

OPTIMIZATION OF DRIVE-IN RACKING STORAGE SOLUTION

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Abstract

Drive-in and/or drive-through racking systems with adequate principle of functioning, as the most common high density storage solution, usually find applications in pharmaceutical, chemistry and food industry. Since the goods are stored into the deep tunnels, traditional aisles are eliminated for manipulation purposes like in the adjustable pallet racking configurations. The main prerequisite for the usage of this type of storage is that the goods must be palletized on the standard and quality pallets. Materials used for the rack structures are light cold-formed profiles. In this paper solutions in terms of the application of different pallet dimensions and its weight were discussed. On the basis of techno-economical analysis of several options, the best solution in term of relation price for the total number of pallets or mass of stored goods will be suggested to the user.

Keywords: storage, drive-in racks, optimization.

1 INTRODUCTION

Drive-in and/or drive-through racking systems are represented as high-density storage solutions consisting of a system of rack tunnels connected in the block. This type of static accumulation system is recommended for large amounts of the same goods with primary usage in ambient warehouses or refrigeration chambers in the food, chemistry or pharmaceutical industry. The palletized goods, one after the other, are usually stored on rail beams, into deep tunnels accessible by forklift trucks for handling operations. This allows exploiting as much space as possible and eliminating the operating aisles traditionally required for service purposes in the adjustable pallet racking configurations. The adequate principle of functioning “First-In, Last-Out” - FILO or “First-In, First-Out” - FIFO must be chosen referring to the stored goods. Depending on the accepted principle, there are two types of

the rack configurations, as shown on the layout in Fig. 1, Drive-In Rack (DIR) and Drive-Through Rack (DTR) [1]. Within the DIR system which provides the FILO operating principle, the forklift truck drives into a lane and moves backwards, allows loading and unloading from the same side of the rack structure. This method for storage products does not require monitoring of deadlines and therefore the first pallet to be stored is not necessarily to be the first taken. The DTR system is very similar to the DIR, in fact identical in the structure, but in terms of operation, the forklift truck could drive through the lane if there were no pallets in the lane. The DTR configuration which follows FIFO storage method is mainly used in food and pharmaceuticals fields. This storage method allows pallets to be loaded from the front of the storage system and unloaded from the opposite side. For both types of racking configurations, the recommendation is to have four pallets in height, a minimum of two but usually three or more pallets in depth (recommended up to seven due to monitoring) and numerous bays in width. Taking this into account, some logistical issues must be considered because if the system is too deep or too high, it will increase operating costs due to the time required to take a load from the storage, or to put a load in the storage. This is simply because the operation of a forklift truck within a rack system must be done carefully and relatively slowly in comparison to the forklift truck’s normal operating speed. After the proper configuration is selected, unit load characteristics determine the required design of the racking components. The most common materials used in the rack structures are lightweight cold-formed profiles and rarely, for special heavy-duty applications hot-rolled steel in standard structural shapes. Primarily starting from the end user’s requirements and following current FEM regulations [2] and EN standards, the design of drive-in and drive-through racking systems is being assessed. The design process almost always involves finding the optimal solution when it comes to the relationship between price and customer requirements.

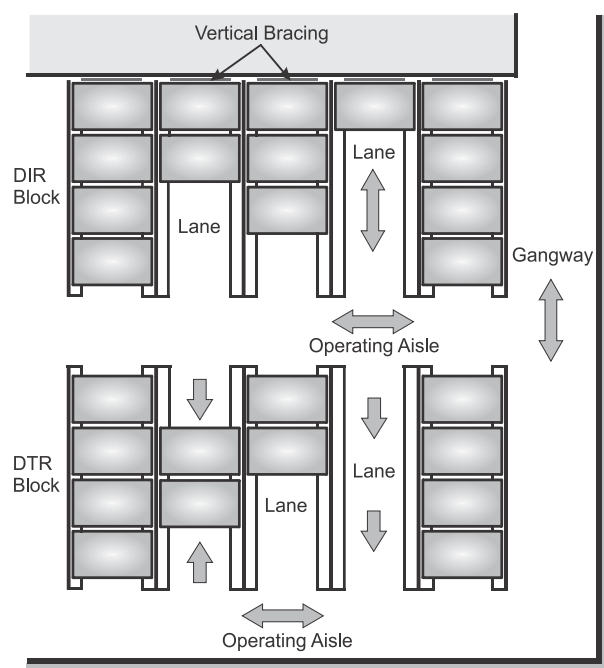


Fig. 1 Layout of a Drive-In / Drive-Through Rack

2 PROJECT TASK – CLIENT'S REQUEST

For the purposes of operating of the newly built facility, the client submitted a drawing with the layout of five cooling chambers shown in Fig. 2, numbered from 1 to 4 with two identical chambers with number 1, which should be equipped with appropriate racking systems.

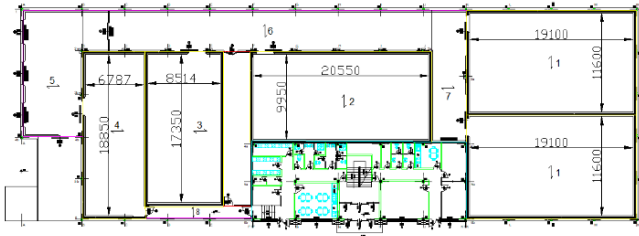


Fig. 2 Layout of the cooling chambers

The dimensions of the clear usable space in each cooling chamber are clearly defined on the technical drawings provided by the client. Each dimension given in Table 1 is defined by the position of the door and the movement of the goods within the chamber.

Table 1 Dimensions of cooling chambers

No. of cooling chamber	Width, mm	Depth, mm	Height, mm
1	11600	19100	8000
2	20550	9950	8000
3	8514	17350	8000
4	18850	6787	8000

Since the storage cooling chambers will primarily be intended for rental purposes to the third parties, i.e., different end users, client wanted to optimize racking solution in terms of:

- use of different type of pallets, standard euro pallets 800x1200 mm and/or so-called industrial pallets 1000x1200 mm, both with maximal height of 1700 mm;
- variable mass/weight of single stored unit – pallet with good; for both type of pallets, it takes into consideration masses of 1200 kg and 1500 kg and
- operation of chambers in plus and minus mode.

The first two requirements caused four options which need to be analysed both in term of technical and economical solution as shown in Table 2.

Table 2 Requested combinations for analysing

No. of solution	Dimensions of pallet unit, mm	Mass of the unit load, kg
1	800x1200	1200
2	800x1200	1500
3	1000x1200	1200
4	1000x1200	1500

Since the basic request was certainly the maximum possible number of pallets inside the chambers, this also resulted in a verification and discussion of a potential solution regarding the orientation of the rack blocks in the chambers.

3 DESCRIPTION OF THE SOLUTIONS

In order to achieve the last-mentioned request, i.e., the maximum possible number of storage units inside the chambers, the orientation of the racking lanes was defined according to the dimension of the chambers, the position of the doors and refrigeration evaporators which in this case are positioned on the shorter walls above the doors of each chamber. This results in the following technical solution shown in Fig. 3:

- DIR configuratons were chosen to be installed in each chamber;
- installation of longer lanes (tunnels) as much as possible;
- installation of DIR configuration without vertical and plan bracing where stability of the system is provided by the “blind lane” – configuration with bracing tunnel.

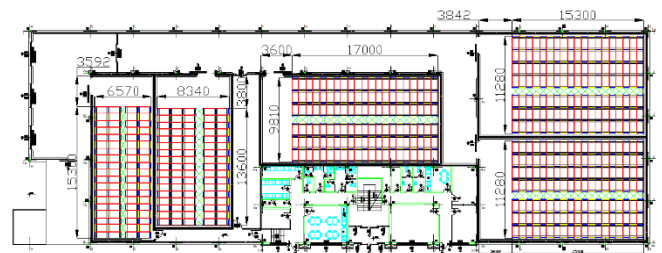


Fig. 3 Cooling chambers with DIR installations

Relying on the long-term experience of engineers, the available construction of the racking structure which belongs to the manufacturer and following all recommendations from [2, 3] for reliable design, all elements of the requested DIR system were defined as follows.

For the safe operation of the DIR system, the first and most important condition is high pallet quality when loaded with the specified goods to be stored.

The pallet dimension of 1200 mm, the spacing between the sides of the pallet (including the pallet load) and the uprights which should be at least 75 mm define tunnel width of 1350 mm, as shown in Fig. 4.

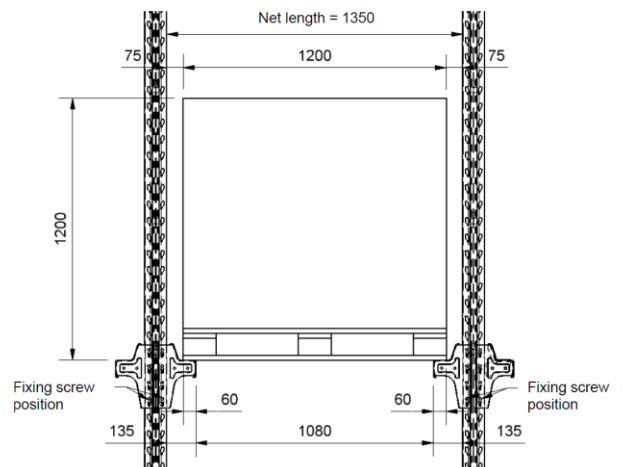


Fig. 4 DIR tunnel width [4]

This tunnel dimension determines the number of tunnels in each chamber according to the appropriate chamber dimensions as shown in Fig. 3.

Further, taking into account available space, the other pallet's dimension of 800 mm or 1000 mm and the minimum spacing of 50 mm between adjacent pallets in the row, maximum depth of the lane in one block was determined for each chamber as shown in Fig. 3 and Table 3.

Similarly, the total height of the system was defined when the total height of the storage unit is added to the minimum necessary distance of 100÷150 mm between the top of the pallet load and bottom surface of the rack cantilever bracket or beam rail when the pallet is seated on the horizontal support surface of the beam rail, as in Fig. 5.

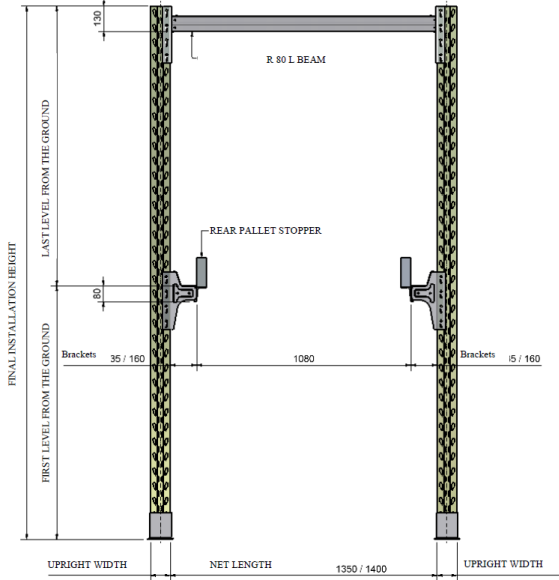


Fig. 5 DIR bay [4]

Table 3 Overall dimensions of DIR blocks

No. of cooling chamber s/DIR block	No. of lanes	No. of unit loads in lane, EUR / IND	No. of levels	Width, mm	Depth, mm	Height, mm
1	7	18/15	4	11280	15300	7725
2	6	20/16	4	9810	17000	7725
3	5	16/13	4	8340	13600	7725
4	4	18/15	4	6570	15300	7725

A typical braced DIR system in each cooling chamber consists of upright frames connected with top-tie beams as shown in Fig. 5 in cross-lane direction forming a basic spatial structure of the block of tunnels, i.e., a group of interconnected lanes. Adjacent upright frames in the down-lane direction are connected both with rails and spacers, shown in Fig. 6.

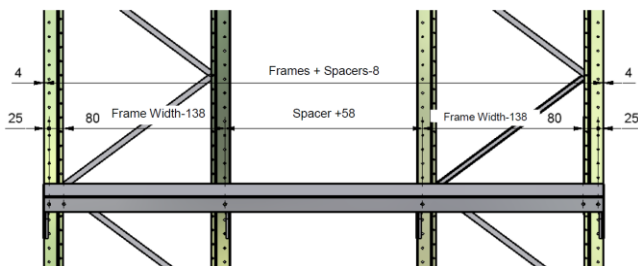


Fig. 6 Pallet support – rail and frame spacer [4]

Unit load, i.e., an individually loaded pallet, lies on the beam rails whose profile is shown in Fig. 7, positioned on the brackets on the uprights shown in Fig. 5.

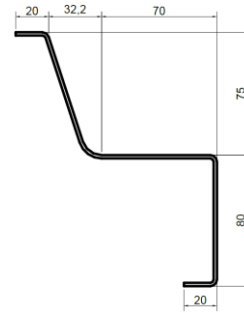


Fig. 7 Pallet support profile [4]

In the down-lane direction upright frame bracing primarily provides stability.

Ground rails are fixed to the uprights and provide visual and mechanical guidance to help the operator to center the forklift truck at the lane entry, as in Fig. 8.

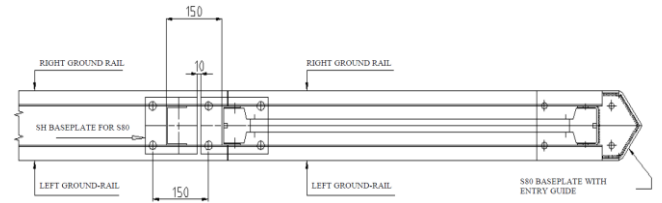


Fig. 8 DIR ground rails coupling with baseplates with entry guide [4]

Pallet entry guides shown in Fig. 9 are elements positioned in front of each beam rail to help the operator to center the unit load at the lane entry.

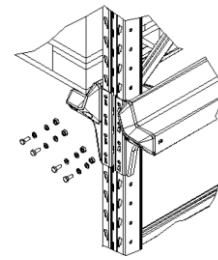


Fig. 9 Pallet entry guides [4]

The rear pallet stopper shown in Fig. 5 mechanically prevents the unit load from falling at the end of the line.

The upright protector is usually an integral part of the baseplate on the entry uprights, as shown in Fig. 10.

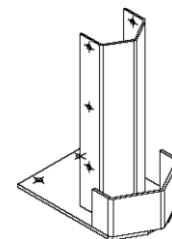


Fig. 10 Baseplate with entry guide and upright protection [4]

Analyzing the data from Table 4, for the same type of pallet, whether euro or industrial, but increasing the unit load from 1200 kg to 1500 kg, which is 25%, total mass (i.e. price) of the rack structure increased by approximately 14% and 10%, respectively.

Keeping the weight of the stored unit but changing the type (dimensions) of the pallet, the total number of stored units decreased by 388 pieces or app. 18%, and consequently, the total price by 7% for the unit mass of 1200 kg and 12% for the unit mass of 1500 kg.

Considering the aforementioned data, the client decided to install solution no. 1 in order to achieve the main goal, which is the maximum possible number of storage units for the minimum cost, sacrificing the scenario with extremely heavy stored units. However, the chosen solution still allows the client to use and industrial pallets even with a higher mass of the storage unit, but according to the recommendations of designer or producers of rack structures.

4 CONCLUSIONS

As has been said many times before, the significance of DIR systems lies primarily in their high-density storage capabilities, which is achieved by eliminating wide operating aisles found in traditional selective racking systems. This increase in storage density leads to significant saving in storage space and labor cost. Additionally, the DIR system with straight movement of forklifts within the aisle provides a stable and safe storage solution, since its operation reduces direct forklift access to each product. Basing their functioning on a FILO principle, their efficiency is reflected in storing non-perishable goods, with less concern for shelf life or products where strict stock rotation is not a critical factor. Designed to store products in deep lanes, making them highly effective for businesses that handle large quantities of a single product, such as food and beverage or pharmaceutical distributors, seasonal goods retailers or producers in the chemical industry. In addition to all previously mentioned, significant design experience and attention are required to properly design such a system. The requirements of clients who may or may not be the end users too are very different and it is necessary to consider all influential parameters in order to properly dimension the DIR structure.

REFERENCES

1. Vujanac, R., Miloradović, N., 2023, *Fundamentals of storage and material handling systems*, Faculty of Engineering Science University of Kragujevac, Kragujevac, 292 p.
2. FEM 10.2.07, 2012, *Drive-in and Drive-Through Racking Drive-in Design Code*, European Racking Federation, Hitchin, England.
3. Vujanac, R., Miloradović, N., Živković, P., Petrović, L., 2021, *Basis for the Design of Drive-In and Drive-Through Racking*, Proc. X Triennial International Conference Heavy Machinery HM 2021, Vrnjačka Banja, Serbia, A. 57-63
4. Dalmine Logistics Solutions, 2015, *Drive in*, Technical manual, Piacenza, Italy.

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