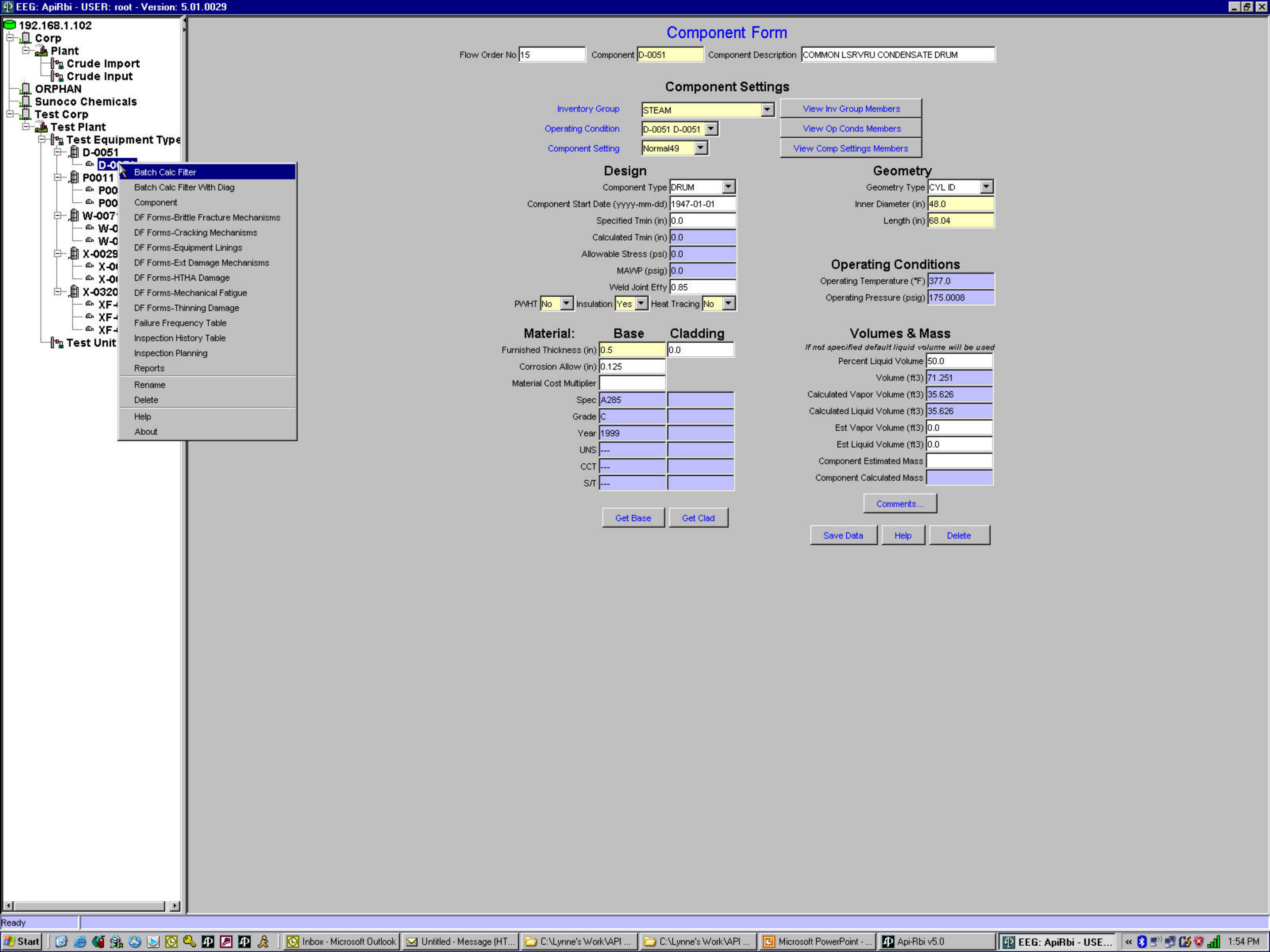
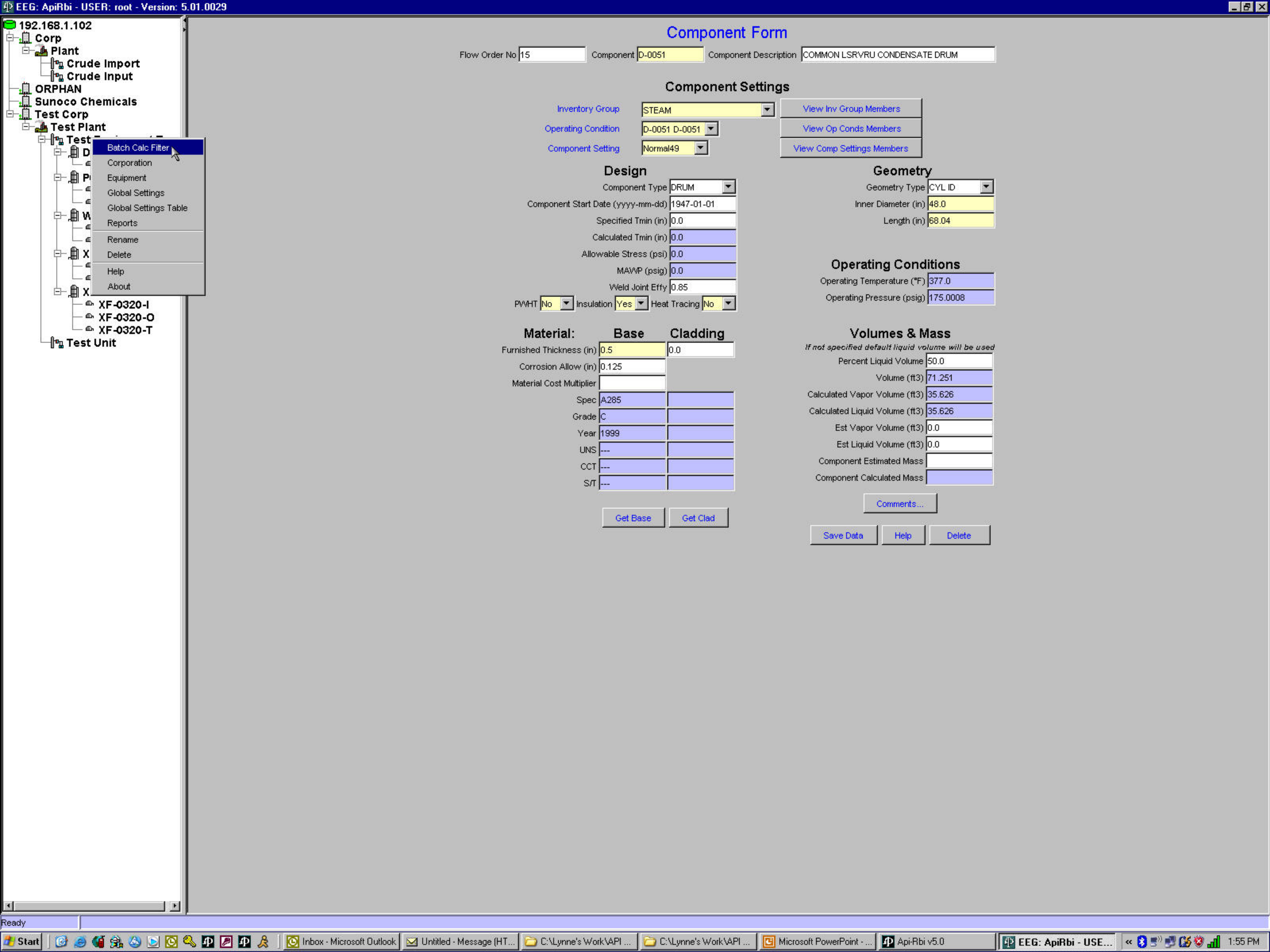


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
P0011
W-007
X-0029
X-0320
Test Unit
Batch Calc Filter
Batch Calc Filter With Diag
Component
DF Forms-Brittle Fracture Mechanisms
DF Forms-Cracking Mechanisms
DF Forms-Equipment Linings
DF Forms-Ext Damage Mechanisms
DF Forms-HTHA Damage
DF Forms-Mechanical Fatigue
DF Forms-Thinning Damage
Failure Frequency Table
Inspection History Table
Inspection Planning
Reports
Rename
Delete
Help
About
Component Form
Flow Order No 15
Component D-0051
Component Description COMMON LSRVRU CONDENSATE DRUM
Component Settings
Inventory Group STEAM
View Inv Group Members
Operating Condition D-0051 D-0051
View Op Conds Members
Component Setting Normal49
View Comp Settings Members
Design
Component Type DRUM
Component Start Date (yyyy-mm-dd) 1947-01-01
Specified Tmin (in) 0.0
Calculated Tmin (in) 0.0
Allowable Stress (psi) 0.0
MAWP (psig) 0.0
Weld Joint Effy 0.85
PWHT No
Insulation Yes
Heat Tracing No
Geometry
Geometry Type CYL ID
Inner Diameter (in) 48.0
Length (in) 68.04
Operating Conditions
Operating Temperature (°F) 377.0
Operating Pressure (psig) 175.0008
Material:
Base
Cladding
Furnished Thickness (in) 0.5 0.0
Corrosion Allow (in) 0.125
Material Cost Multiplier
Spec A285
Grade C
Year 1999
UNS ---
CCT ---
S/T ---
Get Base
Get Clad
Volumes & Mass
If not specified default liquid volume will be used
Percent Liquid Volume 50.0
Volume (ft3) 71.251
Calculated Vapor Volume (ft3) 35.626
Calculated Liquid Volume (ft3) 35.626
Est Vapor Volume (ft3) 0.0
Est Liquid Volume (ft3) 0.0
Component Estimated Mass
Component Calculated Mass
Comments...
Save Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
Untitled - Message (HT...
C:\Lynne's Work\API ...
C:\Lynne's Work\API ...
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USE...
1:54 PM


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test
Batch Calc Filter
Corporation
Equipment
Global Settings
Global Settings Table
Reports
Rename
Delete
Help
About
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Component Form
Flow Order No 15
Component D-0051
Component Description COMMON LSRVRU CONDENSATE DRUM
Component Settings
Inventory Group STEAM
Operating Condition D-0051 D-0051
Component Setting Normal49
View Inv Group Members
View Op Conds Members
View Comp Settings Members
Design
Component Type DRUM
Component Start Date (yyyy-mm-dd) 1947-01-01
Specified Tmin (in) 0.0
Calculated Tmin (in) 0.0
Allowable Stress (psi) 0.0
MAWP (psig) 0.0
Weld Joint Effy 0.85
PWHT No
Insulation Yes
Heat Tracing No
Geometry
Geometry Type CYL ID
Inner Diameter (in) 48.0
Length (in) 68.04
Operating Conditions
Operating Temperature (°F) 377.0
Operating Pressure (psig) 175.0008
Material:
Base
Cladding
Furnished Thickness (in) 0.5 0.0
Corrosion Allow (in) 0.125
Material Cost Multiplier
Spec A285
Grade C
Year 1999
UNS ---
CCT ---
S/T ---
Get Base
Get Clad
Volumes & Mass
If not specified default liquid volume will be used
Percent Liquid Volume 50.0
Volume (ft3) 71.251
Calculated Vapor Volume (ft3) 35.626
Calculated Liquid Volume (ft3) 35.626
Est Vapor Volume (ft3) 0.0
Est Liquid Volume (ft3) 0.0
Component Estimated Mass
Component Calculated Mass
Comments...
Save Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
Untitled - Message (HT...
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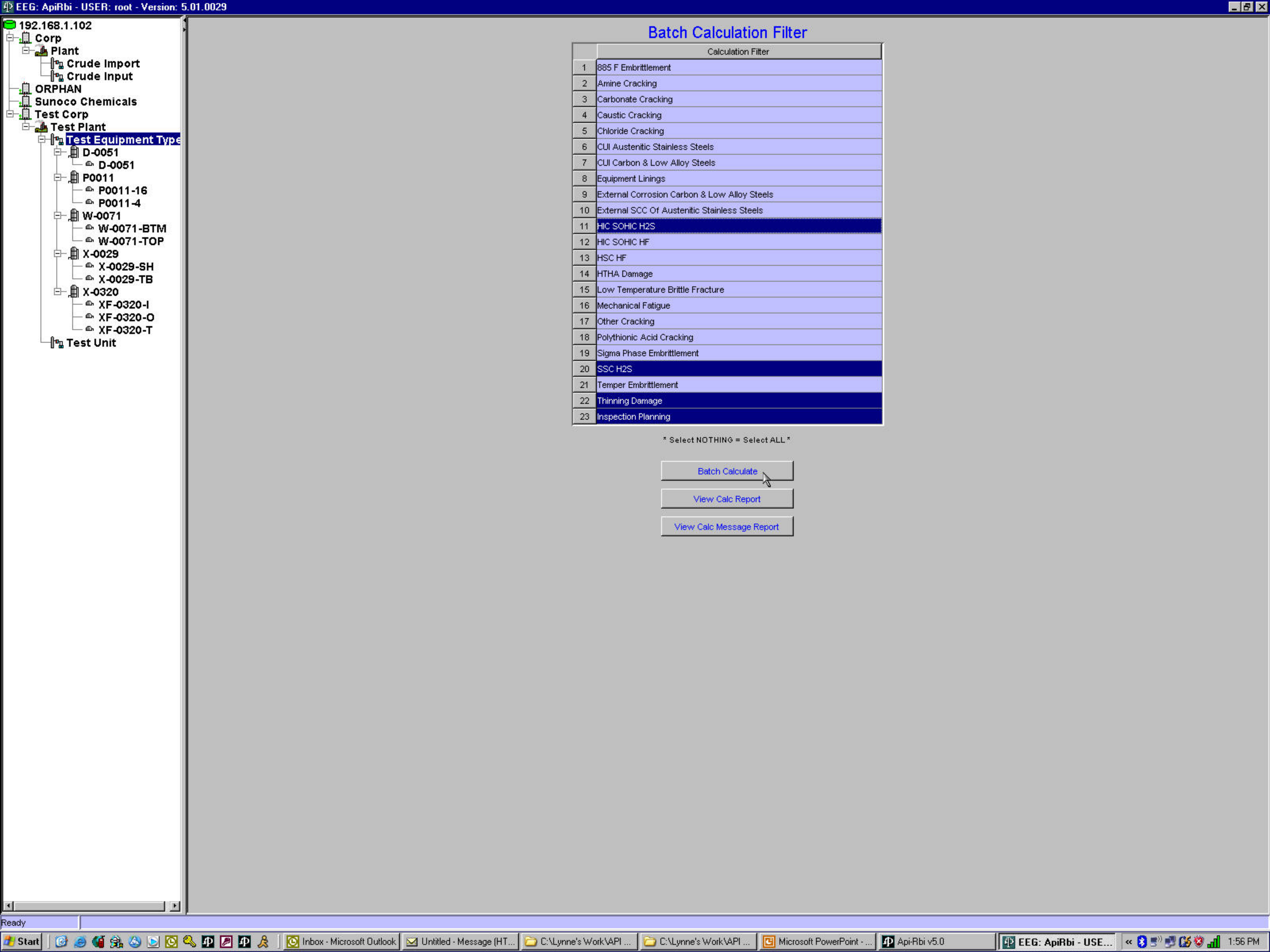
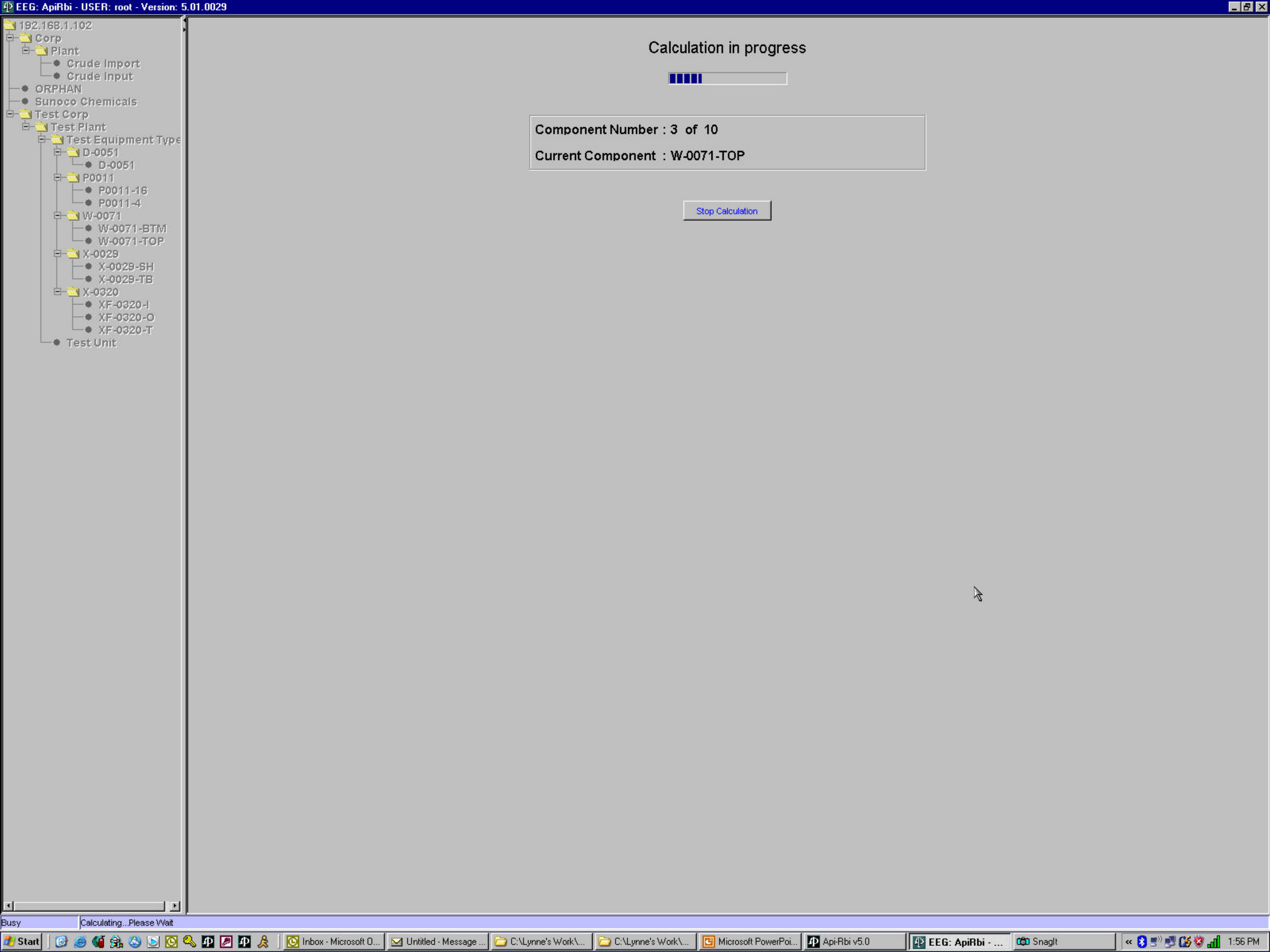
C:\Lynne's Work\API ...
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USE...
1:55 PM


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
D-0051
P0011
P0011-16
P0011-4
W-0071
W-0071-BTM
W-0071-TOP
X-0029
X-0029-SH
X-0029-TB
X-0320
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Batch Calculation Filter
Calculation Filter
1 885 F Embrittlement
2 Amine Cracking
3 Carbonate Cracking
4 Caustic Cracking
5 Chloride Cracking
6 CUI Austenitic Stainless Steels
7 CUI Carbon & Low Alloy Steels
8 Equipment Linings
9 External Corrosion Carbon & Low Alloy Steels
10 External SCC Of Austenitic Stainless Steels
11 HIC SOHIC H2S
12 HIC SOHIC HF
13 HSC HF
14 HTHA Damage
15 Low Temperature Brittle Fracture
16 Mechanical Fatigue
17 Other Cracking
18 Polythionic Acid Cracking
19 Sigma Phase Embrittlement
20 SSC H2S
21 Temper Embrittlement
22 Thinning Damage
23 Inspection Planning
* Select NOTHING = Select ALL *
Batch Calculate
View Calc Report
View Calc Message Report
Ready
Start
Inbox - Microsoft Outlook
Untitled - Message (HT...
C:\Lynne's Work\API ...
C:\Lynne's Work\API ...
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USE...
1:56 PM


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
D-0051
P0011
P0011-16
P0011-4
W-0071
W-0071-BTM
W-0071-TOP
X-0029
X-0029-SH
X-0029-TB
X-0320
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Calculation in progress
Component Number : 3 of 10
Current Component : W-0071-TOP
Stop Calculation
Busy
Calculating...Please Wait
Start
Inbox - Microsoft O...
Untitled - Message ...
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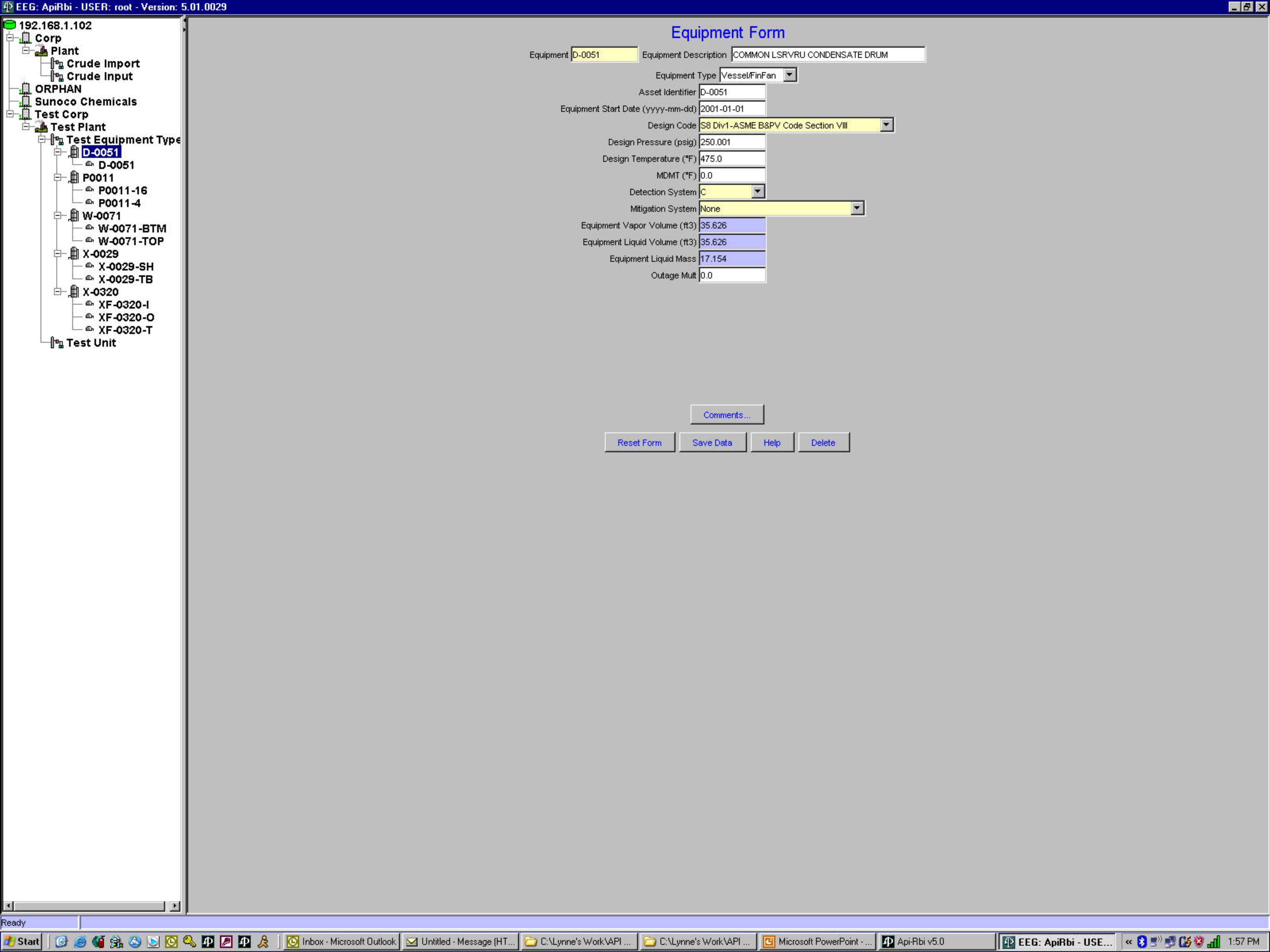
C:\Lynne's Work\...
Microsoft PowerPoi...
Api-Rbi v5.0
EEG: ApiRbi - ...
SnagIt
1:56 PM

Equipment

- Distinctly separate from Component
- Only used for common data for components
- Used like Asset ID in current approach
- Total inventory for item is reported here
- Design Temperature & Pressure entered
- Detection & Mitigation entered



EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
D-0051
P0011
P0011-16
P0011-4
W-0071
W-0071-BTM
W-0071-TOP
X-0029
X-0029-SH
X-0029-TB
X-0320
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Equipment Form
Equipment D-0051
Equipment Description COMMON LSRVRU CONDENSATE DRUM
Equipment Type Vessel/FinFan
Asset Identifier D-0051
Equipment Start Date (yyyy-mm-dd) 2001-01-01
Design Code S8 Div1-ASME B&PV Code Section VIII
Design Pressure (psig) 250.001
Design Temperature (°F) 475.0
MDMT (°F) 0.0
Detection System C
Mitigation System None
Equipment Vapor Volume (ft3) 35.626
Equipment Liquid Volume (ft3) 35.626
Equipment Liquid Mass 17.154
Outage Mult 0.0
Comments...
Reset Form
Save Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
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C:\Lynne's Work\API ...
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USE...
1:57 PM

Equipment Types

- Vessel/FinFan
- Heat Exchanger
- Pipe
- Tube/NS Pipe
- Pump
- Compressor
- Tank650
- Tank620

Component

- Distinct split of information from Equipment level
- 5.0 Improvements over 3.3.3
  - Process Flow Order field added
  - Component type list modified
  - Geometric type
  - Material Database
  - Clad/overlay inputs
  - T_{min} calculator

EEG: ApiRbi - USER: root - Version: 5.01.0029

- 192.168.1.102
  - Corp
    - Plant
      - Crude Import
      - Crude Input
  - ORPHAN
  - Sunoco Chemicals
  - Test Corp
    - Test Plant
      - Test Equipment Type
        - D-0051
          - D-0051
        - P0011
          - P0011-16
          - P0011-4
        - W-0071
          - W-0071-BTM
          - W-0071-TOP
        - X-0029
          - X-0029-SH
          - X-0029-TB
        - X-0320
          - XF-0320-I
          - XF-0320-O
          - XF-0320-T
      - Test Unit

Component Form

Flow Order No 15 | Component D-0051 | Component Description COMMON LSRVRU CONDENSATE DRUM

Component Settings

Inventory Group	STEAM	View Inv Group Members
Operating Condition	D-0051 D-0051	View Op Conds Members
Component Setting	Normal49	View Comp Settings Members

Design

Component Type	DRUM
Component Start Date (yyyy-mm-dd)	1947-01-01
Specified Tmin (in)	0.0
Calculated Tmin (in)	0.458
Allowable Stress (psi)	1.5700000E+04
MAWP (psig)	179.662
Weld Joint Effy	0.85

PWHT No | Insulation Yes | Heat Tracing No

Geometry

Geometry Type	CYL ID
Inner Diameter (in)	48.0
Length (in)	68.04

Operating Conditions

Operating Temperature (°F)	377.0
Operating Pressure (psig)	175.0008

Material:

	Base	Cladding
Furnished Thickness (in)	0.5	0.0
Corrosion Allow (in)	0.125	
Material Cost Multiplier		
Spec	A285	
Grade	C	
Year	1999	
UNS	---	
CCT	---	
S/T	---	

Get Base | Get Clad

Volumes & Mass

If not specified default liquid volume will be used

Percent Liquid Volume	50.0
Volume (ft3)	71.251
Calculated Vapor Volume (ft3)	35.626
Calculated Liquid Volume (ft3)	35.626
Est Vapor Volume (ft3)	0.0
Est Liquid Volume (ft3)	0.0
Component Estimated Mass	
Component Calculated Mass	17.15378

Comments...

Save Data | Help | Delete

Ready

Start | Inbox - Microsoft Outlook | Untitled - Message (HT... | C:\Lynne's Work\API ... | C:\Lynne's Work\API ... | Microsoft PowerPoint - ... | Api-Rbi v5.0 | EEG: ApiRbi - USE... | 1:58 PM

Component Types

Vessel/FinFan

- Column Top
- Column Middle
- Column Bottom
- Drum
- Filter
- FinFan
- KODrum
- Reactor

Heat Exchanger

- HEXSS
- HEXTS
- HEXTUBE

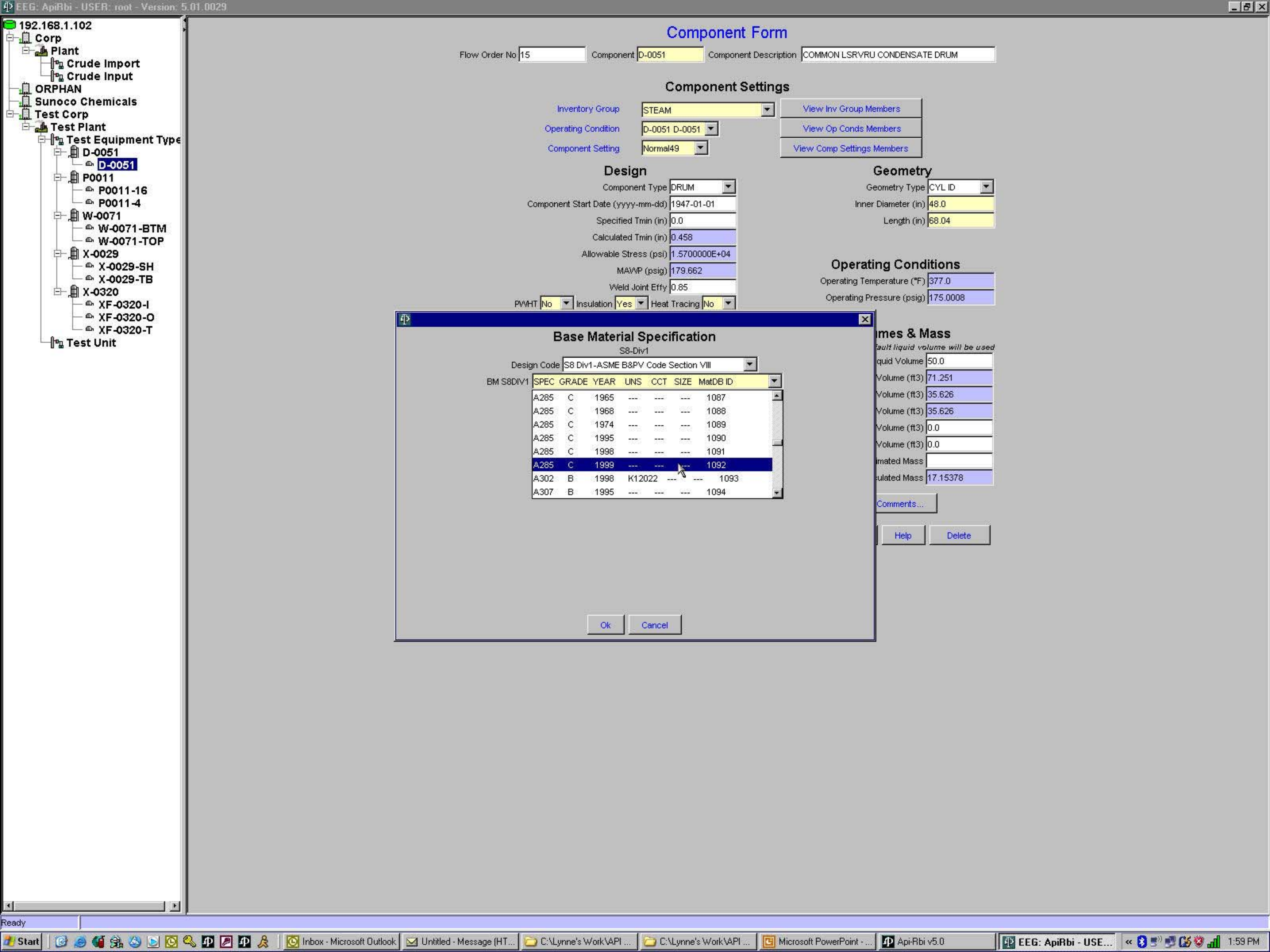
Component – Geometric Types

- CYL: Cylinder (Default)
- ELB: Elbow
- SPH: Sphere
- HEM: Hemi-Head
- ELL: Elliptical Head
- TOR: Torispherical Head
- CON: Conical Shell
- NOZ: Nozzle

Component – Material Database

- Pulldown menu for base material and clad/overlay
- All six fields are populated from pulldown

Component Table				
Variable	**Description**	**Form Description**	**Data Source**	**Type**
B_MSPEC	Base Material Specification	Spec	A material choice list will be provided based on the construction code; a pick from this list will load all of these data fields. Must Be Input, Default=Blank	Char*8
B_MGRADE	Base Material Grade	Grade		Char*8
B_MYEAR	Base Material Year	Year		Char*8
B_MUNS	Base Material UNS	UNS		Char*8
B_MCCT	Base Material Class Condition Temper	CCT		Char*8
B_MST	Base Material Size/Thickness	S/T		Char*8


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
D-0051
P0011
P0011-16
P0011-4
W-0071
W-0071-BTM
W-0071-TOP
X-0029
X-0029-SH
X-0029-TB
X-0320
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Component Form
Flow Order No 15
Component D-0051
Component Description COMMON LSRVRU CONDENSATE DRUM
Component Settings
Inventory Group STEAM
View Inv Group Members
Operating Condition D-0051 D-0051
View Op Conds Members
Component Setting Normal49
View Comp Settings Members
Design
Component Type DRUM
Component Start Date (yyyy-mm-dd) 1947-01-01
Specified Tmin (in) 0.0
Calculated Tmin (in) 0.458
Allowable Stress (psi) 1.5700000E+04
MAWP (psig) 179.662
Weld Joint Effy 0.85
PWHT No
Insulation Yes
Heat Tracing No
Geometry
Geometry Type CYL ID
Inner Diameter (in) 48.0
Length (in) 68.04
Operating Conditions
Operating Temperature (°F) 377.0
Operating Pressure (psig) 175.0008
Base Material Specification
S8-Div1
Design Code S8 Div1-ASME B&PV Code Section VIII
BM S8DIV1 SPEC GRADE YEAR UNS CCT SIZE MatDB ID
A285 C 1965 --- --- --- 1087
A285 C 1968 --- --- --- 1088
A285 C 1974 --- --- --- 1089
A285 C 1995 --- --- --- 1090
A285 C 1998 --- --- --- 1091
A285 C 1999 --- --- --- 1092
A302 B 1998 K12022 --- --- 1093
A307 B 1995 --- --- --- 1094
Ok
Cancel
mes & Mass
fault liquid volume will be used
quid Volume 50.0
Volume (ft3) 71.251
Volume (ft3) 35.626
Volume (ft3) 35.626
Volume (ft3) 0.0
Volume (ft3) 0.0
mated Mass
ulated Mass 17.15378
Comments...
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
Untitled - Message (HT...
C:\Lynne's Work\API ...
C:\Lynne's Work\API ...
Microsoft PowerPoint - ...
Api-Rbi v5.0
EEG: ApiRbi - USE...
1:59 PM

Component – T_{min} Calculator

- Calculated T_{min} is based on code calculations specific to geometry type
- Uses material database selection properties to perform calculations
- Furnished Thickness is actual supplied component thickness (including corrosion allowance)
- Nominal Thickness is a specified design thickness, used if Furnished Thickness not provided (piping only)
- Uses the larger of a structural T_{min} and Calculated T_{min}
- User override by entering Specified T_{min} and corrosion allowance, if desired

Operating Condition ID

- Designed to be used for multiple operating conditions, e.g. intermittant service, multiple operating conditions; start-up, shutdown, regeneration, different process fluids/toxics
- Inventory calculator
  - Calculated component volume based on liquid and vapor contents
  - Uses BRD liquid levels for component type
- Manually entered liquid level override
- Manually adjust toxic leak duration (Default 3 minutes)

Likelihood

- No programming to enable and disable damage mechanisms
- Separated all Damage mechanisms within Damage Types to allow multiple mechanism handling
- Uses Maximum Rate or Severity Factor for each Damage Type
- Sums Damage Factors for Damage Types

Damage Mechanisms - Thinning

- Corrosion rate associated with Base Material and Clad/Overlay
- Modified ar/t

$$\frac{ar}{t} = \max\left[1 - \left(\frac{sthk - crate \cdot time}{t_{min} + C.A.}\right), 0.0\right]$$

where

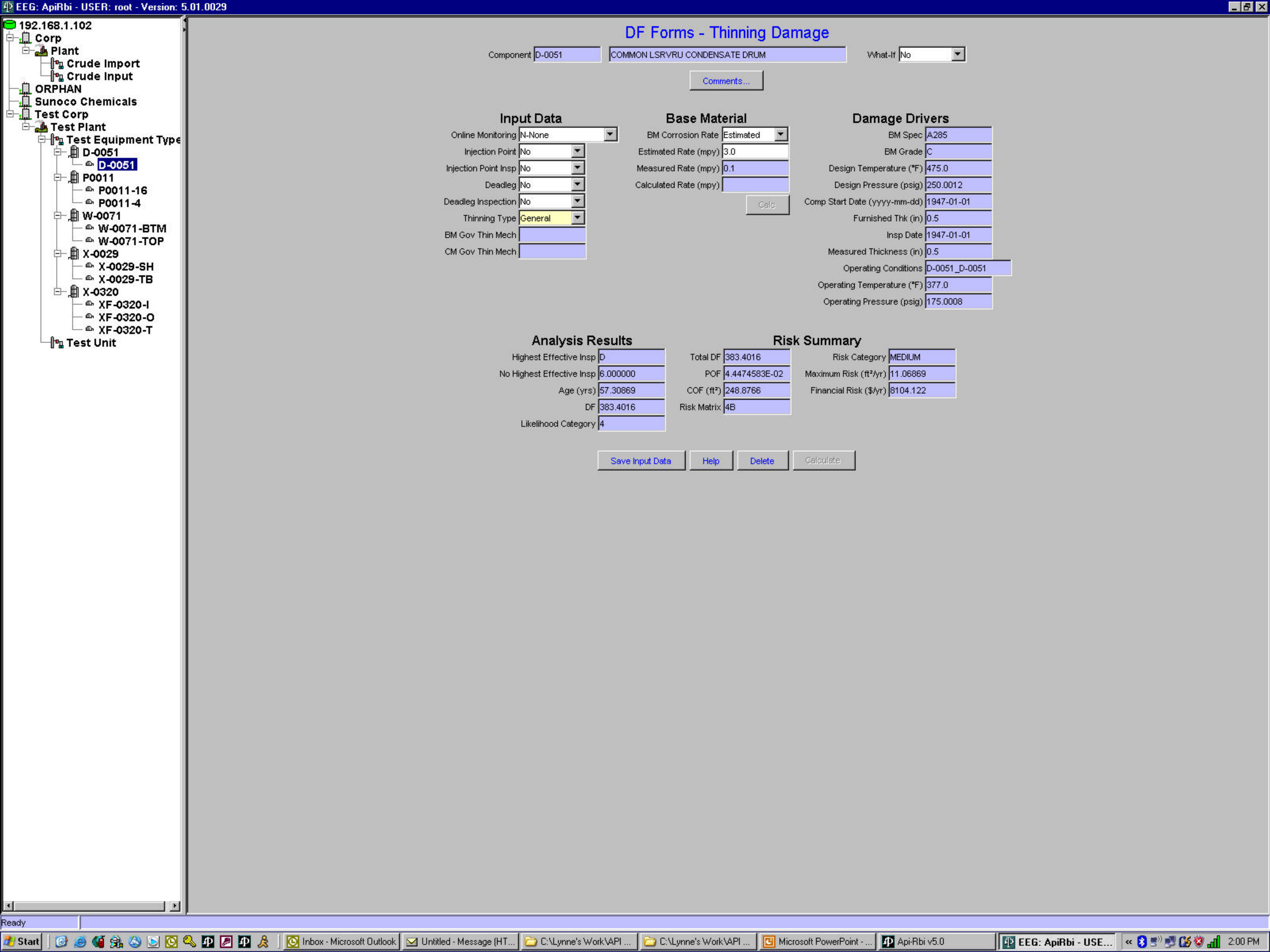
sthk – *most recent thickness reading*

crate – *corrosion rate of the base or cladding material, as applicable, estimate at the time of the most recent thickness reading*

time – *time difference between the RBI date and the date of the most recent thickness reading*

C.A. – *corrosion allowance*

- Smoothing of Damage Factors in ar/t table
- Smoothing of corrosion rates in supplements



EEG: ApiRbi - USER: root - Version: 5.01.0029

- 192.168.1.102
  - Corp
    - Plant
      - Crude Import
      - Crude Input
  - ORPHAN
  - Sunoco Chemicals
  - Test Corp
    - Test Plant
      - Test Equipment Type
        - D-0051
          - D-0051
        - P0011
          - P0011-16
          - P0011-4
        - W-0071
          - W-0071-BTM
          - W-0071-TOP
        - X-0029
          - X-0029-SH
          - X-0029-TB
        - X-0320
          - XF-0320-I
          - XF-0320-O
          - XF-0320-T
      - Test Unit

DF Forms - Thinning Damage

Component: D-0051 | COMMON LSRVRU CONDENSATE DRUM | What-If: No

Comments...

Input Data

Online Monitoring	N-None
Injection Point	No
Injection Point Insp	No
Deadleg	No
Deadleg Inspection	No
Thinning Type	General
BM Gov Thin Mech	
CM Gov Thin Mech	

Base Material

BM Corrosion Rate	Estimated
Estimated Rate (mpy)	3.0
Measured Rate (mpy)	0.1
Calculated Rate (mpy)	

Calc

Damage Drivers

BM Spec	A285
BM Grade	C
Design Temperature (°F)	475.0
Design Pressure (psig)	250.0012
Comp Start Date (yyyy-mm-dd)	1947-01-01
Furnished Thk (in)	0.5
Insp Date	1947-01-01
Measured Thickness (in)	0.5
Operating Conditions	D-0051_D-0051
Operating Temperature (°F)	377.0
Operating Pressure (psig)	175.0008

Analysis Results

Highest Effective Insp	D
No Highest Effective Insp	6.000000
Age (yrs)	57.30869
DF	383.4016
Likelihood Category	4

Risk Summary

Total DF	383.4016
POF	4.4474583E-02
COF (ft^2)	248.8766
Risk Matrix	4B
Risk Category	MEDIUM
Maximum Risk (ft^2/yr)	11.06869
Financial Risk ($/yr)	8104.122

Save Input Data | Help | Delete | Calculate

Ready

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What-If

- Allows user to change all parameters (non-calculated) without permanently affecting the input information
- Calculates locally with minimal operating input information changes
- Performs What-If at damage mechanism level only
- Close function, does not perform a save to the database

EEG: ApiRbi - USER: root - Version: 5.01.0029

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          - XF-0320-O
          - XF-0320-T
      - Test Unit

DF Forms - Thinning Damage

Component D-0051 | COMMON LSRVRU CONDENSATE DRUM | What-If Yes

Comments...

Input Data

Online Monitoring	N-None
Injection Point	No
Injection Point Insp	No
Deadleg	No
Deadleg Inspection	No
Thinning Type	General
BM Gov Thin Mech	
CM Gov Thin Mech	

Base Material

BM Corrosion Rate	Estimated
Estimated Rate (mpy)	3.0
Measured Rate (mpy)	0.1
Calculated Rate (mpy)	

Calc

Damage Drivers

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Operating Temperature (°F)	377.0
Operating Pressure (psig)	175.0008

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POF	4.4474583E-02	Maximum Risk (ft^2/yr)	11.06869
COF (ft^2)	248.8766	Financial Risk ($/yr)	8104.122
Risk Matrix	4B		

Save Input Data | Help | Delete | Calculate

Ready

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Inspection History

- Measured thickness entered in inspection history for use in thinning calculations
- Default is last thickness reading as thinning start date and thickness
- Sigma Phase amount moved to inspection history
- Holds unlimited inspections
- Comments field added for import of inspection history text
- All inspection history merged into one table

EEG: ApiRbi - USER: root - Version: 5.01.0029

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  - Sunoco Chemicals
  - Test Corp
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          - D-0051
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          - P0011-16
          - P0011-4
        - W-0071
          - W-0071-BTM
          - W-0071-TOP
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          - X-0029-SH
          - X-0029-TB
        - X-0320
          - XF-0320-I
          - XF-0320-O
          - XF-0320-T
      - Test Unit

Inspection History Table

	Inspection Type	Insp Date	Ins Cat	Measured Thickness ...	Sigma Amount	Inspection H
1	External Corrosion Carbon & Low Alloy Ste...	1947-01-01	E		NAP	Created by System usi
2	Sigma Phase Embrittlement	1947-01-01	E	NAP	Low	Created by System usi
3	Thinning Damage	1947-01-01	C	0.5	NAP	
4	Thinning Damage	1993-02-01	D		NAP	
5	Thinning Damage	1994-03-01	D		NAP	
6	Thinning Damage	1996-07-26	D		NAP	
7	Thinning Damage	1998-03-01	D		NAP	
8	Thinning Damage	2001-07-10	D		NAP	
9	Thinning Damage	2002-05-02	D		NAP	
10	CUI Carbon & Low Alloy Steels	1947-01-01	E		NAP	Created by System usi

Create New Row | Save Data | Help | Delete

Ready

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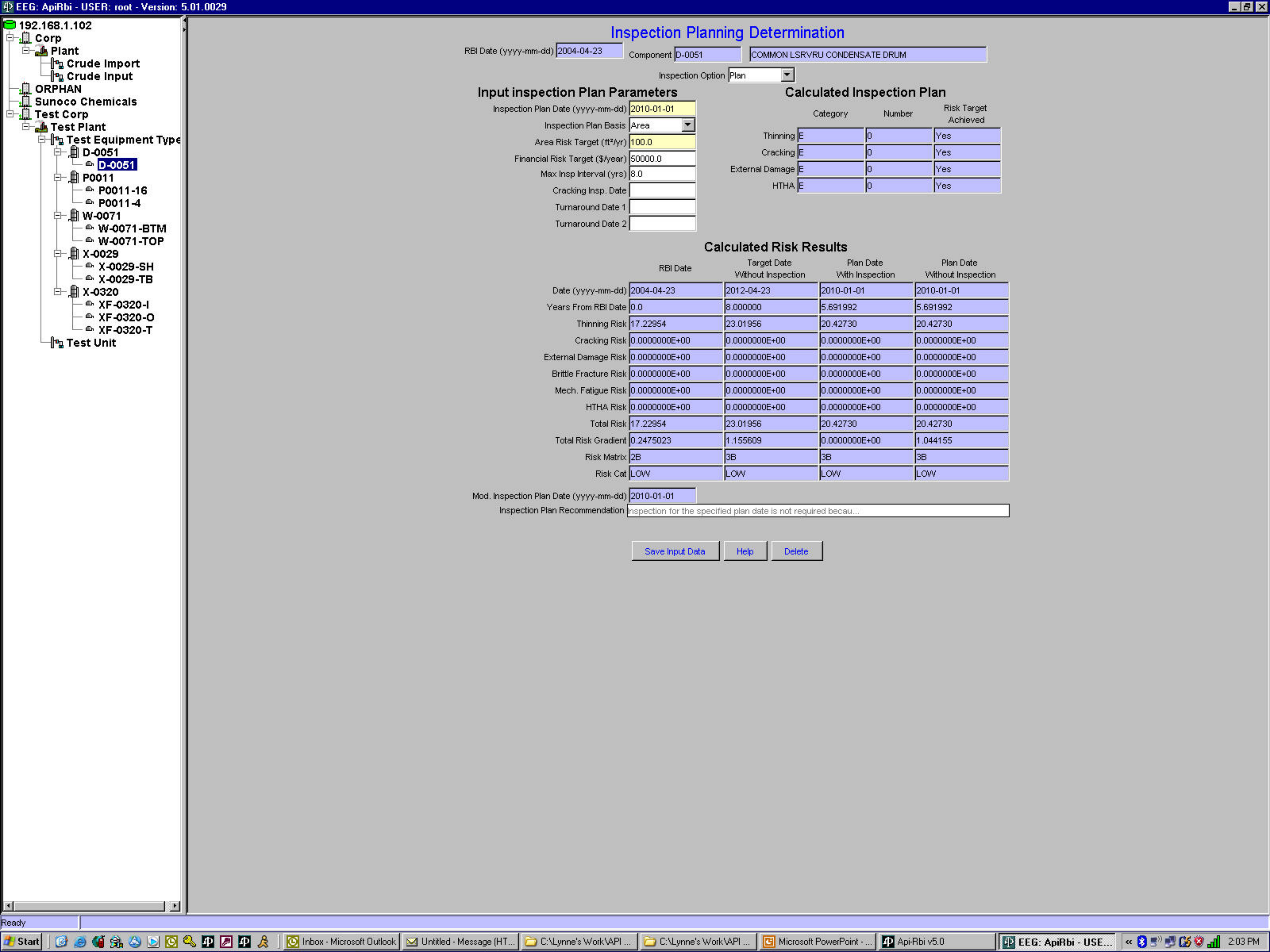
Inspection Planning

- Two options for Inspection Planning
  - Date – Returns a recommended date for inspection based on maximum Area or Financial Risk input and planned inspection (ICats) for each damage type
  - Plan (ICats) – Returns a recommended effectiveness for inspection based on maximum Area or Financial Risk input and date for inspection

Inspection Planning - Date

- Input required is number of inspections planned and effectiveness (ICats) during planning period
- Enter Plan Time in Maximum Inspection Interval field
- Local Target Risk Inputs can be used to override Global Settings
- Calculates Date component reaches Maximum Risk Target (from the RBI Date)


EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
D-0051
P0011
P0011-16
P0011-4
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W-0071-BTM
W-0071-TOP
X-0029
X-0029-SH
X-0029-TB
X-0320
XF-0320-I
XF-0320-O
XF-0320-T
Test Unit
Inspection Planning Determination
RBI Date (yyyy-mm-dd) 2004-04-23
Component D-0051
COMMON LSRVRU CONDENSATE DRUM
Inspection Option Plan
Input inspection Plan Parameters
Inspection Plan Date (yyyy-mm-dd) 2010-01-01
Inspection Plan Basis Area
Area Risk Target (ft²/yr) 100.0
Financial Risk Target ($/year) 50000.0
Max Insp Interval (yrs) 8.0
Cracking Insp. Date
Turnaround Date 1
Turnaround Date 2
Calculated Inspection Plan
Category
Number
Risk Target Achieved
Thinning E 0 Yes
Cracking E 0 Yes
External Damage E 0 Yes
HTHA E 0 Yes
Calculated Risk Results
RBI Date
Target Date Without Inspection
Plan Date With Inspection
Plan Date Without Inspection
Date (yyyy-mm-dd) 2004-04-23 2012-04-23 2010-01-01 2010-01-01
Years From RBI Date 0.0 8.000000 5.691992 5.691992
Thinning Risk 17.22954 23.01956 20.42730 20.42730
Cracking Risk 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
External Damage Risk 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
Brittle Fracture Risk 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
Mech. Fatigue Risk 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
HTHA Risk 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
Total Risk 17.22954 23.01956 20.42730 20.42730
Total Risk Gradient 0.2475023 1.155609 0.0000000E+00 1.044155
Risk Matrix 2B 3B 3B 3B
Risk Cat LOW LOW LOW LOW
Mod. Inspection Plan Date (yyyy-mm-dd) 2010-01-01
Inspection Plan Recommendation Inspection for the specified plan date is not required becau...
Save Input Data
Help
Delete
Ready
Start
Inbox - Microsoft Outlook
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Api-Rbi v5.0
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Inspection Planning - Plan

- Input required is date of inspection during planning period
- Enter Plan Time in Maximum Inspection Interval field
- Local Target Risk Inputs can be used to override Global Settings
- Calculates ICats necessary for the component to remain below the Maximum Risk Target
  - Will generate the next (1) inspection and an effectiveness of A, B or C

EEG: ApiRbi - USER: root - Version: 5.01.0029

- 192.168.1.102
  - Corp
    - Plant
      - Crude Import
      - Crude Input
  - ORPHAN
  - Sunoco Chemicals
  - Test Corp
    - Test Plant
      - Test Equipment Type
        - D-0051
          - D-0051
        - P0011
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        - X-0029
          - X-0029-SH
          - X-0029-TB
        - X-0320
          - XF-0320-I
          - XF-0320-O
          - XF-0320-T
      - Test Unit

Inspection Planning Determination

RBI Date (yyyy-mm-dd) 2004-04-23 Component D-0051 COMMON LSRVRU CONDENSATE DRUM

Inspection Option Plan

Input inspection Plan Parameters

Inspection Plan Date (yyyy-mm-dd)	2010-01-01
Inspection Plan Basis	Area
Area Risk Target (ft²/yr)	100.0
Financial Risk Target ($/year)	50000.0
Max Insp Interval (yrs)	8.0
Cracking Insp. Date	
Turnaround Date 1	
Turnaround Date 2	

Calculated Inspection Plan

	Category	Number	Risk Target Achieved
Thinning	E	0	Yes
Cracking	E	0	Yes
External Damage	E	0	Yes
HTHA	E	0	Yes

Calculated Risk Results

	RBI Date	Target Date Without Inspection	Plan Date With Inspection	Plan Date Without Inspection
Date (yyyy-mm-dd)	2004-04-23	2012-04-23	2010-01-01	2010-01-01
Years From RBI Date	0.0	8.000000	5.691992	5.691992
Thinning Risk	34.69814	46.35852	41.13803	41.13803
Cracking Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
External Damage Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Brittle Fracture Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Mech. Fatigue Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
HTHA Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Total Risk	34.69814	46.35852	41.13803	41.13803
Total Risk Gradient	0.4984856	2.327240	0.0000000E+00	2.102806
Risk Matrix	3B	3B	3B	3B
Risk Cat	LOW	LOW	LOW	LOW

Mod. Inspection Plan Date (yyyy-mm-dd) 2010-01-01

Inspection Plan Recommendation Inspection for the specified plan date is not required becau...

Save Input Data | Help | Delete

Ready

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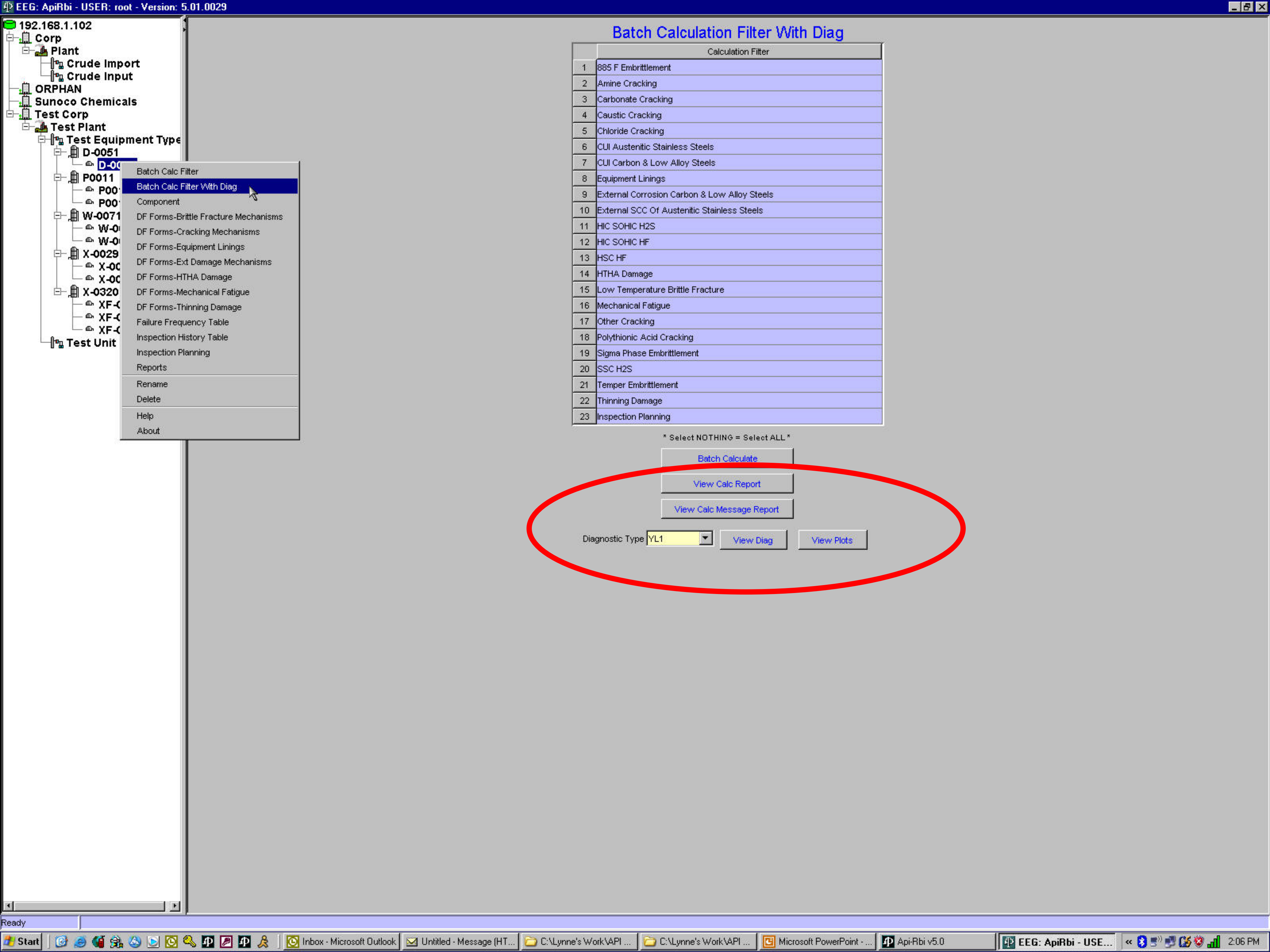
EEG: ApiRbi - USER: root - Version: 5.01.0029
192.168.1.102
Corp
Plant
Crude Import
Crude Input
ORPHAN
Sunoco Chemicals
Test Corp
Test Plant
Test Equipment Type
D-0051
P0011
W-0071
X-0029
X-0320
Test Unit
Batch Calc Filter
Batch Calc Filter With Diag
Component
DF Forms-Brittle Fracture Mechanisms
DF Forms-Cracking Mechanisms
DF Forms-Equipment Linings
DF Forms-Ext Damage Mechanisms
DF Forms-HTHA Damage
DF Forms-Mechanical Fatigue
DF Forms-Thinning Damage
Failure Frequency Table
Inspection History Table
Inspection Planning
Reports
Rename
Delete
Help
About
Batch Calculation Filter With Diag
Calculation Filter
1 885 F Embrittlement
2 Amine Cracking
3 Carbonate Cracking
4 Caustic Cracking
5 Chloride Cracking
6 CUI Austenitic Stainless Steels
7 CUI Carbon & Low Alloy Steels
8 Equipment Linings
9 External Corrosion Carbon & Low Alloy Steels
10 External SCC Of Austenitic Stainless Steels
11 HIC SOHIC H2S
12 HIC SOHIC HF
13 HSC HF
14 HTHA Damage
15 Low Temperature Brittle Fracture
16 Mechanical Fatigue
17 Other Cracking
18 Polythionic Acid Cracking
19 Sigma Phase Embrittlement
20 SSC H2S
21 Temper Embrittlement
22 Thinning Damage
23 Inspection Planning
* Select NOTHING = Select ALL *
Batch Calculate
View Calc Report
View Calc Message Report
Diagnostic Type YL1
View Diag
View Plots
Ready
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EEG: ApiRbi - USER: root - Version: 5.01.0029

192.168.1.102
- Corp
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- Sunoco Chemicals
- Test Corp
  - Test Plant
    - Test
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      - PC
      - W
      - X-
      - X-
        - XF-0320-I
        - XF-0320-O
        - XF-0320-T
    - Test Unit

Context menu: Batch Calc Filter | Corporation | Equipment | Global Settings | Global Settings Table | Reports | Rename | Delete | Help | About

Component Form

Flow Order No: 15 | Component: D-0051 | Component Description: COMMON LSRVRU CONDENSATE DRUM

Component Settings

Inventory Group	STEAM	View Inv Group Members
Operating Condition	D-0051 D-0051	View Op Conds Members
Component Setting	Normal49	View Comp Settings Members

Design

Component Type	DRUM
Component Start Date (yyyy-mm-dd)	1947-01-01
Specified Tmin (in)	0.0
Calculated Tmin (in)	0.458
Allowable Stress (psi)	1.5700000E+04
MAWP (psig)	179.662
Weld Joint Effy	0.85

PWHT: No | Insulation: Yes | Heat Tracing: No

Geometry

Geometry Type	CYL ID
Inner Diameter (in)	48.0
Length (in)	68.04

Operating Conditions

Operating Temperature (°F)	377.0
Operating Pressure (psig)	175.0008

Material:

Material:	Base	Cladding
Furnished Thickness (in)	0.5	0.0
Corrosion Allow (in)	0.125	
Material Cost Multiplier		
Spec	A285	
Grade	C	
Year	1999	
UNS	---	
CCT	---	
S/T	---	

Get Base | Get Clad

Volumes & Mass

If not specified default liquid volume will be used

Percent Liquid Volume	50.0
Volume (ft3)	71.251
Calculated Vapor Volume (ft3)	35.626
Calculated Liquid Volume (ft3)	35.626
Est Vapor Volume (ft3)	0.0
Est Liquid Volume (ft3)	0.0
Component Estimated Mass	
Component Calculated Mass	1141.226

Comments...

Save Data | Help | Delete

Ready

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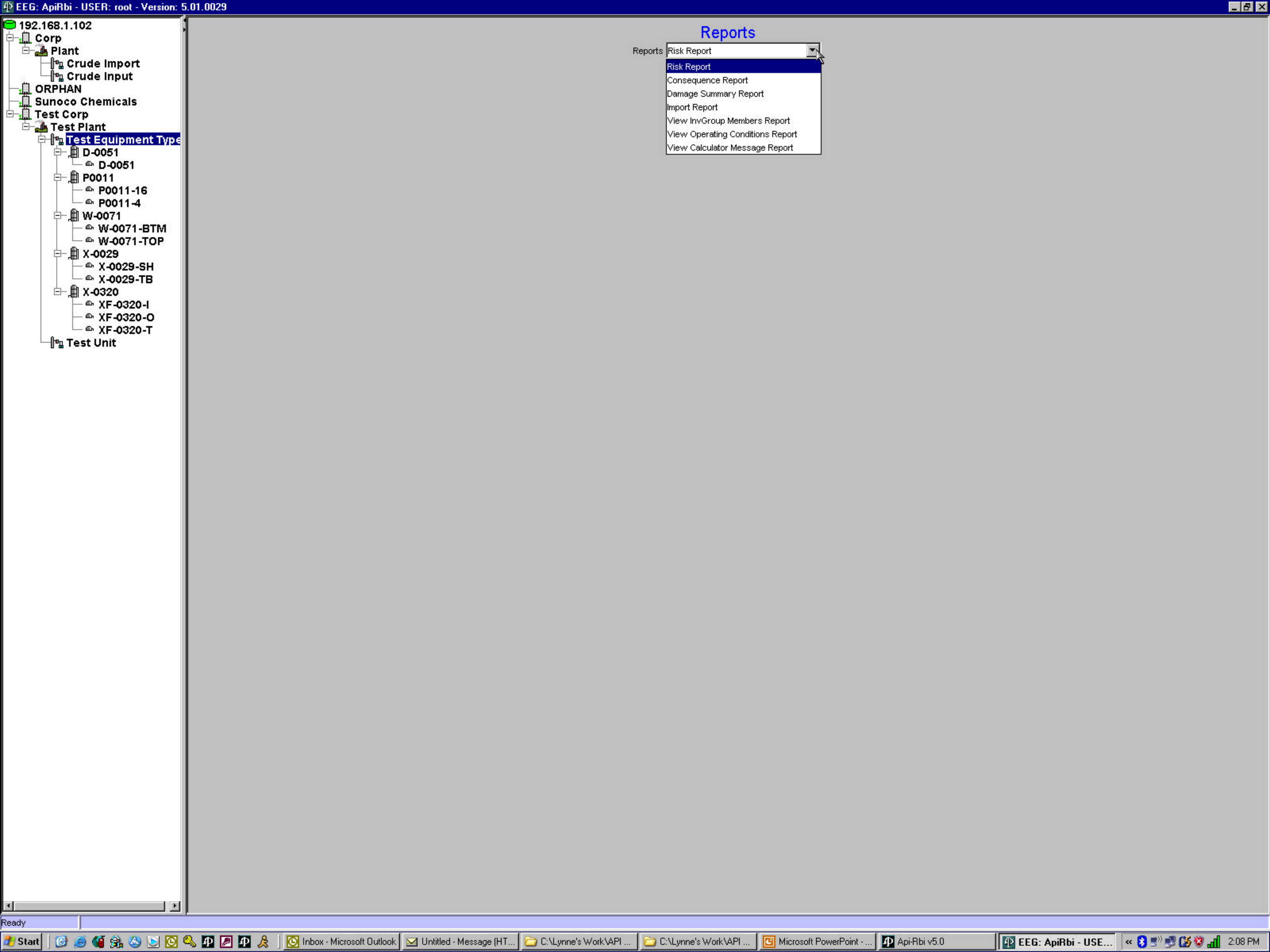
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XF-0320-O
XF-0320-T
Test Unit
Reports
Reports
Risk Report
Risk Report
Consequence Report
Damage Summary Report
Import Report
View InvGroup Members Report
View Operating Conditions Report
View Calculator Message Report
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Nature of RBI Consequence Analysis

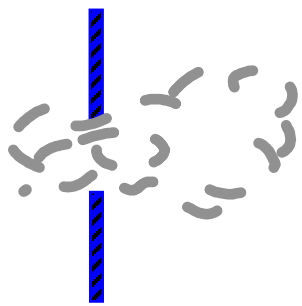
Part 5

Nature of RBI Consequence Analysis

- Provides a coarse consequence analysis
- Intended for relative consequence measures
- Calculates release rates and quantities in software
- Determines dispersion and consequences from software

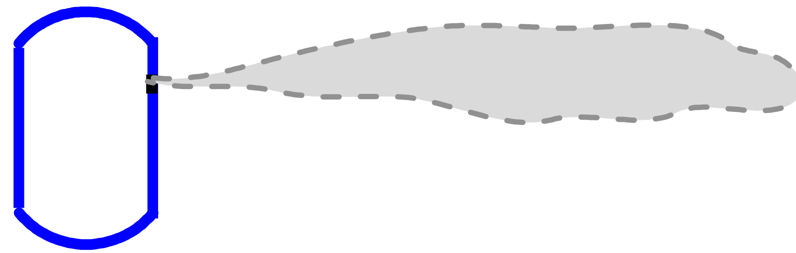
Phases of a Leak

1



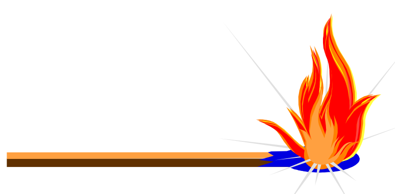
Discharge

2



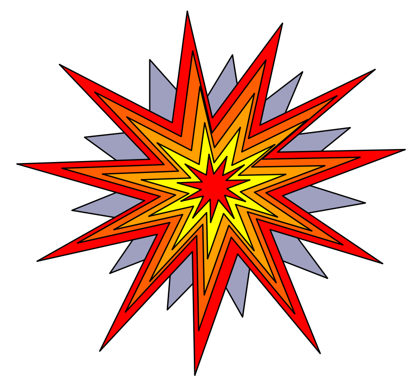
Dispersion

3

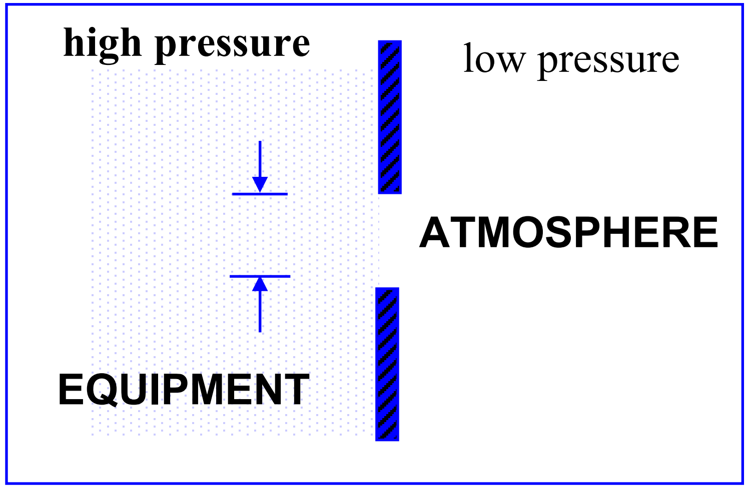


Ignition
(Flammables)

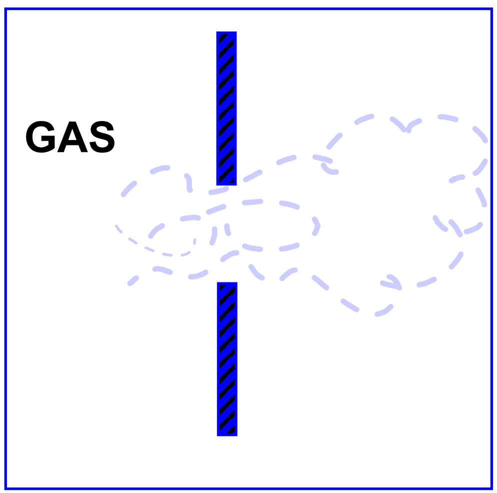
4

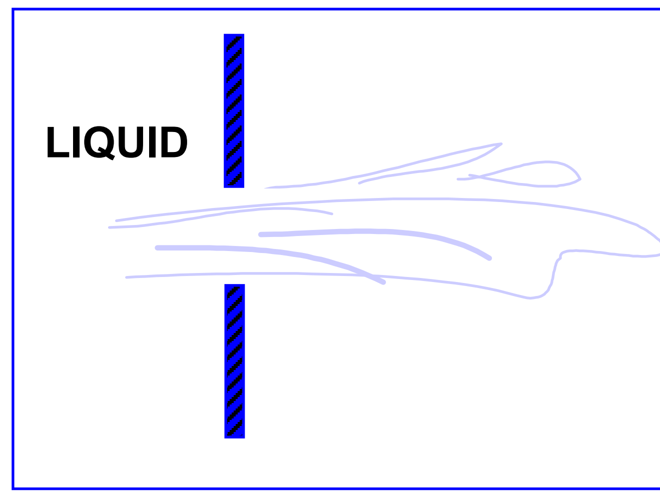


Consequence



A Leak Develops, With A Defined Hole Size





FLUID DISCHARGES THROUGH THE ORIFICE

Critical Factors in Consequence Analysis

- TYPE of release (continuous or instantaneous)
- PHASE in environment
- Discharge Rate/Mass (pressure, volume)
- Duration, if toxic

What Causes an Undesirable Consequence?

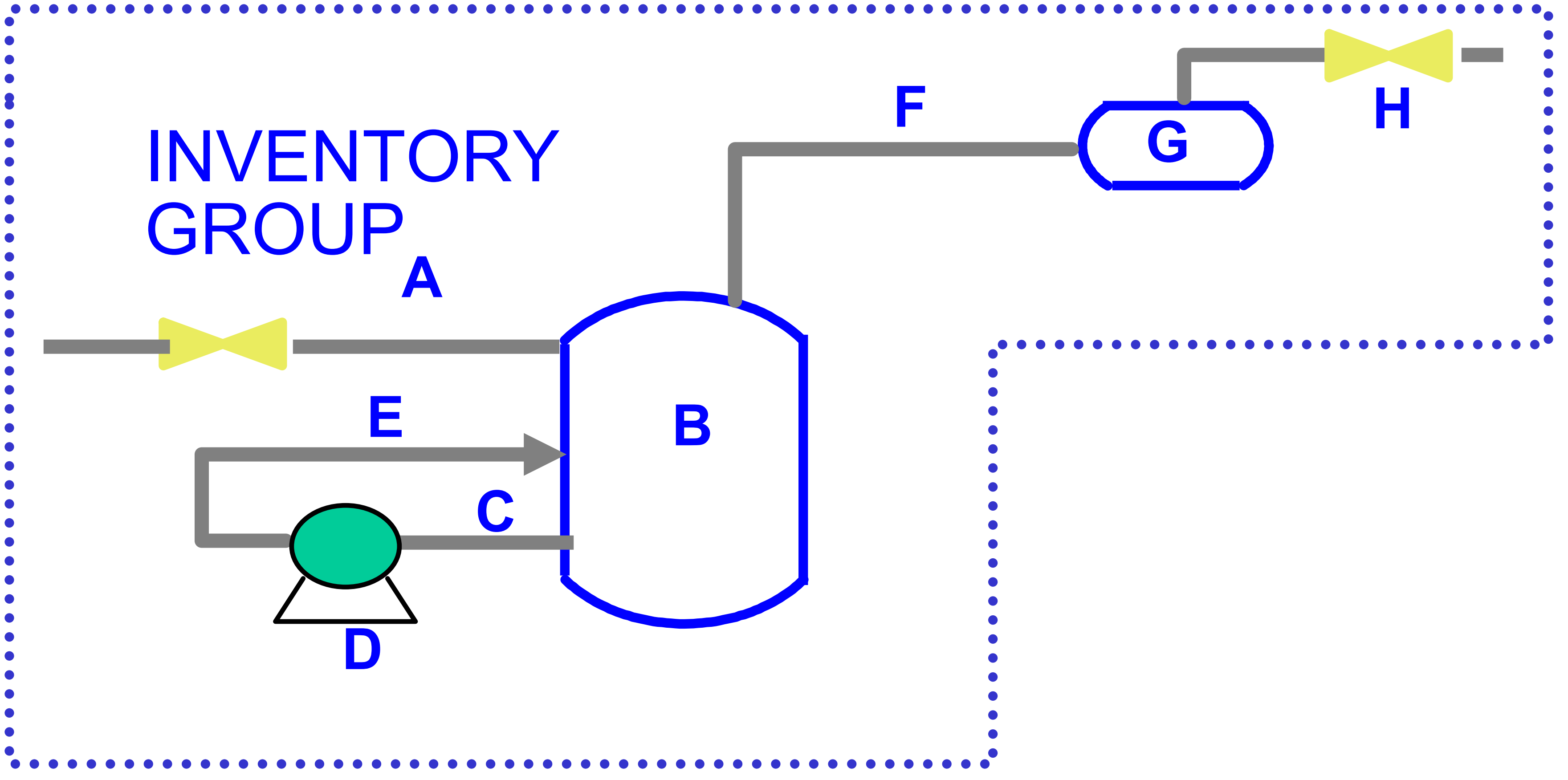
- HEAT from burning destroys equipment, injures people
- PRESSURE WAVE from rapid burning knocks down structures and people, causes flying objects
- TOXIC cloud, for some duration, causes toxic exposure injuries
- ENVIRONMENTAL due to spilled fluid

RBI Effect End Point Criteria

The affected area of flammable/explosive release is based on the following end point criteria:

- Equipment Damage Criteria
  - Explosion Overpressure - 5 psig
  - Thermal Radiation - 12,000 BTU/hr-ft^2 (fireball, jet fire, pool fire
  - Flash Fire - 25% of the area within the lower flammability limits (LFL) of the cloud when ignited
- Personnel Fatality Criteria
  - Explosion Overpressure - 5 psig
  - Thermal Radiation - 4,000 BTU/hr-ft^2 (jet fire, fireball, pool fire
  - Flash Fire - the LFL limits of the cloud when ignited

Inventory Groups



Representative Hole Sizes

RBI approach tries to model full range of leak/break sizes:

- 1/4 inch
- 1 inch
- 4 inch
- rupture

RBI COMBINES ALL FOUR HOLE SIZE RESULTS INTO ONE CONSEQUENCE MEASURE

Calculating or Estimating Inventories

- Inventory is calculated or estimated based on input data available for inventory group, length (height) and diameter

Equipment Type and Inventory Defaults

Pipe: full volume	Column: 0.5 volume
Reactor: full volume	Drum: 0.5 volume
Tank: full volume	Heater: full volume
Exchanger: 0.5 volume	Filter: full volume
Exchanger-TS: 0.25 volume	KO Drum: 0.1 volume
Condenser: 0.5 volume	Pump: zero
Condenser-TS: 0.25 volume	Compressor: zero
FinFan: full volume	

Detection System Rating Guide

Type of Detection System	Detection Classification
Instrumentation designed specifically to detect material losses by changes in operating conditions (i.e., loss of pressure or flow) in the system.	**A**
Suitably located detectors to determine when the material is present outside the pressure-containing envelope.	**B**
Visual detection, cameras, or detectors with marginal coverage.	**C**

Isolation System Rating Guide

Type of Isolation System	Isolation Classification
Isolation or shutdown system activated directly from process instrumentation or detectors, with no operator intervention.	**A**
Isolation or shutdown systems activated by operators in the control room or other suitable locations *remote from the leak*.	**B**
Isolation dependent on manually-operated valves.	**C**

Special Case: Fluids Above AIT

- Fluids released at a temperature above Auto Ignition Temperature are much more likely to ignite
- Treated conservatively in RBI
- P(ignition) = 1 for these cases
- Resulting outcome is fireball (instantaneous) or jet fire (continuous)

Data Entry

- May be necessary to split large or complex vessels into two pieces
  - different damage mechanisms
  - different material of construction
  - different fluid types
  - different fluid phases

Representative Fluid

- Must choose one fluid to represent all fluids in an equipment
- May be necessary to split vessels that have dramatically different fluids

Choosing a Representative Fluid

- Work with the fluid in the largest proportion, on a mass basis
- Try to match molecular weight and normal (atmospheric) boiling point
- Allowance is made in the software to input a stream with some percent toxic
- Flammable consequences not very sensitive to exact fluid match

Representative Fluids

§ C1 – C2	§ **Hydrogen**
§ C3 – C4	§ **Hydrogen sulfide**
§ C5	§ **Hydrogen fluoride**
§ C6 – C8	§ **Water (non-flammable or non-toxic liquid)**
§ C9 – C12	§ **Steam (gas)**
§ C13 – C16	§ **Acid/Caustics**
§ C17 – C25	§ **Aromatics**
§ C25+	§ **EE**
§ Styrene	§ **EG**
§ EEA	§ **Methanol**
§ EO	§ **$AlCl_3$**
§ PO	§ **CO**
§ DEE	

Initial Fluid State

- Liquid or gas only - no mixed phase consideration
- Phase of the fluid INSIDE EQUIPMENT is used

Determining the Final Phase

Phase of Fluid at Steady-State Operating Conditions	Phase of Fluid at Steady-State Ambient Condition	Final Phase in Consequence Calculation
GAS	GAS	GAS
GAS	LIQUID	GAS
LIQUID	GAS	GAS, unless fluid NBP is > 80°F, then LIQUID
LIQUID	LIQUID	LIQUID

Toxic Model

The fifteen choices currently available for toxic are as follows:

1. None
2. H_2S
3. HF
4. Cl_2
5. NH_3
6. EO
7. PO
8. EE
9. $AlCl_3$
10. Phosgene
11. NO2
12. Nitric Acid
13. HCl
14. CO
15. TDI

Consequence Look-Up Results

- Effects modelling for toxic, acids/caustic and steam leaks are also handled by look-up tables
- Toxics, acids/caustics and steam only have injury/fatality consequences
- Personnel hazards handled are
  - Steam
  - Acid/caustic leaks (high, medium and low pressure)

Consequence Look-Up Results

- Steam consequence criteria limited to personnel burns
- Steam consequence for continuous and instantaneous releases
- Acid/Caustic consequence criteria limited to splash (rainout)
- Acid/Caustic splash determined for three release pressures
  - Low pressure: 0 to 20 psig
  - Medium pressure: 21 to 40 psig
  - High pressure: greater than 40 psig
- Acid/Caustic consequence for continuous release only as instantaneous release do not produce rainout
- Isolation and detection credits are applied
- Mitigation systems, such as water spray, are not applied

Detection System Rating	Isolation System Rating	Leak Duration
A	A	20 minutes for ¼ inch leaks 10 minutes for 1 inch leaks 5 minutes for 4 inch leaks
A	B	30 minutes for ¼ inch leaks 20 minutes for 1 inch leaks 10 minutes for 4 inch leaks
A	C	40 minutes for ¼ inch leaks 30 minutes for 1 inch leaks 20 minutes for 4 inch leaks
B	A or B	40 minutes for ¼ inch leaks 30 minutes for 1 inch leaks 20 minutes for 4 inch leaks
B	C	1 hour for ¼ inch leaks 30 minutes for 1 inch leaks 20 minutes for 4 inch leaks
C	A, B, or C	1 hour for ¼ inch leaks 40 minutes for 1 inch leaks 20 minutes for 4 inch leaks

Assessing Post-Leak Response

- Rate the detection, isolation system
- Program will estimate duration of leak, based on the API 581 approach
- Leak duration used in toxic calculation

Adjustments for Detection and Isolation

- Same as shown in API 581
- Adjustments based on ratings of isolation and detection, only
- Fire water deluge not credited

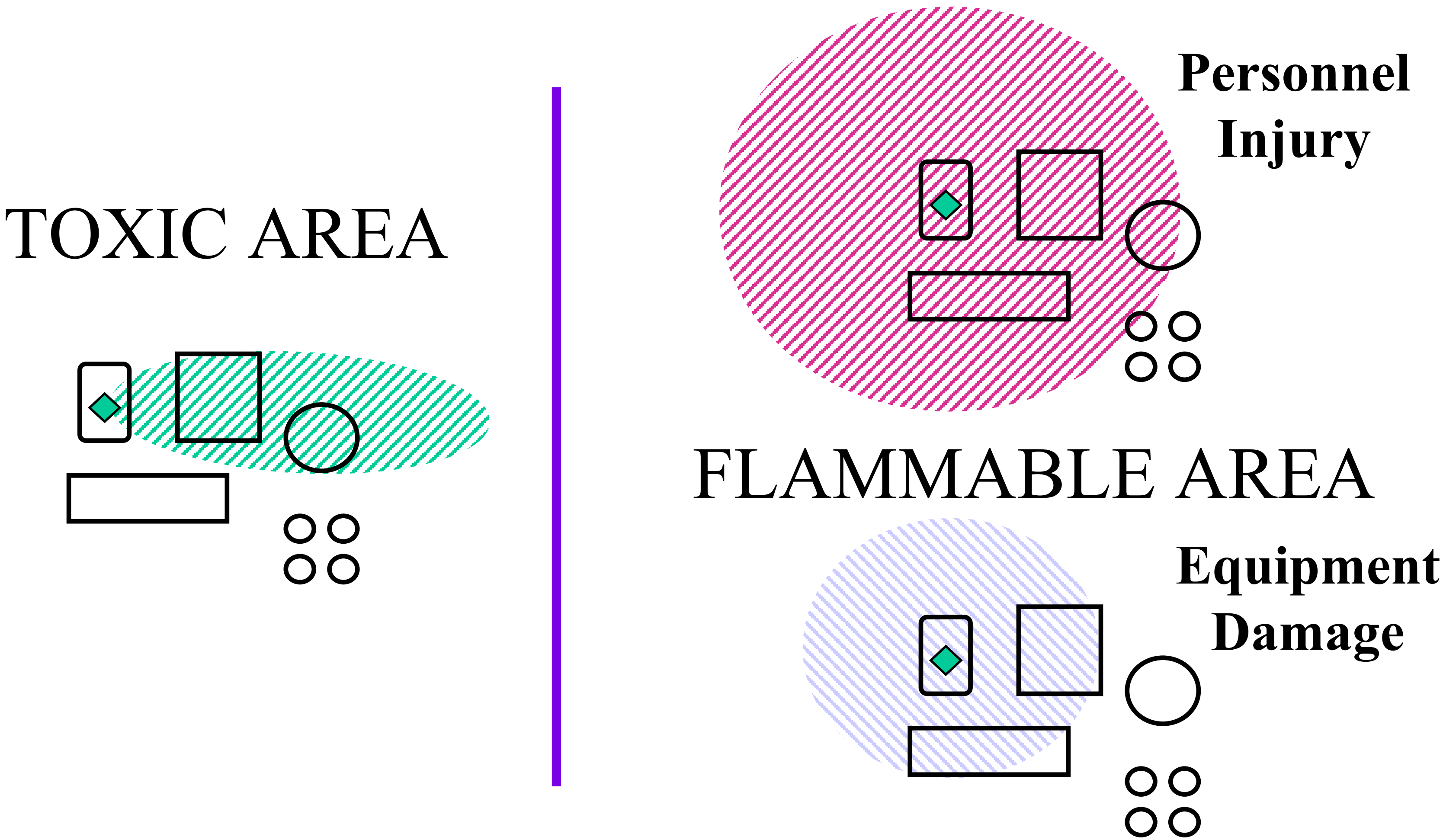
Adjustments for Detection and Isolation Systems

Detection	Isolation	Release Reduction
A	A	25%
A	B	20%
A or B	C	10%
B	B	15%
C	C	none

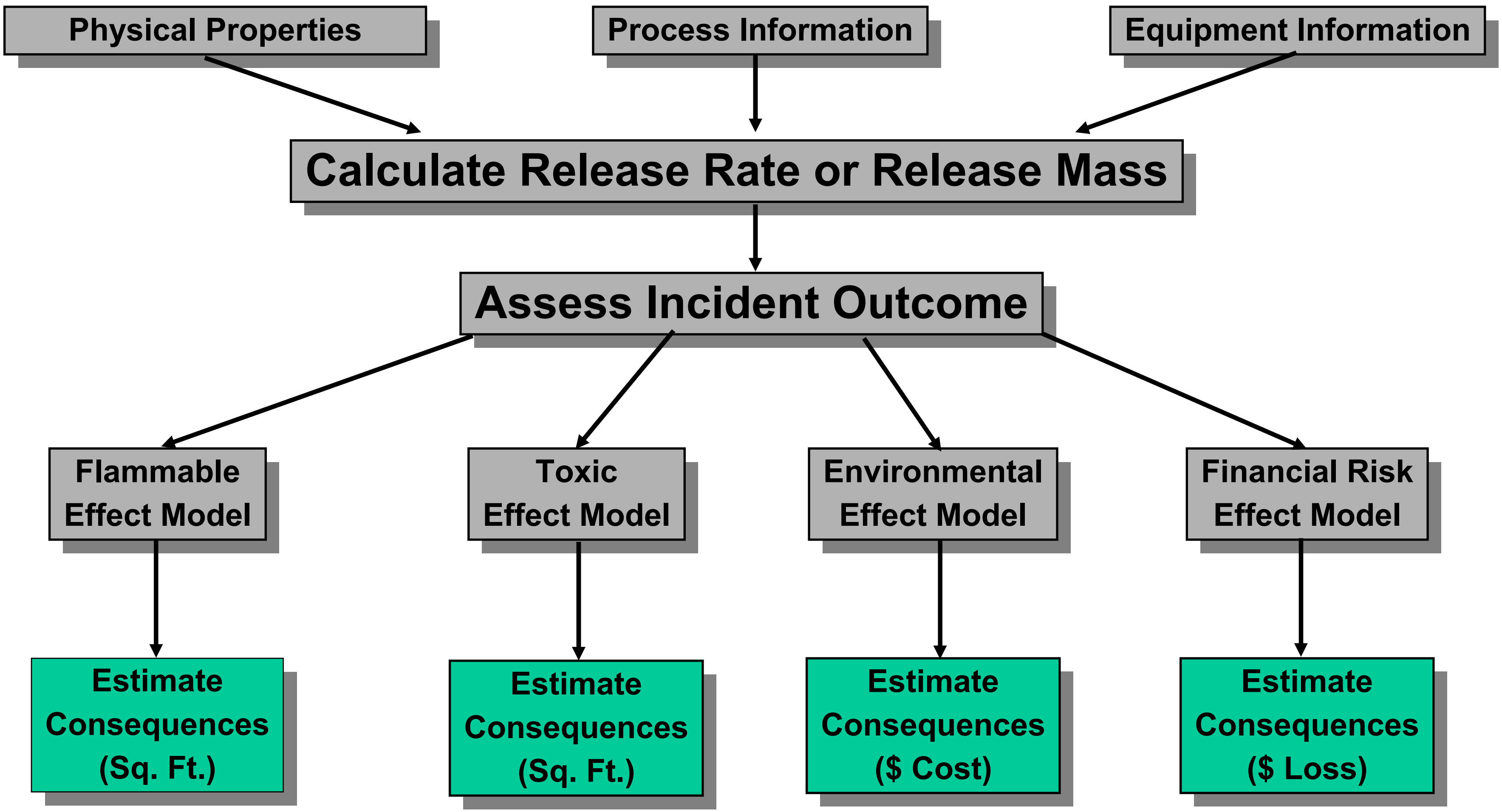
Types of Consequences Analyzed

- Equipment Damage
- Personnel Safety
- Toxic Effect
- Financial Risk

Consequence Measures



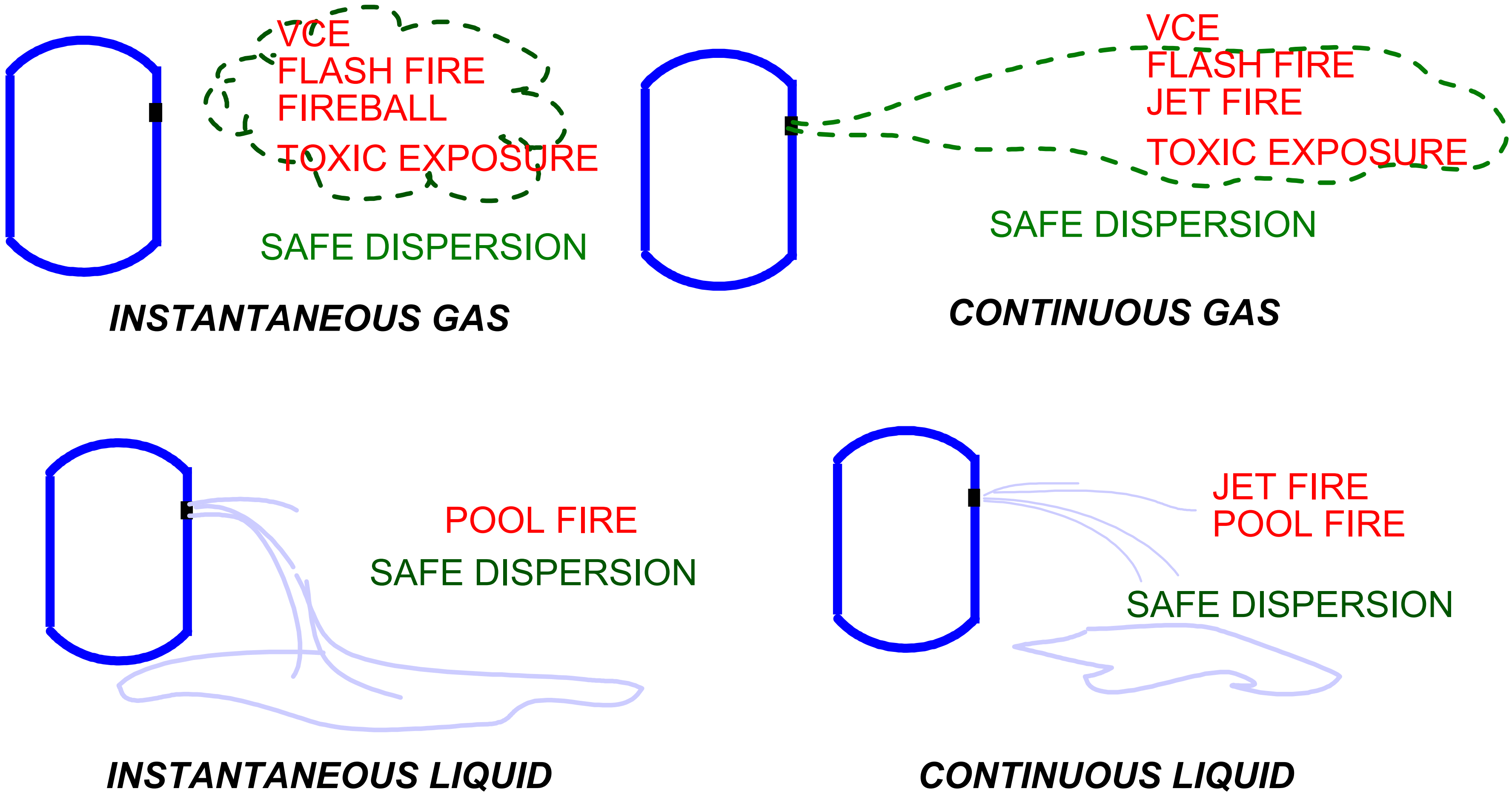
Consequence Calculation



Seven Flammable Effects

1. Safe Dispersion
2. Jet Fires
3. Explosions
4. Flash Fires
5. Fireballs
6. Pool Fires
7. Vapor Cloud Explosions (VCE)

Types of Effects from Releases



Toxic Effects

- Safe Dispersal
- Manifestation of Toxic Effects

NOTE:

If **either** of the conditions is not met, the release of the toxic material results in *safe dispersal*, a technical term used in risk assessment to indicate that the incident falls below the pass/fail threshold.

Stages of Consequence Analysis

- Estimate the Source Term.
- Estimate the effects of the release from the pre-defined equations.

What has been Defined by the Input Data

- Fluid
- Initial Fluid Phase (vapour / liquid space)
- Source temperature
- Source pressure
- Equipment Inventory
- Group Inventory
- Isolation System
- Detection System
- Mitigation System

What is Released (Fluid, Initial Fluid Phase)

Driving Force (Source temperature, Source pressure)

Quantity (Equipment Inventory, Group Inventory)

Adjustment to Release Rate/Release Mass (auto in software) (Isolation System, Detection System, Mitigation System)

Estimating Release Rate

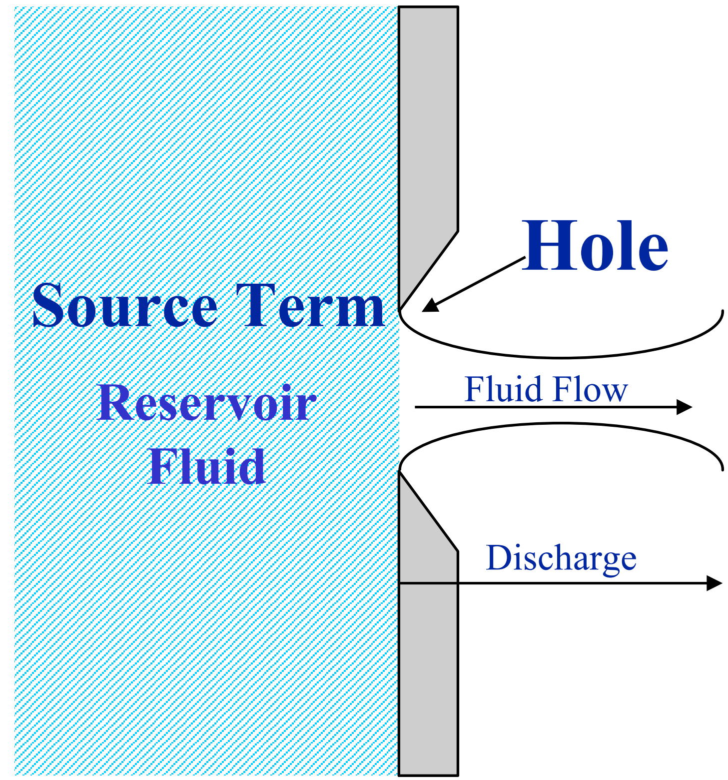
- Release rate calculation based on phase of fluid at steady-state operating conditions
  - Discharge of liquid through orifice
  - Discharge of high pressure gas through orifice (sonic)
  - Discharge of low pressure gas through orifice (subsonic)

Estimating Release Mass

- Release mass estimated as the lesser of two quantities
  - Mass of equipment item plus the mass that can be added to it within 3 minutes
  - Total mass in the Inventory Group
- Release mass will not exceed total mass in the Inventory Group

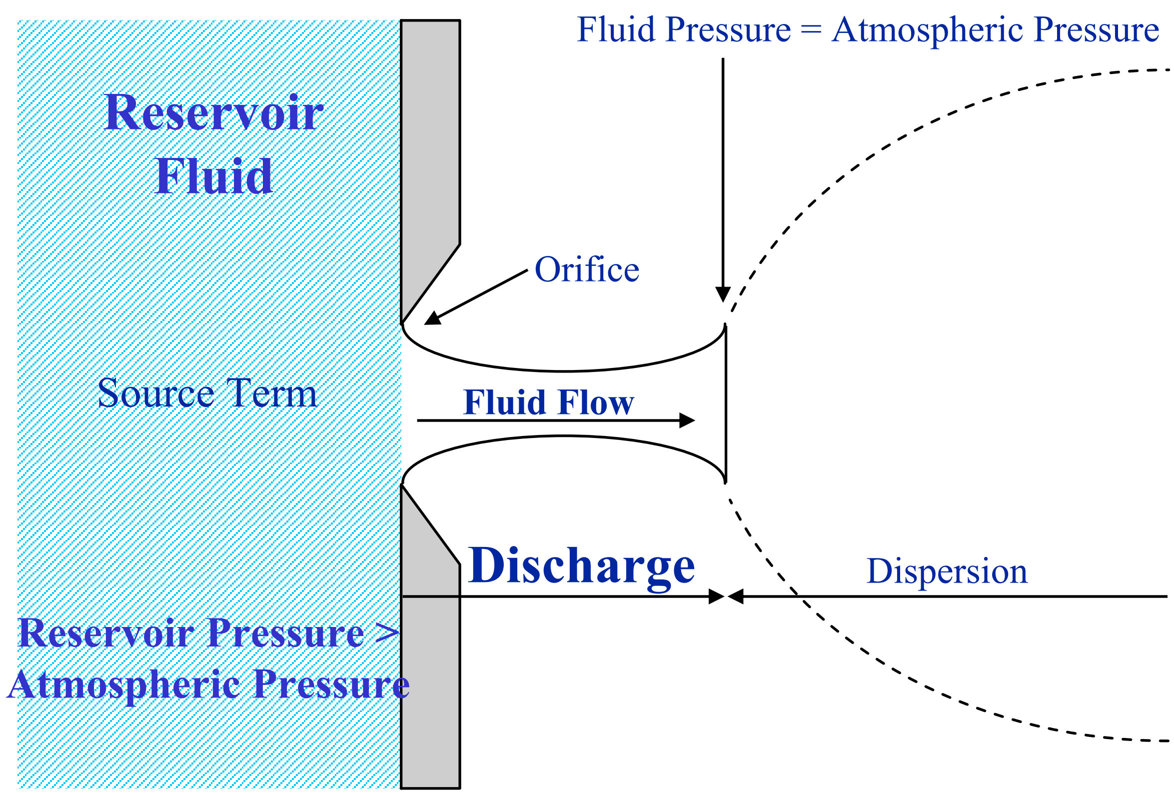
Source Term to Discharge

- Analyst defines fluid type, fluid phase, steady state operating conditions, equipment inventory and group inventory
- Software calculates release rate and release mass for various hole sizes
- Analyst defines mitigating systems that may reduce release rate or release mass



Discharge to Dispersion

- Software determines dispersion type
  - Continuous
  - Instantaneous
- Software determines final fluid phase for effect modelling

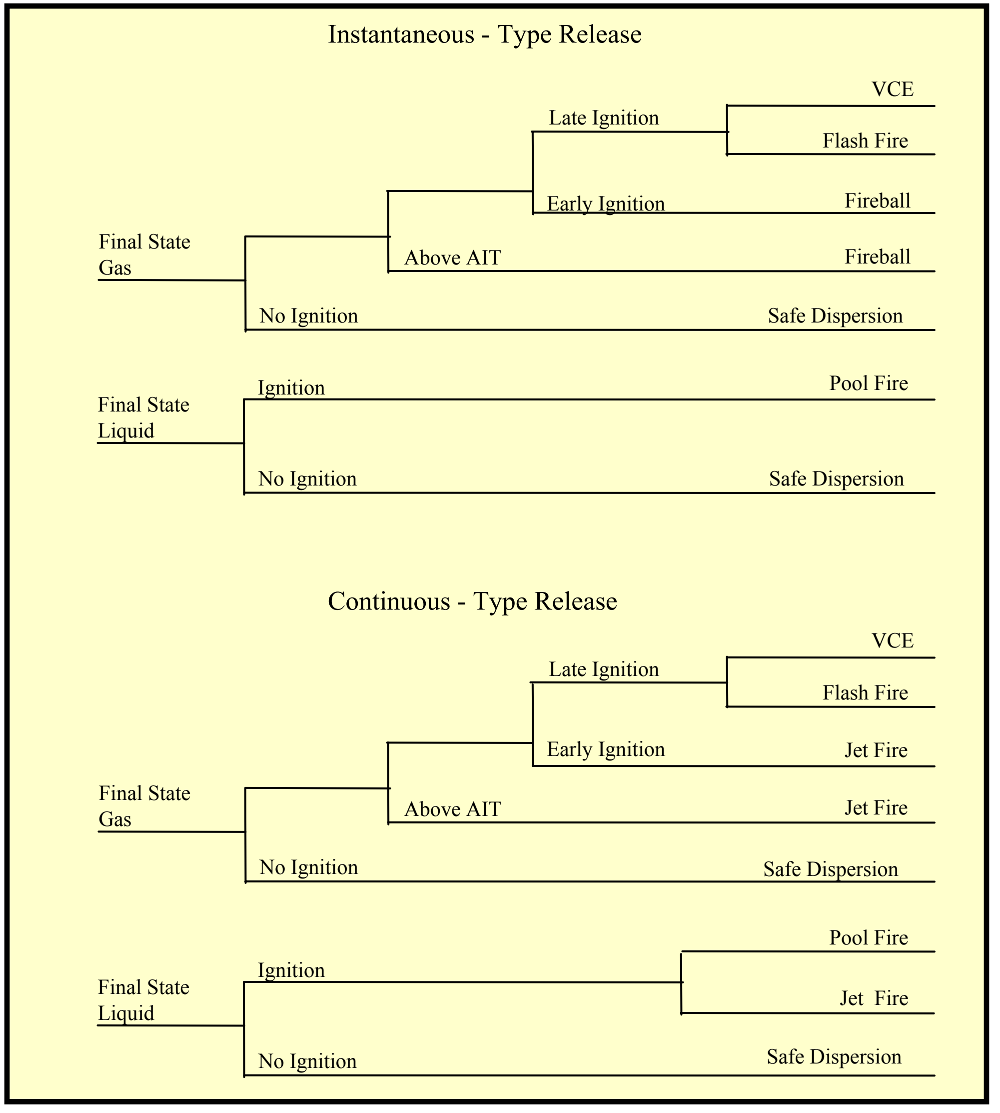


Effects Modelling

- Effects Modelling based on look-up tables
  - Flammable Materials
  - Toxic Materials
  - Personnel Hazard
- Flammable material Look-up tables development
  - RBI Event trees used to determine relative outcome probabilities
  - PHAST runs used to determine magnitude (expressed in area affected) of flammable/explosive release
  - Results are combined to develop equations used in the look-up tables

RBI Event Trees

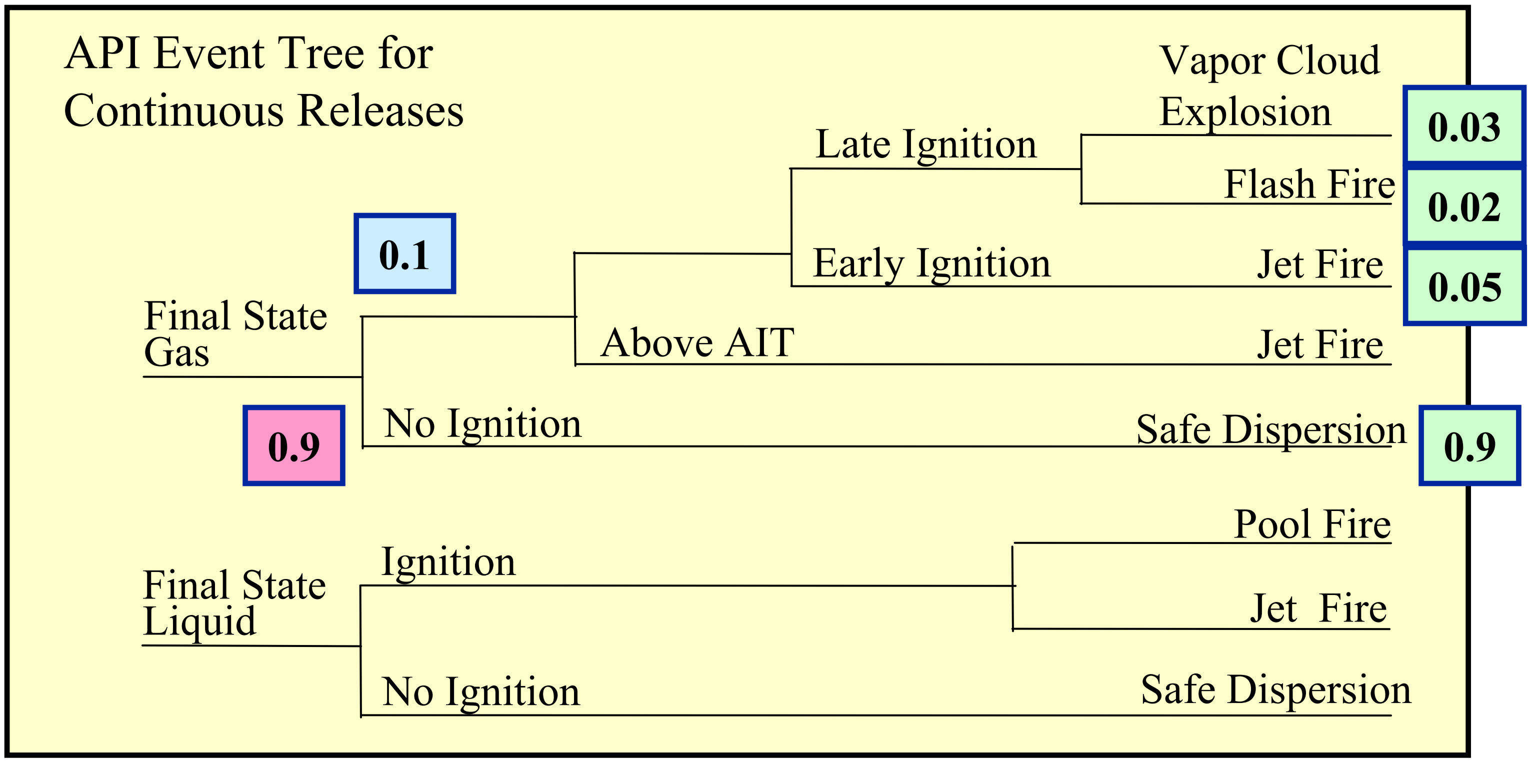
- A single release can have several outcomes.
- Event trees are used to determine the possible outcomes for a release.



RBI Event Trees

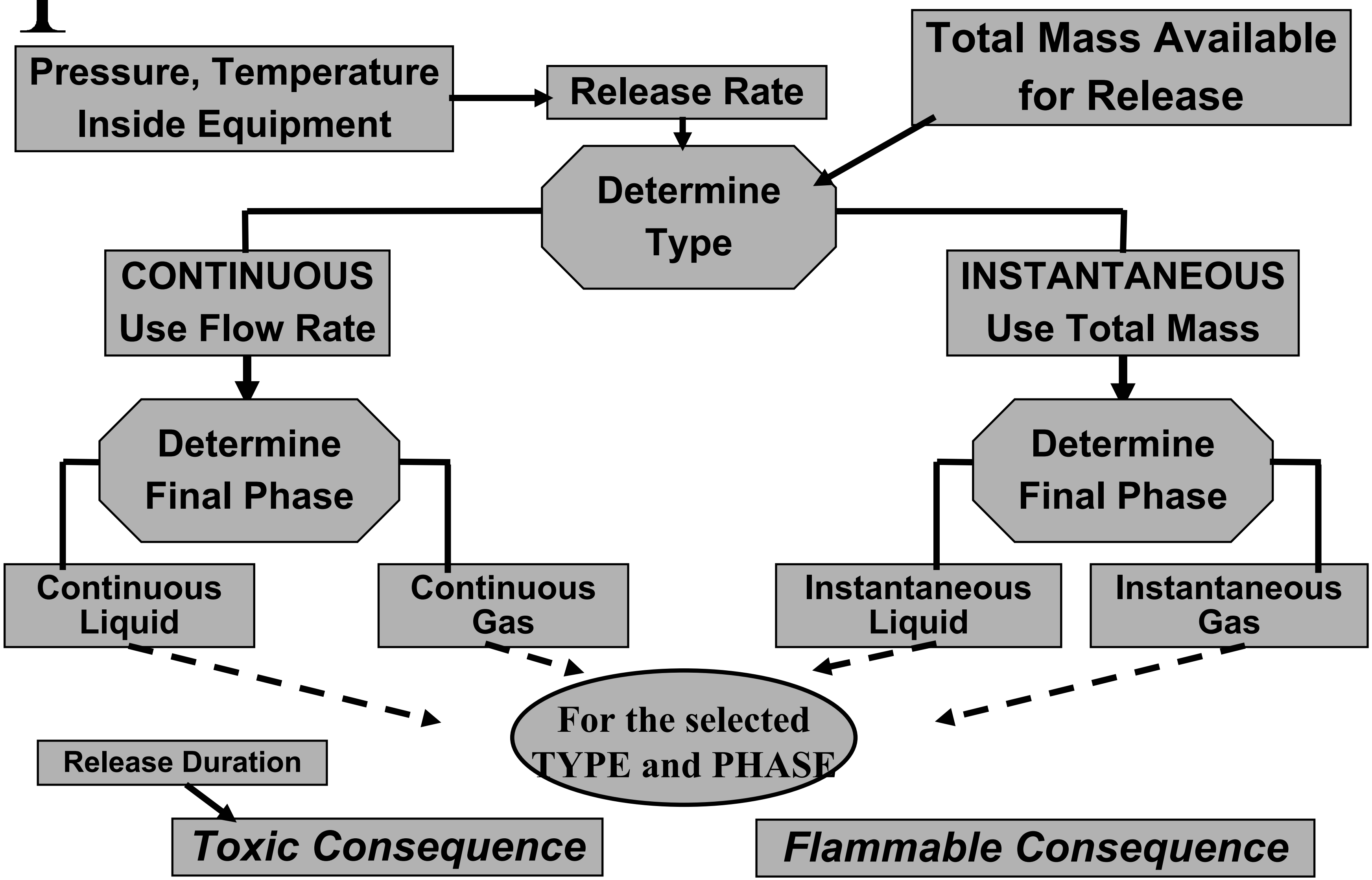
RBI Event Tree - Continuous Release

Probabilities for C3 - C4 - Final State Gas Processed Below AIT

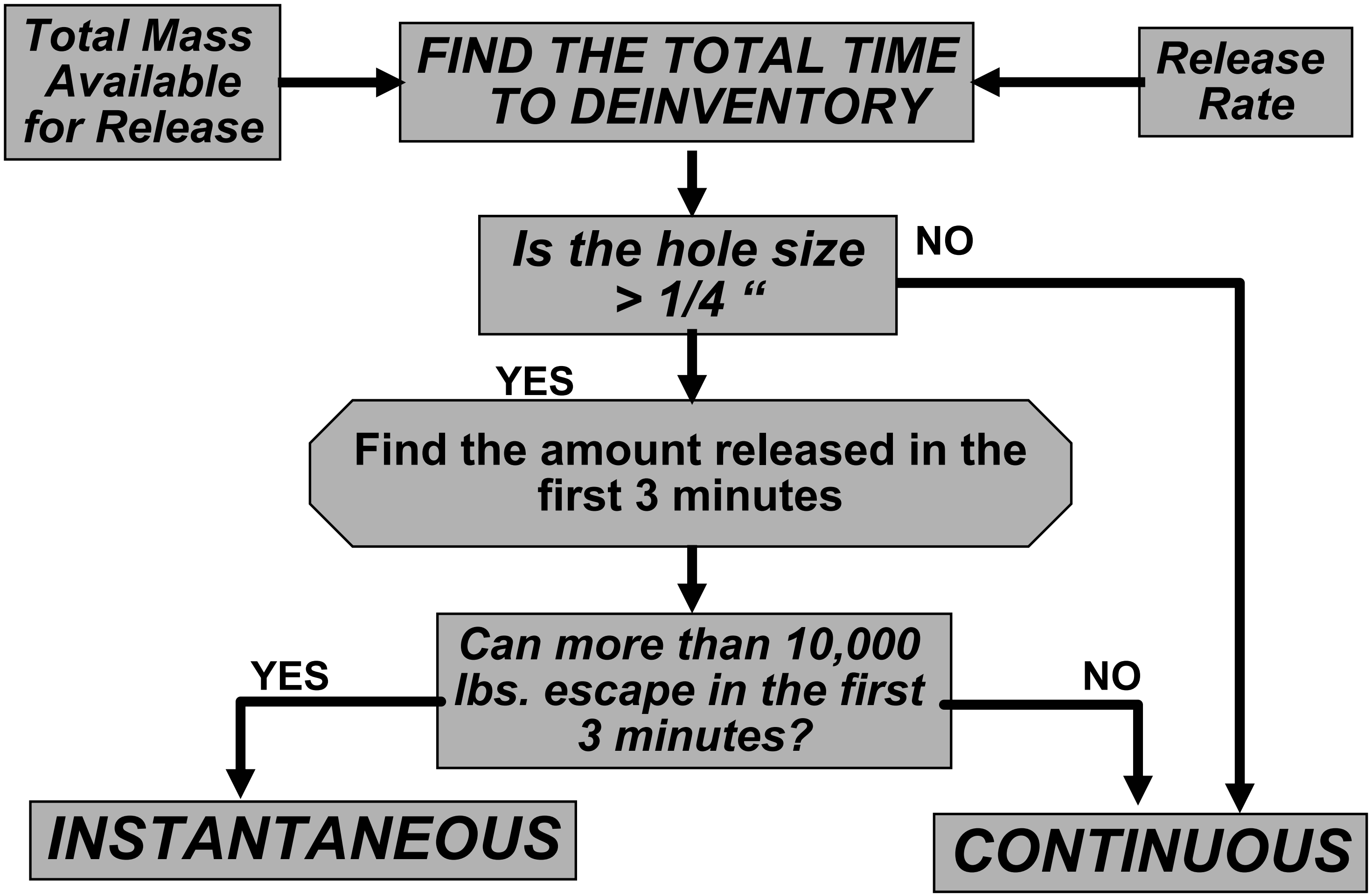


Stage 1 - Estimate the Source Term

1. Determine the available inventory.
2. Determine the release rates.
3. Determine the type of release.
4. Determine the phase of the release.
5. Estimate the effects of Mitigation Systems.
6. Determine the consequence of the release.


Pressure, Temperature Inside Equipment
Release Rate
Total Mass Available for Release
Determine Type
CONTINUOUS Use Flow Rate
INSTANTANEOUS Use Total Mass
Determine Final Phase
Determine Final Phase
Continuous Liquid
Continuous Gas
Instantaneous Liquid
Instantaneous Gas
For the selected TYPE and PHASE
Release Duration
Toxic Consequence
Flammable Consequence

Determining the Type of Release



Estimating the Effects of Mitigation Systems

In RBI, consequence mitigation systems are treated in two ways:

1. Systems that detect and isolate a leak
2. Systems that are applied directly to the hazardous material to reduce consequences

Stage 2 - Determine the Consequence Category

- Consequences are estimated from a set of empirical equations, using release rate (for continuous releases) or release mass (for instantaneous releases) as input.
- The appropriate look-up tables and curves based on:
  - Representative fluid
  - Release type (instantaneous or continuous)
  - Release phase (liquid or gas)
  - Auto-ignition possible?
  - Duration (toxic only)

Consequence Category Definitions

If the Consequence Score is	then the Consequence Category is
from 0 to 100	A
between 100 and 1000	B
between 1000 and 3,000	C
between 3,000 and 10,000	D
greater than 10,000	E

Program Settings

ESTABLISHES THE BASES FOR CONSEQUENCE RESULTS

- Equipment Damage Area
- Potential Fatality Area
- Toxic Area
- Maximum

Nature of RBI
Likelihood Analysis

Part 6

Nature of RBI Likelihood Analysis

- ***Intended for relative measures and rankings***
- Rate/Severity of damage identified by user
- Probability of leak calculated by software
- Likelihood reported by the Damage Factor (DF)
- Reported as Damage factor and Likelihood (Probability) of Failure

Key RBI Terms

- Event/Failure - refers to a leak at a pressure boundary.
- Damage Factor is the extent to which the specific item is expected to fail compared with the average population (Range 1 to 5,000)

Inspection and Risk

The likelihood of a failure can be controlled by

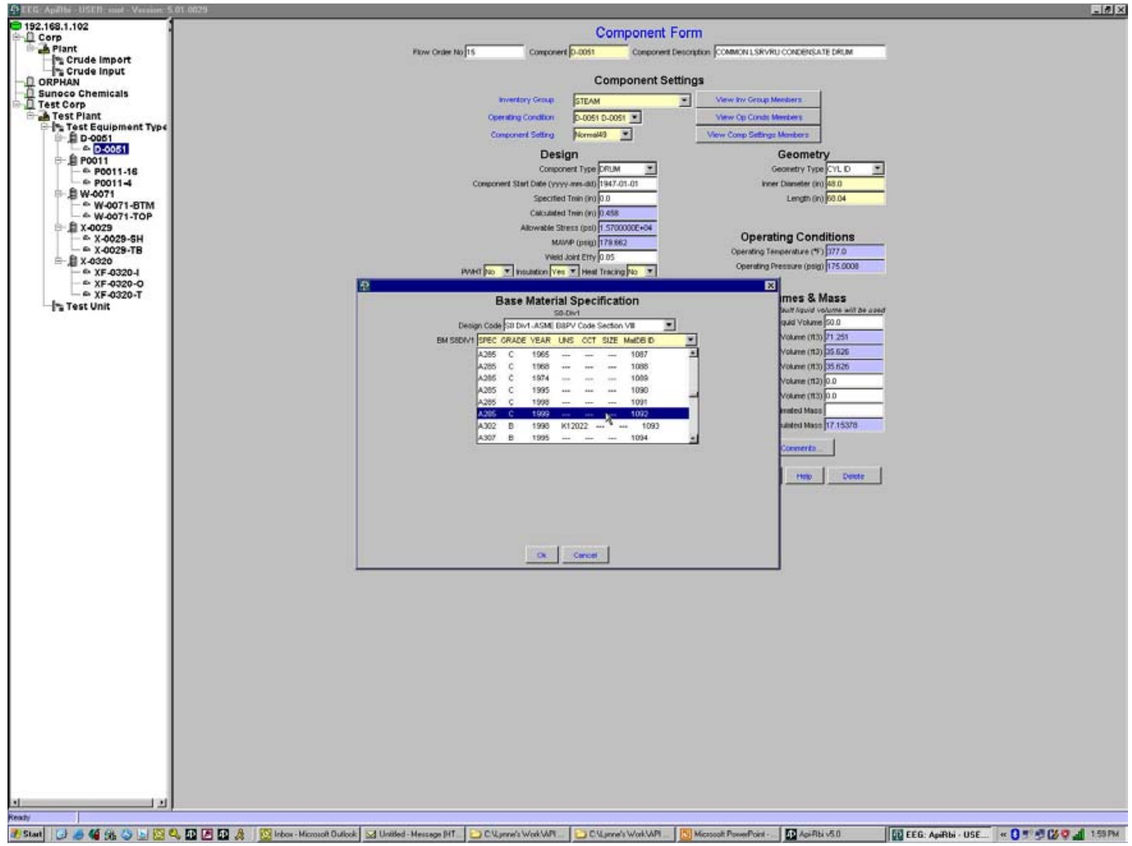
- Recognizing the types of damage possible in process equipment.

AND

- Using the correct inspection method at the right location and frequency to find it.

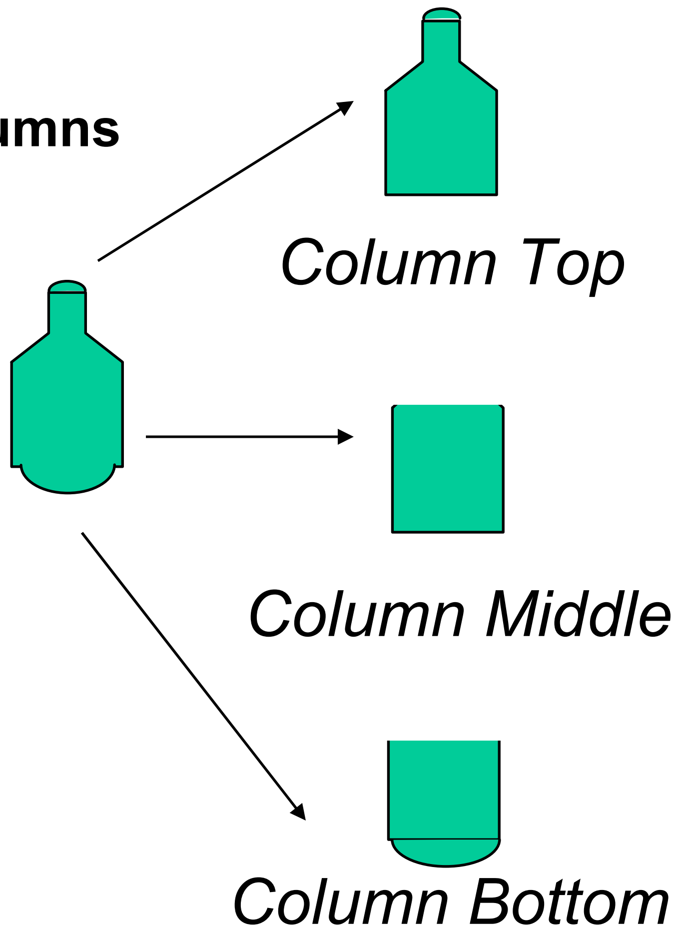
Component – Material Database

- Pulldown menu for base material and clad/overlay
- All six fields are populated from pulldown



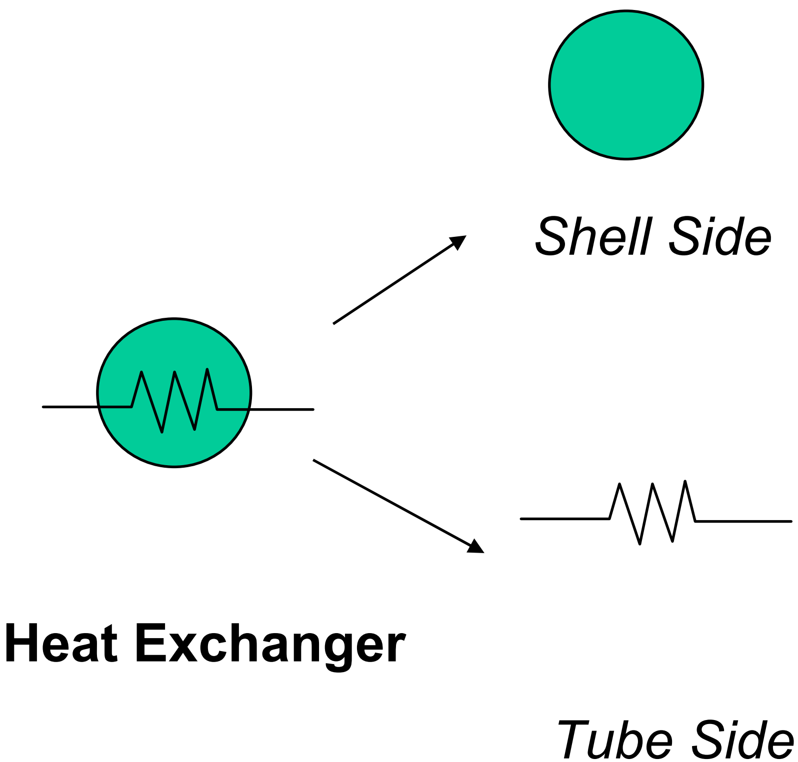
Likelihood Considerations

Columns



- Use rate/severity and damage mechanisms for each section
- Use overhead outlet process characteristics for column tops
- Use bottom process characteristics for column bottoms
- Can include a Middle – consequence is modeled similar to the Top

Likelihood Considerations



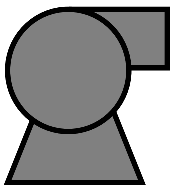
<u>Shell</u>

- Use material of construction for shell
- Use average of process inlet/outlet characteristics

<u>Channel</u>

- Use Channel thickness
- Use material of construction for channel
- Use average of process inlet/outlet characteristics

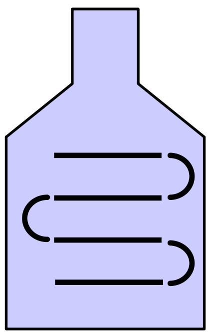
Likelihood Considerations



Pumps

- No damage type and corrosion rate is necessary
- Use suction for inlet pipe conditions and discharge for outlet pipe conditions

Likelihood Considerations

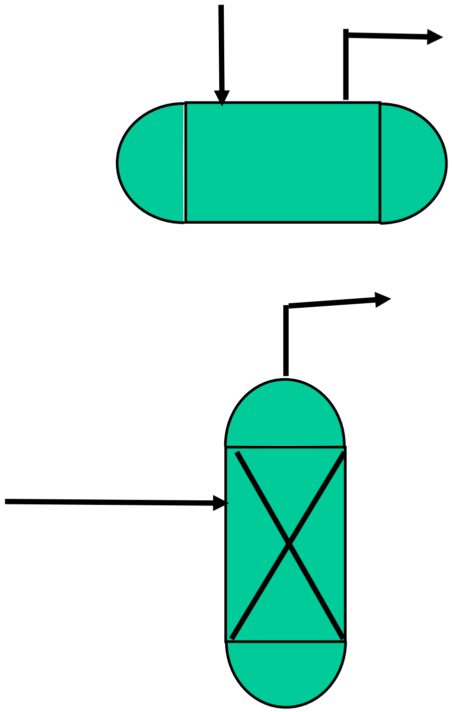


Furnaces

To be added to Version 5.0 in late 2004

- Use radiant section conditions
- Use average tube metal temperature or process outlet plus 100^{O}F
- Use highest tube metal temperature for upset condition

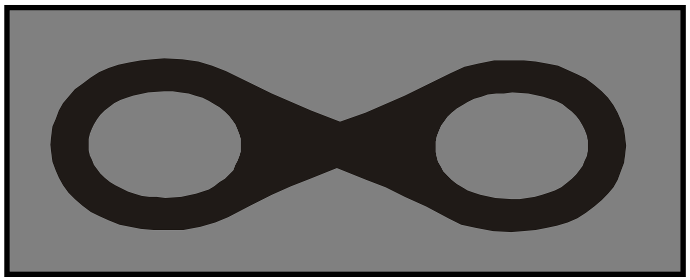
Likelihood Considerations



- Use average operating conditions.
- Use thickness average thickness of shell courses. (or Thinnest Course)
- Use process fluid characteristics of inlet

Drums, reactors, piping, and other equipment

Likelihood Considerations



Fin Fans

- Modeled in three segments: inlet box, outlet box, tubes
- Header boxes modeled as drum (for lower G_{FF})
- Use Material of Construction for boxes and tubes (remember tubes may be different material)
- Length is generally the length of one tube

Damage Modules

The damage modules serve the following four functions:

1. Screen for the damage mechanisms under normal and upset operating conditions.
2. Establish a damage rate in the environment.
3. Quantify the effectiveness of the inspection program.
4. Calculate the modification factor to be applied to the “generic” failure frequency.

Damage Mechanisms

Thinning Module
- CUI
- Atmospheric
- HCl
- HT Sulfide. & Nap. Acid
- HT H_2S/H_2
- H_2SO_4
- HF
- CO_2
- Acid Sour Water
- Amine
- HT Oxidation
- Cooling Water
- Soil/Interface

Stress Corrosion Cracking
- Caustic
- Amine
- SSC
- HIC/SOHIC
- Carbonate
- PTA
- Cl SCC
- HSC-HF
- HIC/SOHIC-HF

High Temperature Hydrogen Attack
- HTHA

Furnace Tubes
- Wrought Furnace Tubes
- Cent. Case Tubes

Mechanical Damage
- Erosion
- Brittle Fracture
- Fatigue (Thermal)
- Fatigue (Cyclic)
- Creep/Creep Cracking

Metallurgical Damage
- Temper Embrittlement
- 885° F Embrittlement
- Sigma Phase

Steps for Calculating the Damage Factor

1. Screen for damage mechanisms and establish an expected damage rate.
2. Determine the effectiveness of inspection programs in confirming damage levels and damage rates.
3. Calculate the effect of the inspection program on improving the confidence level in the damage rate.
4. Calculate the probability that a given level of damage will exceed the damage tolerance of the equipment and result in failure.
5. Calculate the Damage factor (DF).
6. Calculate the composite DF for all damage mechanisms.

Damage States

Damage State Category	Thinning Rate
Damage State 1 The damage in the equipment is "no" worse than what is expected based on damage rate models or experience.	The rate of thinning is less than or equal to the rate predicted by past inspection records, or historical data if no inspections have been performed.
Damage State 2 The damage in the equipment is "somewhat" worse than anticipated. This level of damage is sometimes seen in similar equipment items.	The rate of thinning is as much as twice the predicted rate.
Damage State 3 The damage in the equipment is "considerably" worse than anticipated. This level of damage is rarely seen in similar equipment items, but has been observed on occasion industry wide.	The rate of thinning is as much as four times the predicted rate.

Damage Modules Supplements

- Key to the LOF calculation (Damage Factor)
- They are mini-experts systems to provide an estimate of the likelihood of failure due to various potential damage mechanisms
- Has been particularly tailored for the refining industry with damage mechanisms active for carbon, low alloy, and stainless steels
- Require additional process information for operation
- Main Modules (damage types) are equally applicable to all industries

Damage Modules Supplements

- They provide conservative estimates of a corrosion rate, or likely degree of damage due to various forms of cracking (stress corrosion and mechanical)
- Inspection/monitoring are factored in by putting a certain degree of confidence on the estimate of damage measured/observed based on the scope and techniques used for specific mechanisms

Component – T_{min} Calculator

- Calculated T_{min} is based on code calculations specific to geometry type
- Uses material database selection properties to perform calculations
- Furnished Thickness is actual supplied component thickness (including corrosion allowance)
- Nominal Thickness is a specified design thickness, used if Furnished Thickness not provided (piping only)
- Uses the larger of a structural T_{min} and Calculated T_{min}
- User override by entering Specified T_{min} and corrosion allowance, if desired

Version 5.0 Component Form

Component Form

Flow Order No: 15 | Component: D-0051 | Component Description: COMMON LSRVRU CONDENSATE DRUM

Component Settings

Inventory Group	STEAM	View Inv Group Members
Operating Condition	D-0051 D-0051	View Op Conds Members
Component Setting	Normal49	View Comp Settings Members

Design

Component Type	DRUM
Component Start Date (yyyy-mm-dd)	1947-01-01
Specified Tmin (in)	0.0
Calculated Tmin (in)	0.458
Allowable Stress (psi)	1.5700000E+04
MAWP (psig)	179.662
Weld Joint Effy	0.85

PWHT: No | Insulation: Yes | Heat Tracing: No

Geometry

Geometry Type	CYL ID
Inner Diameter (in)	48.0
Length (in)	68.04

Operating Conditions

Operating Temperature (°F)	377.0
Operating Pressure (psig)	175.0008

Material

Material:	Base	Cladding
Furnished Thickness (in)	0.5	0.0
Corrosion Allow (in)	0.125	
Material Cost Multiplier		
Spec	A285	
Grade	C	
Year	1999	
UNS	---	
CCT	---	
S/T	---	

Get Base | Get Clad

Volumes & Mass

If not specified default liquid volume will be used

Percent Liquid Volume	50.0
Volume (ft3)	71.251
Calculated Vapor Volume (ft3)	35.626
Calculated Liquid Volume (ft3)	35.626
Est Vapor Volume (ft3)	0.0
Est Liquid Volume (ft3)	0.0
Component Estimated Mass	
Component Calculated Mass	1141.226

Comments...

Save Data | Help | Delete

Operating Condition ID

- Designed to be used for multiple operating conditions, e.g. intermittant service, multiple operating conditions; start-up, shutdown, regeneration, different process fluids/toxics
- Inventory calculator
  - Calculated component volume based on liquid and vapor contents
  - Uses BRD liquid levels for component type
- Manually entered liquid level override
- Manually adjust toxic leak duration (Default 3 minutes)

Version 5.0 DF Thinning Damage Form

DF Forms - Thinning Damage

Component: D-0051 | COMMON LSRVRU CONDENSATE DRUM | What-If: No

Comments...

Input Data

Online Monitoring	N-None
Injection Point	No
Injection Point Insp	No
Deadleg	No
Deadleg Inspection	No
Thinning Type	General
BM Gov Thin Mech	
CM Gov Thin Mech	

Base Material

BM Corrosion Rate	Estimated
Estimated Rate (mpy)	3.0
Measured Rate (mpy)	0.1
Calculated Rate (mpy)	

Calc

Damage Drivers

BM Spec	A285
BM Grade	C
Design Temperature (°F)	475.0
Design Pressure (psig)	250.0012
Comp Start Date (yyyy-mm-dd)	1947-01-01
Furnished Thk (in)	0.5
Insp Date	1947-01-01
Measured Thickness (in)	0.5
Operating Conditions	D-0051_D-0051
Operating Temperature (°F)	377.0
Operating Pressure (psig)	175.0008

Analysis Results

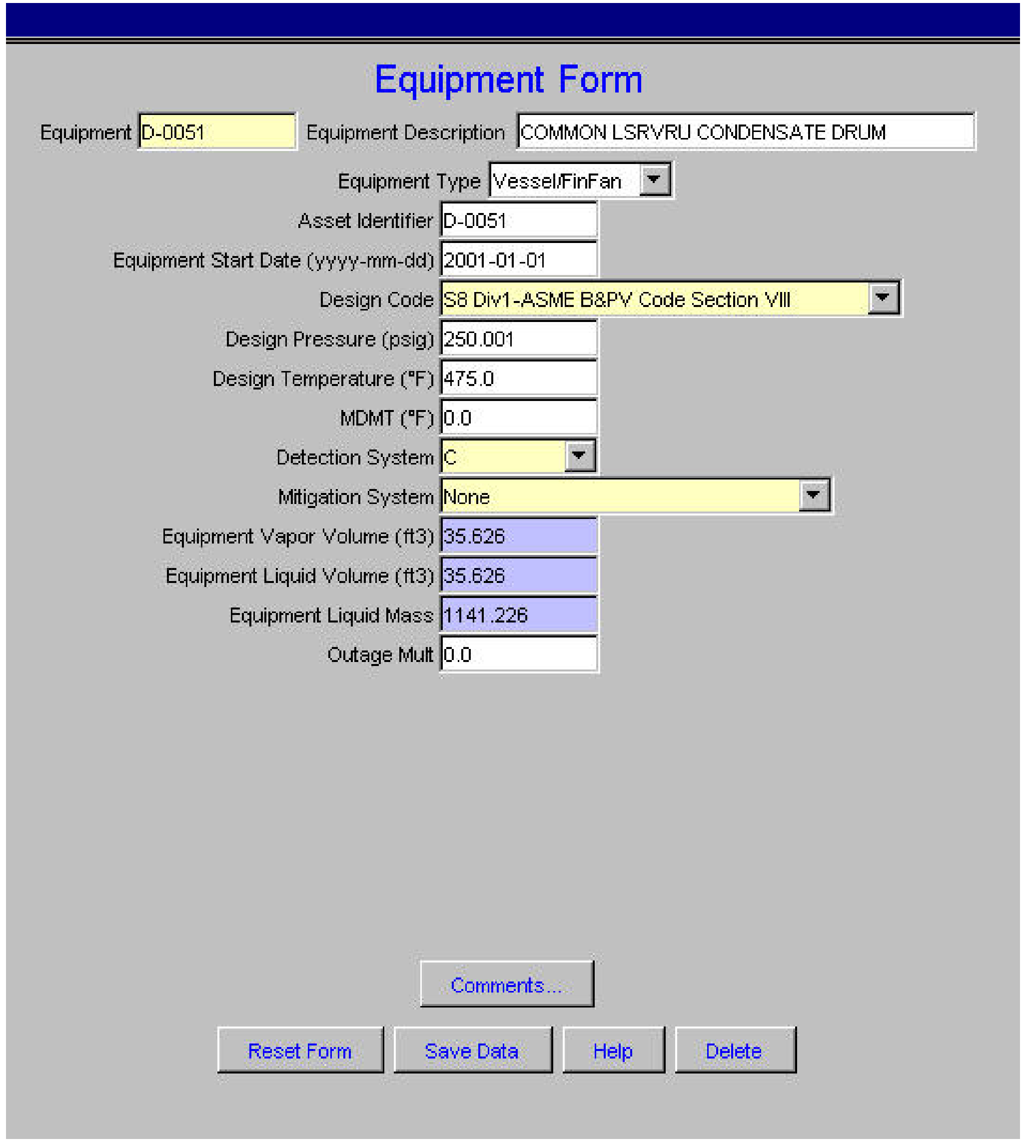
Highest Effective Insp	D
No Highest Effective Insp	6.000000
Age (yrs)	57.30869
DF	383.4016
Likelihood Category	4

Risk Summary

Total DF	383.4016
POF	4.4474583E-02
COF (ft²)	780.1792
Risk Matrix	4B
Risk Category	MEDIUM
Maximum Risk (ft²/yr)	34.69814
Financial Risk ($/yr)	14011.49

Save Input Data | Help | Delete | Calculate

Version 5.0 Equipment Form



Equipment Form

Equipment	D-0051
Equipment Description	COMMON LSRVRU CONDENSATE DRUM
Equipment Type	Vessel/FinFan
Asset Identifier	D-0051
Equipment Start Date (yyyy-mm-dd)	2001-01-01
Design Code	S8 Div1-ASME B&PV Code Section VIII
Design Pressure (psig)	250.001
Design Temperature (°F)	475.0
MDMT (°F)	0.0
Detection System	C
Mitigation System	None
Equipment Vapor Volume (ft3)	35.626
Equipment Liquid Volume (ft3)	35.626
Equipment Liquid Mass	1141.226
Outage Mult	0.0

Comments...

Reset Form | Save Data | Help | Delete

Damage Mechanisms - Thinning

- Corrosion rate associated with Base Material and Clad/Overlay
- Modified ar/t

$$\frac{ar}{t} = \max\left[1 - \left(\frac{sthk - crate \cdot time}{t_{\min} + C.A.}\right), 0.0\right]$$

where

sthk – most recent thickness reading

crate – corrosion rate of the base or cladding material, as applicable, estimate at the time of the most recent thickness reading

time – time difference between the RBI date and the date of the most recent thickness reading

C.A. – corrosion allowance

- Smoothing of Damage Factors in ar/t table
- Smoothing of corrosion rates in supplements

Bayesian Updating

- Used by the damage modules to determine the probability of a given damage state occurring in the equipment being evaluated.

BAYES' THEOREM

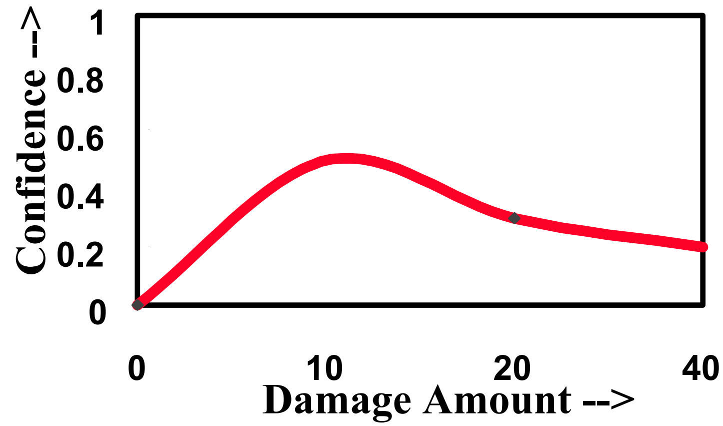
This theorem combines the *prior* probabilities $p[A_i]$ (the expected state) with the *conditional* probabilities, $p[B_k | A_i]$ (the inspection effectiveness) to yield an expression for the probability that an equipment item is in any state A_i given that the item was observed to be in state A_k which results in observation B_k,

$$p[A_i | B_k] = \frac{p[B_k | A_i]\, p[A_i]}{\sum_{j=1}^{j=n} p[B_k | A_j]\, p[A_j]}$$

The probabilities, $p[A_i | B_k]$ are call *posterior* probabilities.

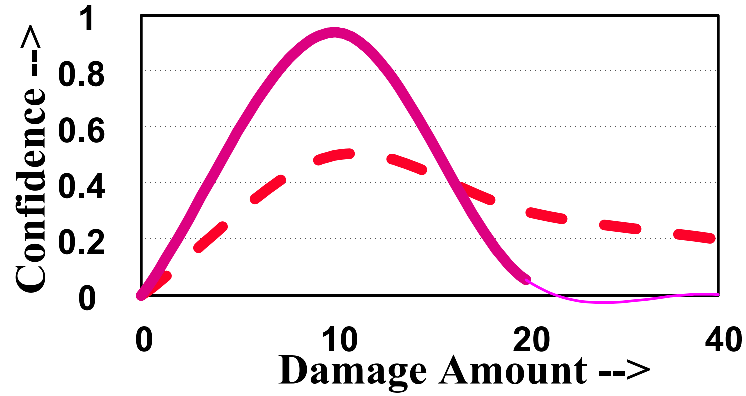
Damage Modules Evaluation: Inspection Updating

- Prior (or current) knowledge, expectation, or expert opinion



- Perform inspection or test to improve knowledge, expectation, or expert opinion

- Updated knowledge, expectation, or expert opinion



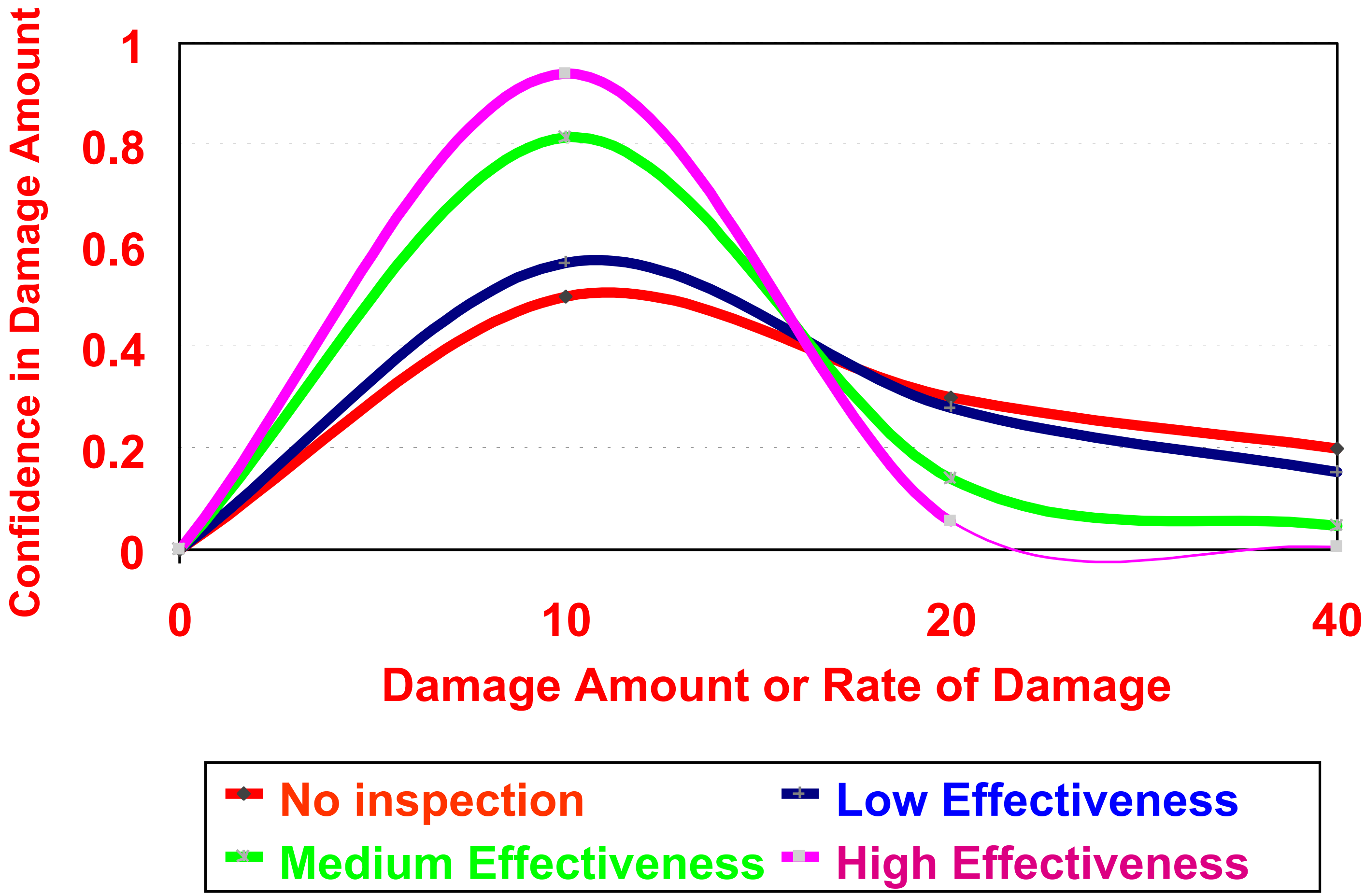
Inspection Effectiveness

- Five categories of effectiveness:
  - “Highly” effective - A
  - “Usually” effective - B
  - “Fairly” effective - C
  - “Poorly” effective - D
  - “Ineffective” - E
- Suggested examples are presented in each Damage Module

Effectiveness Categories

Highly Effective	Inspection methods correctly identify the anticipated in-service damage in nearly every case.
Usually Effective	The inspection methods will correctly identify the true damage state most of the time.
Fairly Effective	The inspection methods will correctly identify the true damage state about half of the time.
Poorly Effective	The inspection method will provide little information to correctly identify the true damage state.
Ineffective	The inspection method will provide almost no information that will correctly identify the true damage state.

Effect of Inspection on Likelihood and Risk



Likelihood of Failure Calculation

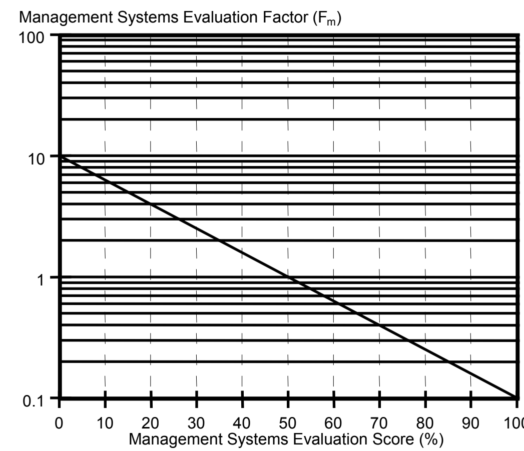
Generic Failure Frequency X Equipment Modification Factor X Management Systems Evaluation Factor

(F_E) (F_M)

Generic Equipment Failure Frequencies

Equipment Type	Source	1/4"	1"	4"	Rupture
Centrifugal Pump	1	6X10**-3	5X10**-4	1X10**-4	-------
Column	2	8X10**-5	2X10**-4	2X10**-5	6X10**-6
Filter	1	9X10**-4	1X10**-4	5X10**-5	1X10**-5
Heat Exchangers	1	4X10**-5	1X10**-4	1X10**-5	6X10**-6
Piping (8")	3	3X10**-7	3X10**-7	8X10**-8	2X10**-8
Pressure Vessels	2	4X10**-5	1X10**-4	1X10**-5	6X10**-6
Storage Tanks	5	4X10**-5	1X10**-4	1X10**-5	2X10**-5

- Damage Factor
  - Damage Rate
  - Inspection Effectiveness
- Universal Subfactor
  - Plant Condition
  - Cold Weather
  - Seismic Activity
- Mechanical Subfactor
  - Equipment Complexity
  - Construction Code
  - Life Cycle
  - Safety Factors
  - Vibration Monitoring
- Process Subfactor
  - Continuity
  - Stability
  - Relief Valves



Critical Factors in Likelihood Analysis

EXAMPLE: Thinning Likelihood Analysis

- Material of Construction (pressure containment **and liner**)
- Process Operation/Upset Conditions
  - temperature
  - corrosive elements and concentrations
- Damage Mechanism(s) active
  - including Localized vs. General corrosion
- **Installation and Years in current Service**
- **Furnished Thickness**
- **Measured Thickness at Inspection Dates**
- Corrosion Rate/Damage Severity
- Inspection Effectiveness/Number of Inspections

General vs. Localized Corrosion

Thinning Mechanism	Type of Thinning
Corrosion Under Insulation (CUI)	Localized
Hydrochloric Acid (HCl) Corrosion	Localized
High Temperature Sulfidic/Naphthenic Acid Corrosion	
TAN ⇔ 0.5	General
TAN > 0.5	Localized
High Temperature H_2S/H_2 Corrosion	General
Sulfuric Acid (H_2SO_4) Corrosion	
Low Velocity	General
</= 2 ft/sec for carbon steel, </= 4 ft/sec for SS, and </= 6 ft/sec for higher alloys	
High Velocity	Localized
> 2 ft/sec for carbon steel, > 4 ft/sec for SS, and > 6 ft/sec for higher alloys	
Hydrofluoric Acid (HF) Corrosion	Localized
Sour Water Corrosion	
Low Velocity	General
</= 20 ft/sec	
High Velocity	Localized
> 20 ft/sec	
Amine Corrosion	
Low Velocity	
< 5 fps rich amine	Localized
< 20 fps lean amine	General
High Temperature Oxidation	General

Likelihood Category Definitions

Damage Factor	*Likelihood Category*
0 - 2	1
> 2 - 20	2
> 20 - 100	3
>100 - 1,000	4
>1,000	5

Data

- Material of Construction (**ASTM specification, grade and year**)
- Liner Material (**ASTM specification, grade and year**)
- Process Operation/Upset Conditions
  - Temperature
  - Corrosive elements and concentrations
- Damage Mechanism(s) active
  - Including Localized vs. General corrosion
- **Service Start Date**
- **Furnished Thickness (at start of services/installation)**
- Corrosion Rate/Damage Severity
- Inspection history and findings
- Inspection Effectiveness/Number of Inspections

Data and Information Collection for RBI

- Data Quality
  - Good quality data is critical to the relative accuracy of an RBI study
  - Validation step is required to review data for errors
  - Experienced personnel are needed for this step
- The Codes & Standards specify data required to conduct an RBI study
- Many other Sources of information exist in an operating facility

RBI Program Considerations

- Changing operating conditions or key process variables can impact the analysis and require re-evaluation
- Each plant must identify the changes or additional data that will trigger the need for re-analysis:
  - Management of Change procedure
  - Modification of process operation
  - Non-normal operating condition impacting susceptibility of damage mechanisms
  - Updated information and findings from inspection

Identifying Deterioration Mechanisms and Failure Modes

- Leads to Loss of Containment
- Critical to Success
  - Role of Corrosion/Materials engineer review
  - Understanding NDE and Damage Mechanisms
  - Impact of operating conditions
    - Normal, upset, start-up, shutdown, etc.
  - Understanding operation vs Chemical and Mechanical deterioration mechanism identification key to success

Identifying Deterioration Mechanisms and Failure Modes

- Categorized into Four (4) Types of Damage
  - Thinning (includes internal and external)
  - Stress Corrosion Cracking
  - Metallurgical and Environmental
  - Mechanical
- Refer to Appendix A in RP 580 for summary of damage causes
- API 571 provides more detailed guidance in the future

Identifying Deterioration Mechanisms and Failure Modes

- Possible Other Equipment Failures and Modes
  - Pressure relief device failure – plugging, fouling, non-activation
  - Heat exchanger bundle failure – tube leak, plugging
  - Pump failure – seal failure, motor failure, rotating parts damage
  - Internal linings – hole, disbondment

Assessing Probability of Failure

- Probability of a specific adverse consequence
  - From a loss of containment due to a deterioration mechanism(s)
  - POF x Probability of scenario = Probability of specific consequence
  - Should address all possible failure mechanisms
  - Should address multiple mechanisms considering conditions
  - Must be credible, repeatable, well-documented
  - Units of measure should include frequency, quantitative or qualitative

Assessing Probability of Failure

- Should consider
  - Deterioration mechanisms
    - Potential, reasonably expected
    - Susceptibility and rate
  - Inspection effectiveness
    - Quantify the effectiveness of the past inspection and maintenance program and a proposed future inspection and maintenance program.
    - Determine the probability that with the current condition, continued deterioration at the predicted/expected rate will exceed the damage tolerance of the equipment and result in a failure.
    - The failure mode (e.g. small leak, large leak, equipment rupture) should also be determined based on the deterioration mechanism.
    - Determine the probability of more than one failure mode and combine the risks.

Likelihood and API Software

- Calculation of the Damage Factor
  - Corrosion rate or Damage Susceptibility
  - Age
  - Inspection histories
- Generic failure frequency

$$\text{Cumulative Damage Factor X } G_{FF} = \text{PoF}$$

Corrosion Rate/Susceptibility

- Direct input
  - Expert opinion
  - Measured or Observed
  - Calculated using the damage module
- Corrosion
  - Localized
  - Generalized
- Cracking

Age

- Age
  - Nearing time to inspect or end of life?
  - Incubation periods for certain damage types
    - e.g. HTHA
  - Thinning start date
  - Changes
    - Operational
    - Repairs
    - Materials
    - Corrosion inhibitors, water wash, etc.

Inspection Histories

- Effectiveness
  - Damage type specific
  - Frequency
  - Cracking
    - Calculates years since last inspection
  - **Inspection results**

Generic Failure Frequencies

- Equipment/component specific
- Sources
  - OREDA Database
  - Marshall report
  - etc.
- Tempered by actual equipment and operating and inspection/maintenance practices

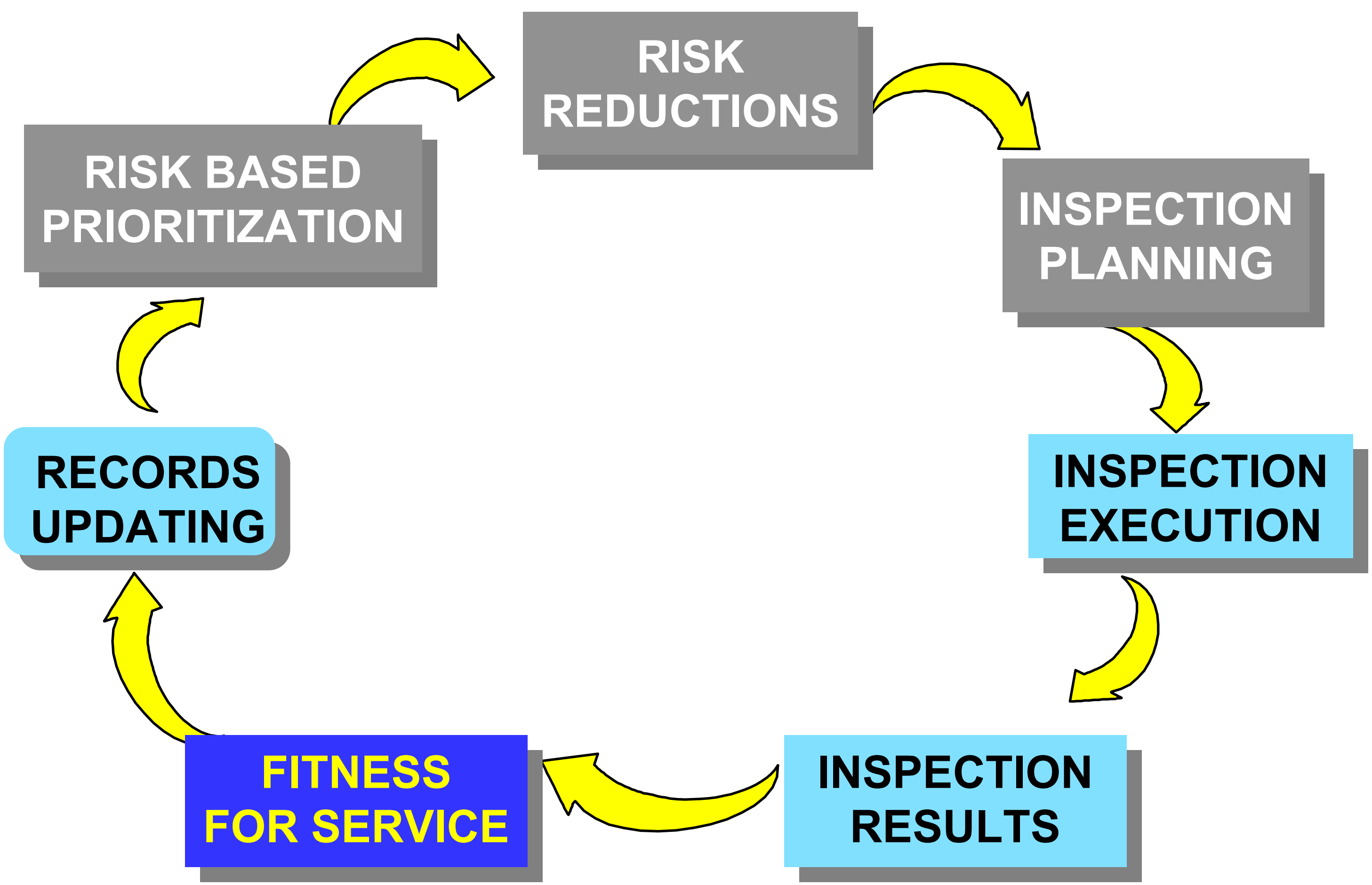
What if the Item Fails the LoF Criteria?

- Check your data for accuracy
- Were conservative assumptions used
- Candidate for replacement or material upgrade
- FFS candidate
- Quantitative Remaining Life

Changing Risk through Inspection

- Changing inspection frequencies
- Changing inspection scope / thoroughness
- Changing inspection tools / techniques
- Changing inspection practices (internal vs. external)

RBI Fit Into Current Practices



Inspection Planning

Part 7

Inspection Planning Methodology

- Inspection reduces the expected likelihood of failure
- Design errors, fabrication flaws, and malfunction of control devices can lead to equipment failure
- The likelihood of failure due to such damage is a function of four factors:
  - Damage mechanism and resulting type of damage
  - Rate of damage progression and escalation of risk
  - Probability of detecting damage and predicting future damage states with inspection techniques
  - Tolerance of the equipment to the type of damage

Inspection Planning Module

Options for Inspection Planning Approach

- Fix when equipment fails or breaks
- Conduct a full inspection on all equipment at fixed intervals (primarily vessels, piping is often neglected)
- Compliance based with the codes / law
- Condition based approach (Likelihood of failure)
- Risk based approach
  - Qualitative
  - Quantitative

Inspection Planning Module

An Inspection Plan includes consideration for:

- Which equipment needs inspection
- Identification of the mechanism(s) driving the inspection
- Interval for inspection
- Locations and coverage required
- Methods/Techniques to be used for inspection
- In addition an inspection plan should include:
  - The acceptable limits for the inspection findings
  - Follow up with fitness for service analysis, if necessary

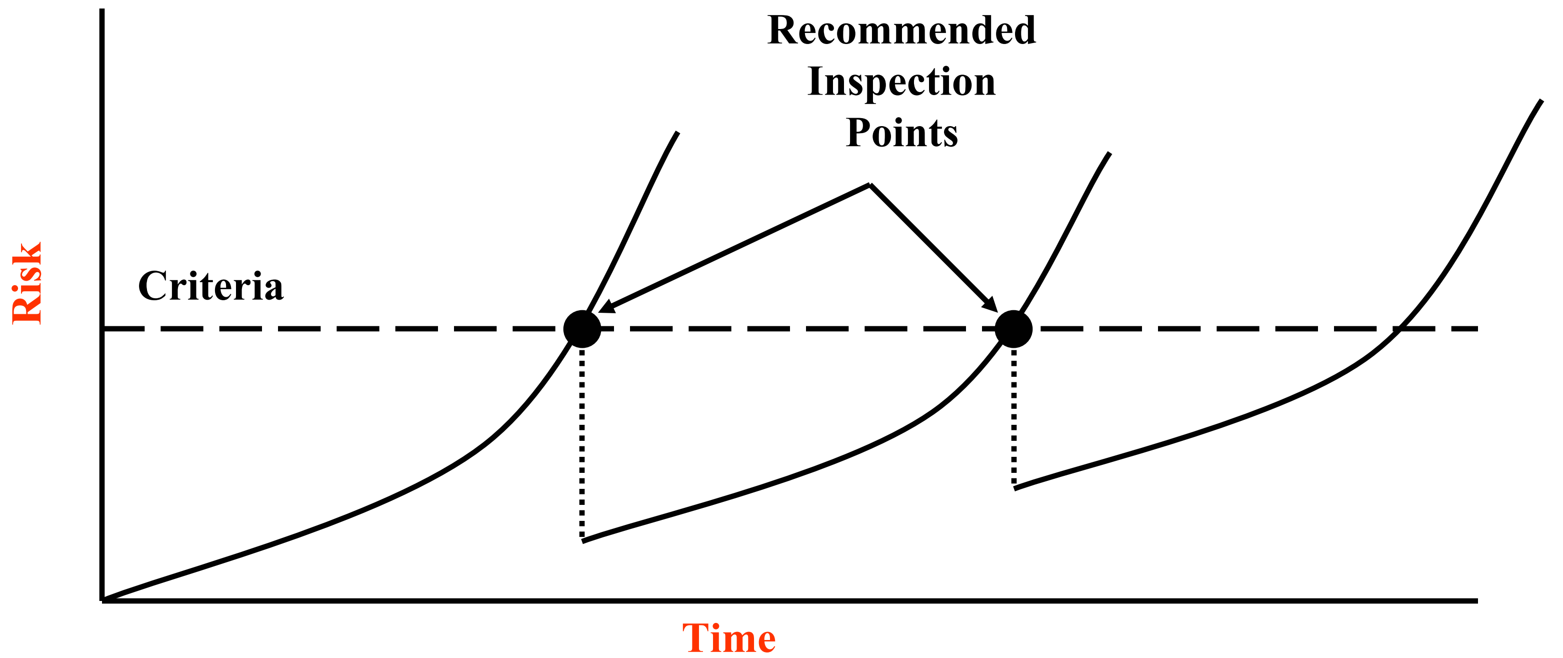
Inspection Planning Module

Objectives of an Inspection Program

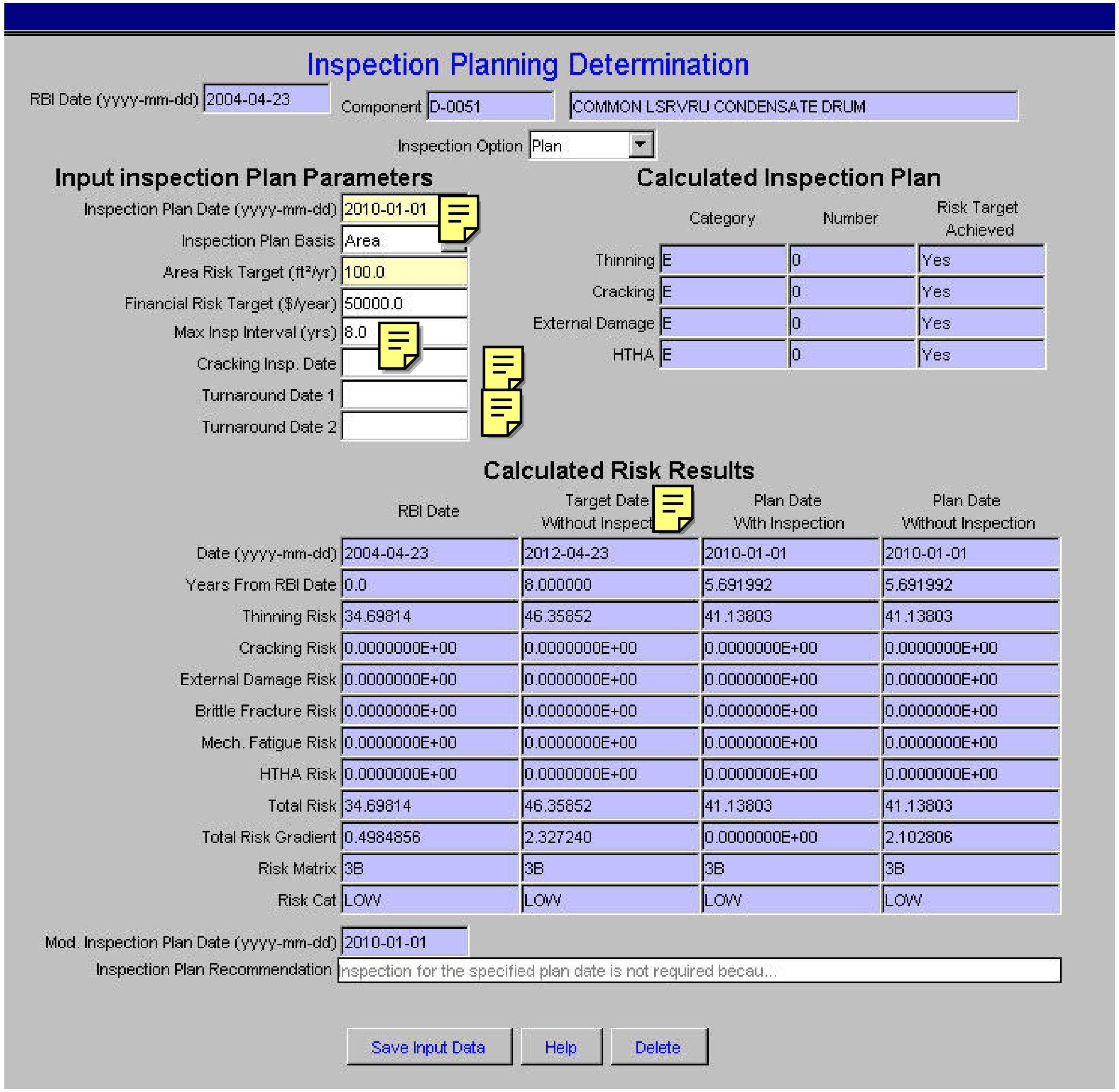
- Prioritization of equipment and piping for inspection
- To minimize downtime during turnarounds
- Identify on-stream inspection candidates
- To achieve more effective use of resources
- Special Emphasis inspection programs
- Assess the impact of turnarounds deferrals

Inspection Planning Module

- Risk will increase until the date of inspection. The calculated risk will decrease after RBI inspection plan is implemented.



Version 5.0 Inspection Planning Form



Inspection Planning Determination

RBI Date (yyyy-mm-dd) 2004-04-23

Component D-0051 COMMON LSRVRU CONDENSATE DRUM

Inspection Option Plan

Input inspection Plan Parameters

Inspection Plan Date (yyyy-mm-dd)	2010-01-01
Inspection Plan Basis	Area
Area Risk Target (ft²/yr)	100.0
Financial Risk Target ($/year)	50000.0
Max Insp Interval (yrs)	8.0
Cracking Insp. Date	
Turnaround Date 1	
Turnaround Date 2	

Calculated Inspection Plan

	Category	Number	Risk Target Achieved
Thinning	E	0	Yes
Cracking	E	0	Yes
External Damage	E	0	Yes
HTHA	E	0	Yes

Calculated Risk Results

	RBI Date	Target Date Without Inspect	Plan Date With Inspection	Plan Date Without Inspection
Date (yyyy-mm-dd)	2004-04-23	2012-04-23	2010-01-01	2010-01-01
Years From RBI Date	0.0	8.000000	5.691992	5.691992
Thinning Risk	34.69814	46.35852	41.13803	41.13803
Cracking Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
External Damage Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Brittle Fracture Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Mech. Fatigue Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
HTHA Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Total Risk	34.69814	46.35852	41.13803	41.13803
Total Risk Gradient	0.4984856	2.327240	0.0000000E+00	2.102806
Risk Matrix	3B	3B	3B	3B
Risk Cat	LOW	LOW	LOW	LOW

Mod. Inspection Plan Date (yyyy-mm-dd) 2010-01-01

Inspection Plan Recommendation Inspection for the specified plan date is not required becau...

Save Input Data | Help | Delete

Inspection Planning

- Two options for Inspection Planning
  - Date – Returns a recommended date for inspection based on maximum Area or Financial Risk input and planned inspection (ICats) for each damage type
  - Plan (ICats) – Returns a recommended effectiveness for inspection based on maximum Area or Financial Risk input and date for inspection

Inspection Planning - Date

- Input required is number of inspections planned and effectiveness (ICats) during planning period
- Enter Plan Time in Maximum Inspection Interval field
- Local Target Risk Inputs can be used to override Global Settings
- Calculates Date component reaches Maximum Risk Target (from the RBI Date)

EEG: ApiRbi - USER: root - Version: 5.01.0029

- 192.168.1.102
  - Corp
    - Plant
      - Crude Import
      - Crude Input
  - ORPHAN
  - Sunoco Chemicals
  - Test Corp
    - Test Plant
      - Test Equipment Type
        - D-0051
          - D-0051
        - P0011
          - P0011-16
          - P0011-4
        - W-0071
          - W-0071-BTM
          - W-0071-TOP
        - X-0029
          - X-0029-SH
          - X-0029-TB
        - X-0320
          - XF-0320-I
          - XF-0320-O
          - XF-0320-T
      - Test Unit

Inspection Planning Determination

RBI Date (yyyy-mm-dd) 2004-04-23 Component W-0071-TOP LSR Splitter

Inspection Option Date

Input inspection Plan Parameters

Inspection Plan Basis	Area
Area Risk Target (ft²/yr)	100.0
Financial Risk Target ($/year)	50000.0
Max Insp Interval (yrs)	8.0
Cracking Insp. Date	2004-04-23
Turnaround Date 1	
Turnaround Date 2	

Input Inspection Plan

	Category	Number
Thinning	E	0
Cracking	E	0
External Damage	E	0
HTHA	E	0

Calculated Risk Results

	RBI Date	Target Date With Inspection	Target Date Without Inspection
Date (yyyy-mm-dd)	2004-04-23	2004-04-23	2004-04-23
Years From RBI Date	0.0	0.0000000E+00	0.0000000E+00
Thinning Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00
Cracking Risk	506.1841	506.1841	506.1841
External Damage Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00
Brittle Fracture Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00
Mech. Fatigue Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00
HTHA Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00
Total Risk	506.1841	506.1841	506.1841
Total Risk Gradient	122.1058	122.1058	122.1058
Risk Matrix	4D	4D	4
Risk Cat	MEDIUM-HIGH	MEDIUM-HIGH	E-

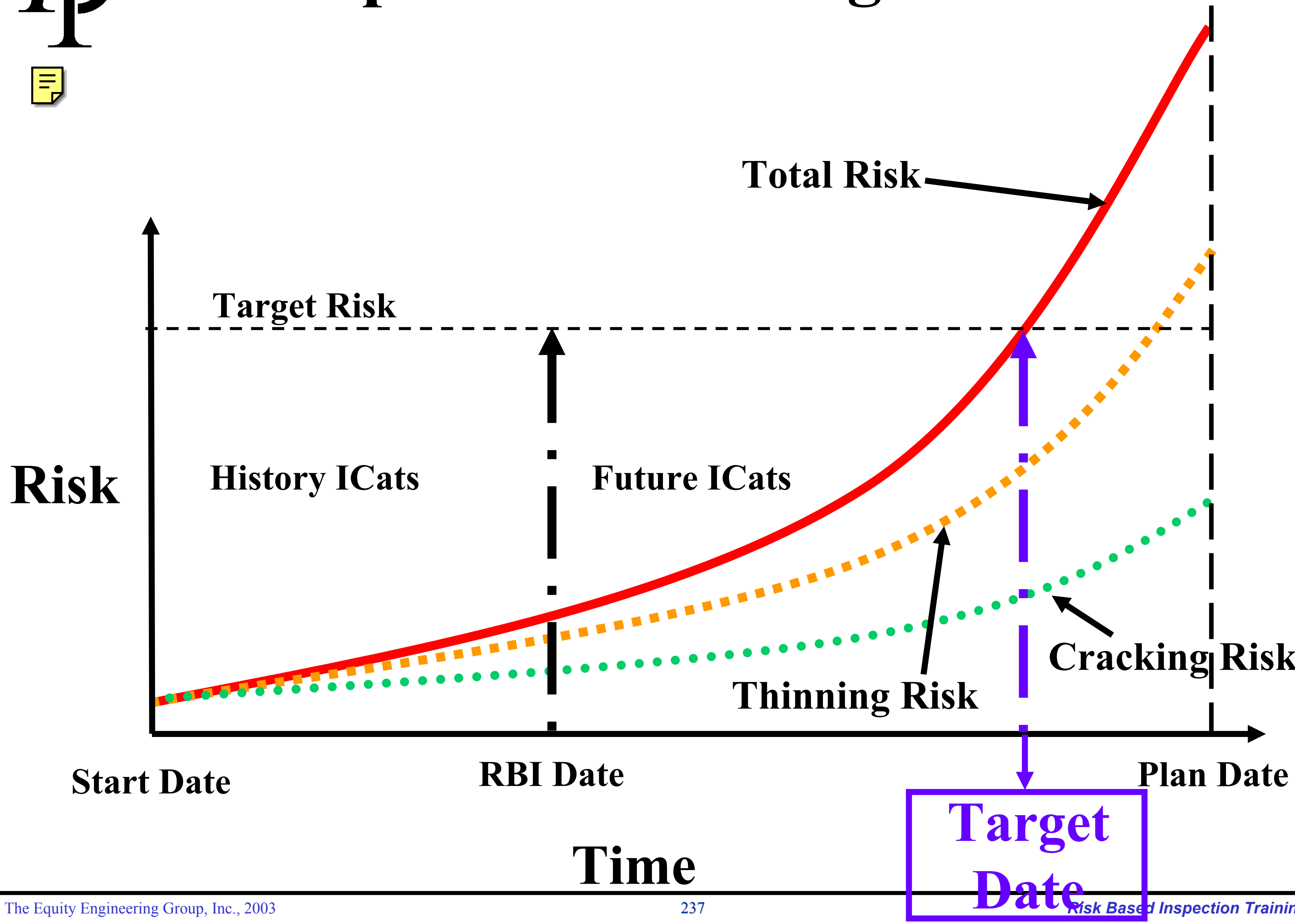
Mod. Inspection Plan Date (yyyy-mm-dd) 2010-01-01

Inspection Plan Recommendation The computed risk at the rbi date is greater than the specif...

Save Input Data | Help | Delete

Ready

Inspection Planning - Date



Inspection Planning - Plan

- Input required is date of inspection during planning period
- Enter Plan Time in Maximum Inspection Interval field
- Local Target Risk Inputs can be used to override Global Settings
- Calculates ICats necessary for the component to remain below the Maximum Risk Target
  - Will generate the next (1) inspection and an effectiveness of A, B or C

EEG: ApiRbi - USER: root - Version: 5.01.0029

- 192.168.1.102
  - Corp
    - Plant
      - Crude Import
      - Crude Input
  - ORPHAN
  - Sunoco Chemicals
  - Test Corp
    - Test Plant
      - Test Equipment Type
        - D-0051
          - D-0051
        - P0011
          - P0011-16
          - P0011-4
        - W-0071
          - W-0071-BTM
          - W-0071-TOP
        - X-0029
          - X-0029-SH
          - X-0029-TB
        - X-0320
          - XF-0320-I
          - XF-0320-O
          - XF-0320-T
      - Test Unit

Inspection Planning Determination

RBI Date (yyyy-mm-dd) 2004-04-23 Component W-0071-TOP LSR Splitter

Inspection Option Plan

Input inspection Plan Parameters

Inspection Plan Date (yyyy-mm-dd)	2010-01-01
Inspection Plan Basis	Area
Area Risk Target (ft²/yr)	100.0
Financial Risk Target ($/year)	50000.0
Max Insp Interval (yrs)	8.0
Cracking Insp. Date	
Turnaround Date 1	
Turnaround Date 2	

Calculated Inspection Plan

	Category	Number	Risk Target Achieved
Thinning	E	1	Yes
Cracking	B	1	Yes
External Damage		0	
HTHA		0	

Calculated Risk Results

	RBI Date	Target Date Without Inspection	Plan Date With Inspection	Plan Date Without Inspection
Date (yyyy-mm-dd)	2004-04-23	2004-04-23	2010-01-01	2010-01-01
Years From RBI Date	0.0	0.0000000E+00	0.0000000E+00	0.0000000E+00
Thinning Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Cracking Risk	326.3441	326.3441	326.3441	32.63440
External Damage Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Brittle Fracture Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Mech. Fatigue Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
HTHA Risk	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
Total Risk	326.3441	326.3441	326.3441	32.63440
Total Risk Gradient	78.72314	78.72314	0.0000000E+00	78.72314
Risk Matrix	4C	4C	4C	4C
Risk Cat	MEDIUM-HIGH	MEDIUM-HIGH	MEDIUM-HIGH	MEDIUM-HIGH

Mod. Inspection Plan Date (yyyy-mm-dd) 2004-04-23

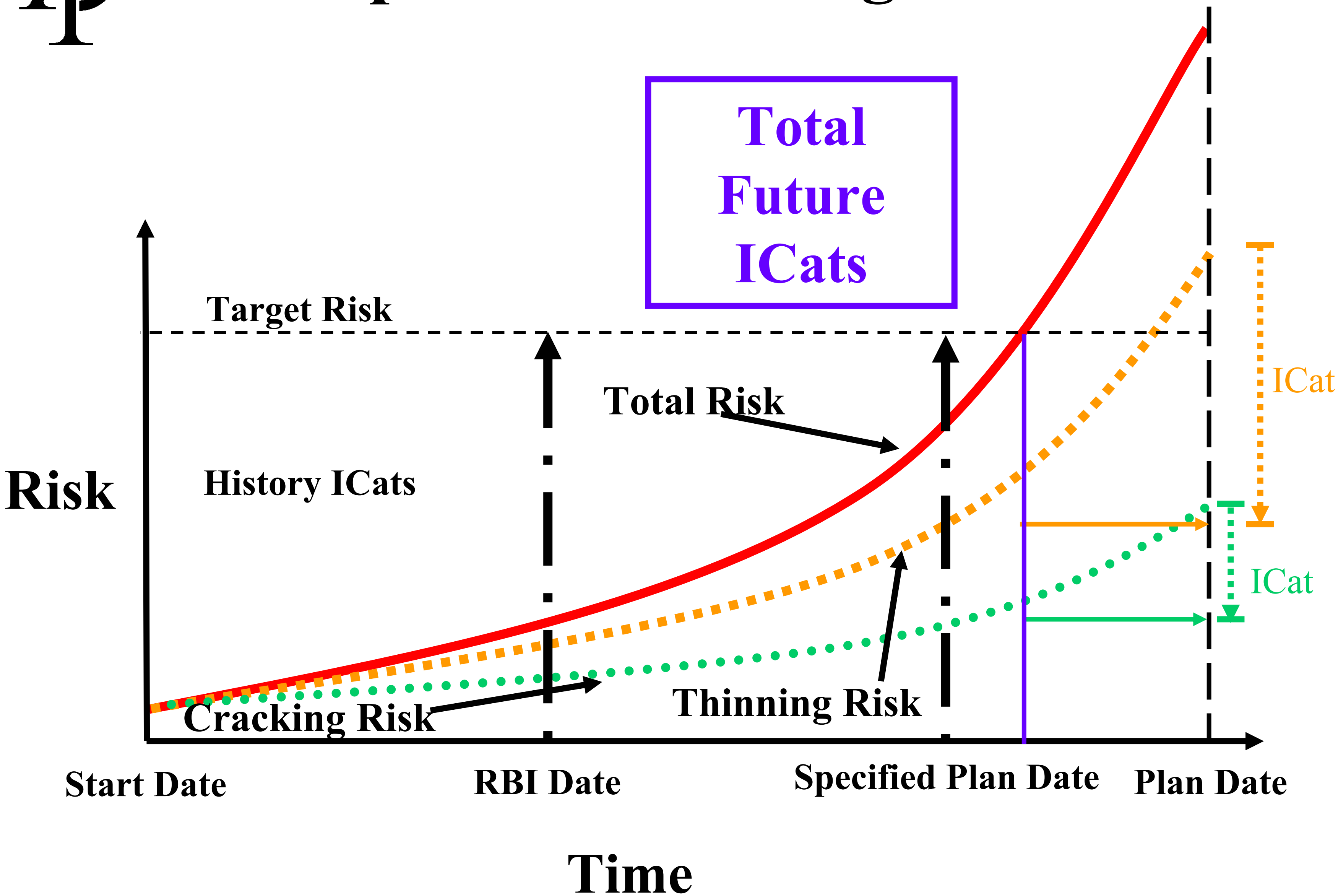
Inspection Plan Recommendation The computed risk at the rbi date is greater than the specif...

Save Input Data | Help | Delete

Ready

Start | Inbox - Microsoft Outlook | Untitled - Message (HT... | C:\Lynne's Work\API ... | C:\Lynne's Work\API ... | Microsoft PowerPoint - ... | Api-Rbi v5.0 | EEG: ApiRbi - USE... | 2:16 PM

Inspection Planning - Plan



General RBI Risk Benefit Analysis (RBA)

Part 8

Risk Benefit Analysis (Future)

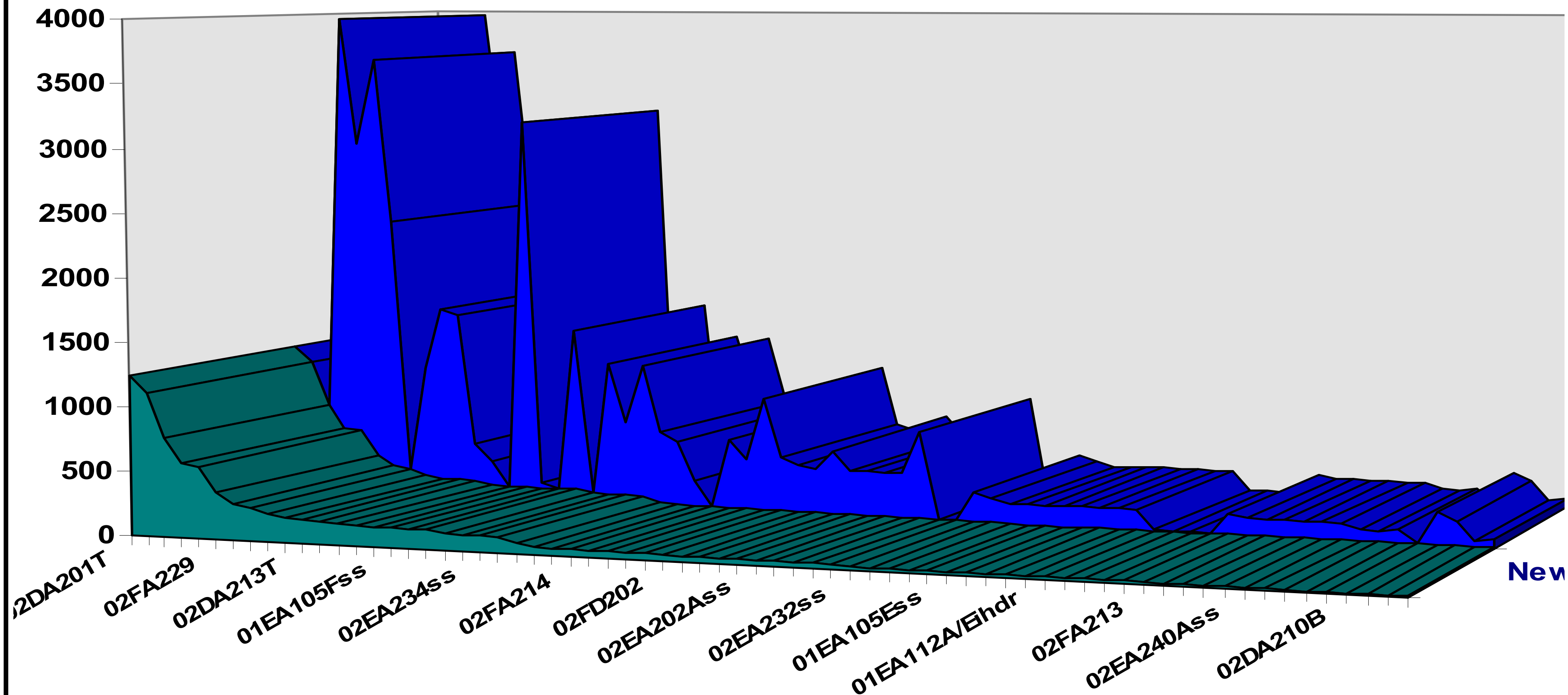
- Current Risk Inputs
- Current Risk Calculations
- Future risk without inspection
- Future risk with inspection
- Replacement Costs
- Repair/Replace Efficiency

- Date for Planned Inspection
- Target Date
- Cost of planned Inspection
- Repair Cost
- Repair Efficiency

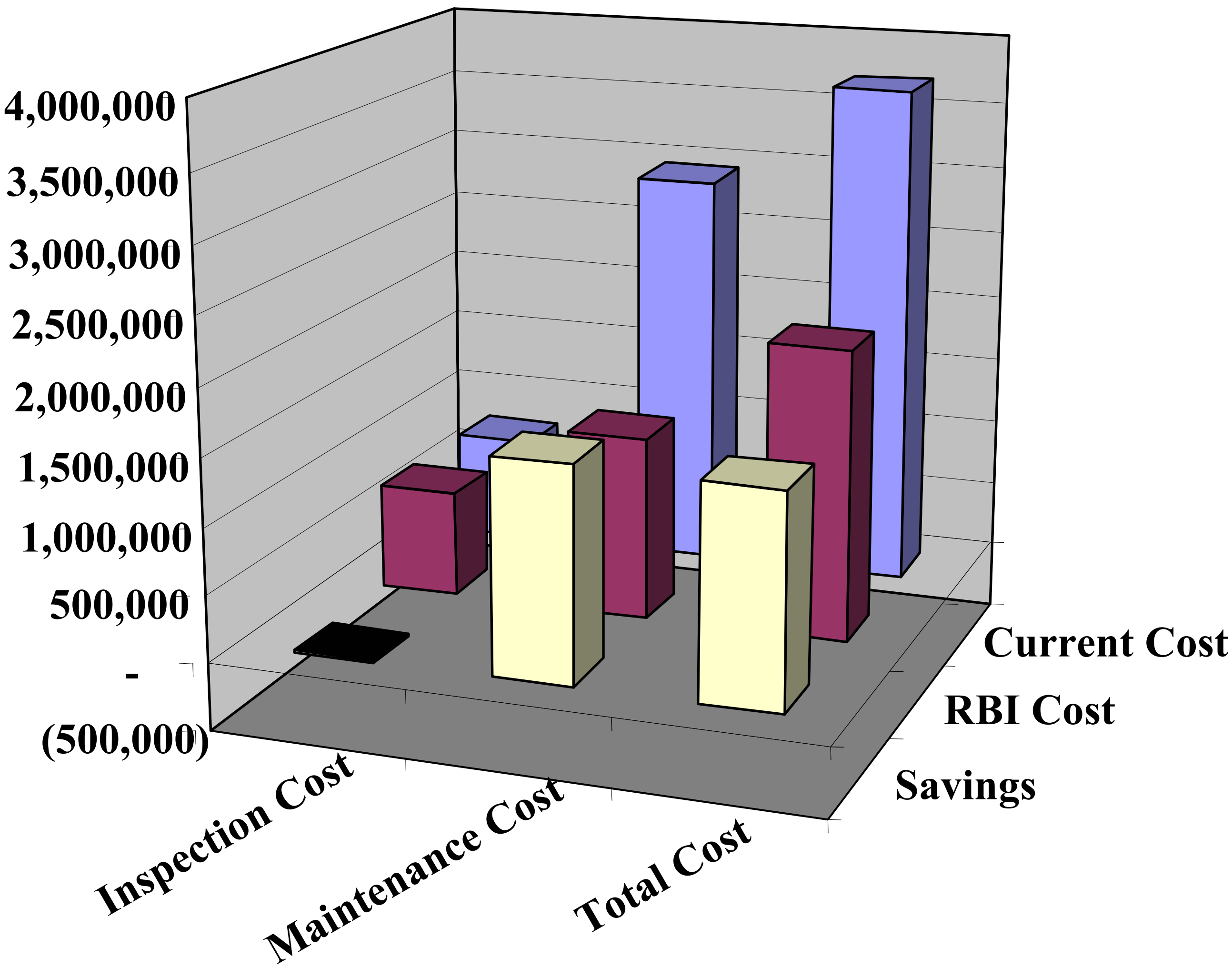
Benefits and Benefit Ratios

- The API-RBI software estimates the following for each damage mechanism
  - Inspection Benefit
  - Inspection Benefit Ratio
  - Repair Benefit
  - Repair Benefit Ratio
  - Replace Benefit
  - Replace Benefit Ratio

Inspection Planning



Inspection Planning

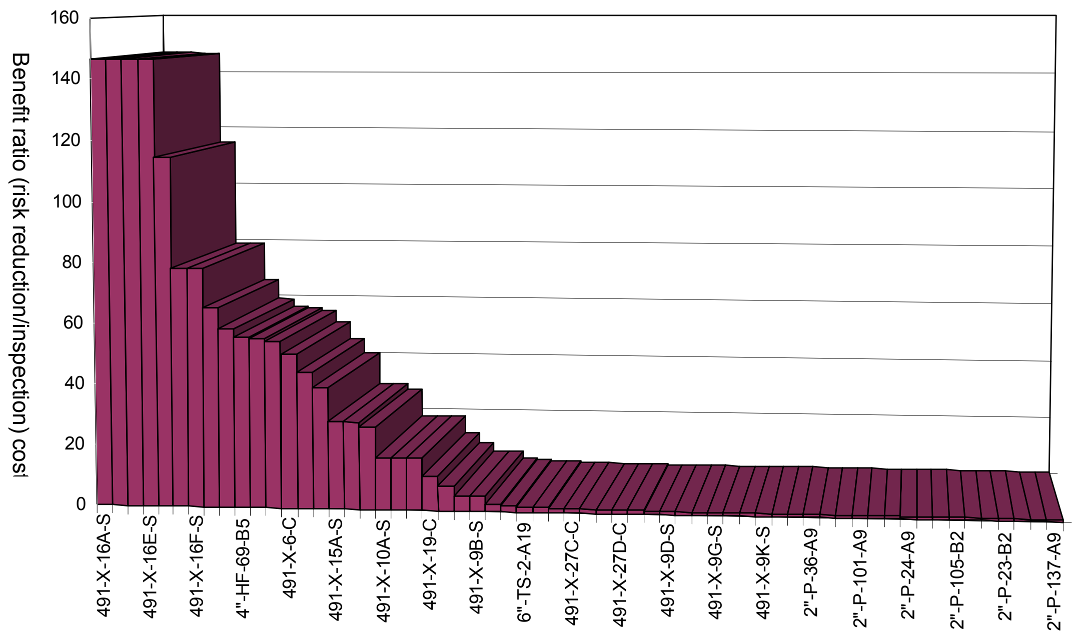


Inspection Planning

- Cost Benefit Ratio is the Relationship between Risk Reduction as a result of an activity and the Cost of that activity or

$$\text{CBA Ratio} = \Delta \text{ Risk } / \text{ Mitigation Cost}$$

- Ranking for prioritization of activities



Overview of API 581

Part 9

Presentation Outline

- Introduction
- Risk Based Inspection Overview
- Interaction with Existing Codes
- API RBI Development Background
  - Contents
  - Consequence
  - Likelihood
  - Technical Modules
  - Inspection Planning
- Future Project Direction

Introduction

- The API Codes were based only on the failure prevention Likelihood of failure, not Consequence of Failure or Reducing the risk of high consequence failures
- RBI assessments result in an equipment risk ranking based on the likelihood of a leak occurring and the consequence associated with that leak
- API 581 provides detailed RBI approaches using methodologies specifically prepared for the refining and petrochemical industry
- API RP 580 provides a guide for users to properly and systematically perform an RBI assessment

Introduction

- The API 581 approach permits the shift of inspection and maintenance resources to provide a higher level of attention on high risk equipment and the appropriate level of attention on lower risk equipment
- Jurisdictional acceptance will be provided by reference from in-service inspection codes (API 510 - Vessels, API 570 - Piping, API 653 -Tanks)
- Applied properly, methods in API 581 provide the benefit of increasing operating efficiencies and unit run lengths of process facilities while reducing, or at least maintaining the same level of risk

Future Directions of the API In-Service Inspection Codes

- Need a firm understanding of potential damage mechanisms (API 571)
- Use RBI API (581 and RP 580) to set interval, scope, method for inspection, supplemented by appropriate monitoring (e.g. API 572, 574, 575, API 571)
- If flaws or damage are found, use FFS (API 579) to assess acceptability for typically one operating period, can be re-endorsed for future operating periods
- Current in-service inspection codes (API 510/570/653) will allow use of RBI & FFS at the option of the owner/user

API RBI Development Background

RBI US Drivers

- Maintain or improve Plant safety
- Compliance with US OSHA 1910 PSM Legislation
- Efficiently operate aging equipment and facilities
- Maintain safe, reliable operations with an increase in run-lengths and decrease in shutdown periods
- Determine the feasibility of increasing the severity of operations
- Identify operation envelopes for key variables driving damage
- Optimize plant resources in highly competitive industry

API RBI Development Background

Need for RBI Development

- Comprehensive RBI approach covering damage mechanisms found in the refining and petrochemical industry did not exist
- Refining and petrochemical industry is unique to the wide variety of processes, construction materials, and damage mechanisms
- Desire to measure and understand the risks associated with current inspection programs as well as measure risk reduction as a result of inspection practices
- Desire to gain acceptance by jurisdiction

API RBI Development Background

API's Definition of Risk Based Inspection

- An RBI assessment is a multi-discipline engineering analysis of equipment for prioritizing and managing the efforts of an inspection program
- The product of an RBI assessment is the decision to inspect using specific techniques and intervals, monitor, replace, conduct a FFS evaluation or perform other mitigation activities
- RBI uses a systematic approach with simplified analytical methods to assess the condition of equipment

Overview of API 581

Contents

- Section 1 - Introduction
- Section 2 - Scope
- Section 3 - References and Bibliography
- Section 4 - Definitions
- Section 5 - Risk Analysis
- Section 6 - Qualitative Approach to RBI (Operating Unit Basis)

Overview of API 581

Contents

- ***Section 7 - Consequence Analysis***
- ***Section 8 - Likelihood Analysis***
- ***Section 9 - Development of Inspection Programs to Reduce Risk***
- Section 10 - Plant Database Structure
- ***Section 11 - Technical Modules***
- Appendices

Overview of API 581

Contents

- Appendix A - Workbook for Qualitative Risk Based Inspection
- Appendix B - Workbook for Semi-Qualitative Risk Based Inspection Analysis
- Appendix C - Workbook for Quantitative Risk Based Inspection Analysis
- Appendix D - Workbook for Management Systems Evaluation

Overview of API 581

Contents

- Appendix E - OSHA 1910 and EPA Hazardous Chemicals List
- Appendix F - Comparison of API and ASME Risk Based Inspection
- ***Appendix G - Thinning Technical Module***
- ***Appendix H - Stress Corrosion Cracking Technical Module***
- ***Appendix I - High Temperature Hydrogen Attack (HTHA) Technical Module***

Overview of API 581

Contents

- ***Appendix J - Furnace Tube Technical Module***
- ***Appendix K - Mechanical Fatigue (Piping only) Technical Module***
- ***Appendix L - Brittle Fracture Technical Module***
- ***Appendix M - Equipment Linings Technical Module***
- ***Appendix N - External Damage Technical Module***

Summary of 581

- Use of the API technical modules will lead to a conservative result, i.e.not intended to be an expert system, intended to be used in place of experience
- RBI requires expertise and documentation for addressing lack of accurate data available
- Determination of the Inspection effectiveness requires practice and specific guidelines - 581 provides direction
- Piping complexity presents a significant challenge to screening process and developing a specific inspection plan

Summary of 581

- Changing operating conditions or key process variables can impact the analysis and require re-evaluation
- Each plant must identify the changes or additional data that will trigger the need for re-analysis:
  - Identify the link between RBI work process and the plant's Management of Change procedure
  - Implementation of modified or new process operation
  - Changes in conditions impacting susceptibility of damage mechanisms
  - Updated information and findings from new inspection results

Summary of 581

- RBI is a higher level, equipment screening process to allow the user to handle large amounts of equipment at one time
- A more complex analysis is often desired but is not necessary for screening purposes
- Need to understand the technical basis of any analysis or approach to realize benefits and limitations
- RBI is a screening method, consistency is more important than accuracy

API RBI Project Background and Future Direction

Part 10

API RBI User Group

ADGAS	SGS (Shell)	Portuguese Welding
Amerada Hess	Flint Hills Res.	Petro-Canada
BP	Irving Oil	Placid Refining
Berwanger	Italian Welding Inst.	Saudi Aramco
ChevronPhillips	JGC Plantech	Suncor
Coastal, Aruba	Lyondell Equistar	Sunoco
ConocoPhillips	Marathon Ashland	TotalElfAtofina
DNV	PDVSA	Valero
Dow	Petrobras	

API RBI Project Phases

- **Phase I** deliverables (complete May 1995)
  - Initial Base Resource Document (BRD)
  - Pilot study applications
- **Phase II** deliverables (complete Oct. 1997)
  - Level I and II software development
  - Technology enhancements / expansion
- **Phase III** (target completion Jan. 1999)
  - Software completion / integration
  - Further technology enhancements
- **Phase IV** (Start June 2000)
  - Creation of User Group (from technology development)
  - Evaluation of results and practical applications
  - Platform change software development project

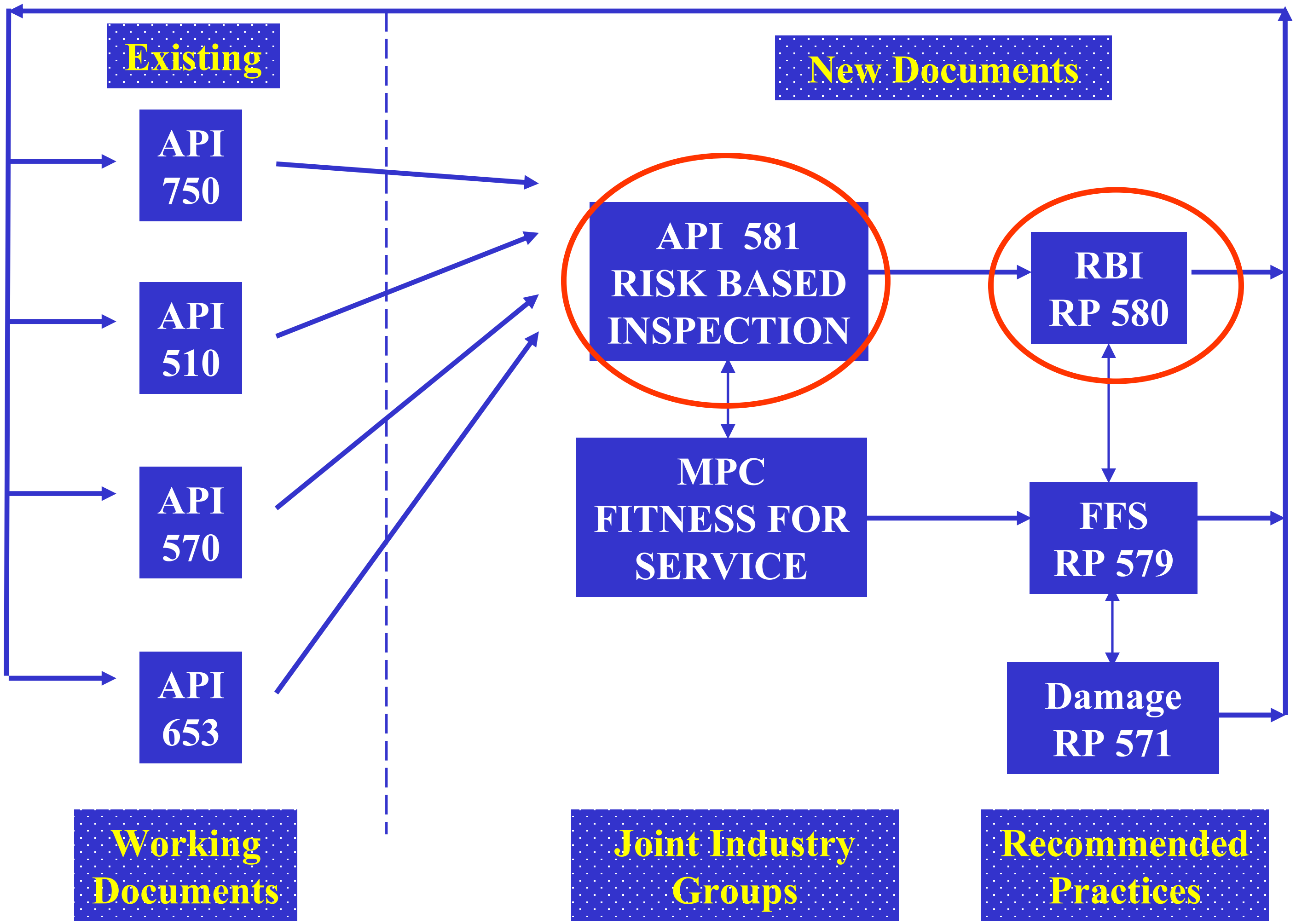
Objective of API RBI Project

- Create an RBI **Methodology** for the Petroleum and Petrochemical Industry along with a User-Friendly **Software** package that includes **RBI Analysis**. The software will come complete with **User Manuals, Technical Manuals, and Training** for implementation by Sponsor Group Members.

API RBI Project

- Project initiated August 1993 with 16 sponsors
- 26 sponsor companies as of January 2004
- Project Value of $3,000,000 over 11 years
- Currently functioning as a User Group
- E^2G as the primary contractor starting November 2001

Relationship Between API Documents



Future Directions of the API In-Service Inspection Codes

- Need a firm understanding of potential damage mechanisms (API 571)
- Use RBI API (581 and RP 580) to set interval, scope, method for inspection, supplemented by appropriate monitoring (e.g. API 572, 574, 575, API 571)
- If flaws or damage are found, use FFS (API 579) to assess acceptability for typically one operating period, can be re-endorsed for future operating periods
- Current in-service inspection codes (API 510/570/653) will allow use of RBI & FFS at the option of the owner/user

Phase IV – User Group Development

- 11 new members companies since October 2001
- Current membership is 26 member companies
- Platform change software development project
- Ongoing technology improvements
  - Enhancements to current approaches
  - Modernizing technology
  - Adding capabilities (new equipment, additional corrosion supplements)

Version 5.0 Overview

- Developed to optimize database implementation with a powerful analysis engine
- A three-tier application
- For a PC installation, the client, database server, and analysis engine server reside on the PC

Version 5.0 Overview

- Contains all capabilities provided in Version 3.3.3 except Cost Benefit Analysis
- Simplified installation procedure
  - Does not require any system modifications
  - Does not require MSAccess
  - Does not require MS Personnel Web Server
- Default database is MySQL
- MSAccess can be used to view and manipulation MySQL database via OBDC

Version 5.0 Overview

- Administration Tool Added:
  - Set database to be used
  - Set user protection
  - Provides import capability from Mining Tool

5.0 Software Architecture

- Three-Tier Application consisting of
  - Graphical User Interface (GUI) on a client
  - Database engine on a dedicated server
  - Analysis engine on a dedicated server
- GUI – written in Java
  - state-of-the-art language for applications that utilize database engines
  - Does not require use of MS Windows Application Programming Interface (API)

5.0 Software Architecture

- Databases Supported
  - MySQL – default database, excellent capabilities, unlimited size, no cost to users
  - MS SQL Server
  - Oracle
  - MS Access – can be used but not recommended, useful for viewing MySQL database via a OBDC link
  - Database access configured through administration tool

5.0 Software Architecture

- Analysis Engine
  - Developed Using ANSI FORTRAN 95 Standard
  - Utilize state-of-the-art proven calculation procedures in E^2G's VCESage Program
  - Extremely fast calculator, will permit advanced engineering calculations (i.e. FAD assessment, Plume Analysis, etc.) without user intervention

5.0 Software Architecture

- New software architecture utilizes ANSI programming languages and Open Source applications
  - avoids issues with MS systems bugs and updates problems
  - Facilities installation issues
  - Can be ported to UNIX
    - Less expensive platform
    - Faster run-time

5.0 Analysis Capabilities

- GUI compatible with MS Windows
- J-Tree showing component hierarchy implemented
- Screen calculations including what-if analysis can be performed
- Analysis Engine based on calculation Procedures in API 581, Second Edition, October 2000

5.0 Analysis Capabilities

- Batch calculations can be performed at the following levels:
  - Unit
  - Equipment
  - Component

5.0 Analysis Capabilities

- All analysis results including graphics are stored in the database
- Default reports provided, new reports can be easily added based on user requests
- Export tool provided to transfer report tables to MS Excel
- Extensive error messages provided including error reporting capabilities for batch analyses

5.0 Analysis Capabilities

- All calculation performed at the component level, separate input file generated for each component, can be emailed to E^2G to facilitate de-bugging
- Diagnostics showing all intermediate and final calculation results can be selected by the user, diagnostic files provide method to facilitate bug resolution

2004 Release

- January 2004 Released Beta Version of 5.0
- January through June:
  - Improve Stability
  - Develop Data Management capabilities
  - Improve User Interface/Friendliness
- June to August
  - Field testing at plant site
  - Continued improvements
- August Release of Production Version 5.0
- August through June 2005 Additional capabilities

2004-2005 Additional Capabilities

- Tank Module
- Heat Exchanger bundle module
- PRV module
- New Damage modules
- Boiler module
- HTHA improvement for C-½ Mo curve
- Addition of Fired Heater Module
- Thermal Fatigue/Mechanical Fatigue damage module
- Improved inspection planning module

Summary of API RBI UG Direction

- Version Beta 5.0 Software released January 19, 2004
- Technology improvements
- Multi-User, Three Tier Platform
- Database capabilities available for Access, MySQL, SQLServer, Oracle
- Additional Equipment modules in available in 2004-2005

2004 Releases & Capabilities

- Scheduled for March 22, 2004 Release
  - GUI
    - Enhance database refresh and save functionality to simplify user input
    - Implement drag-drop move and copy feature on the component J-tree
    - Implement sort capabilities in table views
    - Implement user security based on input from user-group (user assignment can be set in administration tool, assignment of permissible user actions needs to be implemented)

2004 Releases & Capabilities

- Scheduled for March 22, 2004 Release
  - Database/Calculations
    - Provide report to produce Risk Matrix plots and Pareto Chart
    - Add “threading” capability to speed up batch calculations

2004 Releases & Capabilities

- Scheduled for April 19, 2004 Release
  - Database/Calculations
    - Introduce Equipment filter capability
    - Develop export/import capability
    - Develop database synchronize capability
    - Add calculations for underground corrosion and cooling water corrosion

2004 Releases & Capabilities

- Scheduled for May 17, 2004 Release
  - Database/Calculations
    - Implement Case structure
    - Provide report to produce Risk Matrix plots and Pareto Chart
    - Addition of Cost Benefit module

2004 Releases & Capabilities

- Scheduled for August 1, 2004 Release
  - Complete development of the following equipment modules pending documentation and ballot resolution:
    - HE Bundle
    - Tank
  - Implementation of new consequence modeler
  - Implementation of PRD's
  - Addition of Damage Mechanism Screening Tool
  - Implement System, Area and possibly Circuit structure

2004 Releases & Capabilities

- Scheduled for December 31, 2004 Release
  - HTHA improvement for C-½ Mo curve
  - Addition of Fired Heater Module
  - Thermal Fatigue/Mechanical Fatigue damage module
  - Addition of Boiler Module
  - RSF Approach
  - Improved inspection planning module

Q&A Discussion