Unifying Alarms and Operating Envelopes for the Achievement of KPI’s and Business Objectives

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The Role of the Operator

Control the Equipment

ALARM!!

Respond to Alarms

Meet Business Objectives

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The Role of the Operator

- What, apart from the Operator, connects?
  - Control the Equipment
  - Alarms
  - Business Objectives
The Role of the Operator

- What, apart from the Operator, connects?
  - Control the Equipment
  - Alarms
  - Business Objectives

- An Operating Envelope
The Role of the Operator

- What, apart from the Operator, connects?
  - Control the Equipment
  - Alarms
  - Business Objectives

- An Operating Envelope
  - How to see it
  - How to use it
Alarm Terminology - 1

- **Emergency alarms, HiHi-LoLo Alarms**
  - Must be attended to **Now**. Sometimes based on metallurgical properties eg. Max tube temperature

- **Warning alarms, Hi-Lo Alarms**
  - An acceptable operator response can be to ignore alarms because many are false ... sometimes this will be wrong

- **Alerts – inside HiLo Limits, informal, not under change control**

- This is too many levels so there is a trend to combine HiHi-LoLo into Safety Alarms.
Alarm Terminology - 2

- Safety & ESD Alarm Limits
  - Often automatic with no operator intervention possible
  - The GPC method should not be used for Safety Alarm limits.
  - Better Economic Alarms reduce the demand rate on Safety Alarms hence the probability of failure on demand (PFOD) thus increasing plant safety - EEMUA
We think of Alarms defining the boundary of the “Normal Operation” Operating Envelope which is where we achieve Business Objectives.
Reality is different. Because we don’t know where the boundary of ‘Normal’ is we have to widen the Alarm Limits to keep annunciations to a tolerable level – but as the Alarms were meant to define the boundary of ‘Normal’, we just changed the definition of ‘Normal’.
Rationalising Alarms using one-at-a-time methods reduces response time, worsens achievement of Operating Objectives and makes process control harder because we only widen limits to reduce the Annunciation Rate and rarely have time to narrow them.
We need this picture of process and result data for many variables.
2-d simplified Operating Envelope

Quality Constraints
\[ Q > a \cdot PV1 + b \cdot PV2 + c \]

What happens when PV3, PV4 etc changes?

Process variable PV1

Process variable PV2

Good Product Operating Envelope

Nearly Redundant quality parameter

Redundant quality parameters
A simplified Operating Envelope

Quality Constraints
Q > a*PV1 + b*PV2 + c

What happened when PV3, PV4 etc changed

Was a nearly redundant quality parameter but now very important

Still a redundant quality parameter but much less so
N-d Operating Envelope

- Because we can’t visualise an n-d envelope we use Alarms as probes intended to touch its surface in many places.
- But we haven’t had a way to set alarm limits to do this
The Observed Problem -
Plentiful data but no Information
The Root Problem

Human brains are visually oriented

A picture is worth 1000 words

We understand graphs not numbers

But...we can only draw a graph of 2 or 3 variables.....

435 x-y graphs are necessary to show all the interactions between just 30 variables....
One point in a 27-dimensional graph
13,444 points in a 27-dimensional graph

178 variables at 5-minute intervals for 3 months

Notice how clearly different Modes of operation, process excursions and where the plant has actually operated stand out.

This cloud of points is the population of the ‘All Previous Experience’ Operating Envelope

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The existing alarm limits were imported from the DCS. Operation with no standing alarms was never achieved in this 92-day period.

Which Operating Envelope are these alarm limits wishing to identify?
Performance of Existing Alarms

Annunciations per hour and Standing Alarm Count over 92 days. Mode shown by colour
Three Operating Modes

Pink shows the Kerosene Mode Operating Envelope
Blue shows the LGO Mode Operating Envelope
Black shows Stand-by Mode Operating Envelope

Only one set of Alarm Limits for all three Modes ‘lumped together’. A permanent compromise Operating Envelope that is never right.

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New “Lumped-Mode” Alarm Limits

Standby Mode in green. Some alarm limits have been moved inwards to ensure known extremes of operation are alarmed.
These limits might meet EEMUA Guidelines for Alarm Performance but won't help the Operator achieve the plants operating objectives. A Separate set of Alarm Limits are needed for each Mode.
Starting Point for the Alarm Review

Three months of operating data for Kerosene Mode with existing alarms moved in to the boundaries of where the plant has actually operated. In the Review Meeting individual alarm limits will be moved to exclude known bad operation and deleted if considered unnecessary. The next slide gives an example of how the screen might then look together with trend plots for the whole year of Annunciation Rate per hour and Standing Alarm Count. These update automatically as further changes are made to the alarms.
Several alarm limits have been moved inwards to eliminate operation that the Review Meeting considers undesirable. The eliminated points are in black and are less than 2% of all the data for the year. These are the points that would be alarmed by one or more variables if experienced again in the future. The next slide shows the Annunciation Rate and Alarm Count that would result.
In the Alarm Review Meeting - 2

Annunciations/hour and Standing Alarm Count for 92 days of operation in Kerosene Mode. Further changes to the Alarm Limits will update these trends. The Review Meeting might use these pictures to lead them to a closer investigation of the period of alarm activity to the right of the centre line. Perhaps the operating log will show that it corresponds to a known plant incident.
Using Alarms to achieve KPI’s

Turquoise – the Operating Envelope for in-specification Kerosene

Pink – the No-Alarms Operating Envelope for the new alarm limits

Should Pink be larger than Turquoise?

Why don’t we operate inside the in-spec Envelope now?

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Using Alarms to achieve KPI’s

Turquoise – the Operating Envelope for in-specification Kerosene

Pink – the No-Alarms Operating Envelope for the new alarm limits

Should Pink be larger than Turquoise?

Why don’t we operate inside the in-spec Envelope now?

Is it because we couldn’t see it until now?
Using Alarms to achieve KPI’s

Alarm performance of the in-spec Envelope is poor so move to it in several stages of improving control followed by tightening of limits.
Better Alarms Improve Process Operation

New HiHi/LoLo limits forced better operation to avoid nuisance Trips. Trip Rate at implementation 2%, 2 years later 0.1%
OK, so what’s better??

- The ability to visualise whole systems
- The interaction of alarms
  - Effect of alarm combinations
  - Estimate alarm-on periods
  - Maximise operator response time
    - Earlier warning
  - Eliminate nuisance alarms
- SPEED – a complete analysis in a few minutes
CVE Graphical presentation of KPI's with control limits and pre-built Queries for different time-periods allows easy understanding

Still a pdf report but graphical and many fewer pages

Report production automated

Ves file can be provided to allow further investigation or “drill-down”
Alerts

- Recognise that defining the Operating Envelope with fixed alarm limit values implies
  - Independence between process variables hence
    process operation in a rectangular box (a hypercube) enclosing the envelope
  - Alerts account for interaction between variables so give a much better model of an Operating Envelope.
The Used Operating Region

Range P1

Range P2

Used Operating Region

2-D

The Operating Zone
The Best Operating Zone Concept

What would a 20-variable Zone look like?
Using Alarms to achieve KPI’s

Turquoise – the operating envelope for in-specification Kerosene

Pink – the no-alarms operating envelope for the new alarm limits

Does Pink need to be larger than Turquoise?

Why don’t we operate inside the in-spec envelope now?

Perhaps it is because we haven’t been able to see it?
Building the Alerts Model

1. Using Visual Explorer, decide with hindsight where you should have operated by applying objectives (e.g., Inside HiLo Alarm Limits) as a query.

2. ‘Focus’ on the yellow points, remove unwanted variables and ‘save as’. These points represent best past experience to be enforced in the future.

3. Open the file in Process Modeller to create the envelope ready for use. Operating objective is to remain an interior point of the envelope.
Keep the process inside the Green envelope to keep the process inside its HiLO alarm limits. This is the job of Process Control.
Correcting Alert Violations

<table>
<thead>
<tr>
<th>Alert Violation</th>
<th>Advice to correct Alert Violations</th>
</tr>
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<tbody>
<tr>
<td>Lo Alert violation</td>
<td></td>
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Alarms and Alerts in context
Public and Private Alerts

- **HiLo Alarms**
  - ignore interaction between variables so give late warning of process excursions

- **GPC Alerts**
  - take interaction fully into account and display to the operator as a picture. Their role is to keep the process inside the HiLo Limits. They provide corrective advice for the operator

- **Todays Operator Alerts**
  - are values set by the operator and used at his discretion. They can co-exist with the new GPC Alerts. We suggest ‘Public’ and ‘Private’ Alerts as a naming convention.
Results of Field Trial

- **Quality Improvement**
  - **2% immediate Process KPI Improvement**
  - More expected as Operators gain more confidence and implement more of the Advice
  - More expected when the Optimiser is turned on

- **Operations Improvement**
  - High acceptability of operator Advice
  - Advice *reduced start-up time by factor of 6*
Results - 2

- **HiLo Alarms**
  - **Went from 51% correct to 90% correct on first attempt**
  - Now even better so less dependent solely on operator vigilance

- **Alerts**
  - Previously impossible to set at constant values
  - Now multi-variable alarms are so good they are advising operators where to operate and have warned of danger of equipment damage long before any one variable detected a problem.
The New GPC Alarm Rationalisation

Make Consistent

Tighten Objectives
Geometric Process Control for Rationalising Alarm Limits

- **Benefit from**
  - Fewer false alarms – increased belief in remainder
  - Lower annunciation rates
  - More time for the operator to think and respond
  - Earlier warnings of process excursion
  - A Safer Process with higher KPI achievement

- **And**
  - Saves **at least** 20% of man-hours in Alarm Review Meetings
  - Reduces Process Engineers time for Change Management
  - Move towards the in-spec Operating Envelope