SAR 26 Class No. 3450 – claim of 90 mph running – a critical analysis.

The following claim has been made, as given to the present writer from the 5AT Website (quote):

> "That day we hit 90mph with her was really unbelievable on her footplate. John as usual drove her to Orange River where we took on water and gave the fire a shake then headed onwards to De Aar. He gave me the regulator and told me to get her flying. Through Kraankuil we must have been hitting a good 80mph or so and then it's a long steep climb up Rooidam bank when the speed falls to about 60. Her load was 19 coaches and just over 900 tons.
>
> As we get to the top of the bank John says to me "keep her open" and so I keep her wide open and we start racing down the bank towards Poupan. Both of us have our eyes peeled looking at the signals and then John shouts out, "Two off", and on that note I opened her regulator full and the beat from her exhaust was more like the beats of a diesel engine. In the video the rods are just a blur. Photographers were trying like mad to keep up with us on the dirt road alongside the line but we left them behind.
>
> Finally we arrive into De Aar about 16 minutes early and its all cheers from the passengers and photographers but as from the management we were in the pits!!
>
> What we never knew is that the top bosses were in a car taking photos of us and were trying to keep up with us and recorded us at 92mph. We were suspended right away: I was charged for driving a passenger train and of course John got charged for allowing me to drive. Yet though we got suspended for a month, they were soon back at our door begging us back to work as they simply did not have enough crews to cover all shifts. However, we would only go back next day if all charges were dropped and so they agreed and we were told not to do it again ... and we never did."

This claim is certainly quite startling and deserves analysis, as follows.

1. The load is stated as '19 coaches and just over 900 tons.' It is assumed this load is the tare load, as the gross load would probably not have been known by the locomotive crew. The video mentioned ("Steam Fever") does show clips of this trip. The stock visible is standard modern SAR coaches, but the full train is never shown, therefore the number of coaches cannot be seen. Taking all loads from SAR logs given in *The Red Devil* pages 323 – 328 for trains that were made up of normal express stock (1st and 2nd class coaches and restaurant cars) gives the following.

   No. of trains = 9, loaded to 16 – 20 coaches.

   Total no. of coaches, all trains = 166.

   Total tare load, all trains = 6570 metric tons.

   Tare load per coach = 6570 / 166 = 39.6 metric tons. The range on this figure is small, deviation of individual train loads from this figure are –3.3% to +2.5%.

   Estimated total gross load (tare + passenger load), all trains = 6745 metric tons.

   Ratio of gross load / tare load = 6745 / 6570 = 1.0266.

   From this data it is seen that the given no. of coaches and the load do not tally. The discrepancy may have been due to incorrect information given to the locomotive crew by the guard, information that was notoriously unreliable. The possibility of car carrier wagons at the tail end of the train could also affect things. If the load was 19 coaches the tare load would have been 19 x 39.6 = 752 tons and the gross load ≈ 752 x 1.0266 = 772 tons. If the tare load was 'just over 900 tons' the number of coaches should have been 23, giving a tare load of 23 x 39.6 = 911 tons and a gross load ≈ 911 x 1.0266 = 935 tons. It is not known if loads of 23 coaches were ever taken by this train, but the following analysis is made for both possibilities:

   (i) a gross trailing load of 19 coaches, 772 metric tons.
   (ii) a gross trailing load of 23 coaches, 935 metric tons.

2. Speed at Kraankuil: general points for speed analysis.

   The speed at any point on the track is given by $v^2 = u^2 + 2.a.s$ where:

   v = speed at distance (s) from reference position

   u = speed at reference position

   a = acceleration

   s = distance travelled from reference position

Acceleration (a) is a function of the locomotive's tractive effort, its rolling resistance, the rolling resistance of the trailing load, and the gradient resistance. The maximum tractive effort and both rolling resistances are complex functions of speed (v), and the gradient varies continuously along the route. As a consequence the above equation becomes a complex differential equation to be integrated separately over each constantly graded track section. The available information is far too incomplete to render such a precise analysis meaningful, e.g. (i) the available gradient profile (*The Red Devil* page 107) is simplified and does not give all gradient changes, (ii) the video suggests it was a windy day but the strength and direction of the wind are unknown, (iii) the working conditions on the locomotive on the run concerned are unknown, and (iv) most importantly, all available information on 3450 refers to its original modified state – by the time of the run concerned it had been significantly altered, e.g. by removal of the feedwater heater, 40 instead of 50 superheater elements, firegrate changes, etc., which will have significantly downgraded its performance and made the maximum tractive effort – speed curve used for this analysis unobtainable. A very much simplified analysis is therefore all that is possible, which can nevertheless give a reasonable estimate of the speeds 3450 in its final state might have been able to reach.

The approach to Kraankuil is up approximately 7 km at an average grade of 3.7‰ which may be taken to define the speed through the station. From *The Red Devil* page 281 the full-power balancing speeds on this grade of 3450 as originally modified = 122 km/h (76 mph) with 772 tons and 112 km/h (70 mph) with 935 tons. For the reason given above, these could not have been reached on the run concerned with the locomotive in 1990's condition. From the logs given in *The Red Devil* pages 323 – 328, the best at this point was that of 1983-12-20. Speed at Kraankuil was 100 km/h with 820 tons, but speed had been 107 km/h (and generally rising) only 3 km before the station and had probably been eased to avoid excessive speed over facing points. Without this easing it could have been about 110 km/h or slightly higher. This was with the locomotive being worked hard but not quite at full power, which would have given 119 km/h with this load on a 3.7‰ grade. By contrast the run of 1990-09-21 with the locomotive obviously being worked hard and in places at high speed, giving a very fast overall timing, saw speed drop on the 3.7‰ grade from 109 km/h to 102 km/h, with 101 km/h (63 mph) at Kraankuil with only 685 tons. This can be taken as probably a good reflection of its latter-day performance, and with 772 tons the maximum speed that could realistically be expected at Kraankuil on the run in question is taken as 100 km/h (63 mph). With 935 tons, by simple ratio of overall train weights (loco weight taken as 212 tons @ 2/3 supplies), this would be some 85 km/h (53 mph). To summarise:

Claimed speed at Kraankuil "a good 80mph or so".

Realistic maxima: 19 coaches / 772 tons ≈ 100 km/h (63 mph)
23 coaches / 935 tons ≈ 85 km/h (53 mph)

3. Speed at summit of Rooidam bank. This is where it is stated that "speed falls to about 60." Rooidam bank gradually steepens to about 4 km of constant 9.1‰ grade then finishes with approximately 1 km at an average grade of 1.4‰ to the true summit at approximately km 155.5. The point to which the "about 60" refers is not known, so both points are analysed.

4. Speed at top of 9.1‰ grade. Although this can be charged from easier grades beyond Kraankuil, all logs given in *The Red Devil* pages 323 – 328 show that despite this the potential balancing speed was not sustained:

	Date	Gross load, metric tons	Actual speed at top of 9.1‰ grade, km/h	Max. balancing speed at top of 9.1‰ grade, km/h, from *The Red Devil* p.281.
1	1983-02-01	650	92	99
2	1983-12-20	820	≈ 73	83
3	1981-12-15	755	≈ 78	89
4	1990-09-21	685	≈ 66	96

[Earlier in run (1) 100 km/h had been sustained on the same grade at Enslin bank – this was at the very limit of performance.] As in practice the potential balancing speeds were not sustained on the 9.1‰ grade despite charging the bank, these speeds can be taken as the absolute maxima possible with 3450 in original condition even when the bank was charged. Note that run (3) may almost have achieved this, speed being almost steady at 88 km/h before loss of coal feed affected the boiler pressure. Note also the significant lowering of performance in run (4) with the locomotive in final condition. The balancing (i.e. maximum) speeds with 3450 in original condition with the possible loads of the run in question are, from *The Red Devil* p.281:

Load, metric tons	Maximum speed at top of 9.1‰ grade
772	88 km/h, 55 mph
935	73 km/h, 46 mph

As on the run in question the locomotive was not in original condition these speeds would not have been reached, and realistic maximum speeds at top of 9.1‰ grade are:

19 coaches / 772 tons ≈ 80 km/h (50 mph)
23 coaches / 935 tons ≈ 65 km/h (41 mph)

5. Speed at the true summit of Rooidam bank. Measured accelerations of 3450 from the top of 9.1‰ grade to the true summit are:

Date	Gross load, metric tons	Actual speed at top of 9.1‰ grade, km 154.5, km/h	Speed at true summit, km 155.5, km/h	Increase in speed, km/h
1983-02-01	650	92	98	6
1981-12-15	755	≈ 78	84	6

Taking the increase in speed to apply to the run in question, the realistic maximum speeds at the true summit of Rooidam bank are:

9 coaches / 772 tons ≈ 86 km/h (54 mph)
23 coaches / 935 tons ≈ 71 km/h (44 mph)

The final figures estimated in sections (4) and (5) contrast with the claimed "about 60" [mph]. This claim is not much faster than the estimated maximum possible speed at the true summit with a load of 19 coaches / 772 tons.

6. Speed at the foot of the downgrade from the summit of Rooidam bank. South of this summit the line falls to Poupan, rises after Poupan and then falls again. It is not stated where the claimed top speed of 92 mph occurred, but it would have had to be at one of these two dips as afterwards the line has very much a rising trend to beyond Houtkraal which would have reduced any very high speed, and when the line makes its long descent to De Aar there is no (dirt) road paralleling the railway from which the train speed could have been timed (the possibility that this was done from the railway service track can be discounted, as in all probability no-one would be alive to tell the tale if 92 mph were attempted on such a track, let alone on the dirt road!) The speeds at the end of each of the three sections in question have to be estimated, as follows.

7. Speed at the foot of the downgrade towards Poupan. This ends at approximately km 160 just north of Poupan station (closed by the time of this trip?), giving a length of (160 – 155.5) = 4.5 km on an average gradient of 4.22‰. Note that the distance is short and the grade quite shallow. The equation $v^2 = u^2 + 2.a.s$ is used. Taking the load as 19 coaches / 772 tons, u = 86 km/h = 23.89 m/s, s = 4.5 km = 4500 metres. Acceleration (a) is a function of the locomotive's tractive effort, the total train rolling resistance, and the gradient. The first two of these vary continuously with speed, and the best that can be done for a simple calculation is to take values for them at the mean speed over the section. This will give lower than actual acceleration at the start of the section concerned and higher at the end, which discrepancies will tend to cancel out.

   Locomotive weight at 2/3 supplies ≈ 212 metric tons, giving a total train weight of 984 metric tons. The corresponding force acting downgrade = (984 x 4.22) kgf x (9.81 / 1000) kN / kgf = 40.7 kN.

   For the final iteration (others not given), estimated average speed = 105 km/h. At this speed:

   Maximum indicated tractive effort: for the locomotive in original condition (*The Red Devil* p. 267, curve extrapolated) this = 128 kN. At high speed for 3450 in originally modified condition, indicated power and tractive effort = 35~40% > best 25NC values. A reasonable estimate is that for 3450 in 1990's condition, indicated power and tractive effort at speed were reduced by ≈ 10%, making them still 20~25% > best 25NC values. Throughout the subsequent analysis 3450's maximum indicated tractive effort is taken as 0.9 x best original value, = 128 x 0.9 = 115.2 kN at 105 km/h.

   Locomotive rolling resistance (*The Red Devil* p. 266, curve extrapolated) = 35.0 kN.

   Rolling resistance of SAR passenger stock is from SAR equation $\{r = (22.1 + 0.0045. v^2)\}$ N / ton, therefore at a trailing load weight of 772 tons @ 105 km / h, $R = \{(22.1 + 0.0045. 105^2) \times 772 / 1000\} = 55.4$ kN.

   The net accelerating force is therefore (115.2 – 35.0 – 55.4 + 40.7) = 65.5 kN and the downgrade acceleration = (65.5 kN / 984 tons) = 0.0666 m / s^2.

$v^2 = u^2 + 2.a.s = (23.89^2 + 2 . 0.0666 . 4500)$ from which v = 34.2 m/s = 123 km/h (77 mph). (Average speed = (86 + 123) / 2 = 104.5 km/h ≈ chosen estimate of 105 km/h, hence ok.)

By exactly the same method, for a trailing load of 23 coaches / 935 tons, the calculated speed at the foot of the downgrade towards Poupan starting from 71 km/h, = 116 km/h (73 mph). Note that the acceleration is actually more with the heavier load because the acceleration is from and at lower speed (i.e. higher tractive effort and lower loco rolling resistance and specific coach rolling resistance). The acceleration due to train weight alone is independent of the actual weight and depends only on the gradient, therefore is as fast with all loads.

To summarise, the realistic maximum speeds at the foot of the downgrade towards Poupan from the estimated starting speeds at the true summit of Rooidam bank are:

19 coaches / 772 tons ≈ 123 km/h (77 mph)
23 coaches / 935 tons ≈ 116 km/h (73 mph)

These figures contrast with the claimed 90 / 92 mph.

8. Speed at the top of the rise from Poupan. It is necessary to estimate this to get the starting speed for the following descent. Speed at the foot of this upgrade taken as the realistic maximum at Poupan, as above, and the method is the same as for section (7). The upgrade section ≈ 6.4 km long at an average grade of 5.8‰.

Taking the load as 19 coaches / 772 tons, u = 123 km/h = 34.2 m/s, s = 6.4 km = 6400 metres.

Total train weight = 984 metric tons and the corresponding force acting downgrade (i.e. against the direction of motion) = (984 x 5.8) kgf x (9.81 / 1000) kN / kgf = 56.0 kN.

For the final iteration (others not given), estimated average speed = 108 km/h. At this speed:

Maximum indicated tractive effort = 125.9 (*The Red Devil* p. 267, curve extrapolated) x 0.9 = 113.3 kN.

Locomotive rolling resistance (*The Red Devil* p. 266, curve extrapolated) = 36.2 kN.

Rolling resistance of SAR passenger stock is from SAR equation $\{r = (22.1 + 0.0045. v^2)\}$ N / ton, therefore at a trailing load weight of 772 tons @ 108 km / h, $R = \{(22.1 + 0.0045. 108^2) \times 772 / 1000\} = 57.6$ kN.

The net accelerating force is therefore (113.3 – 36.2 – 57.6 – 56.0) = –36.5 kN (= decelerating force) and the upgrade acceleration = (–36.5 kN / 984 tons) = –0.0371 m / s^2 (i.e. deceleration.)

$v^2 = u^2 + 2.a.s = (34.2^2 + 2 . (–0.0371) . 6400)$ giving v = 26.4 m/s = 95 km/h. Av. speed = (123 + 95) / 2 = 109 km/h v's chosen estimate of 108 km/h. Therefore best estimate of final speed is slightly lower than 95 km/h, say 94 km/h (59 mph).

By exactly the same method, for a trailing load of 23 coaches / 935 tons, the calculated speed at the top of the rise from Poupan starting from 116 km/h = 85 km/h (53 mph).

To summarise, the realistic maximum speeds at the top of the rise from Poupan from the estimated maximum starting speeds at Poupan are:

19 coaches / 772 tons ≈ 94 km/h (59 mph)
23 coaches / 935 tons ≈ 85 km/h (53 mph)

9. Speed at the foot of the descent to ≈ km 173. Speed at the start of this downgrade is taken as the realistic maximum at the top of previous upgrade, as above, and the method is the same as for section (7). The downgrade section ≈ 6.4 km long, again at an average grade of 4.22‰. (The steeper section of grade within this (average = 9.28‰) is of very short duration only (≈ 2.6 km.))

Taking the load as 19 coaches / 772 tons, u = 94 km/h = 26.1 m/s, s = 6.4 km = 6400 metres.

Total train weight = 984 metric tons, and the corresponding force acting downgrade = 40.7 kN as in sec. (7).

For the final iteration (others not given), estimated average speed = 113 km/h. At this speed:

Maximum indicated tractive effort = 122.05 (*The Red Devil* p. 267, curve extrapolated) x 0.9 = 109.8 kN.

Locomotive rolling resistance (*The Red Devil* p. 266, curve extrapolated) = 38.3 kN.

Rolling resistance of SAR passenger stock is from SAR equation $\{r = (22.1 + 0.0045. v^2)\}$ N / ton, therefore at a trailing load weight of 772 tons @ 113 km / h, $R = \{(22.1 + 0.0045. 113^2) \times 772 / 1000\} = 61.4$ kN.

The net accelerating force is therefore (109.8 – 38.3 – 61.4 + 40.7) = 50.8 kN and the downgrade acceleration = (50.8 kN / 984 tons) = 0.0516 m / s^2.

$v^2 = u^2 + 2.a.s = (26.1^2 + 2 . 0.0516 . 6400)$ giving v = 36.63 m/s = 132 km/h. Av. speed = (132 + 94) / 2 = 113 km/h = chosen estimate. Therefore realistic estimate of final speed at the foot of the descent to ≈ km 173 = 132 km/h (82 mph).

By exactly the same method, for a trailing load of 23 coaches / 935 tons, the calculated speed at the foot of the descent to ≈ km 173 starting from 85 km/h = 126 km/h (79 mph).

To summarise, the realistic maximum speeds at the foot of the descent to ≈ km 173 from the estimated maximum starting speeds at the top of the rise from Poupan are:

19 coaches / 772 tons ≈ 132 km/h (82 mph)
23 coaches / 935 tons ≈ 126 km/h (79 mph)

These figures contrast with the claimed 90 / 92 mph.

10. Balancing speed on a 4.22‰ downgrade. If this grade were of sufficient length a balancing speed would be reached when the forces in the direction of travel are equal to those opposing the direction of travel and the acceleration is therefore zero. By iteration, with a load of 19 coaches / 772 tons the four forces involved balance out when speed ≈ 140 km/h (87 mph) for 3450 in 1990's condition. This is > the 132 km/h calculated in section (9) and suggests that the grade in question was not long enough to reach a balancing speed, which would be close to the claimed figure of 90 / 92 mph. Note that there are a number of other sections between Kimberley and De Aar where the steepness and length of downgrade are both much more suitable for attaining very high speed than near Poupan where the high speed claim was made. In such places over 160 km/h (100 mph) should be readily possible. However downhill running is not a good yardstick of locomotive performance and, especially when it involves excessive speeding beyond the authorised limit, as in this case, it is rather a matter of the bravery (or foolhardiness, depending on one's viewpoint) of the crew. All the estimated speeds are based on working at full power downgrade, and in my experience this was never done for any appreciable distance precisely because it would have resulted in excessive speeding. It would only have been practised when a crew was specifically aiming for very high speed, which seems to have been the case in the run in question.

11. Summary table of speeds.

Location	Claimed speed mph	Estimated realistic maximum speed for 3450 in 1990's condition, mph	
		Load = 19/752 t tare/ 772 t gross	Load = 23/911 t tare/935 t gross
Kraankuil:	≈ 80	63	53
Top of Rooidam bank	≈ 60		
at top of 9.1‰ grade:		50	41
at true summit:		54	44
Near Poupan:	90 ~ 92		
at ≈ km 160		77	73
at ≈ km 173		82	79

12. Video. The video "Steam Fever" shows the run concerned from about video minute 50. The clip of the train at speed was presumably taken at the downgrade either before or a little after Poupan when going south. It is difficult to judge whether or not the train is going downhill as all grades are quite shallow, but the 2nd paragraph of the description quoted at the start suggests it is believed the video was taken at or near the point of maximum speed. The most beneficial location from the viewpoint of subsequently attaining high maximum speed would be near the top of Rooidam bank. The exact location may be identifiable by those very familiar with the line, e.g. former or current footplate staff, and anyone who can pinpoint exactly where it is (i.e at which km post) is invited to inform Chris Newman / 5AT Website. The speed of the train at this point is readily found by timing the passing of coaches with a stopwatch. This shows that the first 8 coaches pass a given point in 6.0 seconds exactly (average of 10 readings with virtually 100% repeatability.) Given a length over couplers for the stock concerned of some 68 feet, this gives a speed of 8 x 68 / 6 = 90.67 ft/s = 61.8 mph (98.9 km/h). Thus although the speed looks very fast on the video it is fact not that high. If the exact location can be determined, this speed can be compared with the values given in section (11) to provide some corroboration (or otherwise) of the calculated speeds.

13. Miscellaneous points. The following may be considered when assessing the validity of the claimed speeds.

    13.1 They may be exaggerated.

    13.2 The "top bosses" may have exaggerated the speed at which they claimed to have timed the train.

13.3 Mistaking having been told that 92 mph was reached when trying to catch the train up after taking a photo or video (i.e. when having to go faster than the train) with actually timing the train at that speed. An error due to misunderstanding Afrikaans is a possibility here.

13.4 Faulty speedometer in the car used to chase the train: note that 92 mph on the parallel dirt road would have been dangerously high.

13.5 Faulty engine speedometer. even if the speedometer did not extend to the realm of the highest speeds claimed, false readings at lower speeds may have given the crew an exaggerated impression of train speed at those lower speeds, influencing its judgement at higher speeds.

13.6 Mistaking km/h for mph (rail and road speedometers in SA are in km/h.) However the quoted speeds would then be on the low side.

13.7 Using an incorrect conversion factor to calculate mph from km/h (should be x 0.625).

13.8 Speeding at 92 mph, = 64% over the locomotive's maximum permitted speed of 90 km/h (56.25 mph), especially if over facing points (at Poupan?) where there would have been a 100 km/h (62.5 mph) line restriction (post-1990 value), would probably have been a sackable offence. Given this, one must ask why the crew was apparently only charged with changing places in the cab.

13.9 A final and unrelated point is that in the quoted description 3450 is referred to as "her" no less than nine times. I know it sometimes hurts to discover the truth, but I'm afraid this particular 'her' was, and presumably still is, an 'it'.