ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XIV [2016] – Fascicule 1 [February]
ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

1. Rodoljub VUJANAC, 2. Nenad MILORADOVIC, 3. Snezana VULOVIC

DYNAMIC STORAGE SYSTEMS

1-3. University of Kragujevac, Faculty of Engineering, Kragujevac, SERBIA

ABSTACT: High density storage solution such as dynamic flow pallet racks is accumulation racking system recommended for great amounts of good with only few different storage units. Palletized units are stored into deep tunnels not accessible by forklifts for handling operations. These systems have overall objective to increase the cube utilization and to reduce the handling costs. In this case selectivity is sacrificed but the storage density is outstanding. Forklift brings storage unit to and from the racking. Movement of the storage units within racking structure has been achieved through gravity or some other force. Warehouses in food and pharmaceutical industry are the ones who have benefit more from the installation of these solutions. This paper presents introduction of dynamic rack solution. Technical analyses and solution based on investor request to speed–up and reduce cost of handling process will be done.
Keywords: dynamic storage system, flow pallet racks, material handling

1. INTRODUCTION

When choosing storage equipment, an engineer is faced with a wide array of options from the conventional selective rack, push-back, drive-in/drive-through rack, to live pallet storage and mobile storage system [1], [2]. The selection of a rack configuration depends on three factors: unit load, handling equipment and space. The most appropriate way to assess pallet racking alternatives is consideration of selectivity and storage density or space utilization. Selectivity defines the percentage of unit loads directly accessible from a racking aisle. This generated the most common type of rack configuration so-called conventional selective or adjustable pallet racks. That is configuration where rack structure is separated by aisles and each pallet unit is accessible from an aisle. While the selective configuration is the most popular, other configurations provide higher storage density. High density storage solutions such as drive-in/drive-through, push-back, pallet-flow or various automated systems has overall objective to increase the cube utilization and to reduce the handling costs.The aim of this paper is to present a general analysis of dynamic storage system as well as alternative high density racking solutions.

2. HIGH DENSITY RACK CONFIGURATIONS

The efficient use of high-density storage systems has changed over the past years. “First-In, First-Out” (FIFO) method for storage is mainly used in food and pharmaceuticals industry. This method of storage shown left in Figure 1 allows loading of pallets from a front storage system and the discharge from the opposite side. “Last-In, First-Out” (LIFO) method for storage products that do not require monitoring of deadlines and therefore not necessarily the first pallet stored is the first taken, allows loading and unloading from the same face of the rack structure, right in Figure 1.
Drive-in/drive-through racks with loadable aisles are static accumulation racking recommended for great amounts of goods with few various units, as shown left in Figure 2, [2]. Racks store pallets on rail beams, one after the other. The forklift truck drives into the rack aisle to store the pallets. This rack configuration can be typically three or more pallets deep (up to seven) and can be numerous bays wide.

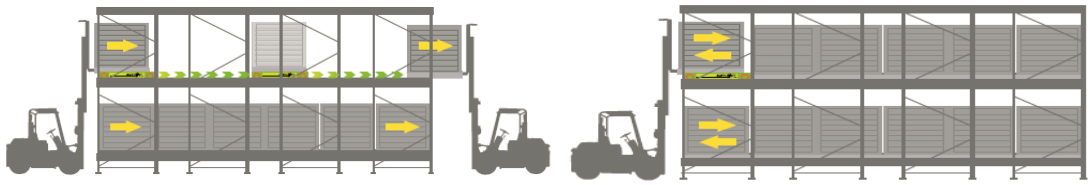


Figure 1. FIFO - "First In, First Out" & LIFO - "Last-In, First-Out" principle

Push-back racks are a special type of multi slides racks that allow the storage of typically two up to five pallet loads in a deep line. The systems work by placing pallet loads on a series of overlapping carts fed forward by gravity on inclined steel rails, which are then pushed back into the rack with subsequent loads, as shown right in Figure 2. As a pallet is loaded from the front, it pushes the pallet behind it back one position. When unloading, the front pallet is removed and the rear pallets automatically come forward to the front picking position. Because the loads are free to flow toward the front line of the rack, the forklift truck driver must control the removal speed to keep subsequent loads from free-flowing to the front of the system. Push-back offers more versatile storage than drive-in/drive-through rack because each lane flows independently and vertical storage operates separately from lanes below.

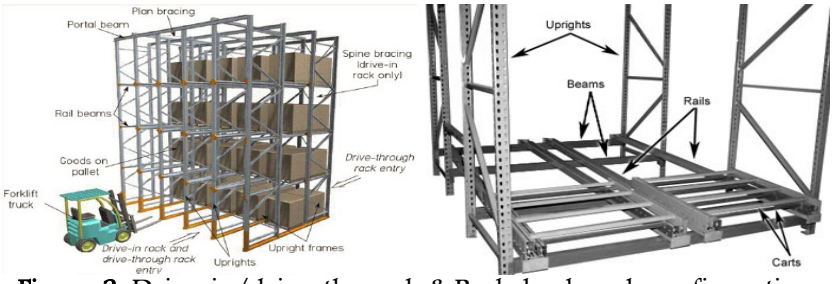


Figure 2. Drive-in/drive-through & Push-back rack configuration

Gravity flow rack or live pallet storage is very similar to push-back in its selectivity and allowable storage density. Each racking line has inclined rails with wheels or rollers, as shown in Figure 3. This allows pallet loads to be inserted into one end and retrieved from the other. Unlike push-back, it is a FIFO system, more suited for temporary storage of perishable items such as food. Because the forklift truck operator is not responsible for controlling flow speed, this system is more circulating and safer than push-back or drive-in/drive-through system. Flow speed is controlled by speed regulators along the slope. Average live pallet storage systems are six or more pallet positions deep and require high reliability as a result. It requires very good quality of pallet.

Figure 3. Gravity-flow rack configuration

3. DYNAMIC FLOW RACK TYPES

The dynamic storages are systems in which the unit loads (pallets, boxes) move, i.e. flow along the rack tunnel. Motion of the unit loads can be achieved in two basic ways:

- **By gravity force** - storage units move due to the gravitational force when the slope of the rack tunnel is big enough; The angle can be from 2,5 % to 5%. It depends on the weight of the load, quality of the pallet, distance between rollers, diameter of the roller and the accuracy of the manufacturing of the construction.
- **By special force** - when the tunnel is not sloping, it is necessary to use a certain force for moving; pneumatic, hydraulic, electromotor roller drive, or forklift trucks force.

Because of the price and lack of energy, gravity flow racks or live storages with the use of the gravitational force are used more.

Considering the track on which the storage unit moves, there are two basic systems:

- **Moving of storage unit on a rolling line**, i.e. wheel or roller tracks, which is common in practice;
- **Moving of storage units by special trolley** with four plastic wheels, sometimes in usage because of the quality of manufacturing, loss of the storage space and a big initial investment.

4. GRAVITY FLOW RACKS WITH ROLLER TRACKS

The construction of these racks is very expensive, requires a great manufacturing precision and is depended on the quality of the pallets, so the investors rarely decide for these storages even where they are the only reasonable solution. This system has its advantages and disadvantages, Table 1.

Table 1. Advantages and disadvantages of gravity flow racks

No.	Advantages	Disadvantages
1	Huge space utilization	Dependence on the quality of the pallets
2	Simple manipulation	Great dexterity in construction
3	The control of the goods movement FIFO principle	Great design engineering and construction experience
4	Simple integration in the management system	High initial investment

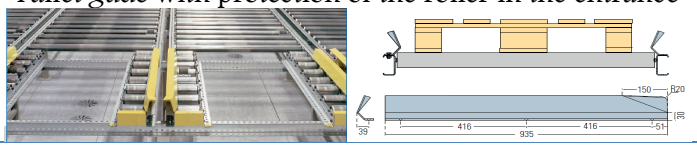
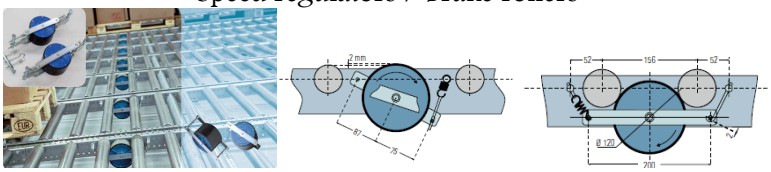
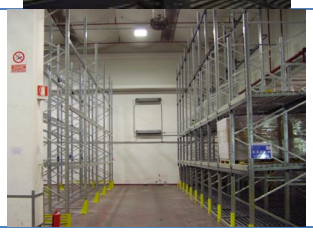
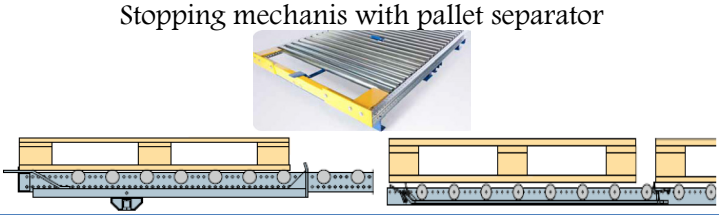
The construction of gravity flow racks with roller lanes can be classified into two basic parts:

» Static part

» Dynamic part

Static part of the rack construction usualy consists of standard racking elements which provide stability in each direction as well as support for dynamic elements, Table 2. Dynamic elements provide safety movement of unit load within rack tunnels.

Table 2. Construction of gravity flow racks

No.	Static elements	Dynamic elements
1	Uprights with protection 	Wheel or roller track 
2	Transversal beams 	Pallet gude with protection of the roller in the entrance 
3	Bracing system 	Speed regulators / brake rollers 
4		Stopping mechanis with pallet separator 

5. COMPARISON OF HIGH DENSITY STORAGE SYSTEMS

Some high density storage system layouts are shown in Figure 4, [3]. Racking systems with 8 deep drive-in, 5/6 deep push-back, and 25 deep gravity flows were applied and compared in storage using 2600 pallet positions.

High density racking solutions such as drive-in-/drive-through, push-back, gravity flow or various automated systems sometimes were extremely expensive, had questionable paybacks and provided different benefit for FIFO/LIFO principle. After the process of reviewing the pros and cons of all these racking types, charts shown in Figures 5 and 6 clearly describe their flexibility and utilization desired in the facility, [4], [5].

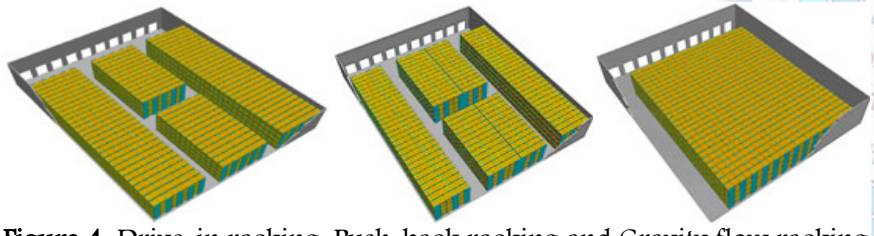


Figure 4. Drive-in racking, Push-back racking and Gravity flow racking

Rack aisles with rolling tracks are manufactured up to 50 m in length (usually 20 m long) and the height is unlimited, i.e. limited by capabilities of the device for material handling and by the possibility of rack installation and maintenance. High density storage system improve utilization, safety, forklift truck productivity and reduce at the same time product or racking structure damage and outside storage requirements. This system has simply ability to completely integrate into the warehouse management system and allow for improved tracking and safety for both the employee

and product. The cost of this system is more than drive-in or push-back rack as shown in the figures bellow.

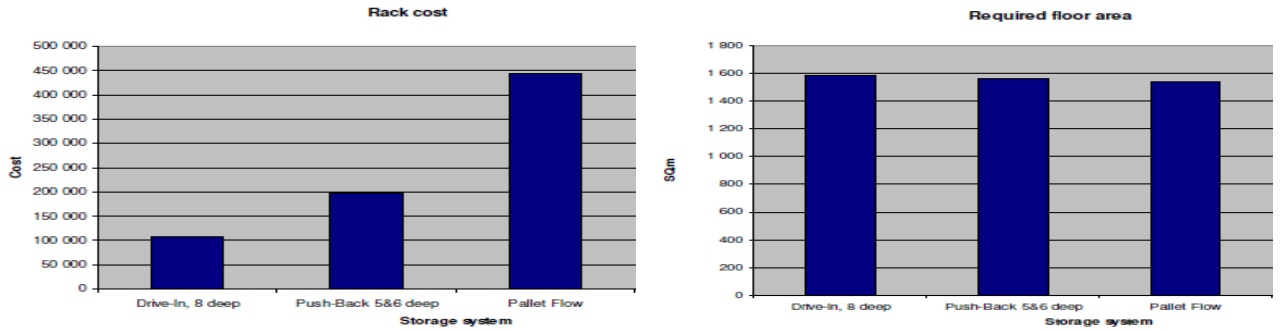


Figure 5. Rack cost and requered floor area

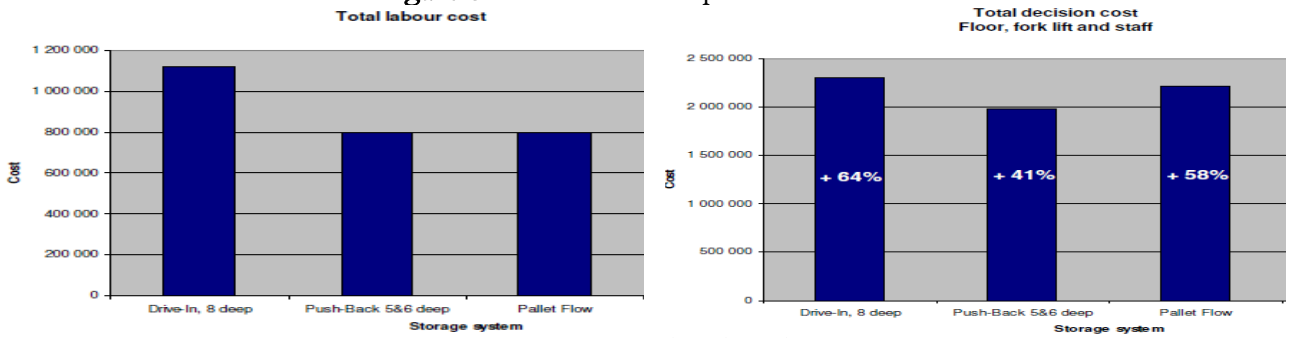


Figure 6. Personnel and total cost

6. CONCLUSION

Dynamic gravity flow racking system is strongly represented as high density storage solution especially in refrigerated chambers, food warehouses, pharmaceutical, water and drink manufacturers. As its name implies, racking doesn't require a forklift truck within rack structure. Primarly usage of gravity roller conveyors brings speed–up of handling process within racking tunnel with easy loading and unloading of unit load by conventional forklifts outside racking system. Forklift operators are free to focus on bringing product to and from the system, without the need to drive into the rack, as the unit load moves within the racking system. This system that had been already successfully installed in the practice, allowes further increases in productivity, reduced damages, improved safety and ergonomics.

Note: This paper is based on the paper presented at The 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology – DEMI 2015, organized by the University of Banja Luka, Faculty of Mechanical Engineering and Faculty of Electrical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA (29th – 30th of May, 2015), referred here as[7].

References

[1] Vujanac R., Miloradovic N., Slavkovic R. (2013). Automatization of Mult-Depth High-Density Storage System. Metalurgia Inetrnational, vol. XVIII, no. 8, p. 49-55.
[2] Vujanac, R.V. (2007). Development of Methodology for Design and Calculation of Carrying Elements of Storage Systems. Master Thesis, Faculty of Mechanical Engineering University of Kragujevac, Serbia.
[3] Vujanac R., Miloradovic N., Slavkovic R. (2006). Criteria of efficient planning of pallet racks, Proceedings of the conference IRMES '06, p. 65-70.
[4] Vujanac R., Miloradovic N., Slavkovic R. (2011): Radio Shuttle Racking – New Generation of High Density Storage System, Proceedings of 7th International Scientific Conference IRMES '11, p. 205-208.
[5] Vujanac R., Slavkovic R., Blagojevic. M., Miloradovic N., (2011). Autosatmover – New Solution for automatic multi-depth pallet storage system. Proceedings of The Seventh International Symposium about machine and industrial design in mechanical engineering, KOD 2012, p. 139-142.
[6] Dugomrulli I, from http://www.dugomrulli.it, accessed on 2015-05-05.
[7] Rodoljub Vujanac, Nenad Miloradovic, Snezana Vulovic, Dynamic storage systems, Proceedings of the 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology – DEMI 2015, Banja Luka, BOSNIA & HERZEGOVINA, 521-524