Improving Operator Performance

Research from the Center for Operator Performance
Antoon Tuerlings, Yokogawa
David Strobhar, Beville Engineering
Mark Nixon, Emerson
Tom Fiske, Yokogawa
<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>Welcome – Yokogawa</td>
</tr>
<tr>
<td>1015</td>
<td>COP Introduction</td>
</tr>
<tr>
<td>1030</td>
<td>Event Prediction &amp; Mitigation – Mark Nixon (Emerson)</td>
</tr>
<tr>
<td>1115</td>
<td>Break</td>
</tr>
<tr>
<td>1130</td>
<td>Shadowbox</td>
</tr>
<tr>
<td>1215</td>
<td>Lunch</td>
</tr>
<tr>
<td>1230</td>
<td>Student Projects (through lunch)</td>
</tr>
<tr>
<td>1300</td>
<td>Procedure Modularization</td>
</tr>
<tr>
<td>1345</td>
<td>Break</td>
</tr>
<tr>
<td>1400</td>
<td>Overviews – Mark Nixon (Emerson)</td>
</tr>
<tr>
<td>1445</td>
<td>Alarm Rates</td>
</tr>
<tr>
<td>1530</td>
<td>New Projects – Tom Fiske (Yokogawa)</td>
</tr>
<tr>
<td>1545</td>
<td>Conclusion</td>
</tr>
</tbody>
</table>
Welcome
CoP Speakers today

Dave Strobhar
Mark Nixon
Tom Fiske

Antoon Tuerlings
Who is the Center for Operator Performance?

Center for Operator Performance
An Industry- Academia Collaboration
www.operatorperformance.org
We had questions –

- How can I make expert operators faster?
- Are alarm targets valid?
- Is it worth changing existing displays to current practices?
- How can I get operators the support information they need, when they need it?
- How do I create a hierarchy?
- What does a good overview look like?
- Should I use a large monitor for the console operators?
So we banded together

- Operating company driven
- Shared risk
- Focus on enhancing the safety and environmental performance of plants
- Open
- Prevent “black-eye” that hurts entire industry
## Research

<table>
<thead>
<tr>
<th>Tools</th>
<th>Knowledge</th>
<th>Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision Making Exercises</td>
<td>Expertise</td>
<td>Alarm I &amp; II</td>
</tr>
<tr>
<td>Procedure Modules</td>
<td>Knowledge Management</td>
<td>Fatigue (Data Mining)</td>
</tr>
<tr>
<td>Display Content (Decision Mapping)</td>
<td>Color Use</td>
<td>Display Metrics</td>
</tr>
<tr>
<td>Event Prediction &amp; Mitigation</td>
<td>Simulator Survey</td>
<td>Use of hand-held devices</td>
</tr>
<tr>
<td>Display Evaluation Toolkit</td>
<td>Training Methods</td>
<td>Large Screen</td>
</tr>
<tr>
<td>Overview Displays</td>
<td>Mental Models</td>
<td>Incident data mining</td>
</tr>
<tr>
<td><strong>Student projects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decision Aids</td>
<td>Use of red for stop/closed and warning</td>
<td>Symbol Size</td>
</tr>
<tr>
<td>Large Monitor</td>
<td>Data Entry Devices</td>
<td>Emergent Features</td>
</tr>
</tbody>
</table>
Event Prediction IV
Update

Michael Baldea/ Mark Nixon
November 19, 2014
Austin, TX
Project Overview

Goal: Develop visual data analysis and decision support tools

EXPLICIT time

n plots
2 dimensions

IMPLICIT time

1 plot
n dimensions

EPM I- II

Task Progress to Date

Concept: 3D Radial Plots

Fault detection: use operating envelope
Task Progress to Date

Concept: 3D Radial Plots

Centroid representation

- Every polygon can be represented by its centroid

Multiple polygons result in multiple centroids
Empirical definition: “If a cardboard cutout of a planar figure is suspended from its centroid, it will remain horizontal”

For any given polygon, the centroid is defined as the average of all vertices in the polygon.

For a near regular polygon, the center of gravity is close to the intersection of the bisectors.
Multivariate Analysis

- A change in the process = distortion of polygon = movement of centroid

- Black and red lines represent the univariate operating envelope for each principal component / variable

- Ellipse represents the multivariate operating envelope for the steady-state data (blue)
Visualization of Large Dataset

Amenable to one scan – one point representation
Filtering of the Centroids

- In a 3D perspective the data is smoothened out in time.
- Before filter
- After filter

![Graph showing before and after filter]
Looking at Transitions – Motivation

} Only looked at faults deviating from a single steady state thus far
  ◦ What about data containing multiple steady states?
  ◦ How to account for process startup/restart (see previous example)?
  ◦ What about batch processes (blending, reaction...)?

} Dealing with process transitions can be difficult
  ◦ Faults can be masked by transition dynamics and be difficult to detect
Looking at Transitions – Purpose of Transition Paths

} Desire to find the “normal” process transition
  ◦ Avoid and/or correct “poor” transitions
  ◦ Prevent operator error/disturbances/malfunction

} If a “good” transition path is known, then transitions that deviate from the path can be considered faulty

} Plant startup, shut down, and batch processes all contain transitions
  ◦ Avoiding poor transitions is key to keeping plants online for longer
COP Projects

- Individual compressor surge
- Column flooding
- Long-term compressor surge
- Flaring event analysis
Long-term Comp. Surge

- Given large compressor system dataset over 16 years
  - 1998-2014 in 2 hour samples
- Smaller datasets at a faster sample rate
  - Aug/14 and Sept/14 in 1 minute samples
  - Validate findings
    - August – detect fault
    - September – no fault TO detect (test for false positives)
- Build model using large dataset and attempt to use model to detect validate findings in the smaller datasets
Results:

- August fault successfully detected
  - Predicted at 11:48 AM
  - Vs: actual at 1:17 PM

- Top contributing tags
  - Second suction level
  - Second stage pressure
  - Third stage suction temperature
  - Third suction level
  - Discharge pressure

- No false positives raised in the September dataset
Column Flooding

Given monthly data of column operation

- 4 months total (June-September)
- 1 minute sample rate
- 60+ variables
  - 75% variance captured on average using PCA

All 8 floods were predicted
Flaring Event Analysis

- Data on a system with flares present
- System properties
  - Multiple process units feeding into a main loop
  - Connected to a compressor that feeds into steam generator outside of the system
  - Flare tower burns off excess gas that the compressor cannot handle
Flaring Event Analysis

- A large dataset is provided for model building purposes
  - 1 year duration
  - 1 minute sample rate – 500 thousand samples
  - 100+ variables

- Try to predict and detect flare events in the year
  - Contains points 500 minutes before and after flare event occurrence

- Project is underway
Future/Impact

} Current Effort
  ◦ Batch processing
  ◦ Phase transition
  ◦ Flaring

} Goal
  ◦ Package software for individual company testing
  ◦ Create tool to work beside DCS
  ◦ Integrate tool into DCS
Training for Improved Decision Making

Gary Klein, Ph.D.
Efforts to Date

- Nature of Expertise
- Decision Making Exercises
- Shadowbox I & II
<table>
<thead>
<tr>
<th>Characteristics of Expertise</th>
<th>Crude Unit Operator</th>
<th>Fluid Catalytic Cracker</th>
<th>Pipeline Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Form expectancies</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>2. Monitor cues</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>3. Anticipate team member needs and limitations</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>4. Know where equipment and human resources can mislead you</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>5. Seek information to spot opportunities</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Adapt the way they perform</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>7. Describe how events came about and will play out</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Utilize time horizons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Use recall processes to overcome memory limitations</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>10. Construct mental simulations</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Decenter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Engage in deliberate practice</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>13. More recognitional decisions than option comparisons</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>
Decision Making Exercises (DMX)

- Good decision making requires practice
- Adapt military training exercises
- Scenario based
- Time pressure
- Ambiguous
- Low cost
- Easy to apply (< 1 hour before shift)
Decision Making Exercises (DMX)

**Project**
Adapted military training exercises to process control. Military use DMX to train platoon leaders to make faster and more accurate decisions during urban operations.

**Impact**
Proved to be low-cost and easy to apply method to enhance decision making.
- One-hour periodically at beginning of shift
- Identified skill/knowledge gaps
- Identified lost practices
- Helps build mental model
Scenario phase 1

Background
It's late spring and the weather for the last few weeks from the South to the Mid-West has been volatile, with several major thunderstorms moving along the Mississippi River. One of these storms knocked out power to a pump station just last week.

Today one of the lines on your console you'll be working is the Beaumont to Creal Springs Line. The Beaumont-Creal Springs 24”- 26” Products Line is 644 miles long. There are six booster stations on this line: Beaumont (BEAU), Sugartown (SUGT), Kilbourne (KILB), Tutwiler (TUTW), Fisherville (FISH), and Obion (OBIN). It also has a Pump Matrix, giving you information on optimal unit combinations and start/stop sequences.

(The Hydraulic Gradient Screen 1 provided should give you a picture of this line's current status.)

Shift change reveals nothing unusual going on with this line.

You spend some time checking your other lines and making sure that everything's on schedule. You're having a busier morning than usual as you spend a couple of hours just “fighting fires” and trying to stay ahead of the problems.

At 1030, SUGT calls you and says they need to do some pump maintenance and need you to shut down the unit for about 20 minutes.

Requirement: You have two minutes. What is your plan for supporting the SUGT maintenance?

A. What do you think is going on here? / What are your biggest concerns right now? (elicit their situation assessment)
B. What are the difficult decisions? (elicit decisions)
C. What things are you paying attention to to figure out what's going on? (elicit cues/factors)
D. What are the potential courses of action you could take right now? (elicit COAs and their COA analysis)
E. Which one would you follow? Why?
Shadowbox Technique

Method

- Present complex scenarios
- Insert Decision Points with a small set of options
- Trainees record their responses and their rationale under time limits/stress
- Trainees compare responses and rationale to a panel of SMEs
- Trainees identify what the SMEs were seeing and thinking that they (the trainees) were not
12:00 PM – Screen Shot #3
The heart of the cold front and thunderstorm has arrived, and you are getting considerable amounts of rain and lightning. Because of this, you decide to cease the ongoing tasks. You pull the outside operators from dumping caustic, and ask the operators withdrawing the catalysts to hold off until the rain and lightning pass.

You are also experiencing alarms in the Gas Con unit. The cold air and rain is affecting the amount of condensing within the units.

Additionally, you begin to receive multiple alarms on the FCC Feed page. For unknown reasons the Heater Outlet temperature seems to be dropping. The Burner Tip Pressure has begun to increase.

* Please use your ShadowBox to record important information.

Now proceed to Decisions 2 and 3 on the following pages.
### Decision 2:

What cues are you monitoring most closely at this moment? Rank these options (1 = most important, 4 = least important). Please explain your rankings.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A) The heater – watching the fuel gas pressure.</td>
</tr>
<tr>
<td></td>
<td>B) Temperatures in the Gas Con unit – avoiding low alarms and checking fans.</td>
</tr>
<tr>
<td></td>
<td>C) Watching the propylene unit charger (splitter head level control valve).</td>
</tr>
<tr>
<td></td>
<td>D) LPR condensing + Flare KO pot levels.</td>
</tr>
</tbody>
</table>

**Explain rationale for your top three rankings:**
# Pilot Results – Refinery FCC

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Expert</th>
<th>Novice</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>88%</td>
<td>80%</td>
</tr>
<tr>
<td>#2</td>
<td>88%</td>
<td>70%</td>
</tr>
</tbody>
</table>
Variations

Variety of response
- Prioritize information to remember
- Prioritize goals
- Prioritize actions
- Anticipatory actions
- Desired information
- Cues via video clips

Presentation
- Paper & Pencil
- Tablet
- PC
Future/Impact

DMX Impact
- Enable detection of mental models to focus training
- Aided in training of new engineers
- Useful in sharing lessons of events

Shadowbox
- Test scalability, is it useful beyond unit for which it was created
- If true, then create
  - ñ library of exercises for COP members
  - ñ training program to allow members to design their own
Student Projects

Decision Aids
Large Screen Impact
A Typical Manifold
Job Aids

- No job aid
- Manifold diagram
- Line demarcation
- Checklist
- Combinations of the individual job aids
Training Checklist

Hydrocracker to Tank 43 and Tank 16 to Truck Rack

- open Valve 19
- CLOSE Valve 18
- CLOSE Valve 17
- CLOSE Valve 16
- CLOSE Valve 15
- open Valve 10
- open Valve 23
- CLOSE Valve 11
- CLOSE Valve 12
- CLOSE Valve 13
- CLOSE Valve 14
- CLOSE Valve 22
Tank 11 and Tank 15
Procedure

- 24 subjects
- 1st visit
  - Training
  - 3 different tasks
  - Questionnaire
- 2nd visit (1 week later)
  - 3 different tasks
  - Questionnaire
- Received IRB approval
Accuracy

Accuracy

- Line D, Diagram, Checklist
- Line Demarcation, Checklist
- Checklist
- Diagram
- Line Demarcation, Diagram
- Diagram, Checklist
- Line Demarcation
- None

(Task Time)
Time

Task Time

Easy
Medium
Hard
Extended Operator Workplace
Scope

} Compare reaction times:
  ◦ Information on large 52” monitor
    ñ 12 feet away
  ◦ Information on small nearby monitor
    ñ 2 feet away
Design of the experiment

- “Information” and “Control” screens
- Changing numbers on information screen
- Control arrows on control screen
- Operator must make change on control screen to keep values within range
Nearby Information Screen
Distant Information Screen
Operator Information Screen
Operator Control Screen
JMP ANOVA Analysis

- Average response times
  - Nearby = 4.30 seconds
  - Distant = 4.64 seconds

- Distance of the target is marginally significant
  - \( p = 0.08 \)

- Longest response time in sections 1 and 9
Situation Awareness (Overview) Displays
Overview Example Review
4 Seconds

Enable the operator to determine the health of the units under their span of responsibility.

If a problem exists, directs them to displays from which they can troubleshoot and correct the problem.

Do this by:

- Present the correct data, well formatted to answer the operator questions:
  - “Is my process ok?” and, “Is it running at the desired target?”
- As the questions are qualitative in nature, the information should generally be presented in a qualitative manner.
## Quantitative vs Qualitative

<table>
<thead>
<tr>
<th>PV 78.5 PCT</th>
<th>SP 78.0 PCT</th>
<th>Time to Assess Experiment (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP 62</td>
<td>Manual</td>
<td><strong>Quantitative Question</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>102</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Quantitative Question</strong></td>
</tr>
<tr>
<td>Quantitative Presentation (less abstract)</td>
<td>118</td>
<td>115</td>
</tr>
<tr>
<td>Qualitative Presentation (more abstract)</td>
<td>101</td>
<td>101</td>
</tr>
</tbody>
</table>

How full is the tank? Am I running at the setpoint and will it stay there?
How Should The Information Be Organized?

- Creates a carefully organized system of displays
  - Navigate directly to primary operating display, and to detail where needed.
  - Display organized by function
  - Typically less than 100 PV’s on the display
- Just for this operator position
- No more than 10 sections on an overview display
An Overview

Supports Operator’s key decisions
- “Is my domain OK?”
- “Is it operating at the desired target?”
- 4-second situational awareness
- Overview Display is always visible

One Overview Display per operators span-of-responsibility
- Display organized by function
- Utilizes qualitative information
- Typically less than 100 parameters on the overview
## Steps to Design Overview Displays

<table>
<thead>
<tr>
<th>Content</th>
<th>Organization</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Do I need every single data point?</td>
<td>- What information is needed for high level situation awareness?</td>
<td>- What is the best frame of reference?</td>
</tr>
<tr>
<td>- What data points are important?</td>
<td>- How do I choose the information for overviews down to details?</td>
<td>- What is the best way to move across screens and into details?</td>
</tr>
<tr>
<td>- What data should be fused into information?</td>
<td>- What information should be grouped together?</td>
<td>- What colors should be used?</td>
</tr>
<tr>
<td></td>
<td>- Which sets of information should be grouped across screens?</td>
<td>- What sizes of font, lines, etc...</td>
</tr>
</tbody>
</table>
Content

What Data Should Be Included In A Display?

- Decision Mapping
- Interviewing
- Facilitation Process
- Key Leading Indicators of changes in the Process
- Story telling
How Should The Information Be Formatted?

Has the process been steady, increasing or decreasing?

Average value, maximum deviation. Are they OK?
Future/Impact

} Impact
  ◦ Overview created for project
  ◦ Positive feedback has led to creation for 11 other consoles in control room

} Future
  ◦ Team moved on to lower levels
  ◦ Creating representation options for key equipment (reactors, heaters)
  ◦ Developing rules for display system creation
Procedure Modularization

Sandeep Purao
Penn State University
Multiple Unit-Operator Alignments

Unit A
Procedure

Unit B
Procedure

Unit C
Procedure

Operator A

Operator B/C

Console A/B/C
Procedure Assessment

} Issues
  ◦ Same steps in multiple procedures
  ◦ Different levels/types of information (task versus training)
  ◦ Different users
  ◦ One size fits all

} Improvement option
  ◦ Break procedures into chunks that can be recombined

} Problems
  ◦ Volume
  ◦ Style/format
Development procedure

STANDING INSTRUCTION NO. DGHE-8

LOSS OF HYDROGEN RECYCLE COMPRESSORS

Feed control valves will close, MA-14 and GH-376 will shut down. Check to see if this has happened.

Close feed control block valve. Also close liquid recycle valve if recycling product.

Fuel gas control valve will close, steam to heater will open.

Shut off makeup hydrogen. Shut down compressor GH-572 if in service.

Start venting plant to H.P. fuel via recycle drip vessel 1252. Notify Cracking.

Start N₂ to plant via suction bottle on compressor GH-504 (open bypass) when plant pressure is 160 psi, close vent to fuel on V-1252 open to flare via LPG Drip 1257. (Close Suction on Com-
Application of Heuristics

if (\(\forall k \in Si, \exists conj \in ConjunctionList | k == conj\),
and \(\forall j \in Si | cond \in ConditionList | j == cond\))
{conjunction(Si) = k; Condition(Si) = j;}

Conjunctions and Conditions

Procedure Chunking

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Action</th>
<th>Target</th>
<th>Step-Break</th>
<th>Conjunction</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue circulating hydrogen until reactor temperature is below 500F, continue stripper bottoms circulation through heater 35 until radiant shutter off hydrogen to compressors 503 and 504. Switch make hydrogen to stop the condensate injection and sour water pumps. Close in lean and fat DEA circulation. Shut down the vent gas compressors</td>
<td>continue hydrogen</td>
<td>continue stripper bottoms circulation</td>
<td>TRUE</td>
<td>until</td>
<td>temperature</td>
</tr>
<tr>
<td>Shut down compressors 503 and 504.</td>
<td>shut down compressors 503</td>
<td>TRUE</td>
<td>vent system</td>
<td>vent system</td>
<td>temperature</td>
</tr>
<tr>
<td>Vent system to flare if necessary.</td>
<td>continue stripper bottom</td>
<td>until</td>
<td>temperature</td>
<td>temperature</td>
<td></td>
</tr>
</tbody>
</table>
# Procedure Elements for Chunking

<table>
<thead>
<tr>
<th>#</th>
<th>Lines of ...</th>
<th>Subject</th>
<th>Predicate</th>
<th>Adverbial</th>
<th>Object</th>
<th>Object M...</th>
<th>Purpose</th>
<th>Condition</th>
<th>Conjuncti...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cooling w...</td>
<td>field</td>
<td>Cooling</td>
<td></td>
<td>water f...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Closeanni...</td>
<td>field</td>
<td>Close</td>
<td></td>
<td>annin valve</td>
<td>in the fee...</td>
<td>and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Shutdown...</td>
<td>field</td>
<td>Shut down</td>
<td></td>
<td>the field f...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Throvwsi...</td>
<td>field</td>
<td>Throw</td>
<td></td>
<td>switch B5...</td>
<td>on DHT e...</td>
<td>to shut He...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>OpenDeluge...</td>
<td>field</td>
<td>Open</td>
<td></td>
<td>Deluge sy...</td>
<td>to HDU an...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shutdown...</td>
<td>field</td>
<td>Shut down</td>
<td></td>
<td>Compass...</td>
<td>at emerge...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Blockoff...</td>
<td>field</td>
<td>Block off</td>
<td></td>
<td></td>
<td>to make H...</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>Manually...</td>
<td>field</td>
<td>manually</td>
<td></td>
<td>unload co...</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>Shutdown...</td>
<td>field</td>
<td>Shut down</td>
<td></td>
<td>Heater 30...</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>11</td>
<td>Startstea...</td>
<td>field</td>
<td>Start</td>
<td></td>
<td>steam</td>
<td>to Htid 29...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Opendam...</td>
<td>field</td>
<td>Open</td>
<td></td>
<td>dampsers</td>
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<td>field</td>
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<td>field</td>
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<td>with norm...</td>
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<td>lean and...</td>
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<td>field</td>
<td>Stop</td>
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<td>onlyenough...</td>
<td>as to avoi...</td>
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<td>if open</td>
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<td></td>
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<td>to flareto...</td>
<td>As</td>
<td></td>
<td></td>
</tr>
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<td>permits f...</td>
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<td></td>
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<td>feed and...</td>
<td></td>
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<td>nitrogen</td>
<td>Purge</td>
<td></td>
<td>system with hydro...</td>
<td>if available...</td>
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<td></td>
<td></td>
</tr>
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<td>27</td>
<td>Ifunablet...</td>
<td>field</td>
<td>Notify</td>
<td></td>
<td>Process...</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
# Loss of Power

**Procedure:** D-900-07.05  
**Revision:** D  
**Effective Date:** 11-Sep-2009  
**Operations Zone:** D  
**900 - ULSD**

## Purpose

Loss of Power

## Scope

This procedure details the steps needed to safely respond in the event of a power loss.

## Procedure

<table>
<thead>
<tr>
<th>Role</th>
<th>Description of Task</th>
</tr>
</thead>
</table>
| CO   | 1. Trip the Reactor Charge Heater Emergency Shutdown System, (I-904) HZ-9056 A.  
      | • Closes Reactor Charge Heater Fuel Gas Emergency Shut-off Valve, fuel gas control valves and shuts down Charge Pump P-901 A/B.  |
| CO   | 3. Trip the emergency fuel gas shut down system for the Fractionator Reboiler with (I-914) HZ-9441A.  
      | • Closes Fractionator Reboiler Fuel Gas Emergency Shut-off Valve WV-9508A and fuel gas control valve FV-9425.  |
Results – 4 Pages of Unique Actions

<table>
<thead>
<tr>
<th>#</th>
<th>Chunk</th>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clear exchanger tubes</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Shutdown Unit</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Isolate frac</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Make Notifications</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Total Reflux</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Secure Heaters</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Trip Charge Heater</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Total Recycle</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Troubleshoot Cause</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Line- up to offspec</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>Secure Amine and H2</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>Bottle in 900 unit</td>
<td>13</td>
</tr>
<tr>
<td>13</td>
<td>Charge Heater ESD</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>Conserve H2</td>
<td>32</td>
</tr>
<tr>
<td>15</td>
<td>Depressure unit</td>
<td>7</td>
</tr>
<tr>
<td>16</td>
<td>Event Follow- up</td>
<td>15</td>
</tr>
<tr>
<td>17</td>
<td>Frac Reboil Heater ESD</td>
<td>9</td>
</tr>
<tr>
<td>18</td>
<td>Isolate Feed Rundown</td>
<td>8</td>
</tr>
<tr>
<td>19</td>
<td>Low H2 operation</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>Prevent Runaway</td>
<td>14</td>
</tr>
<tr>
<td>21</td>
<td>Secure 900 Unit</td>
<td>18</td>
</tr>
<tr>
<td>22</td>
<td>Shutdown Charge</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>170</td>
</tr>
</tbody>
</table>
Procedural Splitter Ver. 0.7

Task 1: Procedure Chunking
Automated Procedure Chunking

**Current State of Procedures**
- Organized by unit
- One per upset/event
- All operators
- Reference other procedures

Convert to plain text

**Future State of Procedures**
Procedures tailored to user with less material to be kept updated

Updating module updates everywhere it is used

Apply heuristics to parse into table

Apply heuristics to create modules of tasks and steps
Future/Impact

Future
- Creating integrated analysis & database software
- Add ability to utilize/insert standard descriptors
- Enable lookup tables to replace instrument numbers for redundant equipment (e.g., heaters)
Alarm Rate Analysis

Craig Harvey, Ph.D.
Louisiana State University
# Alarm Rate Standards

## EEMUA Alarm Rate Standard

<table>
<thead>
<tr>
<th>Long Term Average Alarm Rate in Steady Operation</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1 alarm per minute</td>
<td>Very likely to be unacceptable</td>
</tr>
<tr>
<td>1 alarm per two minutes</td>
<td>Likely to be excessively demanding</td>
</tr>
<tr>
<td>1 alarm per five minutes</td>
<td>Manageable</td>
</tr>
<tr>
<td>&lt;1 one alarm per ten minutes</td>
<td>Very likely to be acceptable</td>
</tr>
</tbody>
</table>

## ISA Alarm Rate Targets

- **Very Likely to be Acceptable**:
  - ~150 Alarms per day
  - ~6 Alarms per hour (average)
  - ~1 Alarms per 10 minutes (average)

- **Maximum Manageable**:
  - ~300 Alarms per day
  - ~12 Alarms per hour (average)
  - ~2 Alarms per 10 minutes (average)
Alarm Displays
- Categorical
- Chronological

Alarm Rates
- 1 per 10 min
- 2 per 10 min
- 5 per 10 min
- 10 per 10 min
- 20 per 10 min

Operator Performance
Categorical Alarm Display
## Chronological Alarm Display

<table>
<thead>
<tr>
<th>Time</th>
<th>Alarm Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:02 AM</td>
<td>PLATFORM LINE STATION 2</td>
<td>AT PUMP 5 &quot;PASS VALVE MALFUNCTION&quot;</td>
</tr>
<tr>
<td>10:58 AM</td>
<td>PLATFORM LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>11:01 AM</td>
<td>PLATFORM LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:57 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:56 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:55 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:54 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:53 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:52 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:51 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:50 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
<tr>
<td>10:49 AM</td>
<td>RIG LINE STATION 1</td>
<td>AT PUMP 25 &quot;POWER TRIP&quot;</td>
</tr>
</tbody>
</table>

### Alarm Controls

- Alarm: On
- Alarm: Off
- Alarm: All

### Alarm

00:14:49
Descriptive Statistics – Mean Reaction Time
(Seconds)

Mean(RT-Sec) Category

Reaction Time (Seconds)

High | Caution | High | Low | Caution | High | Low | Caution | High | Low | Caution | High | Low | Caution | High

1 - 10 Min. | 2 - 10 Min. | 5 - 10 Min. | 10 - 10 Min. | 20 - 10 Min.
Overview

- Minimum of 30 operators will run the experiment.
- Two kinds of alarm display’s will be used (Chronological and Categorical).
- All treatment simulations are 1 hour and the alarm rates used as below:

<table>
<thead>
<tr>
<th>Alarms/10 minutes</th>
<th>Chronological</th>
<th>Categorical</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>25</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>X</td>
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</table>
Response Time by Alarm Rate

![Bar chart showing response time in seconds for different alarm rates. The chart compares categorical display to chronological display.](chart.png)
### RT – Alarm Rates v. Student/Operator

<table>
<thead>
<tr>
<th>Level</th>
<th>Least Sq Mean (sec)</th>
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</thead>
<tbody>
<tr>
<td>Student, 20</td>
<td>A</td>
</tr>
<tr>
<td>93.016354</td>
<td></td>
</tr>
<tr>
<td>Operator, 20</td>
<td>B</td>
</tr>
<tr>
<td>47.676607</td>
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</tr>
<tr>
<td>Student, 10</td>
<td>B</td>
</tr>
<tr>
<td>31.785469</td>
<td></td>
</tr>
<tr>
<td>Operator, 10</td>
<td>B</td>
</tr>
<tr>
<td>24.217462</td>
<td></td>
</tr>
</tbody>
</table>

Students and Operators reaction time for solving an alarm can not be distinguished from one another except at the alarm rate of 20 alarms per 10 minutes.

- Students performed significantly slower than operators at 20 alarms per 10 minutes.
Future/Impact

Impact
- Published alarm targets are at best for novice operators

Future
- Examining smart alarming
  - How to develop and document
- Quantify benefits of alarm management
  - Does alarm management improve performance?
  - Current adoption is article of faith
  - Look at in conjunction with procedure automation
New COP Projects
Background Color

Business case:
Background color and color contrast is a very effective technique for presenting information to operators. The use of appropriate color schemes allows operators to very rapidly recognize and interpret information on the display.

Purpose:
Determine which variables have the greatest affect in selecting the background / foreground color palette for a given ambient light source?

What characteristics, aspects or principles of ambient lighting conditions influence the usability of sets of color on an operator display?

What characteristics, aspects or principles of the display device (screen, monitor, LCD panel) influence the usability of sets of color on an operator display? (examples include viewing angle, contrast ratio, brightness, glare, and treatments.)

How can these findings provide a starting point when considering other situations like uncontrolled environments outside the central control room? Standard office, roving operator in sunlight and shadow, airport gate lounge, etc.

Deliverable:
Ideal color design tool
Large Screen Display Survey

**Purpose:**
A survey of both member and non-member companies is being conducted to determine how large screens are or are not being effectively used in the petrochemical industry and the reason why.

In addition to size and number of monitors, the survey elicits input on the intent of the monitors, the formatting of the data, and suggestions for use.

The survey has sections for supervisors, operators, engineers, and designers.

This survey is open to any operating company, with results provided to all who participate.

The survey is on the ABB and COP websites.

As of March 13, 2015 about 60 responses have been received.

**Factors:**
Location, role of user, utilization, effectiveness, display format, etc.

**Deliverable:**
The survey results will be analyzed to identify current best practices and lessons learned, and will set the groundwork for future research to develop large display standards.
Optimal Workstation

Purpose:
Control rooms are sized to accommodate the console operator’s workstation. The console operator’s workstation has evolved with more information being presented. Where once only three, 15” monitors were present per operator now six or more might be provided along with additional monitors for the business network.

The reduced cost of monitors has resulted in far more of them, with potentially negative consequences. Not only are the excess monitors not adding value, they occupy valuable real estate. This project seeks to answer:

• What is the optimal design for an operating console?
• What factors influence the design
• How does the console design interact with the structure of the display system?

Deliverable:
Part of the deliverable will be to define from an analytic perspective the optimal operator workspace. The results will include the optimal number, size, and layout of the console workstations, with the basis of the layout. The analysis will account for differences in display system structures (i.e., linear versus hierarchical) for similar systems.
Procedure Warnings

Purpose:
Health, Environment and Safety (HES) and informational statements in operating or maintenance procedures are used to draw the operator’s attention to any consequences of hazard exposure as a potential result of performing a procedural step and provide instruction(s) to avoid the hazard.

Un fortunately, there is no clear consensus regarding HES and informational statement representation within procedures. Additionally, there are human performance concerns regarding distracting template formats.

How can warning information be displayed such that operators globally can quickly identify, process, and comply with this information and perform the procedure safely without incident?

Is symbol with text best? Which symbols? What is the optimum placement of each? What is the importance of signal words? What the best color to use?

Deliverable:
Recommendations of symbols, choice of signal words, color formats for symbols, text placement, format of information presentation (levels) within HES and informational statements, color formats for other information and operator/technician training methods.
Handheld Usage

Background:
One of the fastest growing trends in the automation industry is the use of mobile devices. They are significantly changing the way users communicate, collaborate, obtain information, and interface with equipment. Mobile devices have opened up a wide range of applications possibilities, yet companies are struggling to take advantage of their full potential in operations.

Purpose:
The focus of the project is to determine guidelines on how to apply mobile technology based on operator tasks to save time, improve maintenance and prevent accidents. The project will identify important variables to increase the effectiveness of information presented and displayed to operators in situations where mobile devices can support and enhance human decision making.

It will also show how can text aware computing factors, sensor information, and input modalities be combined to provide an intuitive human computer interaction in the context of field operators in the process industry?

Deliverable:
Identification of important variant and invariant attributes that affect handheld displays information presentation. The development of display design policy and guidelines / recommendations for the graphic design targeted on small handheld devices.
Why should I get involved

- Get to direct research – COP is member driven (driven by Champions members)
- No time requirement (limited as you desire)
- Share costs/risk (with active project managements direction)
- Research tailored to your site/problems (driven by operator taken at your site)
Who is the Center for Operator Performance?

Center for Operator Performance
An Industry-Academia Collaboration
www.operatorperformance.org