KEPS SYSTEM

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Defining a Keps System

‘It is fairly common practice to use Keps to hold cages in position, whilst loading and unloading at stations where depth exceeds 1200m.

These mechanical devices located at the stations

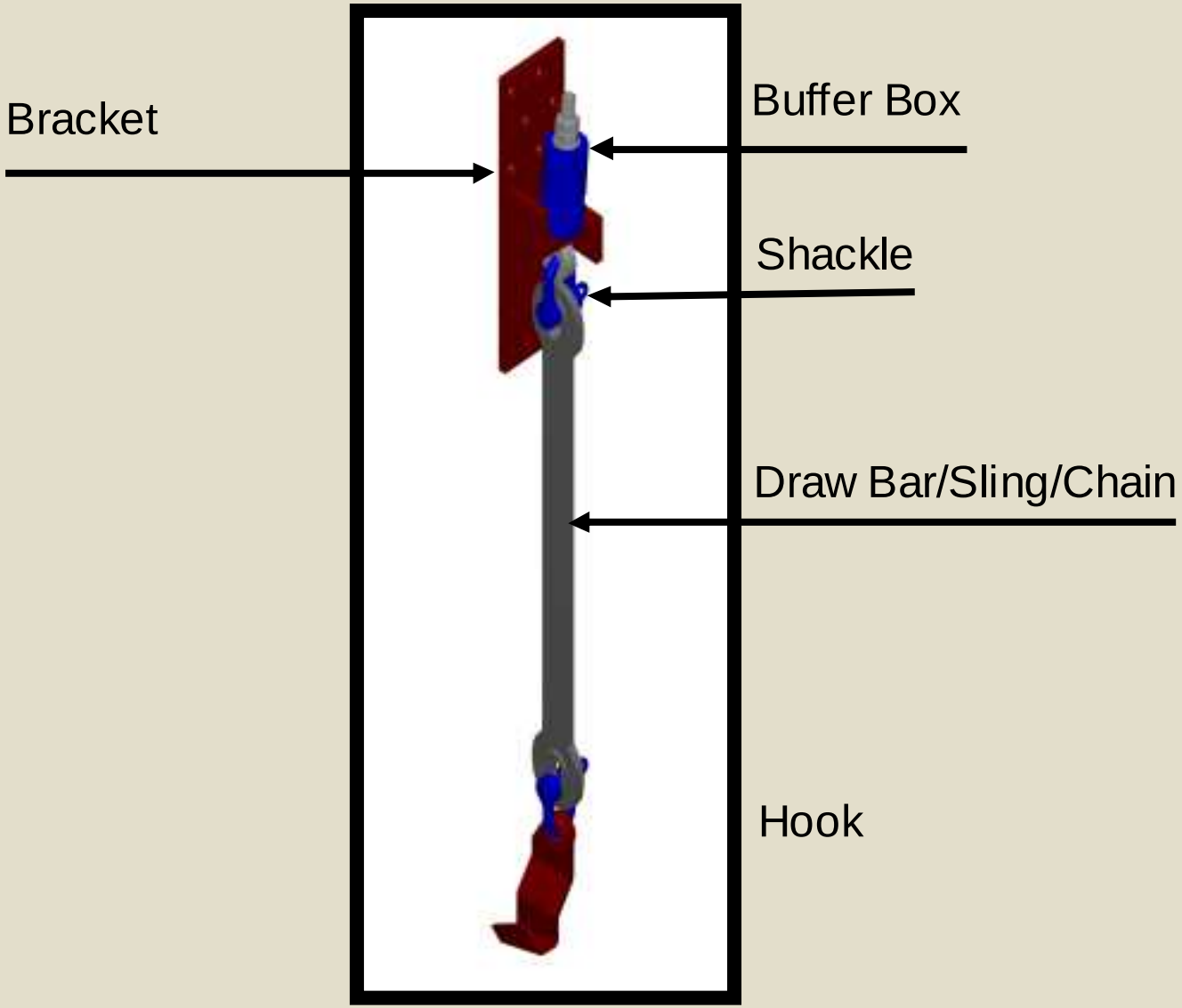
It appears to be common practice to insert Keps whilst cage is traveling at a creep speed of about 0.2m/s. This ensures that the cage stops at the correct level.’

Dr GJ Krige

Principal Structural Engineer

ATD

ILLUSTRATION



ILLUSTRATION

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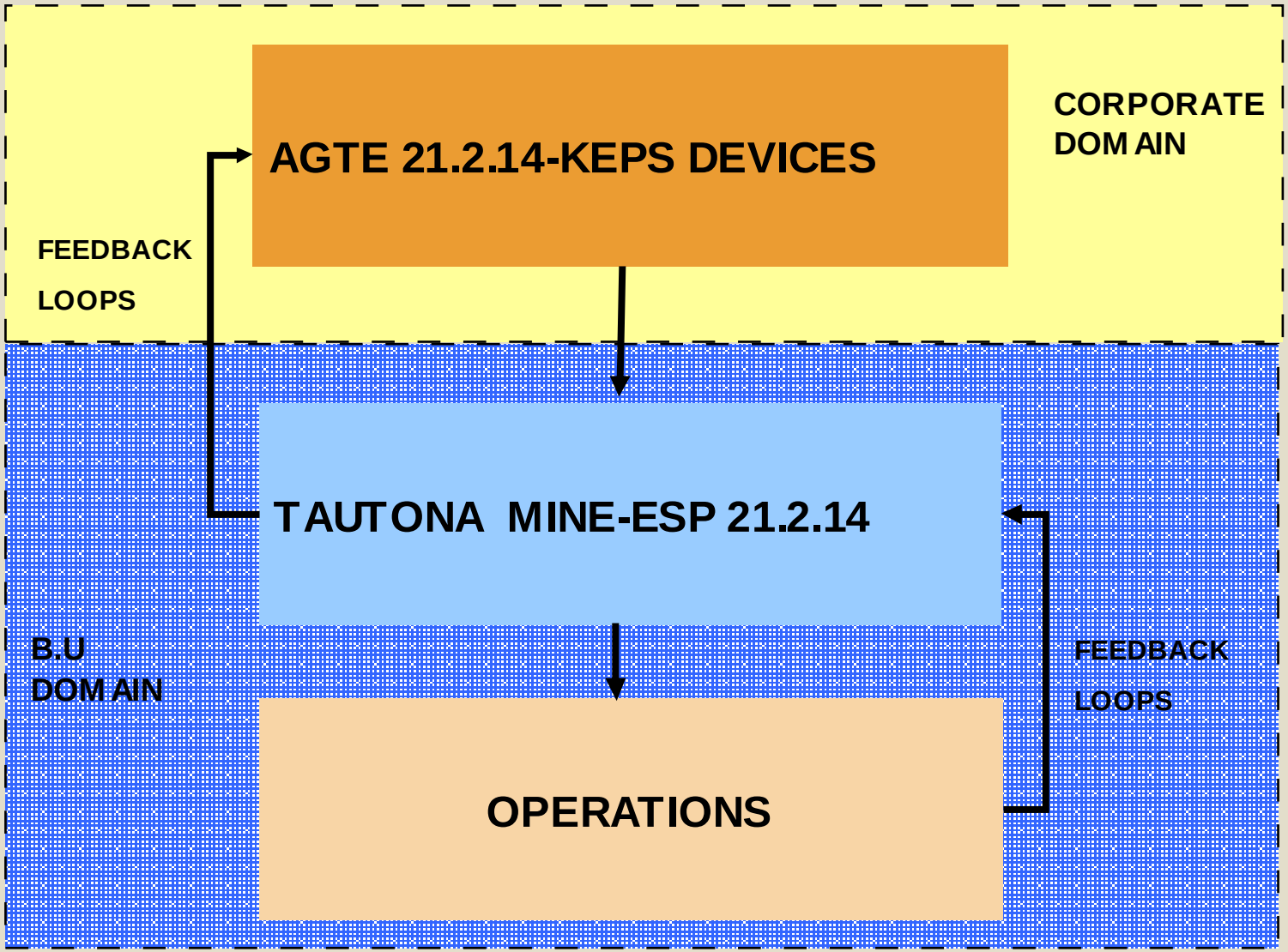
ILLUSTRATION

WHAT GOVERNS KEPS SYSTEM AT AGA



TAUTONA MINE ESP 21.2.14 KEP DEVICES

- Installed on 66 level and 100 level.
- Arrest conveyance in correct position.
- Allow for safe loading / unloading of people and material.
- Understood by all.
- Both kep hooks must be used at all times.
- If only one kep hook is used then the onsetter to stop the cage.

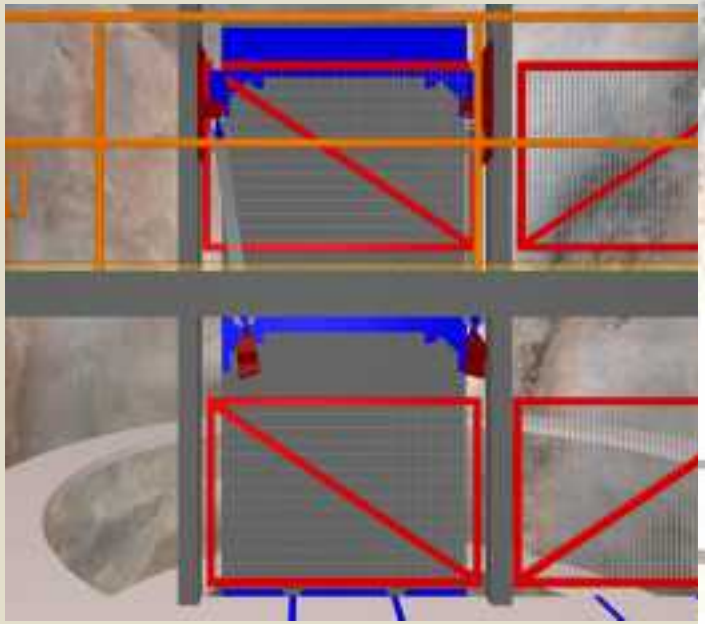
Description of Incident

While lowering the shift to 66 level on the main shaft. The Man Winder Conveyance (M1) slipped from the Keps device and dropped by approximately 2m while employees were exiting the conveyance, injuring 2 employees and fatally injuring 2 others.

Findings: Event Summary

- Driver sends down shift to 66 level.
- Onsetter does not ring “4-2” in time to indicate to driver to approach landing slowly

Findings: Event Summary

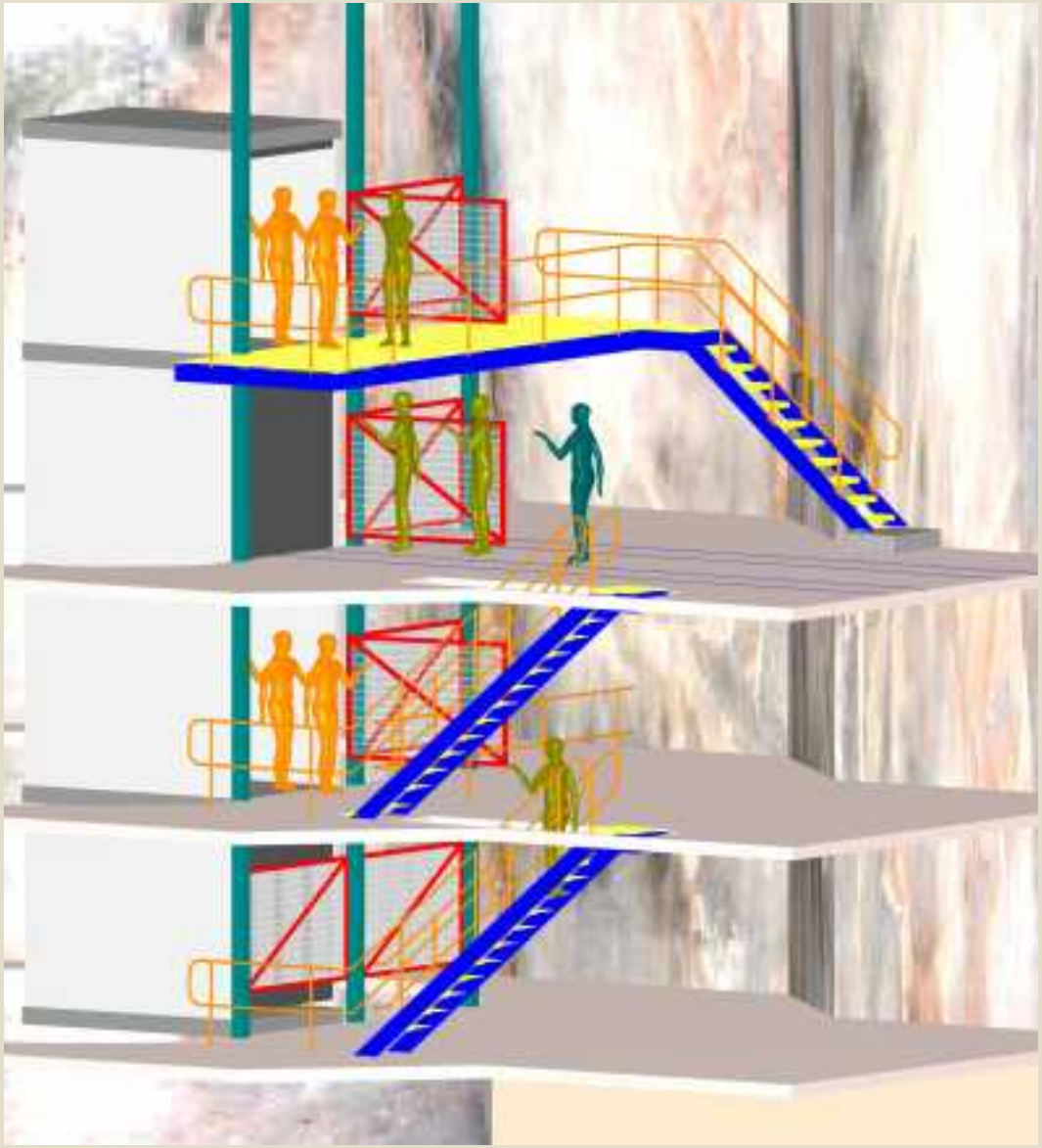


- One helper attempts to hook keps device, failing to do so properly
- The other helper does not attempt to hook keps device and turns to onsetter to repeat procedure
- Onsetter does not repeat the procedure

Findings: Event Summary

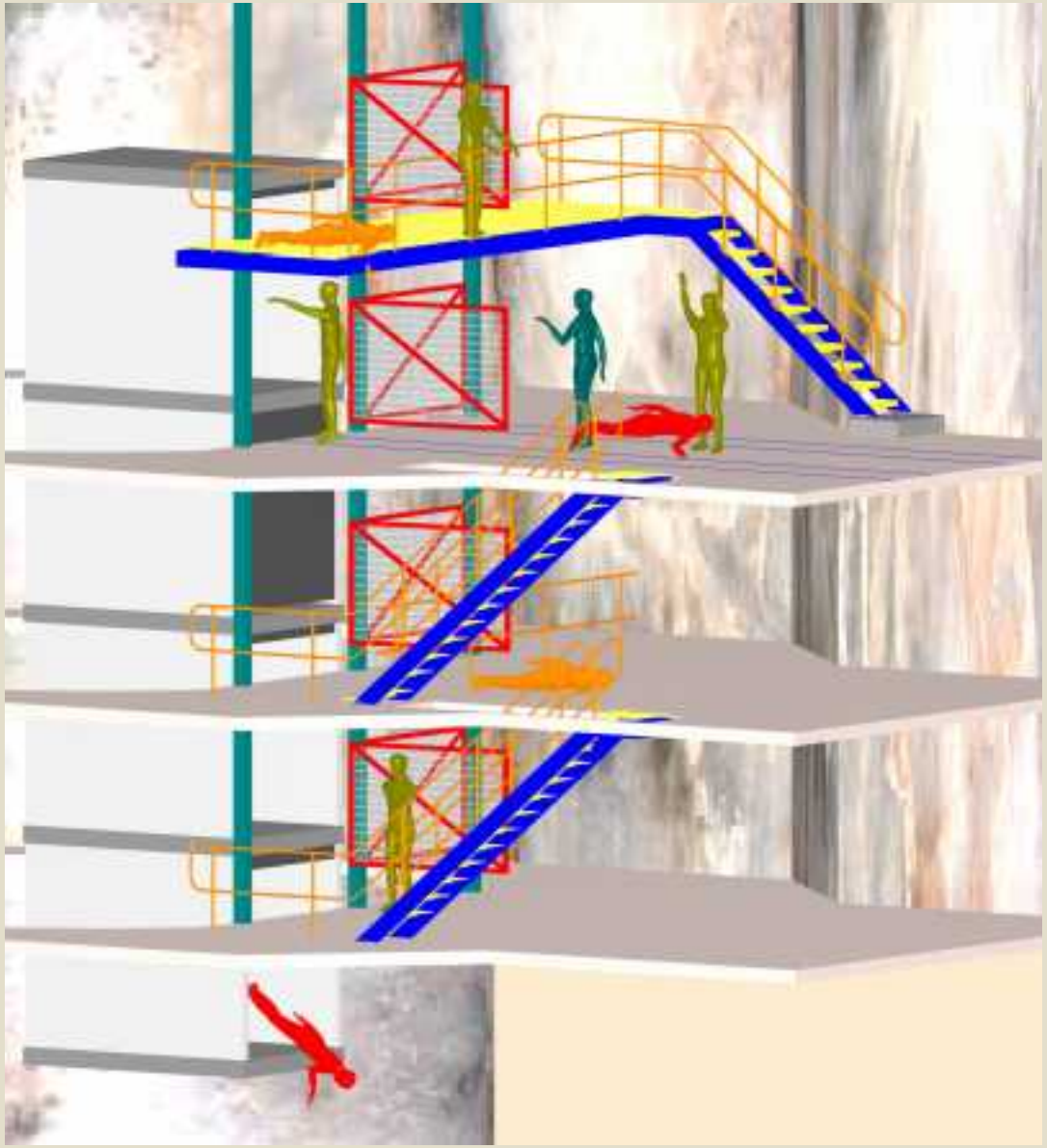
- Winding Engine Driver takes conveyance to “empty cage mark”, paying out approximately 5 numbers of slack
- Winding Engine Driver signals “3” to onsetter and onsetter opens station gate

Findings: Event Summary



- Assistants on top and sub landings open their platform gates
- Assistants on top and sub landings open conveyance doors
- Employees exit at top and sub landings

Findings: Event Summary



- Conveyance slips from partially engaged keps device and drops by approximately 2 meters
- 4 People are injured in the incident, 2 of which are fatally injured

Solution Approach

Audit Review

- Review structural integrity of the Kep members.
  - King Post in the station steelwork
  - Bolting of the Kep Bracket to the Kingpost
  - Bracket
  - Eyebolt
  - D-Shackles
  - Wire rope sling
  - Kep Hook
  - The Kep engagement plate on the cage

Design Audit Review

- Design duty
- Material of construction
- Weld details
- Static strength of members
- Loads on the members
- Fatigue stresses in welds

Design Audit Results

Material of Construction

- Conventional mild steel
- Wire rope slings
  - Lower impact loading
  - Successfully used in the past
  - More flexibility (dynamic loading)

Audit Finding (J)

- Satisfactory

Design Audit Results

Welding Details & Procedures

- No weld details or weld procedures specified on drawings

Audit Findings (L)

- Information to be noted on drawing
- 6mm fillet weld adequate

Design Audit Results

Load Carrying Capacity of Members

- Each member of Kep system evaluated

SAFETY FACTOR BASIS

- Bracket to king post
- Bracket bolts
- Eye bolts
- Sling / Chain / Draw bar
- Shackle
- Kep Hook

LOAD FACTOR

- Station steelwork
- Cage

Design Audit Results

Static and Dynamic Safety and Load Factors

Spring housing restricting coil spring to 45 mm travel (not fully compressed)

RIGHT HAND KING POST

			Static	Dynamic						Note
Kepping speed (m/s)			0	0.35	0.40	0.50	0.60	0.70	0.80	
Applied loads: (kN)		(kN)	88.3	25.8	113.5	192.1	253.9	310.2	363.7	
Web bending capacity of king post (local)	Resistance loads: (kN)	275.5	3.12	10.66	2.43	1.43	1.08	0.89	0.76	(1)
Ultimate load capacity of bracket bolts		1290.0	14.61	49.94	11.37	6.72	5.08	4.16	3.55	(2)
Ultimate load capacity attachment bracket		2262.0	25.62	87.56	19.93	11.78	8.91	7.29	6.22	(2)
Breaking strength of eye bolt		565.5	6.40	21.89	4.98	2.94	2.23	1.82	1.55	(2)
Breaking strength of sling		647.1	7.33	25.05	5.70	3.37	2.55	2.09	1.78	(2)
Breaking strength of 12 t D shackle		635.7	7.20	24.61	5.60	3.31	2.50	2.05	1.75	(2)
Plastic strength of kep hook, at arm		230.0	2.61	8.90	2.03	1.20	0.91	0.74	0.63	(2)
Kep plate bending capacity on cage (local)		238.4	2.70	9.23	2.10	1.24	0.94	0.77	0.66	(1)
Dynamic/Static load ratio				**0.29**	**1.29**	**2.18**	**2.88**	**3.51**	**4.12**	
Proposed min SF on kep suspension members			**6**	**2**	**2**	**2**	**2**	**2**	**2**	
Proposed min load factor on king post and cage			**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	

Audit Findings (L)

- Kep hook required to be redesigned.

Design Audit Results

CENTRE KING POST

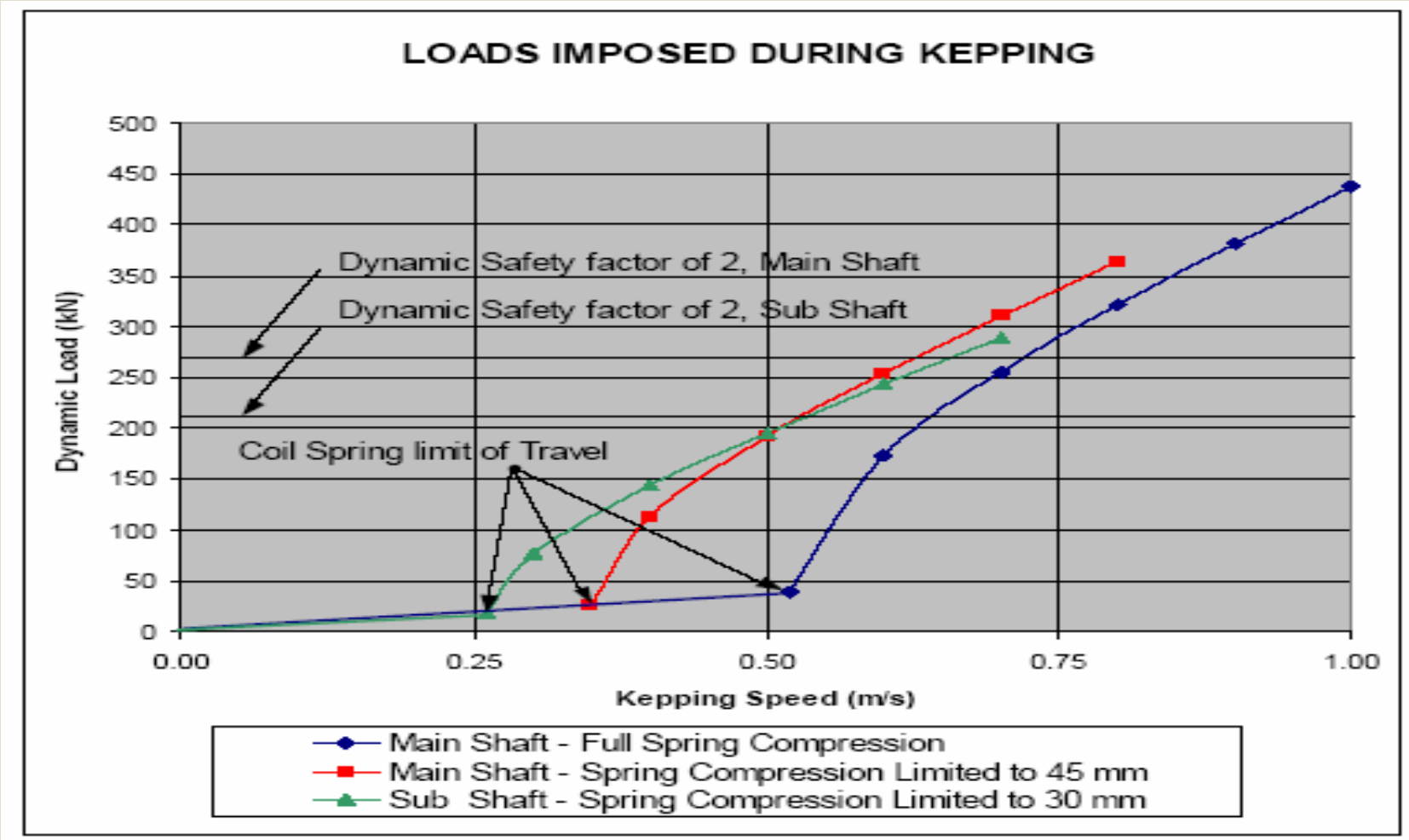
			Static	Dynamic						Note
Kepping speed (m/s)			**0**	**0.35**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	
Applied loads: (kN)		(kN)	88.3	39.63	99.6	164.0	215.0	261.4	305.6	
Web buckling capacity of king post (local)	Resistance loads: (kN)	275.5	*3.12*	*6.95*	*2.76*	*1.68*	*1.28*	*1.05*	*0.90*	(1)
Ultimate load capacity of bracket bolts		1290.0	*14.61*	*32.55*	*12.95*	*7.87*	*6.00*	*4.93*	*4.22*	(2)
Ultimate load capacity attachment bracket		2262.0	*25.62*	*57.08*	*22.70*	*13.79*	*10.52*	*8.65*	*7.40*	(2)
Breaking strength of eye bolt		565.5	*6.40*	*14.27*	*5.68*	*3.45*	*2.63*	*2.16*	*1.85*	(2)
Breaking strength of sling		647.1	*7.33*	*16.33*	*6.49*	*3.95*	*3.01*	*2.48*	*2.12*	(2)
Breaking strength of 12 t D shackle		635.7	*7.20*	*16.04*	*6.38*	*3.88*	*2.96*	*2.43*	*2.08*	(2)
Plastic strength of kep hook, at arm		230.0	*2.61*	*5.80*	*2.31*	*1.40*	*1.07*	*0.88*	*0.75*	(2)
Kep plate bending capacity on cage (local)		238.4	*2.70*	*6.02*	*2.39*	*1.45*	*1.11*	*0.91*	*0.78*	(1)
Dynamic/Static load ratio				**0.45**	**1.13**	**1.86**	**2.43**	**2.96**	**3.46**	
Proposed min SF on kep suspension members			**6**	**2**	**2**	**2**	**2**	**2**	**2**	
Proposed min load factor on king post and cage			**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	

NOTE:
(1) Load factors, static and dynamic: (Ratio of applied loads to factored resistance loads)
(2) Safety factors, static and dynamic: (Ratio of applied loads to breaking loads or ultimate load carrying capacity)

Audit Findings (L)

- Kep hook required to be redesigned.

Link Plates



Audit Findings (L)

- Coil spring effect
- Horizontal force on king post

Design Audit Results

Fatigue Stresses

- Only Kep hook and attachment bracket have welding of any significance

Audit Findings (J)

- Risk of fatigue failure within recommended limits.

Design Audit Results-Conclusion

- Helical coil spring limits dynamic loads to low values at about 0.35m/s
- Dynamic loads becomes very sensitive at higher speeds.
- Speed can be increase to 0.5m/s but require modifications to:-
  - Kep hook
  - Cage Kep plate
  - King post web

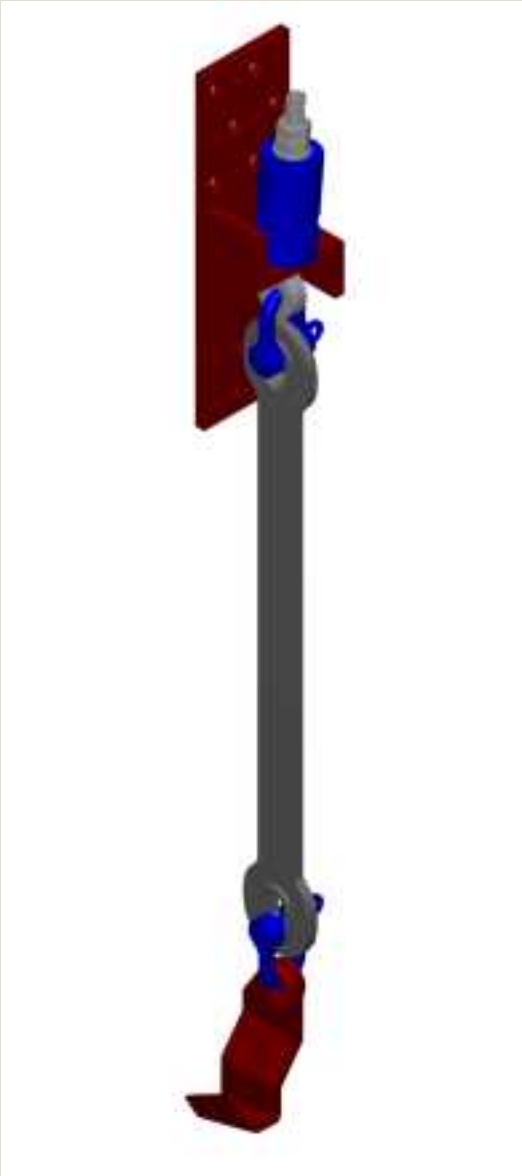
Scoping Exercise

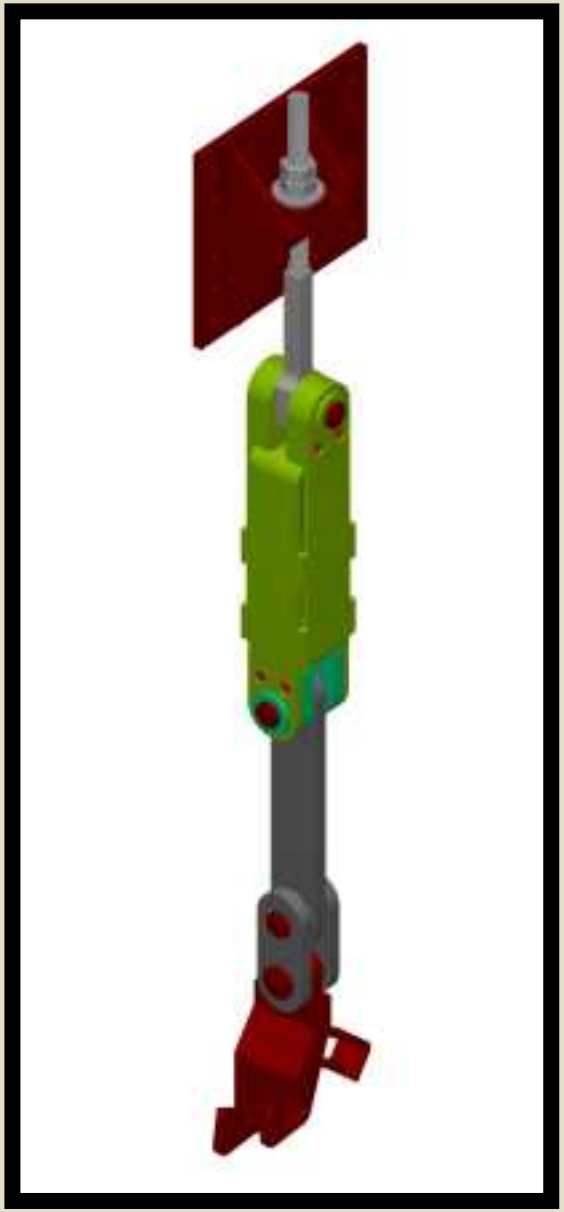
- Practicality of operating at low speeds
- What is creep speed?
- Do you bottom out the coil spring or have mechanical limits?
- New concepts and designs
- Gap between designer interpretation and operator interpretation

New Design Parameters

- Design for 1m/s operate at 0.75m/s
- Same concept
- Kepping cycle time not to be increased
- Fabrication requirements
- Review internal documentation

Old Kep String - New Kep String

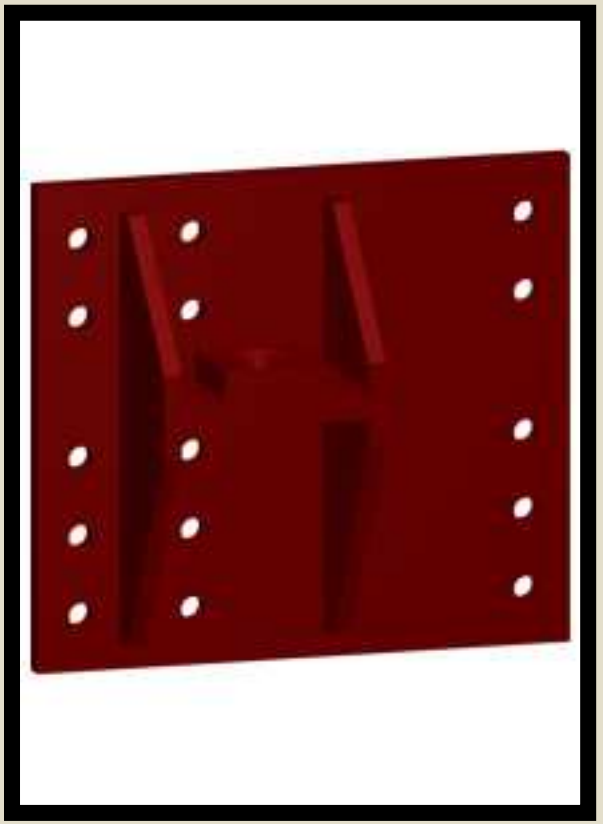




BRACKET DESIGN

OLD BRACKET

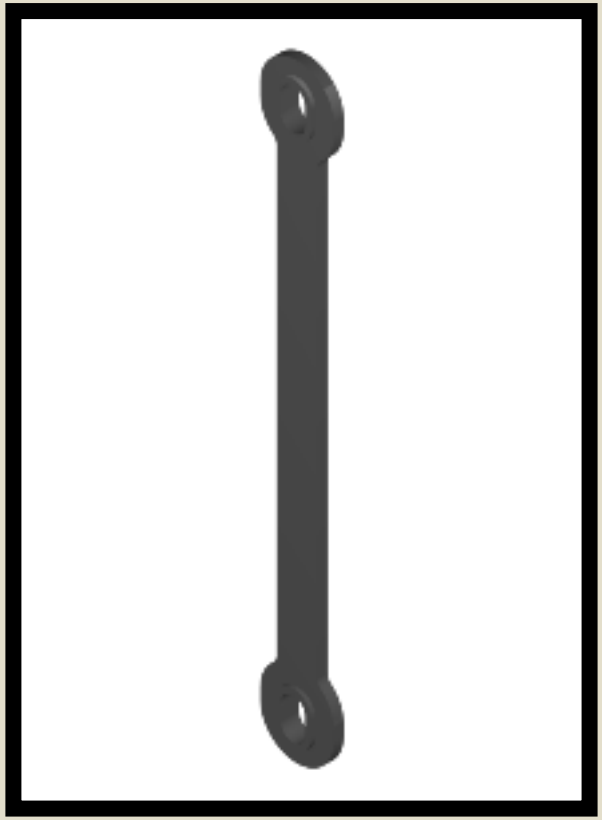
NEW BRACKET



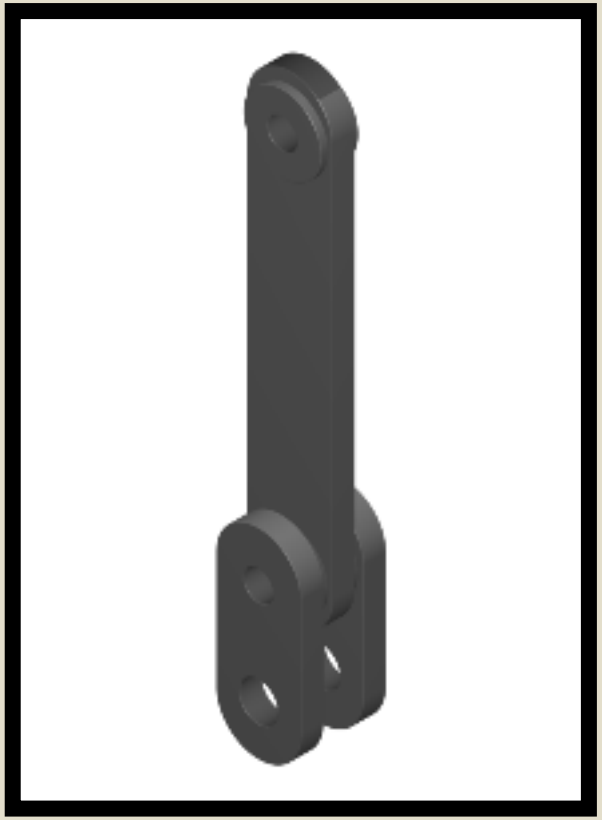
- Spherical washer to allow eye bolt to articulate

DRAW BAR AND LINK PLATES

OLD DRAW BAR

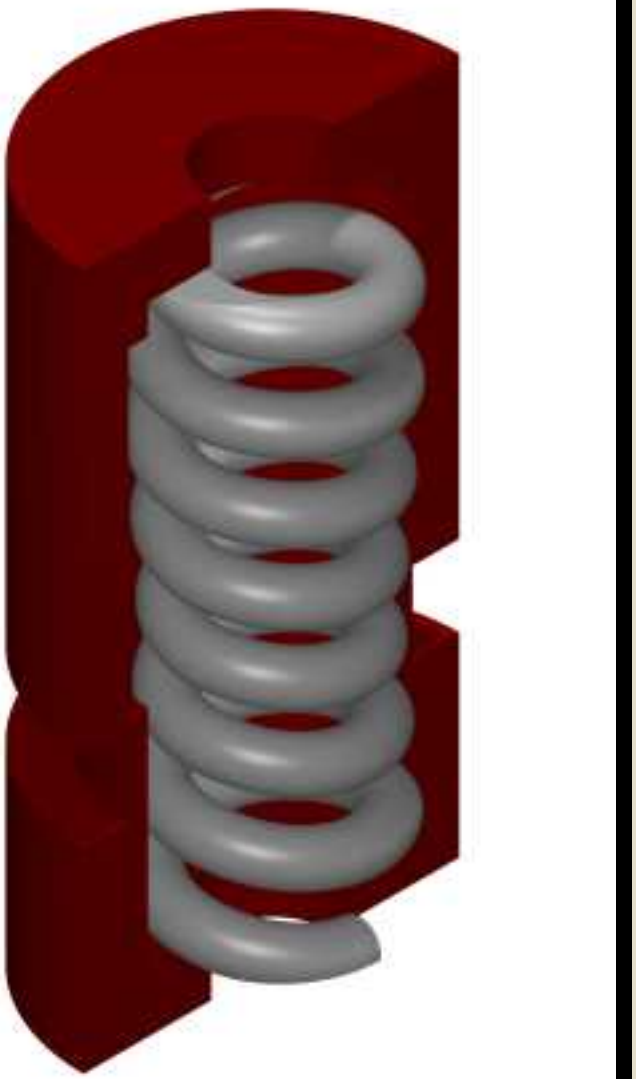


NEW DRAW BAR

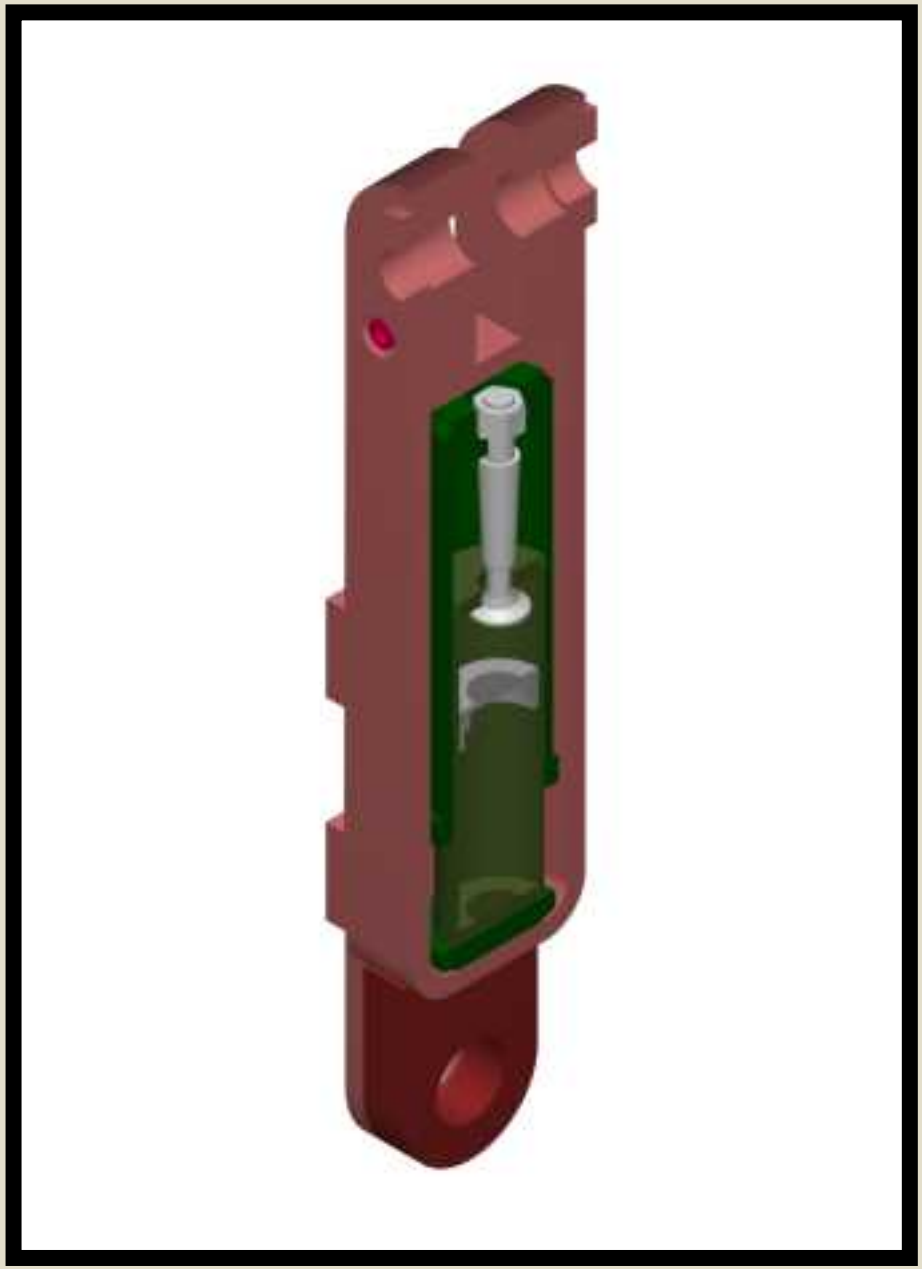


COIL SPRING BUFFER

OLD SPRING BUFFER

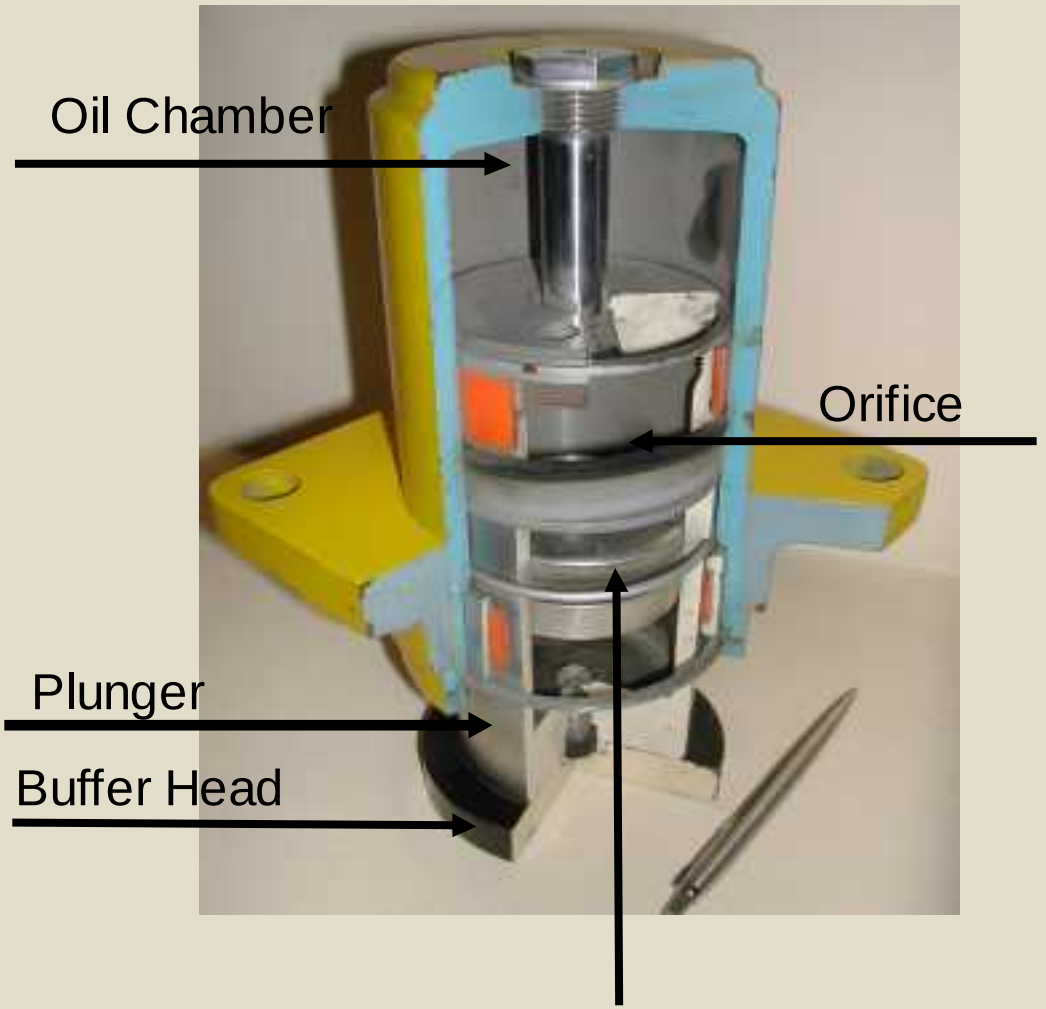


OLEO BUFFER ARRANGEMENT



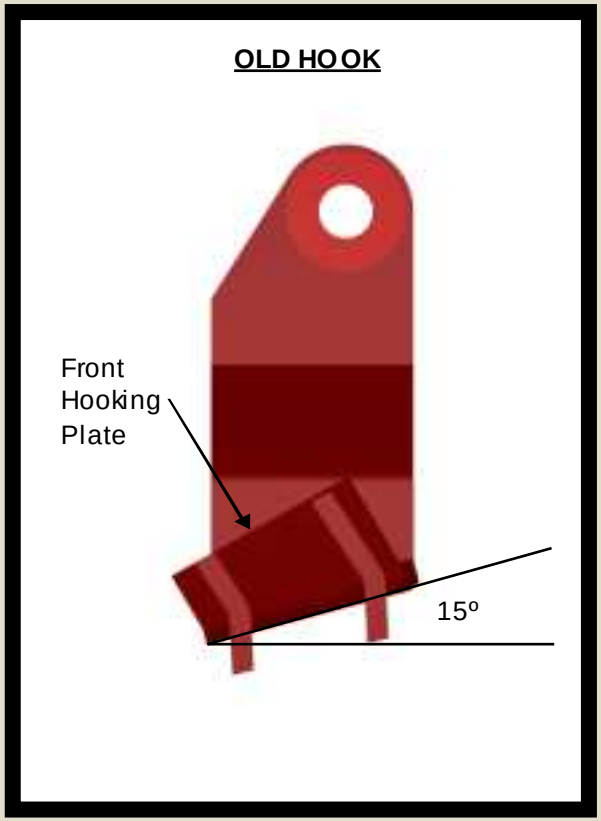
OLEO INDUSTRIAL BUFFER

- A large oil dashpot
- Robust construction
- Under impact the plunger is forced into the cylinder displacing the oil through the orifice.
- Floating separator piston moves towards the buffer head
- Compressed gas pressure increase, it extends the plunger

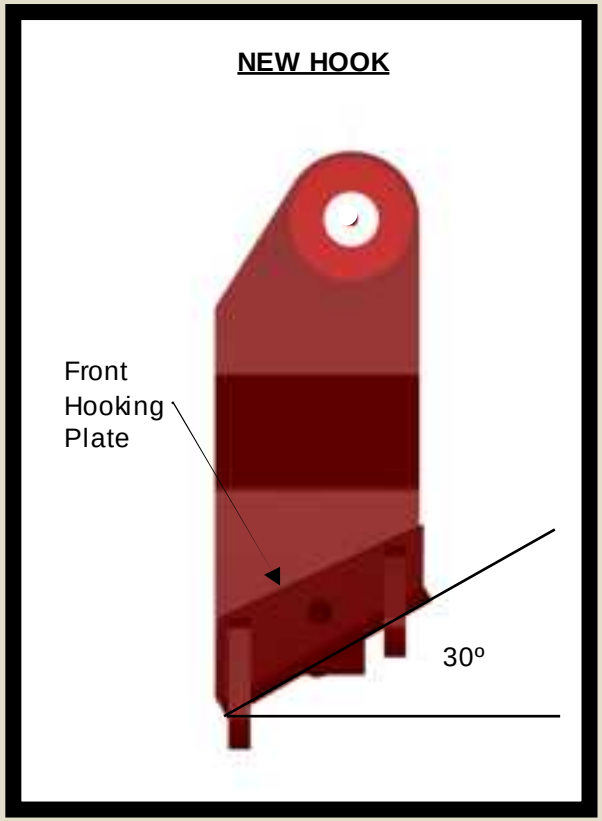


Hook

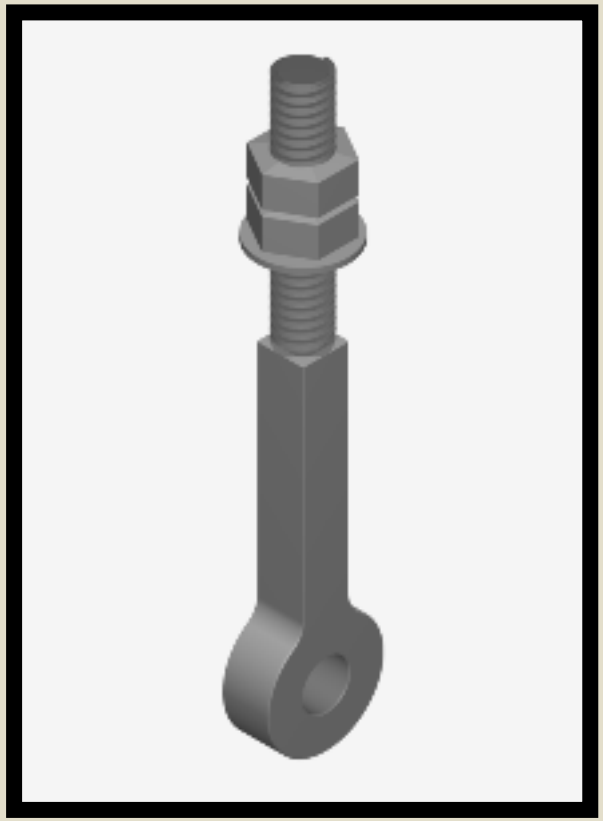
OLD HOOK

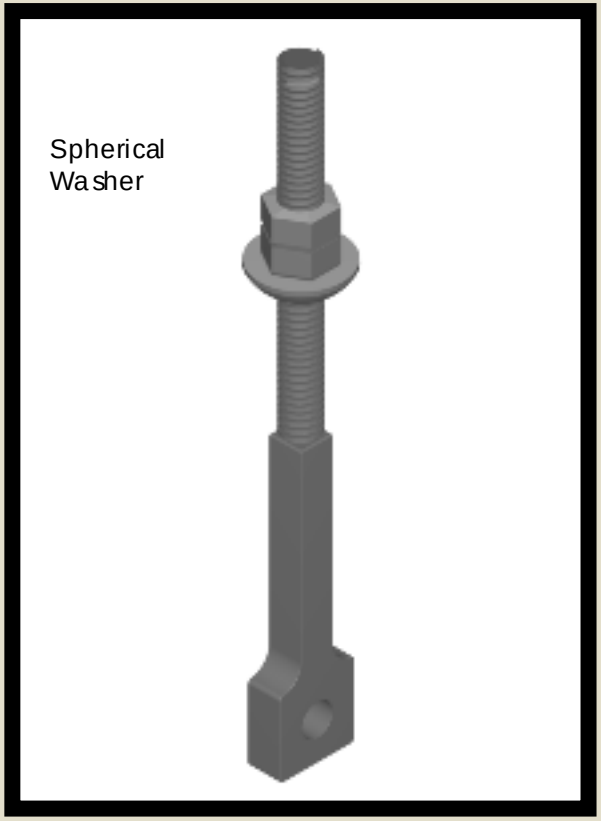


NEW HOOK



Eye Bolts and Spherical Washer





LESSONS LEARNT

- Bridge the gap between designer and operator
- Review guidelines and ensure they are applicable

Acknowledgement

- TauTona Mine
- Colleagues from AGA Engineering Design Services
- ATD – Specialized Engineering consultants

QUESTIONS