Loco. trial No. 288, dated 10th April 1990.
Fitting bursting disks in place of cylinder drain valves.
Applicable to various classes of
Garratt locomotives operating on Rhodesia Railways

Notes to readers

The source document for this file was the Office Copy held in the National Railways of Zimbabwe Drawing Office in Bulawayo. It was discovered, in March 1998, while I was helping with searching for a complete set of drawings of the 15th Class locomotives after No. 398 had been purchased by a private group in New Zealand for eventual export to that country.

The original document was a duplicated copy hence the slightly indistinct type in some places. This was photocopied (with permission) on to A4 size paper while in the Drawing Office and the photocopies scanned when we were back in New Zealand.

The scanned file has been lightly "Photoshopped" to remove most of the artefacts resulting from the photocopying and scanning processes and to increase the contrast to make it more readable.

Any alterations, amendments or corrections done by hand have all been left in place and this file is a reasonably accurate reproduction of the original.

Alan Bailey
December 2010

O.T.M.

NATIONAL RAILWAYS OF ZIMBABWE

OFFICE OF THE
CHIEF MECHANICAL ENGINEER
BULAWAYO

REFERENCE : M.C.M.E.'S CIRCULARS, FOLIOS 15 TO 17 OF 1981.

DATE : 10 APRIL 1990

ORIGIN : M.E (D&D) VERBAL

FITTING OF BURSTING DISCS IN PLACE OF CYLINDER RELIEF VALVES ON THE CYLINDER COVERS: 14A, 15TH AND 16A CLASS LOCOMOTIVES.

CODE OF TRIAL L.T. NO. 288.

1.00 REASON:

1.01 To safe-guard the cylinders in cases where steam locomotives are set in motion prior to draining of condensed water through drain valves.

1.02 To ensure consciousness among enginemen as to the importance of draining condensed water in the cylinders as they will be required to submit a report in the event of the discs bursting.

2.00 ALTERATION:

2.01 The cylinder relief valves are to be replaced with bursting discs secured in accordance with N.R.Z. Sketch Nº.S.L.S.-1017.

3.00 APPLICABLE TO:

3.01 Five each of the following classes of locomotives - 14A, 15TH and 16A as selected by the Mechanical Engineer (Southern Area), Bulawayo.

4.00 TO BE CARRIED OUT:

4.01 At the Bulawayo Steam Sheds and Mechanical Engineer's Workshops, Bulawayo, at the discretion of the Mechanical Engineer, (Southern Area), Bulawayo.

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5.00 INSTRUCTIONS:

5.01 Mechanical Engineer (Southern Area), Bulawayo to advise this office, with copy to Mechanical Engineer (Workshops), Bulawayo on the numbers of the locomotives selected, together with dates of modification.

5.02 Mechanical Engineer (Workshops), to conduct quality tests on bursting discs mounted in the improvised holder manufactured as per National Railways of Zimbabwe sketch No. S.L.I. - 1017. Thickness of each batch of discs required for bursting pressure of 580P.S.I. (4000kPa) to be established on the bench, depending on the material composition.

5.03 Code of Trial to be stencilled on the cab sides of the locomotives concerned.

6.00 REPORTS:

6.01 Mechanical Engineer (Southern Area) to issue regular reports to this office as to the effectiveness of this trial.

7.00 DURATION OF TRIAL:

7.01 Until a satisfactory conclusion is reached.

8.00 SUPPLIES:

8.01 Supplies Manager to arrange for the manufacture and supply of the following items:

NOM	ITEM NO.	DRG/SKETCH NO.	QUANTITY
Body	1	S.L.S. - 1017	120
Nut	4	S.L.S. - 1017	120
Safety Disc	2	S.L.S. - 1016	120
Special Washer	G	136/119	120
Sealing Wire	3	S.L.S. - 1017	
Lead Seal	5	S.L.S. - 1017	120

When the items are ready, Supplies Manager to inform Mechanical Engineer (Southern Area), Bulawayo who will arrange for their acquisition.

8.02 Supplies Manager also to arrange for the manufacture of 15 spanners (special) as per N.R.Z. Drawing No. M-6671/374 which are to be allocated to each of the selected locomotives.

9.00 CHARGE:

9.01 Cost Code 7348: Expense Code 5597.

10.00 DRAWINGS:

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10.00 DRAWINGS:

10.01 Copies of N.R.Z. Sketch Nos. S.L.S. - 1016 and S.L.S. -1017, and Drawing Nos. 136/119 and M-6671/374 to be sent to Mechanical Engineer (Southern Area), Bulawayo and Mechanical Engineer (Workshops), Bulawayo.

CHIEF MECHANICAL ENGINEER

DISTRIBUTION:

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APPENDIX I

OPERATING PARAMETERS

Steam operating pressure (q) $\simeq$ 13 BAR (200 PSI)
Steam superheat temperature (T_s) = 150°C

Relief valve opening pressure = 220 PSI
$\simeq$ 15.168 BAR

Disc set to burst at 20 BAR
$\simeq$ 290 PSI

The South Africans gave a bursting pressure of 580 PSI for the sample supplied but it is felt that a burst pressure of 20 BAR (290 PSI) will suffice since the relief valve opening pressure 220 PSI is already above operating pressure and incorporates a factor of safety (F) given by

$$F_{RV} = \frac{220}{200}$$
$$= 1.1$$

For the disc, $F_D = \frac{290}{200}$
$$= 1.45$$

APPENDIX II

DISC DIMENSION CALCULATIONS

From the design ~~drawings~~ sketch S.L.S 1017

Area of disc $= \frac{\pi D^2}{4}$

$= \frac{\pi \times 0.085^2}{4}$

$= 5,674\ 501\ 7 \times 10^{-3}\ m^2$

Area of disc exposed to pressure $= \frac{\pi \times 0.065^2}{4}$

$= 3.318\ 307\ 2 \times 10^{-3}\ m^2$

From machine design (solid mechanics), for a disc fixed at the edges, the thermal stress is given by

$$\sigma_T = \frac{\alpha (\delta T) E}{1 - \nu}$$

where α = thermal coefficient of expansion
ΔT = temperature change
E = material modulus of elasticity
ν = Poisson's ratio

For a uniformly loaded disc clamped at the edges, the maximum stress due to the applied pressure is given by

$$\sigma_q = \frac{3qR^2}{4t^2}$$

where R = radius of disc
t = thickness of disc.

Hence, total stress on disc is

$$\sigma_{ST} = \sigma_T + \sigma_q$$

For bursting to occur the total stress should at least equal the disc material ultimate tensile strength, thus

$$\sigma_{ST} = \sigma_{UTS} = \sigma_T + \sigma_q$$

Thus

$$\sigma_{UTS} = \frac{3qR^2}{4t^2} + \frac{\alpha(\Delta T)E}{1-\nu}$$

$$\Rightarrow t^2 = \frac{3qR^2}{4\left(\sigma_{UTS} - \frac{\alpha(\Delta T)E}{1-\nu}\right)}$$

From which the disc thickness can be calculated after σ_{UTS} and E have been obtained.

APPENDIX III

OBTAINED RESULTS

Assumed values $\nu = 0.3$

$\alpha \simeq 10.6 \times 10^{-6}$ (Temp range of $0 - 250^{\circ}C$)

Tensile strength, from results obtained at the analytical laboratory

SAMPLE	DIAMETER	ULTIMATE LOAD
1	14.4 mm	36.5 KN
2	14.3 mm	37.5 KN

From stress $\sigma = \frac{\text{FORCE}}{\text{AREA}}$

$$\sigma_{UTS(1)} = \frac{36.5 \times 10^{3} \times 4}{\pi \times 0.0144^{2}}$$

$$= 2.241\,1865 \times 10^{8}\ Pa$$

$$\sigma_{UTS(2)} = \frac{37.5 \times 10^{3} \times 4}{\pi \times 0.0143^{2}}$$

$$= 2.334\,9055 \times 10^{8}\ Pa$$

$$\sigma_{UTS} = \frac{\sigma_{UTS(1)} + \sigma_{UTS(2)}}{2}$$

$$= 228.805\ MPa$$

From the observations $E = 76 \times 10^{9}\ Pa$

$\Delta T = 150^{\circ}$

Substitution of all parameters into formula derived in Appendix II gives

$$t^2 = \frac{3 \times 20 \times 10^5 \times 0.065^2}{4 \times 4 \left(228.805 \times 10^6 - \frac{10.6 \times 10^{-6} \times 150 \times 76 \times 10^9}{1 - 0.3} \right)}$$

$$= 2.820\ 355\ 5 \times 10^{-5}\ m^2$$

$$\Rightarrow \quad t = 5.31\ mm$$

$\therefore$ required disc thickness $\underline{t = 5.31\ mm}$ →

Neglecting thermal effects and using 40 BAR (580 PSI) gives a disc thickness of 3.82 mm, the same as that shown on the South African drawing.

For bench testing without thermal stresses from

$$\sigma_{UTS} = \frac{3qR^2}{4t^2}$$

$$q = \frac{4(5.3 \times 10^{-3})^2 \times 228.805 \times 10^6 \times 4}{3 \times 0.065^2}$$

$$= 8.113 \times 10^6\ Pa$$

$$\simeq 81\ BAR \quad (1189.3\ PSI)$$

LT 286

INTERIM REPORT

TRIAL 288 - CLASSES 14A, 15A, AND 16A BURSTING DISCS.

An initial trial run done on 28 October 1992 with discs fitted on locomotive 372 gave the expected results. No burst disc was encountered on the trip.

Problems encountered are as follows :-

i) BURSTING DISC ADAPTOR

It was observed that the adaptor as designed by the drawing office Chief Mechanical Engineer's sketch S.L.S - 1017 gives problems in removal of a burst disc. As the situation stands, trying to remove a burst disc actually removes the holder. Use of two spanners does not help the situation.

It is thus suggested that the drawing office look for ways of improving the design or any way of locking the holder onto the cover before drivers actually lose hope because of failing to replace burst discs in section.

ii) STEAM LEAK AT TAKE - OFF

It was also observed that at take-off, after stopping for at least ten minutes, steam leaked at the sides of the disc implying that the gasket might not be able to withstand high pressures. However, this was felt an advantage as it helps in quick dissipation of excess pressure which the drain valves cannot dissipate rapidly thus further reducing the possibility of a burst cylinder. It is therefore suggested to retain the gasket as designed at this stage.

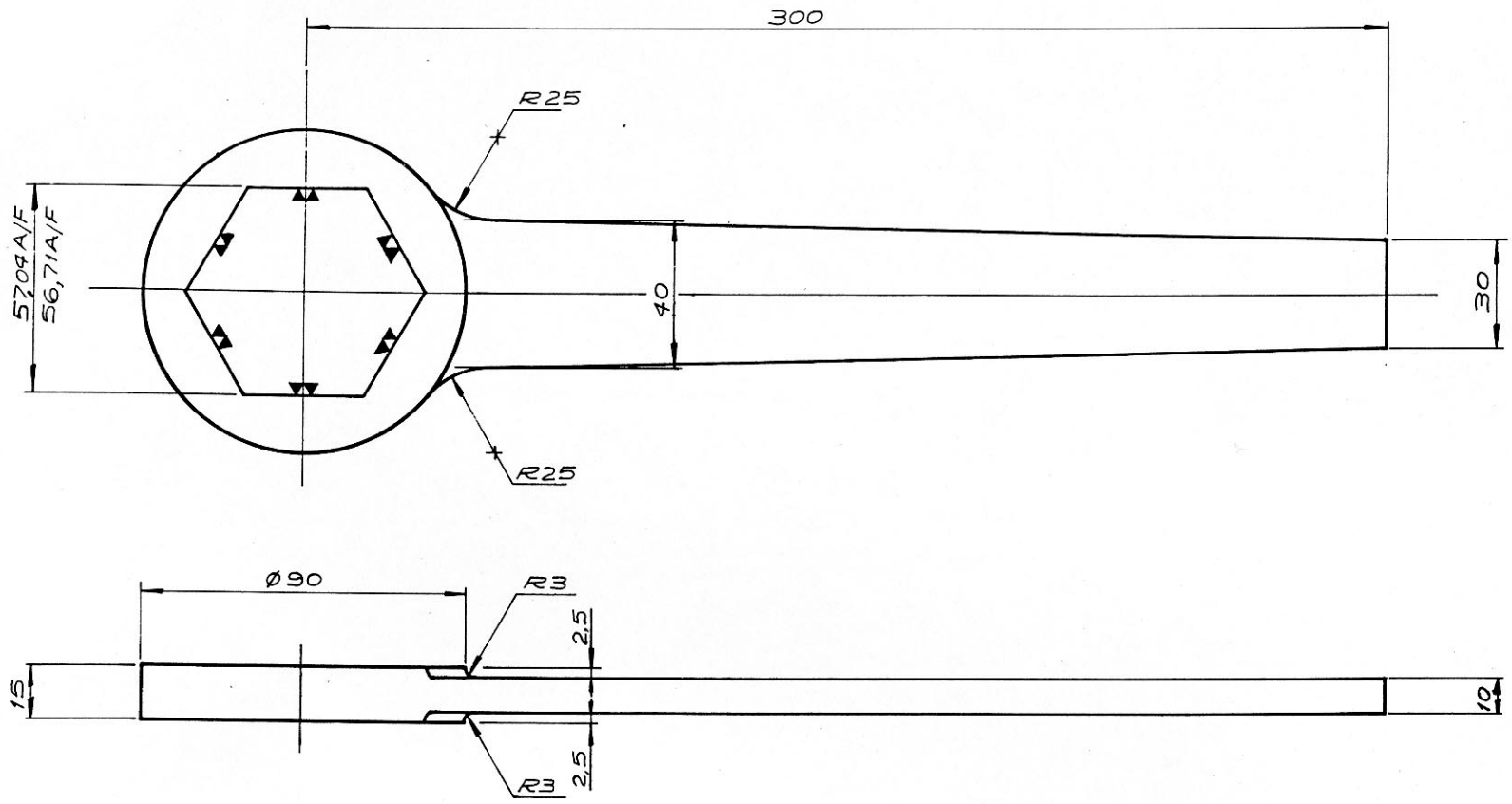
COMPILED : M. MATENDE

DATE : 17 November 1992 (TRIP 28 October 1992 LOCO 372)

CIRCULATION : MECHANICAL ENGINEER (SOUTHERN)
MECHANICAL ENGINEER (BULAWAYO WORKSHOPS)
MECHANICAL ENGINEER (PROJECTS)
STAFF DEVELOPMENT OFFICER
CHIEF DRAUGHTSMAN
MR. M. MATENDE
FILE 31:0007:05

SHOP NOTES.

1. REMOVE ALL SHARP EDGES AND BURRS.



Spanner for bursting disc fitting See SLS 1016.

NUT, BURSTING DISC HOLDER.		14A, 15th & 16A
PURPOSE		CLASSES

REV.	AUTHORITY	APPVD
A		
B		
C		
ORIG.		
REF.	CODE OF TRIAL LT. Nº 288	

MATL:	STEEL, N.R.Z. '52-09' (B.S. 970 GD. 070 M20)	
SCALE:	1 : 2	
FINISH:	MACH.	GRIND
ROUGH:	▼	R ▽
MED.	▼▼	M ▽
FINE.	▼▼▼	F ▽

RING SPANNER.

CODE No. 56-84-3120

NATIONAL RAILWAYS OF ZIMBABWE - MECH. BRANCH

DRN:	Tshuyana 11/89	M- 6671/374
CKD:	S Songue 04/90	
APPVD.	B Wolfe C.D.	
DATE:	16. 5. '90	REV: