SOME SAFETY ASPECTS OF PALLET RACKS

Dragan Đurđević*
University of Belgrade, Faculty of Transport and Traffic Engineering, d.djurdjevic@sf.bg.ac.rs
Momčilo Miljuš
University of Belgrade, Faculty of Transport and Traffic Engineering, mmiljus@sf.bg.ac.rs

Abstract: *Warehousing as logistics function generates different specific activities. Related to this, some of these activities can be possible sources of different kinds of danger, depending on the type and quantity of inventories (goods), technologies, applied equipment, environment, human factors etc. In the palletized goods warehousing domain, selective pallet racks represent typical technology, which has been multiple confirmed and is widely spread. However, the racks themselves (although they are typically statically elements) might be the source of possible danger. Their cause might occur in the phases of their design, construction, exploitation and control. This set of influences and dangers has resulted with introduction of new specific regulations in some of these areas. Having that in mind, the aim of this paper is to point out to some analysis directions and preventive activities related to the safety of pallet racks.*

Keywords: *warehousing, pallet racks, safety, prevention.*

* Corresponding author

1. INTRODUCTION

Warehouse as a system is usually an essential part of any supply chain (SC). Warehousing activities generate a set of tasks, whose realization quality and performances directly or indirectly affect the efficiency of logistics processes in SC. Spectrum of warehouse's types, having in mind the role of warehouse, types of stored goods, size, throughput etc. is very wide. Within this spectrum, warehouses for palletized goods represent a significant group. Within warehouses for palletized goods, technologies based on selective pallet racks are „The oldest and still most popular type, selective pallet rack system utilizes horizontal beams connected to prefabricated upright frames to provide independent, multiple-level storage..." [2]. The most common rack type [01] is adjustable pallet racking-type (APR)", accounting for approx. 80 % of the racking market [4].

Technological solution of APR warehouses is not one-dimensional problem – it depends on three basic subsystems [6]:

- stored goods
- equipment/elements used for warehouse processes and materials handling (MH) (dynamic, statically, personnel etc.)
- facility (building object) where warehouse processes are realized.

Each of those subsystems is described with set of relevant characteristics and they are essential for selection and implementation of some warehouse solution. During warehouse design, first of all, designer has to respect those subsystems and their relevant characteristics. For stored goods, the first is ***unit load*** (dimensions, shape, weight, …), stored, received, processed and shipped quantities, as well as some present specific demands (sensitivity, combustibility and so on).

Equipment/elements used for warehouse processes and materials handling (MH) in APR, respecting different tasks, could be used in wide variety of technical-technological solutions, based on viable combinations of dynamic MH equipment and pallet racks. In this paper set of feasible technological combinations include counterbalanced and reach trucks forklifts and APR. It is obvious that during warehouse design techno-exploitation characteristics (for example, capacity, lifting height, turning radius, aisle width etc.) have to be respected.

Facility (building object) with their characteristics has a great influence on technological solution of warehouse, at the first by setting criteria that limit the use of some types of equipment (statically or dynamically). Here, special treatment has to deal between clear height, (eventually) arrangement of construction elements (walls, columns, etc.), their quality (floor especially) and so on.

Each of mentioned subsystems itself, as well as their combinations, have influence on quality of

warehouse solution and quality of processes functioning. When the main objective of warehouse function is realized (based on productivity and efficiency), very important aspect is the safety of processes realization in the warehouse (WH) system. WH is the place where high quantities of goods are concentrated, typically with high frequently moving of dynamic MH equipment (with and without good) and personnel. Assuming that, there are potential hazards for humans, also for material recourses and the wider environment present. Those facts initiated the need that the area of racks and their use in the WH, with the technical and scientific aspect, have to be the point of interest of potential hazards. Sources of potential hazards may arise in the early stages of rack „life" – during design of APR structure, then during structure elements manufacturing, installation, operation and control. Each of potential hazards (or their combinations) is important for APR safety aspect [4].

Having mentioned in mind, this paper consists of several parts: after introduction (this chapter), second chapter presents briefly presentation of APR components, construction, installation and overview of present regulations and recommendations. Third chapter discusses area of design and implementation of WH design solution. Special attention is given to prevention, use of regulation and/or god practice and manufacturer's recommendations, concerning on safety aspects. The fourth chapter is focused on aspects of safety in APR exploitation, which has set of components – from the proper pallet unit (PU) forming / control to the working conditions in the warehouse. The fifth chapter includes concluding remarks in these issues and potential direction for further activities and researches.

2. SELECTIVE PALLET RACKS - APR

APR is 3D steel/metal structure designed for PU storing. It consists of the basic components shown in Figure 1.

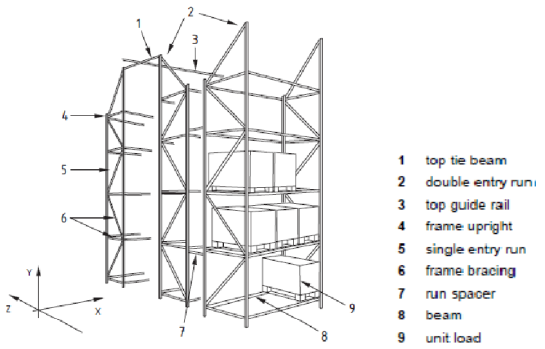


Figure 1. APR components (EN 15620)

APR is the system of upright frames connected by horizontal beams to provide pallet storage levels, which can be adjusted vertically. Each pallet storage position can be accessed individually. [7]

In the area of rack structure as well of its basic elements in practice there are a number of versions that differ in a number of characteristics – capacity, dimensions, type of metal profile etc. Rack elements have been and are now topic of wide researches – from profile manufacturers, equipment manufacturers, specialized institutions for quality control and so on. In mentioned scope few of associations are established and are present: in the USA – RMI (Rack Manufacturers Institute, established 1958); in Europe - FEM (European Federation of Materials Handling) Product Group "Racking & Shelving" was established in 1970 as Section X of FEM and today operates as the European Racking Federation (ERF). Their topics are structural design, layout and configuration design, project specification and safe use and recommendation and standards implementation (Table 1 and Table 2) [4].

Table 1. Review of standards in EN series "steel static storage systems"

First draft*'	EN standard	Published
FEM 10. 2. 02	EN 15512: Adjustable pallet racking systems - Principles for structural design	March 2009
FEM 10. 3. 01	EN 15620: Adjustable pallet racking - Tolerances, deformations and clearances	October 2008
FEM 10. 2. 03	EN 15629: Specification of storage equipment	November 2008
FEM 10. 2. 04	EN 15635: Application and maintenance of storage equipment	November 2008
-	EN 15878: Terms and definitions	July 2010

* The FEM codes with their commentaries are still available.

It could be concluded that in this field process of harmonization of regulations is present, aiming easier manufacturer's market share. In Serbia this field is "covered" with standards (SRPS EN 15635), which are compliant with relevant EN standards.

3. DESIGN AND DEVELOPMENT OF TECHNOLOGICAL WH SOLUTION BASED ON APR IMPLEMENTATION

In forming WH technological solutions as a primary emphasis on the following factors [13]:

a) goods with their characteristics,
b) technology of MH (Materials Handling)
c) facility (building object)

Each of them during design process is present as request generator and/or limiting factor(s). Respecting purpose of this paper, below their briefly

presentation is made, according primarily on safety aspect.

Table 2. Review of FEM codes of practice published, ongoing or planned

FEM code	Title	Published**)
FEM 10.2.05 draft/ not published	Guidelines for working safely with lift trucks in pallet racking installations	October 1999 (final: ???)
FEM 10.2.06 provisional	The design of hand-loaded static steel shelving systems	April 2001
FEM 10.2.07	The design of drive-in and drive-through racking	September 2012
FEM 10.2.08	Recommendations for the design of static steel pallet racks under seismic conditions	May. 2011
FEM 10.2.09	The design of cantilever racking	(mid-2013)
FEM 10.2.10 (FEM 9.841*)}	Storage systems with rail-dependent storage and retrieval equipment - Interfaces	February 2012
FEM 10.2.11 (FEM 9.842*))	Rail-dependent storage and retrieval systems - Consideration of kinetic energy action due to a faulty operation in cross-aisle direction, in compliance with EN 528 - Part 1: Pallet racking	(mid-2013)
FEM 10.3.01-1 (FEM 9.831-1*))	Basis of calculations for storage and retrieval machines - Tolerances, deformations and clearances in the storage system Part 1: General, single-deep and double-deep beam pallet racking	October 2012

* Drafted in liaison with the FEM Product Group "Intralogistic Systems"; their document numbering starts with "9".
** Dates in brackets are target dates.

3.1 Goods

In this paper is assumed that good is presented as palletized unit (PU) - EURO pallet. Designer first of all has to have information about PU number, dimensions and weight. Having those information, he could closer define requests that are concerned on WH technological solution.

Also, the base assumption is that the goods on pallets is stacked in the manner that enables safe handling and that dimensions do not exceed the prescribed tolerances. Figure 2 presents few typical examples of PU dimensions larger than the pallet area and inappropriate goods secured on the pallet – when that PU can affect their placing.

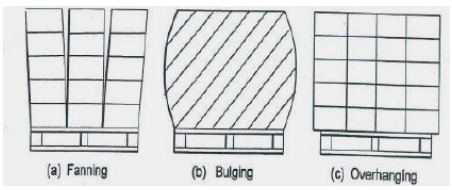


Figure 2. PU that are not acceptable to APR [1]

If such cases are present during WH design, it is necessary to involve appropriate interventions on PU and to respect obtained tolerances. This is very important to APR design, especially beam elements. For APR design also important could be probability distribution of PU height (aiming to define determinative beam height) and weight (to define determinative capacity of vertical frames and the load carrying component) [8].

During design, in this domain could be present problem connected with non-uniformity of load stocking on the pallet (Figure 3). Then, this fact has to be respected during rack elements design. Non-uniform loads result in unequally loaded beams and uprights. A maximum of 10 % for both non-uniformity of load and asymmetrical placement is acceptable (06).

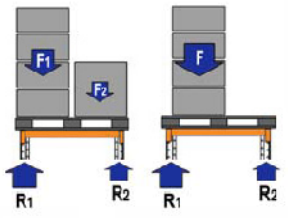


Figure 3. Some examples of non-uniformity of load stocking on the pallet [9].

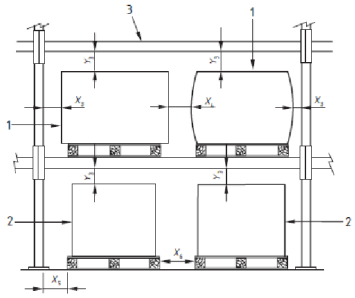
3.2 MH Technologies

In a scope of technological solution of MH in WH, design includes two basic subsystems – pallet racks and forklifts. During design process designer has to define combinations of forklifts according their operating characteristics simultaneously with appropriate pallet rack structure (at first respecting forklift's capacity and max. lifting height). Forklift (according type, construction, dimensions and pallet position on the forks) has direct influence on aisle width, which could differ on data presented in manufacturer's technical documentation. Also, on growing aisle width can influence a intensity of material flow in WH: „In determining reasonable operating clearances, the density and speed of traffic in the warehouse must be considered. In a high throughput operation (a grocery or soft drinks distribution centre being typical), the operating clearances should be increased substantially" [10].

ERF / FEM recommendations in this domain are presented in [03] (pages 35, 38 and 56). Also. during rack elements design it is necessary to respect adequate clearances between PU and APR structure elements, as a function of PU beam height in APR (Figure 4).

Operating conditions in an WH, especially for forklifts in aisles, generate potential hazards of forklift's impact on APR. In order to eliminate impact effects or to reduce them to an acceptable level, different approaches and solutions could be implemented. They could be be related to forklifts and elements of APR structure. On the *forklifts*, aiming to avoid impacts, some of precise guidance system in rack aisle could be implemented; as well

as an equipment for precise PU storage/retrieving. On *pallet racks*, different approaches of upright frame element protection are present (but also with influence on aisle width and obviously on technological WH solution). Some of those protecting elements are shown on Figure 5 [9].



Beam height Y_n from ground up to beam level mm	X_3 X_4 X_5 X_6 mm	Y_3 mm
3000	75	75
6000	75	100
9000	75	125
13000	100	150

Figure 4. Horizontal and vertical clearances in a bay for trucks (EN 15620)

Figure 5. Some protection elements of upright frames.

One of the manners of upright frames protection from the forklift contact impact is construction change. It is done by construction change of lower section of upright frame (Figure 6), which decreases the endanger zone during the maneuver of the forklift. On the other hand, this change significantly influences additional requirements of rack construction, and therefore on the price itself.

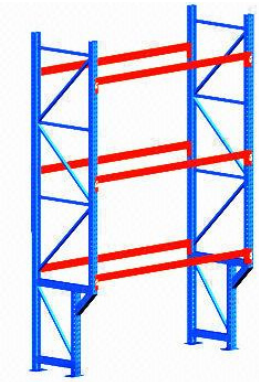


Figure 6. Look of rack construction with changed lower section of frame
[http://firebirds.manufacturer.globalsources.com/si/6008802175854/pdtl/Warehouse-shelving/1028890308/Storage-Rack.htm]

Implementation of the rack construction solutions consists of several aspects. The rack element supplier has to fulfill requirements of technological project of WH construction, as well as the requirements related to the material quality and manufacturing process, which is verified by appropriate standards and attests (i.e. ISO 9001). After the element delivery, adequate implementation is necessary, which requires appropriate supplierćs experience, respecting project solution and conduction appropriate controls of construction tolerance (EN 15620, pages 19 and 20). Special attention is given to construction stability checks, rack anchoring (by quality, position and anchor number) etc.

3.3 Facility

Within technological solution design, the WH project overall (as well as its' elements apiece) has to be primary in accordance with APR solution project and applied forklifts. By doing so: „Clearance to building parts For mobile storage equipment the distance to the walls parallel to the driving direction shall either be between 0,05 and 0,18 m over a height of minimum 2 m or at least 0,5 m. The clearance of 0,5 m shall be measured from the most protruding part of the wall. Near to the ground rails or parallel to the ground rails no slab settlement joints are allowed." [9].

The facility floor requires precise design [5], which has to consider the floor loading, rack type and flatness. From the tolerance aspect, the facilities need to fulfill the requirements from EN 15620, (point 5: Floor Tolerances).

The facility with its' own solution may influence racks and forklifts performance. In this domain, the facility should fulfill the environmental requirements (temperature, humidity, atmosphere aggression, earthquake etc.) [9]. Besides mentioned, other factors as well may influence warehouse process: lightening level of certain area, number of exchange rate related to air ventilation, etc. which can have impact on construction solution.

4. APR EXPLOITATION

In APR exploitation, safety analyzes should include, besides already described factors for the WH design, some other factors as well. As important factor of overall safety, the man himself is included in WH process realization in the rack area, as well as additional safety accessories on the internal transportation paths. In this chapter, each of them will be a subject of short review.

When the ***goods*** are analyzed from the safety aspect, for the WH process it is necessary to provide that PU fulfill requirements of safe workflow. This is primary related to the pallet correctness, pallet load stability, PU dimensions and mode of stacking goods units (especially with PU with mixed goods types). If some of requirements in this domain isn't fulfilled, these PU should be treated with special treatment (requirement for repair, processing, special WH area, etc.).

During the exploitation, the ***facility***, WH and its' elements (floor, lightening, ventilation system, safety equipment, signalization, etc.) have to meet limits defined by the project. This is acquired by appropriate goods housekeeping and maintenance. *The facility floor* must be properly maintained, for the reasons of safe movements and flow of RM equipments. This consists of the floor flatness checks, removal of any damages (cracks, deflections, etc.), hygiene maintenance, etc. *Lightening* must meet appropriate requirements during the exploitations (change, cleaning of light sources). The facility itself and its' elements through the *air conditionig system* must provide predicted working conditions (temperature, humidity, protection of atmospheric precipitation, sealing, and other).

The important safety aspect is also appliance of *signalization* – horizontal, vertical, and light signaling. Besides signalization, appropriate appliance of *additional safety equipment* is also significant, such as mirrors in the spots of decreased visibility, flow crosses related to movement of RM equipment and employees, etc.

4.1 RM equipment

For the WH working process, ***racks*** are subject to different influences which might exceed tolerances determined by project solution. This concerns, above all, following:

- overload of construction elements (which is unacceptable from the safety aspect),
- incorrect load distribution in the rack (for example, deviation from the recommendation for the easier PU are stored on upper levels, and vice versa), and
- beam height modification (mandatory consultation with manufacturer and/or supplier from the capacity aspect and appropriate tolerances respect).

If it comes to construction racks element damages, it is necessary to evaluate level of damages by the authorized person (inspector or competent persons for the WH equipment safety). Deformation level classification is done in accordance with EN 15635 (Figure 7a, 7b).

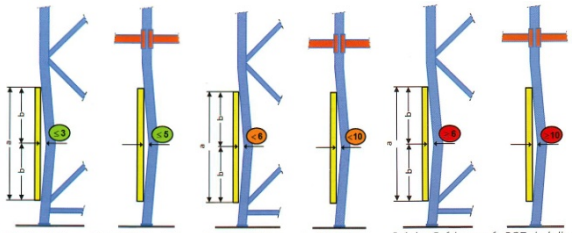


Figure 7a. Upright frame deformation level classification

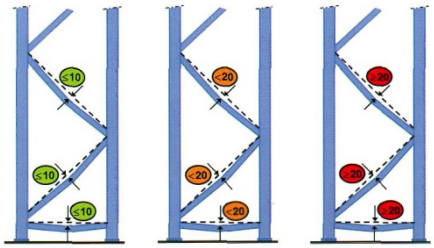


Figure 7b. Frame bracing deformation level classification [3]

Certified person (company) evaluates damage level and classifies it accordingly to CEN code in three damage levels (color highlighted): red, yellow and green risk level – Figure 7a and 7b [3].

For *red risk* instantaneous offloading of PU from the racks is required and adequate repair (commonly change) of damaged rack, before further use;

For *yellow risk,* adequate repair or change of damaged part within the shortest time period is required, where use of rack is possible until the repair is done; and

For the *green risk,* neither load decrease of the rack nor element repair is required (damage is being recorded), whilst during the following control, the check of damage level change is being done.

For beam overloading, no deformation classification is considered (Figure 8) [3]. Allowed deformation is (according to EN 15635) given by the calculation $d \leq L/200$, where L is span of the beam (load carrying component); d mid span deflection.

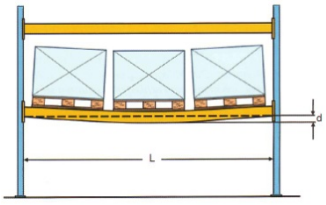


Figure 8. Inspection for overload damage to beams [3]

Rack construction check should be subject of continuous control, and for the purpose of working safety increase. In the literature, it is recommended

that this check is done at least once a year by certified person/company, and visual check to be done once weekly [3]. Also, in case of intervention on rack construction elements, it is necessary to provide proper repairs; in opposite case, this might be one of causes of unwanted event (fall, rack collapse).

For the *forklifts,* during the exploitation:

- the maintenance which provides their prescribed techno-exploitation parameters is necessary;
- eventual safety level increase by additional equipment (respecting solution in this area), such as: elements for drivers' protection (safety belts, cabin improvements, ergonomic control commands, etc.); for more precise driving and more precise handling of WH storage operations (i.e. cameras; forced guidance, etc.).

Due to complexity of determined tasks and great influence on WH process safety, the drivers of the forklifts must be specially instructed to:

- be informed about the significance of dangerous situations which might occur as a result of improper forklift use;
- act in accordance with regulations with eventual damages of object elements, racks or goods;
- visually check the load on the pallet and whether the pallets are proper;
- properly PU handling (during driving, lifting/lowering) aiming of forklift stability;
- properly dispose the pallets in the cell (which provides regular position of PU related to the beam - laterally and by depth);
- respect required lateral tolerances while positioning the PU in rack cell.

If the warehouse processes are not included in WMS, responsibilities and tasks of forklift-drivers are being extended on the assignment plan as well (storage and retrivial) with respecting of rack load limits at the same time. Due to all mentioned, the choice of fork-lift drivers (respecting all necessary psycho-physical characteristics), permanent renewal and improvement of their knowledge and skills must be adequately conducted. Therefore, these aspects must be the subject of continuous and appropriate checks.

5. CONCLUSION

Safety of warehousing processes is becoming more and more complex and important and has to be treated from different aspects. In this paper, the safety is analyzed with the focus of APR appliance, as the most common technology for PU. Also, in this paper, for APR, factors of safety in design, implementation and exploitation, as well as actual regulations, standards and recommendations are included. They provide improvements of project solutions and daily work processes, according to higher safety level with the appliance of APR. Clearly, questions in the domain of safety require further analyzes and improvements, as well as accidents analyzes (causes and consequences) in all WH segments. This is continuous process which has a special significance for logistics. It could be concluded that logistics experts have specific and important role in this field.

ACKNOWLEDGMENT

This work was supported by the Ministry of Education, Science and Technical development of the Government of the Republic of Serbia through the project TR36006, for the period 2011-2014.

REFERENCES

[1] EN 15635: Application and maintenance of storage equipment
[2] Kulwiec, R.A., 1985. Ed., Materials Handling Handbook, 2nd Ed., New York: Wiley.
[3] Oehmann, M., , 2013. Regalprüfung nach DIN 15635, Marius Oehmann, Wilhelmsfeld.
[4] Tilburg, K., 2013. Those peculiar structures in cold-formed steel: "racking & shelving", Steel Construction 6 No. 2, pp 95-106.
[5] Tiburgs, K, 2007. Pallet racking design aspects & safety in use", Logistic Seminar 22/11/2007 ; Bucharest.
[6] Vukićević, S., 1995. Skladišta, Preving, Beograd.
[7] http://books.hse.gov.uk/hse/public/saleproduct.jsf?catalogueCode=9780717662258
[8] http://www.helmsman.co.uk/Portals/0/NewPDFs/pallet-racking.pdf
[9] http://www.loc8uae.com/download/STOW%20Racking%20Design%20Guide.pdf
[10] http://www.werc.org/assets/1/workflow_staging/Publications/414.PDF