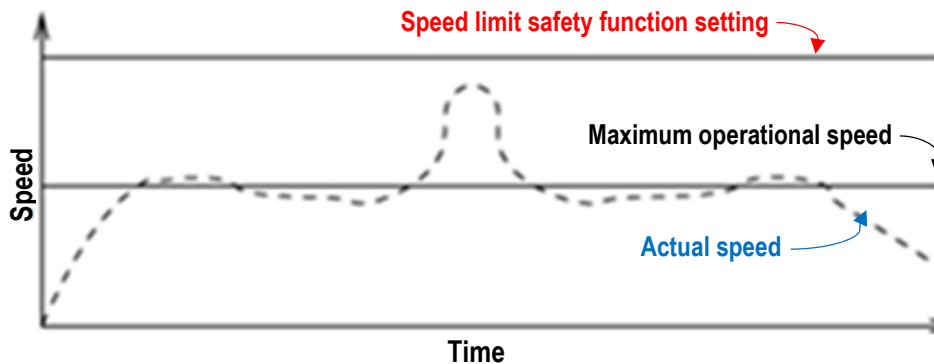


What does “Tolerance” mean when our safety functions are described?

Tolerances are part of our safety functions. Operational limits are used by our robot controller to set internal operational limits (not safety-related) to lessen nuisance stops and also prevent exceeding any safety function limit settings. Think of this as being the “cushion” of our system working (with as few nuisance stops as possible) while staying within the parameters of our safety limit settings. Tolerances and operational limits are “baked” into the control system and not user modifiable. They are basically the framework due to the processors and communications within which the robot operates.

Use of internal operational limits prevents safety faults while allowing for fluctuations in the program behaviour. With operational limits, the robot will operate productively while safety function limits are not exceeded.

For example, when handling a heavy payload, there can be situations where the robot needs to briefly operate above the maximum operational limit to follow a programmed trajectory, yet still not exceed the speed limit safety function setting. Below illustrates the speed limit example:



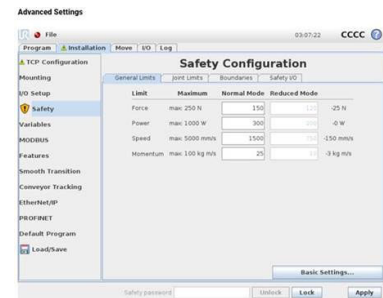
Example of the speed limits (safety function limit and operational limit)

CB3

Using the speed limit as an example, the CB3 speed limit tolerance is 150 mm/s.

Safety sensors have some inaccuracy. Therefore if the sensor measures 250mm/s, then the actual speed could be above or below this value. This is taken into account in the specified tolerances.

With CB3, it just so happens that tolerances are also the “operational limits”. The safety function **tolerance** is used to set the operational limit. CB3 safety function tolerances are shown on the teach pendant in the advanced settings. Operational limits are not part of the safety functions, but the tolerances are. If a 250 mm/s speed limit is configured for the safety function, the operational limit will be $250 - 150 = 100\text{mm/s}$.



CB3 has fixed “operational limits” which are based on the tolerances, which are also fixed. Just think of them as being used by our robot controller to operate reliably without nuisance stops while trying to stay within the safety limit settings.

e-Series

Operational limits are set by an algorithm for improved performance and ease of use. We do not publish the algorithms for e-Series tolerances and operational limits. The tolerances and operational limits are not displayed on the teach pendant. In the User Manual and in the Safety Functions sheet, the minimum tolerances are stated. Like the CB3, operational limits are used by our robot controller to operate reliably without nuisance stops while complying with the safety limit settings. For the e-Series, the minimum speed limit tolerance is 50mm/s regardless of the speed limit safety function setting, however operational limits will vary with the limit settings, i.e. higher safety function speed limit setting results in a higher speed operational limit. See e-Series Functional Safety information in the User Manual. The safety function descriptions and information is available for download.

CB3 “operational limits” are fixed while they are dynamic with the e-Series

Tolerances have the same meaning with CB3 and e-Series, just that the e-Series has improvements. The “tolerances” include the accuracies. Published “tolerances” were determined by functional safety validation using external highly precise testing equipment.

For the CB3 speed limit, the tolerance is 150mm/s – no matter what the setting for the speed limit safety function. When the speed limit safety function setting is 2000mm/sec, this tolerance is relatively small. But if the speed limit setting is low, comparatively this tolerance is large. For the e-Series, the minimum speed limit tolerance is 50mm/s, however the tolerances and operational limits are larger with larger safety function settings.

The safety function tolerances incorporate all the accuracies of the sensors and the complex computations in the safety functions. The determination and reporting of these figures is dictated by functional safety standards. In both CB3 and e-Series, accuracies are rolled into and included in the published “tolerances”. It is not called “accuracy” because this would not quite be right. It is a tolerance due to a combination of the accuracies of sensors, computation, communications... and due to the accuracy of the system used to validate the safety functions for TÜV certification (e.g. if our sensor for measuring distance has an accuracy of X mm, then this is included in the “tolerance” as a part of our TÜV certification).

Tolerances are not visible on e-Series Teach Pendant (TP) screen but are described in the user manual. CB3 displays tolerances on the CB3 TP and also describes them in the Polyscope manual.

Tolerances are internal and not changeable.

They are set for a given robot series. CB3 is different than e-Series. With the e-Series, there is much greater computational capabilities and therefore the ability to compute more precisely what will happen. So e-Series tolerances are tighter and internal “operational limits” are proportional to the safety limit setting.

The only change in tolerances has been from CB3 to the e-Series and not within these series. The warning that tolerances are specific to the software was not useful and has been removed. UR has not changed tolerances within the CB3 series or with the e-Series. Tolerances within a given series are not changed because any change would result in a change to the movement and behaviour of that series robot. But we could change tolerances in future robot series due to improvements in robot design, sensors and computational capabilities.

Since the safety sensors have some inaccuracy, if the sensor measures 250mm/s, then the actual speed may be 25mm/s above or below when measured with external high accuracy equipment. This is taken into account in the stated tolerances.

What does this mean for setup and configuration?

Description	CB3	e-Series
Safety functions...	The safety controller tells the standard controller what to do and if the limit is exceeded, then a stop is initiated. PLd, category 2, except Estop is PLd, category 3	Safety functions monitor (and constantly calculate based on the program and computed trajectories) to prevent exceeding the limit. A stop will be initiated to stop before exceeding a limit. PLd, category 3
Speed limit setting of 250 mm/s.	The operational limit is 100 mm/s, which is 250 mm/s safety function limit setting – 150 mm/s tolerance. The operational limit is also the tolerance.	The operational limit is internally set based on the speed. The operational limit is not related to the tolerance.
	The safety function will trigger a stop at ± 150 mm/s of the safety function speed limit setting. When the robot actual speed is between 100 and 400 mm/s, a stop is triggered.	The safety function speed limit can cause a stop ± 50 mm/s of the safety function speed limit setting. When the robot actual speed is between 200 and 300 mm/s, a stop is triggered.
What does this mean?	The actual speed could be 400mm/s before a stop is triggered (250+150). This is due to the tolerance of 150mm/s. However this is compensated by the robot because the operational limit will be 150mm/s lower than the safety function speed limit setting.	The actual speed could be 300mm/s when the monitoring function thinks it is at 250mm/s. This is due to the tolerance of 50mm/s. However this is compensated by the robot because the operational limit will be 50mm/s lower than the safety function speed limit setting. The e-Series safety controller monitors the safety function to prevent exceeding, so a stop will be triggered prior to exceeding the limit. As a result, it is highly unlikely that the worst case of 300mm/s ever happens because the safety function will initiate before this happens.
Stopping time and stopping distance safety functions	Not available	If a very small stopping distance (or stopping time) is set, the robot will hardly move. The safety controller tries to operate such that no safety function limit will be exceeded. Very low stopping settings will result in very slow operational speeds.
Force limit tolerance is the accuracy	Limit can be set from 100 to 250 N with a 25 N tolerance. A force limit setting of 250 N could have a worst case of a stop being triggered at 275 N, which is 250 N + 25 N. A stop could be triggered at 225 N.	