Attractive points

New points with no moving parts could put an end to train delays

by Dap Hartmann

Failing points are one of the main causes of train delays. The design of the current type of railway points dates back to pre-World War II days, and is in urgent need of replacement. Five Industrial Design students at TU Delft decided to forget about existing principles and came up with a set of points without moving any parts. Instead, an electromagnet pulls the train in the right direction. The system is maintenance-free and much less prone to malfunction. Can it really be this simple? A story about innovative young minds in a world set in its ways.

Near stations in particular, track contains large numbers of points. The electromechanical components, which are in constant daily use, are prone to malfunction. A single points failure can result in long delays a long way down the line.

Manually operated points, 1920. The principle of railway points has remained essentially unchanged since muscle power was replaced by the electric motor. photo: Spoorwegmuseum, Utrecht

Even before we have exchanged more than a couple of words, Wim Verheul produces a model. First he wants to show that the thing works, then we can talk about how the idea came into existence. A section of model track cuts through a plastic landscape with some plastic cattle stuck down in imitation fields. Halfway along, the track forks at a set of points. The points contain the rails for both directions, but there are no moving parts. So how does a train change its destination? Has the engine been fitted with a steering wheel? Verheul unplugs his notebook computer to replace it with a low-voltage model railway power supply. Taking a model engine from a shelf, he puts it on the track. To the left of the points, a permanent magnet is placed. All set for the demonstration, ready for departure, the train starts to move, passes the points, and continues along the straight section. Once again, but this time the magnet is put on the other side of the points. The train branches off to the right, seemingly of its own accord. As is often the case with magnetic phenomena, it looks like black magic.

Grinding to a halt

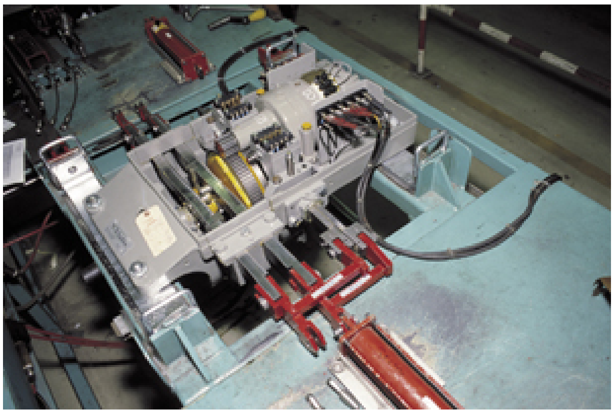
Wim Verheul is the R&D coordinator of Vialis Verkeer en Mobiliteit (traffic and mobility), a subsidiary of Royal Volker Wessels Stevin (KVWS). Vialis has some of its roots in Electrorail, the electrical contracting company of the Dutch railways (NS), and some in Nederland Haarlem, an old family business acquired by KVWS. It is one of the 140 subsidiaries in the Netherlands engaged in property development and the construction of infrastructure. A quick survey revealed that without Vialis the Netherlands would slowly grind to a halt. The company designs and builds traffic control systems (junctions, traffic lights, switches), traffic management systems (such as overhead information systems on motorways), parking and access control systems (car parks with free space indicators, car park direction systems), and railway systems (level crossings, signals, point mechanisms, safety systems, etc.). Within the latter discipline Vialis produces everything to NS exact specifications, but they also try to develop new solutions for the traditional system. Although Rail Infra Beheer (RIB), which manages the railways infrastructure, does itself initiate schemes for renewal, the Dutch railway system remains fundamentally the same. To breathe new life into his work as research & development coordinator, Wim Verheul defined a voluntary design assignment for the 'Design 6' subject at the Industrial Design faculty of the TU Delft. Students Willem Jan de Visser, Abboy Verkuilen, Daan Bakermans, Miguel Bruns Alonso, and Jiske Barten formed the 'Studio Blauw' (= Studio Blue) design team, and took up the challenge for the next six months.
Since there was no direct need for a new product, the assignment brief remained fairly open. But after an analysis of the company's innovation potential, the question being how to improve the availability of a section of railway track became the main target. What are the crucial factors involved, and what is the factor that limits availability most?
Daan Bakermans: "Many delays arise as the result of trains, points, overhead wires or whatever breaking down. We have constructed complete failure trees to show exactly where things can go wrong. Each problem usually has its own specific cause, and the question was of course which of these we were going to tackle. Most of the problems by far turned out to be points-related. Points are the main bottleneck determining the availability of a section of track."

Marshall Aid

A traditional set of points uses a pair of rails, called tongues, which are fixed at one end, while the other end can be moved sideways by means of an electric motor. The tongues do not swivel; the force of the motor actually bends them. This is made possible by the considerable length of the tongue rails. The design is

The moveable tongues of a set of points consist of two rails that are fixed in place at one end at what is called the frog and that can slide sideways at the other end. The tongues are not hinged, but bend along their length.

Switching points is done using a points actuator that uses two rods to simultaneously pull the two tongues to one side. The tongues move about 12 centimetres from side to side.



exactly the same as it was when it was introduced over 50 years ago. The Dutch railway system was drastically modernised after the Second World War as part of the Marshall Plan. Under the reconstruction programme the different lines were unified, and all the old points were replaced with new electrically operated sets. As a result, the Dutch railway system became a copy of the American system. The generous offer of aid came with a heavy ball and chain attached in the form of a track system that involved the U.S. supplying our railways for the next 40 years.

The net result was that for nearly half a century, the design of railway points in the Netherlands did not change.

These days, with railway lines being used to capacity, using mechanical means to actually bend a set of rails so trains can change tracks seems an exceptionally archaic method which it is in the sense that it is a pre-war technology. Moreover, the yoke of four decades of Marshall marriage has put paid to any urge to innovate. Even when the shackles were finally released in the late nineteen-eighties, nothing changed, so it is hardly surprising that a separate railway line has had to be built to accommodate the high-speed rail link. After all, you don't race your Ferrari on a farm track.

No access

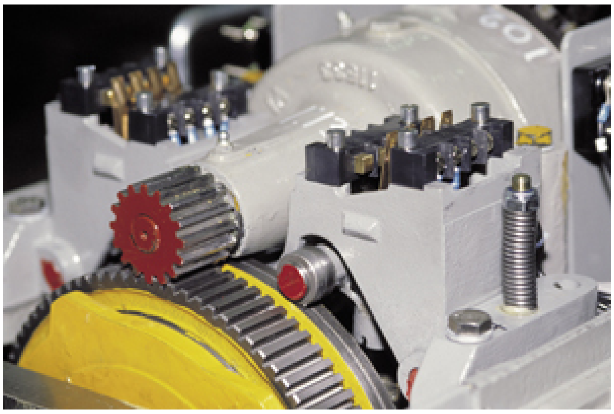
Each half hour's delay of a train carrying 1000 commuters results in the loss of 500 productive man-hours, a quarter of a man-year, or in money terms, more than B 10,000. The Dutch railway system includes approximately ten thousand sets of points, some 300 of which can be found in and around Utrecht Central Station. Each year, an estimated number of 2,000 points failures occur. The main question is of course, why do these points cause so many problems? What is it that makes them go wrong, and how can it be prevented?

Willem Jan de Visser: "Getting hold of this kind of information proved to be much harder than we initially thought. Hardly anything is kept on record Ñ not publicly accessible, anyway. So the only thing to do is to go and ask the people involved, and they are all caught up in bureaucratic hierarchy that prevents them from deciding what they can and cannot divulge. Whatever the case, they tend to be less than eager to have their dirty linen washed in public, certainly not if itÕs to be done by a group of students."

In addition, a lot of NS know-how was lost as engineers and mechanics were pensioned off during a series of cost-cutting reorganisations. What expertise remained was usually kept more or less under wraps under the pretext of protecting 'strategic information'. Know-how on points can also be found at a number of private railways construction contractors that handle construction and maintenance for NS. But even they looked at the students askance and proved less than forthcoming in providing information.

Abboy Verkuilen: "It was very difficult to find out what it is that makes points fail, since we received very little cooperation. For example, we know that certain components fail regularly, but we don't know whether this is because of too little lubrication or because the

A reconditioned points actuator on the test bench. Although points actuators can last as long as forty years, the usual practice is to overhaul them once every decade. If a stretch of track is scheduled for major maintenance work, this usually leads to a premature overhaul. On the test bench, the track rods are represented by the red bars, which are connected to an electromechanical system that simulates the points. Each set of points has four rods, two to move the tongues, and two feedback rods that move with the tongues and report their current position.



The feedback rods move a rotating mechanism consisting of the disc behind the gear wheel. The disc has notches along its perimeter. As the small tracking wheel hits a notch, an electric switch closes. It is a complicated mechanical movement in which the driving part coincides with the position feedback mechanism. The failure analysis carried out by Studio Blauw prompted Vialis to develop a points actuator in which the drive part has been separated from the position feedback mechanism. The use of electronic proximity sensors in the points actuator has made for considerable simplification of the feedback mechanism. Since the innovation is inside the actuator, the improvement can be simply introduced at the next overhaul. If customers are sufficiently interested, Vialis will take the new mechanism into production.

To fix the tongues in position, they are pulled across a cam. This operation take a fair bit of force. The cam mechanism, which is used only in the Netherlands, appears to be a source of failure. ThatÕs why Railinfrabeheer have started looking for an alternative.

material wears down too quickly. With hindsight, this situation probably determined our approach, since the fact that we were unable to look at the points in detail to see what could be improved, forced us to start from scratch. So what we did was to study the principle of railway points as a whole."

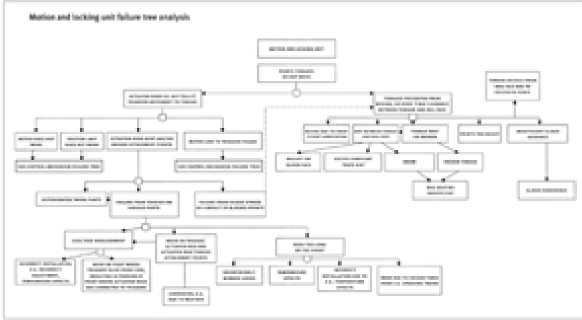
Four overhauls

An added incentive to taking a completely fresh approach was the fact that various minor structural improvements over the years had proved unsuccessful. Time and time again the original design turned out to perform just as well as the new partial improvements. For instance, a number of attempts were made to improve the surface along which the rail tongues slide. The accumulation of dirt forms a major problem, so a slider with a number of slots in it was tried, but this turned out to pick up the dirt even faster. Several other 'smart' alterations also turned out to be less than successful. Although the problem can be ameliorated by regular maintenance, it will never disappear. That's why each of the 10,000 sets of points is overhauled four times a year. The manual lists exactly what has to be done on each occasion. What to lubricate every three months, what to readjust every six months, and which parts to replace once a year. Just imagine what would happen if a car manufacturer sold cars that required four major overhauls each year.

Bakermans: "The main problem is that the thought processes at NS have got stuck in a rut as a result of working along the same lines for over half a century. Many of the NS people have clearly fallen in love with the beauty of mechanization. A lot of them are diehard model railway enthusiasts, who will never give up their system. You can clearly feel the resistance to change."

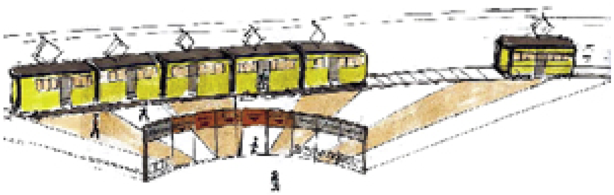
All in all, finding a way to improve the existing sets of points on details seemed a hopeless prospect. So the challenge was set: how to design a new concept that has none of the structural problems causing the frequent failure of the current sets of points? The primary conclusion from the preliminary survey was that the points' moving parts formed their Achille's heel. By the way, there is very little variety in the way railway points operate. The principle of moving tongues is practically the same all over the world. The only real innovation over the past century has been to replace manual operation with a mechanism. The only aspect that shows some variation is the type of switch actuator used. In the Netherlands, only electric motors are used, but hydraulic points actuators are also being produced. The actuator is connected to both tongue rails by means of a complex set of rods, the dimensions of which vary for each individual set of points, no two sets being exactly the same. This makes installation, revision, and maintenance extremely labour-intensive, and consequently, costly.

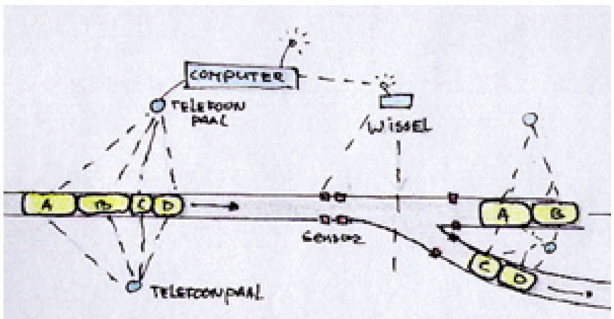
Verheul: "A points actuator has to be anchored in place. A set of rods is then attached to it that leads to the tongues. As a result of the variation in sizes, the permutations are endless. Adjusting a set of points is a high-precision job that is very error-prone because there



After it had become clear to the members of Studio Blauw that points actuators formed a major cause of delays in the Netherlands, they drew up a failure tree chart to map the problems dogging points actuators.

After their broad survey of the current railway network, the members of Studio Blauw had a brain storming session to get away from well-worn thought patterns and come up with original solutions. The results range from the abstract to the highly specific.





One of the first ideas was to have train passengersÕ tickets checked on the platform rather than on the train, after which passengers were grouped according to their destination. Smart points would then direct the different coaches to their respective destinations. The underlying idea was that stations could be simplified and that destinations could be called at with high frequency.

is no single correct position. There is always a certain margin of play, and in some cases the play exceeds the actual movement required. If that is the case, one could say the design is at fault."

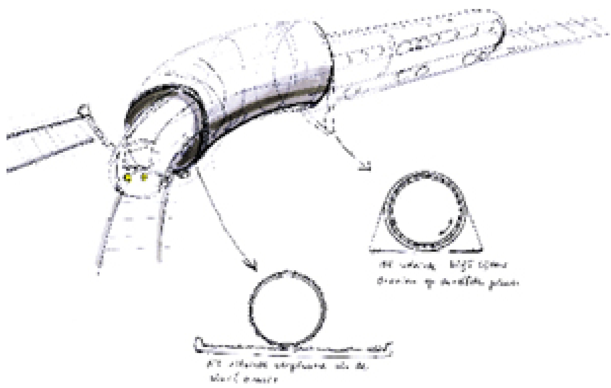
Control errors

Another fundamental design error of the current type of points is that the control system (which shifts the points) is intertwined with the monitoring system (which checks the correct position of the points). In this respect, the design violates a basic process control rule, which states that the monitoring system should always be physically separate and operated independently of the control system. Due to this design error, in actual use the monitoring system fails more often than the points themselves. In other words, in most cases of points failure, it is not the set of points, but the monitoring system that has broken down.

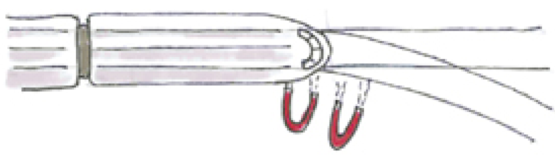
Studio Blauw started by defining the problem (at a fork in the track, a train must be capable of continuing in either of the two directions offered) and formulated the ideal solution (a set of points without any moving parts). The new concept had to evolve by pursuing the ideal solution with a minimum of changes to the current situation. As Oscar Wilde put it, 'Progress is the realisation of Utopias'. As Wim Verheul puts it, "The new system should fit as closely as possible into the present infrastructure. There is no point in coming up with plastic rails or adaptations to rolling stock, for that would ensure that the new points system will never be introduced."

At points with moving tongues, the train continues in the direction laid down by the track. A points actuator uses mechanical means to change the track and the train simply continues in the direction it is pointed in. Without moving parts, the track for each of the directions is fixed, so a way has to be found to somehow force the train into the desired direction. The running surface of the wheels on a train is about 12 cm wide. Each wheel has a flange on the inside to keep the train from running off the track. On each wheel shaft, the clearance between the two flanges and the rails is about 5 to 6 cm. This is more than sufficient to make the train change direction at the points. In the new Delft points design the rails are positioned so that a train will continue along the straight track if the clearance is all on, say, the right-hand side, and if the clearance is between the left-hand wheel and the left-hand rail, the train will veer to the right. The rail sections in the points remain fixed in place Ñ all that is necessary is for the wheel flanges of the train to make contact with the rails in the left or right. The possibility of changing direction in this way is the first major breakthrough. The only remaining problem was how to actually push or pull a train in the right direction.

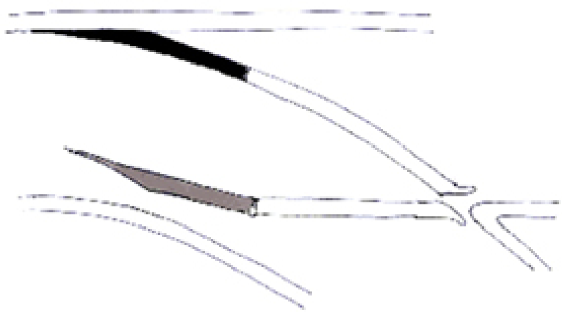
Verkuilen: "Although with hindsight our solution seems obvious, we also looked at a various other methods. For example, can the train be pushed to one side by blowing air or water against it? Perhaps, but it would require enormous compressors, so it would not be a practical solution. Another possibility would have been to lower the rails for the direction you do not want the train to go



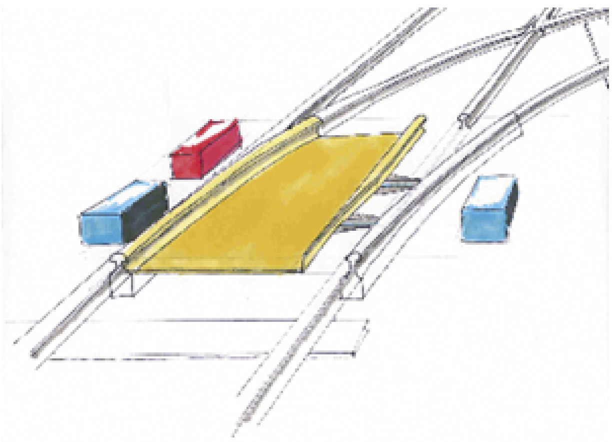
Another idea consisted of a tube around the track that rotates slightly at one end to shift the train to another track.



After having looked at hydraulics, pneumatics, and gravity in succession, the designer came up with the idea of using magnetism.



Why not use hinges instead of simply bending the tongues?



In this scheme, instead of bending the tongues, a large section of the points assembly is shifted sideways.

in, but that would be another mechanical solution, which is not what we were looking for.”

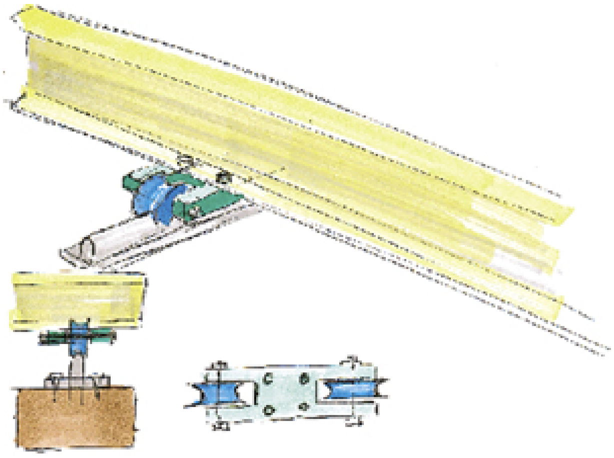
Magnetism

Studio Blauw calculated that a train could be pulled in the right direction using magnetism. In the scale model, it works perfectly using a permanent magnet that acts on the steel frame of the train. Fortunately, the principle of electromagnetism has been invented, so train drivers will not have to stop every so often to position a giant magnet on the correct side of each set of points. The idea is to put two rows of electromagnets alongside each set of points. The preliminary design uses ten coils on each side along a five-metre stretch. The calculations show that simple electromagnets will suffice to supply the necessary force given the available surface area. Although the wheels themselves present a sufficiently large surface, it would be preferable to fit metal sandwich plates to the train bogies to prevent the strong magnetic field from causing a number of undesired side-effects. You don0t want to be seeing passengers’ spectacles flying out of the windows, or laptop computer hard discs, diskettes, or credit card strips being wiped clean. The magnetic field produced by the return current from the overhead wire that runs through the train’s electric system and through the rails back to the power station is many times stronger. Much of this passes through the metal superstructure of the carriages without any problem. However, the electromagnets operating the points could induce powerful Eddy currents in the wheels, causing friction that would wear down the wheels and slow down the train. Therefore, the wheels would have to be modified, for example by constructing them from alternating layers of steel and an isolating material. Such a modification would be contrary to the stated design objective of using unmodified rolling stock.

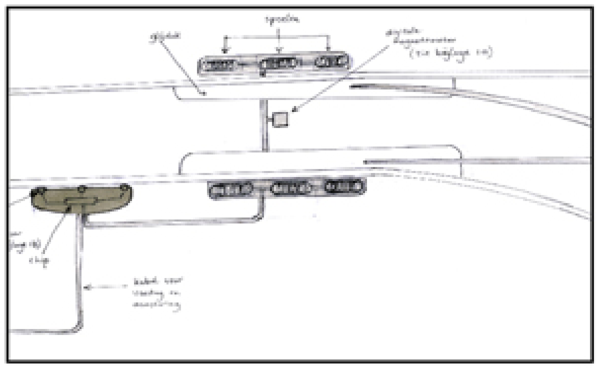
Some other aspects of the magnetic attraction principle also have to be elaborated. One is that the magnetic attraction is inversely proportional to the square of the distance. In other words, the closer the wheels are to the magnet, the harder they are pulled to one side. An elegant solution to this problem can probably be found in the form of a system that provides feedback between the current flowing through the coils and the level of magnetic flux required. Although these are all important details, they wonÕt prevent the concept from becoming a success. A much larger hurdle is the strict safety regulations.

Verheul: “Safety requirements are always the greatest obstacle on the path to innovation. The current points may be error-prone, but at least they are safe. When in doubt, the signals simply show red. In many cases the points prove to be all right after all, but safety comes first. Before you can introduce an innovation, you will first have to answer an avalanche of questions. What happens in the event of a power failure? Can the points be passed from the opposite direction without causing damage or problems? Only if the design passes every safety requirement, will a new concept stand a chance.”

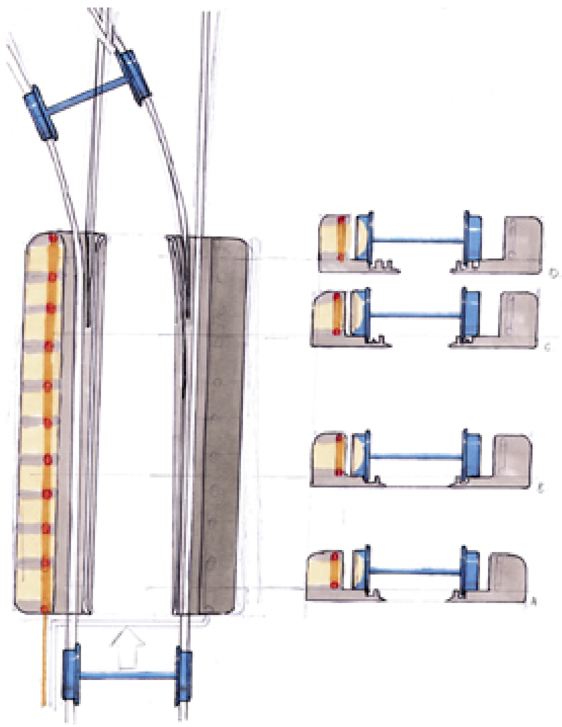
Economy and reliability



It seemed like a good idea to introduce a bearing to minimize the friction between the tongues and the slider plate. It would later transpire that Railinfrabeheer had already had the same idea at one point.



Studio Blauw thought that sensors and electronic intelligence might be used to replace the mechanical feedback system on the tongues to improve the control and feedback functions.



The advantages of the new points design are impressive. The lack of moving parts means that little or no maintenance will be required. A single annual inspection will replace the four overhauls currently needed. The system's reliability is many times higher, since dirt and weather conditions will have practically no effect on the way the electromagnetic points work. During periods of extreme cold, the current points need to be heated. Not so the new design. A conservative estimate, based on a depreciation over a period of 20 years, suggests that the new concept will be cheaper by half. The higher initial investment and running costs (the power for the electromagnets) are more than compensated for by the fact that far less maintenance and revisions will be required. Also, increased reliability will mean that savings exceed the cost of inspection and repairs. The total annual cost currently involved in maintenance and repairs to points will be reduced by as much as 15-fold! Fewer delays and increased availability of each track section will be the real benefit of the new points design.

Wim Verheul is pleasantly surprised by the results. “I think it's fantastic that anyone managed to come up with something totally new for such a long-standing design. I really didn't expect it which is why I tried to continue the project. Sadly, Vialis do not construct points, and the know-how for producing a complete set is spread over a number of different companies. The points construction works in Utrecht weld the track, another set-up provides the foundations and wooden sleepers, we make the actuators, and other companies provide the control and safety equipment.

I have been trying to set up a consortium in which all this knowledge could be represented, to see if the new concept would be viable. There is a great gulf between the policy-makers, for whom the sky tends to be the limit, and the builders who tend to be stuck in their orthodox ways.”

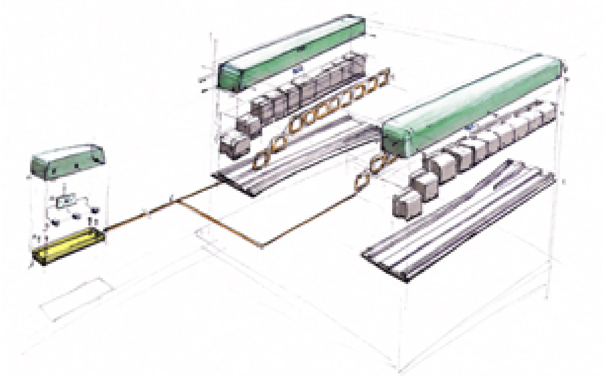
Frog

Verheul instigated searches to find out whether the new concept could be patented. This proved not to be the case, since as far back as 1937 someone else had already arrived at more or less the same solution. Even though similar solutions were proposed during the nineteen-seventies, when magnetic monorail systems were the talk of the day, the concept has never been applied within an existing rail infrastructure. Verheul's enthusiasm found little response within the rest of the consortium. For although the new type of points do away with the moving parts, an old basic problem, that of the frog, remains unsolved. The frog is the horizontal discontinuity in the inside rails of each set of points, the place where two rails meet at a narrow angle. The frog is what produces the banging noise as a train passes the points, and it is very prone to wear.

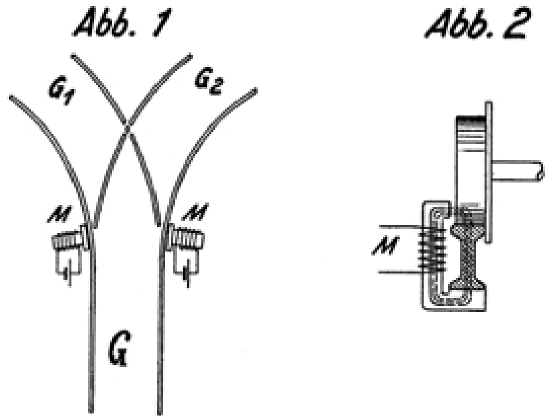
Verheul: “So, however revolutionary your new points design may be, you can forget it unless you can solve the problem of the frog. It probably means going back to the drawing board.”

Studio Blauw had not yet been informed of the latest

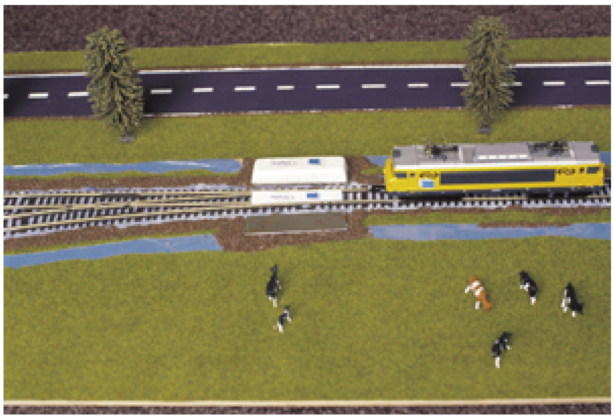
The final choice fell on the magnetic system. It was inspired by the lack of fragile mechanical parts, and it ranks high on the reality scale. The points work as follows. Sets of strong electromagnets are positioned on either side of the track. When the train enters the point area (A), it meets a running surface that becomes gradually wider (B). If the left-hand coil is active, the wheels are pulled to the left, and continue towards the frog (C). The frog is followed by the new track, thus completing the switch (D).



Exploded view showing the modular construction of the magnetic points with the sensor unit (left), the magnetic coils, and the points bed.



Studio Blauw were hoping they had come up with an original idea, but the patent for the basic idea of using magnets had already been granted in 1934 by the Deutsche Reichspatentamt to Dr. GŸnther Jobst from Berlin.



developments.
Verkuilen: “I’m surprised that the idea has foundered on the frog. It’s the last thing I’d have expected, because I see the frog as a minor inconvenience. There has to be different solution to that problem.”
According to Daan Bakermans, a major change of course will be needed within the next ten years: “It does not have to be a completely new type of points system - I daresay it will remain a mechanical solution - but improvements will have to be made to prevent them failing as often as they do. I’m convinced of that.”
Wim Verheul will also have to resign himself to the knowledge that revolutionary innovations are still a long way off. Safety-related issues are treated with the greatest care by both the Dutch Railways as well as Vialis.
“The current infrastructure may be hopelessly out of date, but we will have to make do with it for some time to come. So you have to keep looking for solutions that can be used within the existing system. This is why we are presenting our ideas, to act as a source of inspiration to anyone who cares to muse on the future of railway systems. Of course, I keep hoping that someone will solve the problem of that frog, so the magnetic points design can still be realised. We will be content in the knowledge that we made the first move, as long as someone else finishes the job.”
If the railways are in no real hurry to adopt the new concept, might a potential market be found in the model railway department? After all, the principle works without a hitch on the scale model, and model railway points using small electromagnets need cost no more than the current, electromechanical sets. Any news from Hornby? Alas no, for model railroaders generally want just one thing, which is to recreate the real world in miniature. Sadly, in this respect today’s real world has outlived its usefulness.

For more information please contact
Ir. Henk Kuipers,phone +31 15 278 5626, e-mail h.kuipers@io.tudelft.nl, or
ir. Wim Verheul, phone +31 30 698 3800, e-mail wim.verheul@vialis.nl

Studio Blauw built a simple scale model using model railway components to demonstrate the principle of the magnetic points.

Detail of the frog of an existing set of points. The frog is the point where the two different tracks separate, and is subject to dynamic stresses caused by the wheel of the train as it passes. The frog requires regular maintenance, which is the reason why Railinfrabeheer and the railway maintenance companies are looking for a better alternative. The magnetic points concept of Studio Blauw also uses a frog, since the survey did not highlight it as a problem part. Accordingly, the problem with the frog as a critical component of the current type of points has not yet been solved. Vialis says that the introduction of magnetic points needs to be preceded by a detailed study into a new (partial) solution to this problem. Perhaps these results can then be applied to existing points.