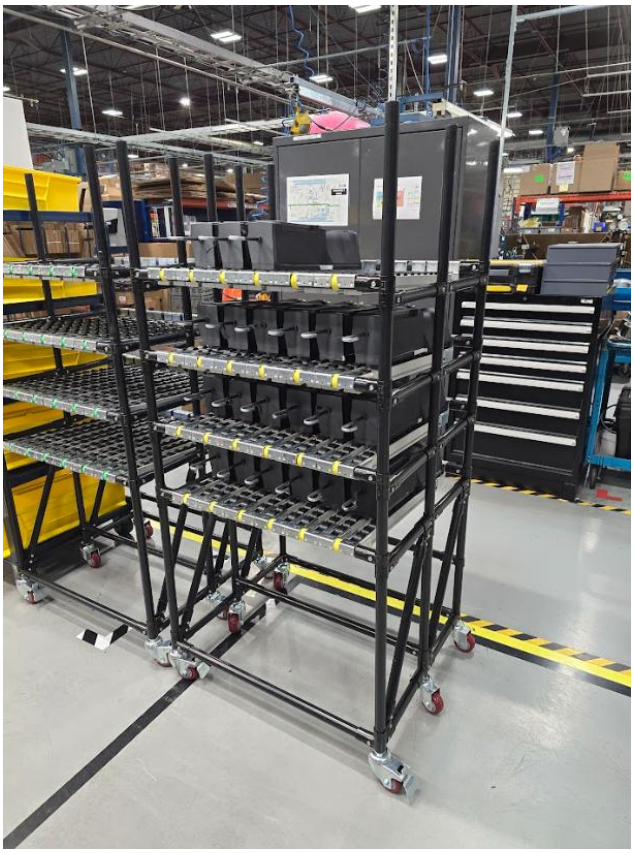
Capacity Analysis of the Small Drying Rack



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Dometic

Weight of each component:

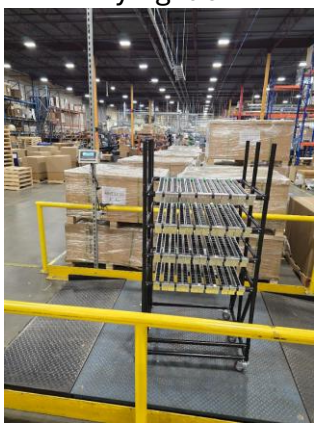
Grouper paint mask Unit

11.44 lbs

Roller Unit

2.18 lbs

Drying rack



168 lbs

From the ground up:

Castors used in the design:

QTY	Title	Capacity	Link
4	Swivel Stem Caster Mounting Foot for 1.08" OD Clamp-on Framing Rail	150 lbs	Swivel Stem Caster Mounting Foot for 1.08" OD Clamp-on Framing Rail | McMaster-Carr
2	Clamp-on Framing Fitting, Swivel Stem Caster Mounting Foot with Brake	150 lbs	Clamp-on Framing Fitting, Swivel Stem Caster Mounting Foot with Brake | McMaster-Carr

Combined weight capacity of the 6 castors:

$$150\text{lb} * 6 = 900\ \text{lbs}$$

Total weight of a full drying rack:

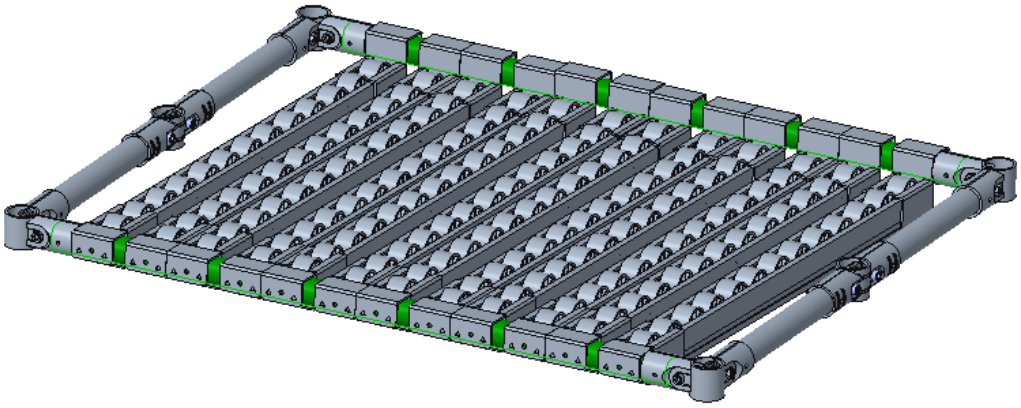
$$(11.44\text{lb} * 24) + 168\text{lb} = 442\text{lb}$$

Factor of safety:

$$900 / 442 = 2.03$$

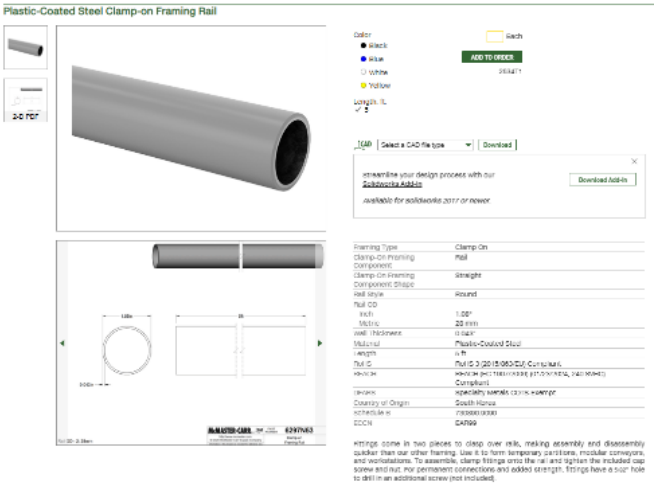
This means that an additional 458 lbs (equivalent to 40 additional grouper paint mask units) can be placed in addition to the full 24 grouper paint mask units before the weight goes over the weight capacity of the castors.

Loading capacity on horizontal bars



Link to bar used from mcmaster: [Plastic-Coated Steel Clamp-on Framing Rail | McMaster-Carr]

Product description of the framing rails used in the build (purchased from mcmaster-carr) do not contain a loading capacity of the frames, as seen to the right.



PIPE SPAN	0.7MM STAINLESS PIPE	1MM REGULAR STEEL PIPE	1.1MM STAINLESS STEEL PIPE	2MM STRONG STEEL PI	SQUARE PIPE	2X-1MM WITH H3-13 INCREASE BY 66%
12″	330.9 lb	766.7 lb	815.1 lb	875.1 lb	4221.7 lb	
24″	181.1 lb	383.4 lb	486.6 lb	687.8 lb	2110.8 lb	
36″	133.8 lb	255.6 lb	346.3 lb	458.5 lb	1407.2 lb	423.3 lb
48″	103.4 lb	191.7 lb	267.3 lb	343.9 lb	1055.4 lb	318.2 lb
60″	90.2 lb	153.3 lb	217.6 lb	275.1 lb	844.3 lb	254.4 lb
72″	71.3 lb	127.8 lb	183.5 lb	229.2 lb	703.6 lb	212.1 lb
84″	66 lb	109.5 lb	150.3 lb	196.5 lb	603.1 lb	
96″	54.8 lb	95.5 lb	129.4 lb	171.9 lb	527.7 lb	

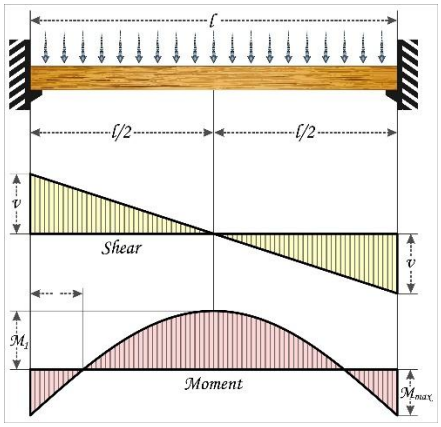
Fortunately, a manufacturer that sells similar framing rails published its loading capacity ratings on their website.

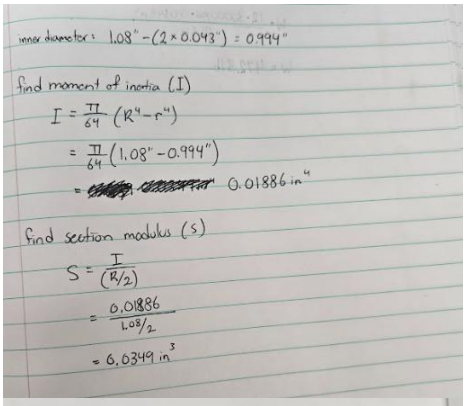
The chart was found on flexpipe's website: [How to calculate the loading capacity for modular structures | Flexpipe],

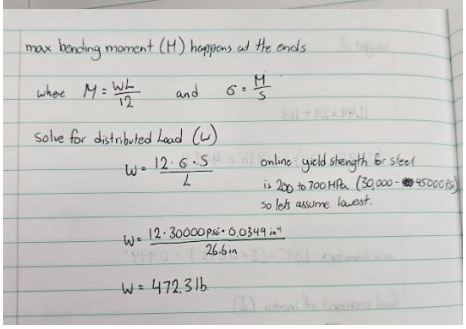
The length of the horizontal spanning bars used in the design were 26.6" and the stainless steel tube is 1.09mm (0.043") thick with a tube diameter of 1.08".

The closest parameter in the loading capacity chart is the 1.1mm with a 24" span, which has a capacity of 486.6 lb per horizontal bar.

To validate this, we can calculate the yield strength by modeling the bar as a double fixed-end beam with a uniformly distributed load, where the aligns with the chart above.







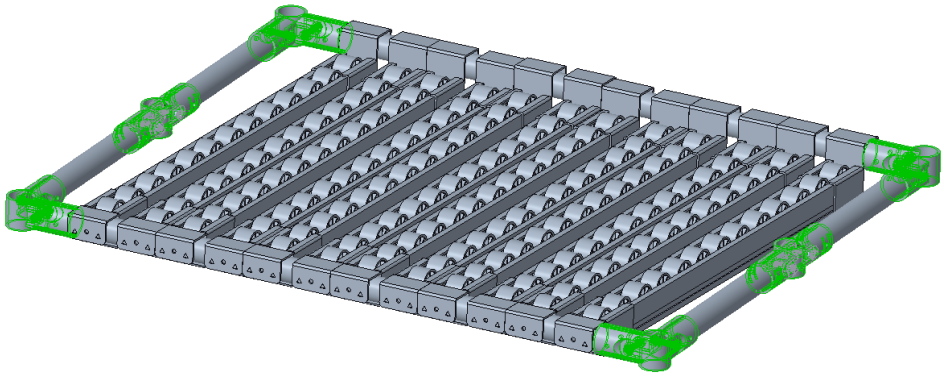
With 2 bars supporting each row of ams grouper paintmasks, both bars can support a weight of 944 lbs before yielding.

With a row of 6 paint mask groupers and 12 roller units:

(11.44 lbs * 6) + (2.18 lbs * 12) = 94.8 lbs

That gives a safety factor of 9.9, an incredibly high factor of safety.

Loading capacity on each level due to the through hole connectors

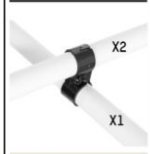


QTY	Title	Link
4	Clamp-on Framing Fitting, Black Painted Steel, 3-Way 90 Degree Through-Hole Elbow	Clamp-on Framing Fitting, Black Painted Steel, 3-Way 90 Degree Through-Hole Elbow | McMaster-Carr
2	Clamp-on Framing Fitting, Black Painted Steel, Cross Through-Hole Connector	Clamp-on Framing Fitting, Black Painted Steel, Cross Through-Hole Connector | McMaster-Carr

Once again, the product description of the frame connectors purchased from mcmaster-carr do not contain a loading capacity, as seen to the right.

As before, a manufacturer published the loading capacity ratings of similar framing joints.

TENSILE STRENGTH TEST OF FLEXPIPE BLACK STEEL JOINTS

PART NUMBER	HJ-1	HJ-2	HJ-3	HJ-4	HJ-6	HJ-7	HJ-90
							
X	319 lb				306 lb		
Y	379 lb	364 lb	> 440 lb		336 lb		
X1		197 lb	187 lb	256 lb		151 lb	305 lb
X2		242 lb	201 lb	235 lb		171 lb	338 lb
X3			321 lb				

With the load of each row being shared along 6 joints (4x HJ2 & 2x HJ4), lets assume the “weakest link” principle where the systems capacity is determined by the first component to fail, being the y axis of HJ-2s (364 lbs).

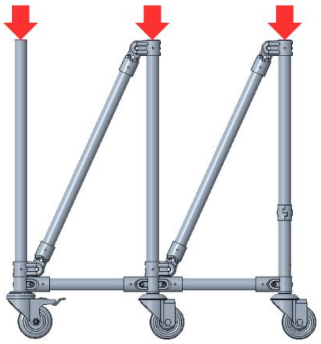
$$364 * 6 = 2184 \text{ lbs}$$

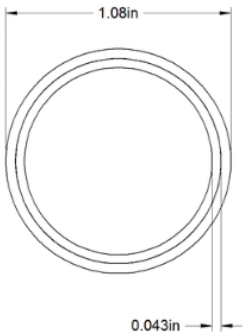
The back two HJ-2s joints it is still capable of holding 729 lbs before failing if it were somehow responsible for all the weight of the 6 paint mask groupers and 12 roller units (94.8 lbs).

Compressive yielding capacity of the vertical frames

This is to look into if the vertical frames can handle the weight of a fully loaded drying rack

Specifically, the vertical section between the bottom rack and the base since that section is the longest and needs to withstand the weight of a fully loaded drying rack (even though its less, let’s just assume the full 168 lbs).





With an cross sectional area of

$$A = \pi R^2 - \pi r^2$$

$$A = \pi(1.08/2)^2 - \pi((1.08-0.043*2)/2)^2$$

$$A = 0.14\ in^2$$

Assuming the vertical rods experience uniform compressive stress from the weight, the vertical rods only experience a stress of

$$73.66lbs / 0.14\ in^2 = 526.14\ psi$$

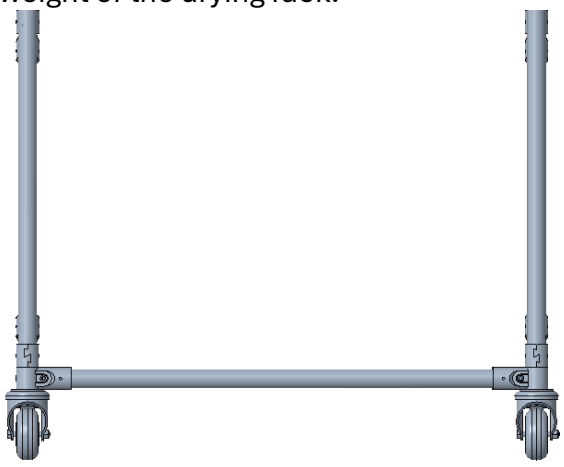
nowhere close to the yield strength of steel, which is roughly 36,000 to 50,000 psi. Even if only 2 columns rods were responsible for the weight of a fully loaded drying rack, it would only experience stress of about

$$442\ lbs / (2 \times 0.14\ in^2) = 1578.57\ psi$$

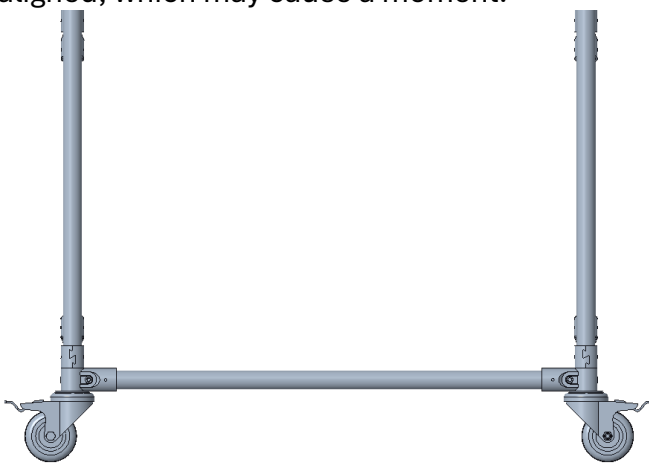
Lateral forces on the frame connectors due to castor offset

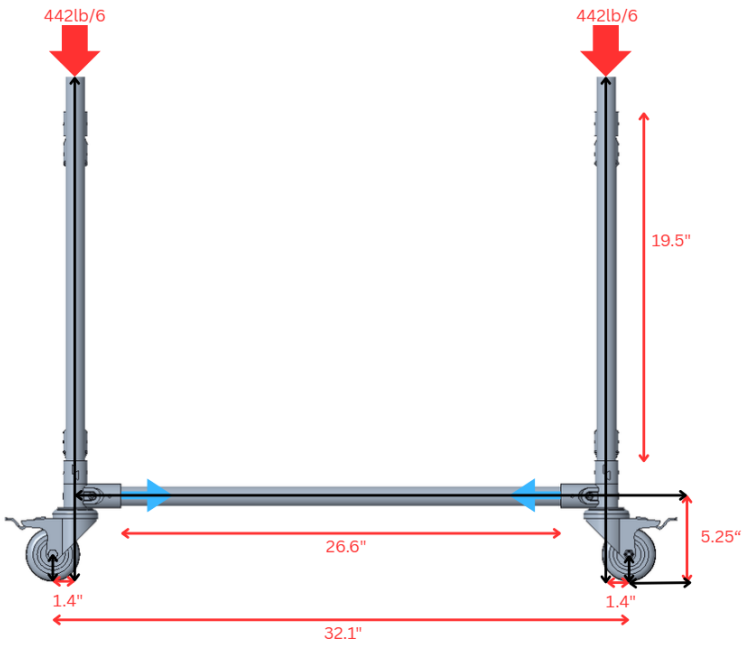
Last aspect of the design I want to explore is how much lateral forces are being put on the horizontal bars due to the castors being offset from the vertical columns, and if the forces would exceed the holding strength of the connectors.

In some some axis, the castors can align with the vertical forces from the weight of the drying rack.



In other castor orientations, the ground contact point and the vertical frame are not aligned, which may cause a moment.





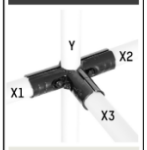
This causes a bending moment (rotational force) caused by the vertical loads being offset from the vertical supports. The downward force creates a clockwise moment on the left and a counter clockwise moment on the right at the point where the wheels contact the ground.

$$Moment = F \times d = (442lb / 6) + 1.4in = 103.14lb{\cdot}in \text{ at each joint}$$

The horizontal bar prevents the vertical poles from pivoting outwards, where the height of the connection point can be used to find the force required to balance the moment about the ground.

$$Moment = F \times d \therefore F = Moment/d = 103.14lb{\cdot}in / 5.25in = 19.64\ lbs$$

This gives a tensile force of about 19.64 lbs at each connector (where the blue arrows are pointing).

PART NUMBER	HJ-2	HJ-3
		
X		
Y	364 lb	> 44
X1	197 lb	187 lb
X2	242 lb	201 lb
X3		321 lb

Comparing that value to what the frame connectors are rated for, the HJ-2 joints can hold 197 lbs in the X1 direction and the HJ-3 joints can hold 321 lbs in the X3 direction, giving the horizontal bars a factor of safety about 9.5.

Lastly, all bolts were tightened down to atleast 12Nm since the holding capacity with 10Nm seemed questionable.