THE American Surveyor

A FOOT IN THE PAST… AN EYE TO THE FUTURE

March 2009

New Technology

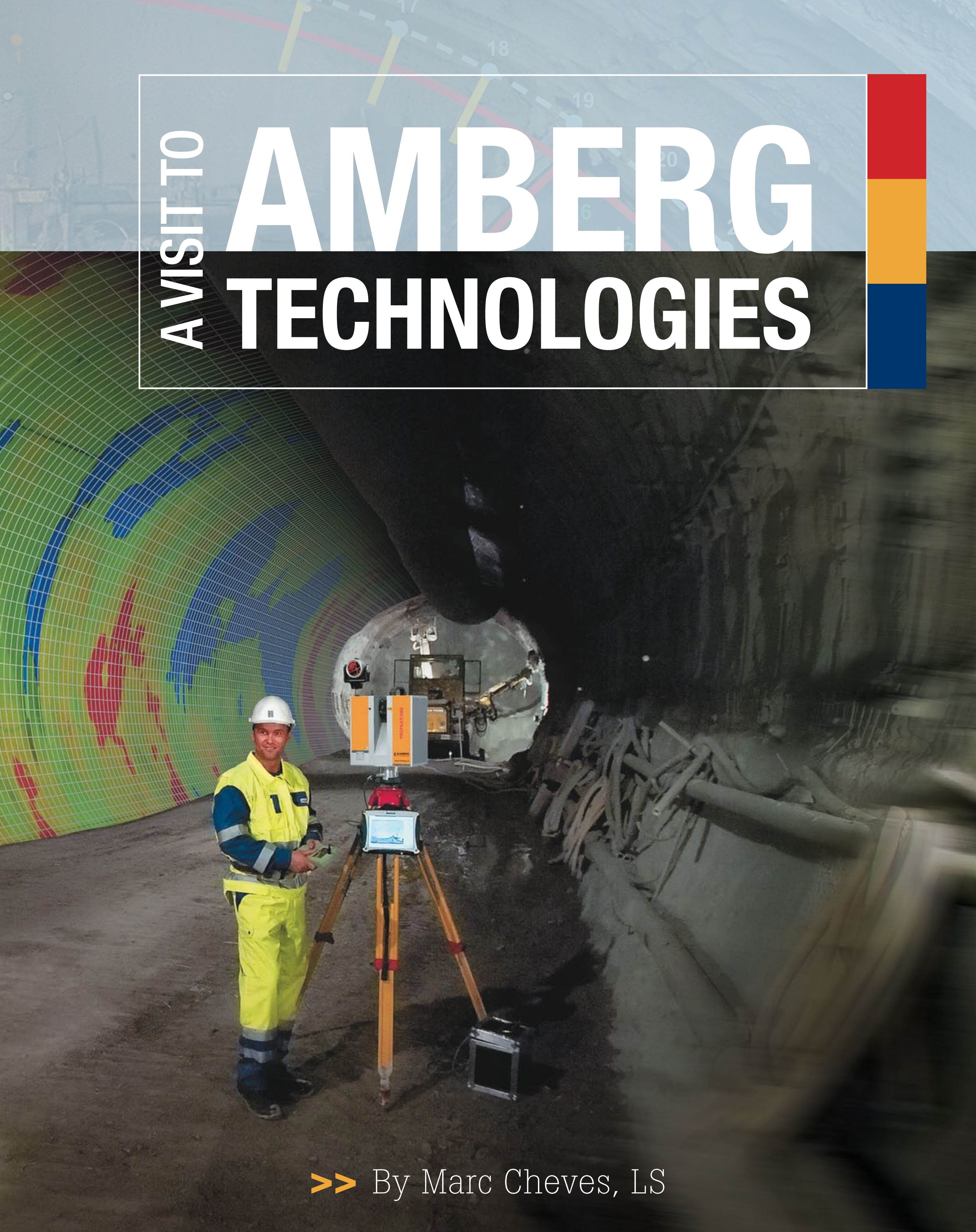
40th Parallel
Boulder celebrates 150th Anniversary

Event Review
Leica HDS User Conference

Industrial Fabrication
Scanning an oil refinery

A computer-generated view showing Amberg's TMS Tunnelscan. The colors represent areas of underbreak and overbreak relative to the design surface. The instrument is the Amberg Profiler 5003 scanner.

A VISIT TO AMBERG TECHNOLOGIES



>> By Marc Cheves, LS

Top of the line GRP 5000 trolley with the Profiler 5003 3D scanner.

As I have written before, one of the things I enjoy most about my job as editor is bringing new technology to our readers, so it gives me great pleasure to present something entirely new in this issue. Last November we journeyed to Zurich, Switzerland to visit Amberg Technologies, a premier tunnel and railroad surveying company. Sensing a boom in rail construction in North America, Amberg is entering this market. Benefits for our readers include a new area in which to diversify.

Switzerland and many parts of Europe have long had a well-run system of rails and tunnels. But the economic boom since the European Union was created has resulted in more road traffic than the system can handle. We complain about traffic in this country, but a Dutch friend once told me about a 100-mile backup (yes, 100 miles) on a freeway leading away from the Swiss and Austrian ski resorts after a major holiday. With ever-fluctuating but generally increasing oil prices and the growing profusion of road traffic, the Swiss have embarked on a massive tunnel-building effort that will piggyback trucks and cars on trains for the passage through the Alps. The most visible project is the Gotthard Base Tunnel, a $6.5 billion, nearly 100-mile system, and Amberg technology is being widely used in its construction. Geotechnical drilling began in 1993, construction of the tunnels began in 2003, and completion is targeted for 2018. When finished, the twin tunnels will carry 200–250 trains per day.

Begun in 1966 by Rudolf Amberg (see sidebar), Amberg Engineering was created to address the specific needs of tunnel building. Today, the privately-held company is run by Rudolf's son Felix, a PhD civil engineer. Highly-educated and widely published, Felix rides herd over what is now called the Amberg Group, which includes Amberg Engineering, Amberg Technologies, VSH–which operates the Hagerbach Test Gallery (see sidebar), and ASIT, which provides risk and safety education for underground construction activities. Amberg's reach is far and wide, with associate companies located all over the globe. Amberg Engineering is involved in tunneling and tunnel refurbishment, a big business since many of the world's tunnels, especially in Europe, were built before WWII. (In Germany, France, Austria and Switzerland, 80 percent were built before 1930.) It is also involved in geotechnics, aerodynamics and ventilation, risk and safety, and project management and consulting.

Unique amongst equipment manufacturers, Amberg Technologies has a team of tunnel and rail surveyors providing surveying and geo-monitoring services. Four Amberg crews are at work in the Gotthard Base Tunnel. But the services side of the company is strictly limited to Switzerland. This arrangement provides Amberg a way to develop and test its commercial products in real-world environments—by experienced professional surveyors—before they reach the public market. Outside of Switzerland, Amberg maintains a strict policy of not providing surveying services, but rather products, selling them through a growing number of highly competent distribution partners. The North American distribution network is now being developed by Brian Daniel, formerly with Loyola Spatial Systems [check out our June 2007 online archive for an article about Brian and Loyola].

Our visit was a real education for us as we learned about the primary methods in tunnel building: Drill and Blast, Jetting, Roadheader, Tunnel Boring Machines (TBM) and the New Austrian Tunneling Method (NATM). TBMs are not new, having been first used in 1845 to construct another alpine tunnel between France and Italy. In the U.S., an early-day TBM was used on the Hoosac Tunnel in 1853. The TBMs were not successful in either project, however, and conventional methods were needed for completion. The breakthrough for TBMs came when it was discovered that a rotating grinding face, studded with cutting wheels, was needed. Behind the cutting face—rotating at one to ten rpm—are large hydraulically-operated circular shields that lock the TBM against the tunnel walls. The cutting face is moved forward, and then the entire TBM is "unlocked," moved forward worm fashion, and the process begins anew.

Invented between 1957 and 1965, the NATM relies on the inherent strength of the surrounding rock mass as the main component of tunnel support. Shotcrete is applied to the tunnel walls, and the tunnel is strengthened not by a thicker concrete lining but by a flexible combination of rock bolts, wire mesh and steel ribs. Sometimes, cast-in-place concrete linings are also employed when NATM is used in soft ground tunneling.

TBMs, which have been extensively covered by television programs in this country, can range in size from a "microtunneling" boring machine that can be as small as 30" in diameter (normally used for pipe jacking projects), to a small bus, to giant 440-meter-long, 3,000-ton, 19-meter diameter behemoths—such as those being used on the Gotthard Base Tunnel—that require 48 truckloads to move around. TBMs quite often include equipment to apply thick pre-cast concrete linings to the tunnel wall immediately behind the face when the surrounding rock will not support itself. Depending on the material, TBMs can advance as much as 25–30 meters per day. With either a TBM or NATM, the rock waste is carried out of the tunnel by conveyor belt or narrow-gauge rail, or even by truck. For some ultra-hard rock conditions such as exist in northern Europe, TBMs will not work and the contractors have to resort to drill and blast. Large TBMs were used in the construction of the Channel Tunnel between France and England. [Check out our March/April 2006 online archive for an article about the Washington Dulles International Airport in which a couple of small TBMs were used in the construction of underground people movers.]

…"aiming" of the tunnel face is critical, and here's where positioning and measurement technology comes in.

RUDOLF AMBERG

A LIFE *IN* THE MOUNTAIN

Nicknamed "Old Tunnel Fox," Swiss-born Rudolf Amberg pioneered much of what is accepted as standard tunnel-building practice today.

Born in 1925, Amberg studied geology at the world-famous ETH (Swiss Federal Institute of Technology) in Zurich, then studied hard coal mining at Delft University in Holland. In 1952 he returned to Switzerland where he worked as a power plant construction supervisor. In 1959 he began his career in tunneling. He founded Amberg Engineering in 1966, and in 1970 opened the Hagerbach Test Gallery to address the need for a real-world place to test technologies and engineering for underground construction (see VSH sidebar).

Amberg spent 45 years innovating technology and bringing many seemingly hopeless projects in on time and within budget. "One cannot see inside the mountain," he said, meaning that beyond the tunnel face, little is known about the conditions. Today, Amberg Technologies employs a high-tech seismic approach to "seeing ahead" with its TSP product line.

An interesting footnote to Rudolf Amberg's accomplishments and vision is that he did not receive a degree from either university he attended. Nevertheless, in recognition of his pioneering efforts, in 1990 ETH granted him an honorary doctorate. Described by some as a grumpy genius, he downplayed the honor saying, "He who always swims with the current never comes to the source." Ever mindful of both fiscal and safety concerns in tunnel construction, his experience yielded a unique perspective. Said Amberg, "There are many experts who praise themselves and their building methods, when in fact, their methods are the cause of the difficulties."

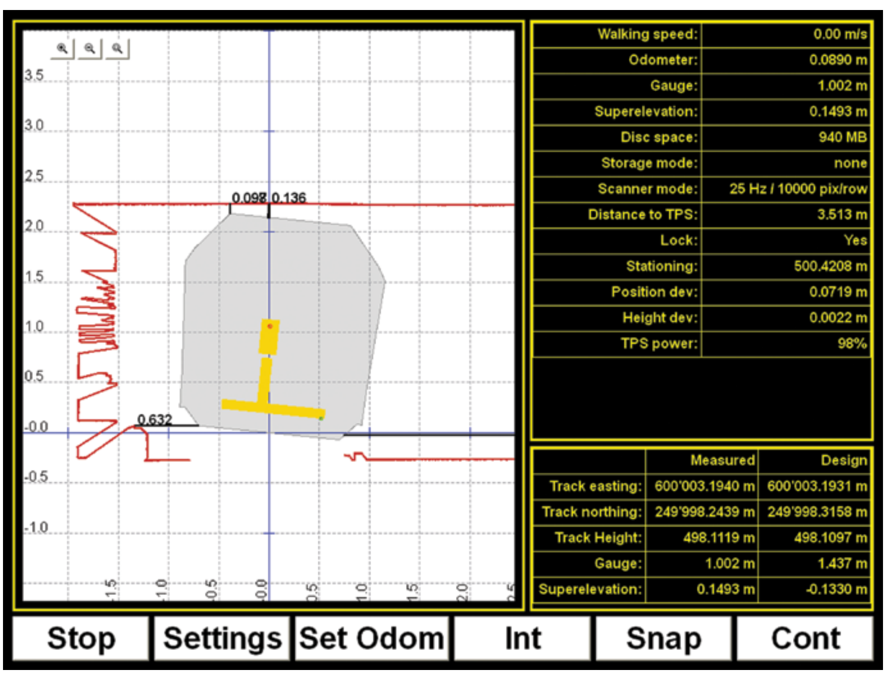
L–R Tunnel Surveying Engineer Oliver Schneider, North America Manager Brian Daniel and editor Marc Cheves watch as the TPS 1200+ is automatically guided by TMS Profile to quickly gather tunnel profiles.

As you can easily imagine, "aiming" of the tunnel face is critical, and here's where positioning and measurement technology comes in. The Gotthard Base Tunnel is using four TBMs, two coming from the south and two coming from the north, and TBMs will be used on about half of the 100-mile total, with the rest drill and blast. Obviously, the desire is for these tunnels to meet at the same point. Just as with dirt work where the contractor tries to avoid overcutting to eliminate the need to bring select material back in, tunnel builders try to avoid what they call underbreak and overbreak. These deviations from the tunnel design surface are not only costly in the case of removing too much material, but because the tunnel walls are often covered with geotechnical fabric or waterproof membranes, underbreaks have a tendency to pierce the lining material. Additionally, studies have shown that the reduction of overbreak of just 10cm for a 1,000 meter tunnel will result in a cost savings of nearly a half million dollars.

Amberg's technology is far more than a specialized application of angle and distance robotic reflectorless measurements and scanning. The company has had an exclusive agreement with Leica Geosystems for its total stations, and in fact, Amberg's Tunnel Measuring System (TMS) has been marketed by Leica in the U.S. and was employed on the Dulles Airport project. For scanning, Amberg employs the Profiler 5003, based on the Zoller & Fröhlich Imager 5006/Leica HDS 6000 phase-shift scanner, but on steroids.

Amberg's TMS product line consists of TMS Setout, TMS Profile and TMS Tunnelscan. The TMS Setout product is an on-board application program for Leica total stations. The sophisticated software provides for automated setout of all facets of tunnel construction relative to the design tunnel axis. This includes positioning drill holes for blasting, arch and rock bolt placement, and excavation profiles, to name a few. There's also a "production mode" allows contractors to do their own surveying by automating routine tasks. A cool module for TMS Setout is "Jetting": often, at the beginning of a tunnel, the material surrounding the tunnel opening is composed of soil and loose, fractured rock. To stabilize these areas, contractors will "jet" grout in a circular, pre-designed pattern, parallel with the tunnel, around the opening. Imagine the difficulty in aiming the drill to obtain the correct spacing, and more important, the correct orientation of the grout hole. TMS Setout allows the operator to place the red laser dot where the drill needs to start drilling, and once that's done, place the laser dot on a circular plate on the centerline axis at the other end of the drill. By doing so, the equipment will drill in the correct direction.

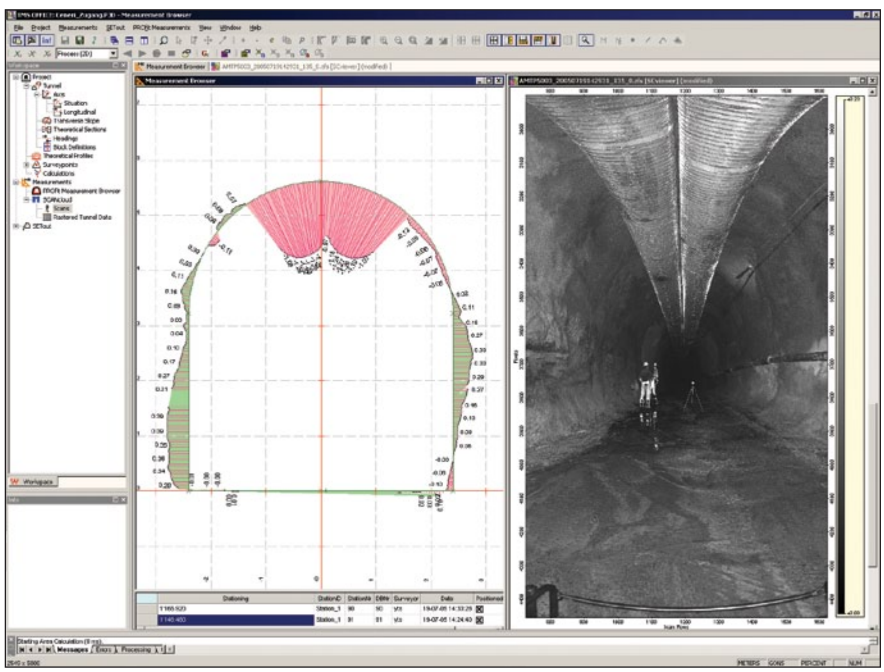
TMS Profile provides automatic 3D profile checks, volume calculations and underbreak/overbreak visualization. To further analyze the data, Amberg has TMS ProFit office software for showing design vs. actual and quantities. TMS Setout and TMS Profile are based on familiar one-point-at-a-time surveying, but TMS Tunnelscan opens the door for high-density, rapid point cloud survey-



Screen showing real-time clearance analysis on trolley laptop running GRP Software.

Standing next to a unique indoor training poster is Surveying Engineer and Business Unit Manager Christian Waldvogel. By shooting three points on the poster, a trainee can orient a total station to the tunnel control, thereby allowing the stored design data to be "staked out."

ing, at nearly a half million points per second. First, the scanner is positioned using the Amberg Positioning Method (APM), a method developed by Amberg to reduce the amount of time needed in the tunnel to "get on the control." After the scan, the millions of points provide no value unless the software is able to extract the needed information. For that, Amberg has TMS ScanRex for geo-referencing the point cloud. This information can be fed directly back into TMS ProFit for as-built analysis and extracting individual profiles. TMS ScanCloud can be used for powerful analysis of scan data and expert knowledge of either scan data or CAD is not necessary. Uses include comparison of two different data sets to determine layer thickness (*e.g.*, shotcrete), volume reports, and color-coded 2D maps showing deviations to project design. TMS ScanSurf adds undulation checks for waterproofing layers. TMS Setout, TMS Profile and TMS Tunnelscan are backed up by



An example of TMS, showing existing tunnel conditions versus the design profile. The image on the right is from scan data.

comprehensive TMS Office software, and all three capture raw measurements for archival purposes.

Another impressive Amberg capability is in seismic surveying for tunnels. I'm familiar with seismic surveying for oil and gas exploration where shock waves are sent *down* into the earth. But because, as Rudolf Amberg once said, "One cannot see inside the mountain," critical safety and cost issues arise in tunneling, and Amberg has developed a "horizontal" solution called Tunnel Seismic Prediction (TSP 203Plus). In 1881, the original Gotthard Rail Tunnel opened. It is said that during its construction around 200 workers were killed, many by explosive inrushes of water. Knowing what lies ahead is also critical for scheduling. To address this, Amberg has created an innovative seismic method whereby 24 small explosive shots are inserted into 1.5 meter deep holes spaced 1.5 meters apart, parallel to the tunnel direction, in the horizontal plane through the tunnel center, and just back from the tunnel face. From the seismic information obtained, Amberg engineers can analyze rock type and condition, faults, and groundwater up to 200 meters in front of the tunnel face. Rudolf Amberg's ambition to "see ahead" continually pushes forward.

HAGERBACH TEST

VSH (VERSUCHSSTOLLEN HAGERBACH)

One of the highlights of our visit to Amberg Technologies was a side-trip to the Hagerbach Test Gallery, about 60 miles east of Zurich. In 1970, Rudolf Amberg, realizing that a real-world site was needed to test technology and procedures, created VSH. The mountain in which VSH is located is composed of some of the hardest rock in Europe. Today, the giant underground facility consists of nearly five kilometers of tunnels, some ranging in size up to a two-lane road. All the infrastructure required for research and development work on materials, equipment and processes are in place, including several fire tunnels and a blasting chamber.

The overall aim is to offer services in test facilities that reproduce practical conditions as closely as possible. In many cases, large-scale investigations identify problems that do not emerge during laboratory tests. Another plus for VSH is that marginal conditions can be constantly guaranteed without having to stop traffic.

VSH was featured in a 2003 Science Channel program about the Gotthard Base Tunnel, a multi-decade project to build the world's longest train tunnel under the Alps. Because truck traffic gridlock in Switzerland impedes the EU's ability to conduct north-south commerce, the $6.5 billion, 8-9 meter diameter, twin-tunnel project—totaling 95 miles of train tunnels and associated cross and safety tunnels—has become a decided necessity. The original Gotthard train tunnel was built in 1881. A century later, the Gotthard road tunnel opened in 1980.

The largest safety issue in tunnels is fire. When opened in 1965 the Mont Blanc tunnel in Italy was designed to carry 450,000 vehicles a year, but by 1997 the number had risen to 1.1 million. In 1999, a truck fire in the Mont Blanc tunnel lasted for 52 hours and killed 41 people. All but seven of the victims had stayed in their cars and were poisoned by fumes from the fire. In 2001, two trucks collided in the Gotthard road tunnel. Parts of the tunnel roof collapsed and 11 people died of smoke inhalation. As part of the design of the Gotthard Base Tunnel (which will carry both freight and passenger trains), much attention has been paid to airtight "safe rooms" and emergency passageways that will allow people to escape.

One of the primary functions of VSH is fire testing, both for firemen trying to extinguish a fire and for the concrete and mortar and materials used in tunnel construction. The fire gallery is equipped with train cars for more realistic training. Additionally, dozens of companies—including Hilti, Siemens and Caterpillar—from all over the world use the facility for such things as rock bolt and equipment testing. A state-of-the-art, federally-accredited materials testing laboratory is in one gallery, and a restaurant

Amberg's tunnel offerings are only part of the story. While tunnel and rail are intertwined and many of the products have cross applications, Amberg's approach to rail surveying takes innovation to the next level. We're all familiar with railroads built with ballast and ties, but many modern passenger railroads use something called slab track. Critical for high-speed trains, slab tracks up to eight meters in length are cast off-site using high-strength concrete and steel supports. Once the slabs are in place, workers can precisely adjust the rail supports both horizontally and vertically, resulting in rails that are within two millimeters of their 3D design position. Europe pioneered the development of slab tracks for its high-speed trains, but China is taking it to a whole new level. [China is currently building approximately 12 kilometers (7.5 miles) of high-speed slab track per day and employing as many as 200,000 people on a single project!] Still, most railroads in the world are of the ballasted type. For these, massive football-field-length specialized trains—called tamping machines—move along the tracks, lifting the rails slightly, re-ballasting and re-aligning if necessary, and then re-leveling the tracks before moving on down the line. This all has to do with maintaining

GALLERY

in another. The underground industry has used the facility several times for conferences and seminars. The facility is even popular with the public, attracting nearly eight thousand tourists per year.

Our host at VSH was manager Andrea Koch, who graciously showed us the facility. A particular thrill for us occurred when Koch set off a five-shot dynamite blast. Even though we were nearly 150 feet away, we could feel the shock waves pass through our bodies. Shotcrete testing is a large part of the research, and Koch showed us one area where they are testing equipment that can "see" behind the shotcrete to determine unseen conditions such as water infiltration.

As part of our tour, we got to watch Amberg's TMS Plus in action, and once we were on the tunnel control, it was fascinating to watch the instrument automatically gather tunnel profiles. Also demonstrated was Amberg's innovative way of showing a drill operator where to drill and how to orient the drill.

The work at VSH is an excellent example of international cooperation that raises the quality of tunnel technology worldwide.

1) Entrance to Hagerbach Test Gallery.

2) An old "baby" TBM—still nearly four meters in diameter—inside VSH.

3) VSH Manager Andrea Koch with map showing the nearly five kilometers of tunnels and galleries inside VSH.

4) An example of the enormous pressures that are possible inside a tunnel. While these NATM ribs were not deformed due a catastrophic event, the deformation took place over a relatively short period of time.

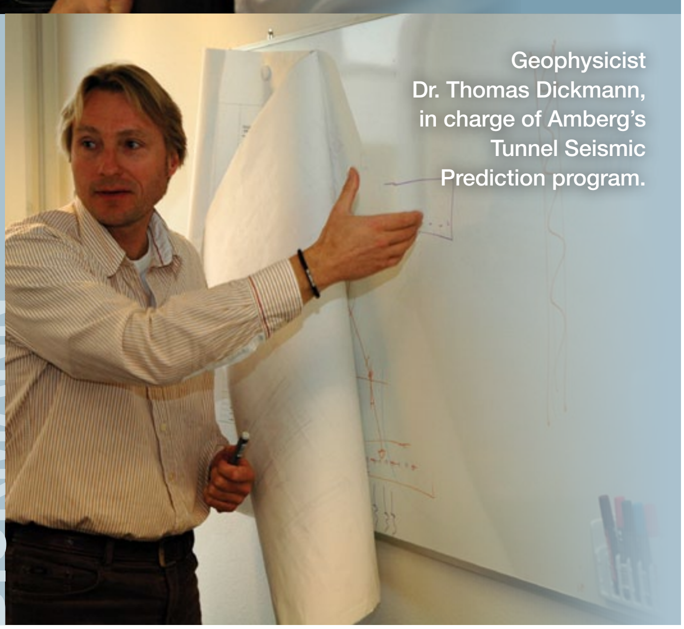
WETTSTEIN

Sales & Distribution Manager Stephan Wettstein

GASSMANN

Director of Technology Michael Gassmann (left) and editor Cheves.

DICKMANN



Geophysicist Dr. Thomas Dickmann, in charge of Amberg's Tunnel Seismic Prediction program.

allowable speeds on the railroad. Smooth tracks also mean less wear and tear on the rolling stock.

Other areas addressed by Amberg include clearance surveys for documentation and analysis, and construction and refurbishment. For design, Amberg addresses initial track recording, route documentation and best-fit surveys. Finally, Amberg also has products that can be used for as-built conditions. To gather data for all these applications, and based on something they call a trolley, Amberg's GRP System FX ranges from simple relative positioning to complex, GNSS-based absolute positioning. Common to all the flavors is the software that stores and displays everything. The modular system starts with the basis for all the GRP series, the TGS FX trolley. It is used for determining gauge–the distance between the rails–and, when in a curved section, the cant, or superelevation of the rails. I was amazed at the accuracy and precision of both the gauge and cant sensors: ±0.3mm for gauge and ±0.5mm for cant. When I asked how the cant sensor works, they just smiled at me, but knowing the Swiss reputation for quality, I don't doubt the claims. To accomodate railroads all over the world, the trolley can be set up for differing gauges (1m to 1.676m), and the built-in odometer is accurate to less than 0.5 percent and has a resolution of 5mm.

The trolley comes in three configurations. First, the GRP 1000, which incorporates a prism column. By adding a total station, 3D track coordinates can be obtained and combined with the gauge and cant measurements of the TGS FX trolley. The GRP 1000 is what the Chinese are using, and in fact, have purchased more than 125 of these units. Ideal for gathering profiles for such things as clearance surveys, the GRP 3000 adds a small motorized laser distance meter, capable of up to 50 points per minute, out to a distance of 30m, and at an accuracy of ±1.5mm. The top of the line is the GRP 5000, which incorporates a Profiler 5002 2D laser scanner or a Profiler 5003 3D laser scanner. The ultra-high speed scanner is phase-based and will range out to 79 meters. The resultant profiles are accurate to less than 10mm relative to the track centerline.

Rounding out the GRP series is the GPS kinematic option which adds a carbon fiber mast for a GPS antenna.

Assembly area for GRP trolleys.

Accuracy goes down slightly to ±20mm H and ±40mm V but the user is no longer tethered by the total station. This means that the user can go from surveying 1,000 meters of track per hour to 3,000 meters per hour. The trolleys are designed to be pushed down the track at walking speed, and the laptop software will let you know if you are walking too fast. I found it interesting that track time is tightly scheduled–imagine a 300kph train coming at you–and that users might only have five minutes to be on the track. It's been estimated that one minute of closure on a high-speed train costs nearly $8,000. Regulations require the users to be able to remove the equipment from the tracks within seven seconds. For all but the GRP 5000, one person can easily lift the trolley off the track. Weight-wise, workplace regulations require two people for the GRP 5000, and it would be a bit unwieldy for one person, but I'm sure that in an emergency, one person could do it.

Amberg Technologies has filled a niche market with exceptional products and services.

All of this hardware and software makes for a very powerful set of solutions for the tunnel and rail industry. Because all the products are highly targeted, efficiency is derived. Whether it's using the scan reflectivity for existing condition assessment, or exporting to a GIS or Bentley's RailTrack, the LandXML-based data provides great flexibility. Amberg gear is in use in 40 different countries and accommodates the fact that construction methods differ from country, as do track gauges.

Capitalizing on the well-deserved Swiss reputation for quality, ISO 9001:2000-certified Amberg Technologies AG has filled a niche market with exceptional products and services. As our world attempts to wean itself away from its dependence on oil, trains have the potential to play a big part. I was surprised to learn that trains carry 52 percent of the freight in the U.S. Granted, our country is large, but certainly in our cities, light rail can alleviate some of the traffic problems. And tunneling is not limited to roads and trains: it is also being used for underground water conduits, storm water and sewage retention, and a whole host of other uses. The timing of Amberg's entry into the North American market is excellent, and I think we'll be hearing a lot more from them.

Marc Cheves is editor of the magazine.