Considerations regarding testing of stopping devices (roll-off safety) on vehicle lifts.

Objective
In the EN1493:2010 a design force of 20% of rated load was defined for each “end stop”.
The original calculations, as well as new calculations, show that the max horizontal component of the force that is acting on one end stop (stopping force), is 8% of the rated capacity.
During the recent discussions regarding the revision of the standard, it was agreed the design load to be 10% on each end stop.
The question was how to test a device practically.

Need and necessity
The difficulty here is that the way the load is applied to the stop, depends on its shape (construction). A common factor is that there is always a tire, which has a diameter depending of the capacity, and is rolling when it hits the stop. What also is always the case, is the vertical resultant.
When thinking about a testing device, it is clear that it should have a circular contact face, a horizontal force should be applied and there must be a construction that attaches the testing device to the runway (track) in order to resist the vertical component. Especially for the heavy duty lifts (category d and up) the forces are so high that a testing device would be quite a construction.
The end stop is a safety device, but it is not in the load path, and it is not loaded every time a vehicle is lifted. It is provided as a secondary means to restrain the vehicle from inadvertently rolling off the track when raised.
For these reasons I think it is not necessary to test the roll of safety devices.

Solution
Added to the paragraph 5.9.6 we can provide a way to calculate the end stop construction.

Relation between wheel size and normative vehicles
It is difficult to establish a relation between the rated capacity and the wheel diameter.
For passenger cars, nowadays the smallest wheel diameter is around 600 mm, but vehicles with a weight equal to a rated capacity of 2500 kg (a), may have a wheel diameter of 790 mm. This wheel size is also found on vehicles in category b and c.
Category d vehicles (between 7,5 and 20 tons) have an average wheel size of about 900 mm, and category e through f vehicles have an average of 1080 mm.
We see special vehicles (off road, like dumpers etc.) with bigger wheel sizes, but these may need a special requirement. With such vehicles not the integrity of the device is at stake, but the function as a stopping device itself: with bigger diameters the vertical component (Fv) gets higher, and when this equals the wheel (axle) load, driving over is very likely. So, in these cases the stopping device may require a greater minimum height.

FIG1

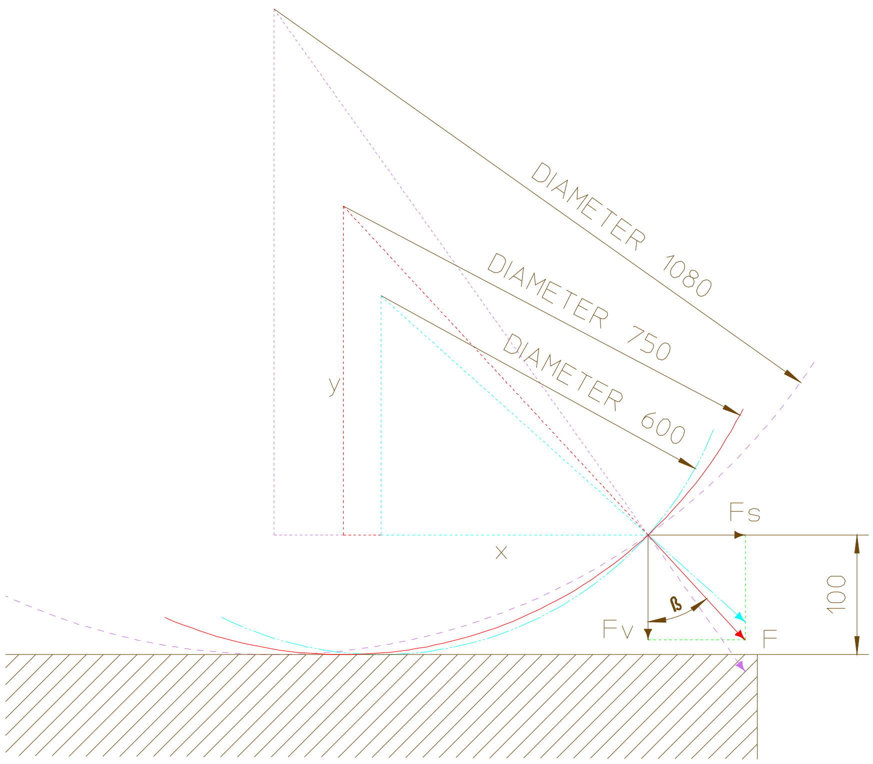

TABLE 1

Normative vehicle				a	b	c	d	e	f	g	h	i	j	k	l
vehicle weight (max) = rated capacity	M	kg		2500	3500	7500	20000	30000	40000	25000	40000	52000	40000	52000	45000
wheelbase	WB	m		2,5	3	3	3,5	4	4,5	12	11,1	11,7	10	11	9,6
runway length	Lr	m		5,2	5,2	6,25	10	14,5	14,5	14,5	14,5	14,5	14,5	14,5	14,5
runway angle (max. see 5.15 c1+ c2)	°	α	[1+ASIN(100/(Lr*1000))]	1,02	1,02	1,02	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
runway angle (max. see 5.15 c1+ c2)	rad	α	[α*2π/360]	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018
axle load 1	AL1	kg		1000	1400	2500	6667	10000	18000	11250	18000	23400	18000	23400	20250
axle load 2	AL2	kg		1500	2100	5000	13333	20000	22000	13750	22000	28600	22000	28600	24750
wheelload		kg		750	1050	1250	3333	2500	2750	1719	2750	3575	2750	3575	3094
loadindexnr.				98	110	117	150	140	144	144	144	144	144	144	144
Average outer wheel diameter	D	mm		**775**	**775**	**775**	**900**	**1080**	**1080**	**1080**	**1080**	**1080**	**1080**	**1080**	**1080**
average wheel radius	Ra	mm	[D/2]	388	388	388	450	540	540	540	540	540	540	540	540
contact angle	ß	°		42	42	42	39	35	35	35	35	35	35	35	35
contact angle	ß	rad		0,73	0,73	0,73	0,68	0,62	0,62	0,62	0,62	0,62	0,62	0,62	0,62
free distance	s	m	[Lr-WB]	2,7	2,2	3,25	6,5	10,5	10	2,5	3,4	2,8	4,5	3,5	4,9
gravitational constant	g	m/sec²		9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81	9,81
rolling resistance coefficient	c			0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
rolling resistance	Fr	N	[c.g.M]	245	343	736	1962	2943	3924	2453	3924	5101	3924	5101	4415
maximum speed	v	m/s	[√(2*(g*sin(α)-Fr/M)*s)]	0,6423	0,5798	0,7021	0,9862	1,2490	1,2189	0,6095	0,7107	0,6450	0,8177	0,7211	0,8532
estimated stopping time	Δt	sec		**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**	**0,8**
			Normative vehicle	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**
vehicle weight (max) = rated capacity	M	kg		2500	3500	7500	20000	30000	40000	25000	40000	52000	40000	52000	45000
wheelbase	WB	m		2,5	3	3	3,5	4	4,5	12	11,1	11,7	10	11	9,6
runway length	Lr	m		5,2	5,2	6,25	10	14,5	14,5	14,5	14,5	14,5	14,5	14,5	14,5
total resulting stopping force on 2 devices	**Fs**	N	[M*v/t]	**2007**	**2537**	**6583**	**24656**	**46838**	**60946**	**19046**	**35537**	**41925**	**40884**	**46873**	**47995**
percentage of rated capacity		%		*8*	*7*	*9*	*13*	*16*	*16*	*8*	*9*	*8*	*10*	*9*	*11*
total radial force on 2 stop devices	**F**	N	[Fs/sinß]	**2994**	**3783**	**9818**	**39227**	**80795**	**105130**	**32853**	**61301**	**72319**	**70523**	**80855**	**82790**
total resulting vertical force on 2 devices	**Fv**	N	[Fs/tanß]	**2221**	**2807**	**7284**	**30510**	**65833**	**85662**	**26769**	**49949**	**58926**	**57464**	**65882**	**67459**
percentage of minimal axle load (AL1)		%		*23*	*20*	*30*	*47*	*67*	*49*	*24*	*28*	*26*	*33*	*29*	*34*

Table 1 shows the maximum forces on the end stops that can be reached with the different normative vehicles. It also shows that normative vehicle f causes the highest forces. This is caused by the combination of a short wheel base and a long track. All vehicles from g through l have lower forces.

TABLE 2

			Normative vehicle	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**
vehicle weight (max) = rated capacity	M	kg		2500	3500	7500	20000	30000	40000	25000	40000	52000	40000	52000	45000
horizontal force on one device	Fth	N	[M/10*9,81]	**2453**	**3434**	**7358**	**19620**	**29430**	**39240**	**24525**	**39240**	**51012**	**39240**	**51012**	**44145**
wheel radius	R	mm		385	385	385	450	540	540	540	540	540	540	540	540
ref contact angle	ß	°	[arccosine((R-100)/R)]	42	42	42	39	35	35	35	35	35	35	35	35
vertical force on one device	Ftv	N	[Fth/tan(ßr)]	**2700**	**3780**	**8101**	**24279**	**41365**	**55153**	**34471**	**55153**	**71699**	**55153**	**71699**	**62047**
percentage of minimal wheel load		%		*55%*	*55%*	*66%*	*74%*	*84%*	*94%*	*62%*	*94%*	*122%*	*94%*	*122%*	*105%*

In table 2 the forces on **1 end stop** are calculated with the horizontal force being 10% of the rated capacity. This doesn't take into account the effect of the long wheelbase of vehicle g through l, and the resulting lower forces thereof. Vehicles category f,h,i,j,k and l have the percentage of min. wheel load calculated with 6 tons wheel load.

It can be seen that all forces, which are calculated with 10% of rated load, are much higher than the real forces as calculated in table 1 (NB, table 1 represents the forces on **2 stop devices**!). It also shows that normative vehicle i, k and l have a vertical force that is higher than the min. wheel load.

There are two possible approaches:

1) Demonstration by calculation with the forces from table 2, which provides sufficient prove of the stability of the construction (stop shall not break).
2) Practical test with an object that represents the wheelradius (R in table 2) or a wheel, that is loaded with the minimal wheel load (50% of AL1 in table 1 with a max. of 6 tons) and subjected to a horizontal force of 10% of rated capacity. (stop shall not break, and test object shall not move over the end stop, which is likely with vehicle i, k and l).

Note: It's remarkable that even the American standard has no testing procedure, other than a functional test on minimum height and deployment characteristics.

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30 June 2017