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What went wrong with Scott's Antarctic motor sledges?

Bill Alp

Independent Researcher

Research Article

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Corresponding author:
Bill Alp; Email: bill.alp@xtra.co.nz

Abstract

Three motor sledges were taken on Captain Robert Falcon Scott's expedition to Antarctica in 1910. They performed poorly, making only small contributions to the polar journey and making no contribution to the expedition's scientific programme.

The motor sledges have received little attention from historians and researchers. No definitive work has been published. The purpose of this article is to provide an authoritative, reliable and complete history of Scott's Antarctic motor sledges.

This article studies Belton Hamilton's concept for a "chain track" vehicle, then traces its development path through two prototype vehicles and two snow trials in Norway. The outcomes of the snow trials and associated recommendations are reviewed. The article then considers Scott's detailed plans to reach the South Pole and his instructions to the Motor Party in pursuit of that goal. Four major problems that prevented the motor sledges from satisfying Scott's instructions are identified.

Several conclusions are drawn. It is apparent that the vehicles were flawed from the outset by poor engineering decisions about track design, engine power and carburetion/airflow. It is unlikely that experimentation or minor refinement in the Antarctic would have produced vehicles reliable enough to make a major contribution to the polar journey.

Introduction

Captain Scott took three custom-built motor sledges to the Antarctic with his *Terra Nova* Expedition of 1910–13. One was lost during unloading. The remaining two performed poorly, making only a small contribution to the polar journey and making no contribution to the expedition's scientific programme.

Reginald Skelton, a graduate of the Royal Naval Engineering College, was Scott's primary advisor on the development of the motor sledges. Skelton played a leading role in testing and refinement until leaving the expedition in March 1910. He was trained in marine engineering but lacked experience with continuous-track land vehicles. From their time together on the *Discovery* Expedition of 1901–04, Scott held Skelton in very high regard. Scott's biographer, David Crane, explained how Scott selected the members of his second expedition:

At this early stage, however, the man he wanted and needed even more than Wilson was his old engineer, Reginald Skelton. From the very first he had decided that "the key to everything"' was motorised transport, and there was "only one person in the world", he told Skelton under a sub-paragraph of a long letter headed *Yourself*, "that combines a knowledge of southern conditions with engineering skill and that is yourself. I have cherished the idea that if I ever went South again you would join — but of course I can understand how your position is awkward by your private affairs as a married man — there is no one I would sooner have than you and I believe that with your help a great journey can be made" (Crane, 2007, p. 337)

In May 1908, Scott and Skelton settled on a design by a British consulting engineer, Belton Hamilton. Several continuous-track vehicles were already in commercial production (for agricultural and construction work), in the UK and the USA. Scott and Skelton were familiar with at least one such, the Hornsby 70 chain-tracked tractor, which had undergone War Office trials in 1907 and a Royal Review in May 1908. Hamilton regarded his own design as an "improvement on the Hornsby machine" (Scott, 1908a).

Snow trials were carried out on prototype vehicles in Norway in 1909 and 1910, but when the vehicles were put to work in the Antarctic, problems soon arose. Scott noted on 24 October 1911, the day the motor sledges commenced the Southern Journey:

> Seeing the machines at work to-day, and remembering that every defect so far shown is purely mechanical it is impossible not to be convinced of their value. But the trifling mechanical defects and lack of experience *show the risk of cutting out trials. A season of experiment with a small workshop at hand* [emphasis added] may be all that stands between success and failure (Scott, 2006, p. 306).

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Scott's reference to "cutting out trials" suggests an unfulfilled testing phase on the Ross Ice Shelf ("Barrier") in the Autumn Depot Programme, or perhaps in the following spring, in order to assess realistic cargo weights for the coming Southern Journey.

This article covers the life history of motor sledges that were based upon Hamilton's design — from his initial prototype, through the Wolseley prototype, to Scott's final polar vehicles and Filchner's subsequent variant. It analyses problems encountered in the snow trials and in the Antarctic. The narrative finishes with the final sighting of one of Scott's abandoned vehicles in 1915. It does not address the subsequent development of better designs by later polar expeditions.

This study finds that Scott's motor sledge programme faced foundational challenges from the outset. The sledges were flawed by poor engineering decisions on track design, engine power and carburetion/airflow.

Scott's faith in motor sledges

By the time the expedition's public fundraising prospectus was released on 13 September 1909, Scott had already invested heavily in developing a continuous-track motor sledge, intended for his main Southern Journey. The prospectus stated, "As the result of two years' experiment a motor sledge has been evolved which has undergone satisfactory trials on the snow of Norway" (Scott, 1909a, p. 4). During the second Norwegian snow trial, Scott expressed satisfaction to *The Yorkshire Post* on 15 March 1910, anticipating the purchase of one or two more sledges (Solomon, 2001, pp. 271–272).

However, once deployed in Antarctica, a critical flaw emerged — the track's wooden rollers proved too fragile, as described in Problem 1 — Tracks had a short working life (below). Charles Wright noted on 8 January 1911, just three days after the first two sledges were landed, "At this time . . . the other two motors were damaged; . . . turning [of the sprockets] ripped pieces from the rollers" (Wright, 1993, p. 72). Scott recognised the seriousness of the problem, and his journal soon reflected a gloomy opinion of the motor sledges. On 20 January 1911, he wrote, "Day has been explaining the manner in which he hopes to be able to cope with the motor sledge difficulty. He is hopeful of getting things right, but I fear it won't do to place more reliance on the machines" (Scott, 2006, p. 99).

By September 1911, Scott had reached a firm conclusion:

> I do not count on the motors — that is a strong point in our case — but should they work well our earlier task of reaching the Glacier will be made quite easy. [. . .] I am still very confident of the possibility of motor traction, whilst realising that reliance cannot be placed on it in its present untried evolutionary state (Scott, 2006, p. 284).

On 27 October 1911, Scott wrote:

> But it is not easy to foretell the extent of the result of older and earlier troubles with the rollers. The new rollers turned up by Day are already splitting, and one of Lashly's chains is in a bad way; it may be possible to make temporary repairs good enough to cope with the improved surface, but it seems probable that Lashly's car will not get very far. (Scott, 2006, p. 309).

Scott saw the sledges as important transport resources and used them to their fullest from the outset — much like the ponies, which were worked until no longer useful. On the Southern Journey, the sledges took enough petrol to reach the foot of the Beardmore Glacier, with no provision for return. He never referred to the sledges as "experimental" — that phase had, in his view, concluded before departure. While younger men (notably Cherry-Garrard, Day, and Wright) used the term "experimental," it appears to have been an Edwardian euphemism for "unsuccessful." No genuine experiments involving the sledges were described. In contrast, the Winter Journey's dietary trials were genuine experiments: three men were given different rations and weighed before and after the journey. The most effective diet was then adopted for the Southern Journey. With two near-identical sledges available, comparative trials (e.g., cargo weights, driving speeds, cooling methods) could have been conducted. That no comparative trials were recorded suggests the sledges were treated as straightforward work-units, not experimental platforms.

In summary, Scott lost faith once it became clear that the fragile rollers would soon fail.

Development of Scott's motor sledges

After disappointing motor sledge trials in France in early 1908, Scott sought a new design suitable for towing heavy loads in Antarctica. He consulted Belton Hamilton, who was developing a "chain track" vehicle (later known as "caterpillar track"). Scott asked Hamilton to send blueprints and a description to Skelton. Hamilton did so on 6 May 1908 (Hamilton, 1908a). Skelton provided a favourable response.

Scott's vehicles were based on Hamilton's patent filed on 13 May 1908, titled *Improvements in and relating to Road Vehicles* (Hamilton, 1909). It described a continuous-track mechanism and suspension system for use on "motor roads," but omitted engine power, transmission and steering details. More on Hamilton's design appears in Hills' *Tank Encyclopaedia* (Hills, 2021). Legros' *Traction on Bad Roads or Land* (1918/2021), a definitive text, outlines engineering principles of tracked vehicles and describes fifteen examples manufactured prior to the end of WWI. Contemporary continuous-track vehicles usually had three to seven bogie wheels at even intervals on each side to support the vehicle's weight — from track to chassis — with no travelling rollers at all. Legros wrote about Hamilton's design:

> The chains were of soft steel links with wooden rollers. It is to be noted that the arrangement adopted differs from any of the other tractors described [in Legros' book], as the rollers travel with and at the same speed as the chain, and the rollers also form the gearing surface with which the driving and idler sprockets engage (Legros, 1918/2021, p. 60).

The Finchley prototype

The first prototype from Hamilton's design was built under his personal supervision (Hamilton, 1910) in mid-to-late 1908. Scott wrote to Skelton on 31 October 1908, saying that Hamilton had invited him to observe a trial of the new vehicle, temporarily horse-drawn, in a field at Finchley, Hamilton's hometown. Scott wrote, "I believe this thing is good" (Scott, 1908b). On 9 December 1908, Hamilton wrote to Skelton, mentioning the horse-drawn trials and saying that he was still awaiting delivery of the engine from the Advance Motor Manufacturing Company of Northampton, which was delaying further work on the transmission (Hamilton, 1908b). We have no record of when the Finchley prototype was completed but later comments by Scott suggest it was much later than he wanted.

Figure 1 shows the completed Finchley prototype. Preferences of the era still favoured traditional coachbuilding materials, so experimental vehicles like this often included far more wooden components than they should. The Finchley prototype was powered by a four-cylinder air-cooled vertical engine supplied by the

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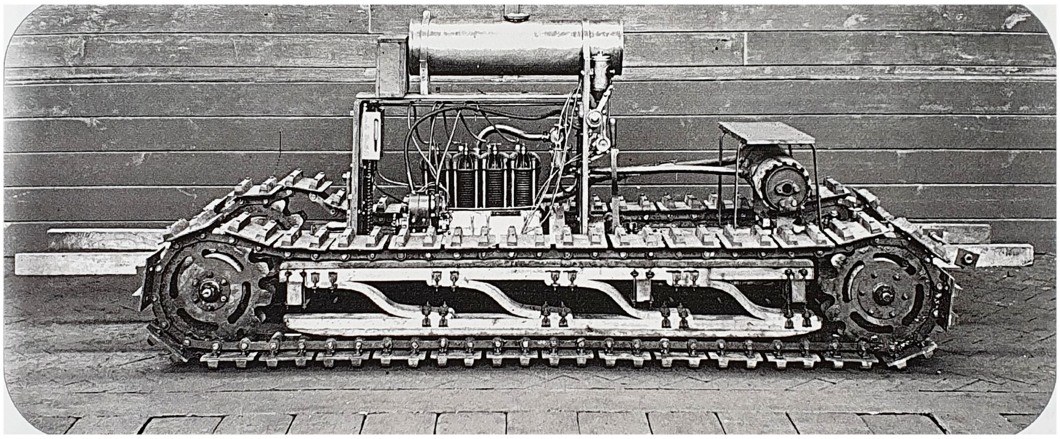


Figure 1. Finchley prototype motor sledge. Image scanned from *Wolseley special products 1901–1926* (Painting, 2018, p. 35).

Advance Motor Company, which manufactured motorcycles and aero engines (Painting, 2018, p. 35). Wolseley had no part in the design or construction of the Finchley prototype, which is readily distinguishable from the later Wolseley prototype by having:

- four separately cast cylinders retained by long shiny bolts from the cylinder head to the crankcase (the Wolseley engine had four cylinders cast in pairs, retained by short bolts)
- wooden (Ash) suspension springs
- a rudimentary driver's seat
- small sprocket wheels (12-tooth)
- a small cylindrical petrol tank above the engine
- no cooling fan
- no gearbox

Referred to as the Finchley Motor Sledge (Skelton, 1909, p. 1), it underwent snow trials in Lillehammer, Central Norway in March 1909.

Testing the Finchley prototype

Skelton managed the trial and subsequently wrote a carefully worded five-page report, *Experiments with the Finchley motor sledge at Lillehammer, Norway, March 1909* (Skelton, 1909), in accordance with Scott's wishes (Scott, 1909b) — factually accurate but minimising the number of separate problems, in order to convey an overall positive impression. Skelton's first paragraph was indeed positive:

> The trial ground used was only about 80 yards square, perfectly horizontal except at the edges, & covered with rather soft snow. Any tractor which would work on this surface would be suitable for the Great Ice Barrier as far as surface conditions alone are concerned (Skelton, 1909, p. 1).

Scott was not involved in the trial because he was unable to get leave from the Navy (Huntford, 2002, p. 232). Hamilton later confirmed that he and Skelton had carried out the Norwegian testing of the Finchley prototype ("Forerunner of the tanks", 1919). Figure 2 shows the Finchley prototype under test in Norway.

An important design issue was soon discovered and readily resolved:

> The first trial of the sledge failed owing to the snow packing into the teeth of the solid wooden [four inch wide] sprocket wheels. This altered the pitch of the teeth, tightened the sprocket chains, [and] caused the fore & aft engine & axle bearers to buckle downwards at the ends, & finally broke some wooden rollers & bent the forward axle.
>
> After repairs were made good a second trial was made, the sledge ran well until it was turned when the snow was swept into the chain & exactly the same breakdown occurred as on the first experiment, showing the solid wooden [sprocket] wheels to be quite useless.
>
> In consequence, skeleton sprocket wheels were designed as shown in a diagrammatic sketch. They consisted of two 3/8 inch iron discs bolted together with a distance piece of wood between them.

Working with these wheels for two hours & giving them every chance to clog, they showed no tendency to do so in any way. In my opinion tractor made with these wheels & other details improved as will be indicated later on, would certainly be a practical success. (Skelton, 1909, p. 1)

With the steel skeleton sprocket wheels being so much narrower than the original wooden sprockets, Skelton firmly directed, "The rollers some of which are Beech & some Birch must have both ends ferruled [a metal cap to strengthen the end], this is most important" (Skelton, 1909, p. 2). There is no record of any ferrules being fitted on later sledges and none are visible in surviving photograph.

The soft snow surface highlighted two further design problems when the sledge sank up to its axles. The sprocket wheels needed to be increased in diameter in order to increase ground clearance. The front idler sprockets needed to be raised (relative to the rear drive sprocket) for the vehicle to better ride over obstacles and be easier to turn. (Skelton, 1909, p. 2). Skelton also made recommendations about gearing:

> The worm & worm wheel now in use give a reduction of 20 to 1; this does not seem to be sufficient, & if the driving sprocket wheels are increased in size the reduction will have to be still more. I am strongly of opinion that a second gear is necessary (Skelton, 1909, p. 3) [Later vehicles had a two-speed gearbox]

Skelton also commented on the Advance engine, "I think it would be an improvement to slightly increase the power" and "There was no sign of overheating, but the engine was not at work for a very extended trial" and "It might be necessary to fit a fan but this presents no serious difficulty" (Skelton, 1909, p. 4).

He warned, "Further experiment is however necessary to obtain the tractive power of this type of sledge. For this purpose the trial ground was of insufficient area" (Skelton, 1909, p. 1). The Finchley prototype's towing power was not assessed during the 1909 trial. The need to measure the force required to tow a cargo sledge had not been anticipated — a simple two-ton spring balance would have sufficed.

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Figure 2. Finchley prototype in Norway, 10 March 1909. Image licensed with permission of the University of Cambridge, Scott Polar Research Institute Archives. (Scott, 1909a, p. 4).

As discussed in Blind spot — variability of snow friction (below), Skelton's report did not anticipate the great variability of snow friction, which later proved fatal. When higher-friction snow surfaces were encountered on the Southern Journey, the towed cargo sledges required substantially more horsepower to move them forward, thereby increasing the load on the engines, which rapidly and regularly overheated.

Transition from Hamilton to Wolseley

The Lillehammer trial in March 1909 showed beyond doubt that Hamilton's continuous track design was, in principle, suitable for towing heavily laden cargo sledges over certain types of snow surface. However, the trial identified several significant problems and many worthwhile improvements.

A substantial cost, therefore, lay ahead to rectify the problems, finalise the improvements and construct multiple vehicles for use in the Antarctic. Another offshore snow trial would also be required at some stage. Scott regarded Thomas Evelyn Scott-Ellis, the eighth Baron Howard de Walden ("Scott-Ellis"), as the most promising financial supporter. Moreover, Scott had found Hamilton to be unsuitable (particularly in working to a deadline). He wrote to Skelton on 19 April 1910:

> My Dear Skelly
>
> A thousand thanks for your excellent report on the motor sledge. It is exactly what I wanted. I should like to proceed to the semi-final stage you propose but must wait till Lord Howard returns. Somehow, I feel that Hamilton is not [Scott's emphasis] the man to complete this job but sufficient for [now] — but meanwhile give me your idea on this subject. Suppose a determination to have an improved machine ready for trial next year, into whose hands would you suggest it be put? I know Hamilton has sound ideas and instinctive talent but he has shown himself unsuitable. One could never trust him to be up to date. (Scott, 1909c)

Direct evidence about the transition to Wolseley after that date is lacking, but available circumstantial evidence leads to a compelling conclusion.

Scott was reliant on Scott-Ellis, his principal financial backer, to continue funding the motor sledge programme. At the same time, he was seeking to replace Hamilton with someone he considered more suitable. During the Edwardian era, Wolseley was a dominant force in the British car market, known for its strong and successful experimental vehicle department. Aligning the expedition with such a reputable British brand would have enhanced its credibility.

In 1909, Scott brought an experimental traction sledge to the Wolseley Motor Company, as noted by Atkinson (1913, p. 1), and the development of the motor sledge was handed over to Wolseley. It appears likely that someone — most likely Scott-Ellis — guaranteed the funding necessary for Wolseley to design and build a new prototype. After April 1909, Hamilton's name disappears from all correspondence between Scott and Skelton.

Wolseley produced detailed design documents for Scott's review, which he forwarded to Skelton on 7 December 1909 (Scott, 1909d). After the second Norwegian snow trial (March 1910), Hamilton issued a statement (Hamilton, 1910) asserting that he should have been credited with the design of the motor sledge described in an article published in *The Engineer* on 1 April 1910.

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Later, from Cape Evans in October 1911, Scott wrote to Scott-Ellis with strong praise for the continuous track system, emphasising that there was "nothing whatever the matter with this principle of propulsion of which you hold the patent." He described the sledges sailing over the snow and expressed confidence in their future, particularly in places like Canada. Scott urged Scott-Ellis to ensure that the patents were secured in all countries (Pound, 1966, p. 268).

Taken together, the evidence suggests that a three-way agreement was reached around April or May 1909 among Scott, Scott-Ellis and Hamilton. Although no documentation has been found, the arrangement may have involved Scott-Ellis continuing to fund the motor sledge development in exchange for a financial stake, possibly through commissions on future sales. Hamilton, in turn, may have licensed his patent rights to Scott-Ellis and received a lump-sum payment.

The British Library (Business and IP Centre) holds information about such patents in the archives of their *Patent Journal*. They advise "... between the 20th and 25th June (inclusive), 1910, the [Hamilton] patent was either assigned, transmitted, or licensed. Not to whom unfortunately" (T. Corsini, personal communication, 9 July 2025). Furthermore, the patent was renewed in Hamilton's name in May 1912, indicating that the 1910 transaction was not an assignment (to another person) and it was not a transmission (which indicated death of the patent holder), so by elimination it was a license for an un-named person, presumably Scott-Ellis, granting rights to benefit from the patent. Corsini continued, "The patent became void through the non-payment of fees (i.e. wasn't renewed for the sixth year) between the 10th and 16th May (inclusive), 1913."

The Wolseley prototype

After the Lillehammer trial of the Finchley prototype, ongoing development work was turned over to Wolseley. Surgeon Lieutenant Edward ("Atch") Atkinson, the expedition's principal report writer in 1913–14, wrote an eleven-page report on *Motor Sledges*. It stated "In 1909 Captain Scott brought to the works of the Wolseley Motor Company an experimental traction sledge fitted with a 4-cylinder [Advance] engine 80 mm bore and 80 mm stroke. [1.61 litres total capacity]" (Atkinson, 1913, p. 1). Painting wrote, "After some initial trials [in Norway] the [Finchley] prototype sleigh was despatched to the Wolseley Tool and Motor Car Co. Ltd., for further development" (Painting, 2018, p. 36).

The Wolseley team was under the direction of Alfred W Dougill, a seasoned automotive engineer and Manager of the Wolseley Experimental Department. Dougill was regarded by colleagues as being ambitious, capable and innovative. Wolseley was known at the time for its cars, aero engines and marine engines, and went on to embrace experimental projects, including Scott's vehicles and a gyrocar for Count Schilovsky, and a streamlined single-seater racing car called the "Moth." The Wolseley team tested the Advance engine fitted to the Finchley prototype for horsepower and found it to be inadequate. Horsepower dropped badly after only ten minutes running under heavy load (Atkinson, 1913, p. 1). It was, therefore, decided that a custom-designed Wolseley engine should be built. It was also decided that a longer wheelbase would be advantageous in areas with crevasses and that a two-speed gearbox should be fitted. This left few components of the original Finchley vehicle (other than some lengths of track) suitable for reuse. Effectively, a new Wolseley prototype vehicle was built from scratch, based upon Hamilton's patent and upon lessons learned from the 1909 Lillehammer trial.

On 7 January 1910, Scott reported progress: "A single motor sledge is in course of construction by the Wolseley-Siddeley Company, and will be ready in February [1910]. Trials will take place in Norway in my presence; I shall test the merits before ordering further sledges." ("South Pole Expedition", 1910) Scott must have been satisfied with the merits of the Wolseley prototype sledge because he ordered two more vehicles upon completion of Norwegian snow trials in March 1910.

Atkinson described the new Wolseley engine:

> Wolseley designed an engine for the new sledges, having 4 cylinders, each 3½ inch [sic] [actually 3⅛ inch] bore x 4 inch stroke [2.01 litres total capacity] fitted with a Bosch magneto DR4a type. On an hour non-stop full load test; commencing at 1150 RPM (with the engine cold) developed 13.4 HP, dropping to 950 RPM at the end of the trial and 7.5 HP. [. . .] For short runs the engine could develop at 1620 RPM 14.66 HP. The best petrol consumption was obtained at 1100 RPM. 13.0 BHP and 0.782 pts [pints] per BHP hour. (Atkinson, 1913, p. 1)

The new Wolseley prototype vehicle incorporated most of the improvements that had been identified in the Norwegian trial of the Finchley prototype, notably:

- larger, 16-tooth sprocket wheels, thereby increasing ground clearance
- pairs of steel skeleton sprockets to replace the solid wooden rear sprocket wheels
- prominent spikes on the track plates
- engine enclosure with adjustable side panels
- a larger petrol tank
- a two-speed indirect-ratio gearbox

A professional journal, *The Engineer*, published an article about the Wolseley prototype motor sledge ("Motor sleigh for the British Antarctic expedition", 1910). The article has an automotive engineer's perspective and includes a photograph of the vehicle prior to testing, included herein as Figure 3. Further details and drawings for this machine were also published in the *Engineering* journal ("Motor sledge technical details", 1910). It underwent snow trials, which led to further refinements and modifications to produce the polar vehicles.

Testing the Wolseley prototype

Snow trials were carried out on Lake Fefor in Central Norway in March 1910. Testers included Skelton, Day and Dougill. They were supported by "the Wolseley people" and observers include Scott and his wife Kathleen, Fridtjof Nansen and Tryggve Gran. Figure 4 shows the Wolseley prototype in action during the trials, with Wolseley's Dougill at the helm.

Bernard Day, a veteran of Shackleton's 1908 expedition, wrote to Skelton on 28 March 1910 (Day, 1910a). Attached to his letter was a five-page report, "Summary of tests at Fefor" about performance tests carried out between 11 March 1910 and 22 March 1910. Skelton had returned to England about a week before the end of the trial and had left Day to complete the trials as he (Skelton) was leaving the expedition over a dispute with Lieutenant Edward ("Teddy") Evans. Unlike Skelton's report the previous year, Day's report focussed on numbers and facts, without providing much descriptive content.

In contrast to the 1909 trials at Lillehammer, where cargo weights were not pushed to the limit (or even recorded), the 1910 trials were

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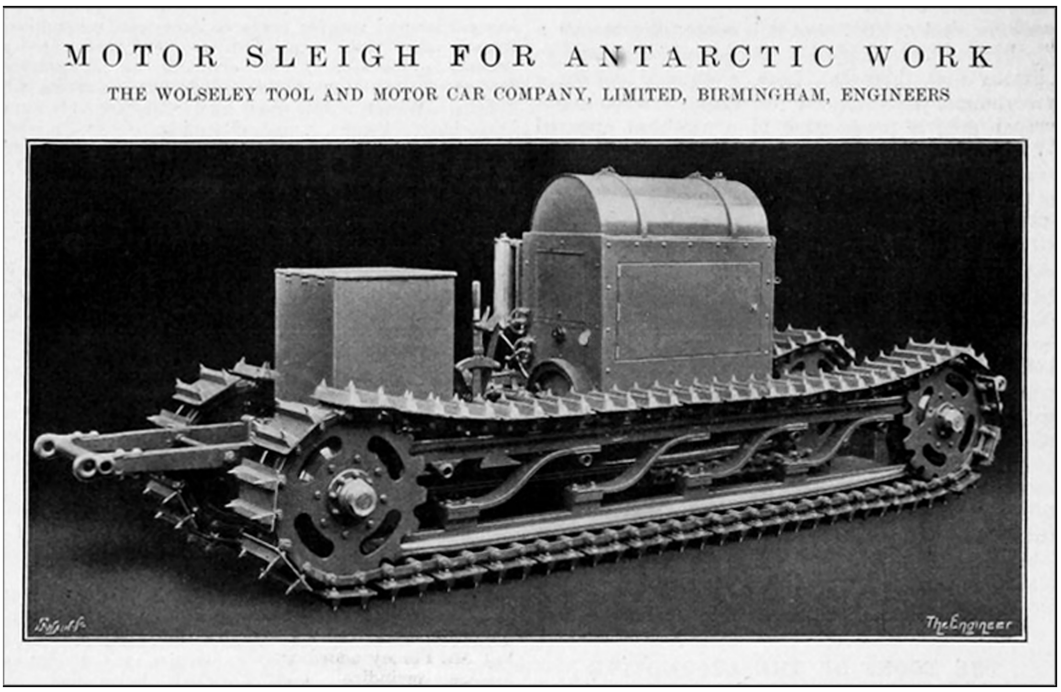


Figure 3. Wolseley prototype motor sledge. Image scanned from ("Motor sleigh for the British Antarctic expedition", 1910).

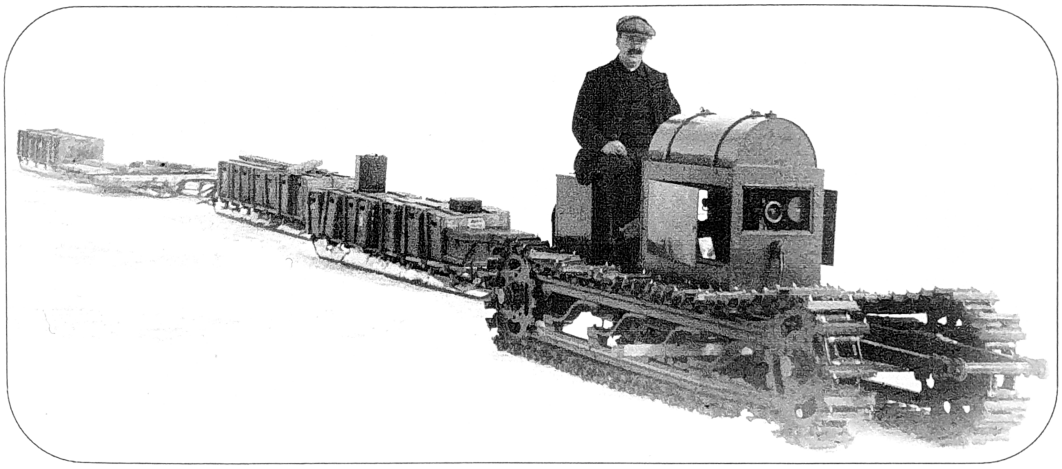


Figure 4. Wolseley prototype at Lake Fefor. Image scanned from *Wolseley special products 1901–1926* (Painting, 2018, p. 37).

focussed on measuring the vehicle's towing capability. For most of the tests, Day recorded the surface conditions, the load, the starting effort required (measured in hundredweight, 112-pound units), the effort required to remain in motion (in hundredweight), throttle setting and fuel consumption. For example, Day recorded the 15 March 1910 results thus (Day, 1910a, p. 2):

> min. temp -8° F
>
> started engine at 10.30 am, ran till 11.15
>
> load 500 lbs
>
> snow v. soft sank 18" deep within 2" of front axle, back axle under snow
>
> starting effort 5½ cwts
>
> average [when in motion] 1½ cwts

The heaviest load successfully towed during the Lake Fefor trials was 7197 pounds (3.2 imperial tons). This was achieved in low gear with the engine running at 1500 RPM (i.e. maximum RPM), at a ground speed of 2.4 statute miles per hour. Day wrote to Skelton again on 1 April 1910 (Day, 1910b) with a list of fifteen recommended improvements, which he said had been approved by Scott. These included:

- a sprung bucket seat (Wolseley's Dougill was most uncomfortable after a long stint of driving)
- suspension springs made of steel, not wood
- rear axle dog jaws strengthened
- overall gearing altered to reduce top speed, which was seen as excessive

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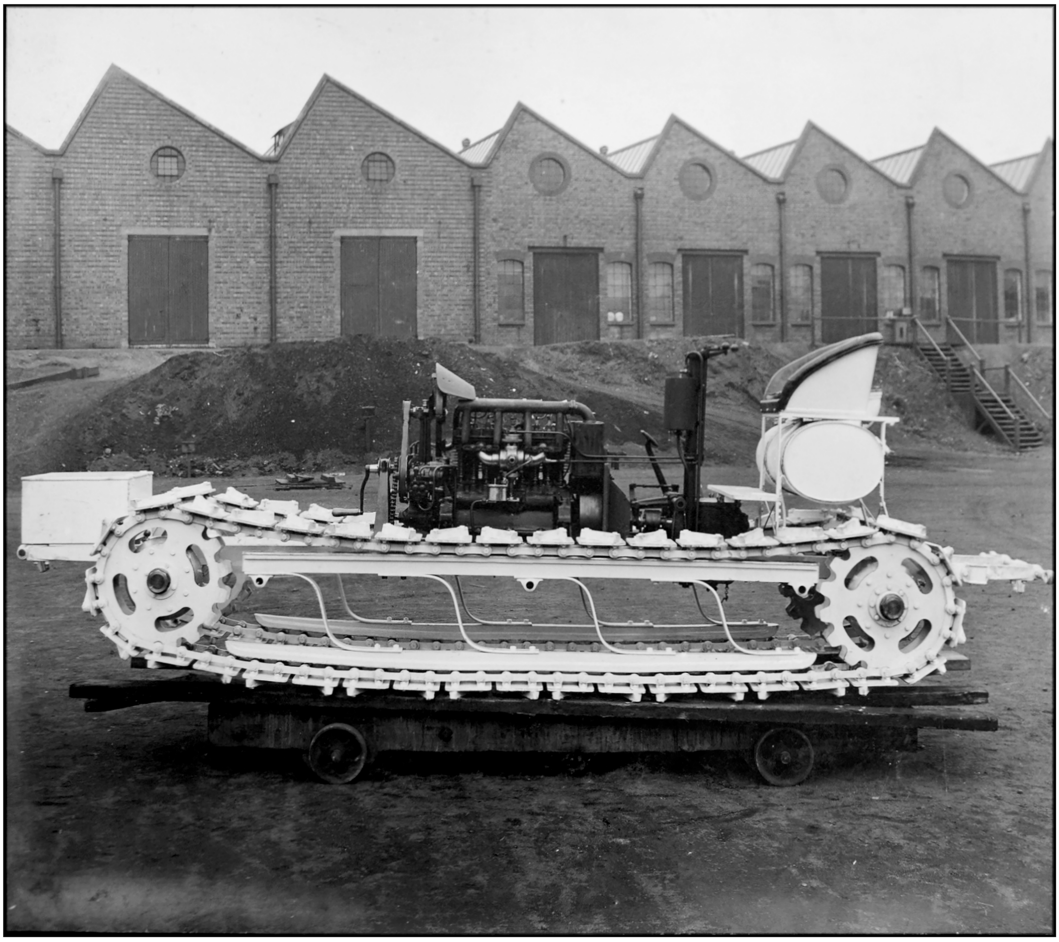


Figure 5. Final version of the Wolseley motor sledge. Image downloaded from https://yuripasholok.livejournal.com/15433150.html.

- track plates must be changeable without unlinking the track
- spikes on the track plates were to be dropped as they had been badly damaged when travelling at speed over hard ice

In a second letter to Skelton, Day reported that a load of three (imperial) tons had been towed at top speed across smooth ice. (Day, 1910b, p. 2).

Atkinson's report on the motor sledges quoted the same test results as Day's letter, along with wordy accounts of some aspects of the trials (Atkinson, 1913, pp. 3–7). Presumably, Atkinson had spoken with Day after the expedition's return to England in order to compile information for his report. He commented on the soft, deep snow encountered in Norway but did not comment on the different surface conditions that could have been expected in the Antarctic. Atkinson's report listed the recommended changes to the sledge, "After these trials at Fefor in consultation with Captain Scott the following list of improvements and alterations was undertaken. In addition advice was given by Captain Skelton, Bernard Day and Mr A. W. Dougill" (Atkinson, 1913, p. 7). The full list of recommended changes exceeds the scope of this article. Typical items were:

- stronger suspension springs (there had been breakages of the Ash springs)
- bonnet is to be redesigned to provide better access for repair work and better airflow
- an aesthetically pleasing colour scheme was proposed — mostly white with polished bonnet and black gearbox and axles
- slotted heads to be used so that screwdrivers and/or a brace could be used in preference to extremely cold spanners
- no split pins were to be used except in the engine (too fiddly or difficult in extreme cold)
- all controls and handles are to be covered with non-conducting material

The completed polar vehicles

Many possible improvements to the Wolseley prototype had been identified from the 1910 Lake Fefor trial. Dougal wrote to Skelton (no longer an expedition member) on 5 April 1910, advising him that "Capt. Scott and Day came here [Adderley Park, Birmingham] this morning and in 2 hours settled all details." (Dougill, 1910). The way was now clear to modify the prototype and to manufacture two more near-identical vehicles. There was no time to waste as the vehicles had to be loaded on the *Terra Nova* before she left London at the end of May 1910.

Figure 5 shows one of the completed vehicles that went to the Antarctic. Differences from the Wolseley prototype included:

- the petrol tank is now under the driver's seat
- no bonnet

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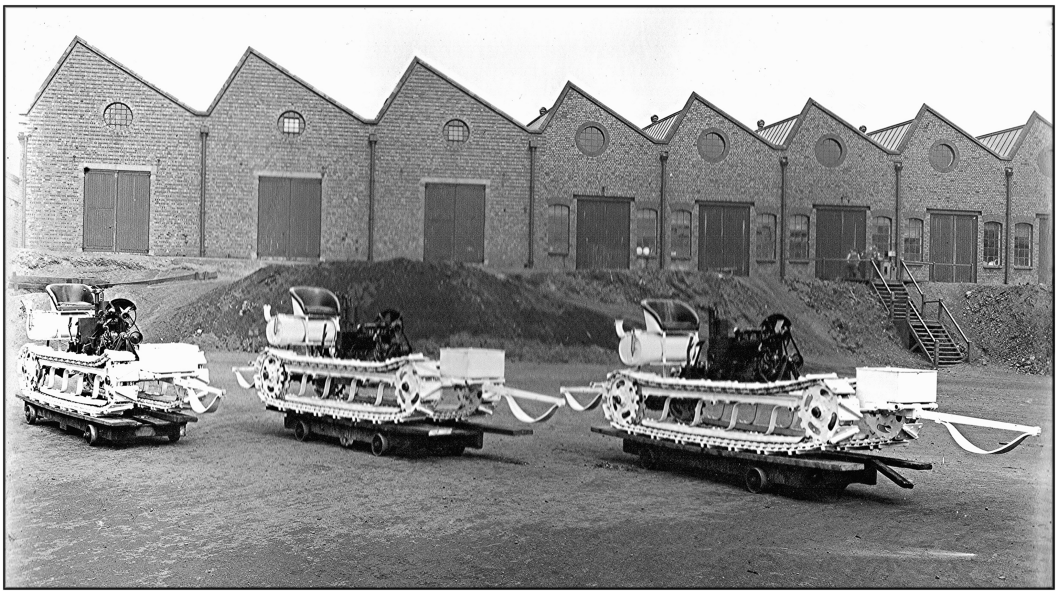


Figure 6. Scott's three motor sledges ready to leave the Wolseley Works in Birmingham. Image scanned from *Wolseley special products 1901–1926* (Painting, 2018, p. 38).

- more comfortable driver's seat
- steel suspension springs
- new colour scheme
- diagonal grips on track plates
- many changes to ease maintenance and repair work in extreme cold

Two additional vehicles were built, essentially the same as the first but with different (lower) gearbox ratios. The third vehicle also had a worm-driven winch fitted at the rear. Figure 6 shows all three assembled outside the Wolseley Works in Birmingham.

Motor sledges in the Antarctic

The three vehicles were taken south as deck cargo on the *Terra Nova*. The first two were unloaded at Cape Evans on 4 January 1911. The third was unloaded four days later but was unfortunately lost in deep water when sea ice gave way.

Several times during the first few weeks ashore, Antarctic weather conditions caused carburation problems with the engines — problems that had not been encountered in Norway. Day attempted to solve those problems by building makeshift wooden bonnets to shelter the carburettors from strong winds and blizzards. However, on the Southern Journey, where the underpowered motors had to be continually run at full throttle over heavy surfaces, the bonnets contributed to severe overheating of the engines.

Day later explained the carburation issue:

> Another source of anxiety was the carburettor. To keep the snow out when blizzards were about, *I had to make a bonnet for each engine* [emphasis added] and this bonnet had to be opened up while the engine was running. This immediately caused the cold air to enter the carburettor if the wind happened to be on that side, and then the petrol would not vaporize. On the engine missing fire, the bonnet would be shut down thereupon the engine ran hot. [. . .] We are thus confronted with the fact that an engine which did not run hot in Norway ran hot in the Antarctic. (Day, 1913)

This explains why vehicles which left England without bonnets (Fig. 6) can be seen in later photographs with crude wooden bonnets fitted (Fig. 9). Day's makeshift bonnets restricted airflow around the engine which directly led to severe overheating of the engines, as described in Problem 4 — Late changes to air-cooling (below).

Plans for the Motor Party's Southern journey

Scott's RGS luncheon presentation, delivered the day before the *Terra Nova* departed London on 1 June 1910, stated that detailed plans for the Southern Journey would be made after learning as much as possible about transport resources during autumn depot laying journeys:

> Returning to the Western Party, I hope that the month of April [1911] will find all safely established in the hut, with suitable depots laid well south on the Barrier.
>
> During the winter, preparations will be made for a great effort to reach the South Pole in the following season. By that time [i.e. after the autumn depot laying journeys] we shall know what reliance can be placed respectively on the ponies, the dogs, and the motor sledges. But in any case a large party of men will be detailed for the Southern Party. (Scott, 1910, p. 15)

During the winter of 1911, Scott created detailed plans for the Southern Journey, including Table VI *Motor Weights* (Wilson, 1911, pp. 5–6). A typed rendition of Scott's table is included herein as Table 1. It shows a maximum total load for the motor sledges of 6290 pounds (2.81 imperial tons) with a side note, "The motors start with 1¼ tons each, & never have more than 1½ tons though they could easily take 2 tons." William Lashly's personal journal provides independent confirmation of the of 6,290 pound figure. It also notes that the motor sledges were to tow five 12-foot sledges plus a smaller one (Ellis, 1969, p. 116).

Figure 7 shows cargo sledges assembled at Cape Evans, ready to be attached to the motor sledges. This image was scanned from the album presented to the expedition's New Zealand Agent, Joseph Kinsey, by photographer Herbert Ponting. Sixteen large petrol cans are visible in Figure 7. Field notes made by David Harrowfield during site preservation work at Cape Evans in December 1977 recorded that many such fuel cans remained on site, some in their wooden cases marked "Capt. Scotts Antarctic Expedition 1910,

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Figure 7. Motor sledge cargo assembled at Cape Evans for the Southern Journey. Image from Kinsey Collection, Alexander Turnbull Library, Wellington, New Zealand, reference PA1-f-067.

Table 1. Scott's planned loads for the Motor Party on the 1911–1912 Southern journey

Motor weights			Table VI	
Fuel sufficient to carry both motors 400 [statute] miles.				
	Starting lbs	Corner camp	One ton camp	
Permanent (men)	290			Reduction of weight per geog. mile = 9 lbs.
Food and fuel (men)	612	Reduction 387 lbs	Reduction 783 lbs	
Spares and tools	100			
Petrol	2230			
Lubricant	840	Addition 10 bags forage 1300	Addition All man food and fuel in depot 563. ?3 fodder bales	The motors start with 1¼ tons each, & never have more than 1½ tons, though they could easily take 2 tons.
Pony food 6 bags	780			
Dog food	500			
Extra butter	25			
	5377	**6290**	**6070**	

SHELL Motor spirit." External dimensions were 38 cm deep, 62 cm long, 33 cm wide, indicating a capacity of 77.7 litres or about 17 imperial gallons (D. L. Harrowfield, personal communication, 7 May 2025). With a density of about 7.3 pounds per imperial gallon, and allowing 15 pounds for packaging (wooden case plus steel can), a full can of petrol with packaging would be approximately 140 pounds. Sixteen cans would weigh 2240 pounds, consistent with Table 1.

3,070 pounds of the starting load (57%) were petrol and lubricant for operating the petrol engines. Only 1,917 pounds (36%) of the starting load can be seen as directly supporting the expedition's exploration objectives, and 500 pounds of that (the dog food) does not appear anywhere else in Scott's detailed workings — possibly some type of non-specific contingency allowance. The quantities of petrol and lubricant were sufficient to take both vehicles 400 statute miles, as noted in Table 1. The

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distance from Cape Evans to the foot of the Glacier is approximately 400 statute miles, suggesting Scott had the foot of the Glacier in mind as the destination (the most optimistic outcome). The distance from Cape Evans to 80½° south, where the Motor Party was to stop and wait for the Pony Party, is approximately 200 statute miles. Scott may have contemplated options for one or both of the vehicles to travel as far as the Glacier (and be abandoned there), or alternatively, for one or both to return to Cape Evans after leaving their loads at 80½° south. Nobody wrote about such options, but it may be more than a coincidence for the arbitrary 80½° location to be exactly halfway between Scott's starting point and the end of the Barrier stage.

If both vehicles had successfully travelled 400 statute miles on the petrol taken southwards, that would have been an average consumption of approximately 2.6 statute miles per imperial gallon of petrol. The vehicles apparently used a lot of lubricating oil, too. Scott's plan (Table 1) provided approximately 96 gallons of lubricant and 305 gallons of petrol for the Southern Journey; an oil-to-petrol ratio of about 31.6%. There may be an error in Scott's calculations here, as Skelton expressed concern when the Lillehammer trials indicated an oil-to-petrol ratio of 5% to 10%, which he thought excessive, recommending a target of 2% to 5% (Skelton, 1909, p. 4). Day noted (Day, 1910c) that the *Terra Nova* would be taking 1700 gallons of petrol and 150 gallons of lubricating oil, a ratio of 8.8%, consistent with the Norwegian trial experience.

Instructions for the Motor Party

Scott wrote precise instructions for all his party leaders, including the leader of the Motor Party, Lieutenant Evans. Those instructions gave effect to Scott's scheme for the Southern Journey, which was presented to the men at Cape Evans on 13 September 1911, along with supporting tables such as Table 1 (above). Scott handed the following instructions to Evans on 20 October 1911:

> Instructions for Motor Party.
>
> Proceed at convenient speed to Corner Camp, thence to One Ton Camp, and thence due South to Latitude 80½ degrees south. If motors successful:
>
> (1) Carry forward from Corner Camp 9 bags forage, 1 bag of oilcake, *but* [Scott's emphasis]see that provision for ponies is intact, viz.: 3 sacks oats, 1 bag oilcake, 4 bags of forage. If motors pulling very well you can also take 9 cases emergency biscuit.
>
> (2) In addition carry forward from One Ton Camp all man food and fuel in depot, viz.: 7 units bagged provisions, 4 boxes biscuit, 8 gallons paraffin, but see that provision for ponies is intact, viz.: 5 sacks oats; and deposit second bag of oil-cake brought from Corner Camp. If motors pulling very well you can also take 2 or 3 bales of compressed fodder.
>
> It being important that I should have latest news of your success I am arranging for dog teams to follow your tracks for some distance.
>
> If motors break down temporarily, you will have time for repairs.
>
> If motors break down irretrievably, take 5 weeks' provision and 3 gallons extra summit oil on 10-foot sledge and continue south easy marches. Arrange as best you can for ponies to overtake you three or four marches due south One Ton Camp. Advance as much weight (man food) as you can conveniently carry from One Ton Camp, but I do not wish you to tire any of party. The object is to relieve the ponies as much as possible on leaving One Ton Camp, but you must not risk chance of your tracks being obliterated and Pony Party missing you.
>
> (Signed) R. F. SCOTT. (Evans, 1961, pp. 142–143)

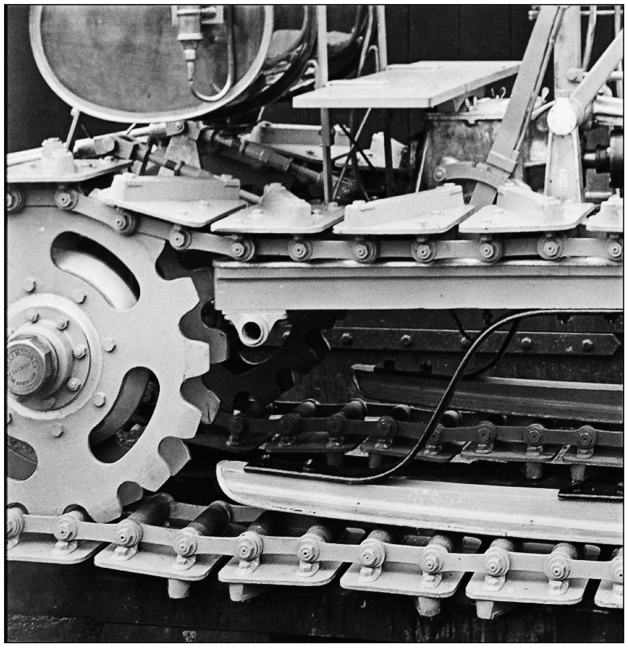


Figure 8. Close-up view of the continuous-track system on Scott's motor sledges, showing rollers.

The Motor Party was to consist of Evans (leader), Day (motor mechanic), Lashly (stoker) and Thomas Clissold (cook). Lashly, as one of the drivers, had been for a short course at the Wolseley works at Birmingham (Ellis, 1969, p. 101). Unfortunately, Clissold was injured prior to commencement of the Southern Journey, so Frederick Hooper (steward) took his place. They left Cape Evans on 25 October 1911.

Problems faced in the Antarctic

Problem 1 — Tracks had a short working life

The Hamilton-designed continuous-tracks were of unusual design, with 74 wooden rollers per track. Figure 8, cropped from a larger image, shows details that cannot be seen in most other photographs of the time. The two skeleton sprocket wheels at each end of the rear axle make contact with the ends of the rollers (each roller being 4 inches long by 1¾ inches in diameter), transmitting driving force to the track plates that make contact with the ground. In some ways, the mechanism is like a big bicycle chain. The rollers in the lower run of the track bear the full weight of the vehicle, as the wide bottom runner glides over them in the forward direction. The sprung weight of the vehicle is transmitted to the bottom runner via s-shaped steel suspension springs. The sprocket wheels bear no weight.

The mechanical friction inherent in this design, with all its moving parts, would presumably have been significantly greater than that of contemporary continuous-track designs. In any event, such friction places a significant strain on the engine when in motion, as discussed in Problem 2 — Engines were not powerful enough (below).

However, the most critical issue with the tracks was their short working life. The motor sledges' first work in the Antarctic was during 11 days of unloading and ballasting the ship, from 4 January 1911 to 14 January 1911. They relayed loads 1½ miles across snow-covered sea ice from the ship to the site of the hut, typically

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completing 6 return trips per day, or 18 miles per day. Loads were varied and not tightly packed (as opposed to loads thoughtfully stowed for a long journey). The priority was rapid unloading of the ship.

Mean daily temperatures over that (mid-summer) period varied from 17.4° Fahrenheit to 25.9° Fahrenheit (Simpson, 1923, p. 13). No engine overheating was reported while unloading ship, and there were no comments about "heavy surfaces" because these were, in fact, excellent operating conditions for cargo sledges. Susan Solomon agrees with Cherry-Garrard's observation that the ideal temperature for towing a sledge (i.e. gliding with least friction) is around 16° Fahrenheit (Solomon, 2001, p. 35).

However, the tracks' rollers were badly damaged while unloading the ship as Wilson explained:

> Ours [motor sledge tracks] have been badly damaged in the landing of gear from the ship. [. . .] much used backwards and forwards on the hard blue ice, and the turning each time did the damage by bringing wood rollers against metal, and ripping pieces out each time — a thing which was not visible till the motors were overhauled at the end when the damage was [already] done. No rollers having gone before only about 30 spares were brought, and some dozens are broken. (Wilson, 1972, p. 135)

The vehicles had no reverse gear, so a U-turn was required at each end of each relay trip. As the front was hauled sideways to make the U-turn, substantial misalignment of track and sprockets occurred, repeatedly damaging the rollers. Damage could have been minimised with an on-board steering mechanism, as noted in Problem 3 — Absence of on-board steering (below). On 3 March 1911 shortly after the "pony disaster," Scott shared some personal worries with Bowers:

> My feelings were nothing to what poor Captain Scott had had to undergo that day [. . .] He said however that he had no confidence whatever in the motors after the way their rollers had become messed up unloading the ship. (Bowers, 1912, vol. 2, p. 94).

Because of the damage to their tracks, the motor sledges were not fit to undertake any further work that season. They could not participate in the autumn depot journeys, which were to have been a testing and refinement opportunity for all modes of Scott's transport. This was a lost opportunity for Scott to discover that Barrier surface conditions, which can be very different from the Norwegian trial surface conditions, would necessitate significantly lighter loads than he intended for the Southern Journey. This subject is discussed in Blind spot — variability of snow friction (below).

During the (southern) winter of 1911, Day manufactured replacement wooden rollers for the tracks, using Meares' spare "chui sticks" (a dog driving staff).

On 21 October 1911, Lashly wrote to Skelton:

> Just to let you know we are about to make a start with the sledges on Monday the 23rd weather permitting, we have had to make good a lot of defects we have found out will not work. [. . .] The aluminium on the bottom of the runners completely done for the rollers, but we have repaired them & made new ones so that we can start (Lashly, 1911).

On 27 October 1911, after the motor sledges made their faltering start on the Southern Journey, Scott wrote pessimistically:

> But it is not easy to foretell the extent of the result of older and earlier troubles with the rollers. The new rollers turned up by Day are already splitting, and one of Lashly's chains is in a bad way; it may be possible to make temporary repairs good enough to cope with the improved surface, but it seems probable that Lashly's car will not get very far. (Scott, 2006, p. 309)

During the Southern Journey, Lashly recorded that several rollers had to be replaced, without noting how many spares remained. (Ellis, 1969, p. 117).

In summary, the tracks fell well short of the working life required for any Antarctic journey exceeding about two weeks in duration.

Problem 2 — Engines not powerful enough

The engines performed well during the 11-day mid-summer period when the motor sledges assisted with unloading the ship. However, from the commencement of the Southern Journey, the engines performed poorly. Observing progress on departure day, 24 October 1911, Scott was apparently surprised, "They are not by any means working up to full power yet, and so the pace is very slow. The weights seem to me a good deal heavier than we bargained for" (Scott, 2006, pp. 305–306). It is unclear whether Scott's reference to "the weights" was about the amount of cargo (which he had personally calculated and Bowers had checked) or whether it was about something else. Possibly Scott's phrase "the weights" was actually about the effort (and hence, the horsepower) needed to overcome the sliding resistance of the snow surface on the runners of heavy cargo sledges. The men rated it as "heavy surface conditions." Scott seemed surprised by the high sliding resistance presented by the snow surface. The mean air temperature that day was minus 4.8° Fahrenheit (Simpson, 1923, p. 10), much colder than during the successful mid-summer unloading of the ship.

The Motor Party recorded dry bulb temperatures two or three times per day after they left base. In the days prior to the vehicles being abandoned, the minimum recording was minus 19.3° Fahrenheit, and the maximum was plus 9.0° Fahrenheit. The average was minus 3.6° Fahrenheit (Simpson, 1923, p. 643). This range is well below the optimal figure of plus 16° Fahrenheit for smooth gliding, leading to substantially greater friction, as discussed in Blind spot — variability of snow friction (below).

The motor sledges did not cope at all well with their southern loads under heavy surface conditions. Evans' memoir *South with Scott* describes how the engines regularly overheated after only 15 to 20 minutes of heavy work on the Southern Journey. Cans of petrol and lubricating oil were dumped at several places along the route, in order to lighten the loads (Ellis, 1969, p. 118; Evans, 1961, p. 171; Scott, 2006, p. 314). From the commencement of the Southern Journey, the vehicles struggled, requiring constant manhandling to make progress. (Ellis, 1969, p. 117) Lashly wrote on 25 October 1911, "Had to drag the sledges up continually and finally relay" (Ellis, 1969, p. 117). The vehicles struggled on for about a week, suffering from multiple big-end bearing failures and a piston breakage. They were then abandoned as being irreparable. Evans noted, "It was easier work now to pull our loads straight-forwardly south than to play about and expend our uttermost effort daily on those 'qualified' motors" (Evans, 1961, p. 173).

One vehicle achieved about 29 statute miles on the Southern Journey (Hooper, 1912, p. 3) — about 15 hours working at full load. The other achieved about 51 statute miles (Evans, 1961, p. 173) — less than 30 hours working at full load. Both were abandoned as irreparable within a week of commencing the Southern Journey. Instead of the 800 statute miles contemplated by Scott (Table 1), the vehicles achieved about 80 statute miles, only ten percent of what Scott had contemplated.

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Lashly had written on 26 October 1911:

> I am beginning to think the motors are not powerful enough to pull the loads over heavy surfaces as they are continually overheating. The distance in each run is about from a thousand yards to a mile. [. . .] The engine is dragging such heavy loads, or may be we say such heavy surfaces. (Ellis, 1969, p. 118)

Day, the other driver, commented diplomatically on the reasons for engine failure, "I attribute this trouble [big end failure] to the great range of temperature, as well as to the excessive strains on the engine caused by the nature of the surface over which we travelled" (Day, 1913).

When a petrol engine is operated continuously at or near full throttle, cooling can become a major issue. Apparently, the drivers (Day and Lashly), having started their engines (typically a 15 to 30 minute process), set the throttle and then walked or pushed or pulled alongside. Maximum speed was about 3 miles per hour. The Motor Party needed to match the speed of the following Pony Party, which was expected to achieve ten to fourteen miles per day. It appears that there was no choice but to run the engines at full throttle for as long as possible. The engines produced severe vibration at high engine revolutions, "There is very little doubt we are in for a hot time as every time I do a run I find it shakes something loose" (Ellis, 1969, p. 119).

There would have been much strain on an early petrol engine running at close to maximum revolutions per minute. This brought typical problems for an overloaded petrol engine — overheating (aggravated by Day's makeshift bonnets, as discussed below in Problem 4 — Late changes to air circulation), failed bearings, broken piston, etc. The motor sledges had no temperature gauge, so presumably "overheating" was characterised by some form of engine seizure — a temporary locking-up of sliding parts. Overheated oil loses its "oiliness," causing the engine to seize. In 1910, the oil industry was still in its infancy, and there were no multigrade oil products or additive viscosity enhancers. It is also possible that oil starvation when starting from cold could have been detrimental to engine longevity.

On the Southern Journey, the motor sledges never achieved more than seven miles per day — less than half the daily distance they achieved when unloading the ship with lighter loads over a less demanding surface. The Wolseley 12-horsepower engines did not produce enough power for the job at hand. Maybe the horsepower shortfall was not great, as Hillary reached the South Pole overland using Fergusson TE20 farm tractors producing just 20 horsepower.

In summary, the Wolseley engines lacked the power needed for towing the loads Scott had specified. They were overloaded for the Southern Journey, prone to overheating and soon failed.

Problem 3 — No on-board steering

A major shortfall in vehicle design was the lack of an on-board steering mechanism. The vehicle was designed to proceed in a straight line across a smooth surface, level or sloping. When the direction of travel was to be altered, human effort was used to haul the front sideways. When the surface was not smooth, human effort was frequently needed to correct the course. Even on a flattish surface, any dip or rise on one side that was not exactly offset by an equal variation on the other side of the vehicle would cause a minor change in direction.

As noted in Problem 1, Tracks had a short working life (above) the process of hauling the front in a sideways direction damaged the rollers. A typical on-board steering mechanism, comprising independent track brakes together with a clutch or differential gear train, would have allowed the track on the outside of any turn to run faster than the track on the inside of the turn, thereby minimising misalignment of track and sprocket. This would have reduced the consequential damage arising from wooden rollers rubbing against metal components, particularly when executing U-turns. The provision of a rudimentary on-board steering system was well within the capability of the Wolseley Experimental Developments team.

The principle of having a human walk in front for much of the time, in order to control the direction of travel, was a significant constraint. Scott's vehicles were thereby limited to human walking pace, and the potential benefit of having a vehicle capable of travelling faster than transport-animals could not be achieved. This was unfortunate, as faster vehicles would have given Scott a chance to match Amundsen's pace.

Problem 4 — Late changes to air cooling

Day's makeshift wooden bonnets, initially installed to shield the carburettors from Antarctic weather, enclosed the entire engine (Fig. 9). Day's challenges, which he may not have fully understood at the time, were that a carburettor needs a smooth and sheltered supply of fresh air while the cylinders, once up to operating temperature, need as much cold airflow as possible. Day's challenges were exacerbated by the Wolseley carburettor being a poor performer when it came to starting a very cold engine. By reducing airflow around the engine, the bonnets contributed to early failure of the engines through overheating.

The vehicles had left England with black-painted engines that were completely open to the elements (Fig. 5). The black colour assisted cooling by radiation of heat energy, while the lack of any engine enclosure assisted convection cooling. However, the bonnets hindered both modes of cooling. In addition, as heat built up inside the bonnet, the temperature of air entering the carburettor rose, reducing the thermodynamic efficiency of the engine. In other words, as the temperature rose inside the bonnet, horsepower fell. This led to greater throttle opening and greater use of low gear, worsening the overheating. Day had faced challenges that were not widely understood at the time. On his own, he had to do something, and the bonnets probably seemed the best solution with materials at hand. Lashly and Scott could have contributed ideas, but Day was the most experienced mechanic in the party so, by default, maintenance and repairs fell to him. It is not surprising that Day was unable to solve all the challenges with the limited resources at his disposal.

Charles Neville's book, *Wolseley Cars in Canada 1900–1920* mentions similar challenges with Wolseley engines and carburettors in Canada's winter. It describes the approach taken by Wolseley (Canada) in 1912:

> Many, if not most of the problems reported to [Wolseley] Head Office [in Toronto, Canada] were attended to at the Depot. A typical example is the situation in which it was found that the Wolseley-built carburettor would not function properly in the cold season. A new induction manifold was designed by Frank Johnson and fabricated locally to preheat the mixture drawn through the carburettor, and a Zenith Carburettor replaced the original Wolseley type. (Neville, 1995, p. 37)

From 1912, four-cylinder Wolseley cars sold in Canada adopted an SU carburettor design manufactured under licence by Wolseley.

Nobody mentioned overheating problems when vehicles with bonnets were run for short trips with light loads and favourable surface conditions. However, on the Southern Journey, cargo loads were substantially increased and surface conditions became much

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Figure 9. Motor sledge with makeshift wooden bonnet. Image downloaded from https://www.coolantarctica.com/Antarctica%20fact%20file/History/biography/day-bernard.php.

more demanding at lower temperatures. Under those conditions, engines had to be run at full throttle for as long as possible, causing severe overheating of the poorly ventilated, highly stressed engines.

Lashly wrote to Skelton after returning from the Southern Journey, explaining how the drivers had attempted to manage carburation problems, "They [the engines] were continually over heating after running a mile at the outside & when we cooled the engine it was a case of closing up to warm the carburettor to get on the way again" (Lashly, 1912). Upon stopping the vehicle after overheating, the drivers opened the bonnet doors until the cylinders had cooled sufficiently, by which time the carburettor was too cold for an easy start. They then closed the bonnet doors to allow residual heat in the engine to warm up the carburettor, at which time the engine could be restarted with less effort than a cold start.

Abandonment of motor sledges

Despite extensive development and testing, the motor sledges did not achieve their planned performance. They were abandoned on the Barrier as irreparable, having completed about 10% of their intended work. Upon finding the first abandoned vehicle on 4 November 1911, Scott appeared to give up all hope for the other:

> Some 4 miles out [from the overnight camp], we met a tin pathetically inscribed, 'Big end Day's motor No. 2 cylinder broken.' Half a mile beyond, as I expected, we found the motor, its tracking sledges and all. Notes from E. Evans and Day told the tale. [. . .]. So the dream of great help from the machines is at an end! The track of the remaining motor goes steadily forward, but now, of course, I shall expect to see it every hour of the march. (Scott, 2006, pp. 314–315)

Lashly wrote to Skelton after the expedition about his experience with the vehicles, drawing some strong conclusions:

> I daresay you will have seen by the papers that the Motors did not go far as they were not powerful enough to pull the loads required of them. They were continually overheating after running a mile at the outside. [. . .] The big end brasses were also a weak spot as we broke 3 up completely. Mr. Day's car only went about 30 miles altogether and mine about 50 from Cape Evans (Lashly, 1912)

An official explanation for the failure would most likely be needed when the expedition returned to civilisation. Scott decided to keep it as simple and as free from blame as possible "Scott had been discussing with Day the report which is to go home about the motors. A moderate success and ultimate failure owing to heating defects is the verdict" (Cherry-Garrard, 1913, p. 339)

Atkinson's official post-expedition report on the motor sledges presented a more balanced picture than Scott had suggested to Day:

> The main troubles encountered in the Antarctic were due to quick overheating after short runs. For this the *great friction of the Barrier surface* [emphasis added] was mainly responsible. The engines are air cooled and ought to have been water-cooled. The main bearings were of aluminium and owing to the extreme degree of cold they developed a large crystal that caused fracture. The patterns [sic] [presumably track plates] in the endless chain were of wood. If they had been of metal they would probably have lasted better. The use of these sledges in the first year landing stores over the icy surface of the sea-ice between the ship and the shore probably settled their fate. They were driven at top speed over this icy surface and the patterns and everything else suffered. [. . .] Owing to the great friction caused by the peculiar Barrier surface [On the Southern Journey] the endless chain with heavy loads did not provide sufficient bearing surface. There was a tendency for the sledges to sink down on their after ends and the forward portion of the machines to be lifted from the snow. (Atkinson, 1913, p. 10)

After the Southern journey

What more could Scott have done?

The question naturally arises, "What more could Scott have done during the expedition (i.e. while in the Antarctic) to obtain better results from the motor sledges?" He could not have redesigned the tracks and constructed new ones to eliminate the vulnerable

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wooden rollers. He could not have boosted engine power significantly. He could not have designed and built an on-board steering mechanism.

If Scott had been aware that the motor sledges were so badly underpowered for Barrier work, he could have adjusted the loads to make the most of the available engine power. Over half the load was fuel and lubricant (see Table 1). A shorter journey — say 200 miles instead of 400 — might have cut 1500 pounds of fuel, allowing the sledges to travel farther before failing.

Had Skelton remained with the expedition, he might have noticed early signs of insufficient power and advised load reduction. But Skelton had been replaced by Evans, and no one at Cape Evans noticed the issue until it was too late.

Blind spot — Variability of snow friction

Several facts appear contradictory: Norwegian snow trials in 1910 proved that a motor sledge could tow a load exceeding three imperial tons, and the engines had sufficient power for unloading the ship in mid-summer 1911. Scott's plans allowed generous margins, "The motors start with 1¼ tons each . . . could easily take 2 tons" (Wilson, 1911), and yet Lashly later reported they were underpowered, "not powerful enough to pull the loads" (Lashly, 1912).

It is suggested that the quality of a snow surface rather than the weight of cargo on the sledge is the primary determinant of towing ease. Snow friction can vary from easy gliding to extreme resistance. Scott and Skelton apparently failed to realise that the snow surface at the Norwegian test sites was not a reliable indicator of what could be expected in the Antarctic, despite Scott having learned on his *Discovery* Expedition that snow friction could shift inexplicably with surface conditions (Scott, 2009, p. 287).

Today, we understand that snow friction when towing a sledge is governed by a complex interplay of temperature, snow structure, load and sliding speed. For nearly 90 years, prevailing theory attributed low snow friction to "self-lubrication," where sliding warms snow grains, producing meltwater that lubricates the interface. This explanation is, however, only applicable when the surface temperature is relatively close to the melting point and the sledge is travelling fast enough to avoid the meltwater re-freezing before the sledge passes. The self-lubrication model of snow friction has recently been challenged in favour of models that are more sophisticated. (Lever et al., 2017)

Skelton's 1909 report may have misled Scott with "Any tractor which would work on this surface would be suitable for the Great Ice Barrier as far as surface conditions alone are concerned" (Skelton, 1909, p. 1). Skelton correctly noted that motor sledge tracks would handle Barrier conditions, but didn't assess how snow friction would affect towed cargo sledges. No one realised that late-October Barrier snow could generate far greater friction than the Norwegian trials or mid-summer unloading.

A limited trial under colder Barrier conditions could have quantified sustainable loads before finalising plans for the Southern Journey. Scott had months to run such tests. In hindsight, had he done so and re-planned the Southern Journey accordingly, the motor sledges could have made a greater contribution to the expedition. After watching the vehicles struggle on 24 October 1911, Scott wrote, "A season of experiment . . . may be all that stands between success and failure" (Scott, 2006, p. 306) — perhaps reflecting a growing awareness of the need for seasonal trials.

In summary, Scott and his advisors had a blind spot regarding snow friction variability, which directly limited the sledges' performance.

The myth about World War 1 tanks

The Times of 10 October 1919 published a letter from Cherry-Garrard, claiming that Scott's motor sledges were a forerunner of WW1 tanks. Hamilton promptly rebutted the claim in a letter published by *The Times* on 19 October 1919:

> As the track-laying or caterpillar device is old and the armoured car is old, I fail to see invention in applying either a caterpillar device to an armoured car or plating with armour and mounting guns on a caterpillar tractor . . . I do not pretend to have any claim in the invention of the Tanks. ("Forerunner of the tanks", 1919)

Despite this rebuttal, Cherry-Garrard later wrote, "Scott never knew their true possibilities; for they were the direct ancestors of the 'tanks' in France" (Cherry-Garrard, 2010, p. 332). In fact, the Mark I WWI tank was built by William Foster and Co. of Lincoln. William Ashbee Tritton (the Managing Director of Fosters) and Walter Gordon Wilson designed and built the prototype WWI tank "Little Willie" in 1915, using components (including the continuous track system) from the American Bullock creeping grip farm tractor (see https://tankmuseum.org/article/little-willie for further reading about Little Willie). The Bullock tractor had an on-board steering system controlled by independent track brakes and clutches.

Little Willie had two iterations as a vehicle. Initially, it was carried on lengthened Bullock tractor tracks, which were custom-made. They proved inadequate due to the problem of "track sag." An alternative track was designed by Wilson and Tritton, and it is this alternative which made tanks practical, by removing the problem of tanks shedding their tracks as well as being a more robust and resilient linkage. This type of track is still in use today on heavy vehicles like diggers and cranes. (A. Hills, personal communication, 25 April 2025).

Motor sledge to be salvaged as a curiosity

On 21 November 1911, Scott and the Pony Party arrived at Mount Hooper Depot, where the Motor Party (now sledge-haulers) was waiting. He instructed Day to salvage one of the motor sledges, "Day will try and get the first car back to the Fodder Depot to be shipped for home as a curiosity if possible" (Cherry-Garrard, 1913, p. 339)

Hooper's personal diary records how Day began repairs on 18 January 1912 and drove one vehicle to the ice edge on 20 January 1912, as the One Ton Relief Party (Nelson, Day, Hooper and Clissold) returned from replenishing One Ton Depot in January 1912:

> We stopped a day at no. 2 car [Day's] which was 1½ m. south of Corner Camp, took on a few tools. Day had to mend No. 1 Car [Lashly's] which was 10 miles in on the Barrier & drive it to the edge [of the Barrier] so as the ship could pick it up when she came. (Hooper, 1912, p. 6)

The sea ice was very thick that season, delaying the ship's arrival at Cape Evans until 5 February 1912. There was much work for the ship to do, including several attempts to pick up Campbell's Northern Party, resulting in insufficient time to pick up the salvaged motor sledge.

As noted in Final sightings (below), this motor sledge was later discovered by members of the Ross Sea Party three years later.

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Second German Antarctic expedition

There was only one order placed for Wolseley motor sledges after Scott's. The Second German Antarctic Expedition (1911–1913), led by Wilhelm Filchner, ordered three. ("Wolseley German Order", 1910). In due course, they were built (Fig. 10) and delivered to Germany, but never reached the Antarctic. Filchner explained:

> For laying supply-depots on the Barrier or on the ice cap, auto-sledges had been built by the Wolseley Company of Birmingham after the model of Captain Scott's British Expedition to the South Pole, with the latter's approval. [. . .] Unfortunately, when the vehicles were delivered to Buenos Aires it turned out that specified, absolutely essential alterations had not been made. Hence, we had to cancel taking auto sledges; the space in the ship thus vacated was used for additional coal supplies. (Filchner, 1922/1994, chapter 1 p. 12)

The nature of Filchner's "absolutely essential alterations" remains unclear. Painting's book *Wolseley special products* (Painting, 2018, pp. 39–40) identified only two significant alterations for the German order (1) a rear-mounted winch gear, and (2) adjustable skids for bridging crevasses and rough ice outcrops (Painting, 2018, pp. 39–40). Photographs of the German vehicles at Wolseley's Birmingham works show that both alterations were made to the completed German sledges. Filchner does not state who was supposed to have carried out the "essential alterations."

It is suggested that at least one subsequent alteration arose from trials carried out in Germany after the completed vehicles had been delivered. Atkinson's post-expedition report on the motor sledges seems relevant:

> The [Second German] expedition was provided with sledges made on the similar model to our own by the Wolseley Company and the brief account of their trials and readjustments may be of interest . . . The main troubles that they had [during their European snow trials] were over running of the runners on unequal surfaces. The technical readjustments were small. Aluminium rollers were eventually substituted. (Atkinson, 1913, p. 9)

Atkinson wrote many official reports upon his return to Britain, always carefully worded, presumably to avoid criticising naval methods and naval personnel. His phrase about "runners on unequal surfaces" is nebulous and does not appear elsewhere, but it does place blame on surface conditions rather than on faulty design or inadequate testing. Atkinson may have been alluding to the fact that when tracked vehicles travel in an arc, the outer track has to cover a greater distance than the inner track. Hence, "unequal surfaces." As described in Problem 1, Tracks had a short working life (above), the fragile wooden rollers in Scott's motor sledge tracks had a working life of a few weeks, being easily damaged when the vehicles made sharp turns and U-turns — a common manoeuvre when ferrying cargo from ship to base station or from depot to depot on the ice.

No information about the German snow trials has survived. They may have been more thorough than Scott's Norwegian trials, with the German team identifying the critical drawback of wooden rollers, prior to their sledges leaving Europe. It would have been more sensible to replace the wooden rollers with aluminium ones using a local (German) manufacturer, rather than sending them back to Wolseley in Birmingham for alteration. This could explain why aluminium rollers are not mentioned in the Wolseley historical records reviewed by Painting.

Apart from Filchner's expedition, the Hamilton motor sledge patent was not taken up by any other venture.

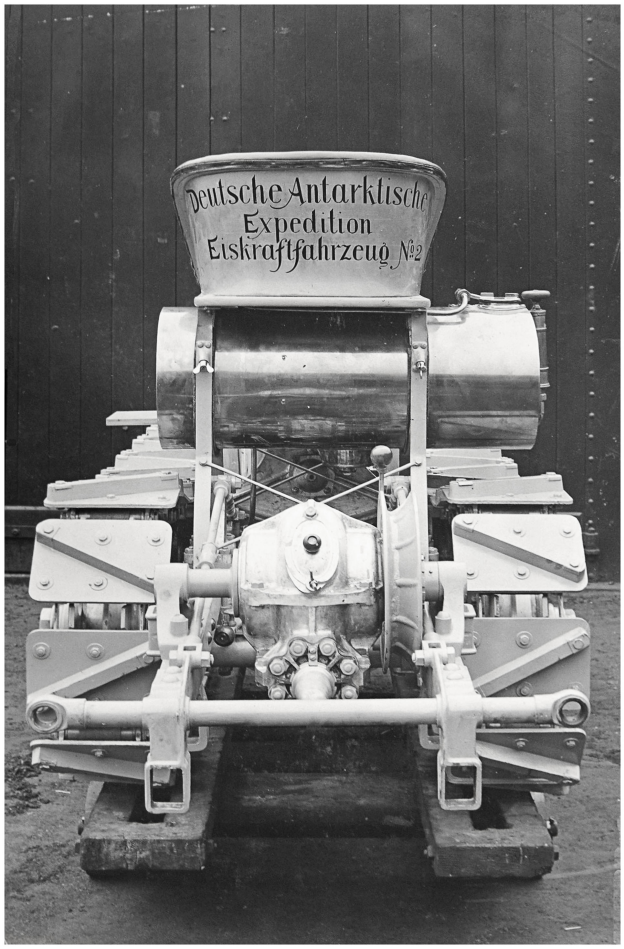


Figure 10. Motor sledge for the Second German Antarctic Expedition. Translation: "German Antarctic Expedition Ice Power Vehicle" Image downloaded from https://yuripasholok.livejournal.com/15433150.html.

Final sightings

In early 1915, Ross Sea Party members from Shackleton's Endurance Expedition found one of Scott's sledges. Aeneas Mackintosh wrote on 31 January 1915:

> I spotted some poles on our starboard side, we shaped course for these and found it to be Capt. Scott's Safety Camp. [. . .] Then we dug round the poles [. . .] after getting down about 3 feet we came across first a bag of oats, lower down two cases of dog biscuits, one with a complete week's rations, another [case] with seal meat. [. . .] About 40 paces to the NW of this depot, we found an empty Venesta lid sticking out of the snow. Smith scraped round this with his ice axe, and presently came across one of the motor sledges Capt. Scott used. It was too far buried for us to wait any longer and get it up. (Mackintosh, 1915, p. 5)

No sightings have been reported since.

Conclusions

Scott pursued the development of motor sledges with notable determination, departing from standard Royal Navy practice and initiating two Norwegian snow trials in an endeavour to develop satisfactory vehicles.

The short working life of the track rollers was the result of a serious engineering design shortfall, not of Scott's making. This failing may have been aggravated by not fitting ferrules to the

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rollers, as strongly recommended by Skelton after the first Norwegian trial.

The engines lacked sufficient horsepower to haul heavy loads across the Barrier's predictable surface conditions — a critical design failure. Operating near maximum revolutions for extended periods, compounded by restricted airflow from Day's makeshift bonnets (intended to mitigate carburation issues), led to chronic overheating and premature engine failure.

Despite having prior experience with Barrier surface conditions during the *Discovery* Expedition, Scott appeared unaware that snow friction on the Southern Journey would exceed that encountered in Norway or during ship unloading.

No load-testing trials were conducted in Antarctica prior to the Southern Journey. Scott seemingly did not recognise the importance of establishing sustainable workloads for the sledges. A lighter load might have enabled greater range, even if at reduced capacity.

Scott's journal is silent on the implications of snow friction for sledges, ponies or dogs, though it reflects extensively on its impact during the Polar Party's return.

Day's well-intentioned makeshift bonnets, intended to minimise carburation problems, aggravated over-heating of the heavily stressed and underpowered engines. Solving the underlying problems was beyond his expertise and available resources.

Scott, perhaps seeking to deflect criticism, understated the sledges' shortcomings and instructed Day to attribute failure solely to overheating. Neither acknowledged the engines' inadequate power. Atkinson's official report (1913, p. 10) offers a more balanced account.

In summary, the sledges were compromised from the outset by flawed engineering decisions regarding track design, engine power and carburetion/airflow. Minor refinements undertaken in Antarctica were unlikely to yield reliable performance. While the motor sledge programme did not achieve its aims, it nonetheless exemplifies the spirit of innovation and resolve characteristic of early polar exploration.

Competing interests. The author declares none.

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