THE STORY OF THE

P&H MODEL 2800

200T Unit Rig

2800 MKI

Frank Clewell

Ed Taylor

Chubby

Thank you for your contribution to the 2800 Story.

Richard Czubkowski

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P&H MODEL 2800

By Richard ñ C h u bCzaujbkòowski

Dedication ----------

This 2800 Story is dedicated to all the original R&D Group, who through their skill, dedication and forward looking design innovations has made the "The P&H" electric rope shovels.

To all the unmentioned people in this story, who worked on ELECTROTORQUE and CENTURION, this story is also about you and your dedication and hard work to make the P&H Mining Shovel the best in the world.

Special dedications;

To Les Price, who was instrumental in the 50' electric mining shovels. Les was the mentor to two novice electrical engineers who stated on the project in 1961.

To Jack Taylor who promoted the design concepts, constriction and selling the 2800.

To Henry Harnischfeger and the Mining Division of the Harnischfeger Corp., who promoted and funded the new big shovel.

To Richard Profio, who started in 1969, was quick to grasp the importance of the 2800 and used his experience and engineering skill to make the 2800 the premier mining shovel to the mining industry. The writer traveled with him to all parts of the world and leaned about mining, the business of mining and an appreciation of miners and what they wanted in a good shovel

To Tom Weber and his dedicated Engineers and designer who carried on the design of the 2800 with innovations. It saddens the writer that Tom never saw the 2800 MKII turn into the 2800XPC.

To Gerry Schmidt and his team of motor designers for the DC and AC shovels motors.

To all P&H Engineers who advance the digital control called Centurion and the advance diagnostic and remote monitoring systems to keep the 2800XPC #1 shovel in the world.

A special acknowledgment and dedication to my long friend and fellow engineer Frank Clewell. His knowledge as an electrical engineer and his practical knowledge of mechanical things was evident in the cabinet assembles he designed. Some of his cabinet designs are used today on the 2800XPC.

Preface ----------

2019, marks the 50th anniversary of the P&H 2800 Electric Rope Shovel. The first of four 2800 units built in Main Plant in West Milwaukee, WI, were erected and went to work at the Kaiser Resources Balmer mine, near Sparwood, British Columbia, Canada in 1969-1970

The 2800 was a radical departure from the electric excavator designs of the last three decades ago. For the first time, the mining world was introduced the biggest hard rock loading shovel , on one set of crawlers and a pioneer static convertor control of DC motors called **P&H Electrotorque**

The concept of a big loading shovel started in the early sixties by a small group of dedicated engineers and detailers. They were lead by Les Price, promoted by Jack Taylor and Henry Harnischfeger.

The roots of the 2800 go back 135 years. The writer tells the story about the Pawling & Harnischfeger Corporation; its beginnings and the origin of the phrase referring to Harnischfeger equipment as **The P & H ò** .Without this past history, the 2800 may not have come into realization

The writer tried to relate the story of the 2800, as he and others remembered it. Almost six decades have past and some of the original engineers and memories also have past.

Harnischfeger Corp. had gone though several major changes with new people and with the loss of past history. The 2800 and the history of a company, which goes back 135 years, should not be lost.

THE BIGGINING of P&H -----

ñT H E P &-H ò

Industrial artisans Alonzo Pawling and Henry Harnischfeger started the manufacturing business that would evolve into P&H Mining Equipment in Milwaukee, Wisconsin USA.

Pawling was a castings pattern maker. Harnischfeger was a locksmith machinist with some engineering training. Both individuals served within the Whitehall Sewing Machine Company factory in Milwaukee. Pawling exited the firm to start a small gear machining and pattern making shop in 1883. Pawling persuaded Harnischfeger to join his firm as an equal partner. Their Pawling & Harnischfeger Machine and Pattern Shop officially began on December 1, 1884.

Pawling and Harnischfeger initially supplied industrial machinery components and assembly service support to large manufacturing operations in Milwaukee. Their customers included industrial knitting machine manufacturers, brick makers, grain drying equipment manufacturers and beer brewers.

In 1887 an overloaded overhead bridge-type crane collapsed within the foundry operations of a nearby heavy equipment manufacturer. Pawling and Harnischfeger rebuilt the crane with an improved and simplified design eliminating the rope and pulleys with a set of electric motors and transmissions. With their immediate success they moved into the overhead crane manufacturing and the service business.

A bank panic in 1893 caused demand for cranes to plummet however, prompting them to look for another product line that might help them reduce business risk amid economic downturns.
Their loyal customers referred Pawling & Harnischfeger as**ò P &-Hò** to this day loyal customers refer to their equipment as ***ñ T h e P & H ò .***

EARTH MOVING MACHINERY ERA BEGINS ----------

By the early 1900ós, they were making machines for constructing and mining. In 1903 the manufacturing was moved to a 20 acre site in West Milwaukee Wisconsin. In years to come this was known as

By 1920, their engineering and manufacturing operation introduced a rugged mechanical shovel named P&H Model 206. It was rated as a ½ cubic-yard and 500

pound pay load. By 1926, P&H digging machinery was effectively in distribution around the world.

Though the years P&H built mechanical earth moving machinery like giant Trenchers, Soil Stabilizers, Pushers(dozer) , Tampers, an experimental Self Loading Shovel and one of a kind machines lost in the archives.

From an ñAutobiography of Henry Harnischfeger, Milwaukee, Wisï

Last paragraph ----------

ñAs I write this sketch, in March, 1929, it is with a feeling of satisfaction that my many years of struggling and hard labor have been rewarded with a business and an organization that any man can well be proud o

Signed by: Henry Harnischfeger

ELECTRIC ROPE SHOVEL ERA ----------

Ward Leonard Controls ----

Over the ensuing decades, P&H earth moving machines evolved into larger, more powerful and more productive prime movers of material. Bucyrus Erie and Marion Power Shovel produced bigger machines which were powered by steam.

In 1930, welding technology made it possible to the fabrication of lighter, stronger machinery versus traditional riveted-design machinery.

P&H not only was an early adapter to welded design, but the firm also designed and manufactured its own line of electric arc welding machinery and welding rod products.

Another technology advance applied to P&H digging machines during the 1930s was the Ward-Leonard DC electric motor drive system. P&H began designing and making their own electric motors and controls starting in 1893 when they acquired the limited assets of the Gibb Electric Company.

Bucyrus Erie and Marion Power Shovel had already started to produce electric rope shovel in the 5 CY range. P&H was well aware of this competition.

The following report may have been the basis for the beginning of the electric rope shovel business.

Excerpts from the engineering report;

PAWLING AND HARNISCHFEGER CO.

THE FIELD OF APPLICATION FOR WARD LEONARD ELECTRIC SHOVELS

ñ*The discussion herein covers only a portion of the Some of the Commercial and Engineering Factors Governing Successful Entry into the Ward Leonard Shovel Field which will be written up in sections as the demand for it rises. The question as to the field is the most important and is therefore discussed first. Wherever statements are based on anything other than definitely known facts these statements are so qualified. The sizes of excavators considered are the two, three, and four yard struck measure shovels and the corresponding draglines.ò*

H. S Jacobs, Electrical Engineer ï October 19, 1931

The W-L System was typical of the time. A controlled rotating exciter (generator) was used to power the fields of the large DC generator delivering DC power to the DC motor to do work. P&H had acquired the Hansen welder design and modified it to be the exciter. Since the AC prime mover and the DC generators and motors were a product of P&H they all could be modified to give ideal characteristics to do work.

These electric shovels had a dipper capacity of 2.0 to 4 cubic yards. They were models 1200WL, 1225Wl. 1250WL, 1300WL and 1400WL. This was the origin of the traditional model designation; Dipper Capacity in CY x 1000.

MAGNATORQUE ----------

In 1946 P&H experimented with an Eddy Current clutch for Hoisting power. Various forms of cooling the clutch were tried. P&H through experiment and engineering, adopted the air cooled Eddy Current clutch to power its hoisting motion. The Eddy Current clutch characteristics were ideal for hoisting the dipper though the bank material. The clutch maintained maximum torque up to full hoisting speeds. The rest of the motion controls were adaptations of the traditional Ward-Leonard system.

Since P&H was the manufacture of the motor and the control, P&H Engineers took advantage simplifying and optimizing the shovel performance and controls.

P&H SHOVEL CONTROLS ----------

IMPEDANCE CONTROL with MAGNETORQUE HOIST -----

The rotating exciter was eliminated. The operator signal, produce by a rotating induction master, was feed into a ólargeô saturating reactor which was feed to the generator fields. These were not closed loop controls but the differential fields of the generators controlled and limited the motion characteristics.

MAGNETORQUE clutch current was controlled directly from the induction master, through the rectifiers, directing the current to the fields of the outer member. Since all the current for the Magnatouque control as feed through the induction master, all P&H operators had very large bicep on their right arm.

ELECTRONIC TUBE CONTROL with MAGNETORQUE HOIST -----

In the 50ôs, the STEEL ALTERNATOR TUBE was available for control rectifier service. They offered a simple device, no moving parts, to control the operatorôs signal to the generator fields. The 70 AMP current was provided by a single phase, center tapped full wave bridge.

ELECTRONIC CONTROL with MAGNETORQUE HOIST -----

A new electronic device called a SCR, Silicon Controlled Rectifier (Thyristors), came on the market. Again P&H, through its own Engineering and innovation, used this device to control the operatorôs signal to the generator fields. The 70 AMP current was provided by a single phase, center tapped full wave bridge.

The control system was a closed loop control with speed and current limits. The operatorôs controllers were unique. A series of SCRôS were controlled by a MAGNETIC FIRING A board plated with Rhodium for long life. The resistors inserted tapered the output to match the proper feel of the shovel motion.

Due to the popularity and sales success of P&H shovels, P&H was considered by GE as one of the biggest users of the 70a., stud type SCRs. This was a simple but effective control which stayed virtually the same for the 2100 and smaller models to this day. This control was called ELECTRONIC CONTROL with MAGNETORQUE HOIST. The control was effective, simple with few parts, easy to work on and to correct problems.

EXPANSION AND MINING CHANGES----------

Harnischfeger hit its stride during the postwar industrial boom in 1957. Engineers, Systems and Production people were needed and hired. In 1959 Walter Harnischfeger became chairman of the company and his son, Henry, became president. During this period, industries were becoming more complex, and Henry Harnischfeger felt challenged to choose between being an average competitor in several tough fields or the leader in two or three. Between 1964 and 1968, Harnischfeger streamlined its operations.

The Construction and Mining Division and Electrical Division were formed. Mineral and metal prices for were coming down. These raw materials were getting harder to mine and their yield was also coming down. Mining had to be done on a large scale for more volume, at a cheaper cost with reduced labor. The existing shovel fleets were old. It seemed like the 15 CY machines and 85 ton to 100 ton truck fleets were inadequate to meet their objectives.

SHOVEL SURVEY ----------

In the late 1950ôs, a P&H survey brought to family of bigger shovel, to make them compatible with the bigger trucks being proposed.

The survey highlighted;

- Larger shovel,
- Lower cost per ton dug
- More reliable
- Less maintenance
- Long and predictable component life
- Lower energy consumption per ton dug
- Efficient to manufacture
- Efficient to field erect
- Parts and service emphasis

1960ôs----------

The time was right for a new shovel and for P&H to maintain its leadership role as a shovel supplier. The engineering departments were re-organized to focus on new product developments while maintaining strong production engineering departments.

The Product Development teams, in the early 1960ôs, were 38th and Burnham St., known as **PROGRESS HALL**. Here the Shovel R&D as well as other products such as Hoists, Motors, Electrical Products and Construction Equipment was developed. It was a time for the new organization, new leaders and with new faces to get started with new product developments

Shovel R&D Group----------

The R&D Shovel group, mechanical and electrical was under Chief Engineer Les Price. The mechanical group consisted of experienced Engineers and Designers; Carl Schneider, Bill Zimmermann, Unban Gall, Henry Barron, Carl Schocka , Roy Clements, Jon Lenich, Harold White and Matt Teitze. Matt was an Electrical Engineers, who work on Magnatouque development, was assigned to design the big pieces of electrical gear which were required on the big new shovel and the ventilation of the machinery deck.

The electrical group consisted of two recent graduates, Frank Clewell and Richard Czubkowski, with limited experience in designing shovel controls. Under the guidance of Les Price, the new Engineers completed their engineering training programs. They would become familiar with shop practices like assembly and wiring of electrical panel, testing Magnatouque shovels, Motor manufacturing, lab work and field experience on a variety of P&H shovels.

Mechanical Tools and Design ----------

The Mechanical Group consisted of experienced machine designers. Their tools were parallel rulers, drafting machines, pencils, velum, look up tables, notes from previous designs and side rules; No CAD, no 3D Printers, etc. Stresses, load moments and various mechanical calculations were done by hand with a slid rule and adding machine.

Layouts were done with pencil on Velum paper and the detailers had to draw the individual parts taken into account the fit and production practices. Some designers would use the point on a dart to accurately make the layout dimensions more accurate. The four function calculators were rare. Slide rules and pencil on paper were the tools of choice. Stress analysis by computer was in its infancy.

Many new and innovated ideas were discussed. New revolving frame, dual hoist motors, propel motor in the lower, skid steer mechanism with V brakes, 25 CY dipper, bigger crawler shoes, side frame and lower, ventilation and lubricating systems etc, etc

Electrical design ----------

Since there were no articles or written papers applying static converters to shovel motions with DC motors, Frank Clewell researched technical papers applying converters to DC motors. Big converters had been applied to dc motors but these were rather steady powering loads. Many control rectifier configurations had been applied in the past using Thyratron or Ignitron tubes.

More modern large Thyristors had been applied to railroad DC motors. GE had books explaining how to configure convertor bridges and how to produce controlled DC.
With this expanse of background studied data, the converter bridge configuration and application to the motors was designed.

The P&H Electronic Control used the Magnetic Amplifier (MFA) for control. It was a simple method to control the 3 PH, 6 Thyristor bridge. Richard Czubkowski deigned a squire wave excited magnetic amplifier with control windings for bias, voltage and current feedback, stability and operator signal functions.

Meanwhile the motor engineering were designing a low speed, high torque DC motor for fast response, especially suited for the static convertors supplies and mining shovels. These were the F series of motors. To enhance the required transient commutation requirements, a laminated field ring structure was employed. This greatly enhanced the interpoles function, resulting in excellent transient commutation. The resulting design with large commentators and armatures, proved as asset to the new innovated shovel control design as well as the shovel performance.

The new P&H DC motor was a radical departure from the standard type, spilt frame mill type motor, as normally used.

Motors were also designed by a slide rule, hand layouts and past experience.

DESIGN PARAMETERS OF SHOVEL ESTABLISHED

- A bigger and true mining shovel than the 2100 ---11-12 CY, 92,000lbs
- New load rating---------- 18-25 CY, 160,000 lbs.
- More hoisting power. Magnatouque hoist clutches not practical.
- Lower kwh/ton
- A need for more dynamic operation
- A need to eliminate upper propel motor and eliminate the bevel gears. Put the Propel motor in Lower.
- A need to improve crowd drive (worm) and protection.

- A need to design SCR/thyristor convertors to produce control DC voltage and current to directly feed motor armatures for each motion.
- A need to improve the operator area and ease of operation.
- A need for a advanced control design to keep P&H the lead shovel maker

The goal of P&H R&D Engineering was to design a new bigger shovel which is to be; new, innovative, with new technology, and a giant leap forward in mining shovels.

Memories OF 1962 DISCUSSIONS ---------

Mechanical ----------
The mechanical design was for an 18 – 25 CY dipper. To lessen the suspended load the dipper back was designed to act as the torsion box for the sticks.

Urethane bumpers were used in between the handle and dipper bottom to save weight

The crowd gearing is subject to destructive shock loading. A design was proposed to create a gear with a urethane segment, as a shock absorber, between the hub and outer gear ring.
This was abandon for a v-belt and sheaves, between the motor and crowd gear box.

The central oil lube system was to be heated by induction heating. This was abandoned and conventional thermostatically controlled insertion heaters were used.

Mechanically, there were many design and production problems that needed resolution before gears, shafts, heavy weldments, structures, castings, forgings etc., could be made. Many of these part and structures were new, big and heavier than seen before in production.

Electrical ----------

Since the application of static converters was new to mining shovels and new to P&H, a system was proposed for lab experimentation.

In 1963, with the new swing sized motor, flywheel, new MFA – new larger field and armature size thyristors, were set up in the mechanical-electrical lab in old BLD. 41. A flywheel was attached to the motor.

The objective was to simulate a swing drive. It was to be a torque drive, four quadrants with reversing fields for motor direction.

The transient protection, over current protection etc. had to be designed and built in the lab. The entire control system was a contained on a vertical plywood panel so that changes and failed parts could be easily replaced.

The lab experiment soon showed the MFAôs were too slow to resp
firing angle of the bridge thyristors for good control current. An armature reactor was manufactured and connected to lessen the di/dt of armature current. A large air gap used to limit the residual flux in the core.

An experiment was tried, using powerful ceramic magnets, to negate the residual flux and increase inductance. This was futile a experiment because after a short time the magnets reversed there polarity and became useless.

The experimentation went on and a torque drive was functional, but not ready for a shovel. The MFA approach essentially did not work for the dynamic requirements of the shovel motions for the control of armature and field currents. It was a learning experience.

The control and motor setup was and eventually used to life test the crowd belts used on the field and future machines.

Two related stories **----------**

Story #1----------

The experimental converter system started early in 1962 in the mechanical/electrical lab in old Bld 41. It was Nov. 1963; we were ready, for the first time, to apply reduced voltage to the converter mock-up. Suddenly H.S. Jacobs, who was the father of the Magnatouque development, came out of his lab offices and announced President Kennedy, had been shot. He got the information through his broker and ahead of the information to the general public.

Story #2 ----------

The setup and motor ï flywheel was visible to people going through the lab.
Mr. Walter Harnischfeger was on his once a week visit to BLD. 41. He and H.S. Jacobs (Jake) were good friends. Mr. Harnischfeger nickname for Jake was to discuss politics and discuss money.

One day Mr. Harnischfeger stopped and approached us. He asked what we were doing. After a lengthy discussion he asked what the things were on the control setup board. We told him about, resisters, capacitors, diode, MFAs etc. He positioned his black hat, rolled the cigar in his mouth and said they look like the things that always burn out in my TV.

He admonished us to use good parts that would not burn out. The Chairman of the Board had spoken. We said ----- Thank you Mr. Harnischfeger. Fortunately he did not offer us one of his black hand rolled cigars.

1965 JOINT VENTURE AND THE EXPERIMENTAL 1900B ----------

To expedite the development, a joint venture partner was investigated. AIG, BBC, Siemens and ASEA were approached. They were all involved with heavy duty application for railroading. ASEA of Sweden was chosen because of their heavy duty application on trains a Thyristors. In 1965 a joint venture was measured ñ initiated.

1900B ----

Through the collaborative effort of ASEA and P&H Engineers, a system was designed. ASEA was responsible for the control/convertors and P&H was responsible for the application and the rest of the shovel system hardware.

A conventional 1900 was a reworked with two hoist motors, field and Armature transformers, joy sticks, capacitor cabinets, ventilation changes, F# motion motors etc..

The main ASEA cabinet consisted of a series of drawers or trays which contained the Thyristor modules, electronic power supplies, control relays, indicator tray for trouble lights and the motion controls. Because of the Thyristors capacity, several motions used Thyristors in parallel

Since the concept was new to mining and mine personnel, the thought was to replace drawers for ease of trouble correction. The control system was labeled ñWorks drawerò. This would eventually prove to be a drawers were too heavy to lift by a single person.

The first Thyristors powered shovel went to work at the beginning of 1968, in the CCI iron mine in Republic Mich. It based on a Model 1900. The static shovel was named 1900B, 12CYcapacity. . The control system was called **P&H ELECTROTORQUE**. The **MKI** was later added to distinguish it from the future designs.

Since it was new technology, it was a frustrating time and learning experience. We had to learn fast because there were four Model 2800s, destined for Kaiser Resources in British Colombia Canada by the end of the year. There was no knowledge or past history of this type of shovel application. We learned by field experience.

Many problems were encountered including soft pit power networks and outages. Transformer impedance was a problem. The secondary ôhad unequal impedance to the primary. Between the impedance of the transformer and the impedance of the supply there are not enough short circuit to blow the fast acting, sliver sand fuses, to protect the thyristors.

Countless of autopsies were performed on thyristors and fuses. It was evident that the short circuit current was not enough to blow the fuse rapidly and the thyristor suffered

over current and failed. The thyristors fault, over voltage or current, could be determined by the size and location of the ruptured Silicon wafer and the degree of fuse link rupture. This was a learning experience for the P&H Engineers.

Tuned capacitor banks were added to the main transformer s e c o n d for filtering and to improve the short circuit capacity for converter operation. This was a start of the RPC, Reactive Power Compensator, featured on all of P&H DC shovels.

The dynamic nature of the loads, produced by the motions, was a problem. The shared power supply between transfer from crowd and propel was a problem. Thyristor failure and fuse blowing were normal.

Failure to have bridge reversing and applying braking power resulted in propel run away and re- winding of the hoist drum cables. The list of problems was long but the experience would lead to the future success to the P&H Electrotouque. .

Through the efforts of two novice engineers, servicemen, an occasional engineer from ASEA, long hours, weekends and good the backing from Les Price, the 1900B survived in the CCI Iron mine. After being tortured by digging Taconite over burden, many changes and reworks, the shovel was sold and transferred to a mine in Arizona.

The basic system proved to be workable. Dynamic motion improvements were apparent while digging and swinging. The system would convert power to do work and invert power to the net when braking a motion. Power consumption was less but was not advertised because the KWH/ton was less as compared to the Magnatouque machines. Magnatouque shovels were P&Hôs bread and butt

The 1900B was the most powerful 12 CY shovel. It was the first shovel with static convertors powering DC motors. It was a first for P&H and around the world.

1968-70 -- FIRST P&H MODEL 2800 with ELECTROTORQUE MKI ------

MODEL	CAPACITY	LOAD RATING	YEARS MFG.
2800 MKI	24-16 CY.	60sT	1969-1975

Preliminaries ----

Starting in 1960, the shovel R&D groups along with Motor Engineering and production people were working on what was needed for the first big shovel. After much engineering discussion, concepts had to be turned into reality. The new big shovel was named **P&H Model 2800 MKI** with **P&H ELECTROTORQUE CONTROL.**

The P&H 2800 MKI were purchased by Kaiser Resources for coal mine in British Columbia, Canada. In fact they purchased four 2800s.

The 2800 was the largest crawler mounted, hard rock loading shovel, to be paired with 200 ton trucks. Beside the innovated control called ELECTROTORQUE MKI, there were many other innovations in mechanical, electrical and operational concepts;

- ¶ 25 CY dipper
- ¶ Heated boom and dipper sticks
- ¶ Whip + cable, power delivery system to the sticks
- ¶ Central cooling fans ducted to motor and converters
- ¶ Heated lube oil supply
- ¶ Splash lubricated bearings
- ¶ Reductions of hand lubrication, Auto lube systems.
- ¶ Sin g l e p r o p e l i n t h e l o w e r w i t h j a w c l u t c h e s
- ¶ Brakes (dual) for steering and digging. No bevel gearing from upper to the propel system.
- ¶ ñ M a r i o n s t y l e ñ d r i v e t u m b l e r s a n d c r a w l e r
- ¶ Tapered roller circle lubricated by auto lube system.
- ¶ Swingers (four swing pinions, each with an outboard anti- friction bearing).
- ¶ Hoist system used two motors driving a transmission in a
- ¶ Totally enclosed oil tight case
- ¶ All Bearings lubed by electric lube pump (heated in cold areas). Hoist system and swing gear boxes ï front and rear,
- ¶ Front end design completely new
- ¶ Power band crowd system
- ¶ Twin leg handle but no torsion box
- ¶ Flat bottom plate on boom for better clearance with dipper back when ñ t u c k i n g d i p p e r ò .
- ¶ Dipper trip mounted on dipper end of dipper handle
  Motor was a squirrel cage induction motor, flange mounted to a totally enclosed gear case. A sheave was provided at the transmission output shaft which was equipped with a short length of cable connected to a counterweighted trip arm. This lever was connected through a chain to the tripping arm on the dipper door. After the dipper was tripped, the AC power to the motor is turned off and the counterweighted arm rewound the short cable back on the sheave ready for the next dipper trip.
- ¶ Push button operation of all control functions; shovel start/stop, brakes, and transfer from crowd to propel.
- ¶ S t a t i c D C m o t o r d r i v e s w / T h y r i s t o r s ñ E L E C
- ¶ On board test features to check control parameters, motor current and voltage and a mode test switch to isolate field and armature for testing.
- ¶ Fast response motors
  Laminated frames with interpoles especially designed for exceptional transient commutation ability.

Shunt field coils encapsulated to their pole pieces.
Patented constant pressure brush springs to assure maximum rush life. Armatures with oversized core, large diameter commentators and dynamically balanced.
Quick disconnect electrical connectors.

- ¶ Tuned RPC for VAR correction and harmonic filtering to converter drives
- ¶ Enhanced performance. No reduction in performance due to low line voltage or temperatures.
- ¶ Joy Stick control. No foot pedal swing.
- ¶ One on board main transformer with multiple secondaries with shock mounted coils.
- ¶ Center gudgeon installed and removed from above.
- ¶ Dry type voltage collectors mounted on the upper for propel motor power and steering controls.
- ¶ Dry type High Voltage collectors are located inside of the swing roller circle between the carbody and the upper revolving frame with collector shoes made of sectors of multiple materials to allow good conduction and cleaning and lubrication of the rings.

START-UP OF THE FIRST 2800 MKI -----

The 2800 went to work at the Kaiser mine in 1969. There were many startup problems. New ideas were modified and some replaced with experienced ideas. With four machines in a row, field problems on the first machine had to be resolved quickly.

Mechanically ----------

- ¶ The sticks were reinforced
- ¶ The crowd sheave connection, to the shaft, had to redesigned because of fit.
- ¶ Outside inlets of the ventilation air had to be modified. Inlets became clogged with snow or frost.
- ¶ The urethane bumper between the dipper and sticks were ineffective and replaced.
- ¶ The mast or boom carrying the dipper trip and stick heater power was a constant repair headache.
- ¶ Shoes and tumblers were modified.
- ¶ The unique dipper trip was not reliable and replaced with a conventional motor, gear case, drum and cable on the machinery house roof.
- ¶ Many more problems were resolved by P&H Engineering

- The Main transformer was a problem from day one. The unit was built by a Harnischfeger subsidiary which made large MVA units but not suitable for the mining environment or for static drives.
- The booster connection produced circulating currents which resulted in thermal problem.
- The main transformer was under sized mainly because if lack of experience with motored shovel motions and the booster connection.
  The system was designed with a single armature supply transformed with multiple secondaries.

  From the 1900B experience it was found that di/dt was best relegated to the convertor system. The new transformers were designed to have an overall low impedance and equal impedance between the primary and each secondary. Because the motions work together, VA, plus and minus, are being transferred between the secondaries, and not replaced to the primary. This had to be considered in the VA rating of the windings.

  The new coils are vacuum impregnated with vanish and over coated to give extra protection to the moisture and dirt of the mining environment. A Milwaukee company, Sorgel made the new transformer coils with copper wire conductors and multiple layers of Nomex for insulation. All the existing transformers were reworked and the coils were placed on the same Urethane shock absorbers.

The items listed were just a few problems that were found after a few hours of operation. Many of these new innovations were modified, reworked and improved by dedicated P&H Engineers and ASEA Engineering who knew that this type of machine was the future in large shovels.

In 1999, the score card reads as follows;
One 2800 MKI ------- 139,000 hours
Second 2800 MKI ----- 135,000 hours

Two other MKI shovels, of the original four machine order, were retired after 100,000 hours.
The original four 2800 had been upgraded, mechanically and electrically. The hours they had acuminated are a tribute to P&H Engineering and Service.
(See Summary)

1975 ---- 2800MKII with ELECTROTORQUE MARK II ------

MODEL	CAPACITY	LOAD RATING	YEARS MFG.
2800 MKII	26-28 CY.	90 sT	1975 - 1983

Mechanical improvements or modification were made based on the experiences from the 2800 MKI. Structure were improved or modified to accommodate the improved load rating.
Thyristors were improving in current capacity and voltage rating.

In 1973, a MKII version of ELECTROTORQUE was designed. The MKII consisted of a CONTROL CABINET and separate oil cooled CONVERTER CABINET designed by ASEA. The Control Cabinet, Transfer Cabinet, Auxiliary Cabinet, and Operator Console etc., were P&H designed and manufactured.

The Control Cabinet had individual rack mounted circuit cards (ASEA Combi-flex) for motion control, armature and field, and RPC control. This cabinet also contained the feedback circuits, power supplies, control relays, field converters and miscellaneous control parts. An input jack was added to the meter panel so test voltages could be measured on the comb flex card.

The Convertor cabinet contained the motion armature Thyristors and the Thyristor/Thyristor RPC switches to control the steps of the tuned capacitor banks. All banks were tuned to approximately the 4.5 harmonic with air core reactors.
Static converters have an inherent poor line power factor when the motion motor is near stall. A stepped Reactive Power Compensation, RPC system, was applied to ELECTROTORQUE shovels to compensate for the inherent VARS.

Since the hoist had two motors, they were connected in series. Two 3PH full wave, double way bridges were connected in series, controlled in booster or push-pull configuration. This reduces the inherent VARS produced by the converters at near stall.

The RPC Switches controlled the tuned banks of capacitors. All the banks were charged to the peak voltage by one of the back to back Thyristors. The system was able to reverse the DC charge periodically on the AC rated capacitors. When VAR correction was need, the RPC Switch would turn on at the peak of the line without disturbing the line voltage, to compensate for the negative VARS produced by a motion convertor. A VAR transducer and the RPC controller connected and disconnected the tuned banks of capacitors as correction was needed.

The original MKII oil cooled converter had a series of over-coolers on top of the Thyristors pole face with the other pole face connected to a long under cooler. This under cooler also served as the AC bus for the various Thyristors bridges. To electrically isolate each Thyristors from the others, a ceramic Beryllium oxide wafer was placed between the top pole face and the over cooler. The individual convertor bridges were equipped with Current Transductors for current feedback

First MKII shovel -------------------

The first shovels were places at Kennecott Copper Mine in Bingham Canyon, Utah in 1975.This were the biggest loading shovel in the pit at 27 CY.

An immediate problem was misfiring of the converters at high current levels. The internal pulse transformer, of the pulse firing modules, was susceptible to miss-fire due to high electromagnetic fields. A metal shield or box was put around the epoxy encapsulated firing modules.

A further problem developed with the firing modules with time. Several modules were x-rayed and engineering determined that the epoxy used, after thermal cycling, was flexible and small components, like diodes, were destroyed because they were fixed in place and could not move with the encapsulation. The problem was solved by conformal coating the circuit boards for placement in the metal box.

Because of the cost from ASEA, P&H Electrical Engineering took over the design of the convertor cabinet and improved their manufacturing and reliability. There was a potential health hazard involved with Beryllium wafers which insulated the pole of the thyristors from the over cooler. P&H Electrical Engineering designed an insulated bellow with an ñOò ring seal, which isolated the oil cooler, and prevented leakage of the cooling oil. Some convertor parts were supplied by ASEA; but the majority of the components were manufactured in-house or by local vendors.

P&H Electrical Engineering also made modification to the original ASEA supplied Combi-flex circuit cards. A P&H company called Control Logic was given the manufacturing drawings of the card assemblies and produced Combi -flex boards. Later, Milwaukee Electronics took over the circuit card manufacturing.

Certain proprietary parts were purchased from ASEA and others bought on the open market. When components became hard to purchase, P&H Electrical Engineering designed new more readily available components. In 1976, P&H had taken over the design and manufacturing of the MKII system.

When the MKI components became unavailable, P&H Engineering designed retrofit control trays using Combi-flex cards and card racks.

RPC Capacitors ------

In 1976, the use of PCBs was being outlawed. The insulating oil in the AC Power factor correction capacitors contained PCBs. The Power Factor capacitors used were compact because of the use of the film-foil technique and insulating oil which constrained PCBs. Since PCBs had to be eliminated, GE approached P&H Engineering to participate in redesigns of the capacitors. The writer participated and a new 600vac, Power Factor capacitors with mineral oil was put on the market. Since the P&H application was unique the insulation oil contained an additive to allow prolong DC to be

applied to the units. P&H also insisted that additional over voltage testing be done on each unit similar to utility test standards. The increase over voltage testing reduced the number of failed capacitor dramatically

Because of the new dielectric oil was flammable a pressure switch was added to the individual capacitor units to prevent rupture. The film-foil capacitors have a tendency, over time, to develop minute shorts between the layers of foil. The shorts produce gas in the oil which over time can expand the capacitor can. Eventually the can may rupture. A pressure switch, inside the can, was connected to a control circuit which disconnected power from the capacitors.

MSHA -----

The Federal MSHA regulations had clauses to protect motors and wiring. Motor had to have individual short circuit and overload protection. Wiring had to have branch circuit protection. Hence, new shovels were fitted with auxiliary motor starters and load panels for branch circuit protection. The electrical system was refined and problems solved.

Improvements were made to suppression of over voltages and for surge protection from the incoming high voltage supply. Improvements were made for reliability.

The thyristor cooling oil was flammable. With dust, poor maintenance and the extreme shock environment of shovel operation, a broken wire or short in the convertor wiring resulted in burning of the bellows, oil leaks and oil ignition. Wrapping the bellows with insulating tape, proper maintenance and fire suppression helped minimizing the problem.

K FRAME MOTORS 1976-77 ----------
The F motors were replaced by the K series motor. The main difference was the elimination of the laminated field structure. The frame or field structure was a rolled heavy plate without the laminated inserts. The rest of the motor designed was mainly the same. The new K motors characteristic were ideal for shovel motion duty, exhibiting good thermal properties and transient commutation capabilities.

1981 ----- 2800XP with P&H ELECTROTORQUE ----------

MODEL	CAPACITY	LOAD RATING	YEAR MFG.
2800XP	28 ï 32CY	110 sT	1982

In 1981-82, the shovels with the XP, Extra Performance designator, were introduced.

Features ----------

- ¶ Higher loading capacity
- ¶ Dual propel motor capable for differential and rotational steering.
- ¶ Air cooled Converter Cabinet for all the motion bridges

- Motion converters with line fuses, no individual Thyristors fuse protection
- Heavy duty load circuit breakers for disconnect and current protection on the AC side of the motion bridge
- MOV protection for each bridge
- Instantaneous over current protection for each bridge based on stall current of the motion
- DIVERTOR protection for bridge DC over current and greatly diminished motor flash-over .

  The DIVERTOR System was self contained in the Converter cabinet. It consisted of a Hall current sensor on the DC output to the motion motors. Charged capacitors, at higher than the maximum DC output bus, were controlled by a Thyristors directly connected to the DC bus. When a DC over current was sensed, a Thyristor applied the capacitor voltage in the opposite direction of the DC output voltage. At the same time the gating of the b stopped. The voltage and current, stored in the capacitors, commutated off the bridge current, preventing motor flashing and limiting the over current of the bridge Thyristors.

- More VAR compensation
- RPC Switch Cabinet ---- Thyristors/ Diode switches
- Simplified RPC Thyristors/Diode switch control using RPC Switch Modules

  An external DC supply was used to charge the capacitors to the peak of the AC line. This resulted in a cost saving and simplified the control system. The AC power capacitors had special additive in the dielectric to withstand the DC voltage without deterioration

- RPC Cabinet containing tuned capacitor banks with air core inductors
- Simplified field control
- Heavy duty load breakers to protect and isolate the capacitor steps
- Better fault light indication system.
- Improved Operator consoles
- Greater relay reliability
- New Main Transformers

  The main transformer underwent a change in vendor. Sorgel had been bought by Squire D and moved the big transformer production out of Milwaukee. NECO who became NECO/Hammond or Hammond, a transformer manufacturer, was chosen to build the Mains (Armature transformers). P&H Engineering worked with NECO. The final configuration would be Copper sheet wound, multiple layer of Nomex insulation and a double vacuum impregnation to insure an outside coating of varnish to ward off the mining environment. The sheet windings had to be configured or arranged to give the specified impedance parameters of this multi secondary transformer.

The coil assembly was than sandwiched between thick insulating boards, placed on the laminated core leg and held in place by jack screws to the core proper. The urethane bumpers were eliminated. The overall design concept was to that the windings were locked in place by the winding technique and the varnish impregnation.

A series of strategically placed duct sticks in the winding, held in place by the sheet winding and vacuum impregnation of the coil assembly allowed for good thermal conduction and thermal overloads. The entire coil assembly was held rigidly in place by the jack screw and the entire unit. The coils and core, would like a solid assembly against the shock and vibration of the shovel.

The design and manufacture had it startup problem. Modifications were made mainly in the use of multiple layer of the layer insulation, assemble and quality control. The improved winding technique and assemble proved to be reliable both electrically and for longevity.

- Disc brakes ï all motions
- Counter rotation steering
- Differential motor speed for on the go steering. Independent crawler control Load sharing while steering
- Structure were improved or modified dictated by increased load rating

1987----- 2800 XP AC ELECTROTORQUE ----------

MODEL	CAPACITY	LOAD RATING	YEARS MFG.
2800XP	28-32CY	120 sT	1987-1989

P&H, for years, had the only DC Convertor system on shovels. BI went to an AC system skipping static DC systems. Although P&H was the shovel leader, pressure was put on to complete with the AC systems.

A joint engineering venture, with ASEA, was started to make an AC system. The Frequency Convertor was modeled after A S E Atóm systems.

The Frequency Converter system was a Thyristors Inverter scheme. In 1987 the first machine was put into operation. It was a learning curve for engineering. The control was sensitive to noise especially static electricity discharges. A wire Screen was put on the glass window on the control cabinet. Numerous noise techniques were employed to lessen the susceptibility to noise.

The Thyristor assembly was attached by a stab assembly for easy unit removal. Due to the vibration and shock of the shovel, the assembly tended to arc under high current, destroying the Thyristor or the entire assembly.

The AC control produced transient motor torques during faults which resulted in structural mechanical failures. The entire system required too much care. Engineering had to work through both mechanical and electrical short comings. The customer and P&H service were ill prepared for this control.

Another machine, a 2800LR coal loader, was reluctantly brought in 1989. The same problem, to a lesser degree, also plagued this machine. P&H had to purchase, not only the shovel system but also spare components because ASEA was obsolescing the present AC system. The adventure was very costly to P&H, in money and time to engineering and service personnel.

Because of the frequency inverter design, expense and rapid expansion of new technology, it was not practical to keep the systems running. One of these machines was converted to a DC system and the other used for spare mechanical parts.

1987 ---- 2800XPA P&H ELECTROTORQUE ----------

MODEL	CAPACITY	LOAD RATING	YEAR MFG.
2800XPA	28-32 CY	120 sT	1988

The functional control of the 5700DR was designed using a Programmable Logic Controller PLC. A PLC was designed for the XPA to replace the logic relays as previously used. The added feature made it possible to add indicators for fault, running alerts etc.

Improvements ----------

- ¶ Swing motor size was increased. Two motors were used instead of four.
- ¶ Cascading the Swing convertors to enhances VAR reduction
- ¶ Main Transformer were upgrade
- ¶ Programmable Logic Control replacing control relays.
- ¶ PROGAMMABLE MESSAGE DISPLAY PMD, located in the operatorôs station and the PLC Cabinet. The PMD was programmed to give operational faults and trouble correction information.
- ¶ PROGRAMMABLE LIMIT SWICHES, PLS, with resolvers mounted on the hoist and crowd gear cases.
- ¶ PLS Control Modules, mounted in the opera limits for crowd/retract and hoist rope payout limits
- ¶ A refinement was made to the RPC system. The fixed banks were reduces down to one. The switched banks were sequenced by control, to allow a ½ bank being switched on between full banks. VAR excursions were reduced.
- ¶ Planetary Transmissions
- ¶ Discs brakes, all motions

- ¶ Various mechanical upgrades were made because of the increase in load rating.
- ¶ All the motion performance numbers; speed and torque were increased. The performance curves were enhanced by taking advantage of the peak commutation capability of the improved K frame motors.
- ¶ New comfort Operatorôs cab
- ¶ Major structural improvements
- ¶ Heftier boom
- ¶ P&H mine matched dipper
- ¶ Raised drive tumbler

1992 ---- AC DESIGN ------

Another engineering collaboration with ABB (ASEA/BBC) was started to design the next AC shovel control. Inverter technology, techniques and devices to control the Adjustable Frequency Systems had advanced. ABB proposed a GTO system. The packaging of the frequency inverters, controls and rectifiers were to be manufactured and designed jointly by P&H and ABB.

There was a difference in philosophy of the control components between ABB and P&H engineers assigned to the project. ABB had proposed there system using GTO. There were other devices similar to the GTO which were in their infancy. The IGBT was firmly in the picture with Siemens and their system running on BI shovels. ABB did not have a suitable IBGT system for shovel use.

A few vendors were looked at. Most were IGBT systems which seemed suitable for shovel service. P&H engineering could not agree on a system .The cost of the ABB GTO system was much greater as compared to the DC system. The project ended in 1994.

XPB ELECTROTORQUE -----

MODEL	CAPACITY	LOAD RATING	YEAR MFG.
2800XPB	44 ï 46 CY	130 sT	1992

The need for a larger capacity shovels and design techniques, allowed the XPA machines to upgrade to the XPB rating. The philosophy of manufacturing was upgraded. Shovels manufactured were almost completely assembled and custom wires in the shop. Then the shovels were disassembled, wiring and mechanical assembles, for shipping. The shovel at the customerôs site was re-assembled.

The XPB was resigned to facilitate partial assemble in the shop and modularize assembles for ease of field erection. An air conditioned Electronics Room, under the Operators room, housed all the sensitive electronics and provide a clean environment for personnel. The power electronics, Convertors, RPC, were placed on the counterweight box to facilitate better ventilation filtered air. The Main Transformer and

HV Switch gear were located on the right platform. These three assemblies could be shipped intact for ease of field assembly.

The custom wiring was replaces with pre-made wiring harnesses and plug and sockets type wiring. The power cables were also pre-cut and lugged to facilitate field wiring. These changes reduced wiring errors in field erection.

Improvements ---------

- ¶ Bigger hoist motor
- ¶ 2 Swing motors
- ¶ Convertor package was upgrade to take advantage of larger capacity Thyristors. The hoist and swings bridges were now rated at 1320kw @ 600vac from 1020kw @ 600vac .
- ¶ Motor capacity also increased.
- ¶ The improve loading in the bank, the motion characteristics were change from a peak power current of 75% of stall current to 85% of stall current. The applied armature voltage was raised from 550VDC to 600VDC.
- ¶ To provide VAR compensation, a new capacitor, of higher VAR rating was used. To improve the reliability of the capacitors, more intensive testing was specified. Because of the higher VAR rating, the fixed step was eliminated. As before, the 1/2 step was intermixed with the full steps resulting into six step system of increased VAR compensation.
- ¶ Improved P L C ô s a n d l o g i c t e c h n i q u e s
- ¶ Operator Consoles
- ¶ Controllers
- ¶ Temperature sensor in motors, bearings and transformers, etc.
- ¶ Improved indications for ease of maintenance, reliability and fault finding and correction
- ¶ New deck plan
- ¶ Upgrade PLC components

DIGITAL CONTROLS -----

The initial XPBs used the analog Combi-flex control modified by P&H. In early 1995, an engineering decision was made to explore a digital control. The main objective was to merely replace the Combi-flex cards and racks with digital control modules, keeping the PLC and peripheral equipment the same. The current philosophy was, change by evolution and not wholesale innovation. A decision was made to go with a Cleveland firm, **AVTRON**. They had the reputation of being the retro-fit kings and private labeled supplied controls to a wide array of industries. P&H partnered with AVTRON to private label the modules.

The Control Cabinet was redesigned by P&H to accommodate the digital modules with all the necessary feedback and control power. Many former components were simplified especially in the feedback circuits.

The same modules called an **AFM, AVTRON Advance Firing Module,** were designed with built hardware that could be used for all motion motor control, motor field control and RPC Control. Five AFM modules are use used to control all shovel motions and RPC functions. The modules contain the control intelligence and the pulse generation for the motion armature and field convertor and the RPC switches.

Specific Firmware (i.e. Software) is loaded to configure the AFM to function as a;

- Hoist Drive
- Crowd Drive
- Swing Drive
- Motor Field Drive(s)
- RPC

The modules also provided;

- Over current protection with Divertor control
- Over Crowding limiting ï The crowd current was modulated by the hoist current.
- Hoist parameters could be programmed emulate constant HP operation.
- The volt-amp characteristics could be set to make maximum use of commutation limits by PC or module display.
- RPC steps settings by PC or module display

The AFM Specific Firmware is loaded at commissioning. Allowed parameter changes are made through a PC, with supplied software, or a display on the modules. The display is also used to display various parameters and faults.

AVTRON supplied the AFM and the entire Control Cabinet assembly. This system was used on Models 4100A, 4100TS, 2800XPB and 4100BOSS from 1996 to 2003. The digital control from AVTRON was unofficially called and labeled **P&H ELECTROTORQUE- PLUS**.

In conjunction with the digital control a MMI (Man Machine Interfaces) or GUI (Graphical User Interface) was added in the control cabinet and Operator

Twenty-five AVTRON systems were applied to 2800XPBs, 4100As, 4100TSs and 4100BOSSs. The AVTRON system was well accepted by P&H customers. It fulfilled, the than philosophy, of merely replacing the analog control with a digital control with no significant cost penalty.

Around 1999, the Electrical Engineering Department was separated into R&D and Production. P&H Management decided to revert back to a partnership with ABB for a Digital control package. The new emphasis was on innovation and complete control of the shovel systems and options by P&H. The last Control Cabinet, manufactured by AVTRON with the **P&H**/**AVTRON AFM** modules, was built in 2003. .

ABB DIGITAL DC CONTROL -----

CENTURION ELECTRICAL CONTROL SYSTEM ------

The latter XPBs were manufactured with the first Centurion ABB control from

The drive system is comprised of two major components;

- **Supervisory Controller to Drives**
  - Speed Reference
  - Control Words (ON, RUN, READY REFERANCE)
  - Torque Limits (SED sheets)
  - EMF Reference
  - Mode Select (testing)

- **Drives** *Centurion /ABB interface to the Armature Drives*
  - Armature voltage feedback
  - Thyristors Pulse firing via synchronizing transformer
  - Armature drives are connected to Field drives via RS-485 to control field current and armature voltage during field weakening

The **RPC** is a standalone that has its own controller (PLC). It also incorporates bank rotation.

- **RPC Feature**
  - Standalone PLC that gets machine type and frequency from Centurion Controller
  - Uses kVAR transducer and summing transformers as before
  - Updated pulse transformer modules for thyristor firing New ABB circuit board for thyristor firing
    - Also connected to its own synchronizing transformer
    - Allows the PLC 24VDC outputs to control bank ON commands

The Centurion electrical control system provides superior performance, monitoring, and data integration capabilities. The supervisory controller, with direct integrated communication with the motor drives, allows precise motor control and fast cycle times. Real-time multi-tasking capability means optimal machine logic sequencing, monitoring, and control.

The Supervisory Controller eliminates the former PLC functions. The I/O system uses the Profibus communication protocol for seamless integration of all shovel subsystems. Low-voltage 23V DC I/O drop points feature open- and short-circuit detection for improved diagnostics and troubleshooting.

The graphical user interface features intuitive, icon-based screens that display vital information, including shovel status, troubleshooting information, and optional production monitoring data and operator feedback system, transforming the data into valuable knowledge, including KPI (key performance indicator) dashboards, graphical analysis tools, predictive modeling, and reporting tools.

XPC CENTURION ELECTRICAL DC CONTROL SYSTEM ------

MODEL	CAPACITY	LOAD RATING	YEARS MFG.
2800XPC	39 -48 CY	135 sT	2006

Feature of the 2800XPC ------

- ¶ Automatic lubrication and compressed air systems with advanced diagnostic and control
- ¶ Temperature monitoring system for all DC motors, drum shaft bearings and shipper shaft bearings
- ¶ Automatic boom soft setdown system (ABSS) and boom profile protection envelope to help prevent excessive loading to the attachment during operation
- ¶ Anti-swing-in-bank system to reduce excessive side loading on handle and attachment
- ¶ Remote hoist control pendant and hoist rope winch to assist in safe and efficient rope changeouts
- ¶ House pressurization system to provide filtered air for cooling and dust repression
- ¶ Optima dippers combine consistent productivity with high durability and maintainability.
- ¶ TripRite system utilizes a brushless DC electric motor with sealed planetary drive unit for reliable trip and slack take up operation.
- ¶ Delta drive low tension sprocket drive system with heavy duty cast crawler shoes.
- ¶ The P & H 2800XPC is built with several features to enhance safety, reliability, and productivity over the lifecycle of the operation.
- ¶ Upgrade RPC controller
  The RPC is controlled with a new micro-controller located in the RPC cabinet.
- ¶ 78 mm Thyristor

Advanced control technology -----

- ¶ Advanced control technologies include the following:
- ¶ Temperature monitoring system for all DC motors, drum shaft bearings, and shipper shaft bearings
- ¶ Drive programming and analysis software
- ¶ Control logic software

- ¶ I/O device monitoring and fault detection
- ¶ Remote health management
- ¶ Extended speed range in hoist and crowd
- ¶ Automatic Boom Soft Setdown (ABSS) and Boom Profile Protection Envelope to help prevent excessive loading to the attachment during operation
- ¶ Anti-swing-in-bank system to reduce excessive side loading on handle and attachment
- ¶ Hoist, crowd, and retract limits
- ¶ Operatorô s C a b
  Hall Effect joy sticks
  Power, fiber optic and Ethernet connection
- ¶ Various improvement to structures to increase the loading capacity
- ¶ Mechanical improvements based on the XPB experiences.

The shovel has multiple options for local and mine site specific conditions in the following areas:

- ¶ Climate control
- ¶ Technology and software
- ¶ Maintenance systems

Technology

- ¶ Universal shovel interface ï Send and receive data with any mine management system
- ¶ PreVail remote health management ï Real time machine health and performance management

XPC CENTURION ELECTRICAL AC CONTROL SYSTEM ------

MODEL	CAPACITY	LOAD RATING	YEAR MFG.
2800XPC	39 -48 CY	135 sT	2010

The **CENTURION** control system basically remains the same as the DC version. The main changes to the shovel are the AC motion motors and the Variable Frequency Convertor, AC IGBT Drives on the counter weight box.

Features of the IGBT system -----

- ¶ A B Bô s D i r e c t T o r q u e C o n t r o l h a s t h e b e s t d
- ¶ Active common DC bus controls the power flow to the Inverter Units and from the shovel maintaining a unity power factor and low harmonics.
- ¶ Our AC drives are compact, air-cooled modular
- ¶ Maintenance-friendly modules are easy-to-replace

Summaries ---------

P&H MinePro SERVICES

MinePro File

· CASE STUDY ·

Study Brief

Longevity-Plus
Invest in a top mining shovel, take good care of it, and what do you get? Perhaps the next best thing to perpetual motion in mining.

Nearly three decades after the first P&H 2800 Mark I electric mining shovel was introduced at a coal property in British Columbia that is now the Elkview mine, it remains very much on active duty. So does another 2800 Mark I that arrived a few months later.

To date:

- One 2800 Mark I machine has topped the 139,000-hour mark; the second exceeded 135,000 hours. A 2800 Mark II shovel dating back to 1980 also has accumulated over 100,000 hours.
- Availabilities for all three are 91.6 percent.
- All shovels remain cost competitive.

Two other 2800 Mark I shovels that went to the mine as part of the first four-machine order each topped 100,000 hours before they were retired because of production cutbacks at the mine.

Long-Lived P&H 2800 Shovels Thrive at Elkview Mine in British Columbia

P&H Mining Equipment scooped the industry in 1969 when it introduced the P&H 2800 electric shovel, a radical departure from the electric excavator designs three decades ago. For one thing, the machine was a bold new design; for another, it introduced to the mining world P&H Electrotoque® drive, the pioneer static converter control system for DC electric motors. The innovative system gave the 2800 more SCR-controlled horsepower than on any other piece of mobile equipment at that time.

Other new features aboard the original 2800 were super-sized electric motors designed and built by P&H, joystick controls, simple built-in diagnostics, propel motors in the lower, and more loading capacity than any previous shovel.

The first four Mark I 2800 models off the factory line in 1969-70 went to the former Kaiser Resources' Balmer mine near Sparwood. After two ownership changes, the property became the Elkview mine in 1993, owned by Teck Corporation, a diversified worldwide mining developer and producer headquartered at Vancouver.

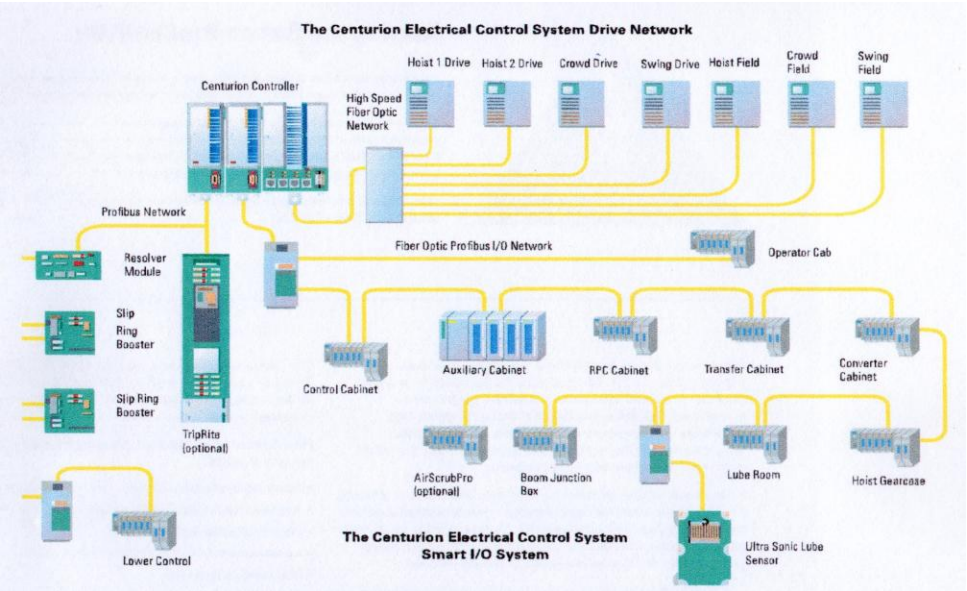
Maintenance the Key

Maintenance, as might be expected, has long been the watchword at the mine. Carel van Eendenburg, Elkview's senior mine engineer who has been associated with the facility since 1980, says, "Our maintenance people grew up with the 2800s way back. We've always been fairly strict with maintenance intervals and have a very good preventive maintenance program."

Working The Same Bank — *One of the original P&H Mark I 2800 shovels (right background) digs in the same bank as the mine's latest P&H 4100A shovel.*

Size progression-------

2800 PROGESSION										
approx	1969-1975	1975-1983	1982	1987	1988	1992	1999	2003	2006	2010
MODEL	**2800MKI**	**2800MKII**	**2800XP**	**2800XP**	**2800XPA**	**2800XPB**	**2800XPB**	**2800XPB**	**2800XPC**	**2800 XPC**
	DC	DC	DC	AC	DC	DC	DC	DC	DC	AC
CAPACITY	24-26 CY	26-28 CY	28-32 CY	28-32 CY	28-32 CY	44-46 CY	44-46 CY	44-46 CY	38-48 CY	38-48 CY
SUSPENDED										
LOAD RATING lbs.	80sT	90sT	110sT	120sT	120sT	130sT	130sT	130sT	135sT	135sT
APPROX.										
WEIGHT lbs.				2,050,000	2,112,000	2,250,000	2,250,000	2,250,000	2,380,000	2,380,000
CONV. COOLING	DRAWERS/AIR	OIL COOLED	AIR COOLED	AIR COOLED	AIR COOLED	AIR COOLED	AIR COOLED	AIR COOLED	AIR COOLED	AIR COOLED
FEATURE	INDICATOR TRAY	INDICATOR LTS.	INDICATOR LTS.	INDICATOR LTS.	INDICATOR LTS.		DIGITAL GUI	DIGITAL GUI	DIGITAL GUI	DIGITAL GUI
					PLC PMD	PLC	PLC	SUPERVISORY	SUPERVISORY	SUPERVISORY
								COMPUTOR	COMPUTOR	COMPUTOR
ELECTROTORQUE	ASEA	ASEA/P&H	P&H/ABB	ABB/P&H	P&H/ABB	P&H/ABB				
ELECTROTORQUE - PLUS							P&H/AVTRON			
CENTURION - ABB								P&H/ABB	P&H/ABB	P&H/ABB
HOIST 2 USED	F695	F695	K925		K-925		K-925	K-925		* CONT. @ 690 VAC
TOT. CONT. @475 VDC			1450 HP TOT.		1450 HP		1450 HP	1450 HP		2772 HP TOT.
TOT. CONT. @550 VDC	600	600								
TOT. CONT. @600 VDC									1600 HP	
720RPM, 1170VAC,24HZ				CONT. 1900HP						
TOT. PEAK			2250 HP		2440 HP		2570 HP	2570 HP	2788 HP	3200 HP TOT.
SWING 2 USED	F172	F172	4 X K236		K-558A		K-558A	K-558A		* CONT. @ 690 VAC
TOT. CONT. @475 VDC			1020 HP		950 HP		950 HP	950 HP		1460 HP TOT.
TOT. CONT. @550 VDC	150	150							1000 HP	
TOT. PEAK			1468 HP		1535 HP		1546 HP	1546 HP	1500 HP	1827 HP TOT.
CROWD	F368	F368	K300		K-925		K-925	K-489		* CONT. @ 690 VAC
CONT. @475 VDC			400 HP		400 HP		400 HP	400 HP		730 HP
CONT. @550 VDC	264	264							720 HP	
PEAK			630 HP		630 HP		630 HP	630 HP	920 HP	932 HP
PROPEL 1/2 USED	F449	F449	K-408		K-408		K-408	K-408		* CONT. @ 690 VAC
TOT. 30 MIN. @475 VDC			405 / 810 HP		760 HP .		760 HP	760 HP		1460 HP TOT.
TOT. CONT. @ 550 VDC	330	330							820 HP	
TOT.PEAK			810 / 1465 HP		1355 HP		1440 HP	1440 HP	1958 HP	2645 HP TOT.
YEARS MFG.	1969-1975	1975-1983	1982-1994	1987-1989	1987 >>>	1992 >>>>>	1998 >>>	1999 >>>	(2008) >>>	2010 >>>
TOTAL UNITS	7	43	57	2	48	<<<<<<<<	66	>>>>>>>>>	45	9
APPROX. # AS OF JUNE 2019										



2800 power data -------

2800 POWER DATA							
		2800 MKI	2800 MKII	2800 XP	2800 XP SER. A	2800XP SER. B	2800XPC --- DC
		ELECTROTORQUE	ELECTROTORQUE	ELECTROTORQUE	ELECTROTORQUE	ELECTROTORQUE	CENTURION
						CENTURION	
MAIN TRANF0RMER		2000 KVA	2000 KVA	2000 KVA (+)	2000 KVA (+)	2000 KVA NEW	2000 KVA
RPC STEPS 60 HZ	FIXED	(900 KVAR)	600 KVAR FIXED	675 KVAR FIXED	675 KVAR FIXED		
	STEPS		4 STEP = 3600 KVAR	7 STEPS = 4725 KVAR	5 STEPS = 3375 KVAR	6 STEPS = 4050 KVAR	7 steps = 4725 KVA
CONVERTOR POWER		FORWARD/REVERSE	FORWARD/REVERSE				
		KW AT 550 VDC	KW AT 550 VDC	KW AT 550VDC	KW AT 600 VAC	KW AT 600 VAC	KW AT 600 VAC
HOIST/PROPEL	CONT. ARM. CONV. KW	1760 KW / 500 KW	1965KW/500KW	2 X 935 KW	2 X 1020 KW	2 X 1320 KW	2 x 1860 KW
	SHORT TIME Ia	30 SEC. @ 1930A. FRD.	30 SEC, @ 2100 A.	15 SEC. @ 3300 A.	15 SEC.@ 2700 A.	15 SEC.3100 A.	15 SEC, @ 3700 A.
	CONT. FLD CONV.	(150 A.)	(150 A.)	150 A.	150 A.	150 A.	150 A.
SWING	CONT. ARM. CONV.	1 for each 2 motors	440KW / 440KW	935 KW	1020 KW	1320 KW	1860 KW
		2 X 440KW					
	SHORT TIME Ia	30 SEC. @400 A.	15 SEC. @1600 A.	15 SEC. @ 3300 A,	15 SEC. @2700 A.	15 SEC. @ 3100 A.	15 SEC. @3700 A.
	CONT. FLD CON.	(150 A.)	(150 A.)	150 A.	150 A.	150 A.	150 A.
CROWD/PROPEL	CONT. ARM. CONV.	600KW / 600 KW	620 KW / 620 KW	750 KW	830 KW	830 KW	1860 KW
	SHORT TIME Ia	30 SEC. @1500 A.	30 SEC. @ 1500 A.	15 SEC. @1650 A.	15 SEC. @1650 A.	15 SEC. @1650 A.	15 SEC. @3700 A.
	CONT. FLD CON.	(150 A.)	(150 A.)	150 A.	150 A.	150 A.	150 A.
		2800XP ---- AC	2800XPC --- IGBT				
		ELECTROTORQUE	CENTURION				
MAIN TRANF0RMER		2000 KVA					
HOIST/PROPEL	CONT. INVERTER KVA	2 X 1200 KVA	IGBT SUPPLY UNIT(ISU)	4550 KVA			
	MAX. INVERTER Ia	640 A.					
			HOIST	1160 KVA			
	CONT. INVERTER Ia	600 A.					
SWING	CONT. INVERTER KVA	1200 KVA					
			SWING	3480 KVA			
	MAX. INVERTER Ia	640 A.					
	CONT. INVERTER Ia	600 A.					
CROWD/PROPEL	CONT. INVERTER KVA	1200 KVA					
			CROWD	1160 KVA			
	MAX. INVERTER Ia	640 A.					
			PROPEL	2320 KVA			
	CONT. INVERTER Ia	600 A,		`			

Acknowledgment s ----------

Individual who contributed to the major designs of the 2800 and Electrotorque;

Matt Tietze---------- Mechanical designed of the main transform with shock mounted coils and the first cooling air systems for motors and equipment on the original 2800.
Dave Stone---------- RPC Module
Garry Morris --------- Diverter Circuit
Bob Mierendorf ï -------- Miscellaneous circuit design, field control electrics
Paul Phillips ---------- Circuit analysis, Specialty circuit design, Early AC shovel
Frank Clewell ----- ELECTROTORQUE design, Air cooled converters, RPC Reactors and RPC cabinets, Order Configuration Engineer
Richard Czubkowski -- ELECTROTORQUE design, First PLC, Digital Control application, Technical sales; Electrotouque Shovels Manuals
Charles Miesner ----- Lab Technician, Servicemen, Programmable Massage Display (PMD)
Steve Jasso ------ Commissioned and educated servicemen on the first digital control; ELECTROTORQUE PLUS
Don Daniels ------ GUI programming contributor
Engineers at ï
ASEA/ABB ï original control
AVTRON/Idec-- first digital control, **Electrotorque-Plus**
Sorgel/SquareD and NECO/Hammond -- transformers

Tom Weber and the Mechanical Group----- Designed structures to increase capacity, planetary transmissions, dippers, structural analysis, lower works and shoes, machinery and operators cabs, etc. (The writer apologizes for not giving credit to the names of individuals who contributed to the designs and analysis.)

The servicemen who, in the early days of ELECTROTOQUE, dedicated their efforts to make it work**; Ed Taylor ï P&H, Aaron Blenco ï P&H** and **Olaf Lonegren ï ASEA/P&H.**

Ps -------- A special thank you to Mark Emerson, Ed Meyer, Dave Wendt and Craig Dickson for filling in the writer memory and R. Profio who found , in his closet, the forgotten words of the founder Henry Harnischfeger, H.S Jacobs and Henry Harnischfegerô speech on the 100th Anniversary of the Harnischfeger Corp.

For history purposes --------

Philippine Engineering & Construction Forum

73 Years of Free Enterprise ï October 1957

This is the story of one company grown and served America well under the rich heritage of freedom. But, in a sense, it is far more than that. For it mirrors the history of many hundreds of American businesses which have ha through courage, imagination, and initiative, have contributed so much to the American way of life.

It is a tribute to the spirit of service that springs from our system of free the men who create new products to do things better, because they have the genuine incentive of reward for their labors.

Most of all, it is a reaffirmation of faith in the system that has enabled this country to surpass the productive achievements of every other country, and to establish the high standard of living that is a source of pride to every American.

Harnischfeger Corporation, Milwaukee 14, Wisconsin

From the address by;

Henry Harnischfeger on the 100th anniversary of Harnischfeger Corp.

December 1, 1984

ñ The Will A Centennial History of the Harnischfeger Corporation by Henry Harnischfeger ï Harnischfeger Corporation, Milwaukee, WI 53201

For all the changes, however, this company has had a basic character from the very first day. At its roots, Iôm convinced; the seedling. Henry Harnischfeger and Alonzo Pawling had specific principles: Superior engineering and craftsmanship in every quality product. A commitment to service after the sale. A deep concern for employees and customers. A determination to find new opportunities and to aggressively pursue them. In other words, the will to succeed.

The immigrantôs dream kiat our first century and looking ahead Looking to our second, I re-dedicate This Company to those principles. I look back with pride. I look ahead with confidence.

FINAL WORDS -----

It all started in the 6**THE P&H** has progressed; six decad

- From works in a drawer, to rack mounted circuit boards, to controls modules,
- From convertors in a drawer to oil cooled convertor cabinets to air cooled convertor cabinets,
- From Fixed RPC to multiple steps,
- From a system known as Electrotorque MKI, MKII to Electrotorque ï Plus to a system called Centurion,
- From simple light indicators to GUIs to remote monitoring,
- From DC motors controlled by Thyristor DC convertors to AC motors controlled by IGBT frequency convertors,
- From a single propel motor in the lower with skid steering to dual propel motors with differential steering,
- From ordinary gear sets in a gear case to planetary transmissions,
- From a shovel with suspended load rating of 80sTons to 135sTons.
- From the **P&H 2800MKI Electrotorque** to the **P&H 2800XPC Centurion**

A half century of progress.

The new 2800XPC digs the dirt faster, more economical due to the ingenuity of the present group of Engineers. The new control system also provides safer operation, less prone to damage, and remotely monitoring. It makes a poor operator look good and a good operator look excellent

The object of this story was to emphasize that the big loading shovel concept was started by the Harnischfeger Corp. The names mentioned in the story are for history. What is most important is that these men, with archaic tools, used their experience, ingenuity and desire to design a big shovel, the 2800.

The Harnischfeger Corp. during the last 25 years has gone to many changes. The name and the people have changed. The hope is that the principles of Alonzo Pawling and Henry Harnischfeger, **Workmanship, Quality and Service**, will never be changed.

The first 2800 was innovative.The 2800XPC is a product of further innovation. It is the product of the development of tools, materials, software and electronics. But most of all, it is the product of dedicated Engineers , with new ideas, that will keep **THE P&H** number one In the shovel industry like the men who designed the first 2800 almost six decades ago.

The Writer ---------

I started in 1957 as a co-op student attending MSOE. During my break terms I worked in Central Engineering, Industrial Engineering, Purchasing and Sales

After graduation in 1961 I received an offer of employment from Harnischfeger and accepted it. Electrical Engineers were needed for the crane and shovel divisions. From my sales assignment, shovel work was my first and only choice.

I was assigned to a training program which entailed work on the crane floor; motor winding and shovel assemble in the old Bld. 65. In Bld. 65 I learned to assemble cabinets, wire them and carry out machine testing. Field testing was done outside in a ñtest fie

My last assignment was in Central Service working on various model machines with a variety of controls. I leaned Impedance Controls and Thyraton Controls. I worked on full electric and diesel-electric machine from Models 1600 to 1855. I worked on the only 1855, twin diesel, shovel front machine, ever built. By the time I was through with my training, I was known as ñChubbyò beca properly. I remained ñChubbyò to my P&H associates and

I was assigned to Progress Hall; the so called R&D office on 38th and Burnham street. My first assignment was to develop a ñfastò Magnetic Amplifier to co Controlled Rectifier or SCR. The object was to develop a large controlled DC rectified to directly control a DC motor. In 1963, the writer and Frank Clewell, under the direction of Les Price, a proposed prototype system of a large DC motor, powered by a controlled DC converter was to be built. Many problems existed. The Magnetic Amplifierôs response was too sl motor.

In 1965 a joint venture was entered into with ASEA of Sweden and a new shovel system, Electrotorque, was born. In 1969 a Model 1900B was the first complete static DC motor shovel control. It was commissioned and put to work in a Taconite mine in Michigan. In later years the system, Electrotorque, evolved as Mark I, Mark II, Air Cooled and Plus.

JOB DESCRIPTION:

Product Engineer,
Project Engineer,
Sr. Project Engineer,
Chief Engineer Development, Mining Electrical Systems,
Engineering Manager, Electric Excavator Engineering
Consulting Engineer ---- Consulting to: Electrical Excavator Group, Dragline Engineering, Drill Engineering, special projects and customers.

In 1968, I started to give technical sales presentations and customer consultations because Electrotorque was new and revolutionary to the mining industry. I represented P&H shovels to mines around the world.

Professional Affiliations: IEEE - Senior Member
WMEA - Western Mining Electrical Association

Technical Presentations And technical writings: IEEE - International Converter Conference
ñ**Application of Thyristors Converters to Electric Mining Shovels**ò 1967

Western Canada Mining Symposium ï
ñPerformance Efficiencyò
ñThe marriage of the mechanical and el optimum performance.ò 1989

VARIOUS PRESENTATIONS:

ISA- Various presentations on DC Static Drive applications.
Local Chapters

WMEA - Various presentations concerning
mining subjects.

ñ Modern Control Systems for Electric Mining ò
(Presentations to)
Russian Ministry of Coal
Coal India
Chinese Coal Industry

Various presentations to customers on their specific needs. (Too many customers to mention)

INTERNAL WRITINGS:

First Care & Op Electrotorque Manuals
Technical sales Brochures. Coined to phase;
ñ Simple and Effective ò

ñ Here ôs Wat Energy Con data paper
highlighting P&H shovels.

ñ Electriplus Shovel Drive System ò
New digital drive system.

VIDEO RECORDINGS: Recordings were made in the old Bld. 65 to show actual control equipment and the new PLC addition to shovel control. These were distributed to field salesmen.

My career was marked by memorable moments in P&H history; the 1900B, fist 2800, MKI, MKII, Air Cooled, PLCôs, 5700LR, -Plus (digital control), 4100 and 5,000 volt shovels. Besides promoting P&H in the US and Canada, travel took me to; Russia, China, India, Africa, Turkey, Australia, Norway, Sweden, Switzerland, England, France, Kobe Japan ,Chili, Peru, Brazil, Spain etc.

I started working when shovels had a dipper of 11Cu. Yd. I retired in 2001 where shovels were rated at 72 Cu. Yd. Oddly enough; the time to fill a dipper and deposit it in a truck was about the same, 25 to 35 seconds.

Richard ò Chubby ó