John Stowe investigates a new bonded surface treatment reported to transform metals into low-drag working surfaces

Performance enhancer

"It's not the work which kills people, it's the worry. It's not the revolution that destroys machinery, it's the friction."

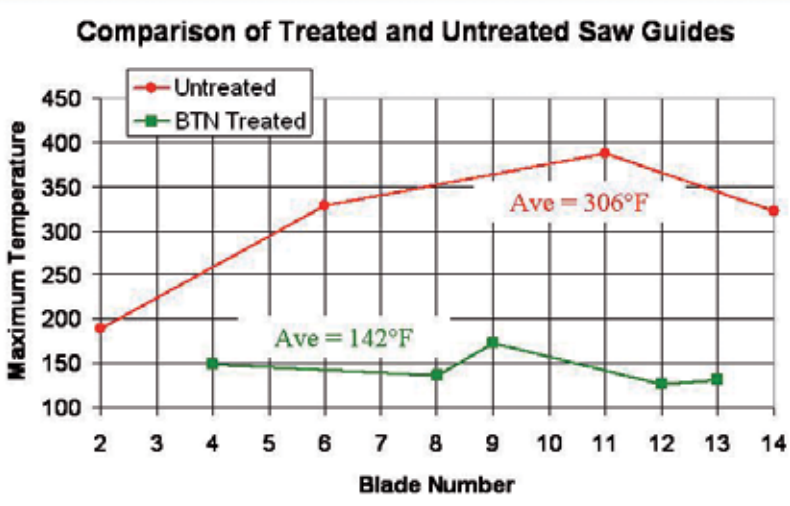
- Henry Ward Beecher

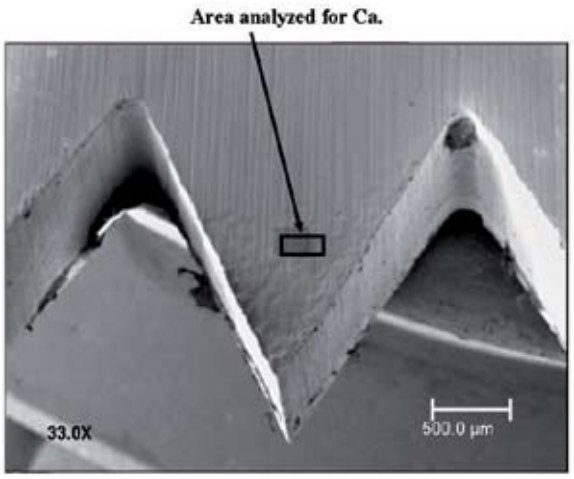
Racing has always been a testing ground for new technologies, and readers of RET have been exposed to a series of articles having to do with material science, coating technologies, and surface treatments. The most recent materials process that has come to our attention is a new surface treatment referred to as 'RF85'. This particular technology is designed to reduce friction by adding compounds containing primarily calcium to the surface of various metals. The RF85 nomenclature was derived from a test performed at the Oak Ridge National Laboratory, where observed friction was reduced by 85% in selected tests.

Currently, there are a number of interesting non-racing applications for this technology that help to illustrate its capabilities, such as powered surgical devices. Because of this biomedical application, RF85 is an FDA approved process, and RF85 is used with processing equipment in the food industry as well, where conventional lubricants can become a contamination threat. Cutting tools, too, are rapidly becoming another major market development for RF85. Tools that have high sliding friction, especially those with zero clearance relief, such as taps and reamers, benefit especially well. Not surprisingly, some of the first racing applications have been with ring and pinions, which also have substantial sliding friction area.

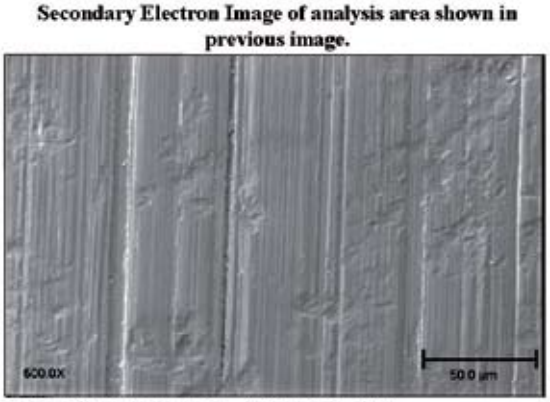
The parent company behind RF85 is Better Than New, LLC. (see sidebar), Better Than New (BTN) provides the treatment service, and if there is sufficient volume, will also discuss equipment installation at or near a customer's location. While the conditioning chemistry is very precise, and needs to be closely controlled by BTN, the treatment itself is a relatively simple bath immersion process. There is also some heat involved, but it is of a low order (comfortably below aging temperature for any common metal), and does not affect

Double Blind Study Shows the BTN Treatment Reduces Saw Guide Block Temperatures by More Than 50%





Secondary Electron Image of Untreated Saw Blade.



Secondary Electron Image of analysis area shown in previous image.

Atomic Concentration Table – *Untreated* Saw Blade

	C (at.%)	O (at.%)	Ca (at.%)	Fe (at.%)
Before Sputter Etching	37.0	39.7	2.6	20.7
After Sputter Etching	5.8	61.9	—	32.3

material characteristics such as hardness, strength, or temper. There is reasonably credible anecdotal evidence of a synergistic benefit when RF85 is applied to two surfaces working against each other: the reduction in friction appears to be greater than a single treated surface alone. The next round of testing at ORNL will centre on both similar and dissimilar materials working against each other, rather than against a 'standard' surface, and will quantify this phenomenon with greater accuracy.

BTN refers to RF85 as a treatment, and not a coating, because it effectively becomes, in their words, "…part of the metal, and wears with, not off the metal like a coating does." BTN initiated an intensive testing regimen with the Oak Ridge National Laboratory, and Sandia National Laboratory, to build the case for its surface treatment. The tests at Sandia were classic ball-on-disk coefficient of friction tests run for 1000 cycles without lubrication. Untreated steel started off with a friction coefficient of about 0.3, which climbed to as high as 1.0 due to material surface degradation and transfer. The same steel, treated with RF85 maintained a consistent value through the test cycle between 0.1 and 0.15…about one half of the starting value for its untreated counterpart.

Testing at Oak Ridge concentrated mainly on the material characteristics and product applications. In addition to the nuclear research for which it is well known, ORNL will also conduct testing for private sources, particularly when there is value for the scientific community or the public at large. As one would expect, technologies that have the potential to reduce energy consumption are of particular interest. ORNL applied their highly advanced equipment to analyse both the treated and untreated saw blade surfaces, as well as their effectiveness.

"ORNL is a multiprogram science and technology laboratory managed for the U.S. Department of Energy. Scientists and engineers at ORNL conduct basic and applied research and development to create scientific knowledge and technological solutions that strengthen the nation's leadership in key areas of science; increase the availability of clean, abundant energy; restore and protect the environment; and contribute to national security.

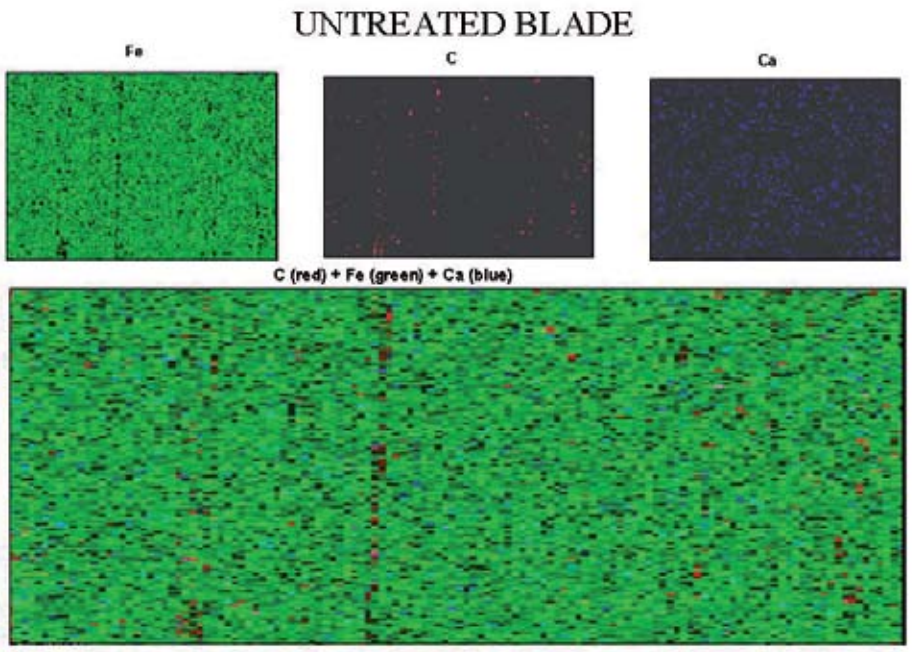
"ORNL also performs other work for the Department of Energy, including isotope production, information management, and technical program management, and provides research and technical assistance to other organisations. The laboratory is a program of DOE's Oak Ridge field office." – ORNL Web Site

"We chose Auger microanalysis because of its effectiveness in characterising ultra-thin films formed on metallic surfaces. At the High Temperature Materials Laboratory, we performed Auger microanalysis using a Physical Electronics model Phi680 scanning Auger Nanoprobe. This instrument is the current state-of-the-art tool for surface analysis… the results for the untreated saw blade are typical for air-exposed steel surfaces… the treated saw blade showed marked differences as compared to the untreated… most notably was the presence of Ca and C… sputter etching of the treated blade did not reduce the C or Ca signals, indicating that they were present as an adherent film and not present as a surface absorbed contaminant."

With all this positive empirical evidence coming from these well respected sources, in addition to the technical material provided from BTN, it was time for RET to look into the nature of the RF85 treatment. BTN is understandably tight-lipped about the precise chemistry of the immersion bath, as well as the methodology involved in creating it, but a few things seemed immediately clear. The first is that this is not a layer created by chemical replacement reaction, since it works with a broad variety of differing materials. The second was that it was neither an infiltration process nor a simple mechanical bond.

RET contacted one of the researchers at ORNL to get his view concerning RF85 treatment. "This appears to be a very strong ionic bond, similar to that which lubrication companies attempt to achieve with advanced oil additives. As contact and pressure are applied from operational forces, the RF85 material seems to be transformed into a tribological film during use." He went on: "If I had to conjecture, I might characterise this film as an ultra-thin layer made up of ionically-bonded nanoscale material, which would account for the high level of durability we observed in our testing."

Some of the first specific product tests were conducted at ORNL in December of 2003 to verify the value of the treatment in a very specialised application – cutting bone. When a doctor is conducting a prosthetic operation, and needs to remove or sever bone tissue, he ▶



Colorized versions of the previous Fe, C, and Ca maps following light sputter etching. Combining the maps (large map) creates a predominantly green map due to the Fe signal. Carbon rich regions can be seen in red. The random blue dots are from the "noisy" Ca map. (Spectral data showed no Ca on this surface.)

normally employs an oscillating sagittal saw. Anyone who has watched one of those late-night medical melodramas has seen one of these devices: with a significant look, the surgeon picks it up, and inevitably gives it a quick shot just before use. The rest is left to the imagination… the real-life problem is that the high-speed oscillation action that gives the saw its controllability also generates a surprising amount of heat. Excessive heat kills some of the surrounding tissue; the faster and cooler the cut, the better, as less 'thermal necrosis' will occur, which in turn results in faster healing on the part of the patient.

"…this shows that the treated saw blades not only cut the bone cooler than the untreated blades, but, also faster. When studying the depth of heat penetration into the bone marrow, I found that the untreated saws resulted in a bone marrow temperature rise of 112 degrees Fahrenheit approximately twice as deep as the treated saw blades. Thus it appears that the volume of damaged marrow is significantly reduced using the saw blade treated by the Better Than New process." – From a report conclusion prepared by the Oak Ridge National Laboratory.

The tests were conducted using a state-of-the-art infrared camera capable of up to 6100 images per second; the apparatus is fully computer-controlled, and calibrated for temperature. This work, along with surface reliability trials, became an important part of the FDA approval process; the significance for the high performance world has to do with the treatment layer. The slightest degradation of the RF85 surface would lead to a completely unacceptable migration of material, which would most certainly enter the patient's bloodstream. The FDA approval is therefore an important validator of the integrity of the RF85 surface film. Later on, a second set of tests were performed to evaluate whether the saw's guide blocks would run measurably cooler with RF85 treated blades. In a double-blind experiment, the treated blades ran more than 50 percent cooler than the untreated blades.

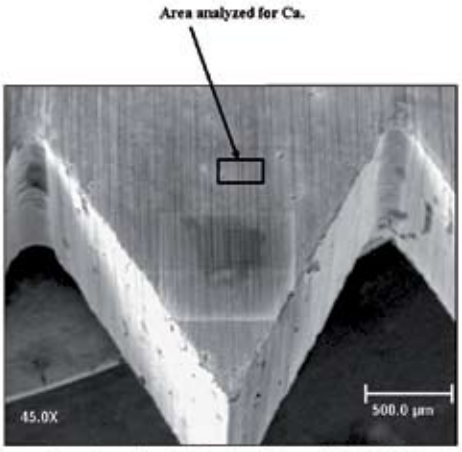
These initial tests done on a critical component underscores BTN's approach to developing markets: establish credibility with an impeccable source directly relevant to a selected, demanding, product area, and then develop it further. Inevitably, because of its performance-driven nature, motorsport became an area of concentration for RF85.

One venue of competition where RF85 is rapidly gaining acceptance is American oval racing. On small dirt and asphalt tracks, the rear axle and differential assembly receive terrific punishment; relatively low cornering speeds, high rates of acceleration, and constant position changes create large torque loads and reversals especially because of the relatively high horsepower and displacements of the vehicles involved. The sliding action that occurs on the faces of ring and pinion gears creates an ideal point of application for any effective friction ameliorant.

One of the most highly regarded specialty suppliers in this field is Tiger Rear Ends of Mooresville, North Carolina, and their durable quick-change rear end has become a favourite in the oval track arena. "There is a lot of snake oil out there", remarks owner Gerald Williams, "And we test everything that we use and recommend before we start passing it along to our customers. We found up to an 8 horsepower gain on the chassis dyno after having the RF85 treatment applied to the ring and pinion." Next, Tiger had an entire rear end treated; this included the axles bearings and gears. In its first 200-lap race, the rear end assembly carried the standard three quarts of oil and a post-race visual examination revealed that the oil appeared to be like new without any observable discolouration or contaminant. From that point forward, Tiger began to progressively reduce the amount of lubricant in the rear end, and installed a temperature gauge on the car's dashboard so that the temperature could be monitored continuously. What they found was that as the oil volume was reduced, the temperature was lowered; it was not until they got down to one-half of a quart that they began to see a rise in temperature.

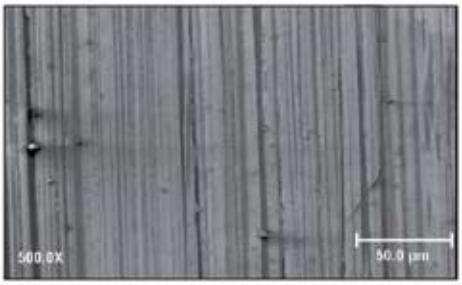
"We have had no failures using RF85," emphasises Mr. Williams, "And that includes rear ends that have gone as much as 6,000 to 7,000 laps." Even when the rear end was run with only one-half quart, it showed no wear, but just a little bit of oil discolouration.

This underscores a point that should be emphasised over and over again: with enclosed lubrication systems, a great deal of the heat that is produced during use is from the lubricant itself, as a result of the molecular shearing that occurs. Reduce the amount of lubricant, and one will reduce the amount of horsepower consumed stirring it up. Often times, the energy losses in the lubricant are greater than ▶



Secondary Electron Image of Treated Saw Blade.

Secondary Electron Image of analysis area shown in previous image.



Atomic Concentration Table – *Treated* Saw Blade

	C (at.%)	O (at.%)	Ca (at.%)	Fe (at.%)
Before Sputter Etching	64.9	12.5	20.6	2.0
After Sputter Etching	66.7	10.1	20.1	3.1

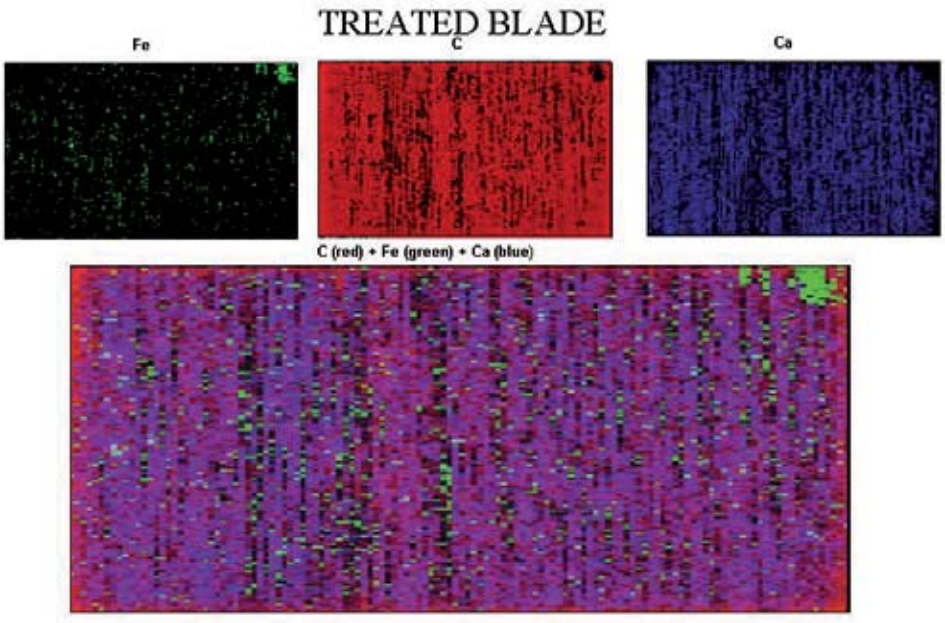
the mechanical losses between the working components, and this is clearly the case here. The mechanical requirement for serious reductions in lubricant volume is to have surfaces made as inherently friction-free as is practically possible.

"We do a lot of testing to make sure that we have the very best, and we spent about two years testing RF85 in our asphalt car. Tiger is a progressive company, and we were among the very first to start superfinishing our components about seven years ago. We now consider the combination of advanced superfinishing and RF85 to be the absolute best possible surface conditioning for highly loaded parts," says Gerald.

After seeing what it did on their rear ends, Tiger asked if BTN would treat some of their band saw blades. "We have to cut through a lot of fairly tough steels for our components. We figure we got about eight times the band saw blade life." Another advantage of the treatment is the fact that a rear end can be immersed as an already assembled unit, as long as it is completely clean. This saves a lot of time and tear down and reassembly.

Keith Dorton of Automotive Specialists is another believer: "My regret is that we didn't start using it sooner." Like many others in the business, he tends to be sceptical about treatments like RF85. "There are a lot of snake oil salesmen out there," he remarks, (this was an expression that RET came across frequently with regard to spurious products and treatments) "And it is difficult to find the time to test when you have so much else going on… we finally got around to trying it out, and on two of our engines, we picked up an immediate 5 to 6 horsepower after having RF85 applied. On one other engine, we did not show that much on the dyno, however, in competition it ran very strong." Even more impressive was what occurred afterwards. "We took that engine and dyno'd it after it had some serious race time on it." Typically, Automotive Specialists will expect a 15 horsepower loss through wear of various components. "There was no measurable loss of power with the RF85 treated engine." In fact, says Keith, "If anything, at the end it was a bit better than it was right after the build, and this engine had 1200 laps on it." Keith has not had the opportunity to perform a full tear down of any of the engines yet, but looking at those parts that are easily observed, such as valve tips and rocker arms, he noted that none of the usual scuffing was visible in those areas. "We are real confident about our dyno figures as well; our testing is fully corrected, and we cycle the engines repeatedly during the test to make sure that we have reliable information."

Another manufacturer of race engine components is interested in



Colorized versions of the previous Fe, C, and Ca maps following light sputter etching. Combining the maps (large map) creates a magenta color due to the dominant C (red) and Ca (blue) signals. Green areas reveal where Fe is present.

BETTER THAN NEW

RF85 was originally developed nine years ago by Better Than New, LLC of Chattanooga, Tennessee. Initially, it was difficult to establish the technology with potential customers simply because the surface of treated material is visually similar to an untreated surface, and is not readily discernable by the naked eye. This situation changed markedly after BTN submitted treated materials to Oak Ridge National Laboratory. The extensive and convincing testing performed at ORNL in a variety of different applications provided the credibility necessary to approach potential customers. BTN's general marketing formula has been to develop a partnership with an already well-established company in a given product area, and build acceptance in the marketplace through that partnership. The orthopaedic/medical example given at the beginning of the article was the first area of concentration for BTN.

Cutting tool applications were the next focal point for Better Than New and RF85. As discussed, low relief geometry tooling, with its attendant high surface drag, was a natural fit. In addition to providing the treatment for individual customers, BTN has formed an affiliation with tap manufacturer Reiff & Nestor (www.rntap.com). Customers can now order taps already treated with RF85 directly from R&N.

Racing was a different case altogether; normally, BTN does not search for publicity for its product; however, after Tiger Rear Ends reported their success with RF85 in *Circle Track* magazine, Tiger was absolutely deluged with phone calls, and BTN realised they had, quite literally, a tiger by the (dare we say it?) rear end. Consequently, Better Than New is opening a plant in Mt. Ulla, North Carolina in May to keep up with motorsport requirements, and has plans for a second plant in Indianapolis later this year. By the time this article is printed, the RF85 website will be up and running; the site will include extensive data from many of the tests referenced in this article, and will be able to answer the substantial majority of questions engineers and potential users will have about the process. Readers will be able to access the site at: www.RF85.com

Better Than New prices its services by the total value it supplies to the customer application being treated. For example, they will treat all parts in a disassembled engine (including the block) for about $1500; there is an additional $100 charge for the heads. A wheel bearing is $25, but they do them for free when a customer sends in a rear end, transmission, or engine. Complete motorcycle engines, including the transmission run about $1200. Quality control is another cost factor: "Because the process is so repeatable, most individual builders and small teams will want to receive their parts with a simple process certification for work completed." Major race teams, and companies involved with defence or aerospace applications can have scanning sampling provided to precisely validate treated surface quality. "ORNL has a scanning electron microscope large enough to accept an entire engine at one time, and this service is available to our customers".

BTN reports that their Racing, Orthopaedics, and Cutting tool divisions are all functioning as planned, and that the next product area focus will be in Nanotechnology applications, beginning in June of this year.

RF85 for entirely different reasons than improving engine performance. Dart Machinery is one of the best-known producers of high-quality, performance-oriented, engine blocks and cylinder heads in the US. Ongoing tests are currently being conducted for cutting tool performance. "We are starting with taps, because that is always one of the more troublesome areas in machining. Our initial tests show that taps treated with RF85 outperform conventional taps significantly." It will be a while, however, before they will be able to fully incorporate them into their CNC machines. "We run our machines on rigid tool life schedules, so we have to be able to quantify the improvement with a high level of repeatability before we bring them online as our standard practice."

At Team Industries they have already developed a figure for tool life improvement: "We have completed an extensive testing regime, and depending on the specific application, tap life is improved 2 to 3 times. We are operating on a tool life management system with our CNC machines, and have adjusted tool replacement schedules based on our tests, and there have been no failures in use." Team Industries is putting threads into grey iron and ductile iron that is used for hydraulic motor housings. "We're running 1500 rpm with a 5/16-24 thread tap. The faster we run them, the better they perform." The taps come treated with a standard titanium-based coating. "We have RF85 applied directly over them, and still get the same increase in performance. Interestingly, we also still have some old-style dedicated tapping machines that run at much slower RPM, and the difference is not nearly so noticeable there – the lesson is, use the treated taps to their greatest capability!"

The people at Better Than New confirmed that the results that Dart and Team Industries have reported have been reflected in other tests as well. Another manufacturer ran a full series of trials using Reiff & Nestor taps that had been treated with RF85. These taps are good, general-purpose taps that have cutting geometry designed to work with a variety of materials at a variety of speeds, using conventional tap geometry. The test was a competition; the standard-geometry RF85 coated taps would be up against application-specific taps from the most respected manufacturers in the field. The RF85 treated taps outlasted the best of the competition by better than 2 to 1…without lubricant, and with measurably lower power draw at the spindle.

BTN reports that high-speed steel, stainless, and titanium respond particularly well to the treatment. While they do confirm that customers like Team Industries have had success going directly over already-coated cutting tools, they make no specific claim for this kind of application. In addition to taps and drills, reams and end mills also benefit greatly. The one cutting tool exception is carbide, which does not respond to RF85, and cannot be treated, although it may be possible to successfully apply it to a titanium nitride (or similarly coated) carbide tool.

BTN will treat sample taps and other cutting tools so the customer can evaluate them in their own plant. Their pricing system is somewhat unusual; when a customer is ready to order, they will normally send in a minimum order of 100 taps along with their purchase price for the item. BTN's charge for treatment is typically 40% of the customer's purchase price…for a minimum 100 percent increase in cycle life improvement. Frequently, there is an adjustment made for extra-large taps. They call this "100 percent for 40 percent", and it reflects their value-based cost structure.

It is worth noting that the REM process, which I reviewed for RET 016, underpinned a reduction in the size of Formula One gearboxes (prior to imposition of the current dimensional criteria). To my mind RF85 could further assist the quest to make all aspects of the powertrain smaller and lighter. ■