FLUKE®

Calibration

Guide to improving Overall Equipment Effectiveness (OEE) through calibration

Application Note

This application note explains why calibration is an important part of process performance. It provides a framework and formulas for measuring Overall Equipment Effectiveness (OEE) and shows how performing regular and accurate calibrations can impact OEE.

Calibration is an indispensable tool for making measureable improvements in process performance. An effective calibration program helps reduce significant wastes of time spent on:

- Unplanned maintenance
- Scrapped product
- Rework

Measuring the impact of these wastes on process performance is facilitated using OEE (Overall Equipment Effectiveness).

OEE is a “best practice” metric for evaluating the efficiency of a manufacturing process. It is often a key performance indicator in an organization implementing a lean production system. OEE identifies the most common sources of manufacturing productivity losses and places them into one of three groups:

- Availability
- Performance
- Quality

OEE is calculated from the formula

$$OEE = (Availability) \times (Performance) \times (Quality)$$

To maximize efficiency, the OEE value should ideally be as close to 100% as possible. Actual values range from 0% to 100%, with a benchmark value typically around 85% that varies by industry.

Availability

A plant represents a considerable investment, and stakeholders expect it to be managed effectively and efficiently. The amount of time equipment is available for operation is the *Planned Production Time*. It includes scheduled maintenance and other factors that might lead to a planned shutdown. For example, most plants schedule downtime for regular maintenance, including calibration of sensors and instrumentation. Planned maintenance reduces the impact of a shutdown on a business. However, even with good planning, *Planned Production Time* can be lost when downtime occurs unexpectedly. The time left after subtracting unplanned downtime from *Planned Production Time* is the remaining Operating Time. The ratio of *Operating Time* to *Planned Production Time* is the OEE metric of *Availability*.

One of the reasons for lost production time is unplanned maintenance. This can occur when a sensor or transmitter drifts out of specification during a production run. The problem may be detected by a Supervisory Control and Data Acquisition (SCADA) system alarm or further down the line after considerable troubleshooting, when quality defects are observed during inspection.

$$Availability = \frac{Operating\ Time}{Planned\ Production\ Time}$$

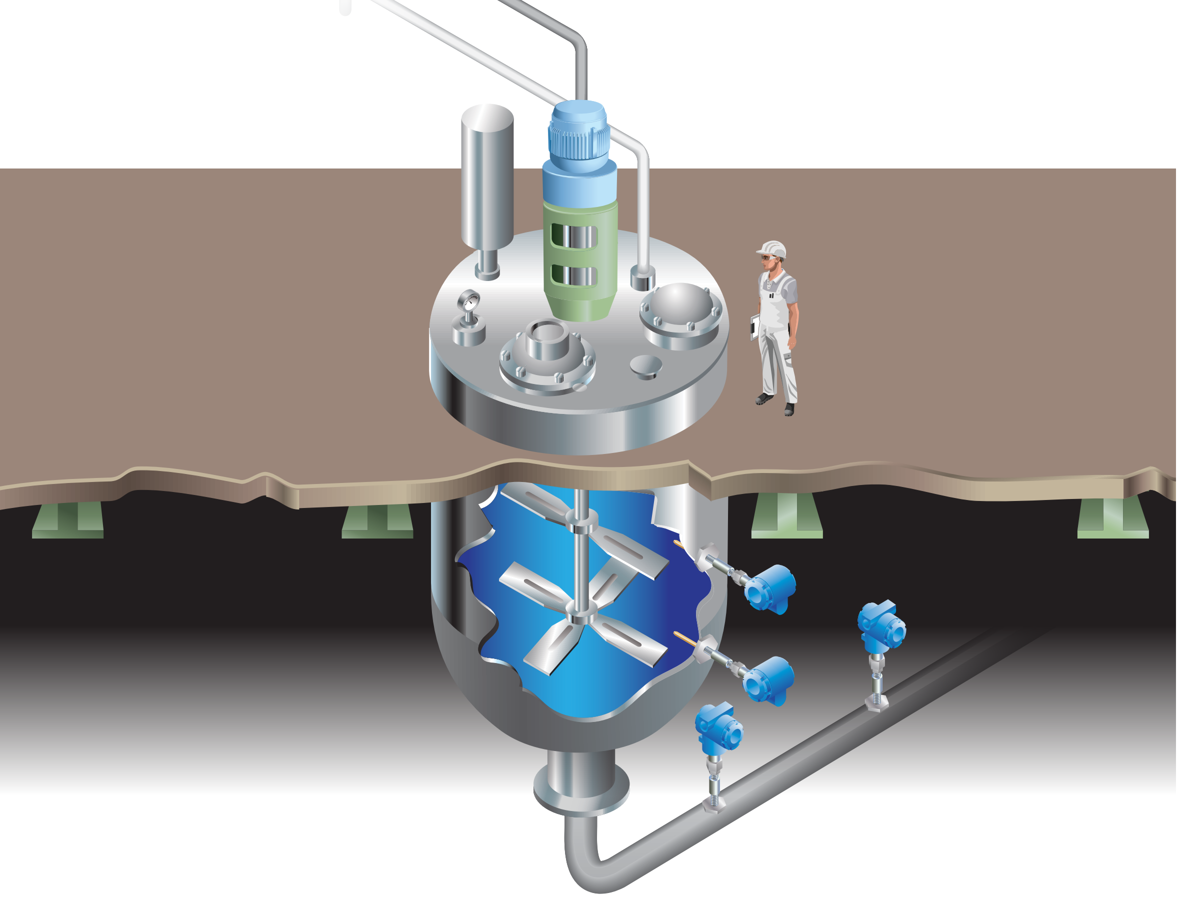

Figure 1. Sensors and transmitters that drift out of specification during a production run can cause unplanned downtime, safety issues, and losses in product quality.

Critical instruments require special attention

In a process facility, instruments are used to monitor and control processes, and some instruments are more important than others. In many cases a high degree of confidence in an instrument's performance is required: for example, consider those instruments that have a direct impact on product quality and throughput, or those that help ensure the safety of personnel, customers, the community or the environment. In addition, certain instruments or systems may be critical during emergency response activities. In a well-managed facility, regular maintenance at predetermined intervals ensures these instruments continually conform to their specifications, so that costly or even disastrous surprises are avoided.

Calibration intervals need to be monitored

To avoid unplanned downtime and other surprises, calibrations should occur at regularly scheduled intervals. Calibration verifies the functionality of the instrument and can reset the drift that all measurement equipment experiences over time.

Longer intervals between calibrations are desirable to help maximize equipment operating time. However, if an instrument is found out of tolerance at the time of calibration, the calibration interval is usually reduced (for example, a policy may require that the instrument be calibrated twice as often when found out of tolerance to mitigate the risk of future recalls due to an out-of-tolerance condition).

To ensure that the period between calibrations is as long as possible, while also ensuring that instruments remain in tolerance between calibrations, wise managers make certain that the equipment used to calibrate their instruments is the best that they can get. They know that a more accurate calibration maximizes *Operating Time*.

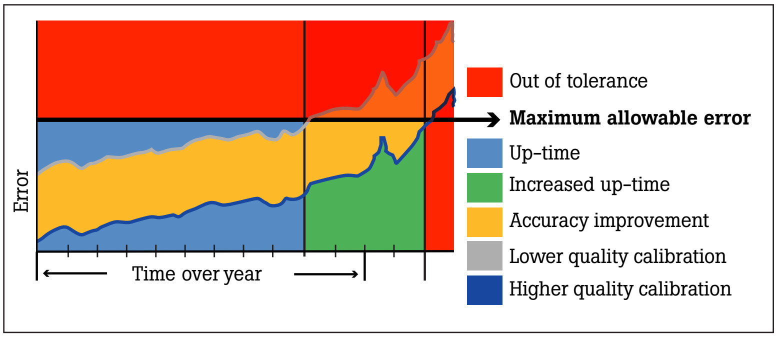

Figure 2. Minimizing error maximizes up-time. Measuring instrument error tends to increase (drift) over time. This error is corrected through calibration. Less error in the calibration means fewer surprises and a longer period of time before the next calibration is required.

Performance

When a process is operating, it may run slower than planned. For example, some operators may not be efficient, accidents may happen, or the equipment may be worn or poorly maintained. These factors combine to slow the process down and contribute to a reduced *Net Operating Time*. The ratio of *Net Operating Time* to *Operating Time* is the OEE metric of *Performance*.

$$\textit{Performance} = \frac{\textit{Net Operating Time}}{\textit{Operating Time}}$$

The key to maximizing performance is to reduce the many short stops that make less efficient use of *Operating Time.*
Net Operating Time is usually calculated this way:

$$\textit{Net Operating Time} = (\textit{Total Units Produced}) \times (\textit{Ideal Cycle Time})$$

Or equivalently

$$\textit{Net Operating Time} = \frac{(\textit{Total Units Produced})}{(\textit{Ideal Run Rate})}$$

Ideal Cycle Time is the ideal amount of time it should take to produce one unit such as a piece or a volume of product. Calculating *Net Operating Time* this way ensures the amount produced is measured and not just how much time was spent producing.

Quality

Quality takes into account the products which do not meet quality standards, including pieces that might require rework. Time spent reworking or producing a rejected product is lost time. Time left after quality-related losses is the *Fully Productive Time*.

$$\textit{Quality} = \frac{\textit{Fully Productive Time}}{\textit{Net Operating Time}}$$

Quality is affected when critical measurements are made by instruments that are operating outside of their designed specifications. Calibration helps to keep critical process variables within the parameters required by the process. When calibrations are not performed properly, occur too infrequently, or if calibration standards lack the required accuracy, then quality may be impacted. When quality problems are detected an unplanned shutdown may follow, which has an impact on *Availability* and further reduces *OEE*.

Example

Here is how we might calculate *OEE* for a hypothetical shift with the following data:

Description	Data
Shift length	8 hours = 480 min
Break	2 X 15 min = 30 min
Lunch	30 min
Downtime	Unplanned calibration = 45 min, 15 min trouble shooting
Cycle time	0.2 min
Total pieces	1500
Reject pieces	180

Availability

To calculate the *Availability* we need to know the *Planned Production Time* and the *Operating Time*.

Plant Operating Time	480 min
Planned Downtime	
Breaks	30 min
Lunch	30 min
Planned Production Time	420 min
Unplanned Downtime	
Time spent trouble shooting	45 min
Time spent w/ unplanned calibration	15 min
Total Unplanned Downtime	60 min
Operating Time	360 min

Operating time

$$\textit{Availability} = \frac{\textit{Operating Time}}{\textit{Planned Production Time}}$$

$$= \frac{360}{420} = 85.7\ \%$$

Performance

The calculation of *Performance* is based on a standard production cycle time, the number of units produced and the operating time calculated above.

$$\textit{Net Operating Time} = (\textit{Total Units Produced}) \times (\textit{Ideal Cycle Time})$$
$$= 1500 \text{ x } 0.2 + 300 \text{ min}$$

$$\textit{Performance} = \frac{\textit{Net Operating Time}}{\textit{Operating Time}}$$

$$= \frac{300}{360} = 85.7\ \%$$

Quality

The Quality calculation is the ratio of Fully Productive Time to Net Operating Time, but you get the same answer if you take the ratio of Good Pieces to Total Pieces.

Total Pieces	1500
Rejected Pieces	180
Good Pieces	1320

$$\textit{Fully Productive Time} = \textit{(Good Pieces)} \times \textit{(Ideal Cycle Time)}$$
$$= 1320 \text{ x } 0.2 + 264 \text{ min}$$

$$\textit{Quality} = \frac{\textit{Fully Productive Time}}{\textit{Net Operating Time}}$$
$$= \frac{264}{300}$$
$$= 88.0\ \%$$

OEE

OEE (Overall Equipment Effectiveness) is calculated by taking the product of the three metrics calculated above:

$$\textit{OEE} = \textit{(Availability)} \times \textit{(Performance)} \times \textit{(Quality)}$$
$$= 85.7\ \% \times 83.3\ \% \times 88.0\ \%$$
$$= 62.8\ \%$$

Improving OEE

If the process is not as effective as it should be, then what can be done to make it more effective? For example, if the benchmark metric of 85% mentioned in the beginning is achieved, then the metrics of *Availability, Performance,* and *Quality* will each probably be in the mid 90's. The above example includes room for improvement in each of the metrics. Here are some things to consider to improve OEE through calibration:

1. Schedule maintenance at a time when it will be least disruptive and ensure that calibration is part of the maintenance program, especially for critical instruments.
2. Follow best practices when calibrating and use the best calibration equipment available to prevent unscheduled troubleshooting and calibration due to nonconforming instrumentation.
3. Reduce planned downtime by carefully managing calibration intervals. This can be achieved by using high-quality instruments, monitoring their performance, and following best practices to maintain them.
4. Strive to maintain a 4:1 test accuracy ratio (TAR) to minimize the risk of incorrectly evaluating the tolerance status of the instruments being calibrated. A 4:1 TAR means that the accuracy of the calibration standard is four times better than the accuracy of the instrument it is calibrating. Incorrectly identifying a nonconforming instrument as "in tolerance" may lead to quality and other potential problems. Incorrectly identifying the instrument as "out of tolerance" leads to increased downtime, more maintenance costs, and shorter calibration intervals.
5. Automate calibration with software to minimize operator time, ensure best practices and speed up the process. In some cases automation can be achieved without software. For example:
   a) A Fluke Calibration 1586A Super-DAQ Precision Temperature Scanner can automate and document a temperature calibration involving a bath, dry-well, or furnace.

Fluke Calibration 1586A Super-DAQ Precision Temperature Scanner automates the calibration of thermocouples in a Fluke Calibration 9190A Ultra-Cool Field Metrology Well.

Fluke 754 Documenting Process Calibrator calibrating a temperature sensor and transmitter with the help of a Fluke Calibration 9142 Field Metrology Well.

b) A Fluke 754 Documenting Process Calibrator connected to a Fluke dry-well using the Hart Drywell Cable automates and documents the calibration of a temperature sensor and transmitter. DPC/Track software is required with the 754 to download the information to a PC and manage calibration data.

6. Reduce planned downtime by carefully managing calibration intervals. This can be achieved by using high-quality instruments, monitoring their performance, and following best practices to maintain them.
7. Reduce rework during production with a properly tuned control system that produces product conforming to its design specifications.

Conclusion

Calibration is an important part of improving the Overall Equipment Effectiveness of processes that use instrumentation to control the quality of both the process and product. An effective calibration program will help reduce three significant wastes of time spent on:

- unplanned maintenance
- scrap
- rework

Such a calibration program will use the best calibration equipment available, and follow best calibration practices including automation where possible. This will ensure that critical measurement equipment is not the cause of an unplanned shutdown or quality issue.

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Printed in U.S.A. 12/2015 6006652a-en