

# TervAlloy™ Degradable Magnesium Alloys



**TERVES**  
ENGINEERED RESPONSE

*Engineered for Enhanced Completion Efficiency*



# Engineered Degradable Alloys from Terves Enhance Completion Efficiency



*Hydraulic fracturing operation*

Terves, Inc., is a leading magnesium material manufacturer with the technical expertise to improve completion efficiency by providing cost-efficient, structural, dissolvable metals that self-clean and do not require drillout. When designed into completion tools, these materials decrease the time and cost to complete multistage wells while reducing the risk of unplanned wellbore flow restrictions. Completion tools incorporating self-cleaning materials enable more stages and more wells to be completed faster and more reliably.

Our TervAlloy™ engineered magnesium alloys can perform the same function as any drillable completion tool material or component and then simply disappear

without intervention. TervAlloy dissolvable metal makes it possible to create improved tooling and design new well completions and can eliminate the delays, risk and cost of millout operations required with metal or composite materials.

Our engineered materials are commercially available in solid billets that can be readily machined or formed into any desired component, including balls and complex parts with tight tolerances to your design.

Unlike parts made with competing powder degradable metal or polymer materials, TervAlloy components have the strength and ductility of aluminum and can be machined easily. Our materials can





*Terves's materials research center*

*Contact Terves for information on frac balls, dissolvable materials or build-to-print components.*

hold pressure during fracturing, perforating and other operations. When exposed to brine, acidic or high-temperature downhole fluids, Terves alloys completely dissolve within hours or days, so the well can begin producing without expensive and time-consuming coiled-tubing intervention. TervAlloy materials eliminate the risk of drillout operations and do not create debris that can stick pipe, block flow or clog surface equipment.

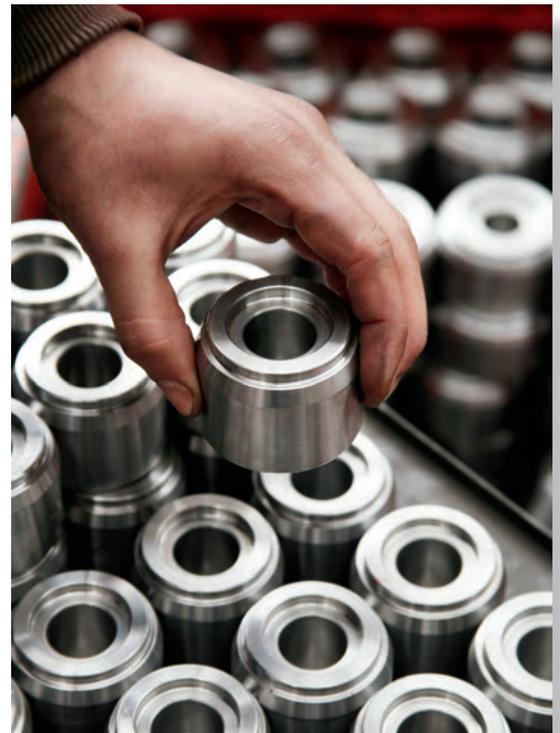
### **Pioneering Magnesium Alloy Research**

At Terves, materials science is our core competency. Our engineering team has conducted pioneering magnesium alloy research and has unmatched experience in developing and applying advanced engineered materials solutions. We have developed a series of proprietary and patented magnesium alloy technologies. Terves's materials scientists and large-scale manufacturing capabilities are available to support your product design team and to meet production requirements for degradable tools and components.

### **Significant Savings for Operators**

TervAlloy frac balls, plugs and other dissolvable components can create significant savings for operators by eliminating ball hang-up problems, reducing drillout and circulating costs, and enabling accelerated production. In addition, by using TervAlloy dissolvable materials in bridge plug and frac ball applications, operators can extend the range of horizontal completions beyond the reach of coiled-tubing units, allowing for longer laterals, increasing contact with the reservoir, and improving well productivity.

TervAlloy materials are available in a selection of alloys to match downhole fluids and temperatures in each application. We manufacture our frac balls in a full range of sizes for use with commercially available sliding sleeve completion systems and frac plugs. Rod stock is readily available for production of bridge plug and completion tool components. Terves also provides machine-to-print services.



*TervAlloy material can replace virtually any drillable component.*

# Five TervAlloy Formulations to Match Your Application

Using patented engineering and design processes, Terves has developed five commercially available TervAlloy Engineered Response Magnesium Alloys (see table). These alloys have usable tensile strengths up to 40,000 psi and a range of dissolution rates engineered for different completion fluids and well temperatures:

- TA-50C – cast/die-cast and heat-treated magnesium alloy with a “slow” dissolution rate
- TAx-50E – wrought alloy with higher strength than TA-50C and the same dissolution rate
- TA-100C – cast/die-cast and heat-treated magnesium alloy with a “fast” dissolution rate
- TAx-100E – wrought alloy with higher strength than TA-100C and the same dissolution rate
- Z-1000C – acid-dissolvable alloy, which disintegrates quickly but only under acidic conditions

Terves manufactures its engineered alloys from patented magnesium-based alloys using proprietary casting, heat-treating, strengthening and coating processes. These processes result in uniform product quality, predictable dissolution rates, high-strength material and significantly lower cost than previous dissolvable metals or polymers.

Available Terves coating materials can enable acid treatments with the disintegrating components in place or delay disintegration completely until a triggering solution is introduced into the well. Coatings permit



*TervAlloy frac balls*



*Precision components made from TervAlloy material*

temporary well shut-in and can facilitate placement of screens or pre-perforated liners without using running strings or isolation valves.

With ongoing research, Terves continues to develop new alloys and coatings to meet customer requirements. Developmental alloys and coatings are in trials for use in fresh water or brine and to enable acidizing sequences.

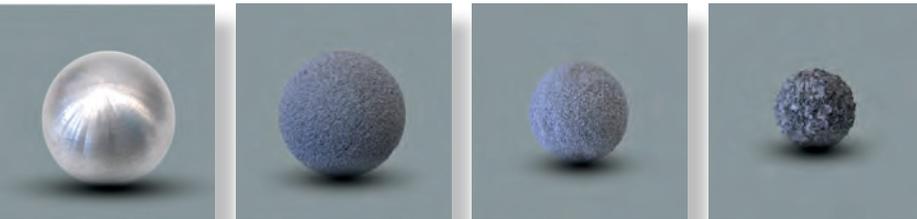
TervAlloy	TA-100C	TA-50C	Z-1000C	TAx-100E	TAx-50E
Ultimate tensile strength (ksi)	36	26	34	40	40
Yield strength (ksi)	22	17	17	30	30
%E	4	4	5	8	9.5
Specific gravity	1.9	2.2	1.8	1.9	1.9
Dissolves in	KCl	KCl	HCl	KCl	KCl
Dissolution rate at 200°F, mg/cm <sup>2</sup> × hr	50	33	990	50	30
Time to unseat 0.09-in. overlap at 200°F (hr)	10	16	1	10	16



# TervAlloy Dissolvable Tools— Materials Science Optimizes Fracturing



Oil and gas operators in unconventional basins throughout North America have recognized the advantages of dissolvable frac balls and completion tools in improving efficiency and reducing costs of multistage horizontal completions. Now, next-generation TervAlloy materials make unconventional completions even more reliable and more cost-effective.



*Disintegrating frac balls hold pressure during fracturing and disappear to enable production, reducing the need for well cleanup operations.*

## **Dissolvable Magnesium Saves Money, Reduces Risk**

Completion operations using non-dissolving frac balls and drillable components have built-in inefficiencies. In multistage hydraulic fracturing completions, frac plugs used in plug-and-perf completions must be drilled out with a coiled-tubing assembly. Remaining debris must be circulated from the hole to remove obstructions and enable the stimulated well to produce at full capacity. With ball drop systems relying on flowback to remove the balls, frequent sticking or ball fracture often requires intervention and drillout. Debris can be hard to remove and can clog surface equipment. Operations to clear these obstructions increase risk, add significant service cost and delay production.

To improve efficiency, operators began using dissolvable polymeric and

magnesium frac balls. Magnesium balls can be used in higher pressure and lower temperature operations, and have been used to complete more than 75,000 stages since 2012. With lower cost and improved tensile and fracture properties, next-generation TervAlloy alloys have been applied successfully in frac balls and other disintegrating tools, including frac and bridge plugs.

## **Next-Generation, Lower-Cost Dissolvable Materials**

Terves's next-generation dissolvable magnesium alloy materials deliver reliable performance in a wide range of oilfield conditions and tool designs.

TervAlloy alloys are lighter and stronger than aluminum alloys but are as stiff as aluminum and not brittle like earlier polymer, phenolic or magnesium composite materials. These new, lower-cost dissolvable metals are easier to store and handle, less likely to fracture, and less prone to early or unpredictable degradation than prior-generation dissolvable metals. With their ductile, tough construction, TervAlloy materials can be machined into balls or complex components with tight tolerances, and can be loaded in tension as well as compression. Once deployed, they respond to wellbore fluid and down-hole temperature to dissolve into the completion fluid at a predictable rate over hours or days depending on the alloy type and component size. After degradation, no debris or obstruction remains.

# Capability to Produce Large Volumes of Engineered Magnesium



NEED PHOTO OF SOLID MATERIAL

*Terves can provide magnesium alloy billets up to 20 ft long.*



*TervAlloy magnesium materials can be machined into frac balls and precise components.*

Terves's 65,000-sq-ft campus in Euclid, Ohio, is a comprehensive facility devoted to the development and production of engineered magnesium materials. This facility includes our:

- Nanomaterials research center
- Engineering test laboratories
- Casting processes
- Deformation processes
- Machine shop
- Pressing equipment
- Sintering facilities

By working with solid alloys instead of magnesium powders used by competing providers, Terves can produce large volumes of materials in a safe, efficient and cost-effective process.

To meet increasing demand for dissolvable magnesium materials, we are rapidly expanding our production capacity both internally and with strategic partner suppliers, adding 500 tons of production capacity. A new 19,000-sq-ft expansion facility is scheduled to begin operation in November 2015, expanding build-to-print machining capacity and increasing chip recycling capacity to minimize waste streams and eliminate disposal costs.



## Focused on Providing Materials and Components to OEMs



*Terves has machine-to-print capability to manufacture components for equipment OEMs.*

TervAlloy material's advantages have been field proven in frac ball and completion tool applications on numerous wells in North American shale plays. Leveraging this experience, Terves remains focused on providing magnesium materials and machined components for service companies and equipment OEMs. We continue to advance the science of applying engineered response materials in the oilfield. Our experts are developing new alloys and coatings, conducting fluid response testing and simulation, and supporting the tool development needs of our clients and partners.

We would like to work with industry partners to deliver the benefits of engineered response materials through a wide range of completion components.

Dissolvable magnesium can provide new functionality to bridge and frac plugs, ball seats, flow-diversion systems, slips and grips, pre-perforated liners, perforating guns, sand control screens and many other downhole components.



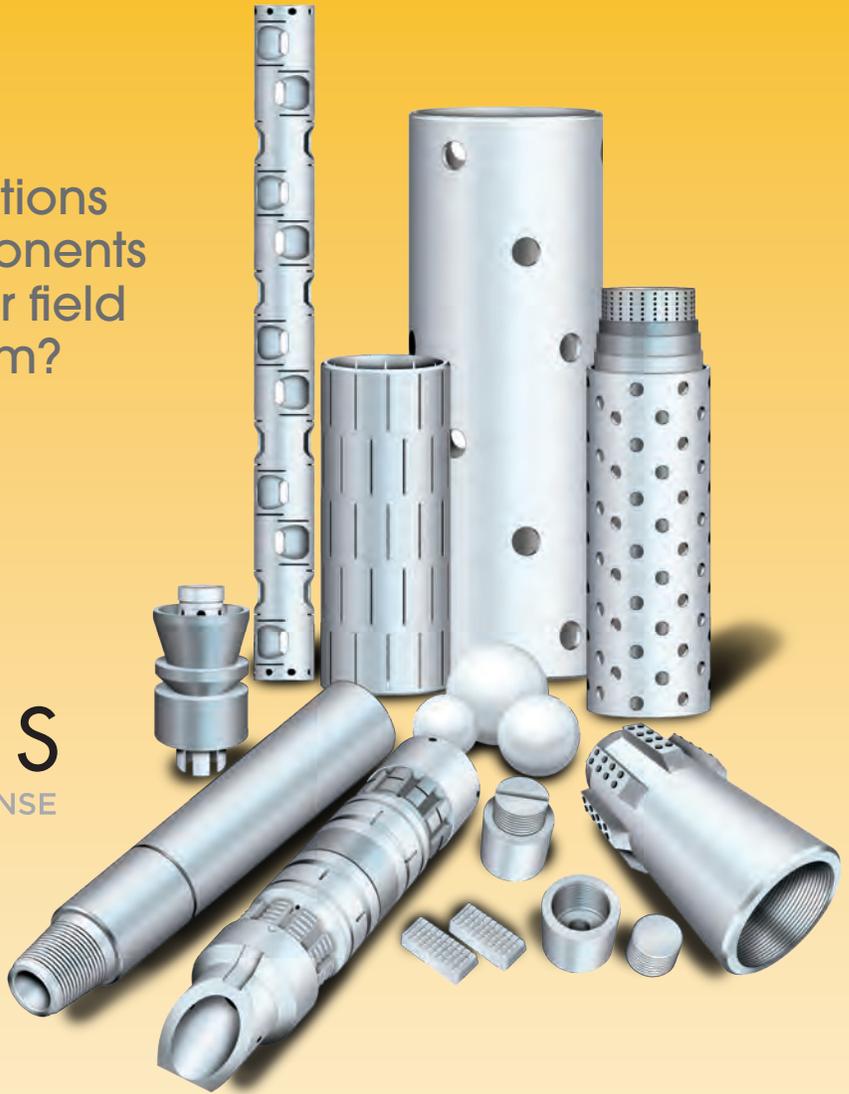
*Our experts support development of tools incorporating magnesium alloys.*

Do you have applications  
for dissolvable components  
in your product line or field  
development program?

If so, we'd like  
to hear from you.



**TERVES**  
ENGINEERED RESPONSE



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