Nitinol **actuator wire**

We've developed cutting-edge Nitinol wire to help advance the performance of your actuator product. This brochure is designed to help you better understand the intricacies of actuator wire. If you have any questions along the way, feel free to reach out to your Sales Representative for more information.

How it works

Simply put, actuator wire is made with shape memory Nitinol, utilizing the material's ability to cycle between two different material phases.

At room temperature, the wire is in its martensite phase. By applying a load, the wire is elongated and can then actuate by applying an electrical current or other means of heat to achieve a phase transformation. When heated beyond the transformation temperature, the material recovers, transforming to the austenite phase. As a result, the wire returns to its original length while performing its intended task, such as lifting a load, pulling release valves, or otherwise applying a force. As the material cools, it returns to the martensite phase and the load causes the wire to elongate again, ready to repeat the cycle.

Using Nitinol wire in an actuator application requires reproducible stroke and stable recovery. The amount of stroke – moving the load a certain distance – can change over prolonged actuator use unless it is properly processed – typically referred to as "training". Nitinol actuator wire is specially processed and trained to provide the stability required for use in an actuator application.

Understanding the benefits of Nitinol actuators

- High power-to-weight ratio, meaning that they have the ability to move relatively substantial loads compared to their small footprint.
- They are very reliable, if used under the recommended parameters, and can last for millions of cycles.
- The phase transformation is a silent operation which is beneficial for many applications.
- Provide improved design flexibility because fewer parts are needed, allowing for a smaller design footprint.

End uses

- Locking/latching systems
- Vents/valves
- Pumps
- Optical image stabilization in smartphone cameras
- Safety relief valve for fire protection
- Interior comfort systems (lumbar support)

Shape memory effect

Nitinol exhibits a phase transformation and alters its atomic structure in response to temperature and applied stress. This phase transformation allows the material to “remember” its shape upon heating. At room temperature, the material transforms to the martensite phase and can be easily deformed or stretched. Upon heating, the wire will transform to the austenite phase and will return to its original, pre-deformed shape. **See Figure 1.**

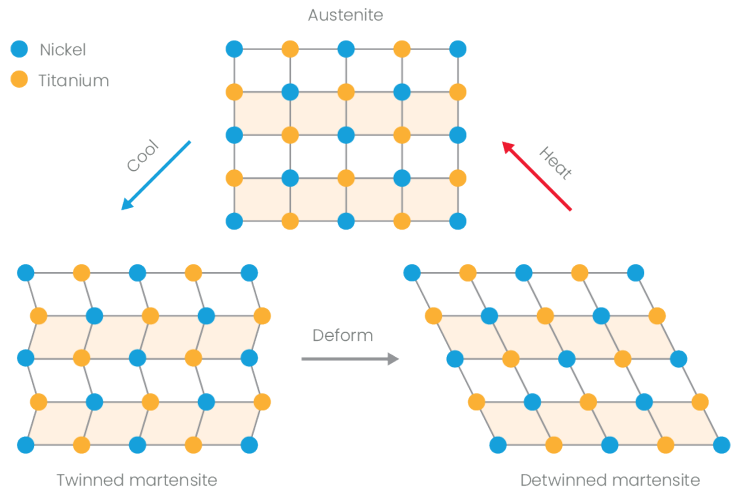


Figure 1. The atomic structure change of Nitinol in response to temperature and applied stress.

Simple linear Nitinol wire actuator

At room temperature with no stress applied, the Nitinol actuator wire is in the martensite phase. A load is applied, and the wire elongates. Upon heating (either via environmental temperature change or with current), the wire transforms to austenite and returns to its original pre-deformed length, lifting the load in the process. **See Figure 2.**

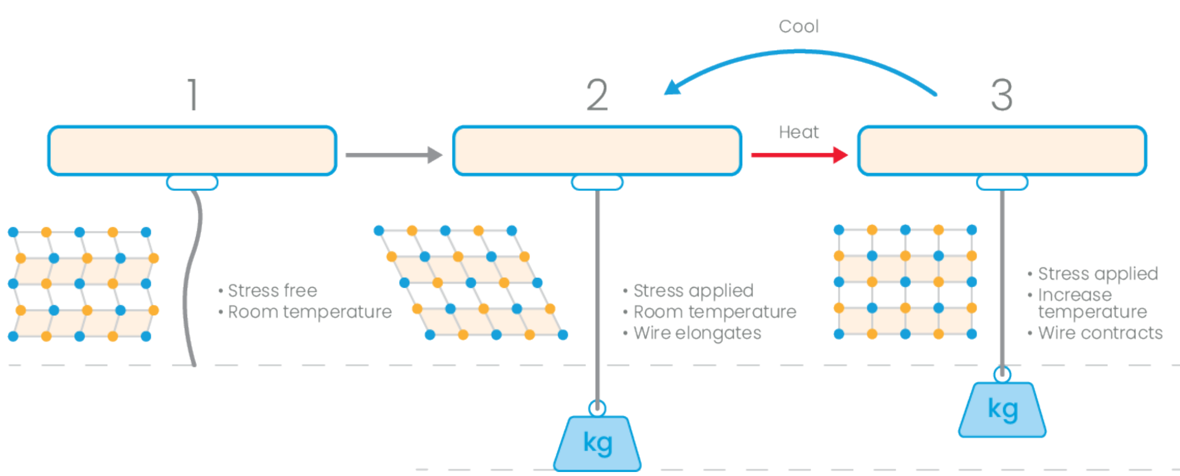


Figure 2. Diagram of a simple linear Nitinol wire actuator with corresponding atomic structure change of the material.

The difference between Nitinol actuator wire and straight annealed Nitinol wire

Fort Wayne Metals' actuator wire is processed specifically to tailor the properties of the Nitinol for use in actuator applications. This ensures the following:

- **Functional stability:** Wire will actuate/reset at the same temperature and achieve the same amount of stroke, cycle after cycle.
- **Dimensional stability:** No noticeable residual wire elongation after multiple actuation cycles.
- **Optimal actuation performance:** Decreased reset time after being heated for actuation and greater work output.

How is our actuator wire characterized?

The actuator wire is held at a constant stress and subjected to a heating and cooling cycle. The amount of strain or "stroke" of the wire is monitored with a change in temperature (see ASTM E3097). Unless otherwise specified, Fort Wayne Metals' actuator wire is characterized with an applied stress of 150 MPa. **See Figure 3.**

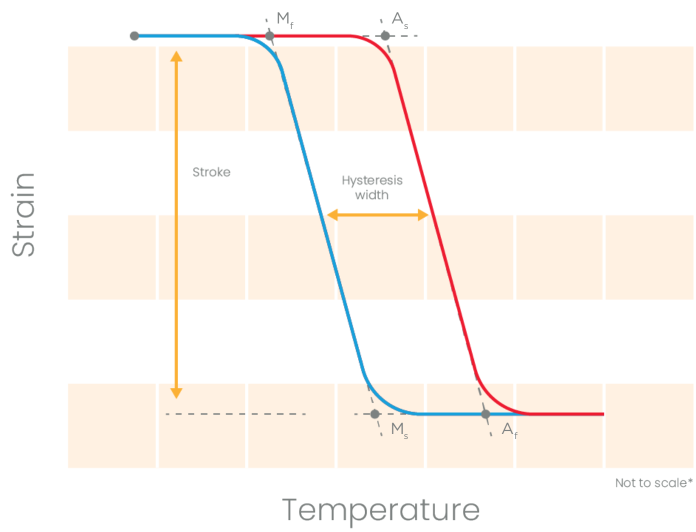


Figure 3. Strain vs. temperature curve for Nitinol actuator wire. Cooling curve in blue, heating curve in red.

- **HYSTERESIS WIDTH**
  The difference between the austenite and martensite transformation temperatures. This temperature delta corresponds to how quickly the actuator will reset after being heated for actuation.

- **AUSTENITE START TEMPERATURE (A_s)**
  The temperature at which the material starts to transform to austenite and contract under a given load. Also referred to as the "actuation start" temperature in actuator applications.
- **AUSTENITE FINISH TEMPERATURE (A_f)**
  The temperature at which the material has transformed to austenite and the wire is fully contracted under a given load.
- **MARTENSITE START TEMPERATURE (M_s)**
  The temperature at which the material starts to transform back to martensite and elongates under a given load.
- **MARTENSITE FINISH TEMPERATURE (M_f)**
  The temperature at which the material has transformed to martensite and is fully elongated under a given load. The actuator wire is now reset and can be heated again for actuation.
- **STROKE**
  The overall change in length of the wire as a result of the material phase transformation divided by the original length. Typically reported as a strain percentage.

Thermal characteristics

The thermal properties of the actuator wire vary with a change in application stress. The figures below show how the transformation temperatures, stroke, and hysteresis width change with application stress.

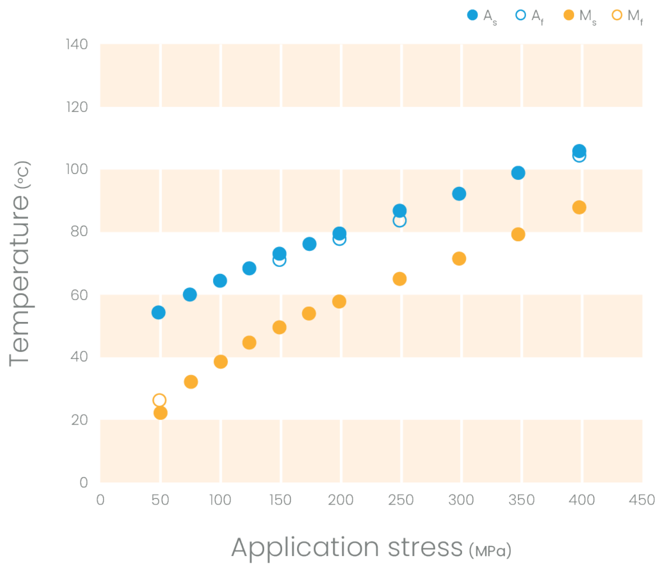


Figure 4. Approximate transformation temperatures at a given application stress for 70°C actuator wire.

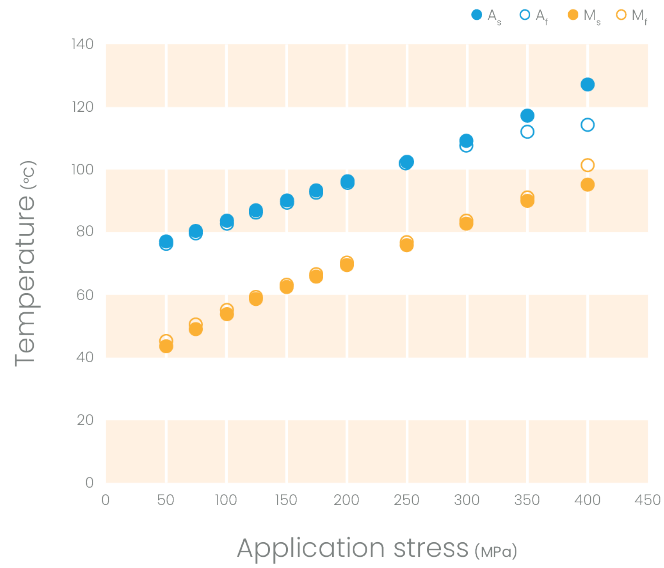


Figure 5. Approximate transformation temperatures at a given application stress for 90°C actuator wire.

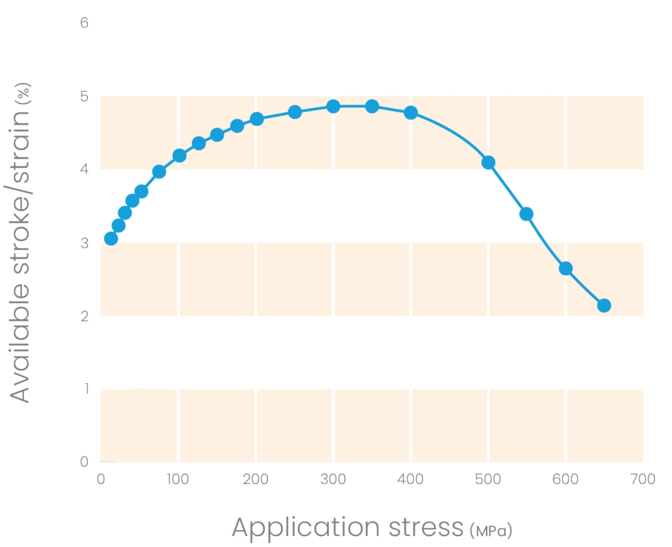


Figure 6. Available stroke as a function of application stress for Nitinol actuator wire.

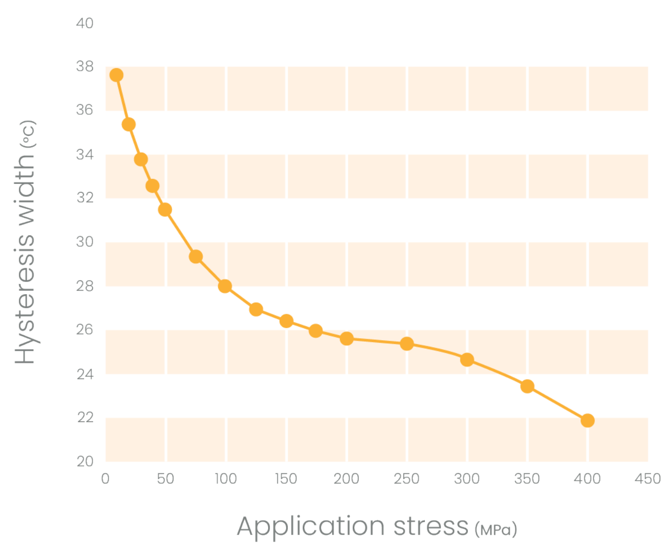


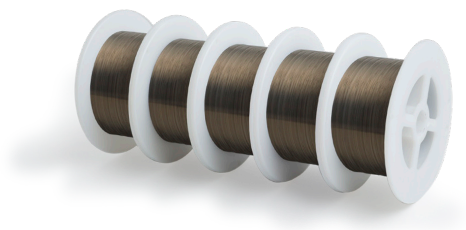
Figure 7. Hysteresis width as a function of application stress for Nitinol actuator wire.

Electrical characteristics

Use of constant current to power the material is highly recommended, although any means (constant voltage, PWM, AC, etc.) may be used so long as appropriate care is taken to not overheat and damage the wire.

SIGNS OF OVERHEATING/DAMAGE TO ACTUATOR WIRE

- Wire glows red/orange when current is applied.
- Wire does not contract when current is turned on.
- Wire does not elongate when current is turned off.
- Wire length is increasing from cycle to cycle.



Wire diameter	Approximate Current (A)*
0.0762 mm [0.003 in]	0.17
0.15 mm [0.0059 in]	0.4
0.2 mm [0.0079 in]	0.6
0.25 mm [0.0098 in]	0.8
0.3 mm [0.0118 in]	1.1
0.4 mm [0.0157 in]	1.7
0.5 mm [0.0196 in]	2.6
0.584 mm [0.023 in]	3.4

*The current values in the chart above will cause the actuator wire to contract in approximately 3 to 4 seconds.

Application considerations

Design engineers are often faced with the challenge of balancing performance tradeoffs when choosing a Nitinol actuator wire. The below table provides a quick reference guide outlining these tradeoffs.

● Positive result ● Negative result

	Pull force	Stroke	Power consumption	Reset time
↑ Diameter	↑	-	↑	↑
↑ Length	-	↑	↑	-
↑ Actuation temperature	-	-	↑	↓

Actuator wire product offerings

Product	Wire diameter	A_s	Hysteresis width	Stroke	Recommended application stress
Actuator wire on a spool	0.0762 to 0.5842 mm [0.003 to 0.023 in]	70 to 90 °C [158 to 194 °F]	30 ± 5 °C [54 ± 9 °F]	4 to 5%	100 to 150 MPa [14.5 to 21.75 °F]

A_s, hysteresis width, and stroke based on 150 MPa application stress. Recommended application stress values are for optimal actuation performance. Application stresses outside of this range can also be used depending on the design requirements of the actuator.

While we provide standard size ranges and operating parameters as a starting point, we're always seeking new ways to innovate. If you are interested in something outside what is listed, please contact your Sales Representative to discuss possibilities.

How can we help?

We covered a lot of ground, but it's more than likely you have questions, and we'd love to help. Contact your Sales Representative for more information.