MB Electronics – A Nearly Forgotten Important Piece of Our History

John Judd and **George Fox Lang**, two old guys with youthful memories of a great American company

A nearly forgotten four-employee machine shop in the shadow of New Haven's Yale University probably gave birth to America's vibration testing industry. Mettler Brothers (MB) Manufacturing established in 1938 by George and Rollin Mettler initially fabricated precision metal components for nearby aircraft engine giant, Pratt & Whitney. As America was forced to immerse itself in the production of war material, MB grew in size and technical stature by specializing in answering the dynamic testing needs of our rapidly evolving aircraft industry. The company emerged as MB Electronics and grew to more than 700 employees. It invented, perfected and marketed a broad range of products, including electrodynamic shakers, large power amplifiers, sine and random controllers, velocity sensors, accelerometers and isolation materials. In its waning days, MB Electronics spawned many pillars of our modern vibration testing world including Unholtz Dickie, Vibra-metrics, BB&K, ACG, VSS, MB Dynamics, Ling Calidyne, the Tustin Institute and one terrific college dean.

George (left) and Rollin Mettler.

The MB story began in the late 1930s and into the mid 1940s when the world was struggling through one of the most horrific wars in history. Much of the industrial world was decimated, and in the late '40s, it began the slow process of rebuilding. Perhaps as a by-product of the war and its remaining political tensions, much of the world's energy was focused on supersonic flight and rocket/missile development, so a "space race" developed. The successful launch of Sputnik by the Soviet Union in 1957 and the dramatic televised failure of the U.S. Navy's Vanguard vehicle launch in the same year catapulted the subject of reliability to the forefront of American technical priorities. To focus the national awareness and increase the pressure for American success, on May 25, 1961, President John F. Kennedy declared that the United States would put a man on the moon within 10 years!

A very important player in all of this was the noted rocket scientist Wernher Von Braun, a staunch advocate of reliability who is said to have commented that about half the failures he experienced in his work with rocket-powered craft were related to acoustic and vibratory stresses. He recognized that these forces inherent in supersonic flight could tear aircraft and rocket structures apart and destroy critical electronic control systems. When Von Braun was reassigned to Redstone Arsenal, he likely exerted his considerable influence on priorities at National Advisory Committee for Aeronautics (NACA) and at the newly formed National Aeronautics and Space Administration (NASA). NASA leaders listened and became important advocates of vibration and acoustic testing – the prime objective being to detect and correct potential structural and component failure modes prior to launch or flight phases. This required the means to replicate the horrendous operational launch environment under controlled laboratory conditions, creating a technology that was initially called environmental simulation testing (EST) and is now referred to as environmental stress screening (ESS). ESS quickly became an important part of all major NASA system specifications.

MB Manufacturing started as a tiny machine shop making small machined parts for Pratt and Whitney Aircraft. Under the war's pressure, it evolved to supply molded rubber vibration mounts and proudly supplied large quantities of vibration-isolating engine mounts for WWII Pratt & Whitney (piston) aircraft engines. The interaction with P&W was very beneficial to MB. During this period, P&W asked MB if it could provide a means to create, measure and control mechanical vibration so that they could simulate the vibration created by an engine and test the isolation properties of its mounts. Recall there were no practical vibration sensors at that time and shakers of the era used rotating eccentric masses!

782 Whalley Avenue, New Haven, Connecticut, circa 1950.

MB Electronics engineering and drafting room, circa 1955.

Vince Thornberg, a young P&W engineer, had developed a device that Pratt hoped could be used to measure and analyze engine vibrations. He had a crude prototype, and P&W wanted to make it reliable enough to survive in harsh engine environments. So MB was challenged to develop a seismic sensor that would measure the instantaneous absolute velocity of the complex vibration of Pratt's engines. The sensor had to live in a harsh world, with temperatures from –60° to 260° C (–76° to 500° F), and it needed a frequency range from 5 to 2000 Hz. This was a tall order in the early 1940s. The result was a series of Vibrometer® velocity pickups that would be used by Pratt & Whitney, the Army Air Force and many airlines to measure/analyze and accept/reject conventional reciprocating and jet engines in final test and in flight for many years until replaced by later accelerometer designs.

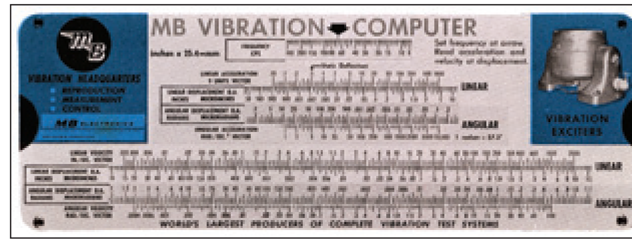
But Pratt wanted more; they asked if MB could produce a device that would actually create *and control* sinusoidal vibration to test and verify performance of isolation mounts and other components. The Mettlers agreed, so they went out and hired a team of engineers who had worked in the dynamics lab at Lockheed Aircraft Company including Karl Unholtz, John Dickie, Emil Oravec, Walt Jarroway and Bob Lewis to develop an electrodynamic shaker for generating controllable forces. Later, they recruited Galt Booth from the Cal Tech Vibration Laboratory and MIT-educated engineers, Tom Warner and Harry Cottle. They found and hired skilled craftsmen Dick Ignatowski and Frank Albino to refine and develop MB's vibration measuring instruments. This team's effort resulted in MB's introduction of the first commercial electrodynamic shaker system (Model C, Series C-1 to C11). The C11 version delivered 50 pounds of force, a 5000-Hz frequency range and featured a built-in concentric coil that measured velocity of table motion; it was used for many years by the U.S. Bureau of Standards for calibrating/certifying vibration measurement sensors. These shakers were absolutely unique at that time; existing mechanical shakers employed a variable-speed motor with an eccentric load to produce vibration.

The initial shaker systems were powered by cumbersome variable-frequency motor-generator (MG) sets and were limited to providing sine waves restricted to the cyclic range of the (mechanically tuned) MG set, generally from 5 to a few hundred Hz. As shakers grew in size and popularity, customers demanded more flexible performance. The market needed more, and the next generation MB systems operated on the same principles as an audio sound system and moved a significant mass instead of a little air. Sinusoidal oscillators were readily available, but high-power amplifiers were not. MB set about designing and refining large analog amplifiers.

It doesn't sound very earth shaking today, but creating a vibration test whose complex content and spectral makeup could actually be timed, controlled and varied to replicate the real-world environment opened up an entire testing industry. Engineers could now realistically perform qualification testing of critical equipment. Through the early 1950s and 60s, MB continued to expand its line of shaker systems to 28,000 lb of force driven by electronic amplifiers ranging up to 200 kW. A June 1960 advertisement bragged of having 20,000,000 watts of audio testing power delivered and working. That same ad named eight MIT graduates who were members of the MB technical staff.

By this time, demand for random vibration simulation testing was growing, and MB again led the way. Theron Usher (a Yale graduate and MB engineering consultant) developed the mathematical basis for practical random testing. His doctoral thesis demonstrated the practical logic of using ±3 sigma signal limits for random vibration testing using an electrodynamic shaker. Thanks to Usher's early work, modern testing and simulation is practical and successful. In the 1950s and early '60s, MB focused on random vibration testing systems and introduced the first automatic spectrum equalizer to shape the forcing spectrum. This made it possible to more accurately simulate the actual (or predicted) operating environment of the specimen. Initial equalizers were completely manual devices akin to a modern stereo's graphic equalizer. Later, automatic spectrum-shaping control and timing of mixed signal sine and random tests evolved. Systems grew to incorporate control of a temperature chamber surrounding the shaker and test article.

While it is famous for its electrodynamic shakers, MB also developed early hydraulic shaker systems. It developed an electrodynamic driver for the first stage spool of a hydraulic servo valve. When applied to dynamic hydraulic cylinders, this provided very long stroke (up to 12 inches) vibration excitation at low frequencies (less than 1 Hz). Alternatively, very high forces (120,000 lb) could be developed at frequencies up to 300 Hz. Hydraulic systems were initially developed and used to test large rocket motors but found other interesting opportunities, including:



Every vibration engineer's pocket companion, the MB Vibration Computer.

Thomas C. Warner surrounded by John B. Maeder, Joseph E. Tripp, Allen Brown and John A. Trevett (left to right).

Don Vanorsdall runs swept-sine test, September 1959.

- The first six-degree-of-freedom motion simulator at Wright Patterson AFB used to evaluate the low frequency motion/vibration tolerance of astronauts.
- The first practical four-wheel automotive road/ride simulator.
- A highly successful (and highly classified) low-frequency, high-power sonar system for the U.S. Navy.

It is fair to say that from the late 1940s through the early '70s, virtually everything of importance in the vibration testing field done in the United States was accomplished or influenced by MB Electronics. An abbreviated list of their industry firsts includes:

- Controlled electrodynamic shaker systems.
- Electrodynamic vibration calibration system with built-in velocity signal coil.
- Velocity standard system used by the U.S. Bureau of Standards.
- Sweep frequency testing with high-frequency shaker driven by a controllable oscillator/power amplifier.
- Variable-frequency test, with automatic level control of displacement/velocity.

Theron Usher Jr. (left) and Yale Professor Walter J. Cunningham, MB consultants.

Sine testing console.

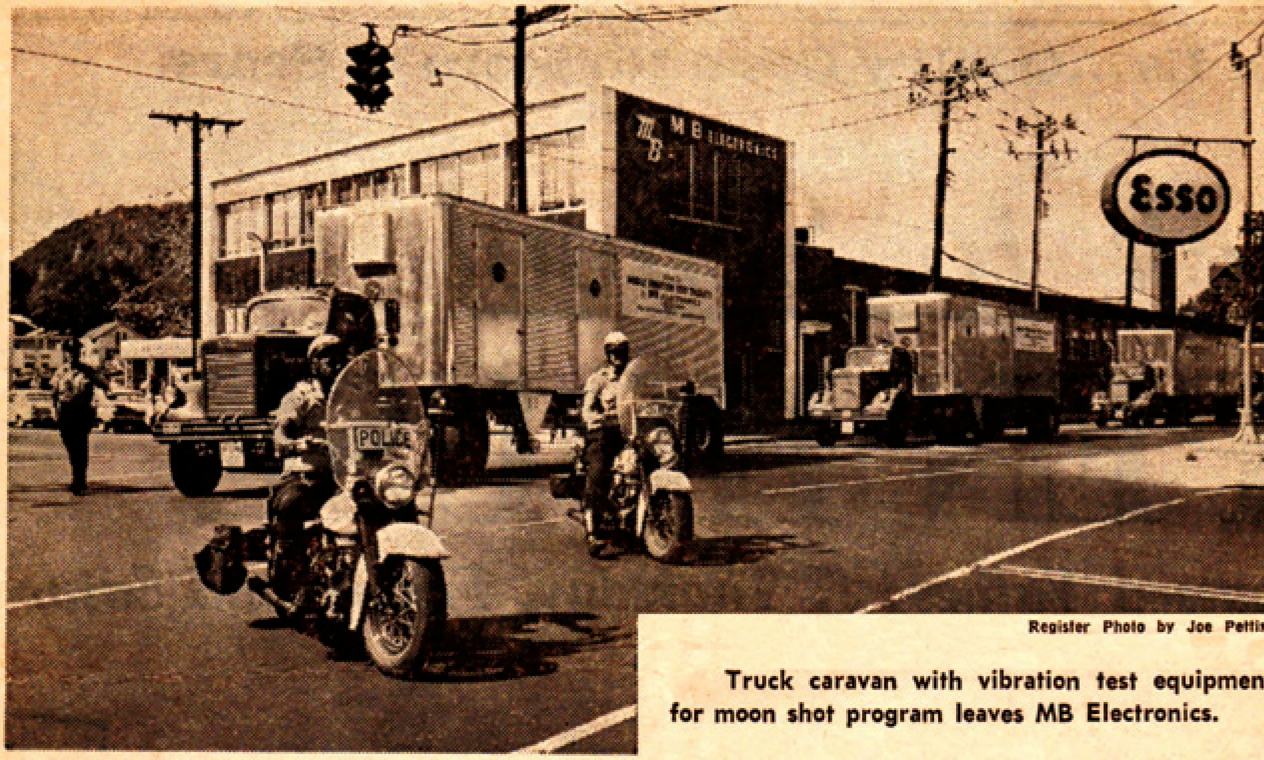
- Peak/notch resonance equalization filters for wide-band, random-sweep testing.
- Automatic random-frequency spectrum analyzer/equalizer.
- Frictionless high-frequency velocity pickup, 5 Hz to 2,000 Hz.
- Magnetically suspended, 700° F velocity sensor (never released).
- First liquid-cooled vibration exciters.
- Six-degree-of-freedom, long-stroke, hydraulic motion simulator for testing astronauts.
- Automatic, long-stroke, hydraulic vehicle road/ride simulator.
- Zero-Drive® constant-voltage system for driving low-level accelerometer signals over long conventional cables without loss or triboelectric noise generation.
- Model C50 was the first electrodynamic shaker to achieve a 100-g level with a 20-pound test load.
- Permanent magnet shaker for USAF with 10,000-Hz resonance for high-frequency calibration.
- Combined 28,000 lb (peak) sine force and 5,000 (rms) lb random force test systems.

Charles E. Maki, Galt Booth, Stephen C. Bogan ad William C. Brown (left to right).

- An 80,000-pound-force, eight-drive-channel synchronized sine/random test system for the Saturn rocket.
- A unique industrial vibration isolation pad trademarked Isomode®, still in use today.
- U.S. Patent No. 3,422,293 (issued to Galt B. Booth, January 14, 1969) protecting the Unholtz Dickie Induct-A-Ring® shaker.

By the mid 1950s through the '60s, the commercial manufacture of environmental vibration testing systems was in full swing. MB was supplying velocity sensors to monitor most Pratt & Whitney engines and was the largest supplier of vibration test systems in the U.S. It was conducting training seminars and supplying equipment to the aerospace industry worldwide. Indeed, during this time when the aerospace industry was challenged to put rockets, satellites and men safely into space, MB's environmental vibration and six-degree-of-freedom motion simulation and testing systems were being purchased and installed in virtually every major testing laboratory throughout the country. This included General Motors, Chrysler, Ford, Westinghouse, GE, Douglas Aircraft, Glenn

THE NEW HAVEN REGISTER, WEDNESDAY, AUGUST 25,



Register Photo by Joe Pettis

Truck caravan with vibration test equipment for moon shot program leaves MB Electronics.

MB Completes Moon Shot 'Crash' Job

By WALTER DUDAR
Register Business Editor

With nearly 500 cheering employes looking on, a caravan of trucks rolled out of the MB Electronics plant Friday with equipment for the moon shot program.

Five custom-built trailer trucks carried $800,000 worth of vibration test equipment turned out in a crash program.

Before the trucks pulled out of the MB complex at Whalley Avenue and Fitch Street, the massed employes heard talks by president Charles D. Brown and Mayor Richard C. Lee, praising them for their cooperation in the special job.

The equipment went to the National Aeronautics and Space Administration (NASA) facility outside New Orleans. There, the Boeing Company will use the MB gear for vibration testing during assembly of the S-1C, the first phase of the Saturn V moon rocket.

The system will simulate the intense vibration expected in the rocket at liftoff at Cape Kennedy early in 1967.

Boeing's Aerospace Division will use the system as the prime contractor for the Saturn portion of the moon shot program.

MB is the world's largest manufacturer of vibration test equipment.

New Line

The firm added another dimension to its image recently when it completed a vertical dynamic balancing machine, the first of its kind ever manufactured in this country, for NASA. The $60,000 machine was made by MB/Trebel, a wholly-owned subsidiary of MB Electronics.

The machine will balance up to 2,000 pounds and can handle pay loads up to 20 feet in height and of any diameter. It is a permanently calibrated balancer and can be completely operated by remote control.

MB-Trebel is continuing to operate the Trebel home plant in Dusseldorf, Germany, for the production of machines for European and Afro-Asian markets. MB purchased the Trebel-Werk G. m. b. H., a West German manufacutrer of industrial balancing machines, for an undisclosed sum, believed to be several million dollars, a year ago.

MB/Trebel machines for the North American market will be made in the New Haven plant in increasing quantities, Brown said. He said there is a broadening market for the balancing machines, both in the aerospace industry and in many other manufacturing areas.

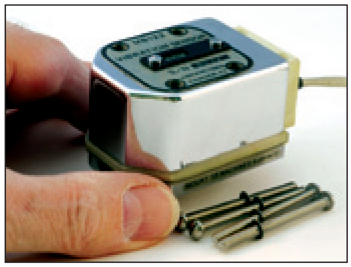
The aerospace industry has particularly strong market potential for MB/Trebel because the vast majority of sounding rockets and space vehicles put aloft are spin-stabilized, just like a rifle bullet. To maintain accurate trajectory, they require balancing.

New Haven Register from August 25, 1965 – MB Electronics ships vibration test system for Saturn V launch vehicle in five custom-built trailer trucks.

L. Martin Company, Boeing, Philco, Sperry Rand, the U.S. Army, Navy and Air Force as well as NASA and many others. MB's environmental test systems were growing in use throughout the world in the UK, France, Germany, Italy, Belgium, Israel, Japan and elsewhere. Vibration and reliability testing had established itself as a key element in successfully meeting and accomplishing the exciting new mission of space travel.

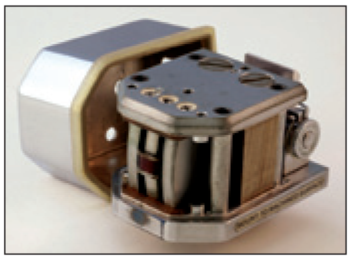
MB Electronics also became an international educator. In the mid 1960s, MB began conducting international seminars at their New Haven facility. Then, Dr. Alf Ratz and John Judd took this show onto the roads of Europe, giving seminars and live equipment demonstrations in the UK, Denmark, France, Belgium, Germany, and Italy. Their demonstrations introduced sinusoidal testing, broad-band random testing, shaped and swept narrow-band testing. The various class sessions trained MB representatives as well as potential and current customers. To facilitate this effort, MB built and exported a custom trailer to house shakers, amplifiers and related demonstration equipment and hired simultaneous translators. This well received educational tour actually led to securing a major order for Israel's first major environmental testing facility.

A Little More About the Vibrometer®



The Vibrometer was a compact (for its era) vibration velocity sensor featuring 100 mv/IPS sensitivity.

The Vibrometer was an early product developed by MB Electronics, and its importance far outweighs its diminutive size. It was the initial key to MB's financial success, and it enabled the complex environmental testing systems that followed it. While this moving-coil velocity sensor has been obsoleted by the modern accelerometer, many lessons learned in the evolution of its magnetic circuit still empower modern electrodynamic shakers today.



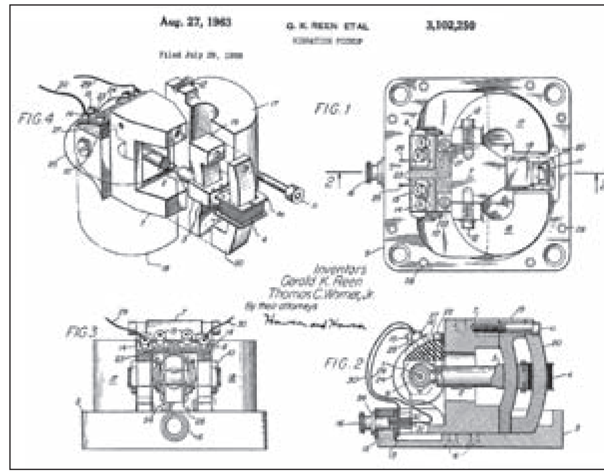
Voltage generating coil (left center) pivots on spring-restrained arm in magnetic field.

Beneath its unusually shaped cover, the Vibrometer housed a unique electromagnetic mechanism built with watch-like precision. Its purpose was to generate a nominal 100 mV/IPS voltage in response to the vibration of its base. Two Alnico bar magnets stood vertically with their south poles on the soft iron base and their north poles held against a soft iron top plate. An arm structure was pivoted behind the magnets and passed between them. The arm's motion was restrained by soft wound hairsprings. A coil of fine wire wound about a rectangular copper bobbin was secured to the arm's free end. This allowed the coil to move in an arc between the upper plate and the base. The curves of three soft iron pole pieces matched the arc of the coil. The coil surrounded the middle of these which was firmly attached to the upper plate and deliberately separated from the bottom plate by a non-magnetic spacer. The two outer curved pole pieces were affixed to the base plate and deliberately separated from the top plate by path-breaking spacers. So the coil passed through a magnetic flux radiating from the inner north pole, through the long axis of the winding, to the two bounding south poles. Therefore, when the coil vibrated (relative to the base), a signal voltage was generated in proportion to the magnetic field strength, the length of wire in that field and the relative velocity between the coil and the poles.

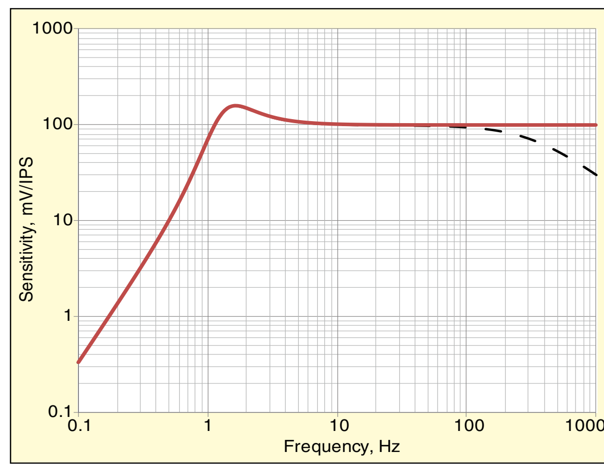
The coil and arm were free to move vertically. The soft springs gave this system a rigid-body natural frequency of about 1 Hz. Vibrating the whole sensor at a frequency above this resonance resulted in the coil remaining essentially fixed in space while the rest of the sensor moved relative to it. Therefore, the device could produce a voltage proportional to the absolute velocity of the sensor's base. To prevent the arm from moving unduly at resonance, a high damping factor (target 70.7% of critical) was required. This was provided by the copper coil form acting as a shorted turn within the magnetic field. So the Vibrometer was intended to be used as an *overdriven* system, measuring vibratory velocity above its low natural frequency. This is very different from an accelerometer, which is an *under-driven* system used well below its high natural frequency.

While an accelerometer requires no internal damping to survive, the Vibrometer needed very significant damping to preclude damaging overshoots at low frequency. The copper coil form was an elegant solution to the damping requirement, but it had a drawback. The coil-form would couple inductively with the measurement coil; this caused an undesired roll-off of the high-frequency response. MB engineers found a unique solution.

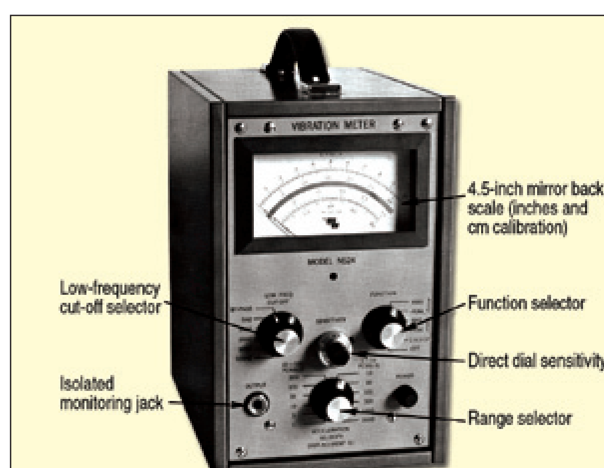
They cut a slot across the coil-form bobbin, breaking its conductive path. This restored the desired high-frequency response, because the bobbin no longer coupled inductively to the measurement coil. However, this open coil form no longer damped the system. A second copper bobbin (a closed form without a coil) was added to the swinging arm and placed in its own flux path at a different radius. Since the bobbins were not coaxial, the damping bobbin did not inductively couple with the measurement coil. This allowed for the needed heavy damping while preserving the velocity sensor's inherent high-frequency response.



Dual-bobbin Vibrometer eliminated the inductive roll-off by breaking the conductive path of the coil form and using a second copper bobbin (minus coil) to damp the system.



Typical Vibrometer sensitivity showing damping-controlled resonance and high-frequency roll-off (broken line) due to inductive coupling between copper coil form and wound coil.



MB vibration meter.

By the 1960s, MB had the broadest line of sine/random shaker systems in the industry, with 12 shaker models with force output from 25 to 28,000 pounds and amplifiers rated from 25 to 250,000 KVA. MB systems were used on virtually every aerospace program, and it was claimed in the '60s that every satellite in orbit had been tested on MB equipment. At the zenith of its prominence, it was honored with a contract to develop and implement a multiple shaker system consisting of eight C126 10,000-lb-force shakers generating 80,000 pounds of force to provide sine and random testing of the Saturn booster rocket. MB shipped the massive system on August 25, 1965 and Boeing's Aerospace Division used it successfully to qualify the S-1C first stage of the huge Saturn V rocket. The test required the simultaneous control of eight shakers simulating the periodic and wide-band random vibration of the expected launch dynamic environment. The vibration tests and the mission were successful, and the for the first time in history, American astronauts went to the moon. So, a tiny Connecticut company called MB Electronics helped America rise to President Kennedy's challenge. In the process, MB defined the U.S. environmental testing industry.

What the men and women of the MB Electronics team accomplished is nothing short of remarkable. MB's technical influence can still be felt today:

- Unholtz Dickie is now one of the foremost manufacturers of vibration testing systems; it was founded by MB alumni Karl Unholtz, John Dickie, Gerald Reen and Don McCluskey. Their Induct-A-Ring shakers reflect magnetic lessons learned from the MB Vibrometer.
- Galt Booth, Stephen Bogan , Andy Grimaldi (and later Theron Usher) left to form Booth, Brüel and Kjær (BB&K), aiding the Danish giant to develop three electrodynamic shakers ranging from 85 to 1500 lb force and featuring interchangeable heads for different applications.
- Andy Grimaldi (designer of MB's very popular C90 and C150 shakers) went on to form ACG, providing shaker refurbishment parts and services to the industry and most of its suppliers.
- In its closing days, MB sold its vibrometer and accelerometer designs to Vibra-Metrics and the balance of its business to Gilmore Industries.
- A few years later, Gilmore sold off the electrodynamic shaker designs to newly formed MB Dynamics of Cleveland, OH.
- As Charles Dickens said, "It was the best of times, it was the worst of times; it was the age of wisdom, it was the age of foolishness." When he wrote this famous line in 1840, did he somehow envision our world 100 years in the future? Perhaps, but we can certainly thank George and Rollin Mettler for taking us along on their ride through our own "best of times."

The authors thank Steve Bogan, Dick Boynton, Galt Booth, Art Diechmiller, Andy Grimaldi, Ron Lindsay, Bob Light, Jack Newton, Tom Warner and John Zamparo for sharing their memories, papers and pictures with us.

Some of the People Who Made It Happen

George H. Mettler and Rollin (Rollie) Mettler, of course

Management

President: Charles Brown, Bill Harrison
Vice President: John Dickie
VP International Division: Emil Oravec
General Plant Manager: John A. Gunnarson
Plant Manager: Erling J. Bligard, Richard B Davidson
Production Manager: John Baker
Sales Manager: Fredrick E. Bradstreet, Arthur Deichmiller, Jack Newton
International Sales Manager: John Judd
Engineering Manager: Robert J. Light, John Zamparo

Engineering

Chief Engineer: William J. Chalmers, Harry N. Cottle, Jr., Emil G. Oravec , Dr. Alf Ratz, Karl Unholtz
Technology Development: Galt B. Booth
Chief Electromechanical Development Engineer: Thomas C. Warner, Jr.
Manager Engineering Test Laboratory: Donald E. Vannorsdall
Engineer: Sal Albraccio, Charles W. Bell, Stephen C. Bogan, Alfred H. Bosworth, Jr., Dick Boynton, Allen Brown, William C. Brown, Joseph E. Chirnitch, Gerry Conover, Sidney R. Cohen, Dick Crook, Ray Cross, Bill DeMarseilles, Rudy Fazio, Lewis W. Gammell, Benedict J. Giangarra, Andy Grimaldi, Gabriel Hajian, Charles R. Maeder, Charles E. Maki, Don McCluskey, Moe Menard, Irv Mitchell, Ed Moran, John Peckingham, Romolo H. Racca, Gerald K. Reen, Walter Reynolds, George F. Rogers, Royce Ryan, Edward P. Sattelberger, Dick Sipfle, Pete Sotere, Joe Sperazza, John A. Trevett, Joseph E. Tripp, Theron Usher, Jr.
Field Service Engineer: Jim Capelli, Sal DeFrancesco, Jim Kavanaugh, Irv Mitchell

Sales Engineering

Warren A. (Shorty) Ellsworth, Jr., Bob Kaye, Ron Lindsey, Tom Lockheart, Dick Maly, Jack Newton, Bruce Peterson, Jim Stephens, Wayne Tustin

Plant Staff, Administration and Support

Frank Albino, Lou Alfieri, Marion Booth, Sarah Cohen, Ray Cross, Chuck Dahlberg, Joe DeFrancesco, Ann DeMarseliis, Dick Fay, Don Firth, Betty Harkin, Joan Gaudio, Arlene Hiltz, Richard Ignatowski, Harry Karoll, Svea Kenney, Max Kowtko, Jim Massella, Ann McCarthy, Elmo McMahon, Peggy Mittwollen, George Ralston, Ralph Riveccio, Pauline Remian, Marion Shields, Joe Silvestro, Mary Stewart, Fred Stirnkorb, Tom Sutcliffe, Roseanne Vallombroso, Jim Verdi

A special note of appreciation to two special people now deceased. For more than a decade, Jim Stephens and Tom Lockhart edited MB's *Vibration Notebook*; they were primarily responsible for capturing and recording the history of this tiny company and its contributions. This article is a tribute to MB Electronics and the industry that they helped to create. SV

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