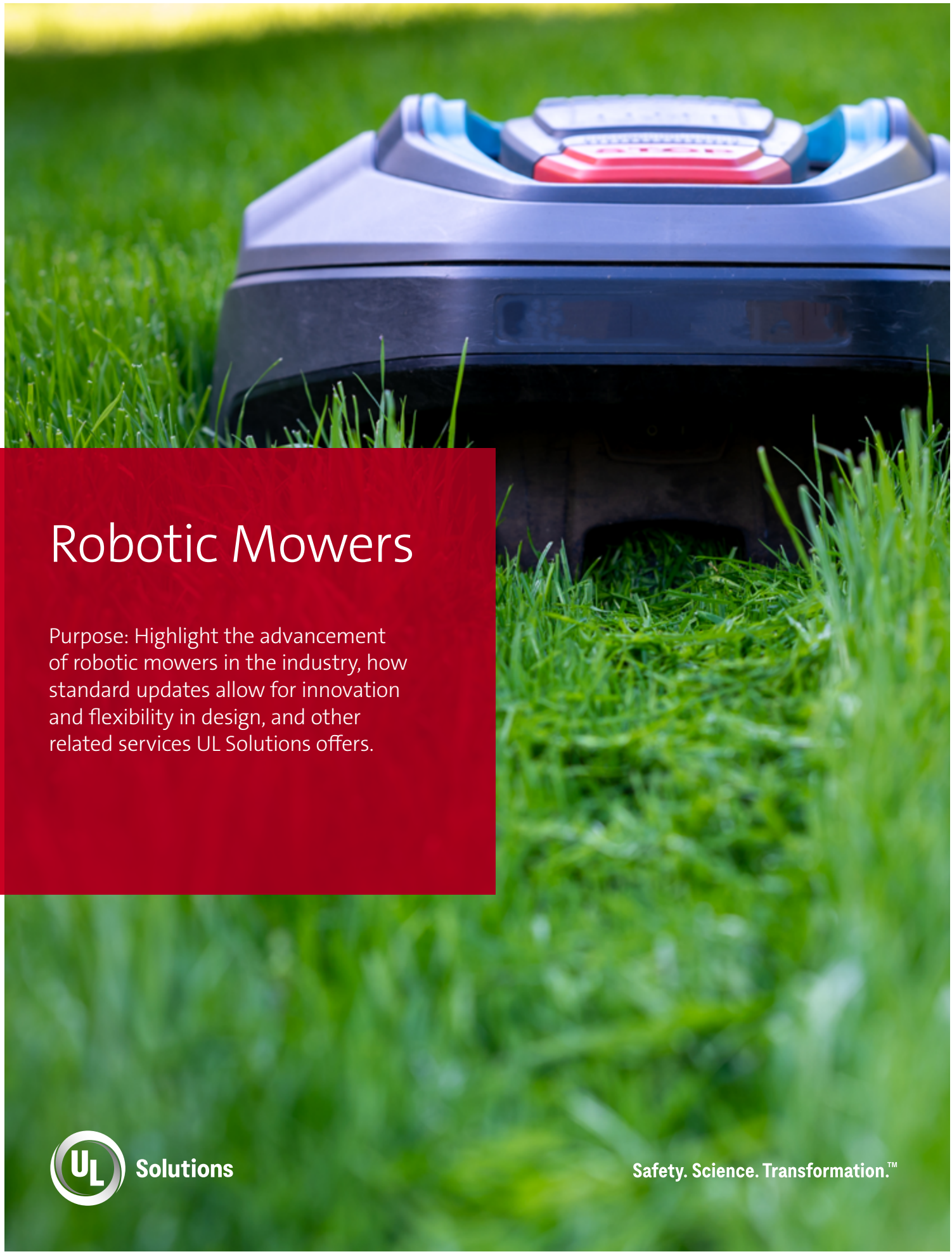

Robotic Mowers

Purpose: Highlight the advancement of robotic mowers in the industry, how standard updates allow for innovation and flexibility in design, and other related services UL Solutions offers.

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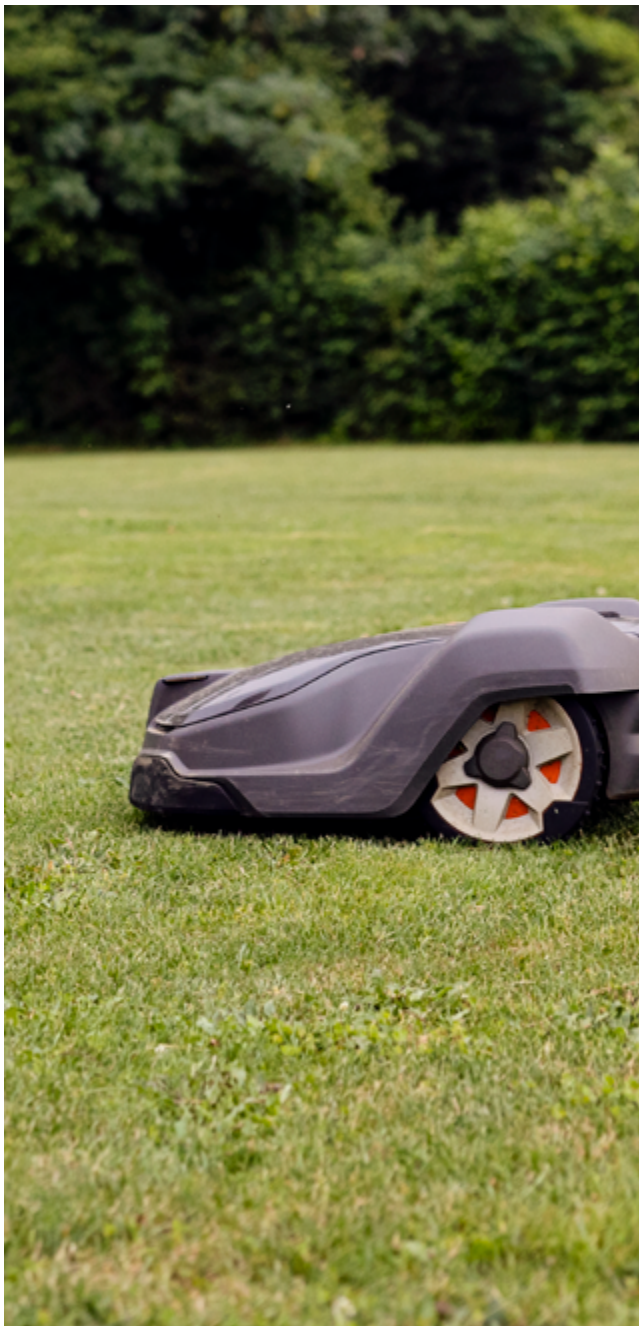


A brief history of mowers

In 1830 Edwin Beard Budding[1] from England invented and patented the first cylinder mower. At that time, the chain had not yet been invented and thus power to the blade was transmitted by a cast iron gear train. Since that early invention, mowers have seen tremendous innovation, adoption, and acceptance globally in residential, commercial, and industrial applications.

It took less than 30 years (1859) for mowers to become chain driven,[2] which allowed for a lighter and quieter mowing experience. The steam-powered mower was patented in 1893, followed by the addition of the internal combustion gas engine in 1902.[3] So now, fast forward to 1969, with the first robotic mower patent of the MowBot by S. Lawrence Bellinger.[4] The MowBot mowed by either automation or remote control, powered by a battery with a border wire and equipped with sensors that returned to a docking station. And thus, the birth of a new product segment was born — robotic mowers.

The robotic mower standard: IEC 60335-2-107

While the first robotic mower patent was granted in 1969, the current standard, IEC 60335-2-107, Household and Similar Electrical Appliances – Safety – Part 2-107: Particular Requirements for Robotic Battery Powered Electrical Lawnmowers, was first drafted for circulation by the IEC in 2004 and published in 2005. The first edition was published in 2012 and the second edition in 2017, followed by edition 2.1 in 2020 and edition 2.2 in 2021.

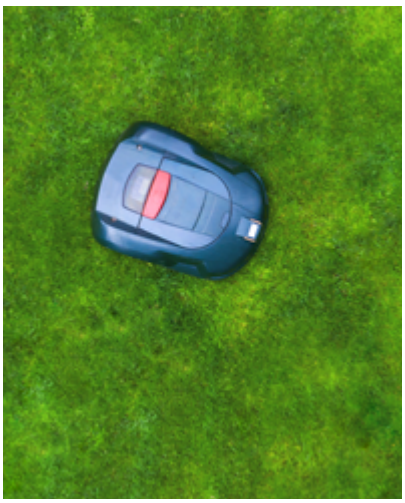
As a standard in the IEC 60335, Household and Similar Electrical Appliances series, many of the general requirements are included in Part 1 of IEC 60335-1. As an international standard, it addresses general requirements for many household appliances. Countries and regions can adapt and, if necessary, amend requirements for their local needs. In North America, 60335-1 is a tri-national standard for the United States (UL 60335-1), Canada (CAN/CSA-C22.2 No. 60335-1) and Mexico (NMX-J-521/1-ANCE). Within Europe, to comply with the European directive, the standard is EN 60335-1.

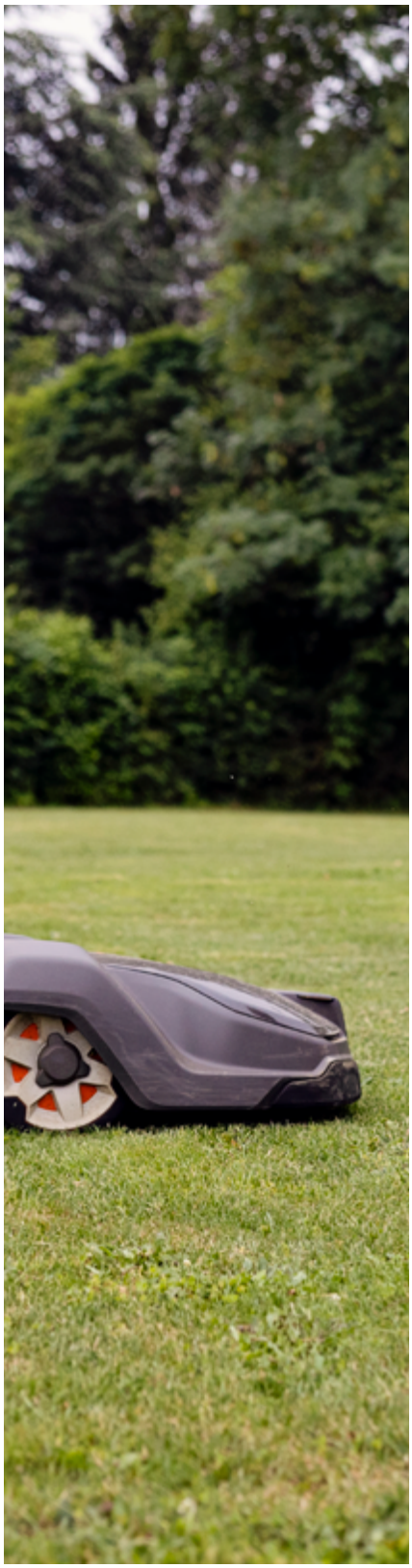
As a Part 2 standard, IEC 60335-2-107 incorporates additional requirements specific to robotic battery-powered electrical lawnmowers that may not be applicable to other household appliances. Additionally, the Part 2 standard can accept, add, modify, replace, or void clauses within IEC 60335-1. To promote and encourage innovation, IEC 60335-1 and 60335-2-107 both go through separate standard development processes. Each standard has a technical committee with members from different industry groups who meet to discuss, propose, and vote on changes to the standard. While only approved technical committee members can vote on standard proposals, anyone is able to submit revisions to standards. To ensure any IEC 60335-1 changes do not negatively impact IEC 60335-2-107, the IEC 60335-2-107 technical committee will review IEC 60335-1 changes and decide what action is appropriate for IEC 60335-2-107. As noted above, some countries may adopt and publish their own versions of IEC 60335-2-107. As such there is an overall IEC 60335-2-107 technical committee in addition to country-specific technical committees.

For North America, the published standard is ANSI/OPEI 60335-2-107.

As the evaluation of robotic mowers continues, so does the evaluation of standards. IEC 62841-1, Electric Motor-Operated Hand-Held Tools, Transportable Tools and Lawn and Garden Machinery – Safety – Part 1: General Requirements, is the current standard for many power tools and outdoor power equipment. Part 1 of IEC 62841 includes the general requirements for the series. Numerous Parts 2, 3 and 4 set forth specific requirements for hand-held power tools, transportable power tools and lawn and garden machinery. The Standards Writing Committee expects expects that revised requirements for robotic mowers will be published in a new IEC 62841-4-X standard sometime in 2023.

While all the clauses in IEC 60335-2-107[5] are relevant to the safe operation of a robotic mower, several clauses are discussed in more detail below. The discussion should not be considered a comprehensive list, review, or interpretation of requirements because no one clause or requirement by itself determines a safe or unsafe design.





Clauses

Clause 20.102 — Safety requirements

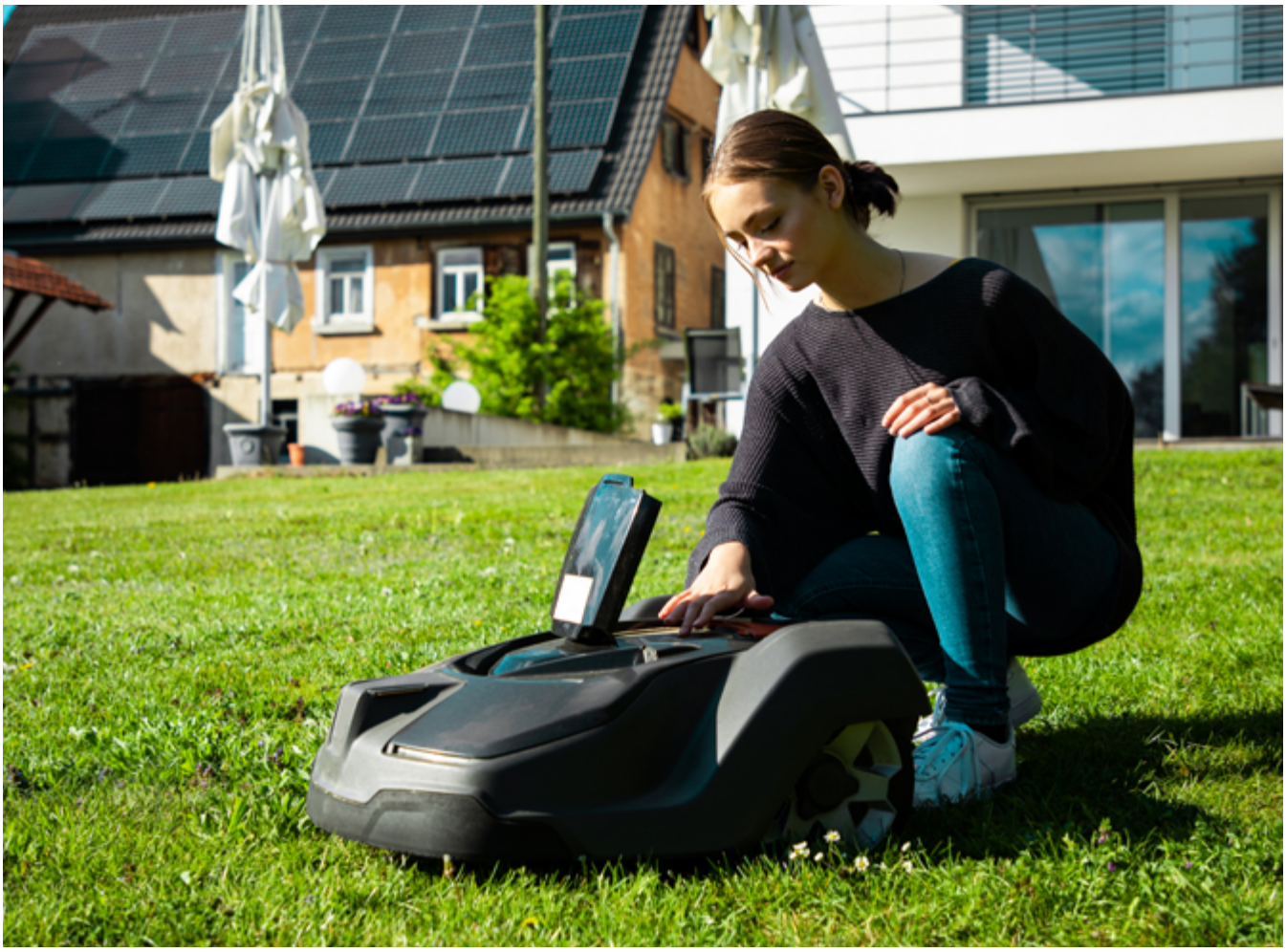
As one would expect, the safety requirements clause in a safety standard includes a long list of detailed requirements. First in the IEC 60335-2-107 list is the Cutting means enclosure sub-clause that specifies that the cutting means, referring to the mechanism used to provide the cutting action, is to extend below the cutting means enclosure. This guards against thrown objects and unattended contact with the cutting means during normal operation. An exception allows for the cutting means not to be below the enclosure if it is a pivoting cutting element or a filament line with a centrifugal force not exceeding 2 Joules. This exception is primarily based on the assumption that a cutting means with a kinetic energy below 2 J should not throw an object with excessive force from the mower.

Numerous requirements state that the cutting means must stop under certain conditions. The sub-clause Cutting means stopping time specifies a stopping time within 2 seconds along with the tests required to validate compliance. The 2-second requirement is met if either the cutting means stops within 2 seconds if a stopping command is generated from various sensors, or the residual energy is below 0.1 J. Certain conditions may also require the mower to stop moving, as outlined in the sub-clause “Traction drive stopping.” A machine must be able to stop the traction drive when a stopping command is generated by a manual stop, manual controller, lift sensor, tilt sensor or obstruction sensor. Distance and time requirements depend on the command-and-control functions used. Additionally, Clause 20.102.6 sets forth the restart actions that must be taken.

The sub-clause Inadvertent access to the cutting means specifies that the design of the cutting means enclosure during operation prevents access to the cutting means as far as reasonably practicable. Compliance is conducted with a variety of test probes to ensure the test is conducted in the most unfavorable cutting position. The test probes are designed with specific angles, depth, thickness, length and/or pivot points to simulate either an adult or a child. Over the years, the standard has been updated to include additional probes that have significantly enhanced the safety of robotic mowers since the standard was published in 2005. The additional test probes now include the following: adult foot probe test, foot probe test for standing child, foot probe test for kneeling child, hand probe test, child arm probe test and the finger probe test.

Clause 21.101.2 — Strength of cutting means and cutting means mountings

Years ago, the predominant cutting means in robotic mowers was a rigid metal blade similar to the cutting means in a traditional walk-behind or ride-on lawn mower. More recent robotic mowers now employ a pivoting cutting element that consists of either a small razor blade or a filament line, which is typically employed on grass trimmers. Overall, the cutting means and mounting means are required to have adequate strength to withstand impact with a solid object during normal operation without causing injury to the operator or to bystanders.



Clause 22.104 — Working Area

As robotic mowers are autonomous when they are placed in automatic mode, they are not permitted to leave the working area or to operate outside the working area. If a mower is outside the working area, it is required to be inoperable. The working area is defined by a perimeter delimiter (wire) or a pre-programmed area.

Clause 22.105 — Sensors

The primary purpose of sensors is to monitor and react to any unanticipated stimulus during normal, safe operation. Depending on the type of sensor and trigger, such a stimulus may cause the robotic mower to deactivate, reactivate or reverse direction. Multiple sensor types may be employed: tilt sensors, obstruction sensors, lift sensors and rollover sensors. If a unit is stopped by an activated sensor, it may only be possible to restart it by taking the actions specified in Clause 20.102.6 Restart procedure.

Current trends in the industry

In the 21st century, the popularity of robotic mowers is growing fastest in Western Europe. During the mid-1990s and into the early 2000s, robotic mowers were becoming more widely available; however, autonomous products were still rarely used in personal or commercial applications. To put the use of robotic mowers in perspective, consider that the first Apple iPhone was released in 2007. Prior to that, personal devices with apps that could monitor, communicate and control did not exist. Today autonomous products are a common part of consumers' everyday lives, with products ranging from vacuums to delivery robots, medical equipment and painting gear, the list of autonomous products continues to grow globally. While the largest share of the robotic mower market and growth is in Europe, the popularity and expansion in North America are not far behind. Both regions are seeing increases in residential and commercial applications.

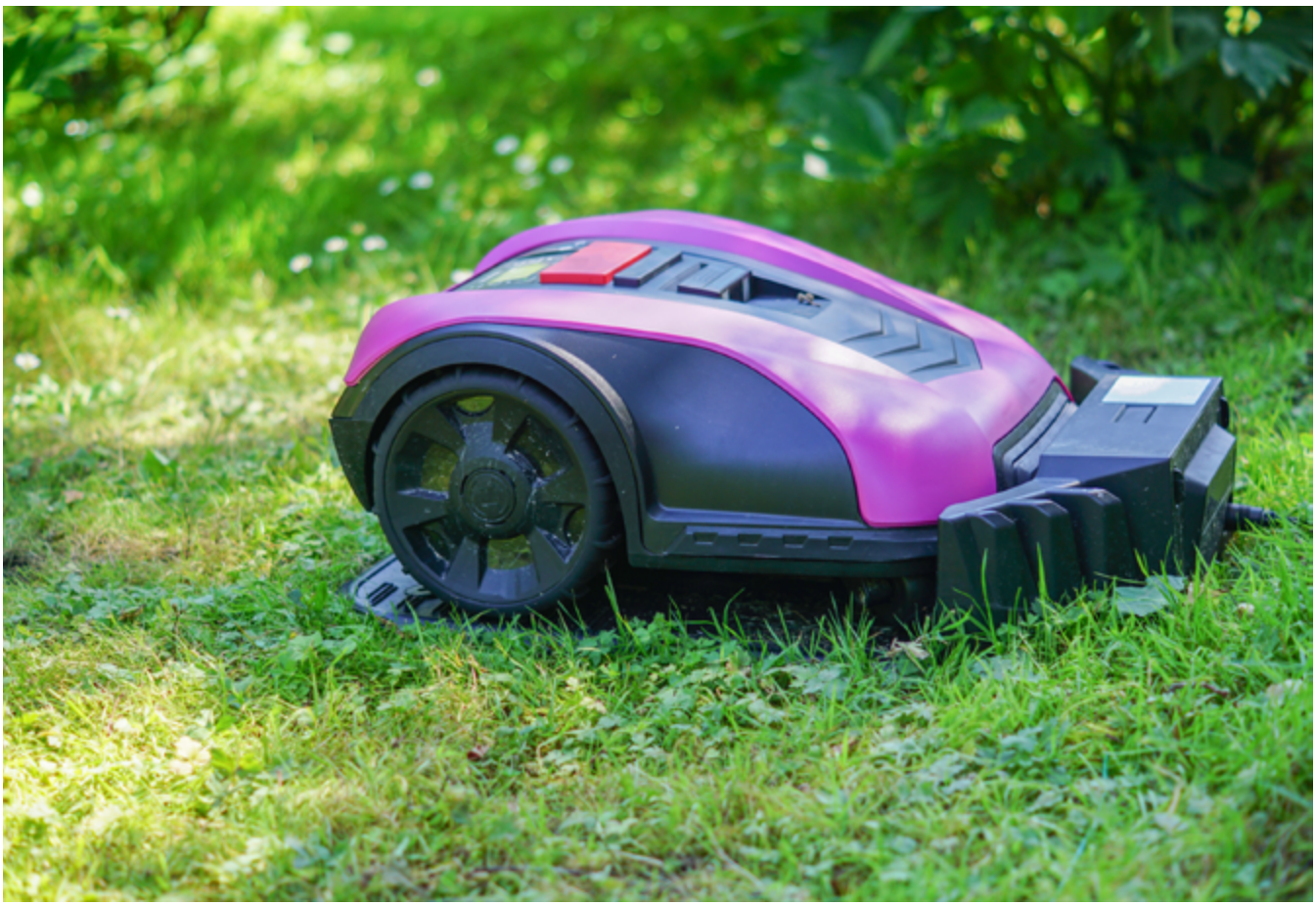
Consumers want the convenience and timesaving benefits that robotic mowers provide. Many regularly schedule their robotic mowers to operate at night. Owners of robotic mowers can effortlessly trim the grass daily, unlike the owners of traditional mowers, who typically wait longer between cuttings and then must push their mower through higher grass. To cut a larger lawn area, the trend is to have a mower with a lighter weight cutting means, typically favoring pivoting cutting elements (razor blades) rather than rigid cutting means similar those in traditional walk-behind mowers. One benefit of lighter weight cutting means is longer operating time before the mower must be recharged. Robotic mowers are often differentiated by the area of lawn they can mow. Larger lawns require longer battery performance to ensure less time at a charging station. Battery life between charges depends on the amount of energy the mower demands, which is contingent on the type of cutting means and the propulsion system that keeps cutting and moves the mower forward. To reduce weight and battery energy consumption, pivoting cutting elements (razor blades) have been more predominant in recent years.

Commercial and industrial robotic mowers have the added benefit of reducing long-term labor costs over the initial price of the unit. The overall design, size, energy, and power source are quite different from those of traditional residential robotic mowers. Those differences are to be expected given that residential lawns are typically under an acre. In contrast, commercial and industrial applications may cover much larger areas, such as public parks, roadside grass, golf courses, corporate business grounds and the like. Today, no design and style seem to predominate because the industry is producing both battery operated and internal combusting gas engines. Blade types, depending on the intended end use, are provided with either pivoting cutting elements or rigid cutting blades. Innovations in sensor technology and artificial intelligence (AI) are developing rapidly within the industry. Lidar, GPS navigation, proximity detection, and ultrasonic sensors are some of the innovations available in today's designs. It should be noted that while IEC 60335-2-107 is called a household appliance standard, it does not currently distinguish between the uses of residential, commercial, and industrial robotic mowers. IEC 60335-2-107 does specify that battery operated robotic mowers must not be more than 75 VDC. No currently published standard exists specifically for internal combusting gas engine robotic mowers. However, various standards have been developed for internal combustion gas engine mowers in the ANSI/OPEI B71 series of standards. Gas-powered robotic mower companies anticipate that a standard will be developed to cover gas-powered robotic mowers.

Battery innovation

As major design elements and factors that can differentiate one robotic mower from another, batteries and battery chargers are integral components in residential robotic mowers. As has long been the trend in both the power tool and the outdoor power equipment industries, batteries are gaining in popularity over cord-connected and internal combustion engines. Battery technology and lithium-ion batteries have dominated the market. Thus, constant demand pushes for longer running batteries with larger energy density and low discharge rates; that are lightweight, compact, and fast charging; and that can maintain their energy density over multiple recharging. Manufacturers continue to offer the ability to interchange their batteries within their portfolio of tools and garden machines. Thus, a battery that powers a leaf blower in the fall and a snow blower in the winter may be able to power your robotic mower in the summer.

IEC 60335-2-107 covers additional battery requirements in Annex KK, Additional requirements for battery operation and charging. Specific requirements for the cells within battery packs are covered by IEC 62133. To comply with battery operation and charging requirements, the batteries must be tested under various normal and abnormal operating conditions, including abnormal discharge, short circuit, overcharging, and others. For some tests, venting of cells is permitted, but fire and explosion are considered noncompliant results. The specific methods and procedures of each test may depend on the design and configuration of the battery pack. Specific requirements must be met for most battery chemistries, but most of the requirements pertain to lithium-ion chemistries. Robotic mowers are not permitted to accept general purpose batteries as energy sources for their primary function.



Connectivity

While robotic mowers may come in many different shapes, sizes, and designs with their own unique differentiations, one thing they all have in common, in addition to mowing, is connectivity. With connectivity comes a whole new set of both regulatory and non-regulatory concerns and challenges.

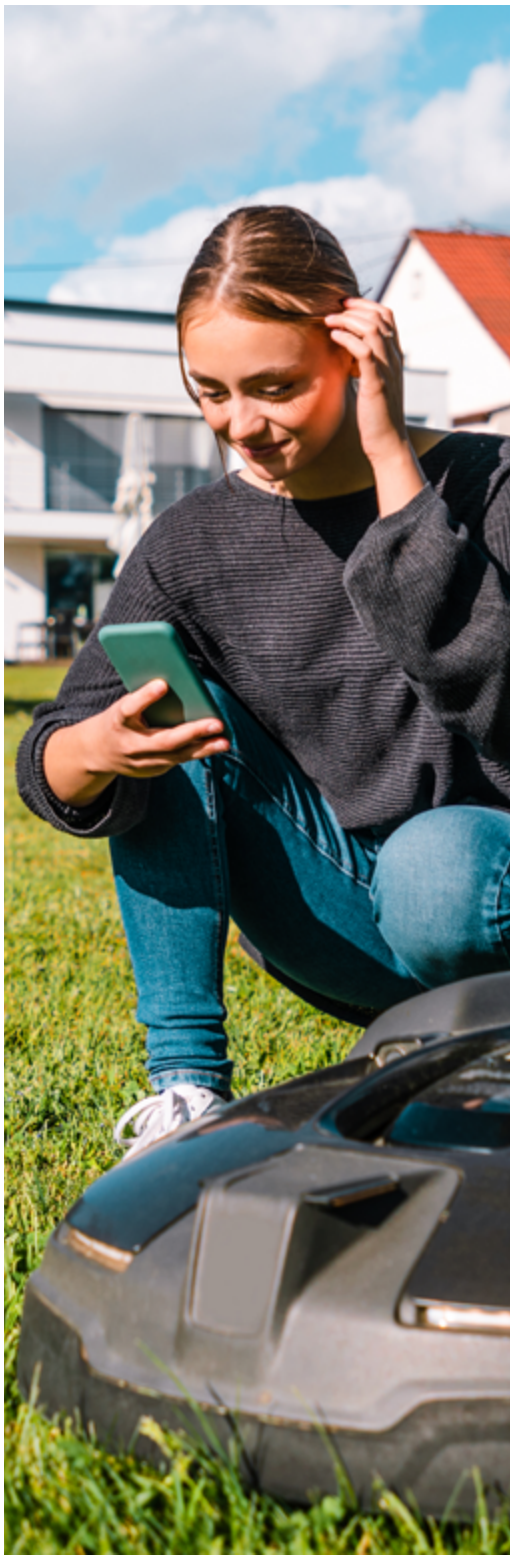
One of the primary purposes of launching a connected residential robotic mower is to make a homeowner's life easier, but some things may cause new challenges, such as:

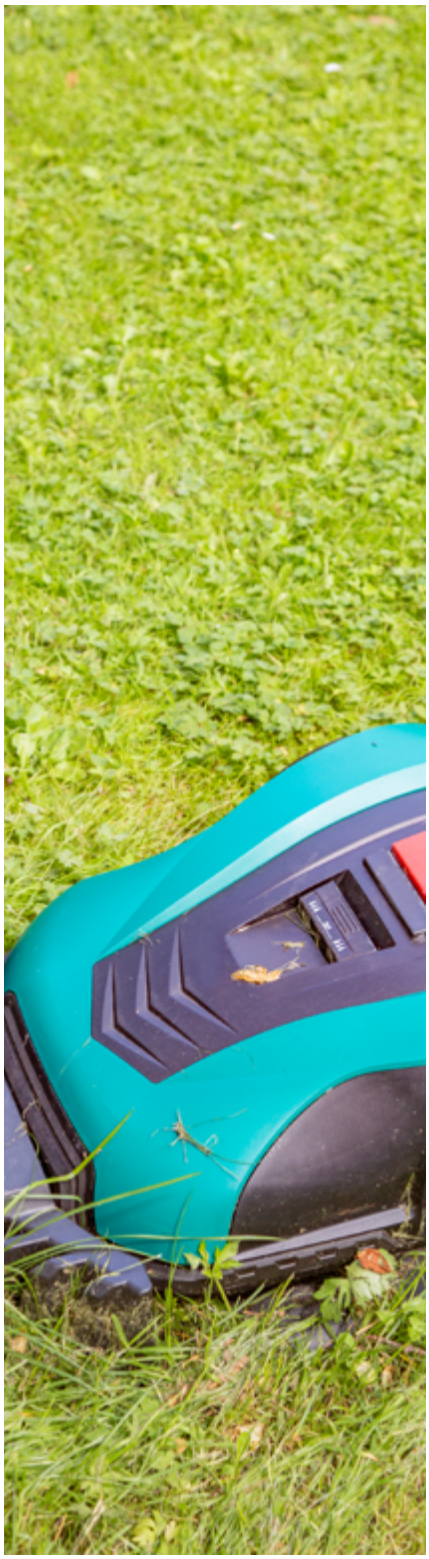
- Not being able to connect their mower after many attempts.
- Not being able to connect their mower to a new router.
- After their phone's operating system is updated, they are no longer connected or getting alerts.
- They do not understand what mower-related error messages mean.
- Something that worked on their iPhone doesn't work on their new Android phone.
- The mower's app crashes, so they stopped using all the smart features.
- Everything was great until the latest app update.

So, a connected robotic mower may only be as good to a consumer as its ability to get connected, stay connected and deliver its intended features. This point shows where a solid understanding of smart device provisioning becomes critical to a user's overall experience. A robotic mower may do a fantastic job of keeping a lawn beautiful, but bad experiences with its smart features may lead to poor online ratings, increased calls to customer care and returned products. A robust provisioning process considers differences in interfaces, user settings, versions of the operating system, stack versions and chipsets. It also considers differences across different types and configurations of Wi-Fi routers.

Testing across an extensive collection of mobile phones and a diverse selection of Wi-Fi routers is necessary during a product's design and development phase, prior to launch and during the life of the product.

Even if robotic mower technology does not change, the technology it connects to continuously innovates. What worked when a robotic mower was first released may not continue to work months or years after the release. Thus, the question for the robotic mower industry is: How will you maintain and upgrade to improve customer satisfaction and the user experience? Unidentified problems can quickly grow, damage your brand and be expensive to correct.





Cybersecurity

Now that we have considered how a robotic mower will get reliably connected, stay connected and deliver its intended features, we shift our focus to cybersecurity. On the surface, a robotic mower may not seem to be an attacker's primary focus, but it is connected to the overall system that an attacker may want to gain access to. Because attackers will exploit any vulnerability, ensuring that a robotic mower's software does not have inherent security weaknesses is a good place to start. Developing and adhering to a test protocol that continuously reviews the latest threats to guard against reported and unreported vulnerabilities is a never-ending process. The list of publicly known vulnerabilities and exposures with patches and Zero-Day vulnerabilities that have been exploited when not patched is always being updated. Cybersecurity risks will increase over time wherever there are vulnerabilities to attack. The risks will continue whether a robotic mower's software is updated or not because attackers are always developing new approaches. What was tested and certified safe at launch may not be safe the day after launch.

Electromagnetic compatibility (EMC) serves a regulatory requirement for robotic mowers in many countries around the world, including in the United States, where the U.S. Federal Communications Commission (FCC) governs requirements. As an intended radiated product with wireless capabilities, these products require specific tests. Radiated emissions and immunity testing are often conducted early in the design phase and are repeated many times to compliance with regulations. As with safety certification, EMC and wireless testing have their own requirements that products must meet before they can be put on the market. Understanding both EMC and wireless testing and how they may impact a product's design and build is important to avoid costly redesigns late in the development process. The EMC and wireless tests safeguard robotic mowers so that they operate safely when subjected to conditions they may encounter while normally maintaining a lawn or recharging at a docking station.

Companies that prioritize a continuous comprehensive connectivity strategy that considers interoperability, cybersecurity, EMC, and wireless can gain a competitive advantage in the robotic mower industry. Connectivity poses a challenge to every industry that produces connected or smart products.

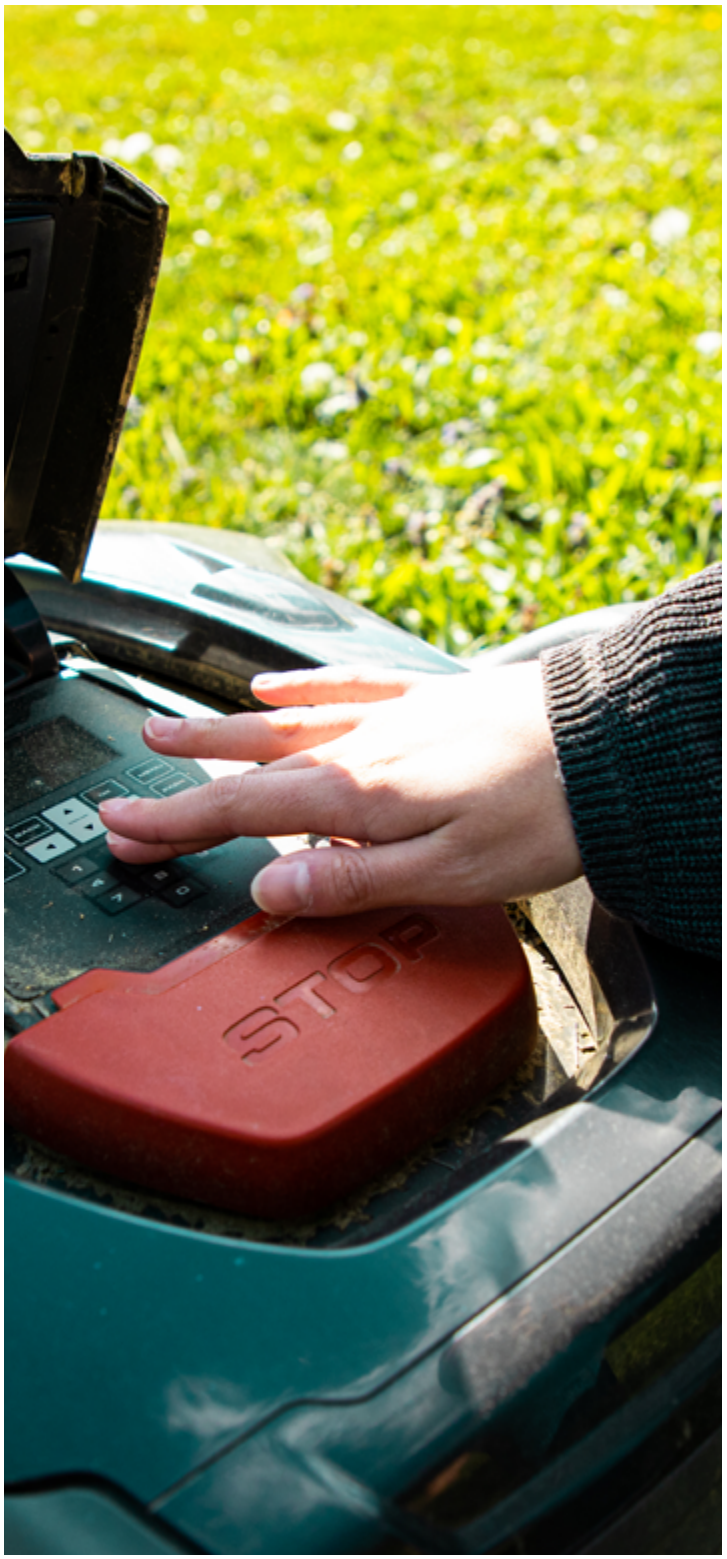
Cybersecurity
risks will increase
over time wherever there
are vulnerabilities to attack

Restricted materials

The last topic, restricted materials, is not specific to robotic mowers or the outdoor power equipment industry and is widely discussed by all manufacturers.

The importance of staying up to date and proving compliance with environmental regulations cannot be overlooked. Because compliance with environmental regulations is mandatory, failing to comply can cost a company millions of dollars.

Each country or region has its own list of restricted materials. Companies hoping to market their products in Europe must be familiar with the regulations set forth by Waste from Electronic and Electrical Equipment (WEEE), Restriction of Hazardous Substances (RoHS), Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) and the Directive on Packaging and Packaging Waste (the Packaging Directive) and follow their updates on a regular basis. In North America, the U.S. Toxic Substances Control Act (TSCA, gives authority to the U.S. Environmental Protection Agency (EPA)), Proposition 65 in California, U.S. Toxics in Packaging, and the Canadian Environmental Protection Act (CEPA) have also seen recent updates and proposed changes. Understanding the rules and regulations; upcoming proposed and confirmed effective dates; different exposure types; when, how, and where to place warnings; litigation risks and the like is a daunting task. In addition to knowing the regulations, many companies compliance with regulations and mitigate risk through testing and a robust supplier declaration program.



How can UL Solutions help?

As a premier global testing, inspection and certification company, UL Solutions has been helping companies get safer products to market since 1894. With offices around the world, UL Solutions is positioned to help manufacturers gain market access by working with their experts during their entire product design phases. UL Solutions will be offering the C-UL-US Mark UL certification Mark indicating compliance with Canadian and U.S. requirements. C-UL-US Marks are available in both legacy and enhanced Mark formats and CB Certification to your robotic mower to IEC and ANSI/OPEI 60335-2-107. Our trained engineers are experts in IEC 60335 and IEC 62841 standards. For connectivity, UL Solutions has been a leading provider, working with small businesses to Fortune 500 companies on their interoperability, cybersecurity, EMC, and wireless challenges with amazing results.

For restricted materials, UL Solutions can provide total knowledge and testing, working with your experts and supply chain to keep you up to date on the latest regulations.

For more information on any of the above UL Solutions testing and certification services, please contact your local UL Solutions sales representative or visit us at bit.ly/OutdoorMachines

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