Alarm Management is the current “hot topic” in the process industries. Overloaded and poorly performing DCS alarm systems are common and have been identified as contributing factors in several major accidents including those at BP Texas City in 2005 and Texaco Pembroke refinery in the UK in 1994.

To improve an alarm system, it is essential to perform an initial benchmark. Benchmarking a system has many benefits. It provides a basis to compare a system against industry best practices as well as a reference point to measure improvements at the end of an alarm management project. Other benefits include creating solid data driven analysis to communicate the state of the alarm system to appropriate stakeholders at a site, and justify further investment in alarm system improvement. Finally, a significant benefit in a benchmark study is the identification of bad acting alarms. As a standard practice, PAS identifies bad acting alarms in the initial benchmark report. Our experience indicates that breakthrough gains can be realized simply by resolving the bad acting alarms.

There are several different alarm problems to examine, with differing solutions. In performing these analyses, some amazing phenomena have been documented, presented here as examples of how bad things can get.

The solution to alarm problems can be achieved by following the seven-step process developed by PAS. The methodology and all other aspects of alarm management are detailed in The Alarm Management Handbook – A Comprehensive Guide, which is available at www.PAS.com and on www.Amazon.com. The implications of, and solutions to these problems are presented in much more detail than can be accomplished in this brief paper. The book is intentionally designed with a very “how-to” focus.

Here are the seven steps to a highly effective alarm management system:

**Always-needed initial steps:**

Step 1: Develop, Adopt, and Maintain an Alarm Philosophy
Step 2: Collect Data and Benchmark Your Systems
Step 3: Perform “Bad Actor” Alarm Resolution

**Steps to implement based on alarm system performance after the first 3 steps:**

Step 4: Perform Alarm Documentation and Rationalization (D&R)
Step 5: Implement Alarm Audit and Enforcement Technology
Step 6: Implement Real Time Alarm Management — and, of course —
Step 7: Control and Maintain Your Improved System

The following examples are taken from analyses from many different process industries, including Refining, Petrochemical, Power, and Pulp & Paper. The facilities are located all over the world. Of course, the specifics are omitted for confidentiality reasons. In every case, there are many “close runners-up” to the “winners” shown, as these are very common problems, spread throughout the biggest names in the processing industry.

All of the analyses shown are based upon the span of control of a single board operating position. Later, when we mention 3,517 alarms in ten minutes, we will be referring to a quantity of alarms presented to a single person, not multiple people.

And now, the top 10 worst-performing alarm systems.

**NUMBER 10: WORST DIAGNOSTIC ALARM PERCENTAGE**

This measure is the extent to which alarms indicating malfunctioning instruments are a percentage of the overall alarm load. A high absolute count of such alarms indicates significant maintenance problems with the instruments. A high percentage of instrument diagnostic alarms indicates that important process alarms are likely to be “buried” in the alarms from the malfunctioning instruments. Our “winner” in this category has both high counts and high percentages – the alarm system is dominated by BAD VALUE Alarms.
Worst Diagnostic Alarm Percentage

71% of the entire annunciated alarm system load is from instrument malfunction alarms. They averaged more than 600 such alarms per day during the 24-day analysis.

Modern sensors can generally provide all of the accuracy needed over the entire range that the process is likely to vary. But some engineers continue to follow the older configuration practices and do not consider the consequences of generating lots of Bad Value alarms during conditions such as startup and shutdown. The correct practice is to configure the instrument for the entire possible range of the process value under all conditions, the accuracy obtained then checked, and if needed, a better sensor specified.

These situations must be addressed in a prompt manner since often an instrument malfunction removes an identified, rationalized indicator of an abnormal situation from the operator’s view. The time that operators spend confirming the instrument problems reduces their attention to other operator duties.

Generally the addition of a new instrument must follow a management-of-change methodology, to ensure it is done properly. So does the removal of an instrument, to ensure that it is truly not needed and the removal is done properly. And functionally, the indefinite toleration of a malfunctioning instrument is the same as removing it. If there is an incident, it will be difficult to explain how a relevant instrument was allowed to malfunction for months – to effectively be removed from service – without the appropriate level of review. This is the stuff of fines and lawsuits.

NUMBER 9: WORST NUISANCE ALARM PERCENTAGE

We usually find that only 10 to 20 different configured alarms make up from 20% to 80% or more of all alarm events in a system. Those most frequent alarms were not originally designed to annunciate hundreds (or thousands) of times per day, but they do. These alarms are called “nuisance” as they deliver no value to the operator. In fact, their high rate of occurrence becomes a hindrance to the operator’s ability to identify important alarms during a process upset. Addressing them and making them work properly will substantially improve an alarm system, provide immediate and much-needed relief to the operator, and is not difficult or very time consuming to do. Our winner in this category:
Worst Nuisance Alarm Percentage

98% of all alarms are from the top ten bad actors. This data is covers a one-year period. (See figure #9 below.)

Figure #9: Worst Nuisance Alarm Percentage

Commentary and Solutions:

Again, in this system, half of the top 10 alarms are related to instrument malfunction, previously discussed. The others are from a pressure switch, a flow meter, and command-disagree signals from several motor-operated valves. Commonly, we see every possible alarm type in the “top 10.”

Chattering and fleeting alarms are where the alarm appears and clears faster than would be possible by the application of an appropriate operator action. The top 10 most frequent alarms usually contain several alarms that chatter or are fleeting. These can be addressed in a variety of ways. First, the requirement to have the alarm and a proper alarm trip point (relative to the normal variation of the process) should be confirmed. Also needed and effective are proper deadband selection (if an analog signal, or proper “mechanical deadband adjustment” of field switches), and the proper application of alarm delay times. ON-Delay times prevent alarms from being annunciated to the operator until they have been in effect for a certain number of seconds, which can eliminate most chattering or “fleeting” alarms. OFF-Delay times do not delay the initial presentation, but instead turn a string of chattering alarms into a longer-duration single alarm event.

The calculation methods, initial parameter selections, and other cures for several similar problems are beyond the scope of this paper, but are covered fully in the chapter “Common Alarm Problems and How To Solve Them” in The Alarm Management Handbook.

NUMBER 8: WORST ALARM SUPPRESSION

In a DCS, you intentionally configure an alarm on a point. You assign values and a priority that cause it to annunciate to the operator. Most DCSs have another setting on the alarm that you can select – an alarm suppression setting. If suppression is “OFF” then the alarm works normally. If suppression is “ON”, then the alarm behaves as if you never configured it in the first place. We call this situation “Alarm Suppression.” This is a potentially very dangerous setting to manage, and we have very often seen it mismanaged in very hazardous ways. It is fundamentally different than intentionally “de-configuring” the alarm.

DCS alarms systems are notoriously easy to change, and inadequate control over such changes is common. Security settings in most DCSs are insufficiently granular to allow operators to make the kinds of changes that are needed, yet restrict them from making inappropriate alarm system changes. The response to a nuisance alarm is often to suppress it. We have seen critical alarms disabled for months, with no records, no approvals, no repair efforts, and no other actions taken. Paper-based management-of-control systems are rarely effective. The practice of uncontrolled alarm suppression is highly dangerous, and unfortunately common.

A very common DCS, for example, has a much-abused suppression setting called DIS-ABLE. When this is used, the alarm event is still produced for the electronic journal, but not annunciated to the operator. Thus, you can analyze the count of alarm events that have been suppressed vs. those the operator sees. Our winner in this category is:
Worst Alarm Suppression

98% of all alarm events have been suppressed from the operator's view. (See Figure #8 below.)

![Graph showing alarm suppression over days]

**Figure #8: Worst Alarm Suppression**

**Commentary and Solutions:**

In this case, the operators have actually made the alarm system almost meet the EEMUA-related “Manageable” rating of ~300 alarms per day. The method, however, was by suppressing the other tens of thousands of alarms – many of the highest priority. This is a hazardous situation.

An ongoing program of nuisance alarm detection and resolution is needed. Alarm settings must be locked down from inappropriate change and undocumented suppression. Needed here (and at many other facilities) is an Alarm Shelving System, in which a programmatic overlay is used to allow for temporary but controlled alarm suppression. A proper shelving system controls, authorizes, and documents suppression of nuisance alarms until they can be repaired. It shows the overall list and relevant status information. It does not allow for such alarms to be “forgotten,” and issues periodic reminders for re-enabling via a “snooze” function.

**NUMBER 7: WORST ALARM PRIORITY DISTRIBUTION**

Alarm priority is used to differentiate alarms so that the operator can address the most important ones first. This is particularly important during upset conditions. Best practice for effective operation is for three different priority levels, with an approximate alarm event distribution of 80% LOW, 15% HIGH, and 5% EMERGENCY priority.

Without a consistent and logical method for determining priority, typically the distribution will be more heavily weighted towards the upper end.

**Worst Annunciated Alarm Priority Distribution**

1% LOW, 80% HIGH, 19% EMERGENCY

Note that we have seen systems configured with as many as 24% of the alarms set to the highest possible priority – which produces a system ineffective at providing truly useful guidance to the operator and actually devalues the importance of those alarms. (See Figure #7 below.)

**Figure #7 Worst Alarm Priority Distribution**

**Commentary and Solutions:**

The best solution for an improper alarm priority distribution is Alarm Rationalization. This is the review of an existing alarm system with the intent of insuring alarms exist only when operator action is needed, insuring duplications are eliminated, documenting the rationale for each alarm, solving various alarm-related problems, and assigning priorities in a logical and consistent manner.

**NUMBER 6: WORST ALARM DAILY RATES – INCLUDING SUPPRESSED ALARMS**

In this measure, we can see how easy it is to generate tens of thousands of alarms events per day with an improperly configured alarm system.
Worst Alarm Daily Rates Including Suppressed Alarms

- Worst Average Daily Rate: 26,665 alarms per day (recorded – 1 every 3 seconds)
- Worst Daily Total: 48,803 in one day (>1 every 2 seconds)
- Based on an 18-day analysis period

Figure #6: Worst Alarm Daily Rates Including Suppressed Alarms

Commentary:
Again, a large difference is shown between the alarms produced on the system and the smaller number of alarms presented to the operator due to uncontrolled alarm suppression.

NUMBER 5: WORST ALARM DAILY RATES – ANNUNCIATED ALARMS ONLY

In this measure, alarm overload of the operator is clearly apparent.

Worst Average Daily Rate – Annunciated Alarms Only

- Worst Average Daily Rate: 10,858 alarms per day (average 1 every 8 seconds)
- Worst Daily Total of this system: 25,324 in one day (average 1 every 4 seconds)

Note that this daily total is not the “peak” worst rate in this paper (shown later) – but of this system, which had the highest average over a long analysis period. The intent is to show that these rates are not “aberrations” – they are sustained conditions.

Figure #5: Worst Average Daily Rate – Annunciated Alarms Only (41 Days)

Commentary:
The rate far exceeds the ability of a single operator to process. The lower-value line indicates the alarm rate if the top 10 most-frequent alarms were eliminated. In this case, the result is still too high, but the difference is quite large.

NUMBER 4: WORST ANNUNCIATED ALARM BURST RATE

(Highest count in a 10-minute period presented to the operator)

“Alarms per 10 minutes” is an important measure. The minutes leading up to an accident have been shown many times to be the time when the alarm system is needed most, and performing at its worst. Human factors studies have shown that the maximum amount of alarms that can be effectively analyzed and dealt with by an operator is approximately 10 alarms in 10 minutes. Such a rate cannot be handled for hours on end, however.

Even if an alarm system “averages” less than the 10-in-10 threshold rate, the system is at high risk for important alarms to be missed by the operator during the periods the threshold is exceeded. The “average” is a very misleading measurement.
**Worst Annunciated Alarm Burst Rate per 10 Minutes**

The worst alarm burst rate consists of 3,517 alarms in a single 10 minute period. About 77% of the 10-minute periods in this 102-day span exceeded 10 alarms.

![Announced Alarms per 10 Minutes](image)

*Figure #4: Worst Announced Alarm Burst Rate per 10 Minutes*

**Commentary:**

This alarm system is much more of a hindrance than a help to the operator.

**NUMBER 3: WORST AVERAGE TIME-IN-FLOOD PERCENTAGE**

Alarm flood analysis is more sophisticated than just “Alarms per 10 minutes.” We define an alarm flood event as beginning when the rate exceeds 10 alarms in 10 minutes, and ends only when the system rate declines to producing less than 5 alarms in 10 minutes – a manageable amount. Alarm floods can make a difficult process situation much worse. Alarm floods can go on for hours or days. For that overall period of time, usually during system upsets, the alarm system can be much more of a hindrance than a help to the operator. The winner:

**Worst Average Time-In-Flood**

This alarm system is in flood for >89% of the time (42 day analysis).

*Figure #3A: Worst Average Time-In-Flood Percentage*

<table>
<thead>
<tr>
<th>Alarm Flood Analysis – Petrochemical System</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Floods</td>
<td>51</td>
</tr>
<tr>
<td>Floods Per Day</td>
<td>1.2</td>
</tr>
<tr>
<td>Total Alarms in All Floods</td>
<td>294,311</td>
</tr>
<tr>
<td>Average Alarms per Flood</td>
<td>5,771</td>
</tr>
<tr>
<td>Highest Alarm Count in a Flood</td>
<td>215,313</td>
</tr>
<tr>
<td>Percentage of Alarms in Floods vs. All Annunciated Alarms</td>
<td>99.7%</td>
</tr>
<tr>
<td>Total Duration of Floods in Hours</td>
<td>899.33</td>
</tr>
<tr>
<td>Percentage of Time Alarm System in a Flood Condition</td>
<td>89.2%</td>
</tr>
</tbody>
</table>

*Figure #3B: Worst Average Time-In-Flood Percentage*
NUMBER 2: LONGEST SINGLE ALARM FLOOD

Flooding can be minor to severe, infrequent to frequent. During a severe flood, the alarm system could possibly be more help to the operator if it was actually turned off, rather than being such a major distraction.

**Longest Flood: 106.8 hours (4.4 days)**

Most alarms in a process unit pertain to the normal operating state of a piece of equipment. However, equipment often has several normal, but differing, operating states. A few common state examples include:

- Running
- Not Running
- Use Feed “A” or “B”
- Make Product “C” or “D”
- Full Rates
- Half Rates

Algorithms are created for the automatic monitoring and detection of various plant states, and when detected the proper alarm settings for those states are automatically put into effect. Since most alarm floods arise from the unexpected shutdown of certain equipment, the proper settings for those events can be determined and placed into effect in real time when such events are detected.

For example, when a compressor trips, there are usually many diagnostic alarms immediately produced. These are a distraction to the operator at that time; the important alarms are from the remainder of the system as the upstream and downstream effects of the shutdown must be properly managed. Only later are the diagnostics needed, for restart of the compressor.

Real-time alarm management is a sophisticated technology, and the implementation involves careful consideration of many factors. While beyond the scope of this article, they are covered in depth in *The Alarm Management Handbook*.
**NUMBER 1: THE WORST-PERFORMING INDIVIDUAL ALARM**

*The winner of the Worst Performing Individual Alarm: A Low Pressure Alarm from a Pressure Controller (note: an Analog Signal, not a pressure switch)*

Our winner very steadily produced an alarm rate averaging over 1,400 alarms per 10 minutes for a period of 41 hours (over 200,000 in a single day). This is 142 alarms per minute, or about 2.3 per second. In combination with three other nuisance alarms, this system produced a single-day peak of 208,311 alarms, the highest single-day total we have encountered (although not by much).

![Announced Alarms per 10 Minutes From a Single Low-Pressure Alarm](image)

**Figure #1: The Worst Performing Individual Alarm**

**BONUS NUMBER 0: A SPECIAL CASE**

*The Highest Sustained Alarm Rate Ever Recorded*

Here is a special case that was not included in any of the above examples. In a new system being brought online, there was a grounding problem with the Safety Instrumented System’s PLC. This caused over two weeks of extremely high-rate diagnostic alarms, averaging over 170,000 per day. The alarms were not configured to be visible to the operator.

The impact on the process network devices associated with extremely high alarm rates can be severe. Historian capacity overflows are a common problem. In extreme cases, significant network or server bandwidth can be consumed, control response slowed, and needed information can be lost.

It was the installation of our PAS alarm analysis software, which successfully captured and analyzed this event data that identified this problem and led to the proper diagnosis and repair.

- Average: 173,657 alarms per day
- Peak: 180,488 alarms per day (> 2 per second)

**Summary:**

Overloaded and malfunctioning alarm systems are common throughout industry. The problems can be identified, isolated, and solved through proven alarm management methodologies, such as those described in *The Alarm Management Handbook*, coauthored by Bill Hollifield and Eddie Habibi of PAS.

It is unfortunate that bad alarm systems continue to negatively impact the profitability, safety and environmental performance of processing plants worldwide. The good news is that solutions are available today to improve the alarm system and to help bring some sanity to the control room.

**About the Author:** Bill Hollifield is PAS’s leading expert in Alarm Management, with multi-company, international experience in all aspects of the subject. At PAS, Bill is Principal Consultant responsible for the Alarm Management work processes, intellectual property and software product directions. He is a voting member of the ISA SP-18 Alarm Management committee, and co-author of the new ISA book, *Alarm Management: Seven Effective Methods for Optimum Performance*. 