Application of Automation within a Public Refrigerated Warehouse

White Paper

GLOBAL COLD CHAIN ALLIANCE®

By the CEBA-GCCA Automation Subcommittee

For the Controlled Environment Building Association and the Global Cold Chain Alliance Warehouses

CEBA
Controlled Environment Building Association

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Members of the CEBA-GCCA Construction/Codes Committee's Automation Subcommittee developed this white paper to assess the application of automated storage and retrieval systems within public refrigerated warehouses.

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This white paper went through an extensive peer review process to ensure accuracy and quality, but it is not intended to be the "final word" on this subject. As processes and technologies change, CEBA and GCCA intend to revise this white paper. Members are encouraged to submit comments for consideration on the white paper at any point. Comments may be sent email@CEBA.org.

Sections of this white paper are also included in the CEBA-GCCA Guide to Effective Warehouse Design, Maintenance, and Modernization (2012 Edition). Both the guide and this white paper are available electronically, free of charge to members of CEBA or GCCA.

About the Construction/Codes Committee

The CEBA-GCCA Construction/Codes Committee, a joint committee of GCCA and CEBA, is the principal resource in drafting and reviewing technical publications and addressing technical questions submitted by members. The committee covers all aspects of temperature-controlled facility construction, including design, cost, materials, and codes. The committee frequently forms smaller subcommittees, such as the Automation Subcommittee, made up of committee members to further explore construction and codes issues.

Any member of CEBA or GCCA is invited to volunteer to serve on the committee. To learn more, please contact email@CEBA.org or +1 703 373 4300.

Introduction

Refrigerated warehouse facilities operate in different fashions, depending upon whether they offer public or dedicated (i.e. private) refrigerated space. Public refrigerated warehouses (PRWs), store a multitude of food products, at a stated rate, for the storage and handling of a customer's product. In addition, PRWs may provide other value added activities, such as case picking, blast freezing and re-packing, for additional stated rates. Dedicated refrigerated space also exists to facilitate a refrigerated warehousing role, but unlike a PRW, it is often specific to a single manufacturer of refrigerated and/or frozen products and dedicated to a single production plant.

Reasons for Considering Automation

Generally speaking, Automated Storage and Retrieval Systems (ASRS) may be considered for the following reasons:

Landlocked

A major reason to consider ASRS when looking to expand an existing warehouse facility is the simple fact that there is limited land available for a conventional warehouse. Indeed, many of the early suppliers and advocates of "high-rise" ASRS construction were from Europe where there are limited opportunities for a sprawling 500,000 sq. ft. facility (think the Netherlands where they are still even "making land").

To highlight the area-conserving nature of an ASRS, consider the following, real- life examples:

- A multiple-deep freezer ASRS with 14 levels rising about 125'-0" above grade. This example contains 20,932 pallet positions and covers 34,695 sq ft, yielding a very low area utilization ratio of 1.66 sq. ft./pallet position.
- A similar sized conventional freezer using double-deep rack (or push- back) with a clear storage height of 40'-0" that holds 23,041 pallet positions in a freezer area of 135,250 sq ft for an area utilization ratio of 5.87 sq ft/pallet position.

Clearly, at over 3.5 times the density of even a typical high-density/high-lift conventional facility the ASRS can, in certain situations, be the only answer.

High Land Cost

Although not technically landlocked it may be necessary to acquire an adjacent parcel of land in order to expand. Depending on the location, the cost/square foot of the land may be a prohibiting factor. Imagine the impact on the decision to go ASRS versus Conventional when, instead of $20,000/acre for adjoining land (about $0.50/sf), it becomes $125/sf (think Sand Island, Honolulu or some metropolitan areas stateside). In the previous, real-life example the land might have been available to support a conventional facility but its total project cost would have been penalized with over $10 million in additional land cost.

Constant 24/7 Operation

The first facilities to embrace the ASRS technology were typically manufacturers operating on a 24/7 basis, as many food plants do, especially in their peak season. Staffing a conventional warehouse for a 24/7 operation can require more than three times the personnel needed for a single shift. The initial fixed cost of the ASRS starts to compare favorably with a conventional since its staffing is always lower and that effect is multiplied.

High Labor Costs

The staffing differential becomes even more pronounced when the facility is located in a high cost labor market.

To highlight this, consider an ASRS with a nominal throughput of 200 pallets per hour, in and out. At an average forklift truck (FLT) rate of 24 pallets per hour one could budget for around eight employees for the inbound and outbound (to deliver pallets to the truck loaders). Assuming the ASRS was fed from production by conveyor and the dock loaders fed also by conveyor spurs, the ASRS could have 18 fewer employees per shift. Allowing only a 3X multiplier the conventional would require an additional 54 employees. At perhaps a fully burdened labor rate of $50,000 per year per employee (wages, fringes, OT) the ASRS could avoid up to $2.7 million in labor cost annually.

Low Labor Availability

Closely related to the issue of high labor cost is that of its basic availability. In some areas the shift in demographics is resulting in a smaller pool of labor to draw from. Some companies fear that with the aging population and declining birth rate, there may be a decrease in the size of the labor pool, which may result in higher labor rates needed to attract employees in the not too distant future. In addition, the inherent cold environment of a PRW provides additional challenges when hiring and retaining employees.

High Full Pallet Activity

Stacker Cranes, or SRMs, like fork trucks, only handle pallet loads and are ideally suited for operations with low case pick requirements. However, the typical speeds and accelerations of SRMs (up to 600 ft/min down aisle and 200 ft/min lifting) greatly exceed those of fork trucks and can result in excess of 30 dual cycles per hour. A dual cycle is one in which the SRM picks up a pallet at the input station, goes into the rack aisle and deposits it and then retrieves another pallet from somewhere else in the aisle and brings it out to the deposit station. In such instances the SRM can handle up to 60 pallets per hour.

Harsh Working Environment

It is well known that productivity is lower in freezer environments as compared to ambient conditions. SRMs, on the other hand, are obviously indifferent to the conditions and in fact operate quite well in freezer environments since the moisture present is virtually nil and corrosion and degradation of electrical connections is minimal.

Tax Implications

Although expensive when compared to conventional facilities, if an ASRS warehouse is constructed using the rack-supported method, much of it can be classified as “building” and thus depreciated typically over 39 years versus equipment depreciation of 15 years. In a detailed return-on-investment (ROI) analysis, this has an impact on the ultimate ROI in favor of the ASRS.

High Value Product

The classic examples of high value product are ethical drugs in the pharmaceutical industry or storage of printed money by the Federal Reserve Bank. In either case, it’s easy to see why keeping people out of such a storage area would be a good idea. This usually isn’t too much of an issue for the public cold storage warehouse.

Needed to Support a “Monument” or Allow for its Expansion

With storage facilities located adjacent to a well-established production operation, any excess land may more often be reserved for the expansion of the production operations rather than warehousing due to the profit generating capability of production. Somewhat similar is the fact that for well-established operations, the cost of relocating the entire production operation to support continued growth is financially impractical. The production operation has become a “monument” and can’t be moved.

Off-Site Storage with Shuttle vs. ASRS

An alternative that is often considered is to build an off-site warehouse nearby on cheap, available land and employ dedicated shuttle trucks to move raw materials to the production facility and finished goods to the warehouse. This shuttle approach can become a very large operation with a 24/7 production plant with continuing, annual cost. In some operations the number of shuttle operations has exceeded 14,000 annually and actually forced a re-examination of ASRS, which was ultimately built to avoid the annual cost.

Energy Cost

On a square foot basis a refrigerated ASRS system will consume less energy than a conventional warehouse since:

- It will have a very low lighting load. They are typically operated in a “lights-out” fashion.
- Reduced people due to automation, therefore is reduction in internal heat loan from people, material handling equipment, and batteries
- Reduced infiltration load since conveyor openings for pallet passage are smaller than conventional FLT doors and usually have vestibules
- Smaller roof area results in lower transmission losses.

Owner Pride

Although relatively rare, there are a few instances of the ASRS being the preferred type of warehouse simply because the Owner wanted to have one for reasons of corporate pride, marketing image or highlighting their “green” environmental image. It’s happened.

Challenges Facing PRW’s When Considering Automation

However, there are challenges a PRW faces when considering the utilization of ASRS technology. Unless governed under a multi-year storage contract, many pubic refrigerated warehouses operate month-to-month, using a 30 day Warehouse Receipt with its customers. In other words, a customer pays for the storage and handling of its product 30 days in advance. That same customer is free to leave and relocate its product at the end of this 30 day billing cycle if it chooses to do so. On average, less than 40% of business is done through contracts. Many dedicated facilities have 5-10 year contract terms, however, typical contract terms are three years and less.[1]

Storage and handling revenue accounts for approximately 80% of the revenue received with the balance received through other value added activities. The two largest expenses, typically incurred by a PRW are labor related expenses and power. Labor related expenses can account for upwards of 50% of expenses while power typically accounts for 15 to 20 percent.

Whether retrofitting an existing warehouse or building a new warehouse, automation should improve upon these two fundamental criteria in order to be considered a viable alternative to conventional warehouse design and operation:

- Improve the storage density of a warehouse thus reducing building footprint and energy consumption;
- Improve the handling efficiency of a warehouse thus reducing labor and material handling requirements

Warehouse automation can clearly improve storage density and handling efficiency. Through the design of a taller structure and very narrow aisle ASRS technology, storage density (i.e. pallets per cubic foot) can typically be increased by 10% to 15% as compared to a structural framed warehouse using two-deep select rack with 40’-0” of clear storage height. Pallet density is further increased when deep lane storage is utilized over select pallet rack configuration. In addition, due to the handling speeds and efficiencies of ASRS technology the need for warehouse operators, operating in these cold storage areas, is eliminated. This elimination of labor also reduces the number of forklifts, batteries, and chargers required to support a fleet of forklifts.

[1] “PRW North American Automation Readiness Study”, GCCA and HK Systems, April 2010

When evaluating the feasibility of integrating warehouse automation into an existing or new operation, certain challenges need to be considered:

- The justification for the incremental capital investment in automation without multi-year storage contracts from its customers;
- Understanding the inherent costs and expenses (both capital and operating) when comparing automated alternatives with conventional warehouse options;
- Maintaining system flexibility in the storage, handling and case pick ensuring that the automated system can adapt to changes in customers and their storage and handling requirements.

The incremental cost to implement warehouse automation can range from $5 million to $15 million depending on the size and complexity of a project. It is a challenge to justify the incremental cost associated with warehouse automation when customers utilize a 30-day billing cycle. It becomes less of a challenge if your customer base has multi-year storage contracts.

Secondly, it is important that a public refrigerated warehouse understands both the capital costs associated with building an automated warehouse, understanding the improvement in labor efficiencies as they pertain to headcount and throughput, and understand the changes in operating expenses such as power, and maintenance. For a company that does not have experience operating an ASRS facility, the development of these costs and expenses can be an uncertainty. Involvement from the design/build contractor and automation integrator becomes very important.

Lastly, warehouse automation is not perceived to be flexible. When designing a system and selecting equipment, the customer order and SKU data tends be based on recent and/or historical profiles. With this information the automation integrator designs a system capable of handling the peak throughput of the current customer requirements. What happens in 3, 5, or 10 ten years from now when the warehouse may have different customers with different storage and handling requirements? What if the case pick percentages go from 15% to 60% in five years because the warehouse landed a large retail distribution account? These concerns are real and shared among many public refrigerated warehouses. Whichever automated system that is selected, the operational parameters and confines need to be carefully identified and evaluated.

Rack Supported vs. Non-Rack Supported Structures

The traditional method of constructing a refrigerated warehouse uses a standard structural or pre-engineered steel frame to form the building, onto which are attached the insulated wall panels, roof deck and roof insulation & membrane to form the building's thermal envelope. Inside, standard pallet rack is erected on an independent floor slab and does not interface with the building steel (at least it shouldn't). An alternate method of constructing a refrigerated warehouse is to use the rack itself as the structural building frame and add the necessary steel features to the rack (wall girts, roof purlins) to carry the insulated wall panels and roof.

Although rack-supported structures are more commonly used in high-rise ASRS structures, they have also been employed in typical low bay warehouses of more standard heights like bottom-of-deck heights of up to 48'-0". Both types will be discussed in this section.

Conventional Warehouse Rack–Supported Structures

To highlight the differences between standard framing vs. rack-supported in a conventional freezer, a hypothetical warehouse of the following dimensions will be considered:

- 250’-0” long x 200’-0” wide x 45’-0” BOD (Bottom Of Deck)
- 50,000 sq ft gross area
- Single-deep rack, 6-levels high

The conventional freezer will feature the following design/construction characteristics:

- Spread footings
- Continuous perimeter foundation wall except at the freezer/dock interface
- A nominal 8” thick floor slab

The rack-supported freezer will feature the following design/construction characteristics:

- A mat slab foundation
- A haunched perimeter portion of the slab except at the freezer/dock interface
- A nominal 10” thick floor slab due to having to absorb the additional wind and roof dead and live loads.

A construction cost analysis of these identical yet differently built facilities using basic unit costs indicates that the rack-supported building will cost between 10 and 13% more due to the additional concrete required in the mat slab foundation and the differential in the rack cost. The rack in the rack-supported building will cost more in order to provide the necessary wind and seismic bracing in addition to the added girts and purlins.

However, as the height of the building increases above 48’-0” BOD, the cost of the free-standing structural steel frame does not increase linearly (quite the opposite; it increases faster due to buckling, bracing and wind moment factors) and the free- standing rack cost also increases due to the additional dead load compounding its own seismic requirements. At some point, determined by market conditions, geographic location (is it in a high wind area? a high seismic area?) and sometimes by the steel, concrete and rack subcontractor’s particular preferences, the free-standing rack system crosses the cost inflection point and costs more than the rack-supported system. Depending on these factors, this will generally occur between the 55’ and 65’ range of BOD heights.

High-Rise ASRS Rack-Supported Structures

Based on the above cursory analysis it’s easy to understand why most ASRS refrigerated facilities are rack-supported; in general, they are usually above 65’ high. At that height, the following factors favor the rack-supported approach:

- As the wind loads increase due to the height, the over-turning and uplift forces are easier to dissipate into a rack structure. These forces are usually distributed into the first set of rack frames along the perimeter walls.

- Similarly, the seismic forces, which are present in the rack structure regardless of the framing system, cease to cause any increase in the rack structure system just because the relatively lightweight walls and roof are now part of it. In all but the most extreme seismic areas, wind loads will generally govern the design.
- Taller rack structures are more easily and economically erected without the hindrance of an enclosing roof structure. Most low-rise, non-building supporting rack is erected in either individual frames or only small sections using boom lifts. ASRS high-rise rack is usually erected in larger, ground-built sections utilizing large cranes and spreader beam assemblies requiring crane heights greater than the building.
- For high buildings, the frame requires a much more complete erection in order to attain the bracing and rigidity necessary to allow wall panel installation to begin. With a rack-supported structure, it is inherently more stable after only a short time and panel erection can commence earlier, thus saving schedule time.
- In high seismic areas, having two different framing/structural systems close together can cause issues. Extra care must be taken to ensure that the rack system and the building framing systems, which have vastly different natural frequencies and response periods, don’t conflict with one another. Additional rigidity might need to be added for independent structures.

Concrete Slab Considerations

Rack-supported buildings obviously require that the supporting mat slab foundation be installed first. Consequently, this must be done out in the open and is therefore subject to the vagaries of weather, which, when pouring a large slab, can present problems. Most ASRS mat slabs are poured in long, narrow, continuous strips from front-to-back using traveling screeds not unlike those found in road construction. The construction joints are then aligned so that they fall in a rack flue. This method typically does not produce an extremely level, smooth-troweled finish since for an ASRS, which has SRMs (Storage/Retrieval Machines, or stacker cranes) running on rails, it is not necessary. Typical acceptable slab flatness tolerances are +/- 1/2 “. The rack frames are shimmed to a level plane using metal “shim packs”.

For a conventional warehouse to use the rack-supported approach pouring the much larger slab out in the open can present more problems. Most large warehouse slabs are poured not in long strips but in a checkerboard fashion and, unlike an ASRS, they do require a much smoother finish and flatness tolerance due to the requirements of the fork trucks running on it. Pouring and finishing such large slabs in the open is difficult due to high summertime temperatures and precipitation.

Fire Protection Considerations

Currently there are no known alternatives to installing fire sprinklers at the roof and within the racks, which is not different than an ambient temperature warehouse. The location and water application requirements of the sprinklers are dependent on the specific product (commodity classifications) planned to be stored and the methodology of storage, typically racks, and the specific configuration of the racks.

In general, for a cold storage environment the sprinkler system type would be a pre- action double interlocked system with piping and detection wire throughout the roof and within the racks. Precautions include:

- Careful placement is necessary to prevent water/ice and/or physical damage.
- Careful fire system commissioning that runs concurrent with the automation equipment commissioning to insure against conflicts with sprinklers and heat detection.

Inflexibility

It is extremely difficult, if not impossible in some cases, to re-rack a rack-supported structure to change the rack openings or the style of rack (single-deep to double- or multiple-deep). The load beams serve as longitudinal, down-aisle bracing and the rack uprights attain some of their resistance to buckling from their location. Altering their elevations should only be done after a thorough structural engineering analysis. Changing the style of rack would be an even greater challenge; so whatever the rack configuration is when it's built, is what it will remain -- regardless of the changes in the business.

Damage Susceptibility

Except in the most catastrophic of cases, an SRM will never run off the floor rail or otherwise hit the rack supporting the building. Clearly this is not the case in a rack- supported conventional warehouse. Rack damage by forklifts is all too common, but now it must be dealt with immediately and probably under the direction of a structural engineer. Further compounding such possible damage is that of refrigeration air units that would also be supported by the rack-supported building. Forktruck impact could now induce damage to an evaporator and cause an ammonia leak.

Conclusion

Rack-supported buildings are generally found in ASRS applications when the building/system height is over some height (60' +/-) as determined by a cost analysis. Due to cost and other problems previously discussed, rack-supported conventional warehouse operations are very rare.

ASRS Building Consideration Items

Construction Considerations

- ☐ Rack erection should be closely controlled to ensure that not too many bays are erected without proper tightening up.
- ☐ Consider using a strongback/spreader beam to erect larger rack sections with the sprinkler pipe already installed.
- ☐ Instead of pouring the slab in "checkerboard" fashion, pour it in long strips from end-to-end using a traveling screed.
- ☐ The AHUs need to be set in place during rack erection.
- ☐ Possible long lead times with many materials coming from overseas.
- ☐ Possible issues with customs for materials coming from out of the country.
- ☐ Crane rails should be thermite welded and continuously supported on a neoprene pad.

Design Considerations

- ☐ Slab flatness and finish are usually not major factors, however the flatness tolerance for the concrete subcontractor should be tighter than the tolerance given to the rack supplier.
- ☐ Check the proximity to airports as an FAA permit may be required or even restrict the height of the building.
- ☐ Although a mat slab foundation is typically used, in poor soil conditions where piles might be needed, one should investigate if alternating methods of soil improvement could be used to avoid piles/caissons.
- ☐ If the rack is to be anchored using drilled expansion anchors, the slab should be designed to be clear of rebar for the top 5 inches or use fiber-reinforced concrete.
- ☐ The vertical joints should be face caulked at the panel seams to help prevent leakage at the panel splice joint.
- ☐ Girt spacing on the corners will need to be closer than in the main wall sections.
- ☐ Roof corners will probably need paver blocks for wind uplift resistance.
- ☐ If roof access is provided, safety tie-off points will need to be provided.
- ☐ Lighting should only be low-level "theater" type lighting in the aisles with wall packs at the run out ends for crane maintenance only.
- ☐ To prevent excessive leakage through access doors for conveyors, provide vestibule-type airlocks.
- ☐ Crane power buss should be mounted low for ease of maintenance. Continuous conductors should be used.
- ☐ Crane aisles need to be fenced-off at the front and rear with interlocked access gates. European crane manufacturers usually require this as part of their own insurance policies and FEM standards.
- ☐ IMP splice details need to be well thought out and defined.

- ☐ Higher wind pressures and potential movement for the IMP panels and the connection to the rack structure need to be considered.
- ☐ High density under floor insulation in lieu of the typical 25 psi.
- ☐ Snow drift load at the adjacent lower buildings, especially on existing buildings, need to be addressed.
- ☐ Building code height limitations.

Scope Considerations

- ☐ Instead of a penthouse on an already tall structure, use centrifugal-type AHUs mounted on a mezzanine in either the front or rear crane run out areas.
- ☐ Consider a reduced oxygen system instead of sprinklers.
- ☐ Lightning protection is very important.
- ☐ Consider the use of architectural graphics or other such features to break up the mass of the building if near residential or architecturally sensitive areas.
- ☐ Roof access is much more difficult – crane platform, ship's ladder, ladder w/ cage
- ☐ Sprinklers – commodity classification; importance during commissioning
- ☐ Lighting – some or none

Conclusion

Refrigerated warehouse facilities operating in different fashions, depending upon whether they offer public or dedicated refrigerated space. Automated storage and retrieval systems (ASRS) should be considered where land availability is limited; land and/or labor costs are high; limited labor is available; or there is high full pallet movement. However, certain operational, financial, and design challenges need to be considered and evaluated.