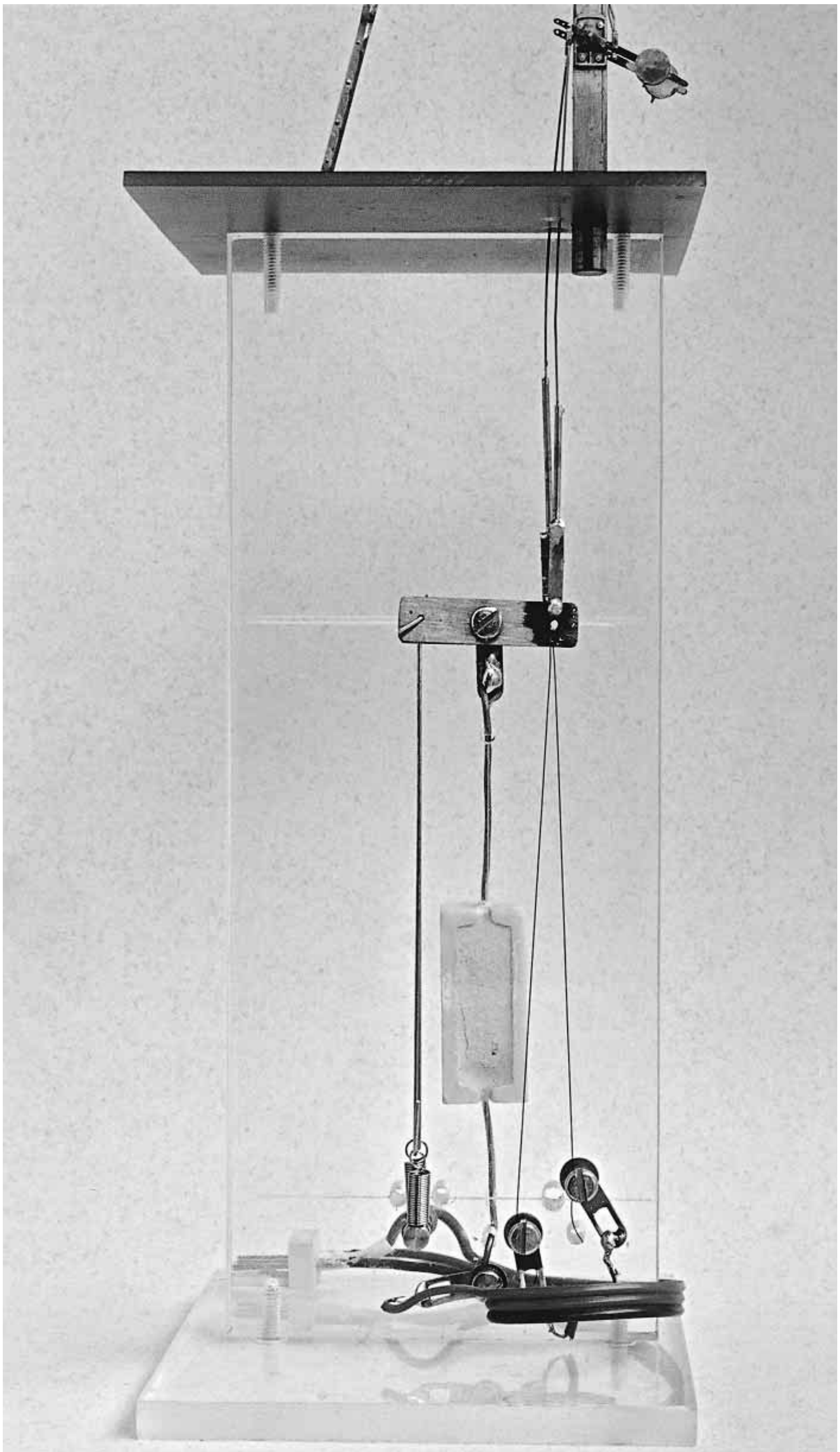


# Space age semaphore operation

Lawrence Boul

Having designed and built the New Zealand Finescale semaphore signal kits, the final challenge was to attach them to an operating device.

The elegance of the McKenzie and Holland semaphore signal was conceived in an age when labour was cheap and the options for mechanical actuation were few. Thus signals were operated manually, via levers, cranks, wires, pulleys and rods. Watching the movement of signals at preserved sites, or on film, reveals the almost lazy action with which the arms move. Not infrequently they bounce on their stops. Attempts to replicate this latter feature have been reported in British journals, but on my portable layout I was primarily interested in replicating a leisurely movement, quietly, and preferably without the expense of a Tortoise or Switchmaster point machine per arm.

The features required were:

- low noise
- slow movement
- simplicity
- ease of adjustment
- moderate cost
- robustness.

As a result, I was drawn to the features of shape memory alloys (SMA). These are alloys that change shape with temperature as a result of their intrinsic properties and conditions of manufacture. Heating is easily achieved by passing a current through the article.

The technical requirements for SMA use are given in the sidebar. This information is taken from *Model Railway Journal* number 73 (1994) and Jacques Le Plat's documentation and website (http://users.skynet.be/pro-rail/).

I have previously built a number of SMA devices. All have worked to varying degrees, but were less than perfect. My initial attempts were rather too complicated. The current version is far simpler and is ideal for my needs. The drawing and photographs illustrate the design basics. The important features are:

- A flat design, where the essential mechanicals can be achieved in a thickness of around 1.5 mm. This means that it is easy to stack up operating units for a signal with multiple arms. Note that the memory wire terminations in the photos are offset slightly, which simplifies electrical isolation.
- Easily adjustable. The mechanism is set up so that the coupling with the signal is a 0.85 mm external diameter capillary tube. This means that the operating wire can easily be soldered into this without clever measurement, and that adjustment is easily achieved by warming the joint. As the off condition of the

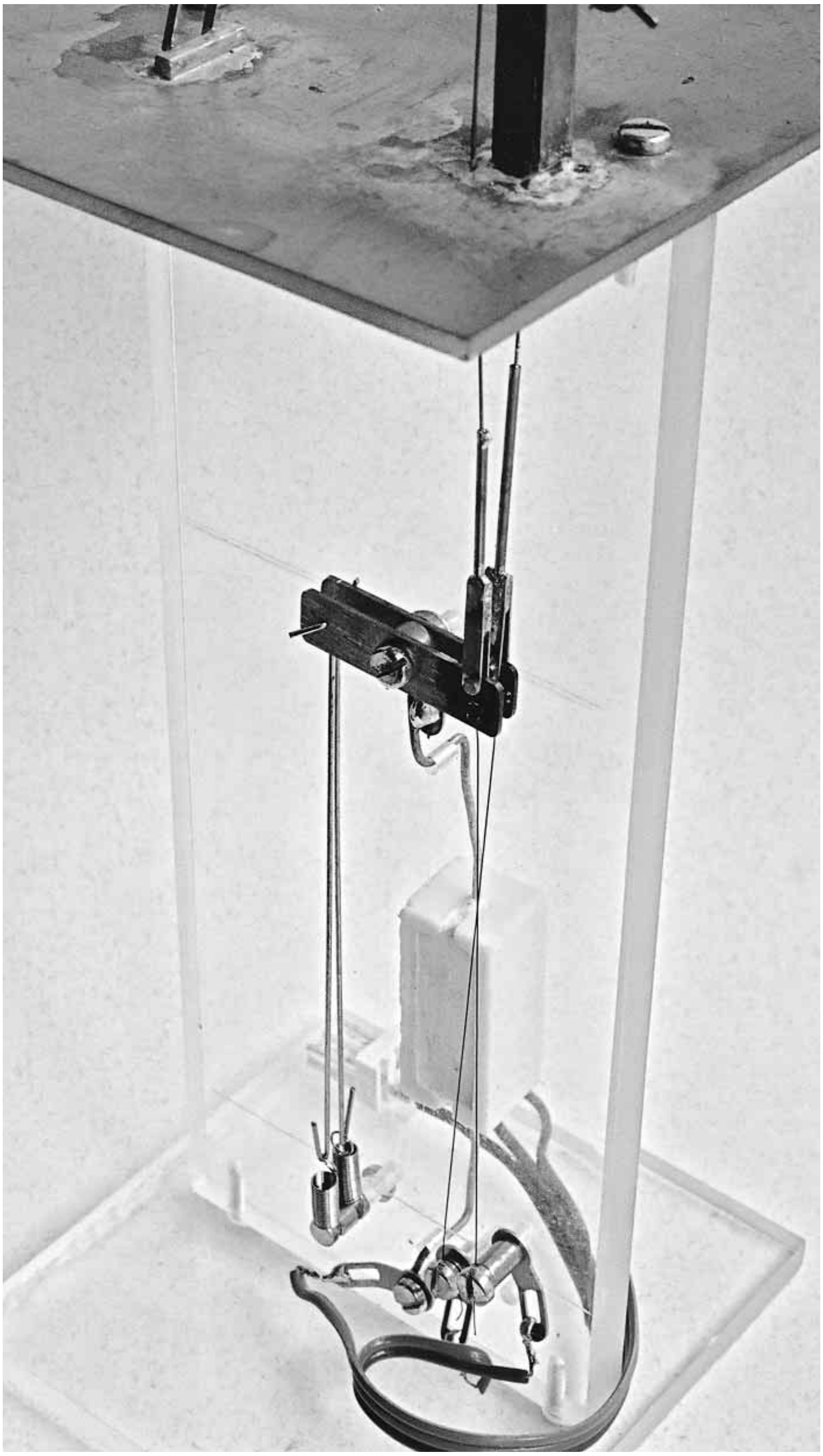
signal corresponds to the cold condition for the SMA, the signal operating rod is soldered within the capillary tube at that state. The total travel depends on the length of the SMA wire. This should be around 60 mm for an NZ Finescale mechanism when set up as shown.

- The SMA is easily replaced in case of damage – though this is reportedly unlikely. I have to say that I have blown a few of these during experiments, but always this has been due to an excess of current due to error on my part. Used properly they should last for a few million cycles, which is probably more than the switch I will use to operate them.
- The SMA is attached without the use of heat (ie solder). At the lever end passing it through three 0.3 mm holes retains it by friction, and at the fixed end a screw between two bushes clamps it.
- Although not an operating requirement, note in the photographs that the baseboard-level mounting plate of the signal is quite large, and that the operating unit base is the same size. This enables the signal to be placed on any side during maintenance, without fear of damage, or for the unit to be placed upright without risk of toppling.

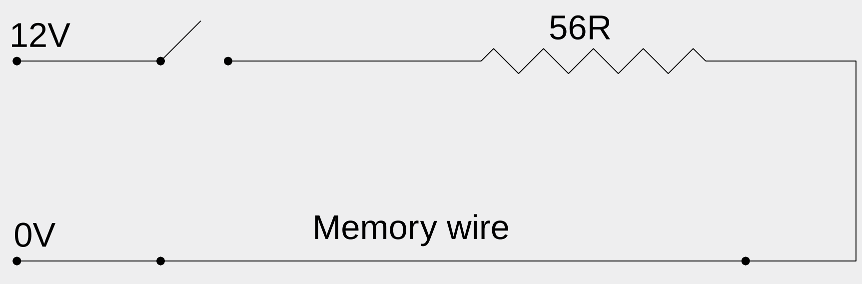
The diagrams show the electrical and physical necessities. I chose a vertically orientated, portable and self-supporting design, because that suits my layout situation. My units are made from clear Perspex as I find it easy to work with, but other materials would be quite suitable. In my units, I have used M2 screws in tapped holes to hold everything together. I have also used turned brass bushes for pivots and wire clamps. These are probably not strictly necessary, but good engineering. The units are very easy to make, requiring simple assembly of simple parts. The trick is in the memory wire – and the hard work there has been done for you.

You can see in the photographs, that I have wired my signals through small sockets to make them easily removable. I have also set them up to run on a 12 V supply, which requires the hefty 5 W, 56 ohm resistor pictured. The resistor could be as small as 2 W, but no smaller, as the current is quite high. The resistor value required for a given supply voltage, based on a device operating current of 200 mA, is given by Ohm's law: R = V/0.2

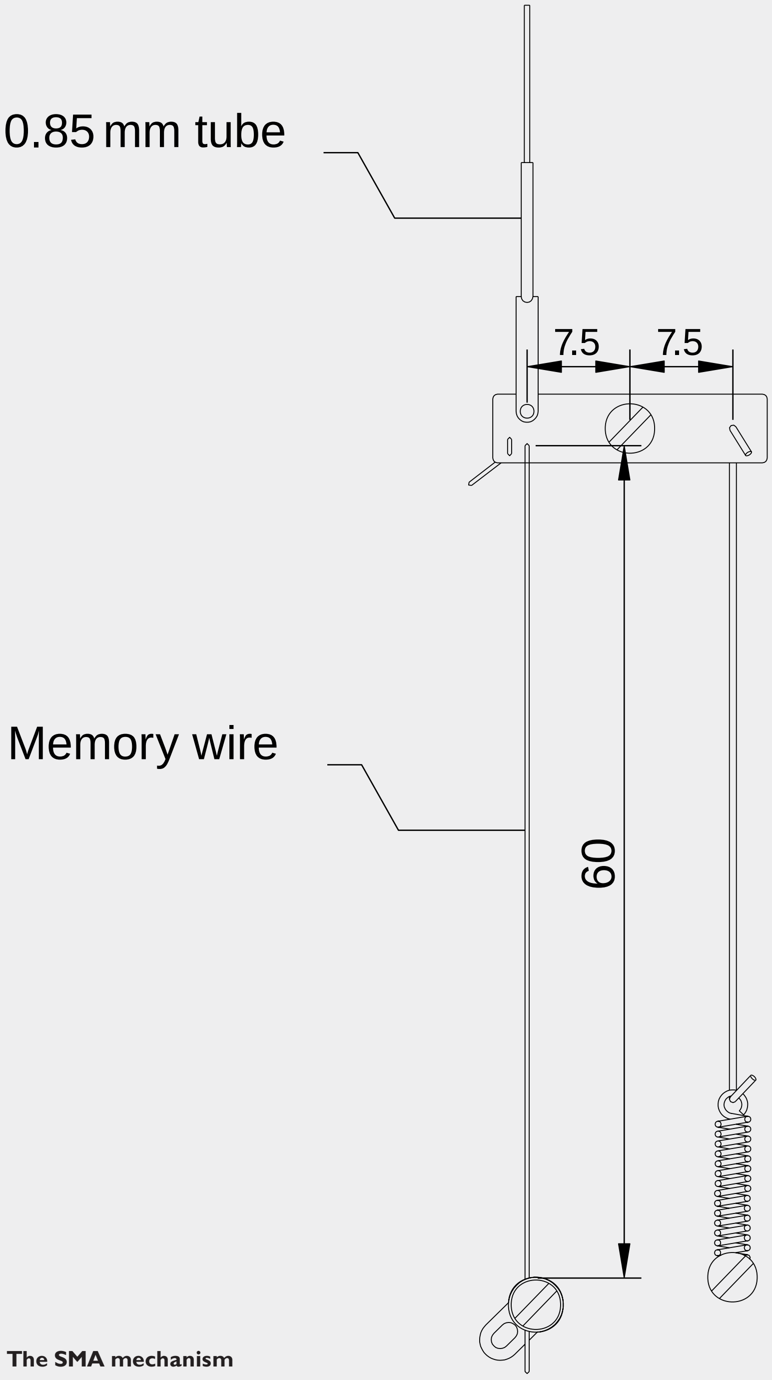
When power is supplied to the mechanism, the memory wire contracts, pulling the signal arm on and extending the return spring. When the power is turned off, the wire cools and the spring contracts returning the signal to off. The action of these devices is silky smooth over a period of 1–2



Photographs and illustrations by Lawrence Boul



**Wiring diagram**



**The SMA mechanism**

seconds. Hard to demonstrate in an article on the printed page!

SMA devices won't overcome flaws in the assembly of the signals, though. At a recent exhibition I had some minor operational problems with one of the signal arms on my layout. The arm concerned does not have the best range of movement, nor is it as free as it might be. Part of the problem was a bit of a technical hitch when painting that saw me freeze the mechanism. Also, as always when preparing for an exhibition, the darn things were only finished a day or two before the show, so we had no opportunity for proper testing or remedial action. The take home message for me is that one has to get these basics sorted out.

## Sources

The memory wire (120 µm) and return springs used were from Jacques Le Plat at Pro-Rail International of Belgium. His introductory kit contains a useful booklet covering theory and practice.

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B-1490 Court-Saint-Etienne, Belgium.
Phone/Fax: (+32) 10 611565 or by e-mail pro-rail@skynet.be.

## Technical bit

Shape memory alloy is used for some very tricky purposes in medicine, aerospace and other high technology industries. Apparently the alloys have been woven into fabric to manufacture a shirt, the sleeves of which automatically roll up when it gets warm. An Internet search will generate a mass of technical details and interesting reading.

For the purpose of signal operation a very fine wire is used which contracts when heated. This property is quite different from that involved in the 'hot wire' signal operation reported some years ago. That involved heating a nichrome wire to make it elongate. With nichrome, the resulting movement is continuous over a range of temperature, and is relatively small – necessitating a long wire. With SMA the movement is relatively large (3.5% with the material I use) and discrete. Which is to say it is either in the short or long condition (or in transition between the two with no over-run). This means that the length of the wire used determines the amount of movement, not the ambient or generated temperatures. The action is in many ways analogous to a muscle, and 'muscle wire' is the brand name of an SMA product marketed by Mondotronics.

Memory Wires are made from a nickel-titanium SMA. Such alloys have the ability to change their crystal structure according to temperature. At room temperature, their crystal mesh is of the martensitic type and it changes into the austenitic type at a pre-defined higher temperature. If an SMA sample is deformed at room temperature by stretching, this 'martensitic' deformation will be cancelled when passing to the austenitic structure and the sample will automatically return to its original shape. The alloy behaves as though it has recorded its original manufactured shape and keeps remembering it through subsequent deformations, hence the term 'Shape Memory Alloy'.

This memory effect is termed 'one-way' since the material only returns to one basic shape. To recycle the process, the sample must be put out of shape by an external force again. A 'two-way' effect can be obtained if the initial deformation is applied at the manufacturing stage so that it is recorded in the metal structure just like the basic undeformed shape. Now the sample not only returns to its basic shape when heated, but also goes back to its originally deformed shape when the temperature drops. In other words, the sample now oscillates between two specific shapes according to temperature. With two-way or reversing SMAs, an external deformation force is not necessary. The material behaves with a dual shape memory, altering shape with temperature alone.

Wire of 120 microns (0.12 mm diameter, or about the thickness of a hair) is convenient for most modelling applications. Such a wire requires a heating current of approximately 200 mA to fully contract. Required voltage can be determined experimentally, and will depend on the wire length. A good method is to connect the device to a model railway throttle and slowly increase the voltage, while measuring the current with a meter. At 220-230 mA the wire will have contracted, and the appropriate operating voltage can be read from the meter. While 200 mA is enough to operate the wire unloaded, in my experiments a bit extra was needed to operate a signal mechanism.

The Pro-Rail wire has been manufactured to offer repetitive contractions of 3.5% of its supplied length. Therefore, a 2 mm displacement will require a working wire length of 2 mm / 0.035 = 60 mm. Or for a 5 mm displacement, a working wire length of 5 mm / 0.035 = 140 mm. Slop in working linkages should be allowed for when calculating the wire length required. Typical lengths for convenient modelling use lie between five and fifteen centimetres requiring a voltage in the area of one to three volts.

For long term reliability, heating currents should not exceed 270 mA and the load should be less than 200 g (or two newtons). If higher loads are required, multiple wires can be used. High temperatures destroy the memory properties, and for this reason the wires should always be crimped or clamped and never soldered.

# Where was that loco?

## Location of locomotives – South Island

### Christchurch

**A**
421
598
602

**Ab**
609
612
615
616
617
665
688
689
692
695
696
697
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704
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720
724
740
750
762
776
780
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798
806
807
809
811
813
821
833

**C**
845
846
847
848
849
850
863
864
865
866
867
868

**Ds**
202
203
204
209
211
212
214

**Dsa**
256
257
258

**Dsb**
305
306
307
308
309
317

**Ec**
7
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9
10
11
12

**F**
13
163

**Ja**
1240
1241
1242
1243
1244
1245
1246
1247
1248
1264
1265
1266
1267
1268
1269
1270

**Kb**
965
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967
968
969
970

**Rm**
50
51
52
53
54
57
58
108
109
110
111
112
113
114
115
126
127
134

**Tr**
18
34
36
62
63
153
154
155

**Wf**
389
390
393
401
468

### Greymouth

**A**
415
418
422
423
424
425
428
471
472
474
475
477
478
578
580
581

**Ab**
610
722
723
755
804
808
820
823

**B**
303
304
306
307

**Ba**
148
499
553

**Ds**
210
213
215

**Eo**
2
3
4
5
6

**Wa**
137
289

**We**
375
376
377

**Wf**
380
383
403

**Ww**
571
573
575
644
669
672
678
679
680
683
684

### Dunedin

**A**
413
414
417
426
470

**Ab**
608
613
658
660
663
690
691
693
694
706
727
728
746
777
779
781
782
*788
*789
*791
*792
*793
*795
812
822

**B**
305
308

**Ba**
497
498
500
551
552
554

**Dh**
758
759
766
772
777
778
779
780
781
782
783

**Dsa**
253
254
255
259
260
261
262
263
264

**Ja**
1249
1250
1251
1252
1253
1255
1256
1257
1258
1259
1260
1261
1262
1263
1274

**Rm**
55
56

**Tr**
35
81
156
164
171

**Wf**
391

**Ww**
574

### Invercargill

**A**
71
161
178
406
407
411
416
427

**Ab**
719
721
725
726
729
730
731
732
778
784
*803
805
810

**Ds**
200
201
205
206

**Dsa**
250
251
252

**Ja**
1254
1271
1272
1273

**Tr**
64
165

**Wf**
379
382
387
394
402
430
433
438
842
844

*Wab conversion

| Class | A | Ab | B | Ba | C | Dh | Ds | Dsa | Dsb | Ec | Eo | F | Ja | Kb | Rm | Tr | Wa | We | Wf | Ww | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | 32 | 81 | 6 | 9 | 12 | 11 | 14 | 15 | 6 | 6 | 5 | 2 | 35 | 6 | 20 | 15 | 2 | 3 | 19 | 12 | 311 |

This table is transcribed from an official NZGR notice, dated 1962, in Colin Barry's collection.