Mining Electrical Maintenance and Safety Association
Clearwater Florida – June 2013

9020 Draglines – AC Drive Applications
Joy Global: A History of Growing Success

First P&H draglines appeared circa 1920 as part of P&H ‘convertibles’ earth moving machines
Joy Global: A History of Growing Success

P&H in 1920 introduced the P&H 210, believed to be the first dragline to be powered by a gasoline engine.

1-1/2 cubic yard bucket
40-foot boom

‘A great success from the start’ according to 1924 P&H brochure
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P&H acquired Page Engineering walking draglines in 1988
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P&H 757

P&H engineering – based on the Page dragline concept - produced highly successful products – notably the P&H 757 series
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P&H 2355

P&H continued to refine its ’55’ series of crawler mounted draglines that today includes the high-performance P&H 2355 crawler-mounted dragline available in diesel and electric prime mover configurations.
Joy Global: A History of Growing Success

Productivity Performance, Operability, Ease of Maintenance, Raising the Bar in Design and Innovation
Joy Global: A History of Growing Success
9020XPC AC

Taking it to the next Level
Joy Global: Long Term Relationship

- Joy Global (P&H) / ABB in longstanding technical partnership since 1970s
- Joint development of industry-first static DC drive
- Joint AC-drive research, trials during 80s and 90s
  Centurion developed and released in 2004 for both new machines and upgrades to existing machines
- AC Drive design and implementation for mining shovels released in 2007
- AC Drive design (air/liquid cooled) for draglines released 2011
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A Winning Partnership


Oil Sand application
Flawless start-up in 2007

Up to 10% increase in productivity  (AC vs DC)
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Shovel AC Drive Systems

Over 30 AC Shovels in service -----------
17 more in production / assembly

AC Shovel Upgrades
- Installed on 10 Non OEM Shovels ---

• 4100 BOSS AC
• 4100 XPC AC
• 2800 XPC AC
• 295B / 395B
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Dragline AC Drive Systems

New AC Dragline ------------------------------

AC Dragline Upgrades
- Installed on 2 Non OEM Draglines ---

• 9020 C
• 9020 XPC
• Russian ESCH 15/90
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Dragline AC Drive System – 9020C AC Deck Layout
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Dragline AC Drive System - Dynamic Modeling
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Dragline AC Drive System – 9020C AC Drives

9020C utilizes low voltage, liquid-cooled drives in order to:
- Provide modular supply and inverter units
- Meet lead Power Factor specification
- Hoist and Drag motors: P&H HAF 8412D
- Swing and walk motors: P&H HAF 8412D
- Motor voltage: 690 volts
- Power units: ABB Multidrive ACS800 liquid-cooled drives
- AC control system with Active IGBT Supply Unit allows adjustable reactive power control and performs harmonic mitigation to comply with IEEE-519
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Dragline AC Drive System – 9020C AC Drives

• Control System: ABB drive integrated with P&H Centurion® control
• Centurion system performs all logic, sequencing, supervisory control, provides advanced diagnostics, troubleshooting and drives the HMI units (GUIs)
• Common control hardware with P&H AC shovels
• Common look and feel with P&H AC & DC shovels for troubleshooting
• Auxiliary transformer: 2 x 1.5 MVA
• System has ability to add additional Active IGBT Supply Unit modules (and thus capacity) to meet mine power system requirements
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Dragline AC Drive System – Main Transformer

- 2 identical units
  - 7 MVA
- Dry-type, Resin Cast
- Manufactured by ABB Germany
- 22,000 V primary, 690 V nominal secondary, 50 Hz
  - Primary taps: +/-2 @ 2.5%
- Cooling: AN
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Dragline AC Drive System - Types

Drive Cooling Options

Air-cooled

Liquid-cooled
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Dragline AC Drive System – System Access

Air cooled IGBT power electronics module
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Dragline AC Drive System – Simple Modules

ACS 800 R8i Module

• DC fuses
• Common mode filters
• Busbar connections

Twin R8i Modules Shown – Air Cooled
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Dragline AC Drive System – Excavator Duty

- Test Unit ISU 2xR8i with LCL
- Vibration test Modulation
- Shock test
- Tested with drive running a 690V, 10kW Motor

Excavator Duty ACS800 Drive Testing

IABG, 3kN Shaking Table
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Dragline AC Drive System – Liquid Cooled

Main advantages

• ABB has decades of experience with liquid-cooled drives
  Marine, mining and minerals, pulp and paper
• Compact size fits better in limited space
• Totally enclosed cabinet suitable for harsh ambient conditions, designed for arc flash compliance
• 98% of drive heat losses carried out with coolant
• Silent operation - Fulfils all noise limits for electrical rooms
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Dragline AC Drive System – ACS800-07LC Scope

• Based on ACS800 liquid-cooled multidrive ISU (IGBT Supply Unit) and INU (Inverter Unit) modules
• Input and output voltage - 690 V
• Totally enclosed cabinet with IP classes:
  IP42 as standard and IP54 as option
• IEC, UL & CSA and marine type approvals
• IGBT supply unit R8i – 10xR8i
• Inverter unit R2i -10xR8i
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Dragline AC Drive System – LC Block Diagram

Operator area

Service area

Remote access

Process area

PLC

Drive Control

ISU

ISU

INU

INU

ACS 800 MD

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Dragline AC Drive System – Liquid Cooled

Internal closed liquid circuit

External liquid circuit

OUT

IN
The liquid cooling system removes heat from the drive
- It usually consists of two separate circuits: an internal closed liquid circuit and an external circuit
- The heat losses are transferred from the internal circuit to the external circuit in a heat exchanger
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Dragline AC Drive System – Design Standards

ACS800-07LC Design Standards

Global Product
UL / CSA Marking

CE Marking
Marine Type Approvals
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Dragline AC Drive System – One Line

ACS800 Low Voltage Drive System
Single Line Diagram

Transformer
22/0.69 kV
- 7 MVA

System 1 of 2

ISU 1
HOIST DRAG SWING WALK

ISU 2
HOIST DRAG

ISU 3
HOIST DRAG
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Dragline AC Drive System – Control System

Simplified circuit diagram of LCL-filter and ISU

LCL Filter

IGBT power module

ACS800-207LC-XXXX-X

DC+

DC−
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Dragline AC Drive System – Control System

- Fast accurate control
- Immediate response to load changes
- Low audible noise and high motor loadability
- Energy savings

Motor state calculation in every 25 µs with a powerful digital signal processor
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Dragline AC Drive System – Control System

Advanced Active Front End Regulation

Basic Block Diagram

- Measuring board
- Q-calculation
- Power factor calculation
- Q-estimation
- Dc-link voltage control
- Q/ PF-control
- \(u_{dc}\)
- AC800M
- \(Q_{\text{ref}}, PF_{\text{ref}}\)
- 10ms
- Current control and modulation
- Switch combination \(S_a, S_b, S_c\)
Reliability from Redundancy

- Built-in redundancy through parallel-connected modules
- Each module is a complete three-phase inverter
- Enables running with reduced output if one module fails
- Provides for higher drive availability and greater machine uptime
- Unique in drives - not available in previous generation drives or competitive units

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Dragline AC Drive System – Drive Configuration
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Dragline AC Drive System – PCR Room
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Dragline AC Drive System – PCR Room

- Common DC busbar
- Single power line connection
- Shared energy and motor-to-motor braking without braking chopper.
- Modular construction

- No separate line reactors required
- Energy savings ~10 – 15%
- Reduced wear on mechanical parts through DTC (integrated backlash protection)
- Operation with reduced power

Active Front End drive – IGBT Supply Unit
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Dragline AC Drive System – Operator Cab

- Ergonomic design for optimized operator performance throughout work shift
- Systems control center design
- P&H Centurion control system
- Built-in CCTV monitors
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Dragline AC Drive System – HMI Screens

Production and Maintenance Friendly Screens
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Dragline AC Drive System – P&H AC Motors

• P&H has a long standing experience in design and the manufacture of AC motors
• Current P&H AC motors based on proven AC and DC motor designs, experience
• HAF8412 Hoist / Swing / Drag/Propel Motor rated 1,600 HP at 714 rpm, 690 volts

Proven P&H AC Motor Designs
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Dragline AC Drive System – P&H AC Motors

P&H AC Motor Review

• Heavy duty mechanical design
• Proven bearing designs
• Lower inertia for improved system performance
• Premium insulation system (class H or better)
• Insulated bearing and a shaft grounding feature
• Designed for increased Dragline performance
  – Increased speed
  – Improved thermal margin, Class B temperature rise
  – Higher Peak Horsepower
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Dragline AC Drive System – P&H AC Motors

- Horizontal & Vertical Mount
- Same motor for all motions
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Dragline AC Drive System – P&H AC Motors
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Dragline AC Drive System – P&H AC Motors

HAF8412 Core Assembly
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Dragline AC Drive System – P&H AC Motors
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Dragline AC Drive System – P&H AC Motors

Stator Coils and Slot Insulation
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Dragline AC Drive System – P&H AC Motors

Stator Coils Lacing and Securing
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Dragline AC Drive System – P&H AC Motors

Full Motor Assembly and Test
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Dragline AC Drive System – P&H AC Motors

- Designed for increased Dragline performance
- Rugged, mining-duty mechanical design
- Proven bearing technology applied
- Lower inertia for improved performance
- Improved Electrical Availability
- Overall system reliability improvements help increase Dragline availability

Rugged Joy Global AC Motors
Joy Global - ABB AC Drive Systems

P&H Walking Draglines
A Joy Global Product
Thank You