**09** – As said before the safety issues were taken into account since the design phase, and therefore are essential to our working cell. Safety considerations are necessary to ensure the physical integrity of the personnel, the integrity of the assets and are demanded by law in order to operate in the European Union. The two main standards concerned in our case are the Machinery Directive 2006/42/EC which stablishes general guidelines for safety procedures such as fences, signs and individual safety equipment, and the ISO 13849-1 which regulates **safety related parts of a control system**, such as interlock switches, sensors and Fanuc’s DCS.

**10** – In order to show how our solution complies with the ISO, I must first briefly explain what this standard requires. Firstly, one must identify the sources of risk associated with his work cell.

**11** – With each risk clearly identified, one must then evaluate the degree of the risk as it relates to severity of injuries, frequency of exposure to the risk and the possibility of avoiding it. The Combination of this information defines a required Performance Level (or for short, PLr) which describes the degree of the risk in 5 levels, from ‘a’, the safest, to ‘e’, the riskiest. On the other hand, every safety related part of a control system has an associated Performance Level (or for short, PL) that can be evaluated in term of its robustness and reliability.

**10reprise** – The ISO, then, requires that the reliability of a safety function be adequate to the risk it deals with, or in other words, that the PL of the safety function be greater or equal to the risks PLr.

**12** – There are three main risks identified in the work cell. First, the access to the pallets. The region between the two conveyors where the pallets must be fed is inside the work envelope of the robot. The feeding mechanism is dependent on the overall design of the plant, but in a worst-case scenario of an employee having to load the pallets this would raise concerns of contact between the robot and the employees.

**13** – Second: falling objects. The robot carries loaded boxes around, and a mishandle may end up in a box being thrown around the facility.

**14** – And Finally, third: Maintenance. For reasons of maintenance employees must need to get in direct contact with the robot, and this interaction must happen safely.

**15** – Following the ISO, the risks can be evaluated as shown in the table. With a required performance level of ‘d’ for the pallet access and ‘b’ for the maintenance.

**16** – Before getting into any control scheme, the problem of falling objects can be easily mitigated with a fence around the working cell, that limits the access to the robot to authorized personnel, protects people from eventual falling objects and as seen in the picture on the left it may protect the employees loading the pallets. The fence, not being a safety function of a control system, is only subject to the standards in the Machinery directive, such as the requirement of warning signs like the one shown in the right.

**17** – The problems with this simple approach are that it still leaves a relatively big zone unprotected, in the loaded pallet’s exit (as shown in the figure), and the area of the fence must be as big as the robot’s work envelope to avoid collisions, which would leave us with a too big of an area for the entire cell.

**18** – And here is the genius of Fanuc’s DCS. The **Cartesian Position Check** is a function that prevents the robot from exiting a given area determined by the programmer. With this function, we were are able to reduce the working area to the minimum necessary, and guarantee there will be no collision between the robot and the fence.

**19** – As for the ISO requirements, the risk associated with the Cartesian position check is a PL ‘d’, and according to Fanuc’s documentation, the function is a PL ‘d’, therefore the solution complies with the norm.

**20** – As for the maintenance safety, it suffices to use an interlock switch in the fence’s door, which turns off the robot as soon as someone opens the door of the cell, leaving no risk to the employee. But the evaluation of the PL for the interlock is a bit more complicated, as It’s evaluation depends not only on the interlock used but also on the whole system implementation. Nevertheless, common interlock systems can reach up to PLe, leaving a wide margin to its assessed risk.