

The History of A&W Tractor Products, Colfax Manufacturing Co. and AW Dynamometer Inc.

Introduction

First, to introduce myself, my name is Aaron Warsaw, the oldest son of Arthur J. Warsaw. I prepared this article to provide readers with the historic events of my father and my involvement with A&W Tractor Products, Colfax Manufacturing Company, and later AW Dynamometer Inc.

This will cover history for the period of October 30th, 1957, through February 26th, 2002.

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My Father's Background.

First, a little background about my father, Arthur James Warsaw. Dad passed away in 2002, which was a shock to all, as everyone thought he would live to be a centenarian. He was born at home in the small village of Anchor, Illinois. Having lost his mother at an early age, his father, older brothers, and sisters raised him through high school.

His father's occupation was a blacksmith in Anchor. Working around metal and the repair of early farm equipment. Having lived in this environment provided him with an early basis for mechanical experience. This would later be a valuable tool in his future agricultural and mechanical design. While his life in Anchor was simple, it did provide him with a well-rounded foundation. After graduating at the top of his high school class, he left home in Anchor at the age of 16 seeking new adventures.

Having left his home in Anchor, he found employment with the Caterpillar Tractor Company in East Peoria, Illinois. He began employment with Caterpillar as a tool crib assistant. A few of his first jobs were the distribution and restocking of production tools, sharpening drill bits, sweeping floors, and tool repair. Later, he was awarded a diploma from Caterpillar for completing their machinist apprenticeship program, promoting him to Caterpillar's machinist trade. After receiving his apprenticeship, he became a supervisor on the crawler pipe layer line with 200 men under his watch.

During his employment at Caterpillar, WW2 broke out, and he joined the Army Air, today it is the Air Force. While in the service, he became a specialist in aviation maintenance. After his military stint, he came home to start an International Harvester dealership in Minier, Illinois.

Being on the ground as an IH dealer, he was always hearing a common complaint about the Farmall M tractor. The major weakness in the Farmall M tractor was that it did not have enough selective speeds for use during field operations, as well as a slow transport speed. This put dad's mechanical mind in gear to find a solution. His firsthand experience repairing the M transmission systems provided him with insight as to how it worked and how it was manufactured. Using the machinist's background, which he received from Caterpillar, he sat down and began designing a retrofit gear package for the M transmission.

Note: I can remember Dad telling me he went to Peoria, Illinois, to get the first set of gears cut for a prototype, and the gears cut used non-hardened steel material. Knowing the material used for the gears was soft, they would work fine for the prototype testing, just to prove the theory. He knew they were not capable of hard continuous usage, but later he would select a lush alloy, while all gears would be made by Lafayette Mfg. After the M's

retrofit, locals noticed its faster transport speed; many accused him of speeding up the engine. But after observing field performance, they realized something was different as the engine speed did not sound any different than other M tractors. They also recognized the speed difference while performing field work. Dad finally let them in on the mystery that he had designed a set of gears and retrofitted the M's transmission.

The gear set increased the number of forward speeds to 9 from the OEM's standard 5-speed. This produced a greater selection of speeds in the field and a higher transport speed. This would become his first of many future patents. Dad later teamed up with Elmo Meiners from Anchor, IL., and the two formed the M&W Gear Co. The company's first product was a retrofit 9-speed gear package used in both M and H Farmall tractors. This package provided the additional gear selection required to increase productivity, all the while providing operators with better ground speed selection. Additional gear selection allowed operators to maintain optimum working speeds under different ground conditions and tillage tools.

At peak production, M&W ships 1000 gear sets per month. During his tenure at M&W, he designed a live power take for the Farmall series tractors, along with his contribution to M&W pistons and sleeves. Dad remained co-owner of M&W until the sale of half of his business in 1954. During a non-compete period after the sale of M&W, Dad was preparing himself for future adventures, starting with the creation of a mechanical brake which would be used as a load absorption unit in a dynamometer.

A Tribute to My Father

I was fortunate to have been given 50 years of my life to spend with my father before his passing. During our time together, he and I worked closely on hundreds of different projects. We spent many hours together on the road, in the shop, working on sales and installation of new equipment at customer locations.

I was blessed to have him both as a mentor and for bringing me into the business world. All the while being my mechanical engineering professor, even though he never had a college degree. When asked how many degrees he had, the answer was a simple reply: 98.6. As he always told me, all this mechanical stuff is simple, just use your head and work it out. While providing me with vast amounts of knowledge and a career opportunity, he also provided me with many additional challenges.

Before my high school graduation, and after I realized he had been preparing me to step into his footprints. I got an early start, having grown up around manufacturing, dynamometers, and agriculture. In the early 1970s, I became co-owner of Colfax Manufacturing and later became the full owner of the company. Dad retired in 1981, at which time I began managing AW Dynamometer for him along with Colfax Manufacturing Co. It was at that point in time that I knew Dad had faith in me to take over in his footsteps.

As dad's time was about to pass, he and I exchanged our past experiences, our many thanks, and our pride in what we had achieved working together over the many years. I have to say it again, my many thanks for the wisdom and guidance you passed on to me, which provided me with the knowledge to create, design, and produce new mechanical devices.

Our Heartfelt Appreciation

Our heartfelt appreciation to the team that made AW Dynamometer and Colfax Manufacturing Co. the worldwide success they were. We cannot forget our employees. Dad and I were fortunate to have a team of very dedicated employees. Their dedicated work ethic and talent went into every product made by both AW Dynamometer and Colfax Manufacturing Company. It was this combination that produced two extraordinarily successful businesses. During our tenure, personnel turnover was so low that it could not have been even classified as turnover, except for an occasional employee retiring. Both dad and I were immensely proud of the fact that most of our employees had been employed with us for more than 20+ years, with a few more than 40 years. We had occasions when an employee would retire and then come back wanting to work for us again.

During our tenure, we never had a layoff, as that was our dedication to the team. We always had copious amounts of appreciation for our sales and service representatives who blanketed America, selling, servicing, and installing dynamometers. Throughout the same period, our export manager, Lee Haspl, arranged a team of overseas distributors. His efforts made the AW Dynamometer label a common name around the world. At one point in time, we exported 50%+ of our production. With Lee's efforts and our additional representative, AW was providing sales and service coverage to 70%+ of the globe.

Rome was not built overnight, nor was AW Dynamometer and Colfax Manufacturing. It was upon our departure in 2002 that we spent 45 years on a completely developed line of proven dynamometers and two phenomenally successful businesses. During this period, Dad and I together built these two companies, one product at a time, one customer at a time.

Many thanks to the laborious efforts of all previous individuals and to our dedicated customers who provided the soul for both businesses. Our customers were a part of our business, not just a dollar bill pasted to their forehead. It was always Dad's and my belief that we would leave a customer with proper operational training, ample product information, and as much practical dynamometer knowledge as possible. Many new operators never knew, as now, just what dynamometers are and what power is. We always gave it the old college try of informing them, hoping a little would stay. We did not just drop off a unit and say Here it is.

From 1957 to 2002, it was Dad's and my hard work that produced many feats, endless creations, and the greatest volume in the history of pto dynamometer production. This will not, nor will it ever be replicated.

The History of A&W Tractor Products, Colfax Manufacturing Co., and AW Dynamometer Inc.

October 31, 1957: Arthur J. Warsaw creates two new corporations registered in the state of Delaware. The business names were A&W Tractor Products, while the second was the Colfax Manufacturing Company.

Being the sole owner, he dedicates A&W Tractor Products Inc. to perform sales and service of products related to the agricultural market. The second corporation, Colfax Manufacturing Company, was designated to perform manufacturing, assembly, and production related to all products to be sold by A&W Tractor Products. Both businesses were in a large garage behind Warsaw's family home in Colfax, Illinois.

1958: Arthur J. Warsaw applies for a utility patent for his innovative design of a water-cooled mechanical prony brake dynamometer. Initially, the design was designated for servicing the agricultural industry, being used as a power testing device measuring torque and horsepower during tune-ups, and the break-in of new and used or rebuilt tractors.

1958: A&W Tractor Products received its first dynamometer order from the International Harvester Co. This initial order was for six hundred units of the model Sand base; a single brake drum dynamometer rated at 900 lb./ft of torque while being able to test 100 horsepower at 540 rpm.

1958: Colfax Manufacturing Co. begins the process of building the large A&W Tractor Product's dynamometer order. Colfax Manufacturing ramps production up to 25-30 units per week, required to meet production schedules.

1959: A&W Tractor Products recalls the first two hundred production Sand Base dynamometers, requiring them to be returned to the factory under warranty. Indications of stress cracks have appeared on a brake stator shaft, which could create weakness and breakage or hydraulic leakage. Defective units were replaced at the factory, requiring the installation and replacement of a total new internal cylinder block shaft assembly.

1959: As initially used for ballast, sand in the lower tank has been removed and replaced with water. The additional water serves as both ballast and additional cooling of the brake. The new unit is now called the Model 1250.

1960: Dad designs a starter booster and applies for a patent. This device was a mechanical gear reduction device that bolted directly to the tractor engine's original starter. This provided a major increase in mechanical advantage over the standard 6-volt OEM starter

system. By providing additional torque, it enabled less strain on the system during startup. It was during this time that many tractors were hard-starting after hard use or in cold weather. This device was manufactured and built by Colfax Manufacturing Co. and was exclusive to the Tractor Supply Co. Colfax Mfg. sold tens of thousands of these starter boosters to the Tractor Supply Co., which they resold to the public.

Note: I can remember as a youth dipping fresh castings in paint prior to being machined and then helping assemble the gears, pins, and bushings.

1960: Issues with dry brakes as used in the Sand Base and 1250 models require a solution or method to correct aggressive torque loading and control issues. It was found that the use of Shell Rotella T engine oil created a more stable load, along with much improved load control. Using Rotella T as an internal lubrication fluid reduced the coefficient of friction while providing additional protection of the friction liner and the brake rotor friction surface.

1960: All new machines leaving the factory require internal lubrication fluid in the brake drum.

1960: Dynamometer brakes, having been used in the field, are converted to the new lubrication fluid.

1961: Dynamometers leaving the factory are now provided with a new hydraulic torque load control system. Details included a dynamically driven hydraulic pump and a new remote load control. The manual hand pump used for load control is replaced with dynamic governor loading.

1961: New direct reading torque arm uses a sliding rpm scale providing operators with a direct horsepower reading gauge, replacing prior analog readouts. Along with the new direct reading torque arm was a replacement for the mechanical tachometers. A new scaled analog rpm meter was belt-driven by a small generator.

1961: The additional new features were the introduction of Model 3000. This new unit was rated at 150 horsepower at 1000rpm and 800 lb. /ft of torque.

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1962: Arthur J. Warsaw has been issued a utility patent for his new prony brake dynamometer design. Patent #3068689 has been issued with ten claims or technical terms as to its uniqueness and operation of the design.

1962: A&W Tractor Products and Colfax Mfg. have outgrown the family garage, and dad is considering a larger facility.

1962: Dad purchases buildings located at 131 East Main St. in Colfax, IL, and moves the manufacturing and production processes to the new location.

1962: Dad adds an additional second brake drum section to his original brake design. This addition increased torque and horsepower capacity beyond his original single-brake design. The new dynamometer was designated the Model Super. It was rated at 165 horsepower at 540rpm and 300 horsepower at 1000 rpm with a maximum torque rating of 1600 lb./ft.

1962: Bear Manufacturing Co. of Rock Island, Illinois, chooses the prony brake made by Colfax Mfg. Co. for use as a power absorption unit to be incorporated in their automobile chassis dynamometers. Colfax Manufacturing Co. is Bear's only OEM provider of single and double-brake drum load absorption units. Power absorption unit production is expected to exceed one hundred units per year.

Note: The founders of Bear Manufacturing invented the electric starter used on the Model T Ford and were a major supplier of wheel alignment equipment. Most people will remember the little bear emblem. 1962: Colfax Manufacturing Co. has been chosen to provide the steel roller assembly, which will be incorporated into Bear's single and tandem-axle chassis dynamometers. Production is expected to exceed several hundred chassis dynamometer rolls per year.

1963: Dad has executed an agreement with the people who developed the Fre-Flo, a dry granular fertilizer and insecticide applicator used while performing field work. This agreement provides Dad with the rights to manufacture, sell, and distribute the product to the agricultural market.

1963: Arthur Warsaw introduces another generation of prony brake with the addition of a third brake section. This was his first attempt to break into the industrial engine dynamometer for direct engine testing at the flywheel. This unit would provide the industry with a small, portable, yet affordable dynamometer for testing engines out of chassis, performing crawler tail shaft testing, and automatic transmission testing. This new model was designated Big Joe with a power rating of up to five hundred horsepower and 2500 lb./ft. of torque. Industrial dealerships and engine re-builders such as Caterpillar, Cummins, and Detroit Diesel were targeted for new sales. This opened a new field for A&W Tractor Products as their first entry into dynamometers used in multiple industrial applications.

1963: A reduction in hydraulic pressure is required to reduce the high working pressures required to produce torque. New cylinder block assemblies will receive an increase to their internal brake piston diameter. Original brake pistons' diameters of 1-3/4" will be increased to 2 1/4". This will reduce hydraulic brake pressure by approximately 65%.

1963: The previous use of Conventional Rotella T motor oil has been replaced with Stein's motorcycle oil.

1963: Colfax Manufacturing Co. produces fifty single-load absorption units for the Maxwell Corporation. The load absorption units are to be incorporated into a Maxwell chassis dynamometer design. Maxwell stated the order will be going to the military.

1963: With the addition of larger diameter pistons, a new sheet metal closure, and the use of Stein's oil, a new agricultural dynamometer was introduced. The new dynamometer, Model 350, was rated at 350 horsepower at 1000rpm and 1900 lb./ft. of torque. Complete sheet metal closure included storage for the instrumentation and provided a competitive appearance.

1965: Newer synthetic maintenance fluids are introduced, replacing the Steins motorcycle oil. The new fluid has a higher working temperature range.

1966: A new agricultural PTO dynamometer was introduced, the Model 375, which was going to replace the Model 350. This model is standard with new white painted flip-up hoods providing convenient positioning and storage of the instrumentation. Instrumentation. The all-new sheet metal will provide a completely new competitive appearance. This unit will carry a 375-horsepower rating at 1000 rpm and a torque rating of 2100 lb./ft.

1967: With semi-successful results selling the Big Joe, a new industrial engine dynamometer was introduced, the new model 4000D. This model brings a new metal sheet

closure along with all current modifications accrued during the past few years. This three-drum prony brake dynamometer was rated at 500+ horsepower.

1969: No sooner after the introduction of the 4000D than the dynamometer market began calling for higher horsepower engine dynamometers. At the present time, Taylor Dynamometer and Clayton are the only two companies building commercial dynamometers capable of testing 2000+ horsepower engines. Dad knew if A&W Tractor Products were to compete in that higher horsepower market, he would have to either build a water brake dynamometer or create another method by which to increase the capacity of his original prony brake design. He realized that it would be impractical to keep adding additional single brake drum sections to increase torque and power capacities. A valiant attempt was made to redesign the original 12 ½" x 7 5/8" drum concept. The determination was made to stay with the same 12 ½" diameter while increasing brake drum length. The new brake drums would be equal in length to those of the two original drum brake assemblies. In addition, all new major internal brake stator components would require total redesign. The new series of industrial engine dynamometers is to be introduced after the experimental stage. The largest model, the 17000D, was equivalent to eight single drum sections. Additional models introduced were the 10000D and the 14000D. The largest model is the 17000D, which has a new quadruple drum brake equivalent to [8] single brake drums capable of 1800 horsepower at 1800 rpm. A second model, the 14000D, was a triple brake drum rated at 1400 horsepower and 6000lb/ft of torque. The 10000D was to be produced using a double-section brake, equal to 4 brakes of the original single brake drum sections. The unit was rated at 1000 horsepower and 4000lb/ft torque.

1969: This was the beginning of an era in which A&W Tractor Products began selling chassis dynamometers in the heavy-duty truck industry. An industry first was the usage of prony brake load absorption units incorporated into a heavy-duty tandem axle chassis dynamometer. The Model 12000D required [2] three drum brake assemblies. The unit was rated at 1000 road horsepower at 60mph.

1969: The first 17000Ds are sold to Detroit Diesel dealers in mining areas of AZ, UT, and MT. These dynamometers will be used to perform engine break-in on 16v-149TT engines after they are overhauled. These engines were rated up to 1500 horsepower and required a minimum break-in time of 4-8 hours under full load.

1970: Some signs show that the smaller engine dynamometer has a larger sales potential than the largest models.

1970: The first 17000D dynamometer brake failed and was replaced under warranty.

1970: A&W Tractor Products changes its corporate name to AW Dynamometer Inc.

1970: In an effort to expand field applications, a new model of dynamometer is introduced using the agricultural line of dynamometer brakes. The two-drum assembly originally used in model 375 is now supported at each end of the brake's water tank using two large bearings. This provided cradled movement, allowing all torque reaction created by the brake drum assembly to be measured, much the same as a water brake dynamometer. It must be known that during dynamic rotation, the brake drum assembly creates water drag, which increases with higher speed applications. This model was designated the Cradled 375, rated at 400 horsepower at 1000 rpm, but at higher speeds [1800-2000 rpm] could test up to 500 horsepower.

1970: All model 17000D's have had brake failures and have been replaced under warranty. Failures are the severing of the brake drums radially, along with internal bearing failures.

1970: Arthur J. Warsaw applies for a patent for a new traction-controlled device, which is incorporated into a 12000D heavy-duty chassis dynamometer. The device provides a new method for vehicle restraint while increasing tractive effort and safety.

1970: All 17000D dynamometers have failed again and have been replaced under warranty.

1971: The continuation of high-horsepower multiple-sectioned brake drum failures is being replaced under warranty. This situation is being monitored very closely as to the primary cause of failures. The most common failures are still the severing of brake drums on their radial axis. Additional issues are recurring of both internal and input bearing failures. At this point, there are no viable solutions to eliminate failures.

1971: Additional failures occurred on models 10000D and 14000D dynamometers. Failures have now become a common issue with all models. Repeated and constant failures are the radial severing of the input brake drum and internal pilot bearing failures.

1971: A last-ditch effort regarding the constant severing of brake drums and constant bearing failures is being made by attempting to create a dynamic lubrication system. The system would require lubrication fluid circulation to be filtered and cooled. This dynamic system required an externally driven fluid pump to force maintenance fluid through the brake's stator shaft. A pair of axially drilled conduits through the brake's stator shaft provided circulation routing of maintenance fluid in and out of the brake's internal cavity. Distribution of fluid was made to key internal areas of the stator assembly, including bearings and friction material. In addition to the external support, there was a complicated internal fluid recovery system. Retrieval and circulation of lubrication fluid from the brake assembly was accomplished with the aid of an external fluid pump. The system's working pressure was exceptionally low, requiring only a maximum of 1-3 psi for circulation. Low pressure was required to protect internal oil seals. Internal oil seals could only operate at a

pressure slightly above atmospheric pressure. Pressures above would purge internal fluid past the oil seal and leak out.

1971: Aaron installs the first new dynamic lubrication system by retrofitting a 17000D in Salt Lake City, UT. After the installation, a 1500-horsepower 16v149TT Detroit Diesel engine was run in as a check of the system.

1971: All 17000D dynamometers have had their brake assembly replaced with the new upgraded recirculating lube system.

1972: Arthur J. Warsaw has been issued a patent US3680368 A for the controlled traction device incorporated into the 12000D chassis dynamometer.

1972: Multiple brake assembly failures for the new series of high-horsepower dynamometers have occurred in less-than-desirable operational times. The smaller 10000D may have a greater operational life as these units are being operated at capacities less than half their power ratings, but even then, they have marginal brake life. As units fail, they will receive the new dynamic lubrication system during rebuilding.

1973: The decision was made to discontinue the program, stop production, and abandon the quest for this design as a high-horsepower industrial engine dynamometer. With all models having had multiple failures, the program was deemed to be no longer financially viable and would not continue. The series was deemed a failure, how well I remember.

Note: Many more details of this project could be written about, maybe in the next article or tutorial. Note: Our greatest gain was a treasure trove of knowledge in the field of tribology, the study of friction. Even today, a few scrapyards find them from time to time. At the time, no books were written about this type of prony brake design and the use of it as a dynamometer; we were on our own. I have since written several tutorials regarding the failures of this type of multiple-sectioned prony brake. In my studies through the years as related to tribology, my conclusion as to these failures resulted from an unbalanced relationship in the coefficient of friction between each section.

1973: Customers who owned a 17000D were refunded their money, and all units were returned to Colfax, IL. The balance of other discontinued models was left to succumb to attrition due to mechanical failures or time. Even today, a few of these old dynamometer bones show up.

1974: The Cradled 375 has been renamed as the Model 4-500, with the same power and torque rating.

1974: Agricultural tractor manufacturers are starting a new horsepower race. Tractors are beginning to receive engine enhancements, increasing power levels and elevated torque rise.

1974: We are receiving field reports that the M&W P-2000 hydraulic dynamometers are overheating and only providing very short test sessions. This was due to new horsepower tractors being produced by the OEMs. At this time, AW only retained 20% of the domestic USA sales of agricultural PTO dynamometers.

1974: Aaron certifies a tractor pull at the Knox County fair in Illinois. Tractors are broken down into different classes based on tractor weight and horsepower. During a specific certification for a class for 15,000 lb. tractors with a maximum of 225 horsepower, it became obvious that a particular tractor had the engine's fuel delivery severely tampered with. As the horsepower approached 250, I signaled the operator to shut down; he was over the 225-horsepower specification. The operator signaled by shrugging his shoulders as to just how much horsepower the tractor has. I continued loading the tractor down, having observed a maximum of 375 horsepower. After reaching maximum power, I continued to lug the tractor down only to stop close to idle speed or the last few engine revolutions. The operator reduced the tractor's fuel delivery, and it was re-certified at 225 horsepower. When all was done, the operator did end up winning the class. It was after the pull that the operator told me they had tried to test the tractor on their M&W P2000 dynamometer at the same settings as my original test. As he explained to me, the tractor just pegged the P2000 gauge, showing over 460 horsepower, and had not even slowed the engine speed down. This was our first field test, which showed that the capacity of the P2000s was highly overrated, even with its rating of 460 horsepower.

1974: The availability of economical commercial digital tachometers was introduced for commercial usage. Prior digital tachometers were only found in laboratory environments and were expensive. With the new availability of the digital tachometer, we decided to standardize models. These would replace our current in-house analog tachometer and generator system, which has been used since 1961.

1974: With the decision to standardize the digital tachometer for all new dynamometers, Colfax Manufacturing Co. issues a blanket order for 1000 tachometers. This order would cover new dynamometer production, along with the addition of field conversions. Colfax Mfg. Co. has begun taking delivery of seventy-five digital tachometers per month.

1974: John Deere introduces the new 8630 model of Four-Wheel Drive tractor rated at 225 PTO horsepower and 25%+ torque rise. During this time, the JD 8630 tractor was released, with a major increase in horsepower, which started a major horsepower race. We had

heard from dealers that while testing the 8630 when using an M&W P2000 dynamometer, they were observing extremely high horsepower readings of 260-270+, and during lug down, tests were showing more than 340-360 horsepower. Also, it was alarming that there were short test sessions before the dynamometer overheated. Being the P2000 was rated at 460 horsepower, it became obvious that the unit was overrated in power capacity.

Note: As history has shown, the P2000 tended to always show high power readings. This resulted from the thinning of the hydraulic oil, heating up, and the operator constantly increasing hydraulic pressure to maintain a constant rpm. The higher the operating temperature, the higher the readings. Another issue was pressure gauge compensation resulting from parasitic losses in the input gearbox. Use of a gearbox was required to increase the speed of a pair of hydraulic pumps. Again, the P2000 did not measure torque and was no more than a loading device with a comparative readout. Production units leaving the factory could never guarantee accuracy better than 85-90%.

Note: History has shown that production delays were related to extended lead times from M&W's pump supplier, Hydreco. Hydreco could not keep up with new production demand, let alone warranty replacement pumps. With many pump failures, M&W was forced to use a new supplier. M&W started using the Tyrone hydraulic pump as a replacement for the Hydreco. The new supplier, Tyrone, produced pumps that were not equipped with a pressure compensation wear ring, and failures could occur after a few hours of horsepower test sessions.

Note: More information can be obtained from my tutorial posted on Dyno Tech Services ' website under the History of Agricultural PTO Dynamometers (1945-present)

1974: The agricultural economy is beginning a period of major expansion. The agricultural market is showing signs of being a seller's market as there is heavy demand for higher-horsepower tractors. With agricultural equipment sales vastly accelerating, AW Dynamometer decides to reposition itself in the agricultural dynamometer market. Repositioning of market share would require reversing the sales ratio between us and M&W Gear Co. At this point in time, AW was only selling about seventy-five agricultural dynamometers per year. The decision was made to dramatically increase the AW sales force using independent sales and service representatives. This also required a very aggressive advertising program, along with challenging M&W to live side-by-side competitive demonstrations.

1974: The increase in the sales force was primarily manufacturer representatives already involved with agricultural markets. They were classified as independent sales and service representatives.

1975: Production of dynamometers by Colfax Manufacturing Co. during the first 5 months increases to about thirty units per month. Our sales are beginning to accelerate, shadowing the increase in large tractor sales. The demand for digital tachometer conversions pushes usage up to one hundred units per month.

1975: Early May, Arthur J. Warsaw's oldest son, Aaron, replaces a retiring Colfax Mfg. employee who had overseen the purchasing and production. Aaron, being part-owner at the time and having been around the business since his youth, found his new duties would put him in charge of all production scheduling, material purchasing, assembly, and machine shop production for all products being sold by AW. Immediately after Aaron took over, he began reorganizing Colfax Mfg. to increase manufacturing and production efficiency. During the first (5) months of 1975, approximately 150 dynamometers were built using thirty employees. Over the next 2 months, Aaron has reduced Colfax Mfg. Co.'s workforce has been reduced to twenty employees. Even with a reduced workforce, in the next 7 months, Colfax Mfg. saw production increase to 12.33 dynamometers per week or approximately 370 machines over the next 7-month period. For the year 1975, Colfax Mfg. production reached 520 dynamometers.

1975: Model 4-500 is replaced with a new nameplate. It is now called the Neb400. This was the beginning of the Nebraska series of agricultural dynamometers.

1976: Aaron receives many requests from local farmers in the Colfax area who would like to have their tractors tested before spring planting. Aaron begins setting aside one Saturday each year before planting to have a "Dyno Day." As word got out, the success of the program grew as he would test anywhere from 10 to 15 tractors each year for the next 7 years.

1976: Yearly production for Colfax Mfg. stabilizes at a production rate of 550 or 10.66 dynamometers per week. Production is being met and is on par with our dynamometer sales.

1977: Red Lion Controls develops a computer from which digital horsepower can be calculated and displayed. In our pursuit of new accessories, it was mutually agreed that the unit would have to be similar in appearance, shape, and size to our existing analog readout. Similarity to the new computer would allow older dynamometers to be retrofitted, bringing them up to a more user-friendly digital readout.

Note: Our single most important request was the addition of a fourth digital display window to be used as a percentage of torque load. A manual adjustment of the torque readout window was used to establish a percentage base of the dynamometer's torque load. Once a 100% base torque load value was established, it could be used to represent the

percentage of torque load for break-in or research. Most importantly, this 100% torque base could be used as a direct measurement of the percentage of torque rise. With the direct digital readings of torque rise, we were preemptive in promoting this important performance measurement. This was especially true as tractor performance increased between the OEMs. We preempted the industry with the first direct digital display of torque rise, later endorsed by all OEM tractor manufacturers.

Note: The cost was very reasonable when compared to previous readouts, as most were only used in laboratory settings. The new computer encompassed a four-function LED display of rpm, torque, direct horsepower, and percentage of torque load. This new package would be a simple replacement for all older analog dynamometers that were cradled. As an option, the new unit will be offered on all cradled Nebraska models of dynamometers.

1977: Colfax Mfg. Co. orders the first 10-horsepower computer prototypes. Units will be placed in field operation for evaluation of reliability and customer acceptance.

1977: The sale of agricultural dynamometers shows that the sales ratio between M&W has been reversed, with AW retaining approximately 80% of the market. At this point, AW has become the major agricultural dynamometer supplier to the USA market. Production of dynamometers by Colfax Manufacturing has maintained 525 units. AW's sales match production as there are indications of a growing export demand from Europe, Australia, Africa, Canada, and Mexico.

1977: Having finished the field horsepower computer prototype period, customers successfully and pleasantly accepted its performance.

1977: Colfax Mfg. has placed with Red Lion Controls a blanket purchase order for one hundred computers with delivery beginning with ten units per month.

1977: John Deere has a very aggressive update of field modifications, which requires the splitting of four-wheel tractors into multiple sections. This program involved older and currently delivered tractors. Dad designs a set of splitting stands from which a tractor could be safely placed and support the separation of the cab, transmission, rear axle, and the front engine axle frame.

1977: Colfax Mfg. orders over one hundred tons of a special mill-run tubing required to start production for the John Deere splitting stands. Through this project, Colfax Mfg. consumed more than eight hundred tons of tubing. Years later, these stands provided a platform on which we created engine test stands and electric motor support tables.

1978: Models 375 and the Neb400 are still outperforming the competition. Knowing tractors are producing greater horsepower, it is also true that tremendous amounts of torque are being produced during lug down tests while measuring the percentage of torque rise. With higher torque values, the double-section prony brake will begin to be stretched on its performance capacities. With anticipation of greater torque loads and wanting to stay ahead of the competition, Aaron introduces a new, higher-capacity dynamometer to the agricultural tractor market. This three-section prony brake dynamometer was designated the Neb 600, carrying a rating of up to 600 horsepower @ 1000 rpm and a torque capacity of 3100 lb./ft. This new unit also incorporated a larger water tank reservoir.

1978: The digital horsepower computer has become standard on all Neb600 dynamometers.

1978: Aaron Warsaw becomes the full owner of Colfax Manufacturing Co. after purchasing all remaining company stock.

1978: Arthur J. Warsaw applied for a patent on the Universal Shop Tool. The innovative design used 3.00 x 3.00 x .220 wall and 3.5 x 3.5 x .220 wall steel tubing as the basis of the invention. Key to the invention was the ability to telescope a 24-foot length of tubing into other sizes of tubing. Other components added portability and provisions for heavy lifting. Our steel mill producing this specialized tubing required a minimum order of 100 tons prior to entering it into a rolling schedule.

1978: Several variations of the universal shop tool were used as a major service tool for John Deere Co. During this period, John Deere required their dealer network to perform field modifications on early four-wheel drive tractors. Factory modifications required splitting the tractor into multiple segments as a method to perform different mechanical updates. The tractors weighed 30-40,000 lbs., which placed safety, ease of disassembly, and reassembly as a priority.

1978: Colfax Mfg. Co.'s yearly production reaches 480 dynamometers.

1978. Sales are still strong, but there is a sense that demand has slowed down and is being monitored.

1979: Colfax Mfg. Co has scaled back dynamometer production as demand has fallen. Production for this year is 375 machines.

1979: The trend towards lower dynamometer sales forces new considerations for new areas and testing applications. Areas being considered are testing combines, power units, and 4-wheel tractors without pto shafts. All applications, plus more, are being thrown into the mix as an effort to increase sales.

1979: Patent US4177978 A was issued to Arthur Warsaw for the universal shop tool.

1980: Sales have continued to slow, and production has been reduced to 325 dynamometers per year. It is our concern that a saturation of the market may have been achieved. The combination of 12% inflation and 18-20% interest rates caused a slowdown that was around the corner. From 1975 through 1980, Colfax Manufacturing Co. produced approximately 2700 dynamometers, which were sold to AW Dynamometer for their distribution throughout the USA. It was during this same period that additional export distribution was provided to some 30 different countries.

1980: Dad and I began the process of experimenting with several types of lubrication fluids and friction materials as we were experiencing an increase in brake failures. These dynamometers were primarily used for industrial applications, though similar issues have found their way into the standard line of agricultural dynamometers.

1980: After extensive product research, we settled on a few areas from which to start our R&D process. I began testing in-house, studying cooling efficiency and the coefficient of friction. Having reached for the stars, we began evaluating methods by which a prony brake dynamometer could achieve 100% conservation of the cooling water. I performed many tests in unknown areas related to cooling efficiency through the utilization of the latent heat of evaporation, as it was related to the brake coefficient of friction.

Note: Previous prony brake water cooling efficiency was a mere 15-17 horsepower per gallon of water based on incoming water temperature of 60°F with a maximum discharge of 140°F. Using the latent heat of evaporation for cooling, the maximum efficiency could approach 210 horsepower per gallon of water or approximately 13 times conventional results. This would have been a first in this industry, as no one else had ever approached 100% water conservation in dynamometers. Only a mechanical brake could achieve such a feat with the water temperature approaching 212°F. Maximum cooling efficiency occurs the moment 211°F water, still as a liquid, is increased to 212°F. This is the point where the energy conversion occurs, and liquid water is converted into steam.

Note: It was my decision not to pursue the quest any further due to the rupture of a brake drum assembly during a test session in Colfax Manufacturing's test cell. Even though I had achieved a maximum efficiency of 74% or 138 horsepower per gallon of water, it was my final decision that operation with discharge water temperatures exceeding 211°F would be too dangerous for the public.

Note: In the end, it was concluded to resort to the original maximum operating temperature, remaining at 140°F. All the while, brake flushing maintenance intervals were slightly increased. It should be noted that there is a lot of additional research information

on this subject omitted from this writing due to the depth and voluminous details of the program. This challenge, along with our research program, provided us with copious amounts of knowledge into fluids, lubrication, pressures, and temperature vs the coefficient of friction. During the whole R&D process, I was fortunate to have performed all in-house testing along with a great amount of road time chasing prototypes all over the USA. The knowledge gained during this process was priceless.

Note: Throughout the whole R&D process, I provided Dad with process information and results. It was this accumulation of information that provided Dad the basis for his improved prony brake patent application. Many additional and valuable details occurred during this program, as it took approximately 1 ½ years of R&D before we felt comfortable releasing new products to the public.

1980: Aaron places several new prony brake prototypes into existing customer locations.

1980: As the agricultural market slows down with lower sales, new areas for usage and applications must be sought out. A new line of industrial engine dynamometers for smaller dealers, portable and stationary chassis dynamometers, and special applications is sought.

1981: Dad retires, moving to East Peoria, Illinois. At this point, Dad was no longer involved in the day-to-day activities of the business, even though he and I were constantly communicating with each other.

1982: Arthur J. Warsaw applies for a patent on an improved version of his original prony brake design.

1982: Being satisfied with the improved prony brake, I created three new portable industrial dynamometers. These were introduced along with supporting accessories. Units would serve the diesel engine and heavy-duty automatic transmission industries. The new models were the I-300, I-600, and I-900. Their power range was from 300 to 900 horsepower. Complementing the series were newly designed options such as engine flywheel adapters, engine carts, cooling columns, printers, and constant torque packages.

1982: Design and performance tests have started for a new series of portable chassis dynamometers. Being satisfied with the test results, Colfax Mfg. begins production of chassis dynamometer models 9200, 9600, 9800 for AW's resale. Units will provide testing capabilities ranging from 200 – 500 road horsepower in both tandem and single axle vehicles.

1982: Higher energy and fuel prices are being supplemented by the increasing sale of the less expensive propane. Major oil companies are promoting dual-fuel propane conversions

for light-duty vehicles. Finished field conversions require load testing to be performed using a chassis dynamometer for proper adjustment of air/fuel ratios. Our single axle chassis dynamometer model 9600 appears to be a natural unit for this field.

1982: AW Dynamometer receives a major recommendation by 7 major propane producers across the United States.

1983: Aaron Warsaw is now managing both Colfax Manufacturing Co. and AW Dynamometer.

1983: Aaron approves component changes to all power absorption units. Changes were made to standardize components by reducing inventory. Changes include 2.188 - 34 tooth splined input shaft, shear pin flange upgrade, and compound water seals. Internal upgrades were the addition of high-temperature oil seals and compound sealing of the internal/external connecting lids. Internal stator shafting was upgraded from the SAE 1 ¾ – 10 tooth to the SAE 1 ¾ x 20 tooth involute. These changes are the first since the resizing of the brake piston size, dating back to 1963. Even with changes, brakes are still based on the original prony brake design dating back to 1957.

1984: Arthur J. Warsaw is granted a new patent for the upgraded improvements to his original prony brake design. Dad is both the owner and assignee of the patent.

1984: Aaron creates three new dynamometer models for use in the electric motor industry. Models include the I-300E, I-600E, and I-900E. This series had a test range from 300 to 900 horsepower. With our knowledge of testing, a 2-pole or 3600 rpm electric motor could have major operational issues in this speed range, as it would severely stretch the original brake capabilities. Our knowledge of operation above 2000+ rpm would create cavitation on the drum assembly, which could destroy the brake while being detrimental to the electric motor vibration analysis.

1984: Sales manager William Kalkman and Aaron Warsaw secure an exclusive contract with EIS of Atlanta, GA. Contract grants EIS the exclusive right to sell the 'E' series of AW dynamometers through their distribution system. The 'E' series provided a new line of dynamometers to the electric motor repair industry.

1984: Aaron creates three new pto dynamometers, staying ahead of the competition. Units will use a version of the newly improved prony brake. New models are the Neb2-300, Neb4-600, and Neb6-900. Later, these models would be renamed Neb230, Neb460, and Neb690.

1984: All models leaving the factory are now standard with the Model 1700 digital horsepower computer.

1985: Aaron develops a small motor test kit, which is integrated into the E-series electric motor dynamometers. This kit allows intermediate testing of smaller two-pole electric motors. Additional accessories were being developed as this new market evolves.

1985: Sales are accelerating for electric motor dynamometers along with optional accessories and options. New options include time-saver adapters, lock rotor stall pump, small motor test package, and test stands.

1985: Aaron creates the model I-1200E, which is to serve a niche electric motor market used for testing low rpm, high torque, DC traction motors. This four-brake drum was built to achieve test requirements up to 4000 lb./ft of torque.

Note: This unit had never been given any consideration for use involved with direct flywheel testing of diesel engines. Only a couple of these units would be built, as I refrained from building them from the beginning. With our previous experience with multiple-sectioned prony brakes having major failures, it was only with reluctance that we even produced them. As far as testing of high-horsepower applications, I reduced the unit's power ratings.

1987: Aaron creates a new version of a pit model chassis dynamometer rated at 700 road horsepower at 60 mph. The model 9850 will use 18" diameter rolls, major bearing capacity upgrades, and the use of a one triple brake absorption unit. This unit was to be targeted for testing tandem axle class 8 truck semi-trucks. This was an upgrade from the model 9800, which used 12-inch diameter drive rolls and was rated at 500 hp.

1987: Aaron begins pushing the sale of chassis dynamometers. Sales of chassis dynamometers are now being used in the propane conversion market, natural gas, emission testing, and the heavy-duty class 8 truck markets. Competitors include Taylor, Power Test, Clayton, Super-Flow, and Mustang. Aaron has begun to aggressively pursue the sales of chassis dynamometers on both the East Coast and the Front Range of Colorado.

1988: The state of Colorado requires chassis dynamometers at all testing stations performing diesel opacity tests. The chassis dynamometer must create a steady state load as required to perform accurate opacity testing. All private inspection sites performing diesel opacity tests must have a chassis dynamometer to receive state certification.

1989: The new LCD horsepower computer is now available for all dynamometer production. The Model 2000 computer will replace the old LED Model 1700 computer. Since the production of the Model 1700, a horsepower computer, more than 2700 computers have been sold on new machines, as well as field conversions on older machines.

1989: The Neb600, Neb2-300, Neb4-600, and Neb6-900, along with all industrial dynamometers, are now standard with the model 2000 LCD horsepower computer.

1989: Aaron Warsaw designs three completely new heavy-duty, high-capacity chassis dynamometers, models 18000B, 24000A, and 24000B. The 18000 series incorporated 18" diameter rolls, while the 24000 series was equipped with 24" diameter rolls. B represents a tandem-axle configuration while A represents a single-axle unit. Tandem-axle units incorporated a pair of triple drum load absorption units; each rated at 3000 lb./ft. producing a horsepower rating total of 1160 horsepower at 60 mph. Standard with this series is a new load control servo system providing the vehicle's operator with unsurpassed control of load and speed. System control of vehicle speed during dynamic testing can be regulated to within .1 mph or 3 engine rpm.

1989: The Electric motor market is desiring a dynamometer for testing smaller motors. We developed five models using a Stromag air-cooled electric brake. Units were compact and could be mounted on a stationary workbench or a portable work platform. Continuous testing ranged from 5 to 40 horsepower.

1989: Several times a year, Aaron travels to Colorado, continuing his sales and service follow-ups on 12 chassis dynamometers, performing more than 18,000 emission tests per year.

1989: The Electric motor industry is requesting dynamometer load capacities up to 2000hp. As was documented earlier, it was our experience with testing high horsepower, dated back in 1969-1972, that we knew there was no place for a prony brake design.

Note: It was our knowledge of the uncontrollable surface skin friction created by a prony brake drum rotating through water at speeds above 1500 rpm that we realized a new prony brake design was not in our wheelhouse. With our experience in high-horsepower applications, it was realized that it would require a water brake to fill the testing requirements.

Note: It was the accumulation of Art and Aaron's years of experience in the dynamometer field that they combined their thoughts as to what the desirable performance characteristics would be required of, and what it would take to produce a water brake. Requirements started with the mechanics for safe operational speeds for testing 50-60Hz, 2 through 8 pole motors. In addition, there would be high torque requirements of DC traction motors up to a power range of 2000+hp.

Note: William Froude was an English engineer and a hydrodynamicist (an individual who studies liquids in motion), along with being a naval architect. Froude was cited with many

principles in fluid motion, his most obvious being the Froude number, Mach one, and fluid efficiency. Around 1974, we obtained a barn find of a Froude water brake dynamometer. Having found information about the unit, I dated it as being a 1935 model. The rotor in this unit was only about 9" in diameter, which lent itself to high-speed testing up to 9000 rpm. By having disassembled the dynamometer for study, along with additional research, we began our development of a water brake.

1990: Our main requirement was to develop an absorption unit capable of absorbing high torque at low speeds. The final rotor and stator brake concept used was not comparable to the Froude, but the vortex principle was similar. Our design did not introduce incoming water into individual low-pressure points of the rotor vortex as did the Froude. Knowing the quality and availability of materials used in Froude forced us to make a lot of substitutions. Again, this was our first attempt at building a commercial water brake.

1990: Casting pattern equipment required to build a prototype water brake is ready. External stator casting is made using aluminum, while internal rotor components are made of cindered bronze. Initially, it was our desire to use naval bronze for the rotor and stator, but we lacked commercial availability as well as a quality foundry. Years later, I substituted the material used for external stator components and replaced them with the same cindered bronze as the rotor. Material substitution on the stator resulted from metal sublimation on the stator housing created by high pressures at the water discharge outlet.

1991: Colfax Manufacturing has built the first water brake and is ready for in-house testing. Our initial test results provide us with the desirable torque capacity we were looking for.

Note: The greatest amount of time during our first year of in-house prototype testing was spent finding the optimum method for load control. Unlike the Froude or Schenck water brake dynamometer, we did not introduce incoming water through low-pressure ports in the stator. We sacrificed one vane on each of the stator casings and forced water directly into the rotor vanes. Discharge water was removed through the lower stator housings and directed to drain. Manual inlet and outlet water valves served as both load control and temperature regulation. Incoming water sources could be tap water or water pumped through a cooling system, which operated as a constant torque load control. This type of load control operation was fine for high-torque electric motors but proved difficult when used to test internal combustion engines. Froude and Schenck used governor loading as their method for testing engines. In many ways, our method was a bit crude, but it did work.

1991: I secured several customers to perform industrial engine testing of the prototypes. The agreement was that I would install a unit and follow up with additional improvements that came from their or our in-house experience. This was the least expensive method for

getting operational hours on the units. These units would see large Detroit Diesel, Cat, and Waukesha engines. I personally replaced these prototypes on a rotational schedule every three months. I would take the units back to the factory in Colfax, Illinois, for inspection and available upgrades.

1992: We are now the only agricultural PTO dynamometer producer in the USA. We were a worldwide producer of agricultural PTO dynamometers, with the only competition being in Europe.

1992: The 2000-horsepower water brake dynamometer is now ready for sale. The model 20000E is now available for sale to the electric motor industry.

1993: The dynamometer product line is now complete as we are now selling and servicing agricultural dynamometers, industrial engine dynamometers, chassis dynamometers, electric motor dynamometers, and numerous special applications requiring a prony brake design.

1995: Art and Aaron have been approached by the Alamo Group. When Alamo purchased M&W, all the original dynamometer material was included in the sale. After having met with Alamo's management, it was the dynamometer portion of the business that they wanted to sell. It was reasoned that dynamometers had nothing in common with their current line of products. Alamo made us an offer to purchase all remaining dynamometer components and materials. As both dad and I agreed to decline the offer. In the end, there was nothing that could complement or advance our product line other than a closing chapter into M&W as ever being a competitor to us.

1996: Arthur and Aaron have decided to sell their businesses.

2002: January 19, Arthur J. Warsaw passed away after a short illness.

2002: February 26th, both Colfax Manufacturing Co. & AW Dynamometer are sold.

Additional History of My 33-Year Tenure

To bring things forward, I will start again from the beginning, which started in 1957 and ended in February 2002. The latter date was when both AW Dynamometer and Colfax Manufacturing Company were sold. Through those 45 years, some 7700 brake drum assemblies were produced by the Colfax Mfg. Co., of which approximately 7100 assemblies were used to create a dynamometer and then sold to AW for their resale.

At the beginning of 1975, an era started that continued through 1981, in which agricultural equipment was in a seller's market, which included pto dynamometers. During those 6 years, it was Colfax Mfg. Co., which produced more than 2700 PTO dynamometers, which were then sold to AW Dynamometer. During those 6 years, we out-produced, out-performed, and overcame a powerful yet well-established competitor, M&W Gear Co.

During my official 33+ years [1969-2002] of working for or owning Colfax Mfg. Co. I saw the accumulated production of approximately 6100 dynamometers. Here is an approximate breakdown of the dynamometer quantities by industry.

4700+ agricultural PTO dynamometers

700+ electric motor dynamometers

100+ chassis dynamometers

100 engine dynamometers

500 + factory rebuilding of dynamometers returned to customers

Another production statistic is from the beginning of digital horsepower computers to the final day the businesses sold; we put in service 4100 digital horsepower computers. This, along with other production volumes, was one of the major reasons we were successful around the world. This will remain unchallenged for many, many decades. My years of working with prony brake dynamometers have provided me with a vast amount of experience working with a multitude of OEMs, governmental agencies, diesel emission testing, nuclear power industry, and research firms.

This being a partial list, it does not include the numerous agricultural, electric motor, automatic transmission rebuilders, diesel engine rebuilders, and chassis applications I have been involved with.

Here are a few customers I worked with during my tenure.

Behr -OEM

Eagle Bus- Dino - OEM

Caterpillar -OEM

Jasper Engine and transmission

Valley Irrigation - OEM

Arctic Tom Cat – OEM

Chillicothe Metals - OEM

Nissan Forklift - OEM

Flexonics - OEM

University of Maryland

Farm Journal

Bell Aero Aerospace Division of Textron - OEM

John Deere Industrial - OEM

John Deere Agricultural - OEM

US Air Force

International Harvester - OEM

Navistar - OEM

BG Products – OEM

Volvo

Mach Trucks

Cummins

York International OEM

United States Marine Corps.

Ohio Gear - OEM

Stewart & Stevenson

Illinois Tool Division of Sparoid - OEM

City of Denver

City of Austin, Texas

Fiat Allis OEM

Shell Oil Co.

Southwest Research

Phillips Petroleum

PG & Electric

Power Cutting Inc. - OEM

O & K Trojan - OEM

Honda - OEM

Crown Lift Trucks - OEM

Sien Mining Equipment - OEM

B & G Products - OEM

Ransom Mowers - OEM

SS Truck – OEM

US Postal Service

University of Wyoming

Sanitation Department of Queens

Switzer

Walker div of Tenneco

Gillig Coach - OEM

Sumitomo Gear Box - OEM

US Penitentiary, Terre Haute, Ind.

Hydro Gear - OEM

Dana Spicer - OEM

National Lime

Amoco - OEM

Cooper Nuclear Power Station

Conrail Amtrac

Conroe Drilling

General Electric - OEM

Vermeer - OEM

This information was prepared by Aaron Warsaw for his personal life reference to the history of A&W Tractor Products, Colfax Mfg. Co., and AW Dynamometer Inc., covering the period from October 30th, 1957, through February 26th, 2002.

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