The Great Storm and the fall of the first Tay Rail Bridge

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"Twas about seven o'clock at night,
And the wind it blew with all its might, …
And the Demon of the air seem'd to say –
'I'll blow down the Bridge of Tay' "
William McGonagall (1890).

On Sunday 28 December 1879 at around 1915 h (all times given are local) the central spans of the first railway bridge across the Firth of Tay, linking Dundee with Fife, fell in a storm, taking a train and 75 passengers with them. There were no survivors. Formally opened in May 1878 (although carrying trains for eight months before that), and designed by Sir Thomas Bouch, one of the premier railway engineers of the time, the bridge spanned one of the two main obstacles to an increasingly rapid train journey between Aberdeen and London, the Firth of Tay on the east coast of Scotland; the other barrier was the Firth of Forth, some 80 km to the south (Fig. 1). Until then, the only option for railway passengers was to disembark at Granton or South Queensferry on the south side of the Firth of Forth, cross the Firth by ferry and then board a train at Burntisland, Fife, cross to the south shore of the Tay and catch a second ferry to Dundee. The new bridge thus cut an hour off the journey time (Dow 1989). At a length of 3264 m (almost 2 miles) the completed bridge was the world's longest. The highest part (known as the 'high girders') rose 88 ft (*c.* 26.8 m) above the high water mark (Swinfen 1994; Martin and Macleod 1995). It was the 13 high girders which fell in the storm.

The storm

Much has been written from an engineering viewpoint about the construction of the bridge, the circumstances of its fall and the aftermath (see, for example, Prebble 1968; Dow 1989; Swinfen 1994; Martin and Macleod 1995; Lewis and Reynolds 2002). In contrast, however, discussion of the weather of that night is sparse and often anecdotal. The only formal account was written shortly after the disaster (Buchan 1880). The 125th anniversary of the bridge's fall provides a timely opportunity to synthesise the weather events of that night. Although often referred to as a gale, the term 'storm' is used here, reflecting the reported magnitude of the winds (between force 10 and 12 on the Beaufort scale). Much of this information is taken from Buchan, who collated weather observations from around Scotland at the time of the storm. Throughout this article, original units are given as cited, with imperial or metric conversions as necessary.

By all accounts the winter of 1879 was notable. Weather was bad throughout December all over Europe, with the Seine frozen at Paris (Prebble 1968; French 2001, in Schaefer 2004). It has also been noted (French 2001, in Schaefer 2004) that the colder weather that winter may have made the ironwork of the bridge more susceptible to failure, due to freezing. The weekend of 27/28 December had been characterised by strong south-westerly winds across Scotland, with several ships being wrecked on the east and west coasts (Swinfen 1994). There was a lull in the storm on the Sunday morning, with the Tay estuary being reported as smooth until well into the afternoon (Swinfen 1994). At dusk, around 1600 h, it started to rain and the wind freshened; the storm was well developed at Dundee by 1800 h (Prebble 1968; Swinfen 1994).

The track of the storm was calculated by Buchan (1880) from contemporary accounts and records gathered mainly from Scottish lighthouses. The data presented in Buchan's paper have been used to show the track (Fig. 1), and the associated pressure observations (Table 1) also show the storm's characteristics. The central track of the storm was

Fig. 1 The track of the storm and location of places mentioned in the text. SQ – South Queensferry. (Base map © EnchantedLearning.com.)

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Table 1

*Pressure observations on 28 December 1879, converted from Buchan (1880)**

	Station (See Fig. 1)								
	Dhuheartach†	Kyleakin	Wick	Armagh	Glasgow	Edinburgh	Aberdeen	Dunecht	Dundee‡
Local time									
0900		1000.78							
1000	1003.00								
1100	995.77								
1200	989.00			1004.50	1003.69		1002.91	1003.96	
1300	989.00			1001.19	1002.17	1002.54	1001.73	1003.29	
1400				997.87	998.78	1001.42	1000.54	1001.76	
1500				995.60	994.28	997.73	998.71	999.73	
1600	978.85	980.46		994.96	990.28	992.99	994.45	996.34	
1700	972.06			996.48	987.51	989.81	990.11	990.93	975.17
1800	970.03	968.61	978.12	998.65	988.05	988.83	982.05	987.88	
1900	985.61		976.13	1000.51	988.69	988.66	981.17	983.98	981.94
1930			972.27						
2000		982.15	970.30	1002.19	990.42	989.94	977.31	949.78	
2100	993.63	988.52	967.66	1003.36	992.79	991.81	975.01	980.09	
2200			970.03	1003.96	995.60	994.41	980.19	985.00	
2300		993.60							
2400			982.90						

* Conversion used 1 in mercury = 33.86 mbar (Meteorological Office 1972)

† Name changed to Dhu Artach in 1964

‡ Dundee data taken from Prebble (1968)

from South Uist to Wick (Fig. 1). At 1600 h the storm's centre was just west of South Uist. It moved east-north-east to Dingwall (reaching there at 2100 h) and thence north-east out to sea near Wick, eventually moving to the east of Orkney and Shetland (Fig. 1). The rate of progress of the storm between 1900 and 2100 h was about 3.5 times the average progressive rate of storms in this part of Europe (Buchan 1880). A more recent analysis (Saunders 1999) has suggested that this was a European windstorm – a severe cyclonic storm that tracks across the North Atlantic towards north-west Europe in the winter months, capable of generating hurricane force winds (the Burns Night storm of 25 January 1990 was a similar event).

One of the characteristics of the storm noted by Buchan (1880) was the fluctuations in pressure, ranging from just under 970 to 1004.5 mbar (Table 1). Observations made in and around Dundee reinforce this, where pressure started to drop from noon, with a sharp fall being noted at 1600 h (after sunset) by retired Admiral Dougall, who also reported that the wind turned to westward at 1700 h (also the time of lowest pressure reported there, around 28.8 in (just over 975 mbar)), then a further three points to westward before increasing to heavy gale (Prebble 1968). Thus, by 2100 h the wind was blowing down the valley of the Tay at right angles to the bridge (Schaefer 2004). The effect of the wind would probably have been enhanced by local topography. The Tay valley, including its lower part forming the Firth of Tay proper, is not a linear feature. Although oriented broadly west-south-west, the river has cut an irregular channel, with several major bends and changes in river width. The valley is relatively narrow at Perth (around 0.5 km), but widens to a little over 5 km some 27 km downstream from Perth and 5 km upstream of the bridge. The bridge crossed the Firth of Tay at a constriction, where the Firth is around 3 km wide (slightly shorter than the length of the bridge, which curved at the north bank), and the Firth then opens up to an estuary mouth around 5 km wide, 16 km from the bridge. Consequently, any winds blowing from the south-west and west would have been channelled down the valley and through the constriction near the bridge, thereby increasing their effect.

There are no direct records of the strength of the wind at the time of the storm (anemometers were not readily available at that time). Instead, we must rely on contemporary observations, usually based on the Beaufort scale, to gauge the wind strength. Accounts vary, but wind speeds of between 70 and 80 mph (*c.* 36 m s^{-1}) were reported (Science Museum 2004; Schaefer 2004), although a possible gust of 105 mph (*c.* 47.3 m s^{-1}) was noted (Martin 2004), and Admiral Dougall's observations using the Beaufort scale suggest winds of force 10 to 11, corresponding to speeds of 75–85 mph (up to *c.* 38.3 m s^{-1}). Within the city, slates were being blown off roofs and chimney pots blown down. Three loaded coal wagons (with an estimated total weight of 30 tonnes) were blown 400 yards (*c.* 274 m) uphill, along a siding (Prebble 1968), and by 1800 h, with the wind almost due west (straight down the Firth of Tay), the glass roof blew off Dundee Tay Bridge station. When the last train to cross the bridge from Dundee left at 1750 h the railwaymen reported carriages heeling over on the bridge with the gusts of wind (Prebble 1968). Accounts suggest that the storm was at its height at 1900 h, with a pressure reading of 29.00 in (*c.* 982 mbar) at that time. There was a major gust of wind around 1915 h, strong enough to bring down a large tree in Admiral Dougall's garden (Prebble 1968). This time corresponds with the (limited) eyewitness reports of the bridge's fall.

The fall of the bridge was witnessed by some people on both sides of the Tay, especially those living near where the bridge joined the land, but reports of a fall were initially dismissed (Prebble 1968). However, at Dundee Tay Bridge station it had become apparent by 1930 h that something was seriously wrong, as signalling and telegraph communications with the south side of the river had been lost – although some railway workers crawled across the bridge in the teeth of the gale, and found the high girders missing, no trace of any survivors was found on the bridge, or in the water below (Prebble 1968). A rescue boat sent out that evening had similar ill luck. At first light the damage became obvious as the high girders had disappeared (Fig. 2).

Drawing on Dundee's strong shipping tradition, during the following week many vessels sailed between the bridge and Dundee, initially searching for survivors and then, latterly, for bodies and debris. Prominent in these activities was the arctic explorer and navigator Captain William Adams (the author's great-great-grandfather). Over the course of the next few months a total of 46 bodies were recovered from the Tay and from sites around the coast of Scotland where they had drifted with the tide (Prebble 1968). Additionally, much light debris (carriage parts and personal possessions) was washed up along the riverside and around the coast, but a major salvage operation was required to raise the high girders and the main body of the train. The locomotive was recovered, refurbished and returned to service. Known afterwards as 'The Diver' it was finally retired from service around 1925 (Prebble 1968). Initial accounts (Anon n.d*; Lawson n.d) suggested that up to 100 people died in the disaster, but the figure generally accepted today is around 75 (Prebble 1968). Whilst the exact number has never been fully determined, an upper limit of 80 has been suggested. Had the accident occurred at the same time during any other day of the week it is likely that around 300 passengers would have been on the train (Prebble 1968).

By Monday morning, the weather was calm, but the storm had wreaked devastation across a swath of central Scotland and the Highlands. Not only had the Tay Bridge fallen and the city of Dundee suffered damage, but also the tower at Kilchurn Castle on Loch Awe fell that night, telegraph wires were brought down throughout the country and many hundreds of mature trees had been blown down at Dunecht, Aberdeenshire, between 2100 and 2200 h, whilst in Glen Lyon, just north of Dundee, forests of old (well-rooted) Scotch firs were blown down (Buchan 1880; Crawford 2002). Although no data are available, it is possible that the damage from the Tay Bridge storm may have been on a par with that of the October 1987 storm, which brought down an estimated 15 million trees and caused significant structural damage in southern England (Burt and Mansfield 1988).

The bases of some of the surviving steel columns of the bridge were found to have been bent upwards from their brickwork supporting columns, indicating the force of the wind (some had one or two layers of brickwork pulled upwards with them) (Martin and Macleod 1995). It has been suggested that this was a significant feature of

* No date.

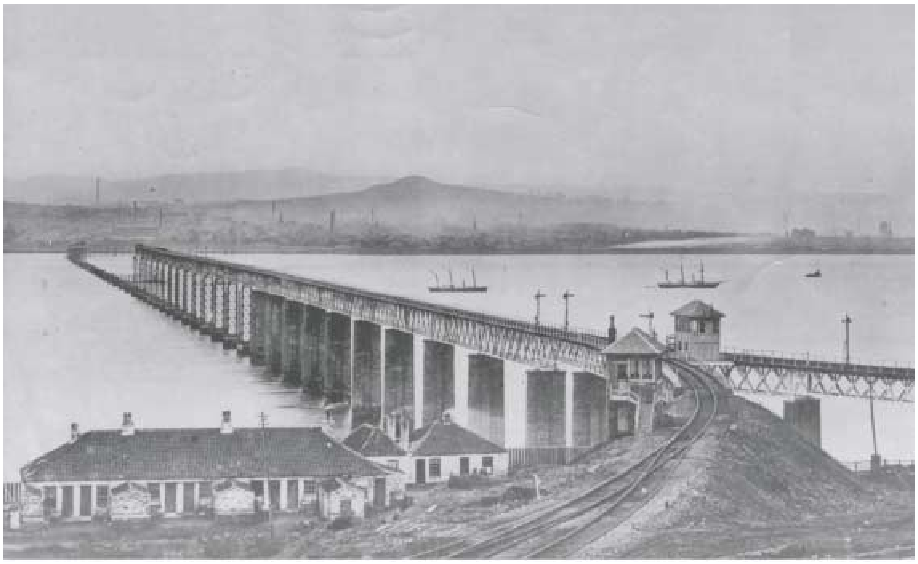

Fig. 2 The bridge after the fall of the high girders, early 1880. The view is to the north, with Dundee in the background. (© D. C. Thomson & Co. Ltd.)

the collapse (Martin 2004) and could have been an indication of waterspout activity, or at least the swirling and lifting phenomenon in the wind reported by Buchan (1880) and partially reflected in the broader-scale pressure trends (Table 1).

Aftermath

There has been much speculation about the sequence of events that night, and discussion of how much blame should have been shouldered by Bouch (who died a broken man 10 months after the bridge fell). Did the bridge bring down the train, or did the train bring down the bridge? Would the bridge have fallen anyway? Opinion is divided, and we may never have answers to these questions. The gusts of up to 80 mph (36 m s^{-1}) may have been primarily responsible for the collapse, with the additional effect of the train on the bridge being negligible (Swinfen 1994). More recent analysis (Martin and Macleod 1995) has suggested that there were design flaws in the bridge which made it more likely to collapse, and that Bouch changed his original plans for a more robust structure to save money, a view supported by the court of enquiry after the disaster (Martin 2004). Conversely, Dow (1989) has presented evidence to suggest that it was the train being blown off the rails and against the sides of the high girders which caused the bridge to collapse, a view favoured by Thomas Bouch.

Although the wind that night was much stronger than the bridge tolerances allowed for, in all probability the intensity of the storm was greater than might have normally been expected given the knowledge of the time and the lack of modern understanding of wind loading and dynamics (Martin 2004). Interestingly, in the scheme of such things, the storm which brought the bridge down was not that severe. The winds were of less intensity than the October 1987 storm (which gusted to 51.5 m s^{-1} (*c.* 115 mph) (Burt and Mansfield 1988)), the Burns Night storm (gusting to 105 mph, *c.* 47 m s^{-1}) (Saunders 1999) or, according to contemporary accounts, the Edinburgh hurricane of 24 January 1868 (Buchan 1880). None of these, of course, approached the ferocity of the 1703 storm (with estimated gusts of *c.* 77 m s^{-1} (*c.* 172 mph) (Lamb 1988; Wheeler 2003). In all probability the storm of 1879 would not have achieved such notoriety if it had not brought the first Tay Rail Bridge down, and today it is rare to find it in the annals of 'major storms'. It is also highly likely that, if the bridge had not fallen in this storm, another storm would have brought it down at some stage, perhaps with even more horrendous loss of life.

Following the fall of the bridge, work on Bouch's railway bridge across the Firth of Forth was suspended. The modern Forth Railway Bridge is a new design by different engineers. A new railway bridge across the Tay, designed by William H. Barlow, opened in June 1887 and is still in use today, and the stumps of the brickwork which supported the columns of the old bridge can be seen beside those of the new one (Fig. 3).

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Fig. 3 The new Tay Rail Bridge, looking upriver (west) from Dundee, 27 July 2004 (note the stumps of the old bridge pillars at the water's surface and the new 'high girders') (© P. J. A. Burt)

References

Anon. (n.d.) *In memoriam*. Undated memorial leaflet published after the accident

Buchan, A. (1880) The Tay Bridge storm of 28th December 1879. *J. Scott. Meteorol. Soc.*, **5,** pp. 355–360

Burt, S. D. and Mansfield, D. A. (1988) The great storm of 15–16 October 1987. *Weather*, **43,** pp. 90–114

Crawford, E. (2002) *Tay Bridge and associated lines.* http://www.railscot.co.uk/Tay_Bridge_and_associated_lines/frame.htm, accessed 10 August 2004

Dow, W. M. (1989) Destined for disaster. *Scots Mag.*, December 1989, pp. 275–286

Lamb, H. H. (1988) The storm of 15–16 October 1987: Historical perspective. *Weather*, **43,** pp. 90–114

Lawson, C. S. (n.d.) The Tay Bridge disaster. Undated pamphlet showing a series of prints, probably prepared in late 1879 or early 1880, *Dundee Courier and Advertiser,* 1 March 1975, Dundee, Scotland

Lewis, P. R. and Reynolds, K. (2002) Forensic engineering: a reappraisal of the Tay Bridge disaster. *Interdisciplinary Sci. Rev.*, **27,** pp. 1–12

McGonagall, W. (1890) The Tay Bridge disaster. In: *Poetic gems*, 8th impression, 1955, David Winter and Son Ltd, Dundee

Martin, T. (2004) *The Tay Bridge disaster.* www.tts1.demon.co.uk/tay.html, accessed 10 August 2004

Martin, T. and Macleod, I. A. (1995) The Tay rail bridge disaster – A reappraisal based on modern analysis methods. *Pro. Inst. Civ. Eng.*, **108,** pp. 77–83

Meteorological Office (1972) *Meteorological glossary*. Her Majesty's Stationery Office, London

Prebble, J. (1968) *The high girders*, 2nd printing. Pan Books Ltd, London

Saunders, M. (1999) *European windstorms and the North Atlantic Oscillation.* http://www.bbsr.edu/rpi/meetpart/ew/saunders1.html, accessed 20 August 2004

Schaefer, A. J. (2004) *The Tay Bridge disaster.* http://filebox.vt.edu/users/aschaeff/tay/tay.html, accessed 10 August 2004

Science Museum (2004) *The Tay Bridge disaster.* www.sciencemuseum.org.uk/on-line/heavy-weather, accessed 10 August 2004

Swinfen, D. (1994) *The fall of the Tay Bridge.* Mercat Press, Edinburgh

Wheeler, D. (2003) The Great Storm of November 1703: A new look at the seamen's records. *Weather*, **58,** pp. 419–427

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