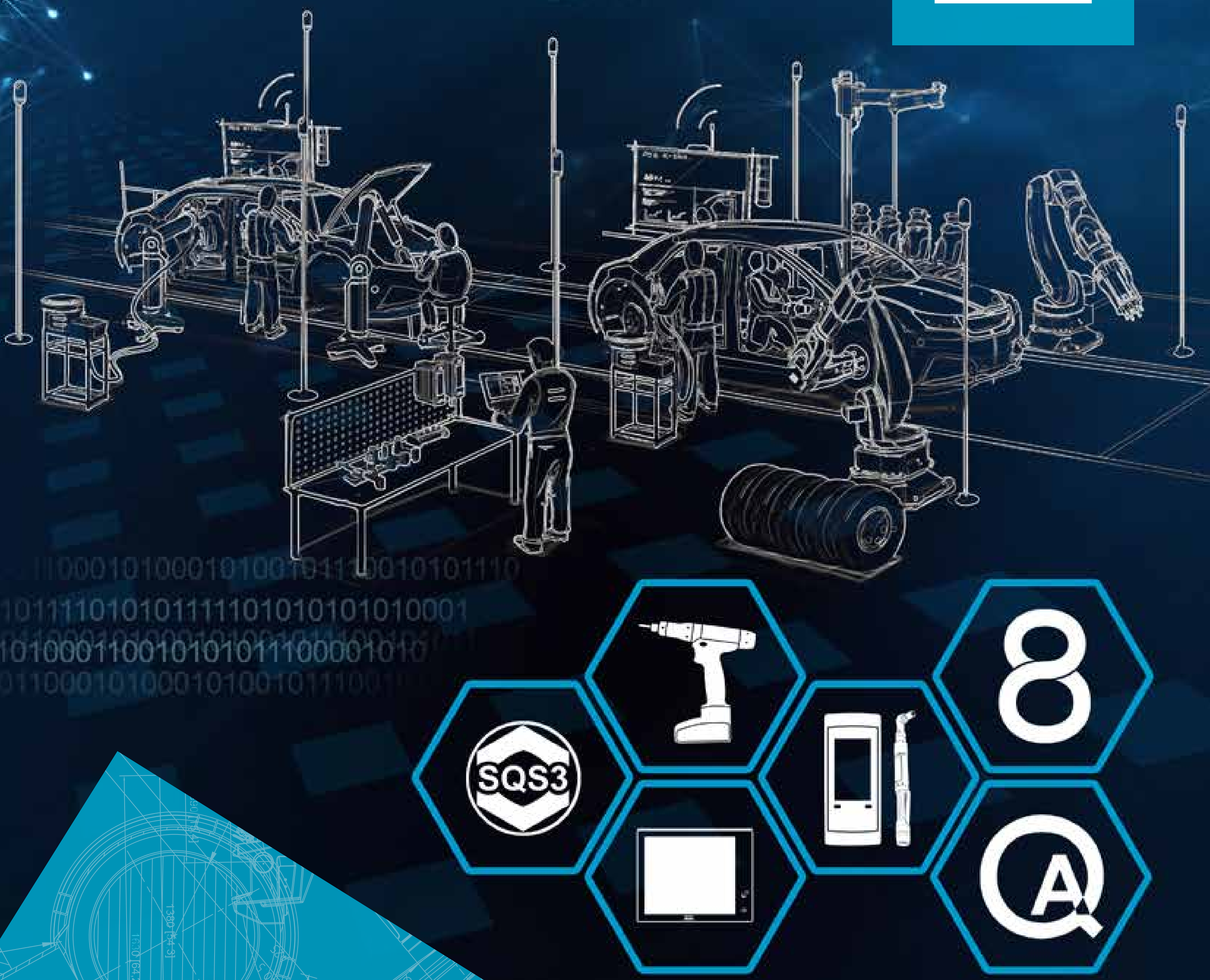


Error proofing the production process

Striking the right balance between cost and quality in assembly

Contents

Introduction

Striking the right balance between cost and quality is an ongoing challenge for every manufacturer, regardless of their scale or the complexity of the products they assemble: Focussing too much on quality can reduce throughput, while focussing too little can increase costs due to reworking or repair and erode customer confidence. Ultimately, this can result in damage to a manufacturer's brand and reputation. As a result, error-proofing in the production process, even for just one step in the process, has become a key issue for manufacturers seeking to deliver quality efficiently and profitably.

Quality in the assembly process relates to every aspect of production, such as joint quality, process quality and product quality. Regardless of the specific focus involved, ensuring quality relies on knowing who did what, when and how.

At the core of this is information, or data, which is the key ingredient feeding the rapid digitalisation of manufacturing and assembly in a trend often referred to as Industry 4.0 or Smart Factories.

At Atlas Copco, we enable the vision of Industry 4.0 in manufacturing through our Smart Connected Assembly concept, where advanced industrial software combines with state-of-the-art hardware, connected assembly tools and smart accessories to create a fully integrated assembly solution. Smart Connected Assembly aims to provide manufacturers with effective solutions for delivering and managing tightening strategies in the production process needed to maintain quality control and increase uptime in production critical operations.

This white paper describes the seven steps that form a cumulative approach to quality and is designed to help you develop an assembly roadmap for the future.

Understanding Current and Future Production Needs

Using the characteristics below, we have categorised levels of complexity in the assembly process to identify strategies to improve quality. However, please note that this information is intended as a guideline only and it is likely that a manufacturer with Basic Needs today may have more Complex Needs two years from now. Conversely, an organisation with Very Complex Needs may not yet have implemented some of the strategies we have mapped in this area and therefore may get value from reviewing those strategies.

Atlas Copco's Smart Connected Assembly are designed to be flexible and fully scaleable from the outset to accommodate any future increase in product variation or complexity.

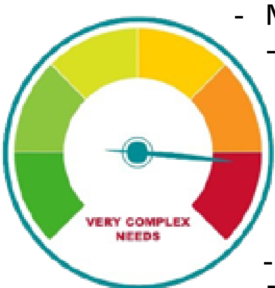
Basic Needs

- Manufacture between 100 production units a day
- Rarely make changes to the production line
- Batch build
- Low regulatory requirements
- Limited use of temporary staff and/or apprentices

Complex Needs

- Manufacture between 100 – 500 production units a day
- Annual/bi-annual changes to the production line
- Build to sequence
- Moderate regulatory requirements
- Some use of temporary staff and/or apprentices
- Low to medium screw/bolt count per unit
- Starting to adopt Lean Manufacturing

Very Complex Needs



- Manufacture over 500 production units a day
- Regular monthly/quarterly changes to the production line
- Build to order
- High regulatory requirements
- High use of temporary staff and/or apprentices
- High screw/bolt count per unit
- Lean Manufacturing is an integral part of the production process
- Elements of assembly are safety critical
- Production KPI's are measures and audited
- Quality KPI's are measured and audited

The Seven Steps to Securing Product Quality

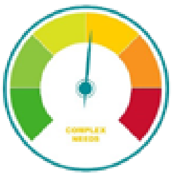
The quality of an assembled product is affected by several factors, including operator influence, use of incorrect fasteners, missing components, omitted fixings and using the wrong parts. Here, we outline seven steps that manufacturers can take towards securing product quality in assembly. These steps build on one another, enabling organisations to adopt tools and technology with a view to handling increasing demands for traceability and control in production.

It should be noted that steps 1-4 primarily apply to products assembled with fasteners in the manufacturing process. Steps 5-7 apply to all manufacturers, including those with processes that do not include fasteners.

Step 7: Use data for continuous improvements

Step 6: Secure Process Reliability

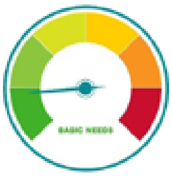
Step 5: Introduce Reject Management and Part Control



Step 4: Introduce Process Error Proofing

Step 3: Introduce Joint Control and Angle Monitoring

Step 2: Introduce Torque Control



Step 1: Classify Joints

Step 1: Joint Classification

Joint classification is at the foundation of the seven steps and clarifies the requirements for each application. For example, the VDI Standard (VDI/VDE 2862 Blatt 2) defines threaded fastening classes and minimum requirements for the assembly tools used and serves as a cross-disciplinary basis for the use of fastening systems and tools in plant and mechanical engineering. These guidelines used in the automotive industry were first published in 1999 and were updated in 2015 to include inspection requirements. Broadly, the VDI Standard divides joints into three risk categories: A (safety critical), B (function critical) or C (Customer Critical), as detailed below:

Joint Class	Classification	Minimum Demand From Tightening Equipment	Minimum Inspection Efforts
A	Safety Critical – failure of the bolt will result in danger to life	1 control variable (torque) and 1 monitoring variable (angle). Must collect results for further analysis.	Machine capability Process capability Trained operator
B	Function Critical – failure of the bolt will lead to major malfunction	1 control variable (torque) and 1 monitoring variable (angle).	Machine capability Process capability Trained operator
C	Customer Critical – failure of the bolt will cause customer annoyance	1 actuating variable (torque).	Machine capability

In addition to understanding the classification of the joints in an assembly, it is also important to understand what influences torque to ensure the joint design is correct for the application: Too little clamping force results in joint failure through relaxation or loosening, while too much force may result in sheared bolts. As a result, a number of factors must be considered when designing a joint, including the joined materials, lubrication, bolt length and diameter and the thread pitch.

Step 2: Torque Control

The next step up to securing quality is to use an assembly tool that delivers a precise and predetermined torque. A shut-off tool does what you might imagine – it shuts off when it achieves a specified torque. Process quality is still operator-dependent, but bolt failures due to under- or over-torque are reduced or eliminated.

Examples of shut-off tools include clutch tools, shut-off pulse tools, and shut-off nutrunners. These tools are suitable for Class C bolts where the minimum demand from tightening equipment is one actuating variable (torque). However, these tools are not suitable for Class A or B fixings as they don’t record a monitoring variable (angle).

Step 3: Joint Control & Angle Monitoring

A tool that shuts off when the desired torque is reached is a worthwhile investment in product quality; however, there are several other possible errors it will not address. Introducing joint control and angle monitoring (measuring the degrees of revolution of the bolt head) gives you the ability to detect a missing washer, to detect that the operator forgot to tighten a screw, or that they made a tightening on an already-tightened screw, known as a 're-hit'.

Tightening strategies to improve joint control include:

- Batch Count – ensures all screws are tightened, counts only OK tightenings, and signals output "Batch OK"
- Re-Hit Detection – the tool automatically detects if the tightening is done on an already-fastened screw
- Angle Monitoring – monitors the tightening and/or the rundown angle to detect process deviations such as the wrong screw being used, a missing washer or misaligned parts
- Speed Control – reduces tool speed in the final tightening phase to reduce the risk of stripping screws

A Class A safety-critical tightening is one where if the bolt fails it can result in danger to life. As a result, Class A fixings require advanced controlled industrial tools to ensure and prove that critical bolts are tightened correctly. Atlas Copco offers a range of tightening control systems to meet this requirement:

- Torque control using a transducer that is traceably calibrated
- The ability to store the torque data in a local control unit
- The ability to send the torque results 'upstream' to higher level systems, such as Atlas Copco's ToolsNet for long term storage
- Continuous monitoring of the whole tightening process by using not only torque transducers and angle encoders, but also other parameters such as current limits
- The possibility to use Statistical Process Control to detect and correct deviations to the result even before a tightening outside of the limits is produced.

Atlas Copco is constantly innovating and has introduced a number of features to its tools to eliminate operator influence and to improve user ergonomics. These features include True Angle, Turbo Tight, the new Low Reaction Tools and TBP battery pulse tools.

Our next-generation tool controller, the Power Focus 6000, uses virtual stations to allow the control and monitoring of multiple wireless tools via a single physical controller.

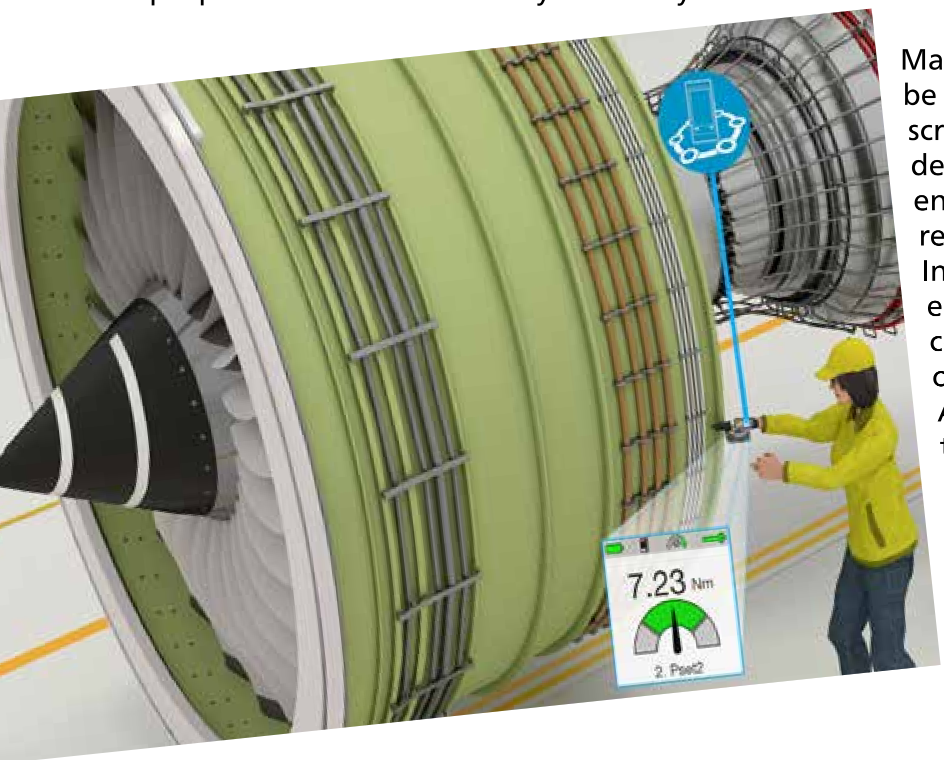
STEP 4: Process Error-Proofing

The next step to zero-fault production is to design processes in such a way as to prevent errors occurring, or to secure an error once detected and correct it at the source. Error-proofing applies to all manufacturing processes, including those that do not use fasteners, such as the addition of a spring to a pushrod without which the product would fail.

Process error-proofing steps include:

- Reducing human error by introducing greater automation in the tool process
- Securing the errors that do occur by giving the operator clear feedback on where it happened, so they can correct it
- Utilising tool interlock and line control to prevent tools being used on the wrong product, as well as to prevent products with errors progressing any further in the production process.
- Automation to reduce human error in the manufacturing process means introducing Human-Machine Interfaces (HMIs), user interfaces or dashboards that connects an operator to the process they are undertaking. HMIs can be used in the assembly process for a range of functions, which include:
- Visual data displays
- Production tracking
- Monitoring Key Performance Indicators (KPIs)
- Recording and monitoring machine and assembly tool inputs

These interfaces include screens and tablets, as well as warning systems, such as stack lamps or sirens, that immediately signal to the operator that an error has occurred.
Smart Connected Assembly controls the assembly process via barcode scanning or sending data or PLC signals to inform the tool controller which product is in the workstation and the corresponding assembly process to be followed. This provides several benefits: Firstly, it eliminates errors due to incorrect program selection. Secondly, it allows variant-specific programmes to be configured, enabling the same tool to be utilised for multiple product variants and assembly processes, saving money and space on the production line. And finally, it enables the tool to report results against a unique product ID for traceability and analysis.

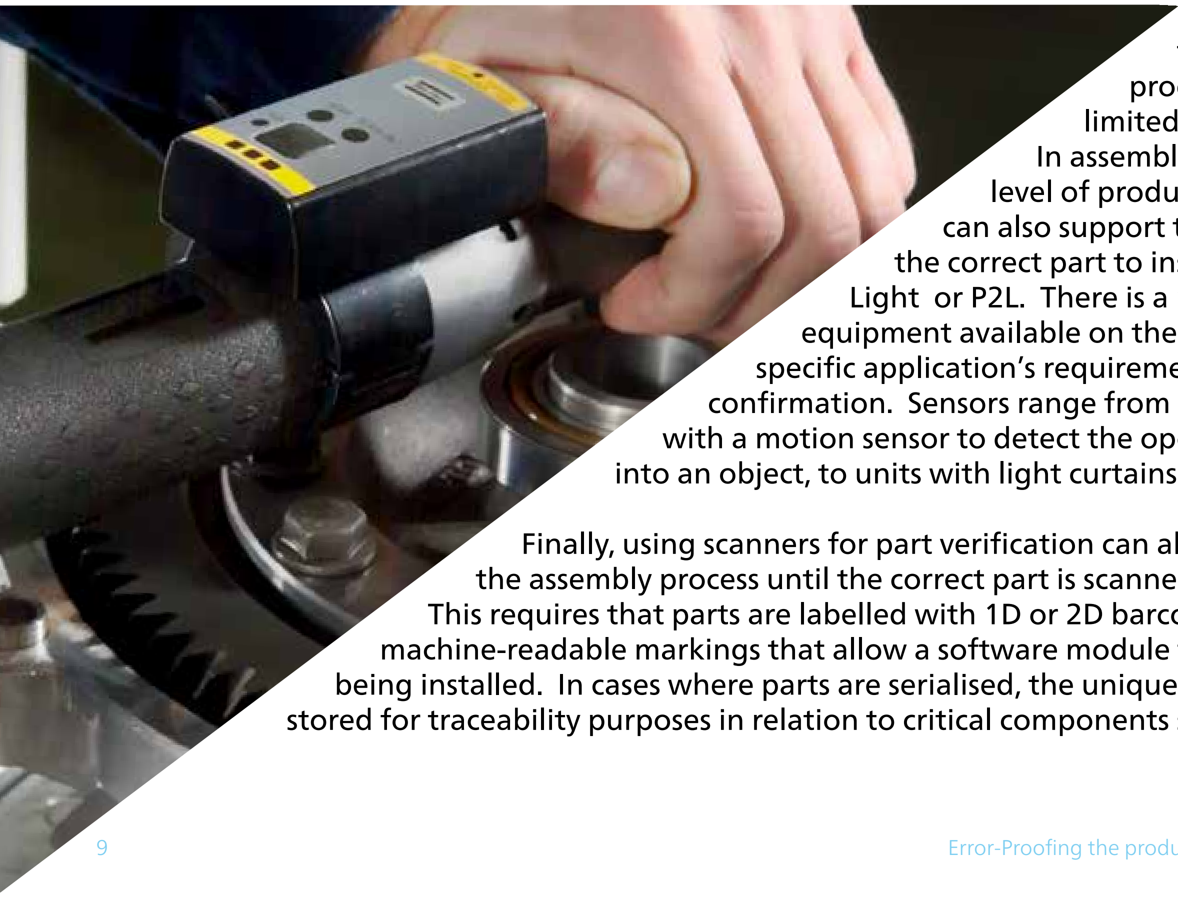


Many Atlas Copco assembly tools can be specified with eHMIs - Tool-mounted screens that give the operator full process details, such as bolt status and also enable them to select a repair program if required. Further functions, such as Tool Interlock, halt the assembly process if an error is detected, locking the tool until corrective action is taken or a supervisor overrides it.
A further Line Control measure stops the assembly line, ensuring the process is complete before continuing. All of the data from these elements can be fed into a No Fault Forward strategy that saves money by eliminating rework and preventing faults escaping that may lead to costly warranty claims and unhappy customers.

Step 5: Reject Management & Part Control

Until now, all of the steps towards product quality have focussed primarily on hardware – tools, tool controllers and accessories – with advanced controls and feedback mechanisms. The next step up to secure quality involves the use of systems to more tightly control the process, broaden the elements of quality that are controlled and manage rework in a traceable manner. These technologies include Operator Guidance, Pick to Light, and Part Verification.

Basic Operator Guidance is possible using socket selectors and batch counts by programming fastenings into batches and using a socket selector with lights to indicate which socket the operator must select for a specific fastening procedure. This approach relies on the operator being well-trained on their assigned station, as well as the ability to use the socket only on the fasteners it is intended for. Visual operator guidance, such as with the Atlas Copco Synatec system or Scalable Quality Solution, SQS, uses a display in station to guide the operator to the next bolt; this approach eases the training burden. In both applications, the tool is disabled until all the requirements for its use, such as correct product in station, correct socket installed and/or correct point in process, are met. SQS manages the assembly process for many different product variations and is ideally suited for assembly and subassembly stations, backup stations and repair areas.



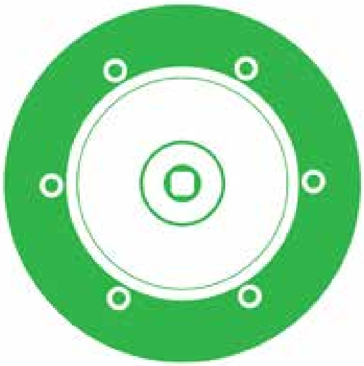
It is important to remember that product quality isn't just limited to bolts and screws: In assembly lines with a high level of product variation, systems can also support the operator to select the correct part to install by using Pick to Light or P2L. There is a range of P2L sensing equipment available on the market to suit a specific application's requirements for accuracy and confirmation. Sensors range from lightbulbs combined with a motion sensor to detect the operator's hand reaching into an object, to units with light curtains and push buttons.

Finally, using scanners for part verification can also be used to interlock the assembly process until the correct part is scanned to minimise error. This requires that parts are labelled with 1D or 2D barcode labels or similar machine-readable markings that allow a software module to identify the part being installed. In cases where parts are serialised, the unique identifier can be stored for traceability purposes in relation to critical components such as car airbags.

Step 6: Secure Process Capability

Now it is time to Secure Process Capability by properly managing and auditing tools and processes. Manufacturers must routinely check their tools to ensure they are capable and operating within defined limits. These checks, usually carried out by a Quality Assurance team, enable you to detect when a tool is going out of calibration. Furthermore, ensuring that tooling is operating correctly facilitates faster diagnoses of other issues affecting quality, such as issues caused by the operator or by the quality of supplied parts.

Atlas Copco offers a range of products for Quality Assurance teams to support Tool Check, Joint Check and Visual Inspection activities with the STa6000 portable quality assurance tool, state-of-the-art STwrench, and STbench joint simulator mobile calibration bench.



Measure with accuracy

As a reliable base, you have products that measure every application result.

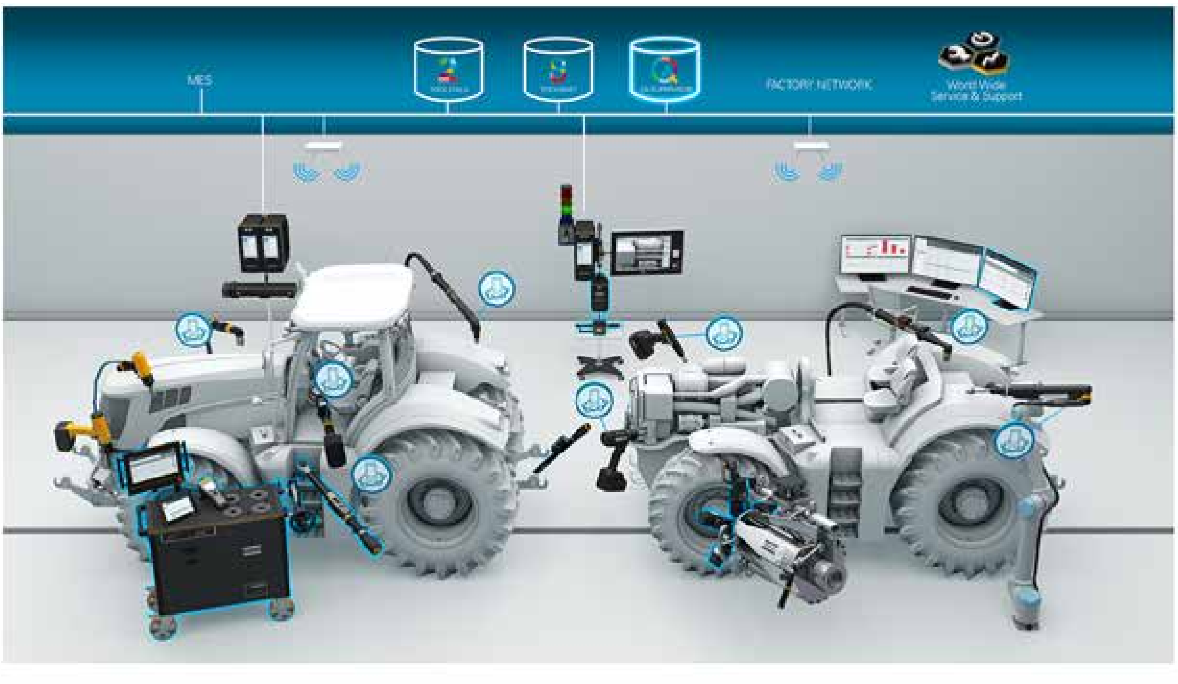
The Atlas Copco STbench and our transducers. These products makes sure you can test tool capability – either in the crib or along the line.

Collecting and executing

To take care of the data reported from the tools, you have products that collect the data. With the STpad and STpalm at hand, you can program tests, guide your operators in execution and collect results. And with the STa6000 you can collects data on tool performance, repeatability and accuracy for all types of power tools and torque wrenches.

Managing and Verifying

Overlooking this, you have the QA Supervisor managing the process. QA Supervisor is installed on a server and can easily be accessed via a web browser. The software Quality Supervisor is the core of the solution – gathering data, delivering insight, and handing out tasks.



Step 7: Data for Continuous Improvements

The final step is the utilisation of Data for Continuous Improvements through the use of advanced software. Nearly all of the Atlas Copco products used as examples in this white paper utilise software to operate and possess the ability to send data to software applications such as Atlas Copco's ToolsTalk 2, ToolsNet 8, and QA Supervisor packages. Software is a tool in itself, for tracking and analysing what is occurring on the assembly line, enabling real-time analytics into the performance of tools and processes. These applications support root-cause analysis of defects, feeding continuous improvement initiatives that improve efficiency and increase profitability.

ToolsTalk 2 is Atlas Copco's next generation of software for controller programming. The software is geared to provide quick and easy configuration, as well as complete visibility and traceability of the entire assembly line structure. It allows you to manage multiple controllers simultaneously, import and store tool programmes and export new programmes to controllers remotely. A central database stores tightening programmes and changes for full traceability.

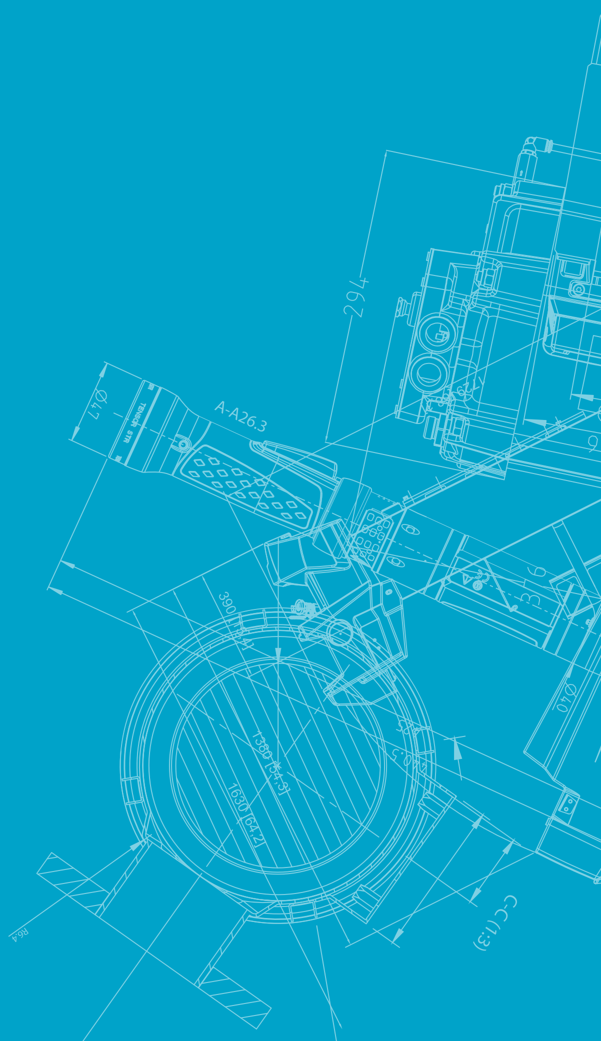
ToolsNet 8 is software that collects production data from any tool controller that supports Open Protocol and offers production analysis personalised to your needs. It is a Web-based application accessible from any device running a supported browser, making it portable and accessible. It provides great insight into production through real-time reporting and notification as well as statistical analysis to help you spot trends and perform root cause analysis.

QA Supervisor is another Web-based application for your Quality team to configure and manage tests – joint checks, tool checks, and inspections. It operates as a central data collector for configuration and results data – tool information, calibration records, joint specifications, test routes, and results. Connected devices such as STPad, STWrench and STBench send data electronically, eliminating data entry errors and putting your data at your fingertips immediately. The software makes any audit quick and effective with its clear historical data presentation.

Summary

Error-proofing has become a core focus for every manufacturer seeking to strike the right balance between cost and quality, regardless of their scale or the complexity of the products they assemble. Atlas Copco's Seven Steps to Securing Product Quality aims to provide manufacturers with a scaleable and flexible roadmap to meeting both current and future needs by taking a structured approach to introducing error-proofing into every aspect of the assembly process.

By combining the right tools with the right software, Atlas Copco's Smart Connected Assembly technology provides manufactures an intelligent, scaleable and flexible error-proofing solution to deliver efficient quality in the assembly process that protects brand integrity and customer confidence.



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