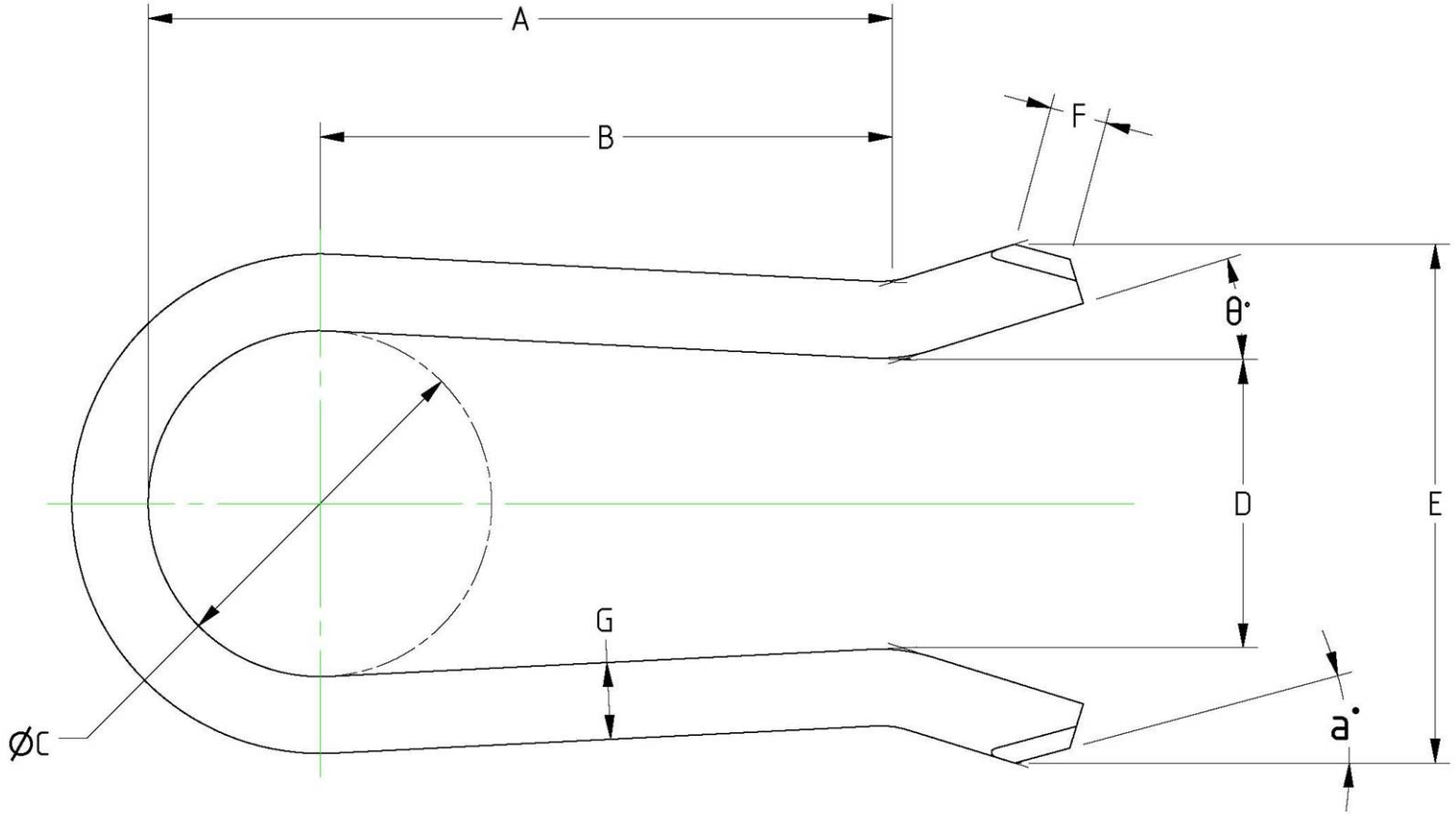
STAPLES



Post Second World War

Hydraulics used in mines for control systems
1946 Kelle Patents first Staple based on **12 Mpa** (1750 psi)

1950's – 1970's

Development of low seam Longwall type mining, using 6 leg supports
Staple technology (Stecko) adopted in longwalls

1970's – 1990's

Roof support designs improved to 4 & 2 leg shields
1979 Greenwalt Patents 'D' section staple
Hydraulic pressure increased from 20 Mpa (3000 psi) to **35 Mpa** (5000 psi)
1988 Hinksman Patents 'Super Stecko'
In-bye Pantec / main gate drives increase pump flow requirements
Guaranteed set at **42 Mpa** (6000 psi)

1990's to date

Electro- hydraulic controls
Out-bye pump stations + Monorails (increased flow)
Yield valve pressures raised to **52 Mpa** (7500 psi)
DN63, 35 Mpa (5000 psi) Monorail supply

Longwall hydraulic incidents

255 reports over 8 years

C.M.S. Insurance NSW

159 hydraulic hose or fitting failures

(54 of which were fitting related)

3 of these were fatalities

Gretley – Shield cylinder Intensification **(fluid Injection)**

South Coast – LHD Accumulator fitting failure **(fluid Injection)**

Angus Place – Pump station, disconnect under pressure **(fluid Injection)**

Appendix B

Staple Failure Modes

The following failure modes have been identified from previous examination of damaged staples.

1. Corrosion – General.

2. Corrosion – Pitting.

3. Corrosion – Crevis (local to the retention collar contact covered surfaces).

4. Wear – Abrasive + Corrosion (local to the retention collar contact surfaces).

5. Fatigue + Ductile Fracture.

6. Brittle + Ductile Fracture.

7. Corrosion Fatigue + Brittle + Ductile Fracture.

8. Corrosion Fatigue + Ductile Fracture.

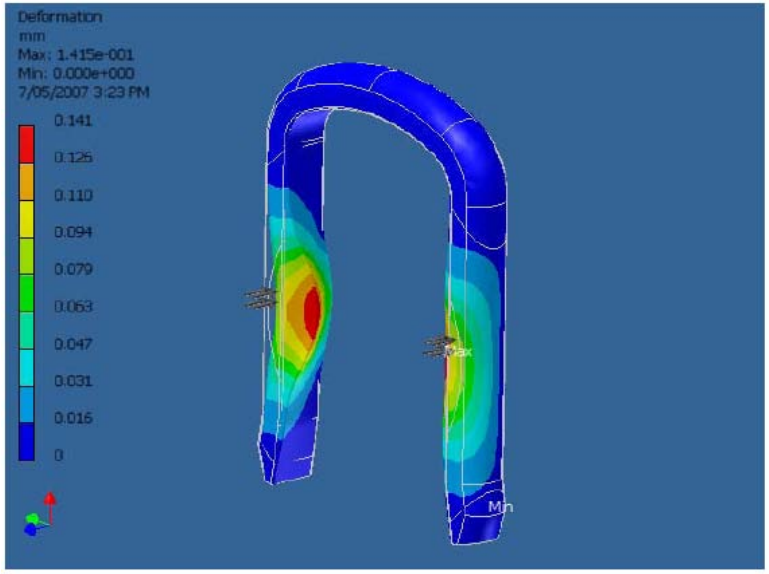
9. Hydrogen Embrittlement, Brittle Fracture (SCC related to the electro chemical reactions associated with Zinc plated, hi Carbon steel type staples).

10. Permanent shape deformation, in terms of an inability to maintain the original as manufactured shape after the initial insertion of the staple into the connection fittings.

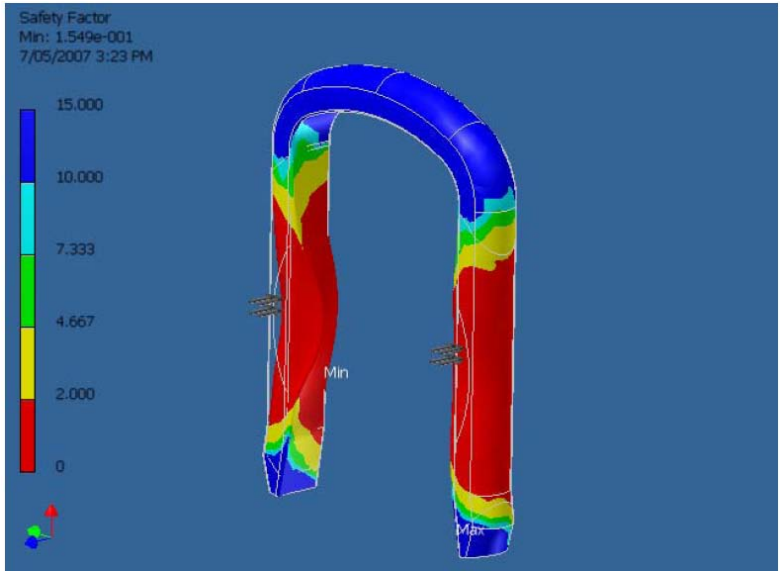
Known Staple limitations

FEA & FMEA

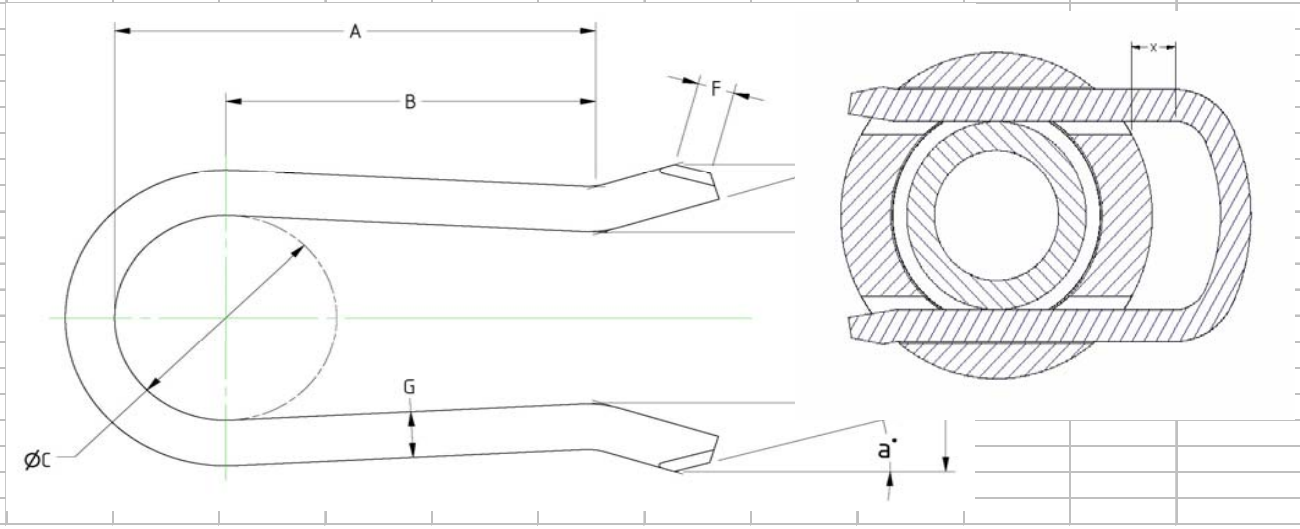
Deformation



FOS



STANDARDS	DN	A ± 0.5	B ± 1.0	C ± 0.5	D +0.5 -0.0	E +0.5 -0.0	F +1.0 -0.0	G SQUARE	G WIRE Ø	H ± 0.25	*a*	θ ref.	TOLERANCES ARE DIFFERENT FROM NCB 638 & DIN 20043	Nominated Working Pressure (bar)
BS 6537 *SQUARE SPRING*	10	38	19	14	12.5	22.9	3	3.93 4.07	NA	4	10º	8º		380
BS 6537 *SQUARE S/S*	10	41	26	14	13	25	3	3.93 4.07	NA	2.5	15º	20º		380
BS 6537 *ROUND S/S*	10	37	18	14	11.8	24.2	3	NA	4.78 4.72	NA	20º	10º		380
	DN	**A ± 0.5**	**B ± 1.0**	**C ± 0.5**	**D +0.5 -0.0**	**E +0.5 -0.0**	**F +1.0 -0.0**	**G SQUARE**	**G WIRE Ø**	**H ± 0.25**	*a*	**θ ref.**	TOLERANCES ARE DIFFERENT FROM NCB 638 & DIN 20043	
SAE J1467	10	NA	NA	NA	NA	NA	NA	4.07 3.93	4.78 4.72	NA	NA	NA		
	DN	**A**	**B ± .25**	**Ø C**	**D**	**E**	**F ± 1.0 - 0.0**	**G SQUARE**	**G WIRE Ø**	**H**	*a*	**θ ref.**	TOLERANCES ARE DIFFERENT FROM BS 6537, SAE J1467 & DIN 20043	
NCB 638	10	37	18	14.13 13.87	12.30 11.80	24.7 24.2	3	NA	4.78 4.72	NA	20º	10º		280
	DN	**A + 0,2 - 0.0**	**B + 1.0 - 0.0**	**C**	**D ± 0,5**	**E ± 0.2**	**F MIN**	**G SQUARE**	**G WIRE Ø**	**H ± 0.25**	*a*	**θ ref.**	TOLERANCES ARE DIFFERENT FROM BS 6537, SAE J1467 & NCB 638	530
DIN 20043	10	38	26	14	12.5	22.9	3	4	NA	-	NA	NA		



Staple fatigue test

ENGINEERING **YOUR** SUCCESS.

Staple fatigue test summary

	Super Staples **DN50 / -32**		Super Staples **DN40 / -24**	
Nominal rating	350 bar	420 bar	350 bar	420 bar
	'D' profile staple most successful, Laminated staple least successful		'D' profile staple most successful, Rectangular section least successful	
Most successful		Parker	Parker	Parker
Part No.	TBA	SS175D-32	SS175D-24	SS175D-24
Material grade	304 S/S	420 S/S	420 S/S	420 S/S
	no failures	no failures	no failures	no failures

	Standard Staples **DN20 / -12**		Standard Staples **DN12 / -8**	
Tested to	350 bar	420 bar	350 bar	420 bar
Most successful	DBT		Parker	
Part No.	DBT-12	TBA	S175-8	TBA
Material grade	1605 S/S	2205 S/S	420 S/S	2205 S/S
	mean / mode	mean / mode	no failures	mean / mode
	54.8k & 50.5k	184.6k & 202k		195.6k & 202k

Staple fatigue test conclusion

- Stainless steel (420) staples best results
- ‘D’ profile most successful Staple
- DN20 least successful <50k cycles
- DIN20043 & BS 6537 male & female
  are inter-changeable, but neither standard adequate for staple demands at current operating requirements

Typical shield advance

The sequences identifiable in this chart roughly match the functions described in the "West Wallsend Shield Auto Sequence" (ASQ) description. It is not entirely clear where item 3 begins, or why the leg annulus pressure is close to 300bar between the 8.5 and 9 second points. It has been postulated that the high annulus pressure at this time is an "inertial" effect associated with base lift or shield rocking during advance.

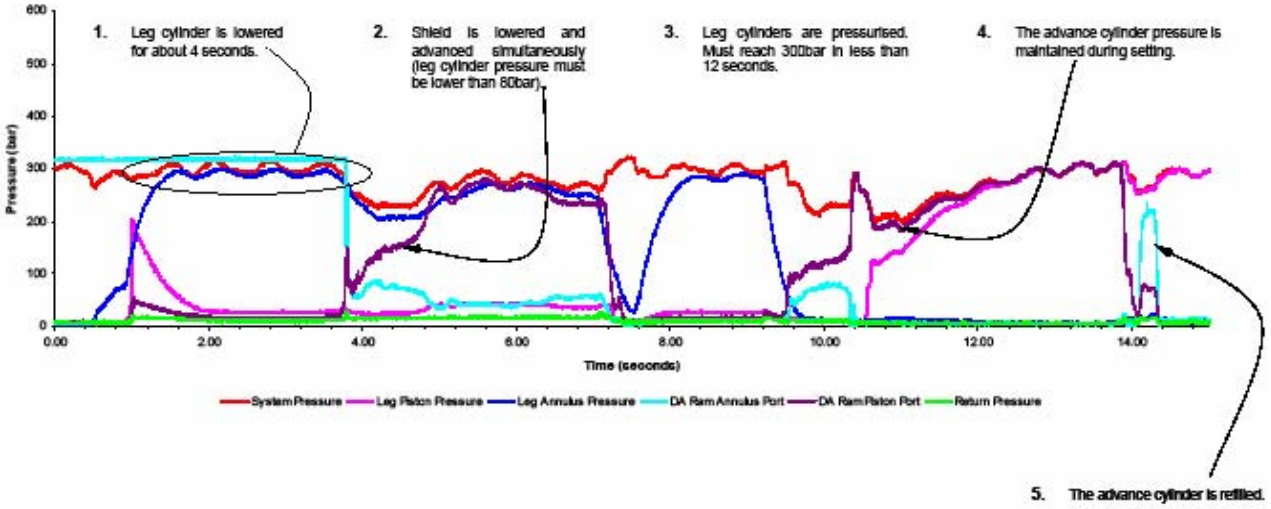
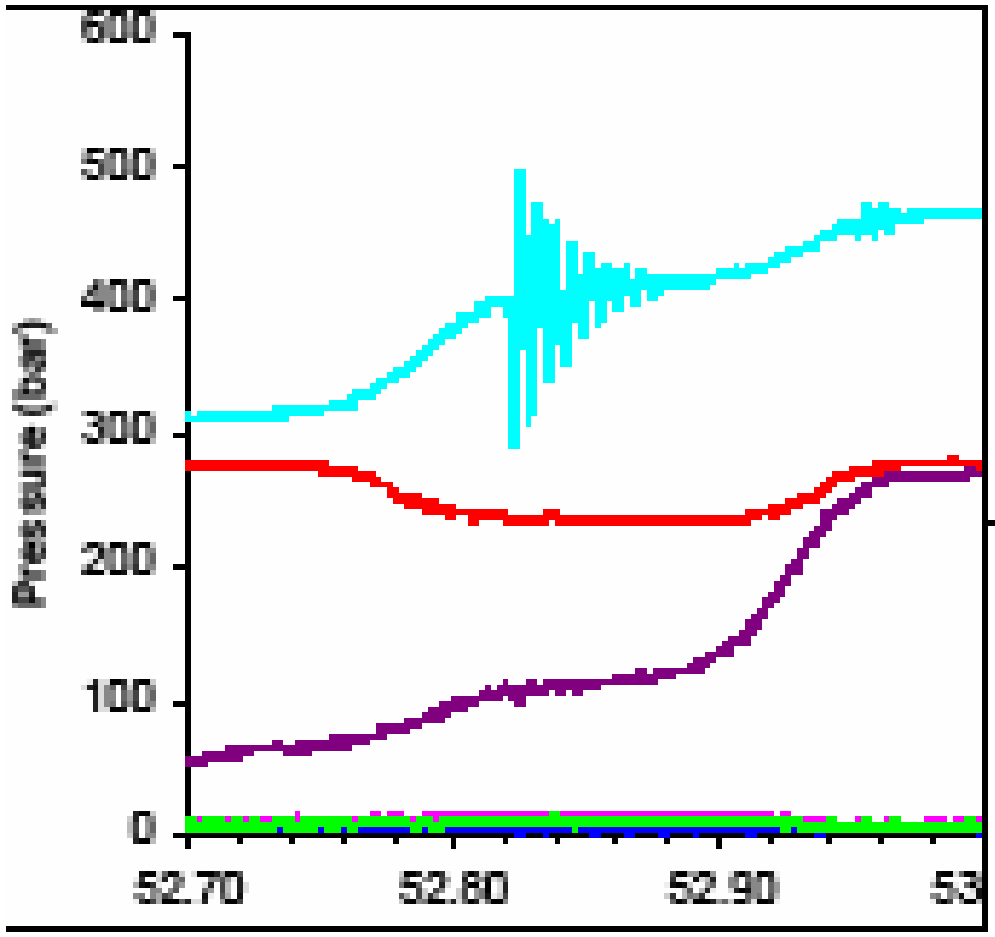


Figure 6 Automatic Shield Operation Characteristics (Normal Longwall Operation, After EV9 & EV10 Replacement)

Worst case



Some pressure "spikes" oscillate at ~150Hz, probably due to POCV instability. The pilot pressure (the DA ram piston pressure) appears to plateau during the instability.

Life cycle management

Based on WBM study of West Wallsend Longwall + others by Bucyrus (DBT) & Joy Mining.

Critical circuits identified are DA advance, Base lift & legs lower

Based on typical Longwall advance rate = 1650 PA

Pressure cycles per advance (auto advance) = 2

Maximum peak* pressure cycles per advance = 22

Best case:- 2 pressure cycles per advance

ie, 1,650 Advances x 2 cycles / advance = 3,300 cycles PA

Worst case:- 22 measured peak pressure cycles, during advance *

ie, 1,650 Advances x 22 cycles / advance = 36,300 cycles PA

Hence staple life can be determined by dividing, rated cycles by anticipated cycles. Based on DN20, some **staples will have failed within the first 8 months** as first DN20 staple failures (regardless of staple manufacture) occurred by 26,000 cycles.

**Advance patterns affect the number of peak pressures per advance,*
ie number of chocks advanced, sequence of advanced chocks, roof & floor conditions etc

Pressure characteristics in given circuits may also vary based on 'push back' from adjacent shields during automatic advance, shearer & web cut (when passing shield), manual face realignment.

**Impact of over pressurization approximates to increased fatigue at a ratio of cubing (X3)*
ie impact of a 500 bar load (as recorded) is four (4) times that of a 350 bar system operating pressure.

Staple fatigue test implications

The report concludes that standard staple lock staples should be Stainless Steel, square section, where grade 2205 duplex has the most consistent characteristics. Super staple lock staples should be 'D' section where grade 420 stainless or 2205 duplex.

- DN20 staple is the most susceptible to cyclical demand. Future Longwall designs may need to review the appropriateness of the DN20 staple in critical applications.
- Repeated use of staples has also been identified as a key contributing factor in staple life. Staples are consumable and must not be reused, if safety & integrity of the union is to be maintained.
- Advance, base lift & legs lower circuits identified as highest recorded peak pressures in Longwall circuit. (Typically DN20)

Critical application staples, such as DA, Base lift & legs lower should be replaced every Longwall move

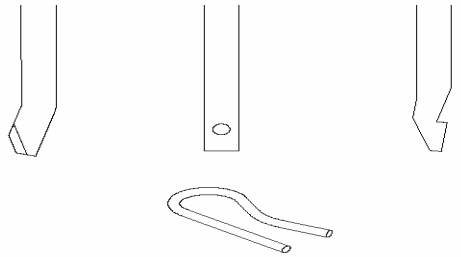
Staple Retention

- Staple retention addresses two basic elements, walk out and containment of staple legs in the event of fatigue failure
  - Walkout is the progressive tangential displacement of the fitted staple in a ‘staple lock’ coupler and is typically the result of high frequency hydraulic pulsations.
- Preventing staple walkout can be achieved by various devices, including, Bucyrus cable tie (Pat. 2006906264), mechanical plates and clips
  - Other staple devices such as metal strips fitted after the staples are installed (in manifolds), also have the ability to prevent staple ‘walk-out’.
  - It must be noted staple ‘walk-out’ devices do not offer any additional protection when staple leg fails.
- Containing staples addresses potential walkout + legs falling out
  - Alternate staple retention devices include tapes and straps

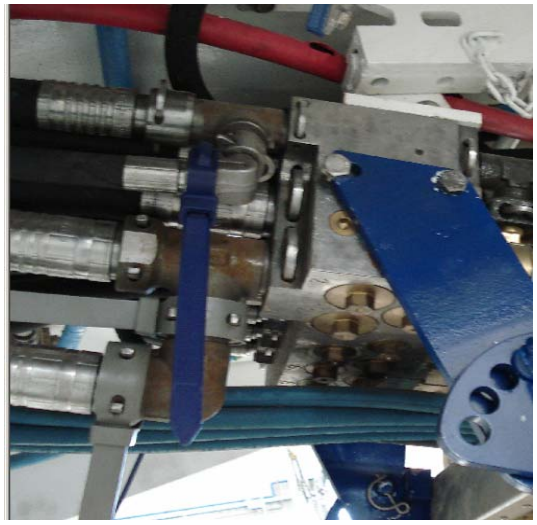
Staple Retention

Staple retainer

Staple & Mine sleeve retainer - Velcro straps, electrical insulation tape (fitted over installed staple)



Staple walk-out prevention



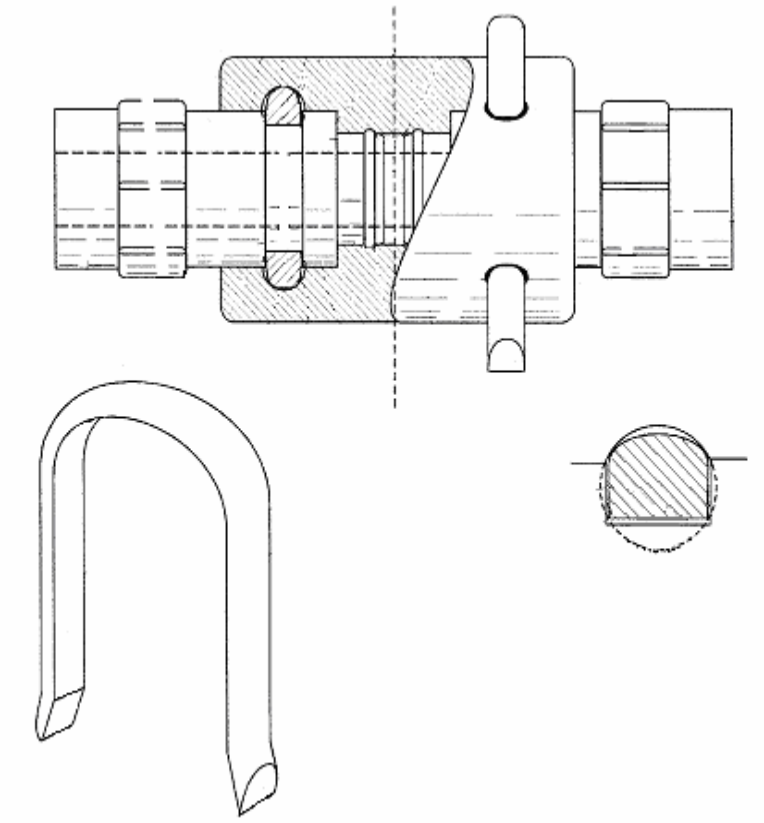
Bucyrus Cable tie
(Pat. 2006906264)

Rubber band (fitted over installed staple)

XSTRATA COAL
NSW

Standard Specification
for the supply of
Staple Lock Fittings

42 MPa Staple standard



PROPOSED ISO SUBMISSION Based on DIN 20043 / SAE 1467 / NCB 638 / BS 6537

420 bar Staple-lok fittings for hydraulic power-transmission circuits, primarily used in mining applications.

Forward:

This proposed standard applies to staple-lok fittings and adaptors, which are used to connect hydraulic fluid based systems. The proposed standard seeks to clarify minimum material and dimensional requirements for a 420 bar connection, whilst maintaining a 4:1 factor of safety.

The proposed standard defines

minimum working pressure of the assembled fitting (including its staple)

relevant testing and conformance standards

arrangement of components & their individual dimensions

material specifications for the components

corrosion resistance of metal components

identification

minimum burst pressure

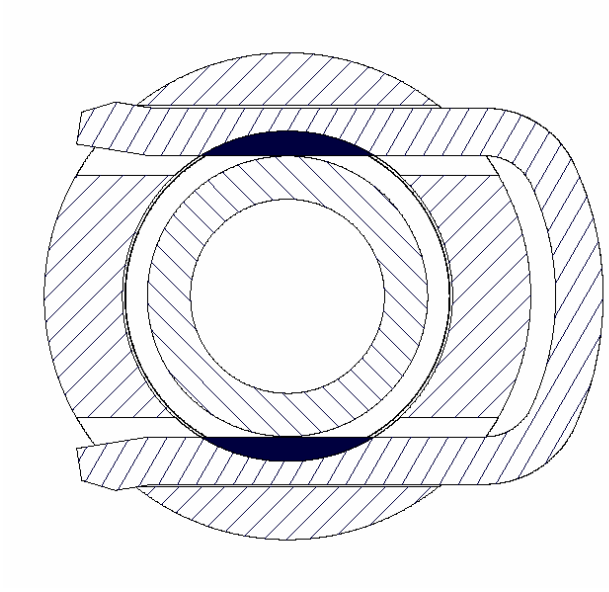
impulse requirements of the assembled fitting

Section 1/. Minimum working pressure

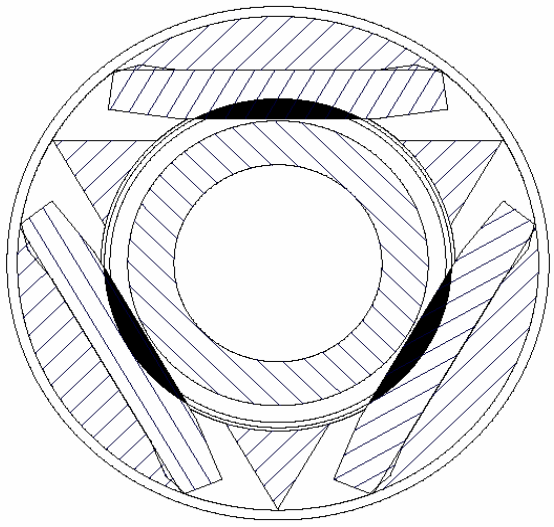
Table 1 Minimum working pressure of the assembled staple-lok fitting based on 4:1 FOS per ISO 7751

Staple alternatives

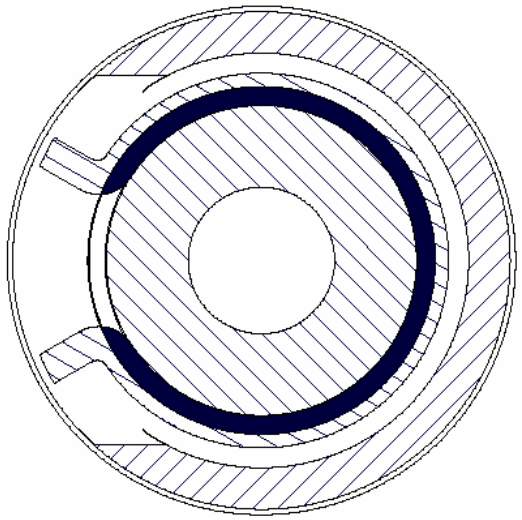
Showing area engaged



Typical
Staple lock



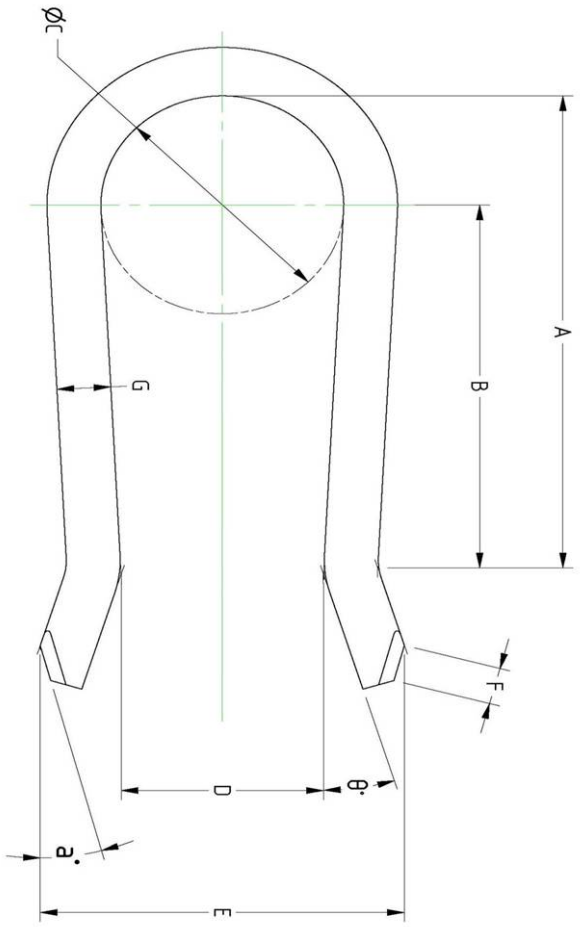
3 pin + garter



Clip-lok
Patented

Do's + Don'ts for Staples

Based on metallurgical evaluation



Do's

- Understand cyclical demand
- Use staples once ONLY
- Obtain material Certificate of Conformance

Don'ts

- Hardness >40 HRC
- Electroplated (Hydrogen embrittlement)
- 304 Stainless (sulphur resistance)
- Barbed legs (broaching female)
- Identification stamped on legs

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SAFETY ALERT

Longwall staple failures

INCIDENT

There have been a number of recent incidents of failed staple lock fittings with

INVESTIGATION

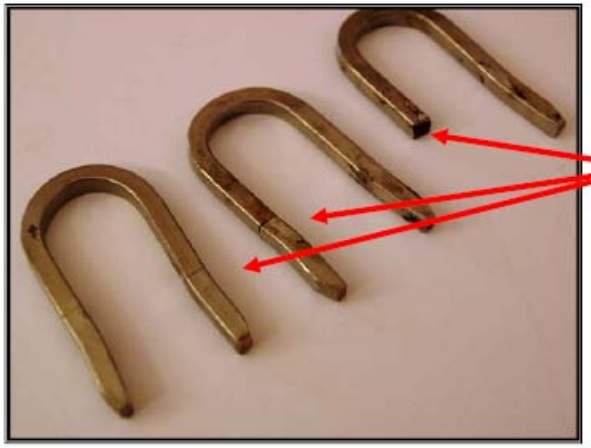
Visual audits of the longwall equipment have failed to identify any broken staples. The investigation is continuing to determine the causal factors in the incidents. General staple failure modes include, but are not limited to;

- Broken staples
- Cracked staples
- Physical abuse of staples
- Fatigue exceeding service life of the staples
- Overload of staples, evidence by witness marks (i.e., the staple has been overloaded past its design yield loading which has weakened the staple)
- Mechanical overload from external sources being hit by debris or excessive bending moment
- Wear of staples
- Wrong specification for staple material and dimensions
- Poor quality control of staple manufacture
- Corrosion.

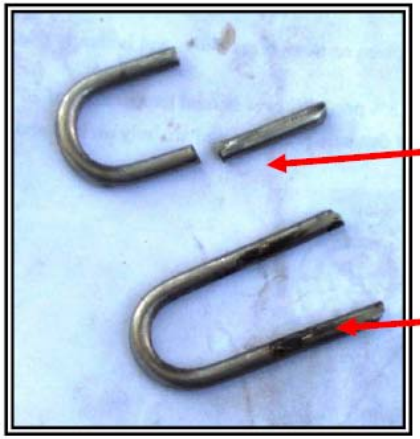
NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SAFETY ALERT

Longwall staple failures



Staple legs broken and cracked



Broken Staple Legs

Wear Marks

Staples worn and starting to wear where the hose is contacted

Wear marks

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SAFETY ALERT

Longwall staple failures

RECOMMENDATIONS

KEY

1. Audit staples in the high-risk areas on longwall equipment for damaged staples (outlined above in general failures). Also look for staples migrating out of position.
   Note: The cracked staple legs may not be visible in situ.
2. Staples should be correctly positioned and positively retained.
3. Replace a sample of the staples in the high-risk areas and have these staples inspected and tested for integrity. (Attempt to determine the staple life). This may require advice from suppliers and manufacturers in assisting to determine a wear rate for staples, given service life and location within a hydraulic system.
   High-risk areas may be:
   - Areas nominated by the operational risk assessment
   - High-duty cycle operations
   - Staples located around the walkways
   - High-pressure positive set applications
   - Areas where intensification is likely.

KEY

4. Periodically audit the face for staple condition and retention.
5. Appreciate that staples have a limited service life (undetermined). This same approach is to be used for hoses, fittings and all components.
6. Replace the staples when hoses and components are replaced (i.e., use the staples once).
7. Provide suitable levels of safety where the personnel usually operate. Consider a hard barrier (guard/cover) between the high-risk areas and where the personnel usually operate (both operators and maintenance personnel).
8. Provide suitable levels of safety for employees and contractors when performing maintenance.
9. Generally operate the equipment from a remote location to limit exposure (time and space between the employee and the hazard).
10. Consider a secondary means of retaining the staples (consult with the manufacturer to determine if they have alternate methods).
11. Identify the special staples in the circuit and ensure correct spares are available at the mine and that tradesmen are aware of the special staples (special staples could be the long staples that retain two or three hoses/ports or components).
12. Only use compatible staples and fittings. Do not mix and match different types and manufacturers' staples and fittings.

STAPLELOCK ASSEMBLY GUIDELINES

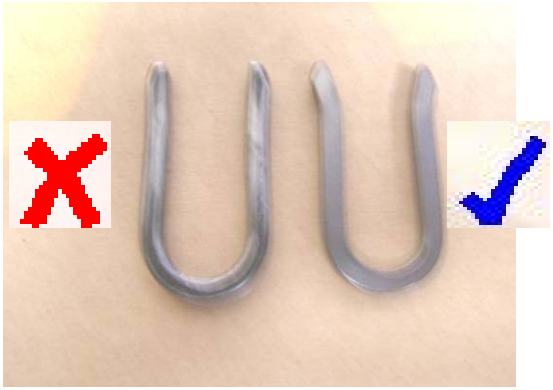
•Don’t start to assembly a hose without a staple available, a left hose may be forgotten, and the system pressurised

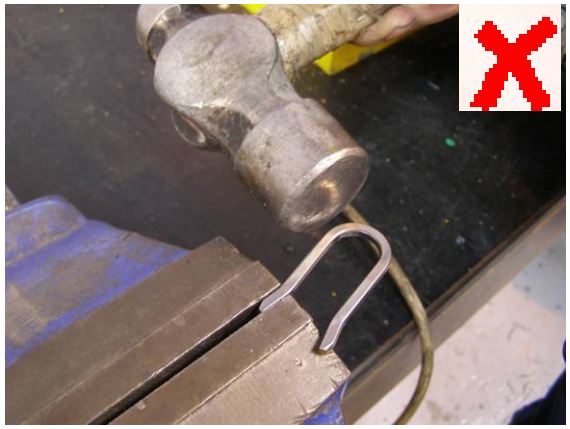
•NEVER FIT STAPLES INCORRECTLY – Just one leg

•NEVER FIT STAPLES INCORRECTLY – Assemble the staple fully through the fitting

STAPLELOCK ASSEMBLY GUIDELINES

•NEVER FIT STAPLES INCORRECTLY – Don’t straighten staple legs to enable easier fitting, the crank is essential to the staples design

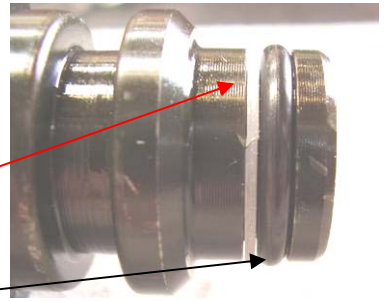




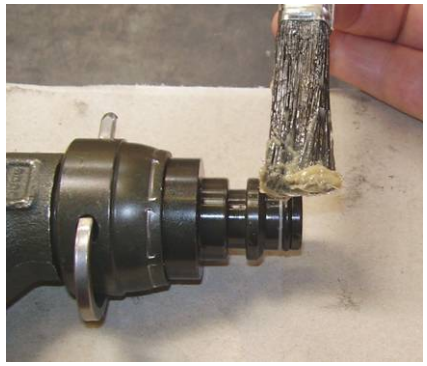
STAPLELOCK ASSEMBLY GUIDELINES

Staplelock connector guidelines, suggested method of assembly

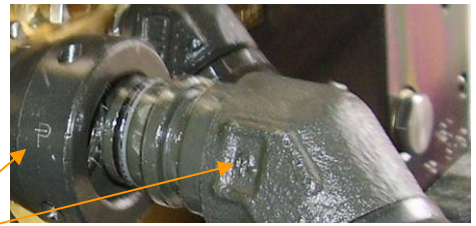
- Prior to assembly check O-Ring is assembled outboard to Back Up Ring



- Lubricate around O-Ring and B/U Ring as necessary with approved grease or lubricant, ensure no transfer or ingress of dirt

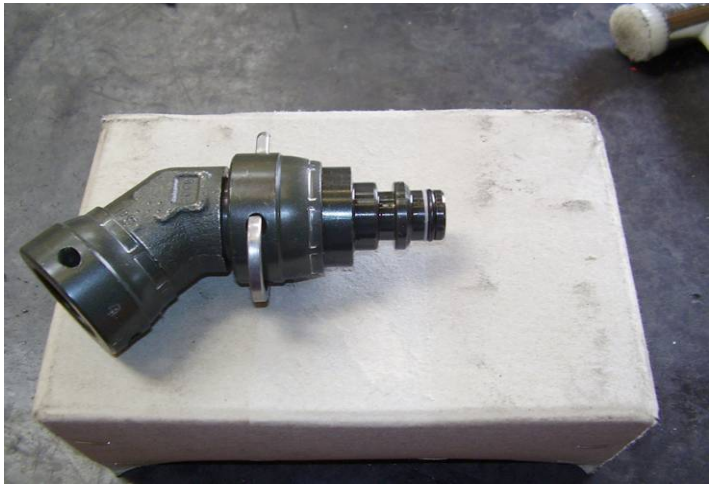


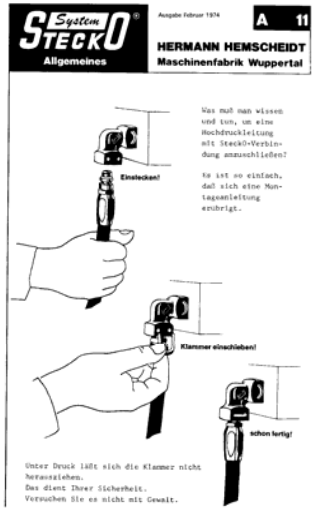
- Offer male end square to female port, do not attempt to force home at an angle



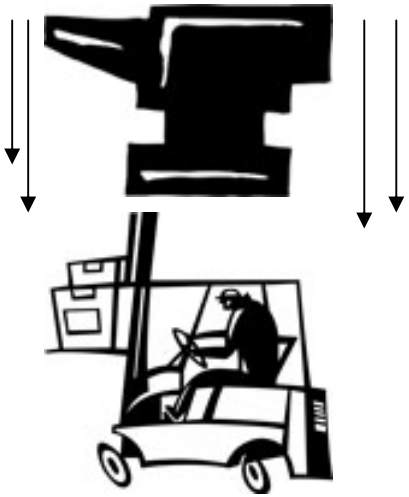
STAPLELOCK ASSEMBLY GUIDELINES

- Push male end fully into female port, ensuring the staple holes in the female line up with the staple groove in the male
- Line up staple square with the staple holes in the female adaptor, and drive fully home with a plastic headed hammer, ensure staple legs are fully through the assembly
- Always ensure all open ports are properly capped/plugged with the right size cap/plug, to prevent ingress of dirt into system





STAPLELOCK ASSEMBLY GUIDELINES



=

•NEVER attempt to remove staples from a pressurised circuit

•When freed from coupling a pressurised hose will whip with severe force causing serious, probable fatal injury

Indications of pressurised circuits are :-

Rigid hoses

Connections are hard to turn

Staples feel solid and very difficult to move

•IF IN DOUBT ASK, fully check pressure has been decayed before carrying out any work

•NEVER assume return line circuits are low pressure applications, apply the same safeguards as high pressure circuits

•NEVER attempt to feel for hydraulic leaks, fluid injections can be fatal, and hard to diagnose

STAPLELOCK ASSEMBLY GUIDELINES

- Tools are available for disassembly of staples
- Always avoid the use of excess force on hose ferrules
- Always take care not to damage hose ends, adaptors or mating parts
- Always lever out staples rather than use direct force

STAPLELOCK ASSEMBLY GUIDELINES

Remember hydraulic fluid under pressure can be dangerous, always follow recommended procedures. Never cut corners, always treat equipment with respect. IF IN DOUBT ASK, don't risk injury.

Thank You!