SPARK ARRESTERS USED IN NEW ZEALAND

INTRODUCTION

The following article was written by David Berry, several years ago, for submission to one or more of the British railway magazines. Whether it was ever published, I do not know. Line side fires, caused by preserved steam locomotives running on the main lines, were an issue at the time and David felt that he could contribute something towards avoiding the problem based on his many years experience in New Zealand.

David served his working life as a Mechanical Engineer for the New Zealand Government Railways and, both before and after his retirement, was involved with many of the NZ preservation groups. He was a perfectionist and could be both highly valued and highly wearying; demanding in the extreme when it came to inspecting smokeboxes and ashpans. Those who ignored his advice tended to start fires; those who listened did not.

When the article was being written, I was privileged to be asked by him to proof read it and offer suggestions. I therefore feel that I may have contributed in some small way to its content. As the subject of spark arresters has recently come up on the Steam Tech discussion group, I thought it an appropriate article to bring to the group's attention.

The origin of the article below was a proof copy that David gave me. I do not know whether it was the final version, but believe it was. I have taken the liberty of correcting the odd typo and making a few minor additions to make it more complete and understandable to those not familiar with the details of New Zealand and its steam locomotives. As well as including David's diagrams of the two types of "Waikato" spark arresters, I have added a diagram of the "Cage" arrester, added details of the type of perforated plate used for these, and re-scanned the diagrams of the "Cyclone" arrester from page 45 of "The Steam Locomotive" by Ralph Johnson.

There is reference in the article to "Soft" and "Hard" coals. The Soft coals come mainly from the underground and open cast mines near Huntly, in the Waikato district of the North Island. The Hard coals come mainly from relatively small underground mines on the West Coast of the South Island around Westport, Greymouth and, more inland, near Reefton. The soft coals tend to be reasonably consistent in quality. The hard coals on the other hand, because of the very contorted geology where they are found on the western slopes of the Southern Alps, tend to be rather variable. The coal from any one mine can vary considerably over time, even from the same seam. Users of hard coal play a continuing game of varying their supplier (it is usually bought direct from the mine, or from Solid Energy who have now bought up most of the mines) in light of their running experience in regard to such things as ash content, clinkering tendency, pyrites content, etc. Soft coals have a lower calorific value and are cheaper, hard coals have a higher calorific value and are more expensive; you get what you pay for. From the operational point of view, hard coals are probably more practical simply because the fireman has to shovel less coal !

Not included in the article are details of more recent evidence that line side fires can be caused by the type of cylinder lubricating oil used on steam locomotives. I suspect that this was not known when steam was in everyday operation. If it had been, certain aspects of the design and operation of steam locomotives might have been different. But that is another story.

One of the problems of operating preserved locomotives is that their running is often intermittent. Some of their components, particularly those made of mild steel, tend to suffer much more from corrosion than they would have done when the locomotive was in every day service and everything kept hot and dry. Steam Incorporated has tried to overcome this problem by experimenting with different materials. One of our locomotives is fitted with a "cage" spark arrester where half of the perforated plate is 316 stainless steel and the other half is made from Corten (a copper bearing steel often used for tender water tanks). Both materials are more expensive than mild steel. The screen plates have now been in operation for about 13 years and show no sign of needing replacement. Our conclusion is that Corten (being the less expensive of the two and easier to punch) is probably the most economic option.

Alan Bailey
Steam Incorporated
10th March 2009

SPARK ARRESTING APPLIANCES ON NEW ZEALAND RAILWAYS STEAM LOCOMOTIVES

By David W.H. Berry
B.E.(Mech), B.E. (Elec), C.Eng., M.I.E.E., G.I.Mech.E

With the increasing effect of greenhouse gasses, global warming and changing climates it should not be surprising that a fire problem has finally caught up with British steam locomotive operation. What is surprising is that no active steps seem to have been taken to fit effective spark arresting appliances so that operations can continue in the summer months.

With its high mountain ranges New Zealand has a wide range of climates which can occur within geographically close districts. For example, in the north of the South Island the railway passes through Koromiko, which is a dairy farming area with lush green grass, then passes into the drier grape growing area around Blenheim and then on to Lake Grassmere where there is so little rain that there is a successful solar evaporated sea water salt works. All in a distance of 30 miles.

In some areas, droughts of up to three months during summer and autumn are not uncommon.

In the days of regular steam locomotive operation the line side vegetation, mainly grass, used to be burnt off before the fire season but, since steam locomotives ceased being used by NZR, this no longer applies. In the summer and autumn months there can be a prolific amount of very dry and inflammable grass right next to the track. In other places there can be gorse, bracken, pine plantations or commercial grain crops right up to the railway boundary. In addition to these problems, strong winds during the hot months and the remote (from road access) location of some parts of the railway line can result in any line side smoulder rapidly developing into a major conflagration.

Yet, with proper attention to design and dedicated maintenance, it is possible to regularly work coal burning steam locomotives in these conditions without setting the countryside alight.

My own experience as a young engineer was to be given the job of monitoring fires set by steam locomotives in the Canterbury area during the last days of steam. Also, since I had an interest in these things and subsequent involvement with preservation groups, my experience did not stop there.

The basic principle of setting fires was investigated by Professor Goss of Purdue University in the U.S.A., during the early years of this century. By setting trays of naphtha alongside the track he established that, to start a fire, sparks had to exceed a certain minimum size or else there would not be enough heat in the spark to cause ignition by the time it reached the ground.

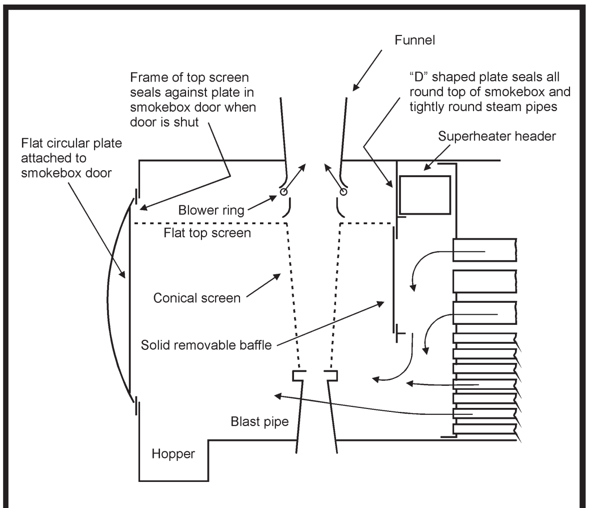
New Zealand steam locomotives can use two types of coal; hard and soft. The soft coals have a calorific value of about 10,000 BTU per lb and a moisture content of about 20%. When they are stored in a heap they start to lose their moisture content and the coal crumbles to what eventually becomes a fine powder. The hard coals have calorific values between 12,000 and 13,500 BTU per lb. The harder the coal the less likely it is that the lumps will break down. Yet glowing embers of soft coal seem more durable than similar sized embers of hard coal.

Our experience was that the size of permissible spark depended on the type of coal.

Smokebox spark arresters can be divided into three categories:

1) Screens
2) Grinders
3) Separators

Locally, locomotives fitted with screens were known as having cage type spark arresters. The screen that evolved in N.Z. consisted of 12 SWG (0.104”) steel sheet having slots 0.109” wide by 1/2” long. Total slot area was 30% of the area of the sheet. In most designs the screens were placed across the smokebox about 2/3 of the way up with a cone made out of screen material running down to the top of the blast pipe. Only the flue gasses passed through the screen and the exhaust steam traveled unimpeded up the inside of the cone.



CAGE TYPE SPARK ARRESTER

Canterbury, in summer, was regarded as the highest fire risk area and the combination of screens and hard coal was considered the best to prevent fires.

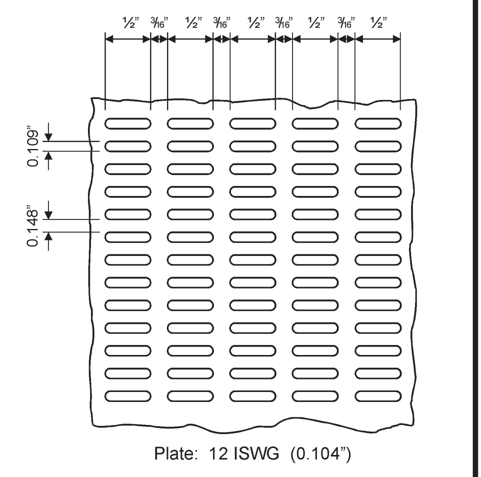


Plate: 12 ISWG (0.104”)

Details of slots in spark arrester plates

(From NZR Drawing No. X.12499)

My experience has been that if the screen area is made too large or there is insufficient draught it will block up with soot and if it is made too small it will block up with cinders. Screen holes are made with a punch which leaves a slightly tapered hole. The side where the punch enters is smooth, with rounded edges, and the side where the piece is punched out is rough. It was important to place the rough side towards the fire.

Screens could be a curse when lighting up with wet wood as soot and moisture could block them. A heavy wire brush on the end of a long handle was used to clear them. It was always advisable to do this before a locomotive left the shed.

To remain effective, screens had to be regularly inspected to ensure no gaps greater than 0.109” developed anywhere. Distortion and other movement of the screens is liable to occur, particularly against the sides of the smokebox, the tubeplate and the smokebox door. Inspection is carried out by the inspector taking a piece of welding rod 1/8” diameter into the smokebox and trying to poke it through any gap. To inspect the seal between the smokebox door and the screen the door has to be closed behind him.

Even with this small gap screens are not effective with soft coal and locomotives with screens have to be limited to hard coal if there is any risk of fire.

In the late 1920’s the N.Z.R. fitted a number of locomotives with the American “Cyclone” pattern of spark arrester. As a spark arrester it is a “grinder”. The idea being that the cinders are ground against the side of the drum and, in the process, are cooled and extinguished.

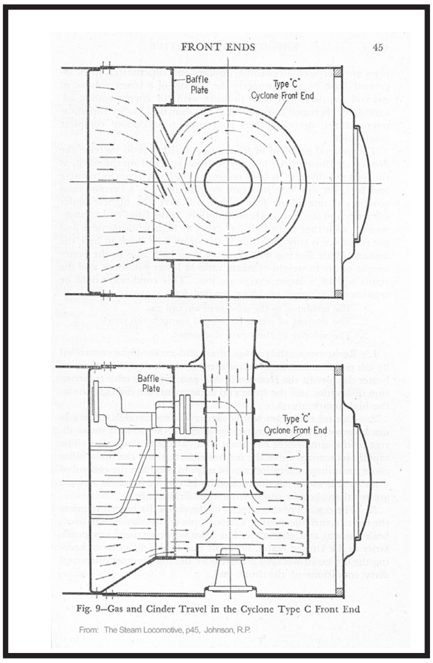


Fig. 9—Gas and Cinder Travel in the Cyclone Type C Front End

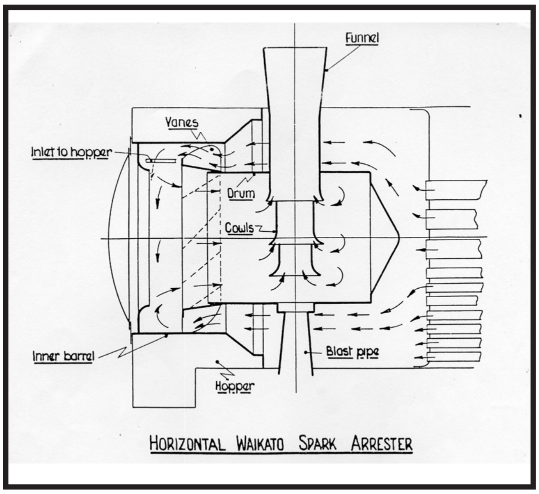
From: The Steam Locomotive, p45, Johnson, R.P.

The “Cyclone” spark arrester consists of a vertical drum sitting on the blast pipe and extending to the base of the chimney. A series of vanes facing the tubeplate set the flue gasses into a vortex so the cinders are thrown out against the drum, the smoke coming out of the chimney having a sort of twisted appearance.

They were gone before my time but those that worked on them considered the locomotives steamed well, the principal objection being the way in which they threw the ground up cinders out of the chimney.

Since the N.Z.R. had to pay a royalty on the “Cyclone” they designed their own in the 1930’s which still used the vortex principle except the vortex was in the horizontal rather than the vertical plane. This was called the “Waikato” after the principal soft coal producing area of N.Z. Since it was widely used for many years several locomotives that are fitted with it have survived into preservation and are still operating.

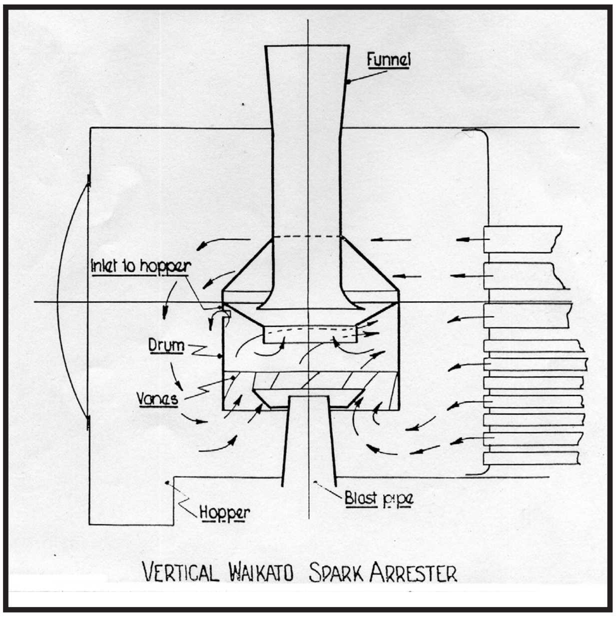
It consists of two concentric drums fitted into and in the same plane as the smokebox. The outer drum front rim abuts against the outer surround of the smokebox door and the inner drum is set back from the door a bit and fits between the blast pipe and the base of the chimney. It is closed off at the tubeplate end.



HORIZONTAL WAIKATO SPARK ARRESTER

The flue gasses travel through the annular space between the two drums where, towards the smokebox door, vanes create a vortex. The cinders are thrown out against the outer drum and pass through it via slots which are placed rather high up. The cinders then accumulate in the space between the smokebox and the outer drum, and fall to the bottom of the smokebox. As the inner drum is set back from the smokebox door the flue gasses then spiral into it and travel back to the blast pipe and up through the chimney.

At the front sides of the smokebox there are small doors from which the accumulated cinders are removed. Some locomotives had a small hopper at the front of the smokebox giving extra storage volume. The hopper has to be cleaned out regularly otherwise, if it fills up, the cinders are no longer collected and what grinding action there is, is inadequate to put them out. So the locomotive starts throwing live sparks and sets fire to the countryside. It is advisable to clean out the hopper about every 100 miles.



VERTICAL WAIKATO SPARK ARRESTER

It is a very effective spark arrester but, unfortunately, there is a price to be paid for dragging the flue gasses through the drums and creating and destroying the vortex. A locomotive fitted with a “Waikato” spark arrester has to have the blast cap area reduced by approx 6% when compared to a locomotive of the same class fitted with a cage arrester. They also sound different; the exhaust from a cage locomotive goes “woof” whereas a “Waikato” goes “wah”.

One disadvantage of the “Waikato” spark arrester was that when it was in place it was not possible to see the tube plate and taking it out was not the quickest of operations.

In later years the N.Z.R. produced another design of spark arrester which was called a “Vertical Waikato”. While it was more similar to the "Cyclone", it may not have been an attempt to circumvent the "Cyclone" patent as a similar design evolved on some of the privately owned logging railways and it could have been copied from there.

In this design a stationary fan is fitted around the blast pipe. Sitting on the outside rim of the fan is a vertical drum which reaches to the base of the chimney. There is a ring towards the top of the drum acting as a single baffle. While its intention is to ensure only small cinders get past it I have often wondered how much use it really was.

Since the drum is shaped like a milk can that is just what the depots called it.

A number of locomotives fitted with this arrester have survived into preservation. Larger locomotives with short chimneys are not so popular to work on as the vortex in the exhaust tends to fan the smoke out as it leaves the chimney increasing the amount of smoke drifting down into the cab.

I have watched a Vertical Waikato start throwing sparks when, at about 25 MPH, the valve gear was placed at maximum cutoff and the regulator pulled wide open. Of course, no one should operate a locomotive like this.

As with screen arresters, it is essential that all components of the other types of arresters fit neatly together and no cinders can bypass the device. Again the piece of welding rod poked into all gaps is the best way of checking this.

I still watch, with both fascination and apprehension, a cage type locomotive working hard at night in dry weather conditions throwing a shower of small sparks, yet if the arrester is in good order there is no trouble with line side fires. Perhaps the real fascination is in watching one of the Waikato's not throwing any visible sparks at all.

In retrospect, the people who designed these things had no appreciation of aerodynamics and just produced something that worked. Given a proper understanding of aerodynamics and gas flow I am sure an effective arrester can be designed that has much less aerodynamic drag.

Experience in service, however, was that most fires started from cinders escaping from the ashpan area.

Since the 1930's, the ashpans of most N.Z.R. locomotives had ash hoppers with bottom doors, many of them air operated. The bottom doors were opened in the depots and the ashes dropped straight down into the ash pit. With wide firebox locomotives those parts of the ashpans from which the ashes did not drop out of their own accord were washed out. With suitable design it is not necessary to go underneath locomotives to rake out ashes.

These locomotives had no ashpan dampers. On wide firebox locomotives the ashpan was extended out and upwards at the sides of the firebox and this was the main air intake to the ashpan area. This entry point for the air also had the side effect that, when working hard, the strong draught tended to blow any ash, resting on the flat areas at the side of the pan, into the hoppers. On narrow firebox locomotives the ashpan was extended out and upwards at the front and rear of the firebox.

Older locomotives that had ashpans with dampers had a hinged plate which had a series of 3/8" holes drilled in it. This plate was located between the damper and the ashpan and was clipped in place while the locomotive was working. It was swung upwards when the ash in the pan was raked out.

I had no real experience of these older locomotives in service and most of those that remained were confined to shunt yards. Since cinders smaller than 3/8" were known to start fires I had reservations about this hole size. When a group of NZR volunteers overhauled and re-commissioned F163, a 20 ton 0-6-0 saddle tank locomotive built by Dubs in 1880, I consulted an elderly retired Chief Mechanical Engineer. As a result we replaced the drilled plate with one having a section of commercial perforated plate, the hole size being approx 0.1" diameter.

I am pleased to report that this locomotive has had quite a bit of main line running in very dry conditions. This locomotive has a screen arrester and the only occasion it gave any trouble was when it went to Hamilton, which is the provincial capital of the Waikato area, and ran a number of short distance trips for a local charity. The grateful organizers produced a quantity of the local soft coal for free which the crew did not have the heart to refuse. Fortunately no serious damage was done.

When ashpan hoppers are fitted with bottom doors there is always the possibility of hot cinders escaping through the inevitable clearance between the door and the hopper. This can be completely eliminated by connecting the overflow of one of the injectors to a perforated pipe suitably positioned above the hoppers. The content of the hoppers is quickly turned in to a sort of gritty porridge that effectively prevents the escape of hot cinders. When this is done, a small "tell tale" pipe is attached to the injector overflow pipe, in a suitable place visible to the fireman, to indicate when the injector is overflowing.

Like spark arresters, ashpans have to be given rigorous and regular inspections. Again, the best inspection tool is the piece of 1/8" welding rod and care should be taken to ensure that there are no gaps where the pan butts up against the foundation ring or there is anywhere else where the rod can be got through.

To do this properly the fire bars have to be removed and the ashpan cleaned of ashes. Faults that are liable to develop are corrosion, the warping, cracking and movement of plates, and doors that do not lock closed properly and/or can vibrate slightly open when the locomotive is running.

Many faults can be picked up by getting inside the firebox and, with good lighting outside, looking for light coming through cracks and holes.

In conclusion, I would like to reiterate that the type of arrester has to be suitable for the coal being used. Also, to be effective, it has to be subject to rigorous and regular inspections during the fire seasons. Effective spark arresters can also be fitted without much visible alteration to the appearance of the locomotive.