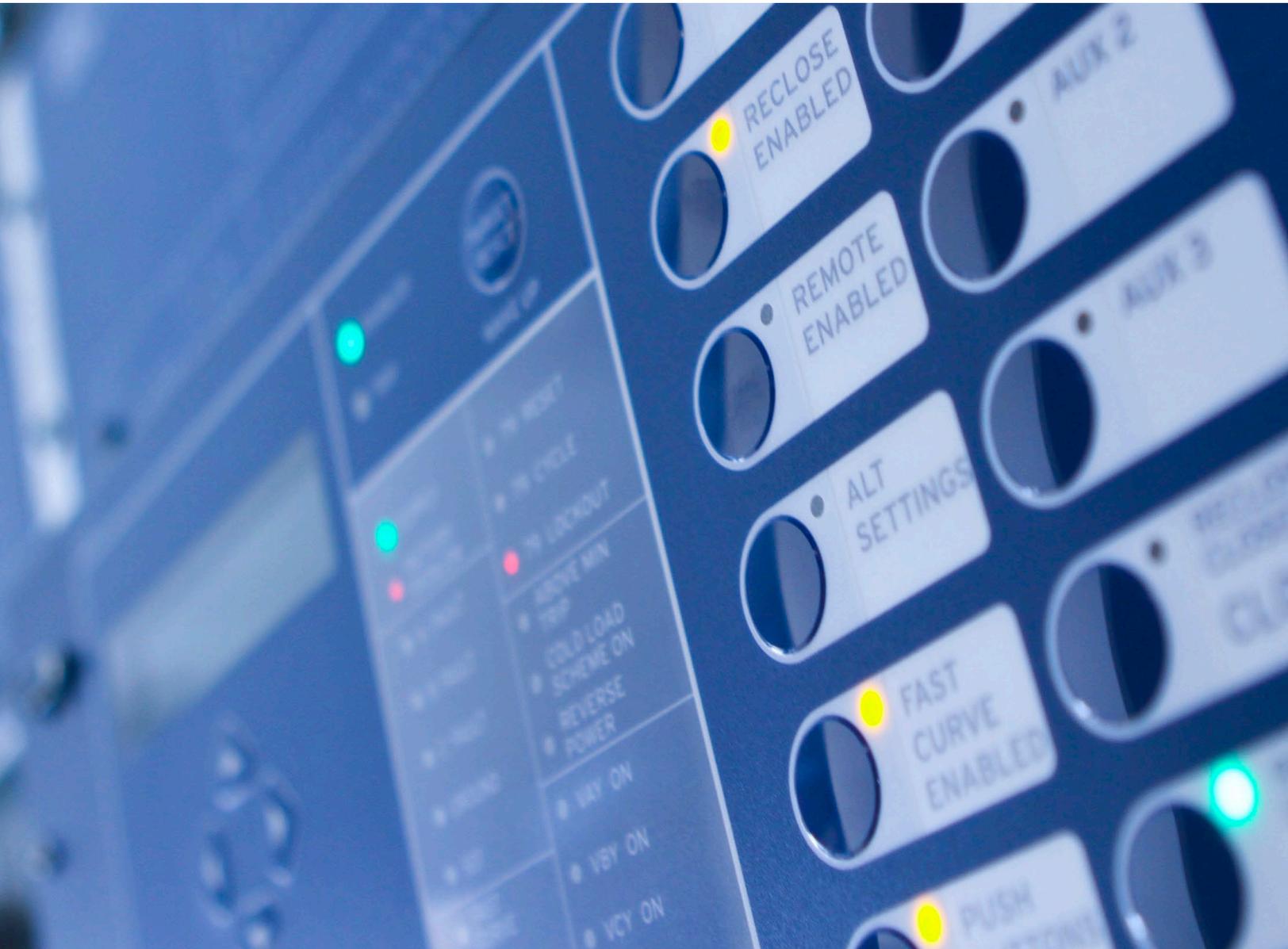


Quality and Reliability at SEL

Understand. Create. Simplify.





A Note From the Director of Quality

At SEL, our employees drive quality and are driven by it. Edmund O. Schweitzer, III, taught the very first SEL employee that they owned quality, and to this day we continue to do the same for every new employee. Every SEL employee knows that their quality responsibility is to understand the need or problem to be solved, create effective solutions, and seek to simplify our processes and products. It's what we call: "Understand. Create. Simplify."

We warranty our products for 10 years, design them to last more than 20 years, and after serving our customers for over 30 years, we don't charge for repairs—regardless of the age of the product. One of our reliability measures is the mean time between returns for repair (MTBR). Our observed MTBR is well over 200 years and continues to increase. This means, if you have 200 SEL products installed on your system, you can expect to return less than one product per year for any reason, including failure or damage due to misuse, lightning, fire, water, ice, solar exposure, chemical corrosion, wildlife, overvoltage, overcurrent, vandalism, and user error. If a customer returns it for repair, we count it in this reliability measure.

Our Quality Management System is certified to the International Organization for Standardization (ISO) 9001 standard, Quality Management Systems Requirements. This certification is evidence that our critical design, manufacturing, and business processes meet the exacting requirements of this internationally recognized standard.

SEL's commitment to quality is a necessary and integral part of our business because of the lives and critical infrastructure our products protect. As we follow our quality policy to understand, create, and simplify, we invent the future of electric power.

Travis Mooney

Director of Quality
Schweitzer Engineering Laboratories



Defining Quality and Reliability

The SEL Quality Management System stems from our defined purpose and values.

The purpose of SEL is to make electric power safer, more reliable, and more economical. Everything we do is measured back to this statement to ensure our actions are staying on course.

Our values guide our actions and lead us to continuously improve quality in every area of our company, including product development, manufacturing, business operations, technical support, customer service, human resources, safety, and environmental stewardship. The table below outlines several of these values and the quality-related actions they lead us to take.

We never compromise values for financial gain or short-term expediency. The SEL executive management team regularly reinforces these values through weekly all-company meetings. The same values have guided us since the founding of the company in 1982.

Value	Action Guide for Quality
Quality	Understand the problem, create an effective solution, and always seek to simplify. Identify, measure, and improve our processes. Get to the root cause of every problem.
Customer Focus	Lead in price, quality, features, innovation, delivery, and service. Encourage customer feedback.
Discipline	Commit and deliver. Follow and improve processes.
Integrity	Make clear promises to customers, and exceed their expectations. Assume responsibility.
Creativity	Create the best possible solution that meets the needs of our customers.
Ownership	Share expertise with others to help us succeed. Accept responsibility for our quality of work. Respond to customer feedback.

What Is Quality?

At SEL, quality means that a product or service conforms to its published specification (conformance quality) and meets or exceeds the customer’s expectations (perceived quality). Our products must meet both of these criteria, and it starts when we conceive of a new product, service, or system.

We strive to understand the customer’s expectations and needs, the problem to be solved, the prior art, and the available technology. We know we understand something when we can teach it, so we teach our customers and each other. Our engineers apply an in-depth understanding to create new and innovative solutions to difficult problems. We don’t wait for a standards committee or a regulator to tell us what to do. Instead, we invent our future. We believe no job is done until we have simplified the output as much as possible. We value simple solutions because we know simpler things are usually higher quality and more reliable.

These same concepts drive our factories and panel shops. Engineers and managers there understand the critical aspects of our products that we assemble and test, the available assembly and test methods and technologies, and our customers’ expectations and needs. We create simple and effective assembly and test methods and then continue to simplify those processes to drive out possible errors.

After we identify the simplest and most robust way to assemble and test the products, we measure the output of the processes and make continual improvements, always guarding against creeping complexity. Identifying, measuring, and improving processes requires accepting individual responsibility for the quality of our work and getting to the root of every problem. We do all of this work to deliver a product, service, or system that meets current customer needs, performs as intended, and operates reliably over a long life.

What Is Reliability?

Reliability is the probability that a product or system will perform its specified function for a specific time period in a defined environment. Reliability is often expressed in terms of failure rate, which is the number of failures observed in a time period divided by the total units operating in that same time period.

For power system protection and communications products, higher reliability means higher system availability and fewer removals from service per year due to failures or damage. Reliable performance also minimizes maintenance expenses and ensures that customers never miss a fault.

Achieving Quality and Reliability

Improving Product, Service, and System Performance With Customer Feedback

We use customer feedback to assist in our efforts to exceed their expectations. Our worldwide ten-year product warranty facilitates the return of our products for root cause analysis and repair. Our customer feedback process and the Newton-Evans Research Company protective relay manufacturing survey of electric utilities also provide valuable feedback that we use to improve our products and services.

SEL Worldwide Ten-Year Warranty

Equipment manufactured by SEL is backed by our exceptional worldwide ten-year product warranty. This warranty is the best in our industry. After serving customers for over 30 years, we still don't charge for repairs, regardless of the age of the product or the cause of failure. Even if customers damage it, we fix it for free.

Our warranty and our repair practice encourage customers to return products for repair. Our Product Hospital responds to every returned product quickly and drives to root cause, allowing us to learn and improve. Our performance standard is a 72-hour repair time; if our technicians cannot duplicate the customer's reported problem, we replace the affected hardware at no charge.

Customer Feedback Provides Product Performance Data

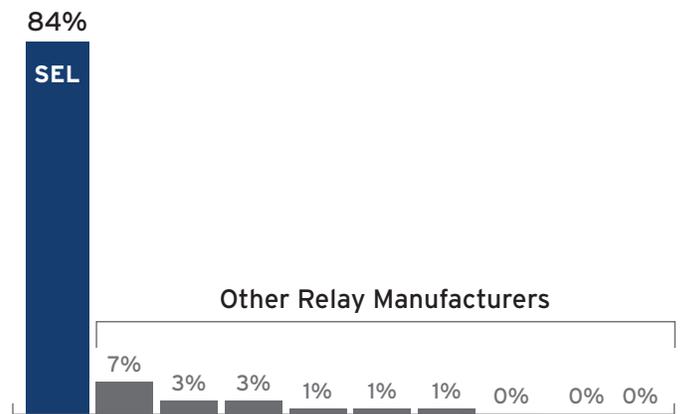
SEL values feedback and uses a customer feedback process to collect information about expectations and our products' ability to meet those expectations. We log, track, and analyze feedback for trends and use the information to improve our processes, designs, and materials. The process ensures we promptly and completely address customer concerns and determine the root cause. We use positive responses to learn, share, and reproduce superior customer experiences.

Consistent with our customer focus and ownership values, any SEL employee can open a feedback form for a customer. A customer service representative manages the process, ensuring a prompt solution, and follows up to ensure the customer is satisfied.

Our goal is to promptly address the feedback and achieve customer satisfaction on all issues. SEL uses the customer feedback process not only to resolve problems but also to identify opportunities for improvement and to replicate outstanding experiences.

Newton-Evans Research Company Customer Survey

The Newton-Evans Research Company periodically conducts an independent customer survey. Respondents among protection and control engineers and engineering managers from North American utilities rank top relay manufacturers in the areas of technology, price, features, technical service and support, security, ease of use/setup, maintenance, and web/Internet information. For over a decade, they have ranked SEL as the #1 relay manufacturer. We use the customer feedback provided in this survey as another performance gauge to evaluate and improve our processes, products, and services.



Percentage of first-place votes in the 2016–2018 study.

A high-quality product operates reliably, to specification, over a long service life.

Measuring Product Performance With Observed Data

Some manufacturers describe product reliability by providing a reliability projection based on component count. While this method is useful as a comparison of product designs, it often does not correlate well with field performance.

SEL measures the observed quality and reliability of SEL products using the actual data from product returns and repairs. SEL tracks product ownership by serial number, so we know our installed base of products. We use this information along with our repair history to calculate and track the following product performance measures.

Initial Quality (IQ)

SEL calculates monthly product IQ using reported errors during the first day of use and number of products shipped.

SEL tracks IQ errors, which may be due to order entry errors, incorrect accessories or documentation, shipping damage, or product performance. We review factors affecting our IQ metric daily in order to quickly identify any new problems. When we find a problem, we analyze it to determine the root cause and initiate corrective actions to eliminate or reduce future problems.

$$IQ = \frac{\text{The number of observed failures during the first day of service.}}{\text{The number of products shipped in a one-month period.}}$$

Mean Time Between Failures (MTBF)

We use the number of failures and our records of the number of products shipped to calculate observed product reliability in terms of MTBF.

The MTBF is a measure of hardware failures that may be a result of product design, the manufacturing process, or defective components. This measure does not include field service upgrades or application-induced failures (i.e., hardware failures resulting from product misapplication).

An MTBF of 500 years means that for every 500 products in service, a customer can expect an average of one hardware failure per year. The annual failure rate is the inverse of the MTBF, so a 500-year MTBF can be interpreted as a failure rate of 0.20 percent per year.

$$MTBF = \frac{\text{The number of products in service for a specific period of time.}}{\text{The number of products returned for repair during the same period.}}$$

Mean Time Between Returns for Repair (MTBR)

The MTBR reflects the number of unscheduled removals. We calculate this metric similarly to the MTBF and include all returns counted in the MTBF and also every other reason for customers to return a product for repair, including misuse, mishandling, confusion (i.e., the returned product is actually fully functional), weather, and fire.

An MTBR of 200 years means that for every 200 products in service, a customer can expect an average of one return for repair for any cause per year. The annual rate of return for repair is the inverse of the MTBR, so a 200-year MTBR can be interpreted as a return rate of 0.5 percent per year. SEL introduced this measure to better represent the customer's experience with our products.

$$MTBR = \frac{\text{The number of products in service for a specific period of time.}}{\text{The number of observed failures during the same period.}}$$

Maintenance Indicator (MI)

The MI measurement includes repair actions counted in the MTBR plus maintenance actions taken due to SEL-recommended firmware or hardware upgrades, as shown in the table below.

Category	MTBF	MTBR	MI
Hardware and Mfg Process Errors	■	■	■
All Reasons for Repair, Including Damage		■	■
Recorded Maintenance			■

Outgoing Quality Assurance

Quality inspectors measure outgoing quality and validate new and existing processes by testing a sample of each day's manufactured products and new product pilot builds. Inspectors perform a visual inspection and verify through product operational tests that products function and are built to specification. Inspectors immediately report any errors for root cause analysis and corrective action.

Reliability Reports

We use product reliability reports to communicate to our customers their quality experience with our products. Any customer can request a product reliability report, which contains performance measures for product reliability and metrics specific to that customer's experience.

Improving Product Performance

SEL has improved our product hardware reliability continuously since 1984. We not only strive to understand the root of every product failure, create product improvements, and continually seek to simplify our products and processes, but we also regularly audit our Quality Management System processes, conduct ongoing reliability testing, and act on customer feedback.

External Review of the SEL Quality Management System

The SEL Quality Management System meets all of the requirements of the ISO 9001 standard and has been certified to ISO 9001 since July 1994. The latest certificate is available at selinc.com/SELquality. External auditors annually examine the SEL Quality Management System for compliance with the ISO 9001 standard. We seek this certification as evidence that our critical design, manufacturing, and business processes meet the exacting requirements of this internationally recognized ISO program.

We manage our type-test laboratory independently from our product development organization. This laboratory is certified to the ISO 17025 standard, General Requirements for the Competence of Testing and Calibration Laboratories. Our laboratory uses the latest equipment, calibrated to national standards, to ensure our products survive in harsh substation environments and outdoor enclosures.

Ongoing Reliability Testing (ORT)

The purpose of ORT is to monitor the long-term reliability of SEL products. During ORT, we subject products to extreme electrical and environmental conditions for extended periods. The results help us design and manufacture highly robust products that meet or exceed recognized industry standards and the operating conditions required by customers.

Acting on Customer Feedback

Quality personnel meet monthly with design engineers to review recent data from customer feedback reports and product repairs. When we identify elevated failure rate trends, we take action to understand the root cause, create improved product designs, and simplify products and processes when possible.

Stop Shipments

If we identify a process deviation, or if a product is not performing according to our specification or according to a customer's reasonable expectation of performance, then we stop shipment of the product. Any employee can initiate a stop shipment request if they suspect a quality issue. While we determine the root cause of the problem, we keep customers informed of any affected shipments and work together to deliver solutions for their immediate needs. We restart shipment only after we determine the root cause or demonstrate effective containment. We also take appropriate action to prevent the problem from recurring.

Service Bulletins

If we discover a problem that may affect products already shipped, we inform customers through Service Bulletins. Service Bulletins include an explanation of the identified problem, root cause, impact, observed defect rate, affected products by customer, corrective actions, and recommended maintenance solutions. This notification allows the customer to make an informed decision on how to address the issue.

Product Hospital

We support our ten-year warranty through our Product Hospital. Here, our technicians use root cause analysis to identify and correct a problem. The Product Hospital provides technical support for customers in addition to unit repairs. We drive improvements on our current and future products using the analysis and solutions from these returns.

Designing Quality and Reliability Into SEL Products

Design Process

The SEL design process is documented, controlled, and certified under the ISO 9001 standard. The SEL Research and Development (R&D) Division applies this process to new product development and product enhancement projects.

We carefully review product concepts to ensure they meet customer needs. During the planning stage, a project manager assembles a cross-functional team from various SEL divisions, such as R&D, Sales and Customer Service, Manufacturing, and Quality. Key deliverables from this phase are a detailed project plan and a detailed product system specification, including key customer requirements and regulatory and compliance standards.

R&D works with Manufacturing to create robust designs that adhere to the SEL Design for Manufacturability (DFM), Design for Test (DFT), and Design for Automation (DFA) guidelines. SEL designs products for a 20-year life using the following strategies:

- Keep designs simple and reuse proven, robust designs.
- Select the most reliable components specified for high-temperature operation.
- Apply components well within specified ratings.
- Test products beyond specified performance and type-test limits.
- Perform ongoing review of product repair data for design improvement opportunities.

Design Tests

Verification Testing

During product development, experts on the development team verify designs by conducting detailed product functional testing in the R&D laboratories.

We independently manage our compliance test laboratory where we perform regulatory and voluntary type testing. SEL tests for electromagnetic compatibility as well as environmental and mechanical design compliance.

Both our R&D and our compliance test laboratories are accredited to the ISO 17025 standard. This accreditation provides independent evidence of the competence of our laboratories and the SEL commitment to quality. In addition to meeting and exceeding industry-accepted design standards, many SEL products conform to the requirements of outside certification and standards bodies, such as UL, CSA, CE, EA, EPRI, KESCO, ABS, and LAPEM.

Margin Testing

During type testing, SEL personnel conduct tests with a margin well beyond the applicable IEC or IEEE requirement. The table below shows examples of tests conducted on most SEL products at margins beyond industry practice and beyond SEL specifications. Tested products pass not only the SEL certification level but the SEL margin level, as well. This margin testing benefits customers by ensuring extra robustness of the product to any transient or high-stress conditions.

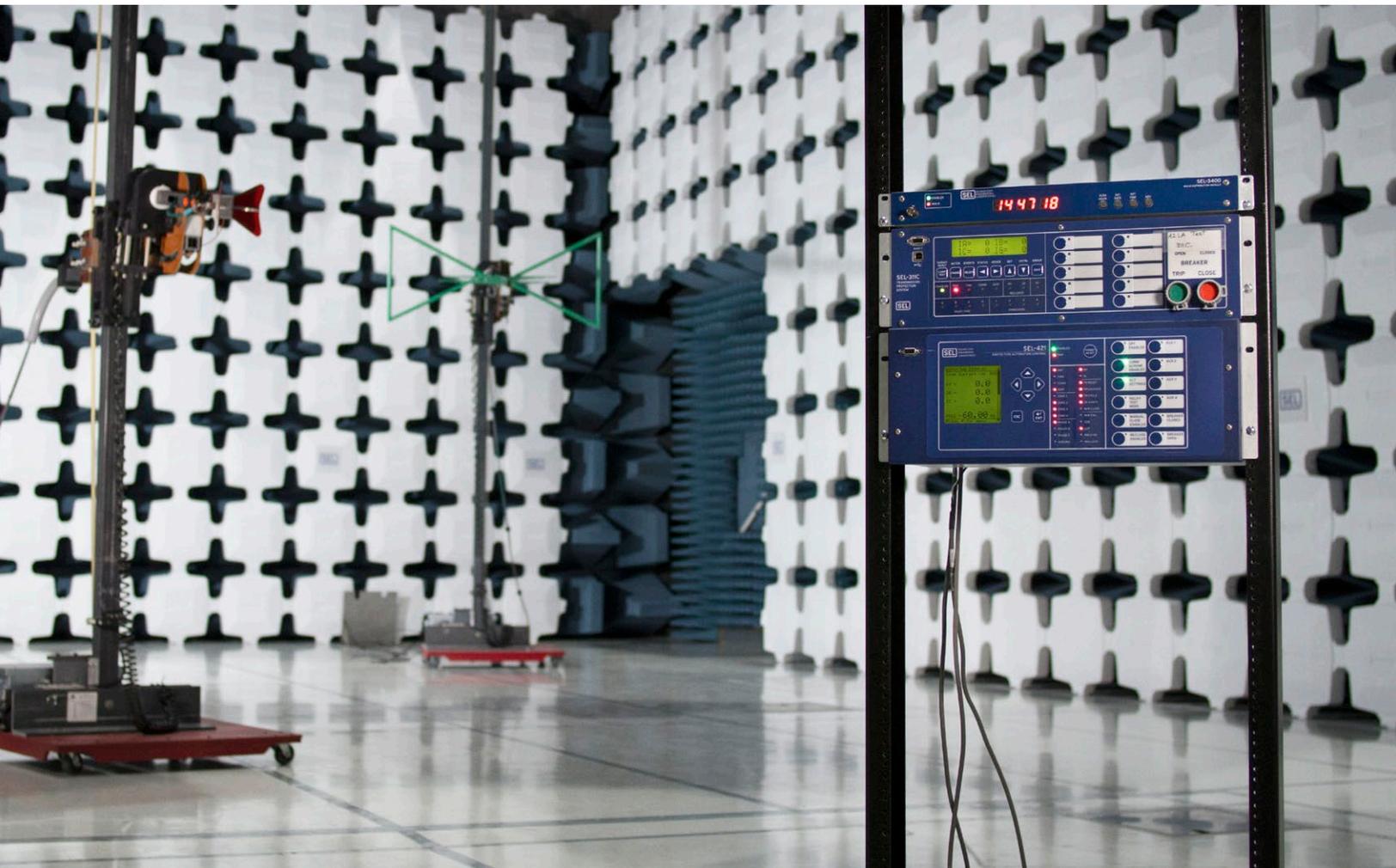
Test	Industry Practice	SEL-Certified	SEL Typical Margin
Electrostatic Discharge (ESD)	6 kV contact/8 kV air	8 kV contact/15 kV air	12 kV contact/20 kV air
Dielectric Strength (HiPot)	1.5 kV	2.5 kV	2.75 kV
Temperature Range	-20° to +70°C (-4° to +158°F)	-40° to +85°C (-40° to +185°F)	-45° to +90°C (-49° to +194°F)
Electrical Fast Transient	Zone A: 4 kV at 5 kHz Zone B: 2 kV at 5 kHz	Zone A: 4 kV at 5 kHz Zone B: 4 kV at 5 kHz	Zone A: 4 kV at 100 kHz Zone B: 4 kV at 100 kHz
Magnetic Field	30 A/m 60 s, 300 A/m 3 s	100 A/m 60 s, 1000 A/m 3 s	120 A/m 60 s, 1200 A/m 3 s

Product Validation

Prior to manufacturing qualification, validation testing simulates a variety of actual customer product applications using an advanced Real Time Digital Simulator (RTDS®) and staged systems. Manufacturing qualification includes pilot builds to ensure repeatable manufacturing processes and product performance. Test engineers use automated test stations to confirm product performance to specification for every product.

Vulnerability Testing

The SEL product security life cycle ensures continuous monitoring and improvement of product robustness and quality. SEL regularly performs vulnerability scanning and fuzzing on product communications interfaces and protocols. Alongside internal test suites, SEL employs third-party verification and scanning tools.



Building Quality and Reliability Into SEL Products

State-of-the-Art Manufacturing

SEL uses a formal procedure to plan, monitor, and complete new product introductions. We use our DFM, DFT, and DFA guidelines to implement best practices, and we document, control, monitor, evaluate, and improve day-to-day manufacturing operations. The following are key actions in this process:

- Documenting work instructions.
- Measuring and reporting on key performance requirements.
- Performing thorough functional and environmental stress tests.

SEL uses state-of-the-art equipment and controlled processes to build to the highest workmanship standards (IPC-A-610 Class 3). Class 3 is the most stringent level possible, which is appropriate when products must function in uncommonly harsh environments with no downtime, such as life-support and aerospace system applications.

We continuously train our assemblers and inspectors on the latest manufacturing processes. Through formal testing, employees recertify regularly, based on SEL process requirements and industry standards.

We perform in-process tests to ensure high-quality performance. At each level of testing, we record and review defects and act on quality measures daily.

Quality and Reliable Materials

Supplier Partners

SEL qualifies suppliers that provide production materials or components through a careful selection and evaluation process, which may include an onsite audit of their facilities and processes. We strive to develop positive relationships with our suppliers by hosting an annual supplier conference, during which we share the criticality of our mission and our customers' operations, SEL values, information about our quality system, and supplier quality expectations. We encourage our suppliers to understand, create, and simplify along with us, and we welcome opportunities to work with our suppliers and assist with developing improved solutions.

Assuring Material Quality

We monitor supplier quality performance by conducting an incoming inspection on high-risk parts prior to releasing them to the manufacturing floor. Acceptable parts conform to all specified requirements.

Because some nonconformities cannot be found through visual inspection, we continue to monitor material quality throughout the assembly process using numerous tests. We deliver any part that fails to the Supplier Quality laboratory to confirm the failure. When possible, we work with the supplier to perform failure analysis and develop a more robust process through supplier corrective action to prevent future errors from occurring. We purge any suspect parts to ensure containment and prevent factory escapes.

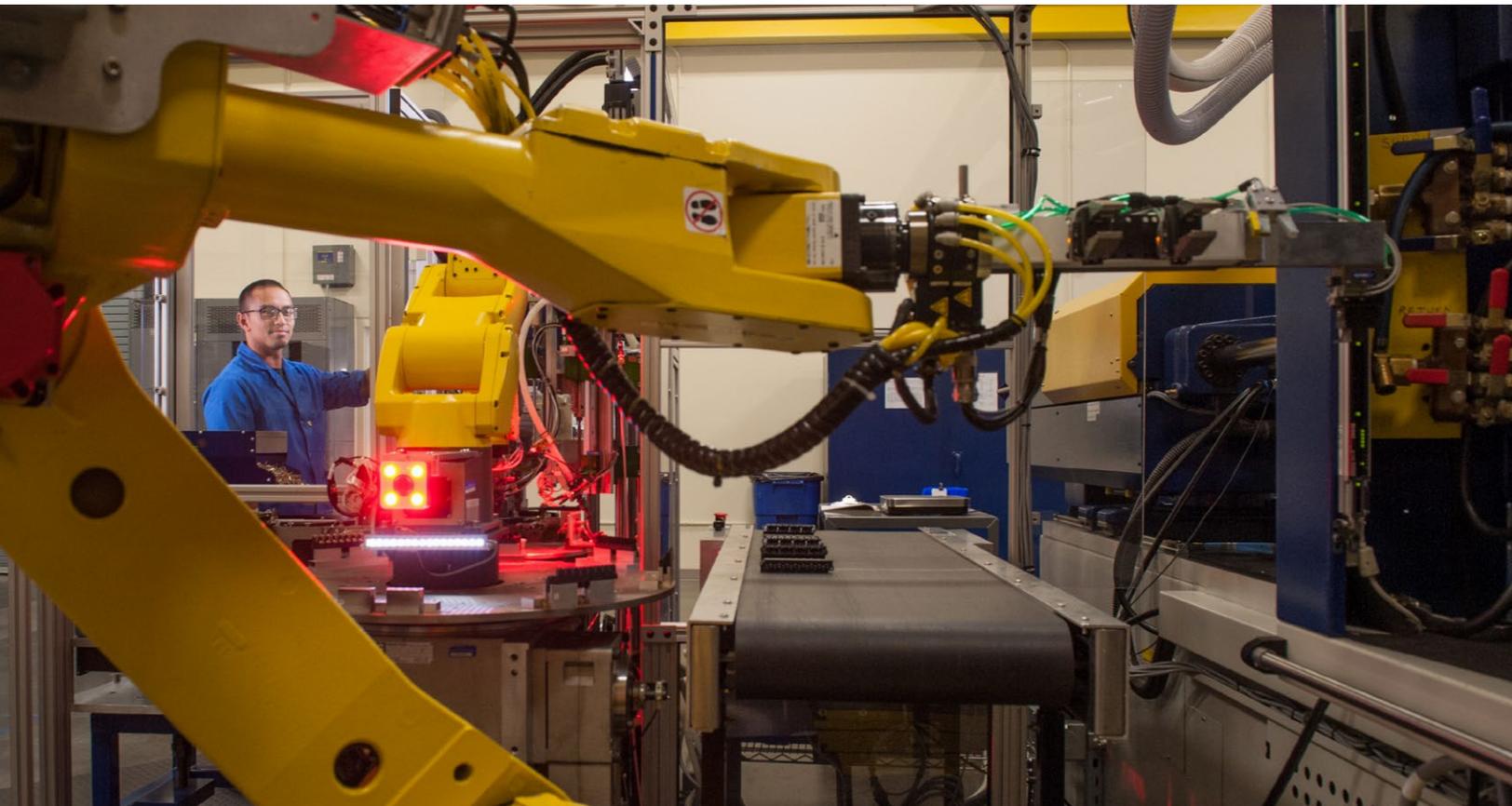
In-Depth Protection From Counterfeit Parts

SEL does not use counterfeit parts and has detection processes in place throughout the assembly process, from receiving to final test, to prevent their use. If suspected, SEL performs numerous tests to determine the authenticity of the part.

The Independent Distributors of Electronics Association defines counterfeit electronic parts as “items that are produced or distributed in violation of intellectual property rights, copyrights, or trademark laws.” These parts may include used electronic parts represented as new, may not contain the proper internal construction, and may be sold with modified labeling, all of which aid in their detection. In addition to visual comparisons, we electrically verify component specifications.

Vertical Integration

SEL designs, manufactures, and installs an increasing number of component types in our products, including plastics, magnetic devices, metal cabinets, rotary switches, and test switches. Developing diverse manufacturing capabilities has added to the technical roots and expertise of our company and has helped minimize supply chain disruptions.





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