Taller Tales (all grown up?)

HPA looks at 42' clear

We have moved into one of those periods that are invoked in the curse: *May you live in interesting times*. The interesting issues we will look at in this paper have to do with the new ESFR configurations allowing increased clear height in buildings serviced by ESFR systems. They require some interested analysis **between the technology of ESFR and material handling forklift equipment**.

To set the stage:

For a period, ESFR systems have been limited to ceiling heights (effectively roof deck heights) of 45' with a maximum storage height of 40'. That arrangement has led to today's standard 36' clear, (and 40' clear with special roof designs), for buildings with 56' column spacing. There is a special UL approved system for a 48' deck height and 43' top of storage, however, it came with a restriction of 8' minimum aisle width. Now there are at least 3 others specially listed ESFR sprinklers for 48' ceilings, all of which accommodate less than 8' aisles (6', 5' and even 4' aisles).

Recently a new set of tests resulted in FM approved arrangements for both a 50' and 55' maximum deck height. These arrangements come with 6' and 8' minimum aisle restrictions. An important distinction with all of these 48' and higher protection schemes is that they are only good for cartooned unexpanded group A plastics. Commodities worst than this will require some other sort of fire protection system (drop ceiling or in rack sprinklers).

A Quick rule of thumb based on subjective viewpoint

Before we delve into the detail of the issues and surface a few considerations, here are a few **gross generalizations** you can grab ahold of if you are in a hurry, or head to the last page.

If you bought the largest SUV they make and live in the biggest house on the highest hill in your neighborhood, then check out the new 55' deck height arrangements and consider a column grid spacing of 56' to 58'. Extra in-rack sprinklers can be implemented if needed to get you around most of the complications for users with VNA material handling equipment.

If you keep to an expense budget, drive a car that gets great gas mileage, and are attracted to value then check out the 48' deck height UL approved Tyco K25 system and a 56' column grid.

If those two descriptions don't fit well, or you are the curious type who wants to understand the specifics driving the rules of thumb, the rest of this paper will discuss ESFR, clear heights, racking systems, material handling fork lift equipment and how higher buildings will affect structural designs. It turns out that the restrictions on aisle width have large ramifications. Going higher than 36' to 40' clear moves into a realm of giants where different material handling systems may begin to affect decisions.

If you are a user and your company has committed to a specific material handling configuration and you are trying to understand what clear height and column spacing can optimize your operations; give us a call, we need to talk.

ESFR Configurations

There are a range of different ESFR configurations approved by several different codes and testing bodies available for building design today. From a practical point of view the specific approval body may be a moot distinction when the fire suppression contractor applies for permitting. **Local jurisdictions will typically approve configurations formally approved by UL or FM** even if they haven't been adopted into the NFPA yet.

This table shows the current range of system configurations likely to be approvable by the local jurisdiction. We can now build ESFR serviced buildings with deck heights up to 55' to store up to 50' high.

ESFR Design Configurations HPA, Inc.

Max Deck Ht	Max Storage Ht	Typ. Clear Ht	Approved by	Aisle restrictions
35'	30'	30'	NFPA, FM	NA
40'	35'	32'-36'	NFPA, FM	NA
45'	40'	36'-40'	NFPA, FM	NA
48'	43'	42'	NFPA, UL	8'
48'	43'	42'	UL (Tyco)	5'
48'	43'	42'	FM (Viking)	6'
50'	45'	44'	FM (Viking)	6'
55'	50'	49'	FM (Viking)	8'

These are current as of 2/16/20
Each approval is for specific head designs, pressure ratings and number of heads
Commodities allowed are consistent across these approved configurations
Types of racking allowed are consistent across these approved configurations

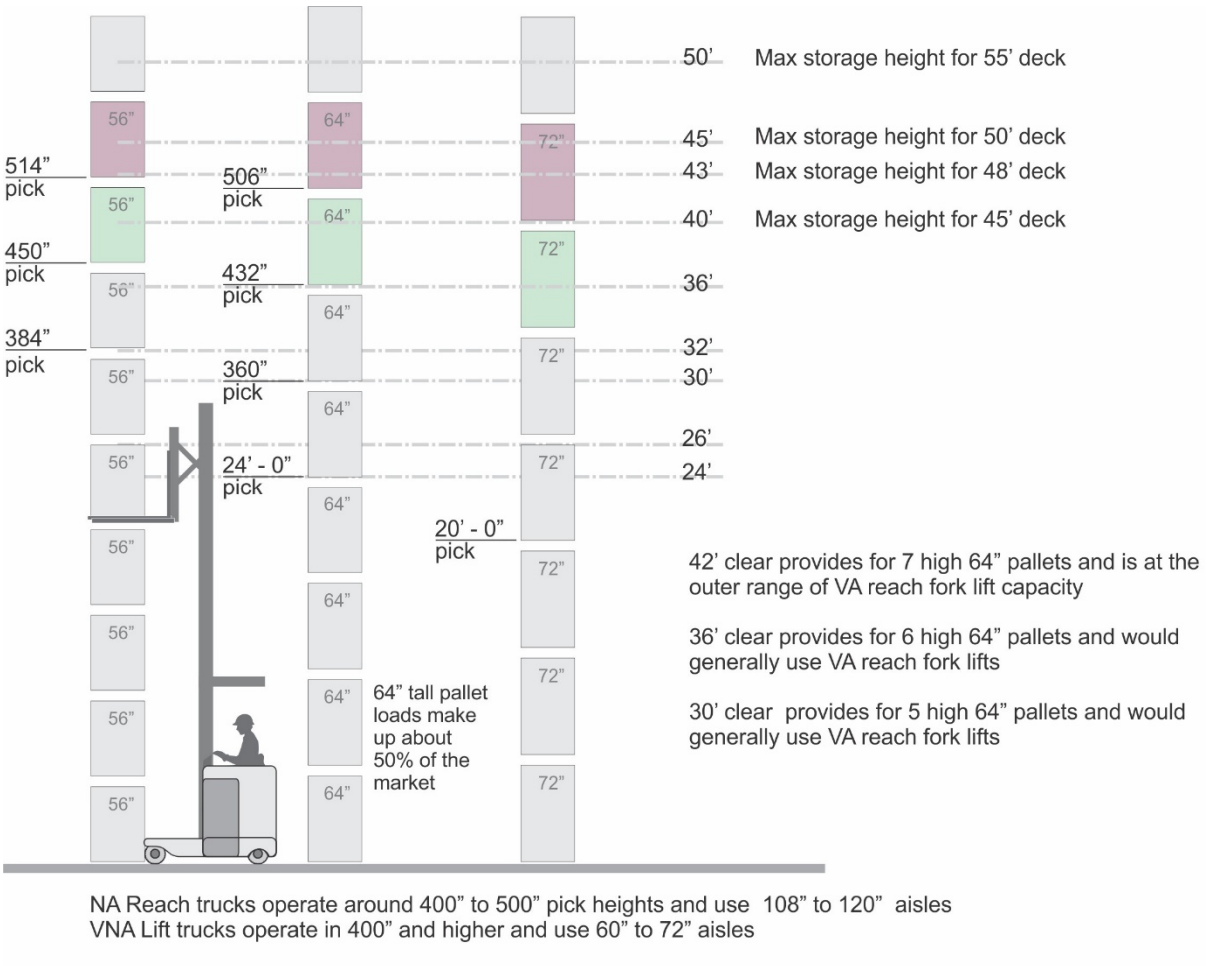
So, we *can* go taller and store higher while keeping ESFR sprinklers the primary suppression system.

Let's look at ***why*** we would want to go taller, the ***compromises*** that may be involved, and the ***ultimate value*** proposition.

First, we will look at rack storage systems and the associated material handling equipment to point out an ironic problem with the taller building ESFR configurations. We will also surface a few structural issues that mean more than incremental cost increases. The HPA bottom line recommendations are on the last page if you just want to skip ahead.

This diagram illustrates the usual rack storage arrangements in relation to the ESFR requirements and clear height. In earlier white papers on 36’ clear and 40’ clear buildings we showed that going from 32’ clear to 36’ clear had significant advantages for increasing storage capacity for most rack configurations. We also discussed why going from 36’ to 40’ clear had a less compelling set of advantages but would still make sense for some users.

This iteration of our diagram goes higher to show the ESFR configurations up to the current maximum storage height of 50’.



The advantages of going from 36’ clear and jumping to 42’ clear can be seen in the green shaded pallet layers. Going from 36’ to 40’ gets one extra pallet layer for the 72” pallet arrangement. Going to 42’ clear also adds an extra layer for the 64” and 56” pallet arrangements. There are also many users today that can configure pallet or case racking flexibly to take advantage of any incremental increase in clear height. There appears to be little advantage to a pure pallet rack operation to go to a 45’ clear condition. The next level that provides a significant advantage would be the 50’ clear condition.

While this diagram establishes the general capacity advantages of jumping to 42’ clear, there are a number of correlated issues regarding material handling equipment that must be looked at.

Forklift Equipment and Aisle Widths

Most rack storage today in large distribution centers is serviced by reach fork trucks. These typically fall under the designation of narrow aisle forklifts (NA). They can work effectively in five to six level rack arrangements but up at that sixth level and higher they are maxing out their capabilities. In a 36' to 40' clear building they are usually configured with a few extra battery and mast options to pick the top rack level. The associated aisle width with this augmented equipment grows from around 8'-6" in a 32' clear building to about 10' as you get to 40' clear buildings. Lift manufacturers will tell you these fork trucks can make picks at higher levels, but understand their utility is limited on high picks by weight and speed.

Some 36' to 40' buildings are housing racking systems that use a different kind of material handling equipment. Sometimes called swing reach trucks, transtackers, or order pickers, these fork trucks don't turn in an aisle to make a pick. They have forks that extend perpendicular to the line of travel or that rotate. Generally, the driver moves up with the forks to the level of the pick. These are generally classified as very narrow aisle equipment (VNA). They operate in a range of aisle widths from 4'-8" to just over 6'.

This equipment is designed for picking higher than the reach forklifts. They can be productive over the 5 levels a reach fork truck excels in. The downside is that VNA equipment is much more expensive than NA equipment. Today, most distribution centers are using NA equipment with single selective rack. That has worked out since the ESFR maximum heights were within the capability of NA equipment. Well, until now that is…

The Problem

Now buildings designed to the new ESFR approvals facilitating clear heights of 42', 44', and 49' will be moving outside the effective height range of the NA equipment. **Today, VNA equipment is the natural approach to fully utilizing a building that is over 40' clear** and this is the fulcrum of the issue. The higher buildings are most effectively serviced by VNA equipment but the ESFR approvals restrict the smaller aisle widths associated with the VNA equipment. **There are available protection schemes for less than 8' aisles, especially under max. 48' ceilings. 50' and 55' ceilings can accommodate 6' aisles.**

There are now two exceptions. **UL has approved a Tyco manufactured K-25 head configuration for a deck height of 48', storage height of 43', and minimum aisles of 60". FM Global has approved a Viking K28.0 head for a deck height of 50', storage height of 45' and minimum aisles of 72".**

Up front we indicated that if you are into bigger is better that you can build your 55' tall building and lease it too. It does require a bit of a hack for VNA users though.

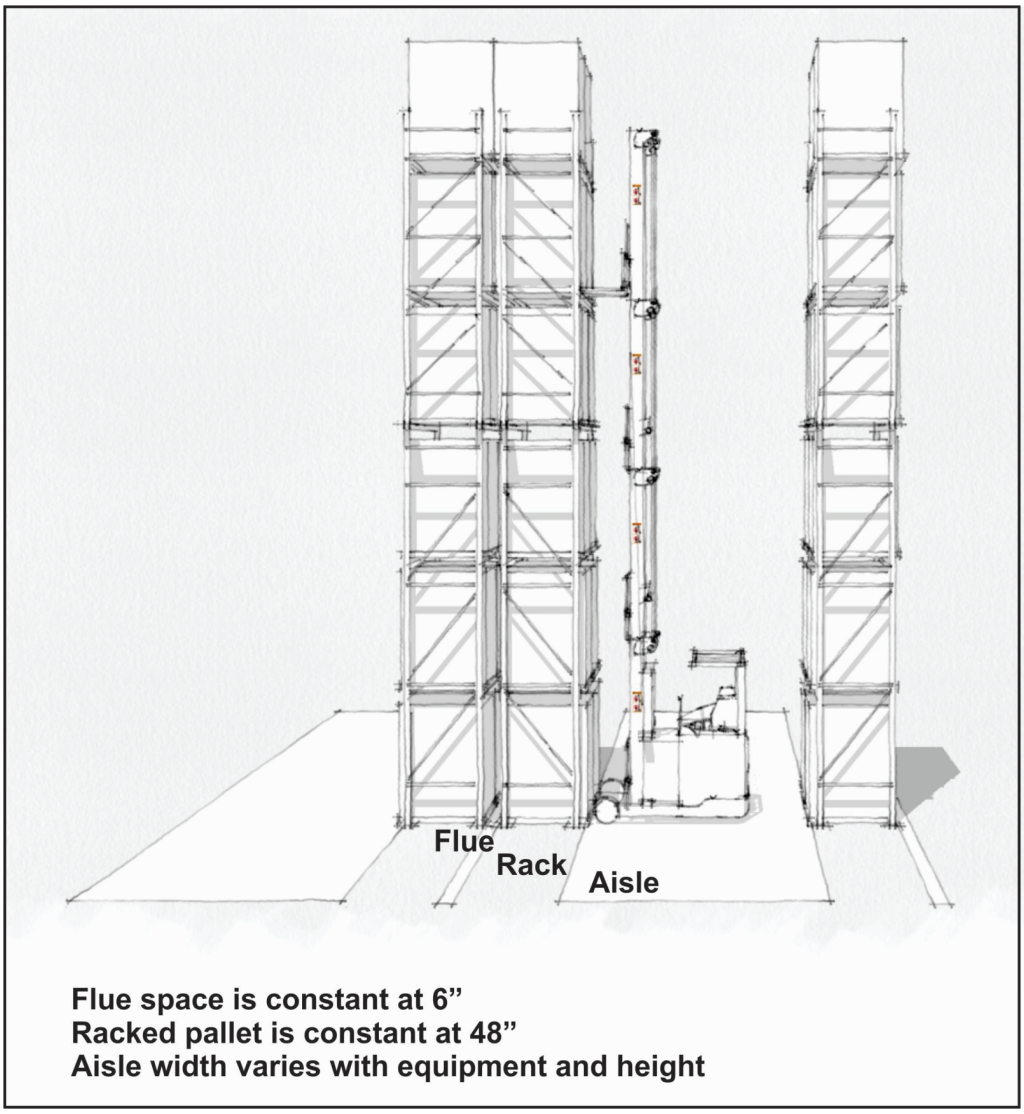
If, on the other hand, you are the more value-oriented person we mentioned but still trying to get ahead of the pack, The UL listed 48' high building will accommodate almost all types of NA and VNA equipment in appropriate aisle widths without any in rack sprinklers up to a storage height of 43'. The FM listed 50' high building with it's 6' aisle will accommodate some types of VNA installations.

Column Grids

We have circled around ESFR configuration heights and aisle widths of NA and VNA material handling equipment to land in one of our favorite topics: column grid dimensions. **The 56' column bay promoted by HPA has become the industry standard for building at 36' and 40' clear because it accommodates**

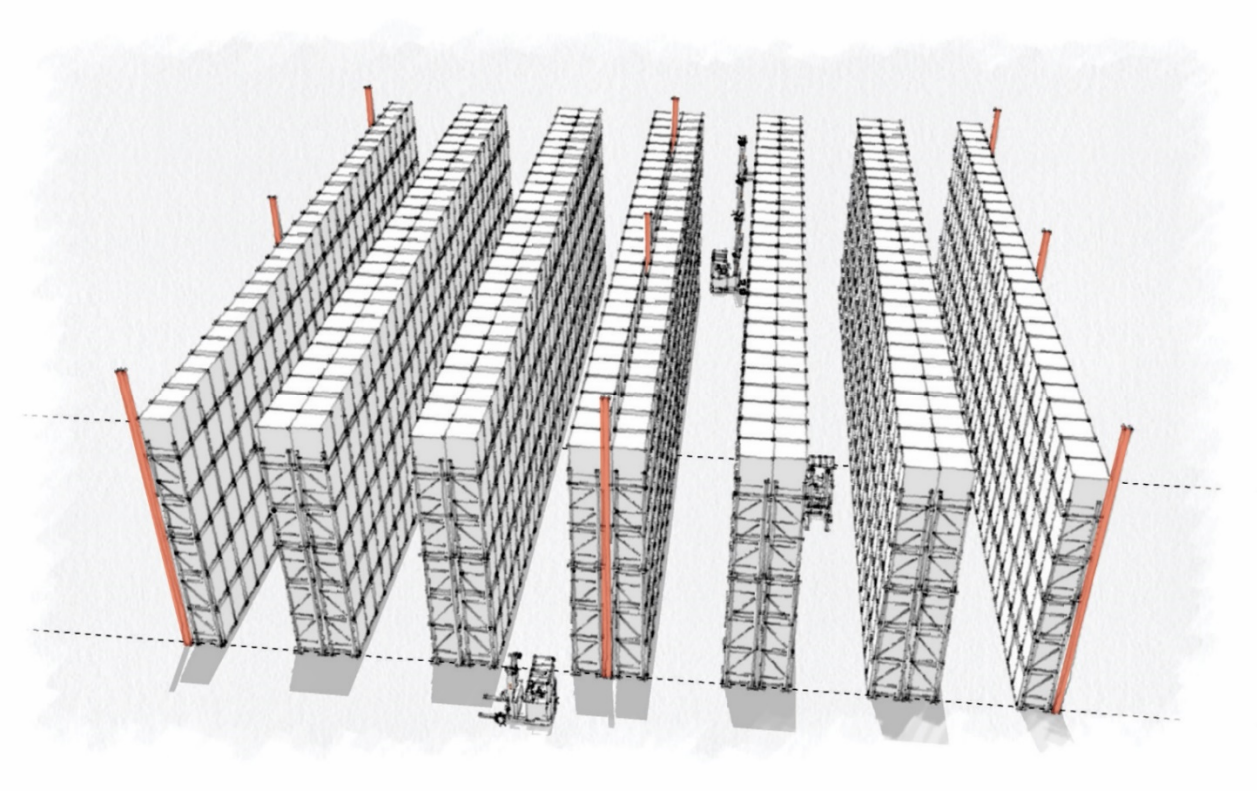
many NA rack layout and VNA rack layouts with minimum inefficiency. How does this bay dimension accommodate the increased likelihood of VNA equipment in a building 42’ clear and higher?

The illustration below shows a NA reach fork truck in a typical rack aisle. If we assume that pallet sizes are relatively standard at 4’ and that we stay with the NFPA minimum flu requirement of 6” then our only variable to optimizing a column bay for the rack layout is aisle width.



This illustration shows a layout with three rack aisles and single selective racks between columns. This arrangement is used in most distribution centers today. A fully optimized layout would have 6 rows of 4’ pallets, three aisles of a specified width, two 6” flue spaces, and two flue spaces that accommodated the structural columns themselves. In keeping with optimizing with minimum dimensions, the columns are generally 10” tubes and adding 1” clearance means calculating 6” of space on each side of the bay where the column occurs.

For this three-aisle arrangement and a 56’ column bay the resulting aisle width is 10’. This is a very good aisle width for most NA equipment picking up to a 36’ clear building. But when the clear height goes up to 40’ or higher the narrow aisle reach fork is really at its limit. One reach fork truck manufacturer has a configuration set up for these heights with criteria for a 10’ 4”. Another major forklift manufacturer says the aisle should be 118” (just under 10’) when picking the maximum rated height with their equipment of about 36’ pick height. There are some users that prefer an even larger aisle, seeing it as increasing operational speed. There are specifications out there from these users for 57’ to 58’ bays.



Different lift manufacturers publish different specifications on aisle widths and pick heights, especially in the VNA lines of equipment. VNA equipment is much more expensive and requires more sophistication to operate effectively. Many manufacturers have the capability to customize this equipment for varying aisle widths and pick heights. One major manufacturer can deliver VNA equipment for aisles ranging from 66” to 74”.

On the following page, we have created a table that calculates several column grid spacing alternatives based on varying aisle widths and number of aisles between columns.

Rack Aisle to Column Spacing Comparisons

1/6/2020 **HPA, Inc.**

Palletized Racking Configurations

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
Standard Aisle (Counter Balance)	144 in	12	288 in	432 in	576 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			498 in	744 in	990 in
Industry Norm 52'			41.5 ft	62 ft	82.50 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
NA Aisle (Reach Truck)	104 in	8.67	208 in	312 in	416 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			418 in	624 in	830 in
Industry Norm 52'			34.83 ft	52 ft	69.17 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
NA Aisle (High Pick Reach Truck)	118 in	9.83	236 in	354 in	472 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			446 in	666 in	886 in
Industry Norm 56'			37.17 ft	55.5 ft	73.83 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
NA Aisle (42' High Pick Reach Truck)	126 in	10.50	252 in	378 in	504 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			462 in	690 in	918 in
			38.50 ft	57.5 ft	76.50 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
VNA Aisle 56' optimum	64 in	5.33	128 in	192 in	256 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			338 in	504 in	670 in
			28.17 ft	42 ft	55.83 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
VNA Aisle Tyco UL Variation	60 in	5	120 in	180 in	240 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			330 in	492 in	654 in
Industry Norm 56'			27.50 ft	41 ft	54.50 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
VNA Aisle Viking FM Variation	72 in	6	144 in	216 in	288 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			354 in	528 in	702 in
			29.50 ft	44 ft	58.50 ft

	inches	feet	Two-aisle spacing	Three-aisle spacing	Four-aisle spacing
VNA Aisle Narrow Variation	56 in	4.67	112 in	168 in	224 in
Flue	6 in		18 in	24 in	30 in
Pallet	48 in		192 in	288 in	384 in
			322 in	480 in	638 in
			26.83 ft	40 ft	53.17 ft

This table indicates that the optimum VNA aisle width in a 56’ bay spacing would be 64”. There are several manufacturers with this specification. If we go to the minimum aisle width allowed in the new ESFR Tyco UL approved 48’ deck configuration, we see it is also accommodated with some inefficiency in a 56’ bay. The FM approved system for 50’ high roof decks requires a 6’ minimum aisle and it would not fit well in a 56’ bay.

All VNA equipment is not created equal, however. Some equipment specifies aisles closer to 6’ than 5’. This table says that as the aisle moves above 64”, the layout no longer fits neatly between columns and some rack positions will be lost to column locations. If optimization on a 6’ aisle was desired, for example, the column bay would be 58’ 6”’.

These calculations are based on optimizing to minimum requirements. Some operations, for example, may require larger flu spaces than NFPA requires as part of their standards. Some may specify a larger aisle for their NA reach trucks for ease of operation. The 56’ bay spacing accommodates both NA and VNA layouts well and remains our recommendation on buildings above 32’ clear up to 40’ clear. A 40’ clear building is right at the gray zone where a 56’ bay will work well for many users but there will be some who ask for a 57’ or 58’ bay. Going over 40’ clear our recommendation would be to use 56’-58’ bays.

Structural Gotcha’s

There are problems with just adding 3’ to 10’ of concrete into the height of the tilt up panels to estimate increased construction cost. The current designs for 40’ clear buildings are pushing against the incremental panel thickness and frame adjustments that have been made as we have gone from 30’ clear to 40’ clear. The new taller buildings will have a few challenges that are likely to make cost increases more than just incremental.

Panels will be getting thicker or will add pilasters.

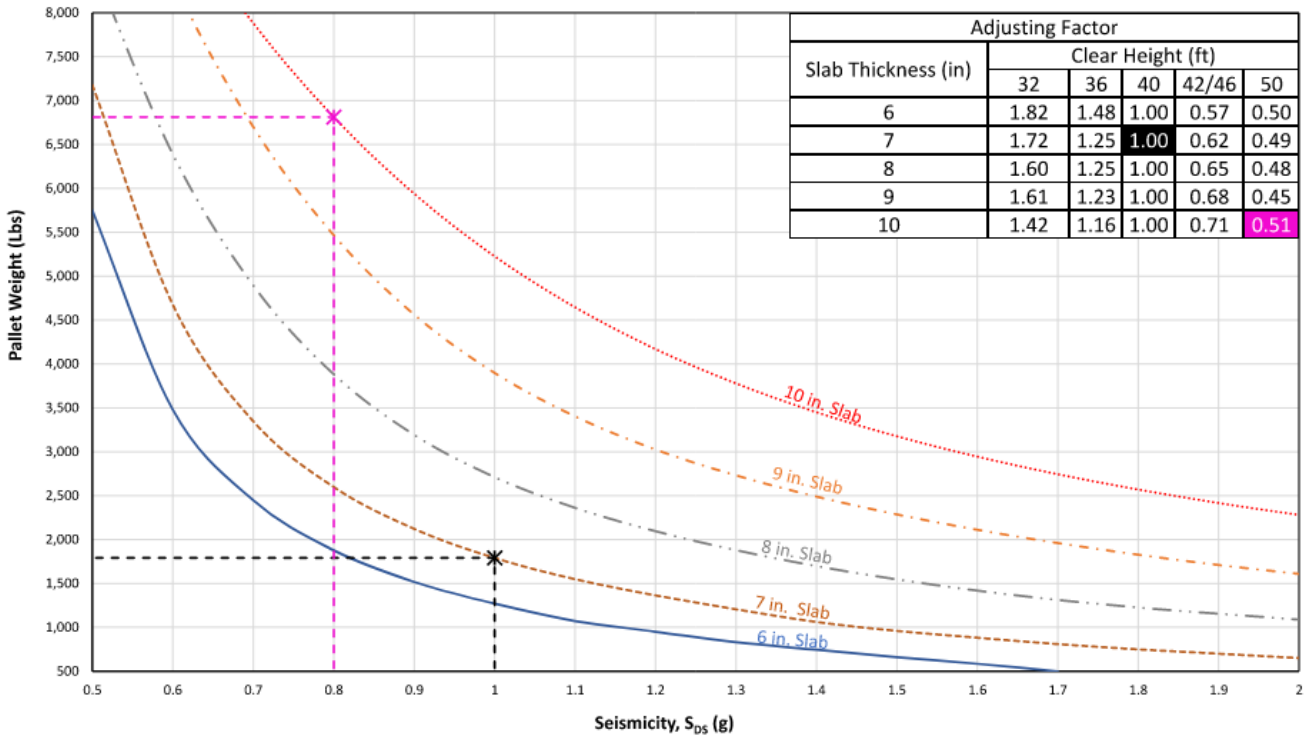
The extent of the increase will depend on the local seismic factor. The 40’ clear buildings have maxed out the 10” to 11” flat panels. We do have some tricks to mitigate this with roof designs, but there will be additional costs overall required.

Slab reinforcing will become a standard requirement

There is an ongoing discussion on the need/wisdom of reinforcing the slab in 36’ to 40’ clear buildings. Going taller will tilt the equations toward reinforcing. The issue isn’t carrying additional weight in the rack legs, it’s in the increased height of the racks that need to be tied into the slab for the seismic overturning forces. This lateral force pulls at the slab and requires it to act structurally instead of just transmitting a downward force. As with roof configurations and increasing panel thickness, we have some tricks with reinforcing approaches that will mitigate the costs. But if you were leaning to unreinforced slabs in your current buildings, start pricing it into these taller buildings.

Building clear height, pallet weight, and seismicity play a critical role in determining the slab thickness and reinforcing. You should consult with your structural engineer to determine what is right for your site. Below is a chart to help determine how thick slab is needed to support the desired pallet weight for a 40' clear building. A table is provided to correlate the results to buildings with different clear height.

For example, for a 40' clear building with a seismicity of SDS=1.0g, a 7" slab can support a pallet weight of 2712lbs. A building with 50' clear and SDS=0.8g, a 10" slab can support 6812lbs adjusted with the 0.51 adjustment factor.



Adjusting Factor					
Slab Thickness (in)	Clear Height (ft)				
	32	36	40	42/46	50
6	1.82	1.48	1.00	0.57	0.50
7	1.72	1.25	1.00	0.62	0.49
8	1.60	1.25	1.00	0.65	0.48
9	1.61	1.23	1.00	0.68	0.45
10	1.42	1.16	1.00	0.71	0.51

Sloping Slabs

It has become common practice in the western US to slop the slabs of large buildings at .5% to minimize grading costs. Think about an 800,000-sf building, 600’ wide by 1,320’ long, running parallel to the street it fronts on. That street is going to be at about 2% minimum slope to drain water. In that case, over the 1,320’ length of the building, the street changes elevation by something like 26’. If the building slopes the same direction at .5% slope its finish floor changes over 6’ in elevation, minimizing grading work.

The finish floor changing over 6’ in elevation sounds pretty drastic, put in fact you drive by these buildings all the time. You cannot tell the difference in a sloped slab or a non-sloped slab without full survey equipment. Sloped slabs have been standard practice in large buildings for over 25 years and there are many millions of square feet in existence. Some have super-flat floors and are serviced by wire guided lift equipment. The FF-FL numbers used to specify slabs are *independent* of the overall slab slope. That’s correct, a sloped slab may also be a ‘super-flat’ slab.

Having said all that, HPA is going to recommend that **you should not slope the slabs on these taller buildings**. While there is no real technical problem, there is a perception problem. Material handling equipment manufacturers have a difficult time getting their head around the practice of operating on a sloped slab even if their equipment is already in successful use in such a building. The issue gets increasingly sensitive as the racking gets taller and tolerances get tighter.

This means that if you are factoring in grading savings from a sloped slab into estimated construction costs on a building 40’ clear or higher, you may want to reconsider. The savings ranges broadly based on actual sites and buildings, but on some specific situations it can rise into seven figures. HPA continues to recommend using .5% sloped slabs in buildings under 40’ clear where a cost savings in grading results.

HPA bottom line recommendations:

Difference between structural clear height and maximum storage height? ESFRs require 36" clearance from deflector to top of storage. The sprinkler head is 12" to 14" below roof deck (maximum 18"). Top of product must be no closer than 4' below the bottom of deck. Additionally, 12" should be provided from the top of product to the bottom of trusses.

There are several 48' listed ESFRs that accommodate 6', 5' and even 4' aisles. A building with a 48' maximum deck height and a 42' clear height can use the new ESFR configurations with the Tyco UL approval, which has a 5' minimum aisle width requirement. Buildings with a 50' maximum deck height and a 44' clear height can use the FM approved sprinklers (e.g., K22s, K25s, K28s).

40' clear buildings can work without special roof designs or interior drains. 42' clear building can work with reduced roof slope and tapered joists in first bay.

A building with a 55' deck height and 50' clear is not as flexible today as it might sound but it can be made to work for VNA equipment with additional sprinkler configurations. There are two options here, one requires 8' min. aisles, the other 6' min. aisles. Both are ceiling-only protection schemes from FM Global.

A 56' column bay is still the most efficient solution going over 32' and up to 40' clear unless the user's operational criteria are known ahead of design.

For buildings above 40' clear a 56'-58' structural bay should be considered.

It is time to stop sloping slabs and to start reinforcing them in buildings 40' clear and higher. This will raise grading costs on some sites with significant topography.

Be aware ESFR systems cannot protect anything and everything. If you're over 40' maximum interior roof height, all that can be protected with ceiling only ESFR sprinkler systems is the standard cartoned unexpanded Group A plastic commodity. Commodities worse than this (e.g., consisting of exposed and/or expanded Group A plastics) will require additional fire protection. Aisle narrower than the minimum aisle rating for the selected sprinkler will also require additional fire protection, typically in rack sprinklers.