Appendix I

PCS MATRIX TRANSPORTATION OPTIMIZATION PRESENTATION

HAGLER SYSTEMS

PotashCorp

PCS
Matrix Transportation Optimization

October 17, 2006 NCPC

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http://www.haglersystems.com/

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Phosphate Pit Process Developments

- **KNOWN:** Increased Concentration = Increased Production (at lower cost per ton)
- **QUESTION:** Is matrix system concentration limited by pump suction performance?
- **ACTION:** Joint IMC / GIW study proved that increased suction performance (using a "super-suction" pump) will provide increased concentration
- **RESULT:** GIW developed a new matrix pump patterned after existing dredge pumps resulting in 3x suction performance
- **FUTURE:** Based upon the success of this test, FIPR funded another study (No.: 0404068, $150K) to further investigate the effect of solids on matrix pump suction performance

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Application to PCS

- Analysis by Hagler Systems demonstrated that the "super suction" pump approach would be beneficial to PCS
- PCS AFE granted to purchase new matrix pumps

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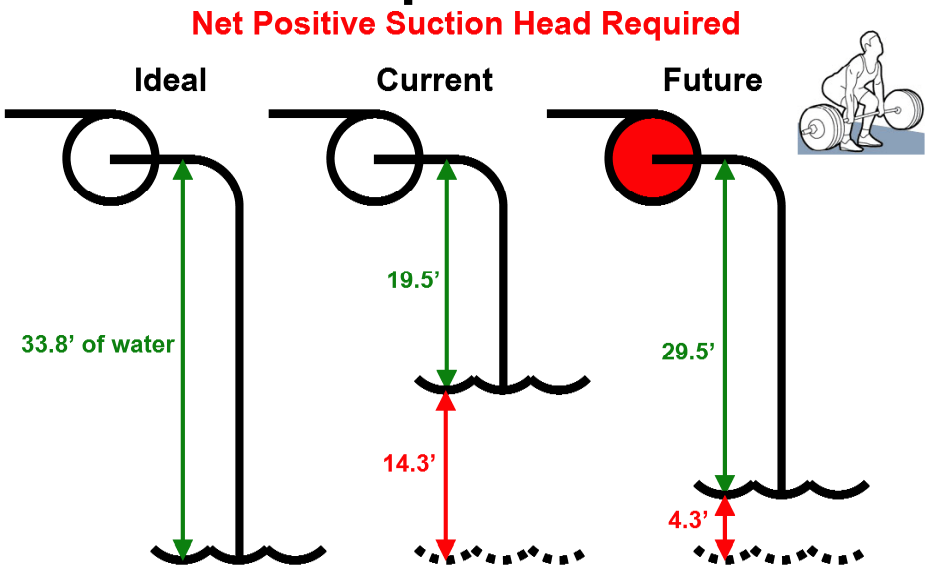
Pump NPSHR

Net Positive Suction Head Required



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20 x 25 LSA 62

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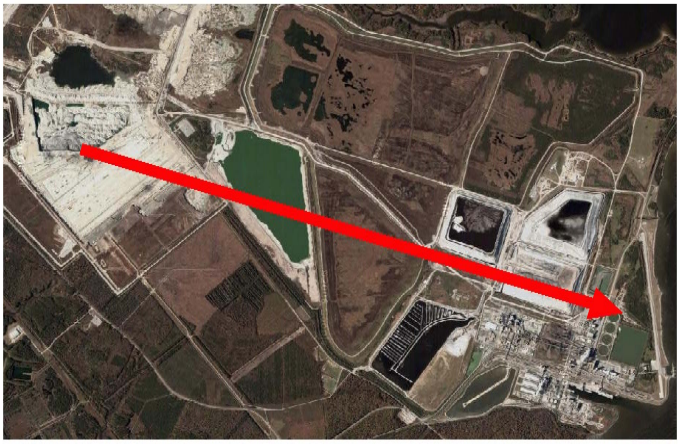
Optimize Matrix Transportation From GROUND to PLANT



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Buckets and Pipes

Ground → Buckets → Pipes → Plant

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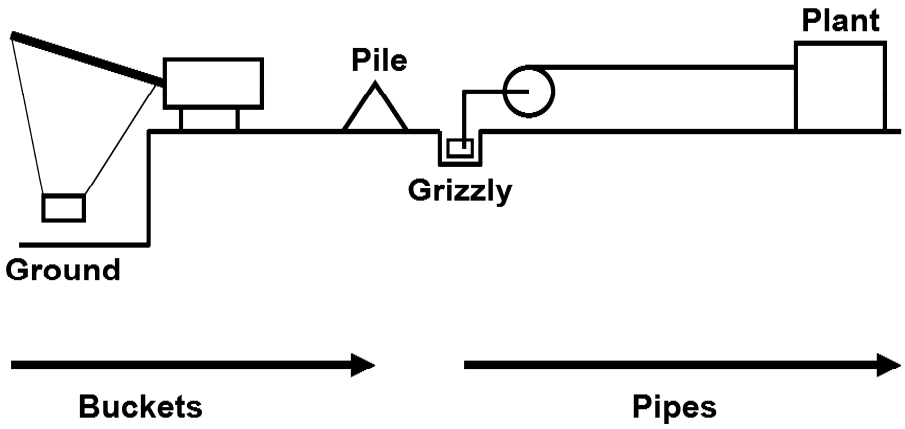
Buckets and Pipes



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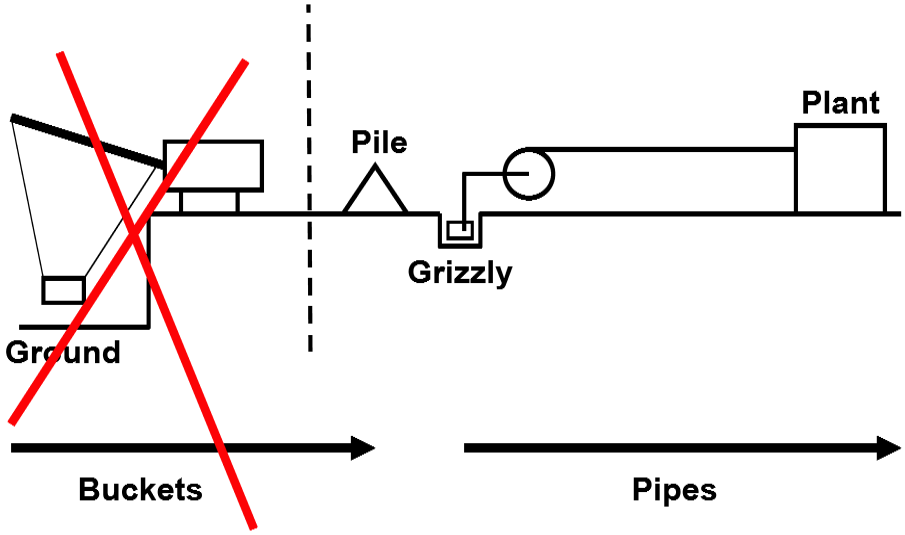
~~Buckets and~~ Pipes



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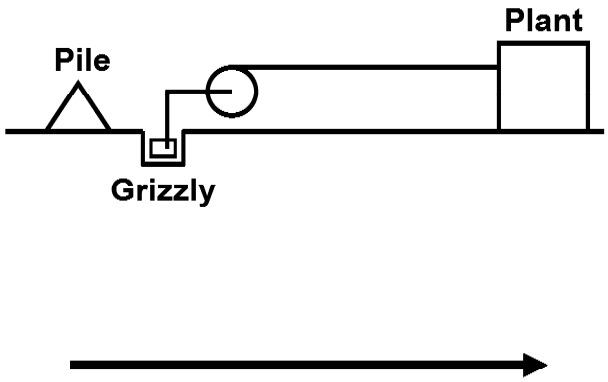
Pile to Plant



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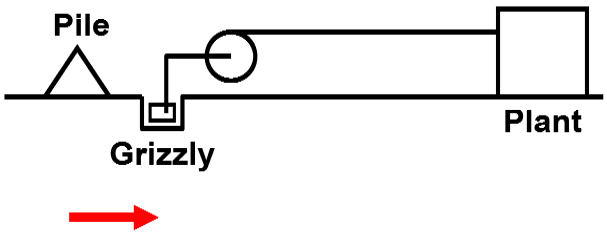
Pile to Grizzly



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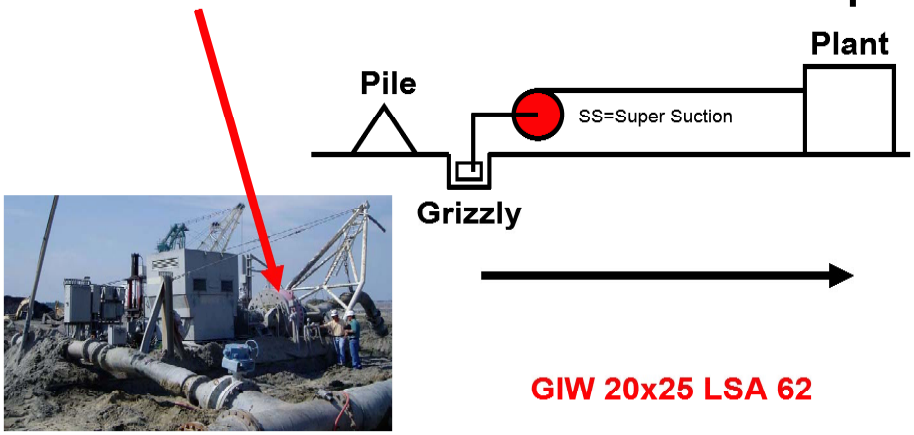
Grizzly to Plant

MAXimize Suction Performance of Pump



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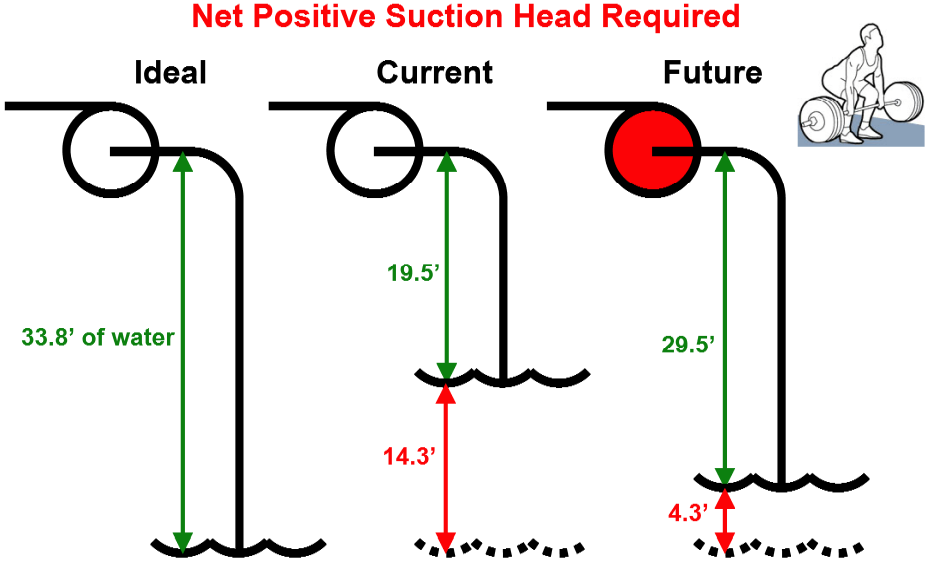
Pump NPSHR

Net Positive Suction Head Required



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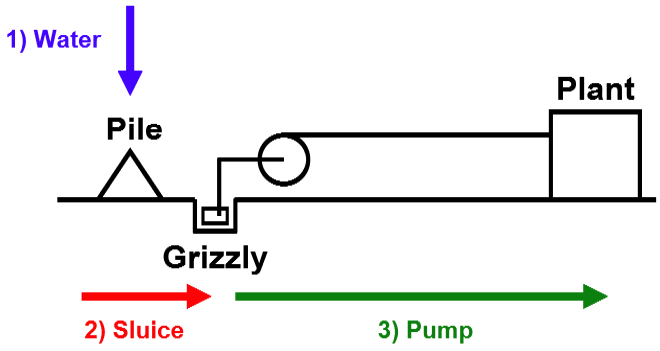
Process 1 2 3
System Concept:
Pile to Plant



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Process 1 2 3

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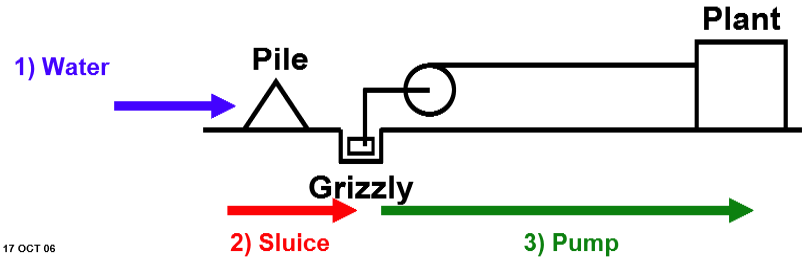
Process Control Concept: Pile to Plant

- Process 1: Water to Pile => Fixed Flow Control
- Process 2: 3 P's => Gun **P**ressure, **P**osition, **P**opulation
- Process 3: Automatic Pit Level Control



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Process 1 2 3

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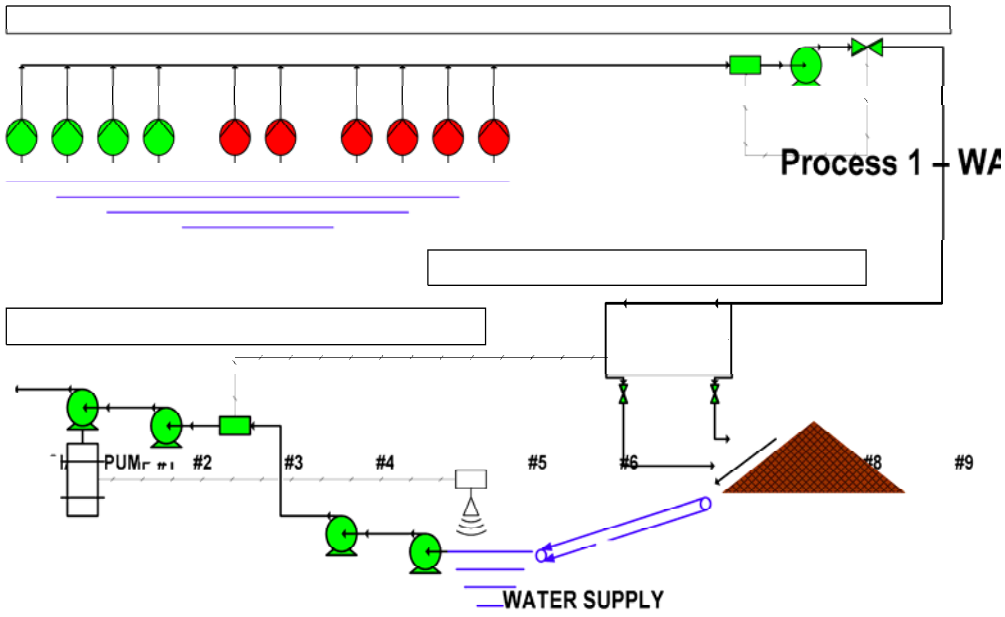

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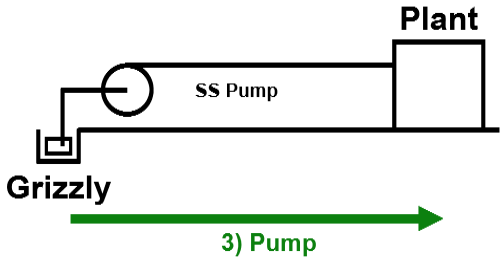
Process 3
Grizzly to Plant Pumping System

- Minimum Stable Velocity
- System Head
- Automatic Pit Level Control



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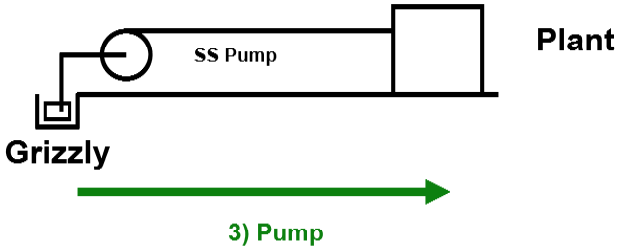
Process 3
Grizzly to Plant Example
Line #19 – 21" Pumping System

- 1 Fix Total Water = 12,000 gpm
- 2 Add 2000 ton/hour = +3,000 gpm
- 3 Automatic Pit Level Control = 15,000 gpm Slurry



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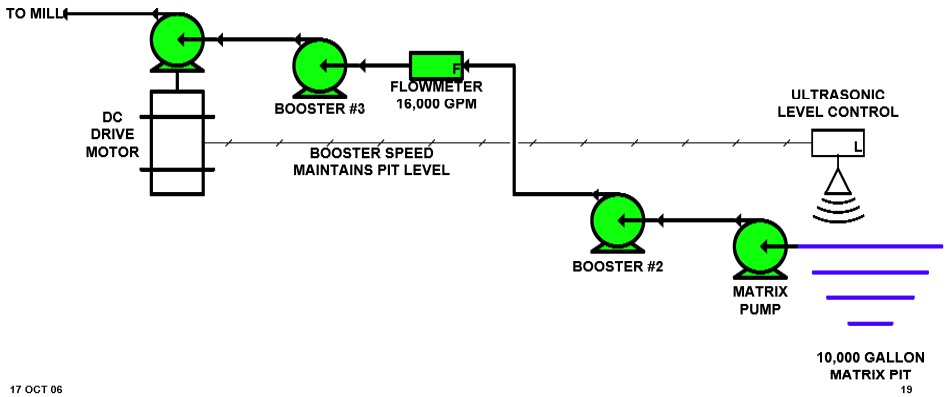
Process 3

Grizzly to Plant Pumping System

Process 3 – Grizzly to Plant = Water + Solids = 12-16000 gpm



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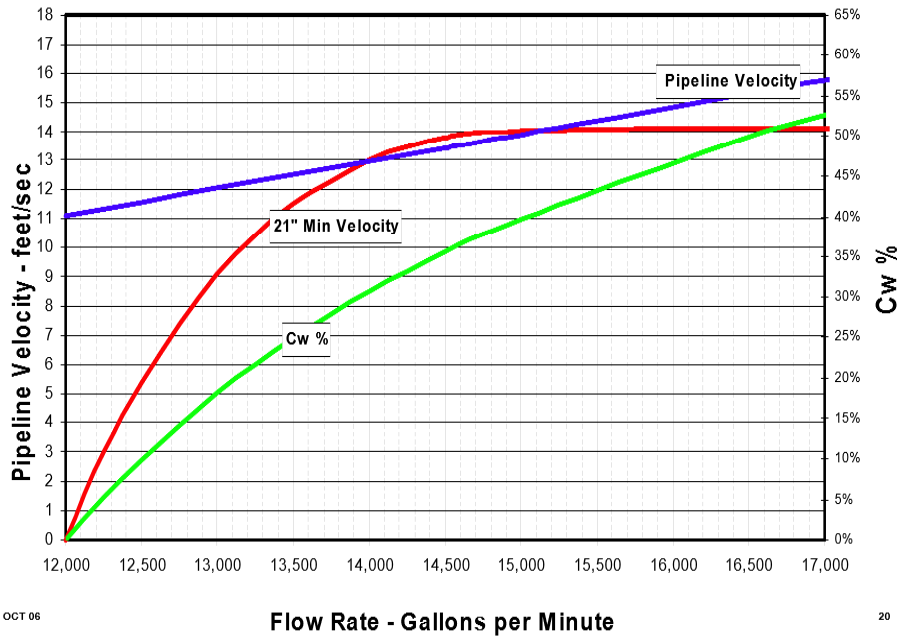
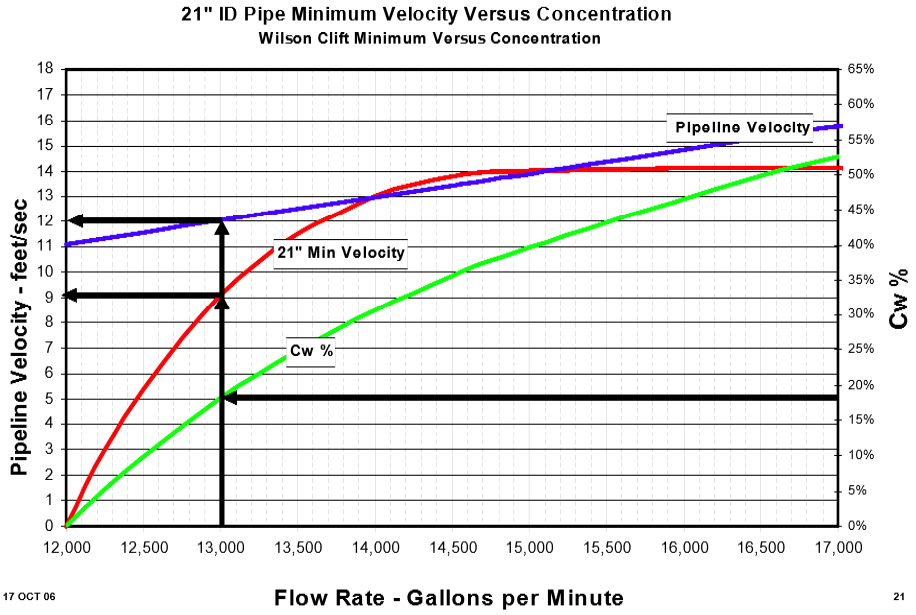
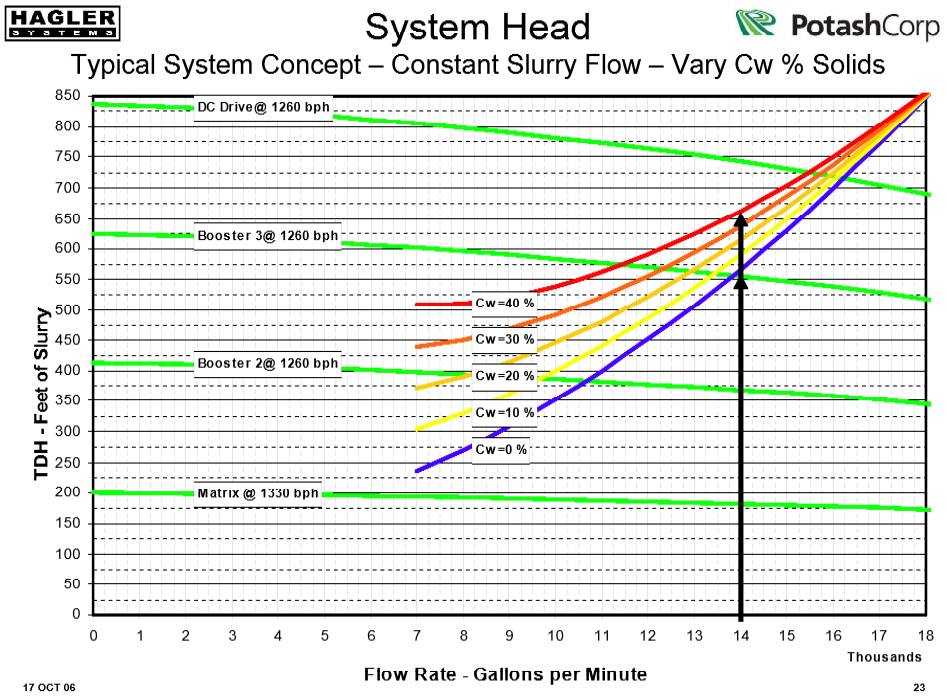


System Stability - Pipeline Velocity
Constant Gun Water –Variable Slurry Flow



System Head Example

- #19 Line – Finger Line #6
- 7,900 ft. 19” ID Pipe
- 10,100 ft. 21” ID Pipe
- 115 ft. Static Elevation (35 Bench, 80 Plant)
- 20 K Factors Loss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System Head
PotashCorp
Typical System Concept – Constant Slurry Flow – Vary Cw % Solids
DC Drive@ 1260 bph
Booster 3@ 1260 bph
Booster 2@ 1260 bph
Matrix @ 1330 bph
Cw=40 %
Cw=30 %
Cw=20 %
Cw=10 %
Cw=0 %
TDH - Feet of Slurry
Flow Rate - Gallons per Minute
Thousands
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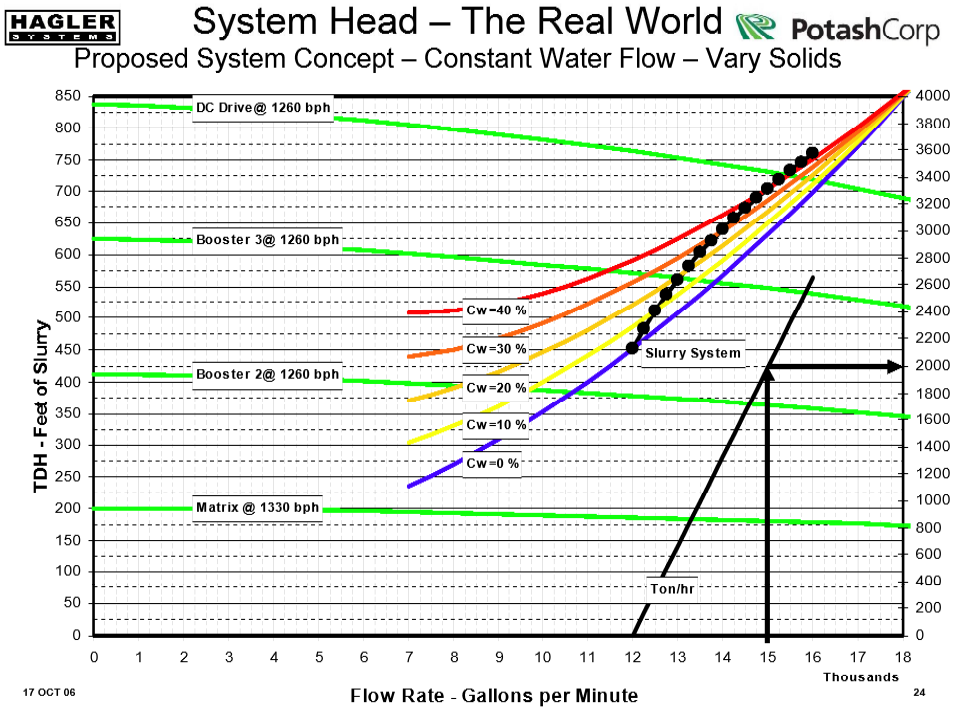
HAGLER SYSTEMS
System Head – The Real World
PotashCorp
Proposed System Concept – Constant Water Flow – Vary Solids
DC Drive@ 1260 bph
Booster 3@ 1260 bph
Booster 2@ 1260 bph
Matrix @ 1330 bph
Cw=40 %
Cw=30 %
Cw=20 %
Cw=10 %
Cw=0 %
Slurry System
Ton/hr
TDH - Feet of Slurry
Flow Rate - Gallons per Minute
Thousands
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HAGLER SYSTEMS

System Head – The Real World

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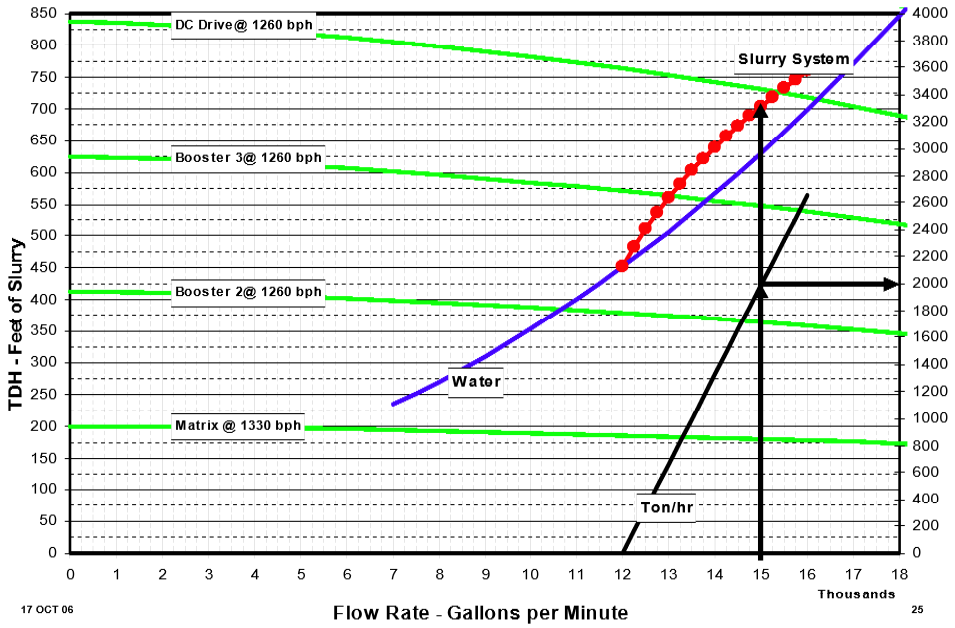
Proposed System Concept – Constant Water Flow – Vary Solids



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Pipeline System

Q Begin *	Step *	S.G.Solids	S.G. Carrier	Insitu SG	Desired SGM
12000	250	2.65	0.998	1.9	1.18

* If Q Begin and Step = 0, Use Default

Total Length = 18000

Conduit Section	Nominal OD	Wall/DR	Pipe ID	#1 Length	#1 K
	22.00	0.500	21.000	10100	10.1
#2	20.00	0.500	19.000	7900	10
#3	0	0	0.000	0	0
#4	0	0	0.000	0	0
#5	0	0	0.000	0	0
#6	0	0	0.000	0	0
#7	0	0	0.000	0	0
			Static	115	

0 feet Normal Static When Submerged Static = 0 Pipe , ID=21

Min Vel	Cw % Solids	Cv Solids	SG	Flow (gpm)	TDH water	TDH ft-slurry	Yd/hr Wet	Ton/hr 0	peline Veloc (ft/sec)
0.0	0%	0%	0.998	12000	451	452	719	0	11.12
3.0	5%	2%	1.032	12250	465	483	734	166	11.35
5.4	10%	4%	1.064	12500	478	511	749	332	11.58
7.4	14%	6%	1.095	12750	493	537	764	497	11.81
9.1	18%	8%	1.125	13000	507	560	779	663	12.04
10.4	22%	9%	1.154	13250	521	582	794	829	12.27
11.5	25%	11%	1.182	13500	536	603	809	995	12.51
12.3	28%	13%	1.208	13750	551	622	824	1161	12.74
13.0	31%	14%	1.234	14000	567	640	839	1326	12.97
13.5	33%	16%	1.259	14250	582	657	854	1492	13.20
13.8	36%	17%	1.283	14500	598	673	869	1658	13.43
14.0	38%	19%	1.306	14750	614	689	884	1824	13.66
14.1	40%	20%	1.328	15000	630	704	899	1989	13.89
13.8	42%	21%	1.350	15250	647	718	914	2155	14.13
13.8	44%	23%	1.371	15500	664	733	929	2321	14.36
13.3	45%	24%	1.391	15750	681	746	944	2487	14.59
13.0	47%	25%	1.411	16000	698	759	959	2653	14.82

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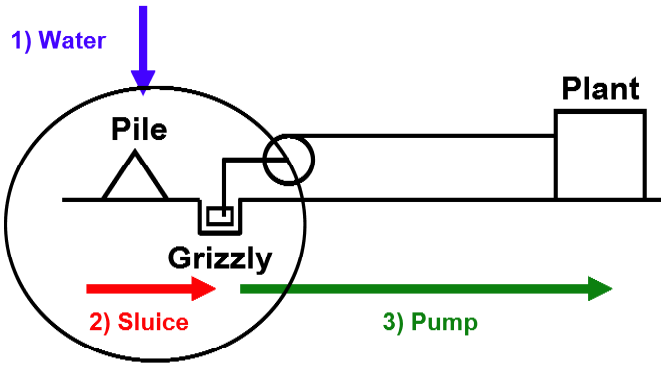
Process 2
Pile to Grizzly



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Process 2 - Pile to Grizzly
Process CONTROL = 3 P's
Constant Water Flow, Vary..

- **P**ressure of Guns
- **P**osition of Guns
- **P**opulation of Guns

NOTE: Constant Water Flow is Key to Matrix System Stability per minimum velocity calculations

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Trailing Suction Hopper Dredge

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TSHD Drag Arm

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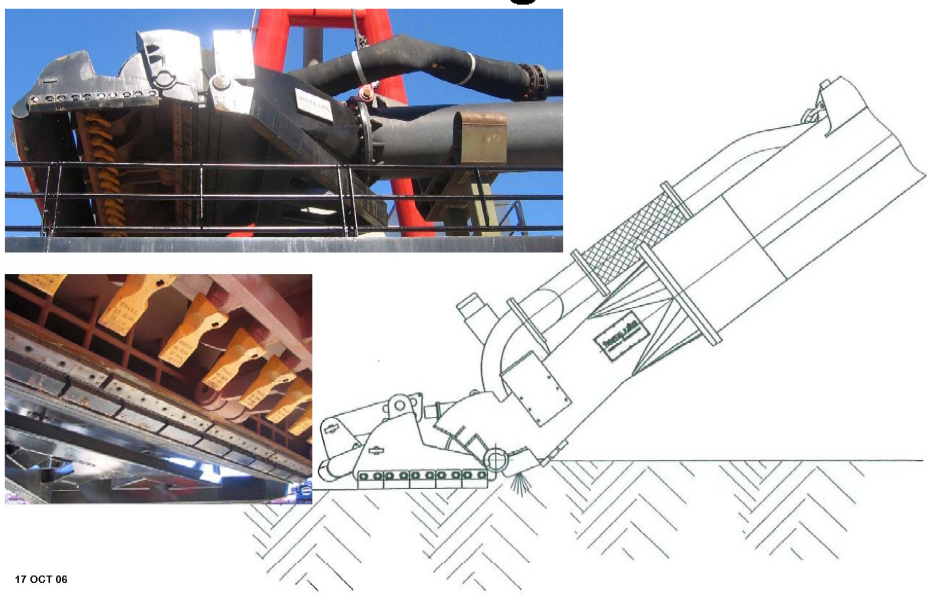
TSHD Drag Head



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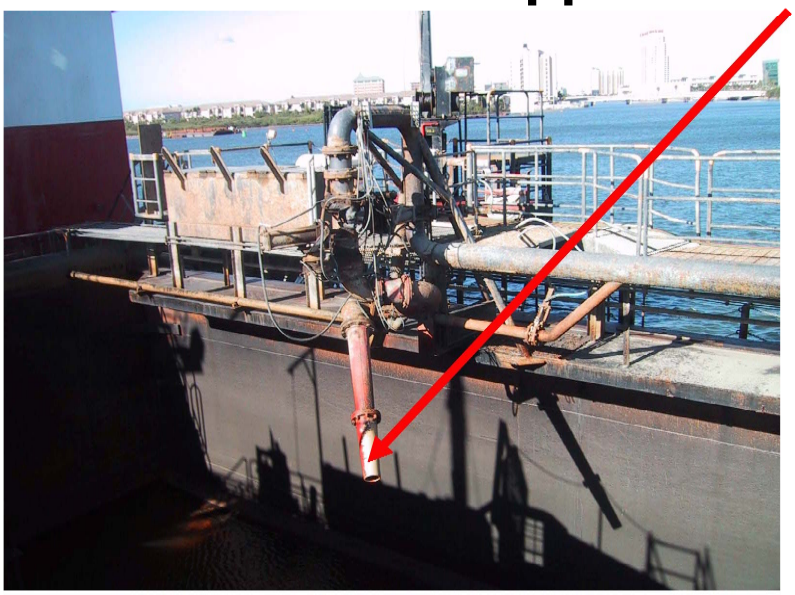
Inefficient Nozzle Application



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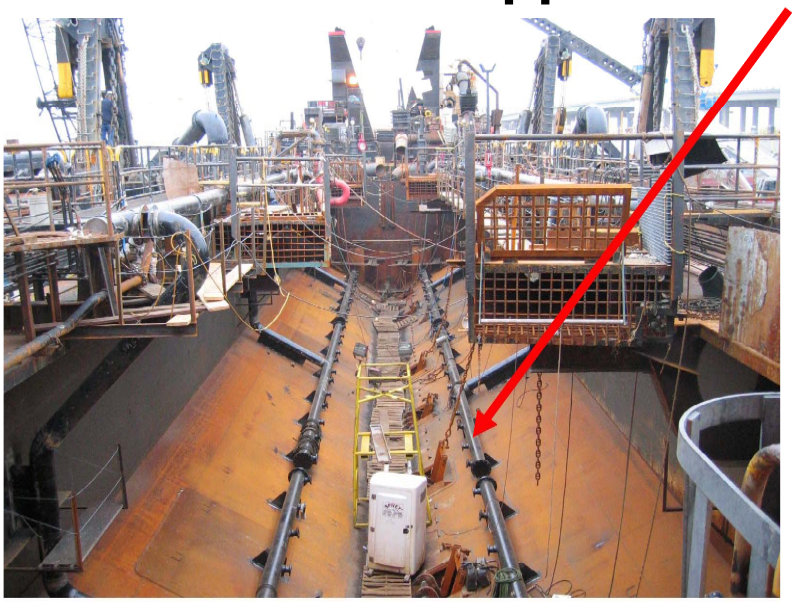
Efficient Nozzle Application



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Calibration: SG of Sea Water

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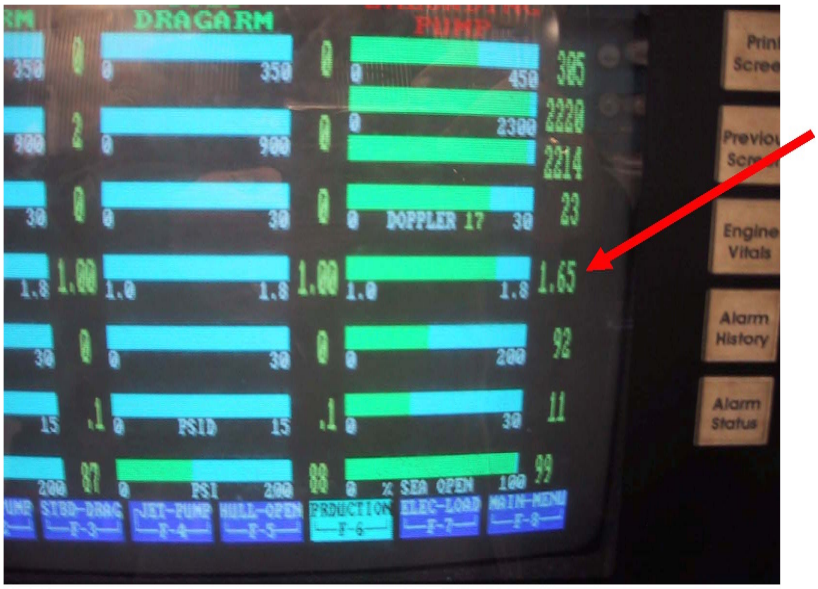
Measurement: SG of Matrix



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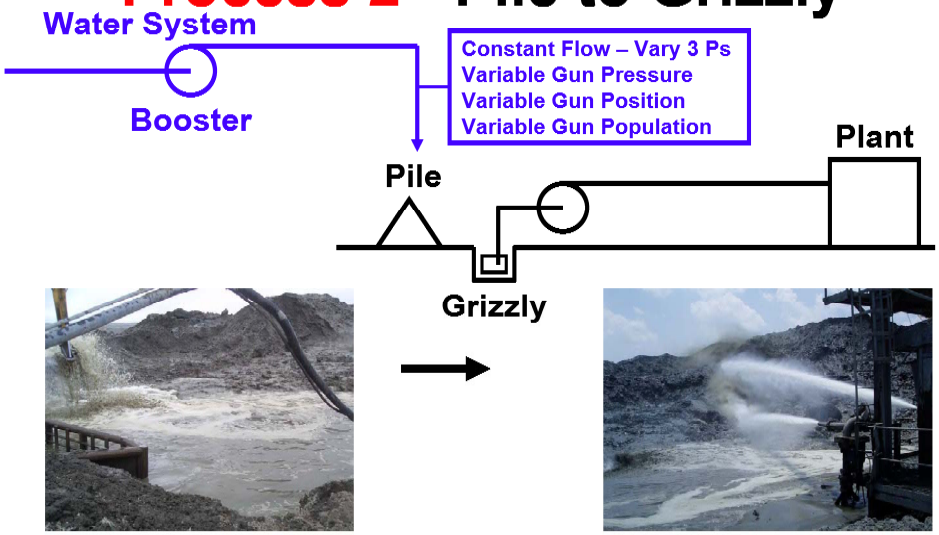
Process 2 - Pile to Grizzly



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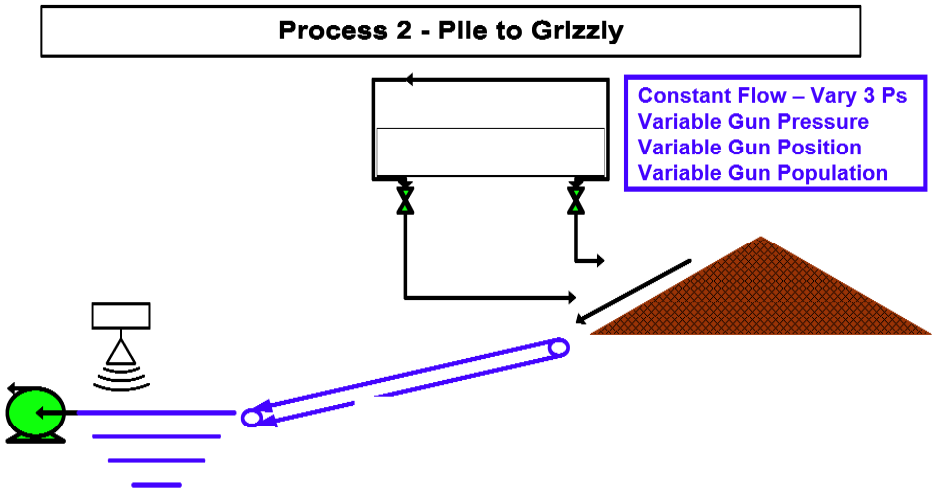
Process 2
Pile to Grizzly



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Process 2 - Pile to Grizzly
Summary

- Least Controllable Process
- Whether Practical or Not – Empirical Study is Required in order to optimize the 3 Ps as a function of Matrix Conditions
- With System In Control: Constant Water Flow, Constant Pit Level…..
- Production or Measure of Performance = Slurry Flow – Water Flow
- Process variables must be fixed to determine effect of changing single variables.

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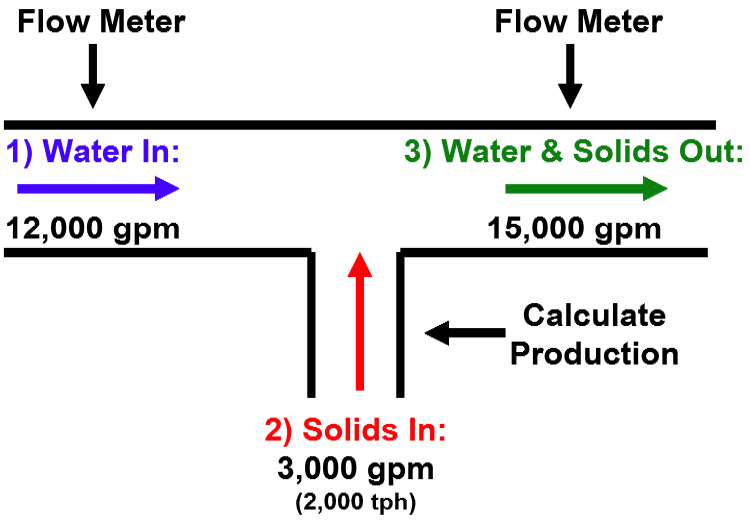
Measure of Performance



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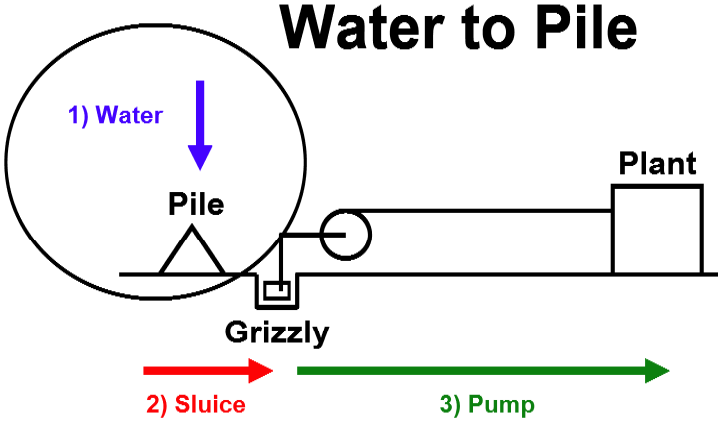
Process 1
Water to Pile



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Process 1 – Water to Pile

- Must Fix Water Flow to Guarantee Pumping System Stability
- Proper Operation will Improve Pump Life (No Low Flow!)
- With System In Control: Constant Water Flow, Constant Pit Level…..
- Production or Measure of Performance = Slurry Flow minus Water Flow
- Process variables must be fixed to determine effect of changing single variables.

HAGLER SYSTEMS

Water System Proper Operation

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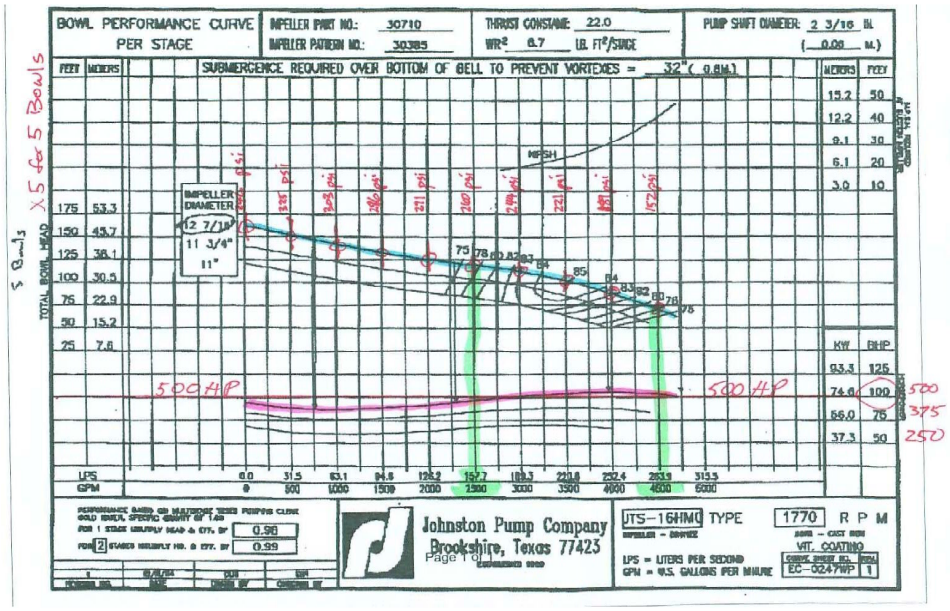

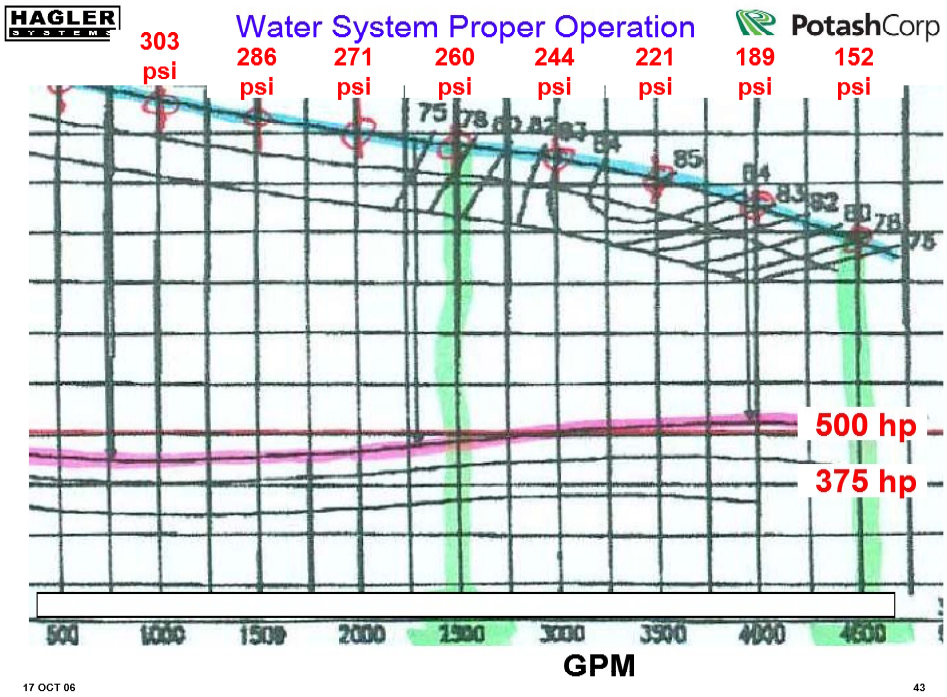
HAGLER SYSTEMS
Water System Proper Operation
PotashCorp
303 psi
286 psi
271 psi
260 psi
244 psi
221 psi
189 psi
152 psi
500 hp
375 hp
500
1000
1500
2000
2500
3000
3500
4000
4500
GPM
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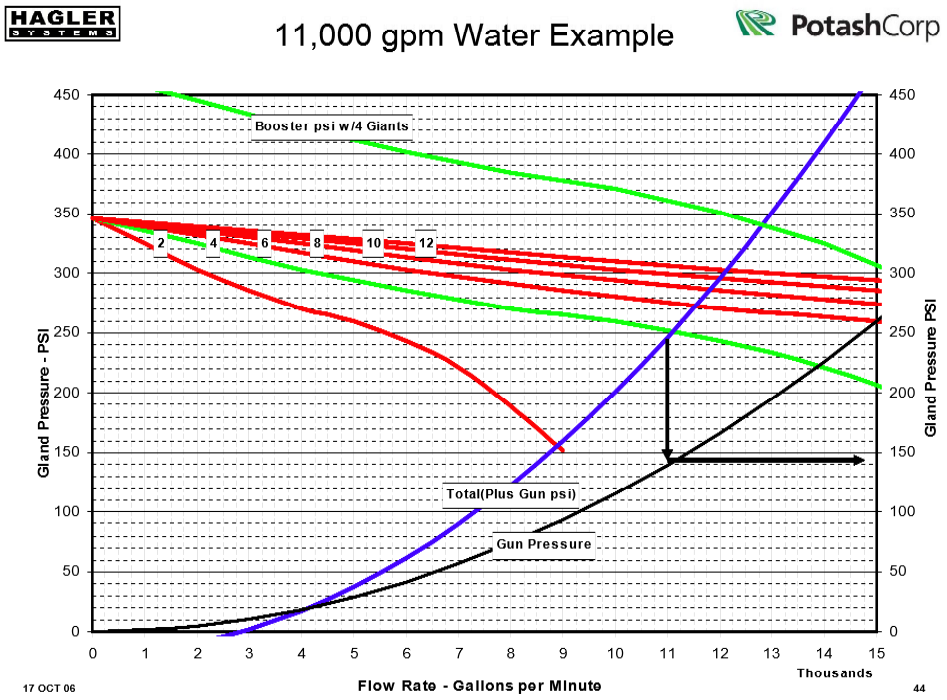
HAGLER SYSTEMS
11,000 gpm Water Example
PotashCorp
Booster psi w/4 Giants
2
4
6
8
10
12
Total(Plus Gun psi)
Gun Pressure
Gland Pressure - PSI
Gland Pressure PSI
Flow Rate - Gallons per Minute
Thousands
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HAGLER SYSTEMS

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Giants Pumps vs. Giants Pumps with a Booster Pump

Example @ 12000 gpm

- 12,000 gpm with 8 Giants
  = 1,500 gpm each = 430 hp x 8
  = 3,440 hp @ 286 psi

- 12,000 gpm with 3 Giants & GIW Booster
  Giant = 4,000 gpm each = 510 hp x 3 = 1,530 hp @ 189 psi
  Booster = 913 hp @108 psi

- Total = 2,443 hp & 297 psi = **$300,000 / yr. Savings**

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HAGLER SYSTEMS

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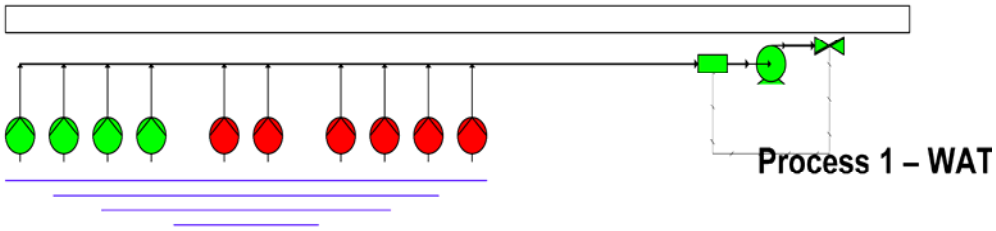


Pump # 7; Booster = GIW WBC with 44in. Imp. @ 585 rpm; 915 bhp; 4 Giants; GUNS=221 psi

HAGLER SYSTEMS

Assembly #	Impeller Dia	Impeller T/D	Full Dia.	Pump Type				SE Head	SE Eff
Z0084	44.00	1.006	43.750	WBC	10			0.00	0.00
Drive RPM	**Drive Ratio**	**Pump RPM**	**Impeller Tip Speed**	**Motor type**	**MAX BHP**	**lugdown Option**			
585	1.000	585	6744	Synchronous	1250	0	Adjust	0.00	0.00
							Final SE	0.00	0.00

Qty Giant?	Lg. Particles	S.G.Solids	D50	D85	% Fines	Slurry SG	Insitu SG	S.G. Carrier	Cv Soil	Cw Solids	Cv Solids
4	Semi-Rounded	2.65	200	460	0%	1.00	1.90	0.998	0.00	0.0%	0.0%

Flow (gpm)	Pump RPM	Head (ft slurry)	Eff (%)	Slurry BHP	NPSHR (ft)	Speed Ratio	Lug-down?	Smoke Limit?	Yd /Hour	Ton /Hour	Total PSI
0	585	282	0.0	377	6.8	1.00	FALSE	FALSE	0	0	469
2000	585	279	27.8	506	8.6	1.00	FALSE	FALSE	0	0	445
4000	585	274	47.9	577	10.2	1.00	FALSE	FALSE	0	0	422
6000	585	269	62.3	654	11.7	1.00	FALSE	FALSE	0	0	402
8000	585	263	72.1	737	13.1	1.00	FALSE	FALSE	0	0	385
10000	585	257	78.5	824	14.7	1.00	FALSE	FALSE	0	0	371
12000	585	249	82.2	915	16.5	1.00	FALSE	FALSE	0	0	351
14000	585	240	83.9	1,008	18.6	1.00	FALSE	FALSE	0	0	325
16000	585	229	84.0	1,102	21.2	1.00	FALSE	FALSE	0	0	289
18000	585	218	82.8	1,195	24.3	1.00	FALSE	FALSE	0	0	246

#8 #9

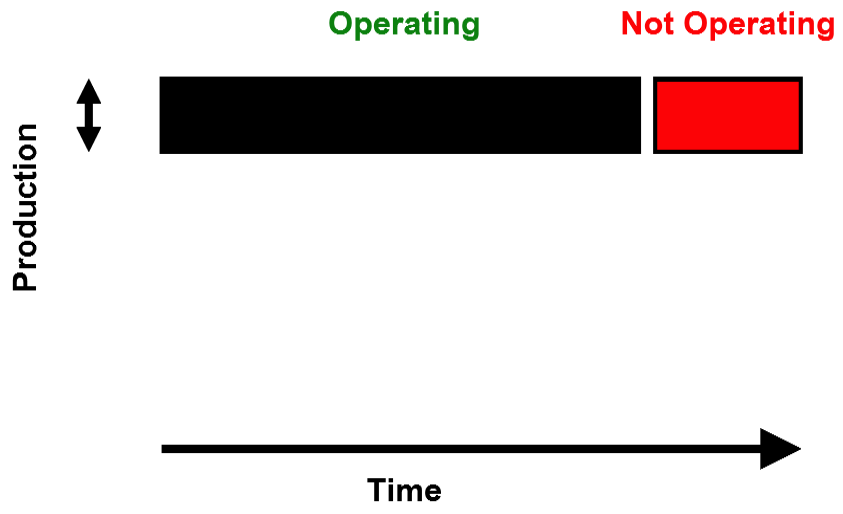
WATER SUPPLY

17 OCT 06 46

HAGLER SYSTEMS

PotashCorp

Increase Production & Efficiency



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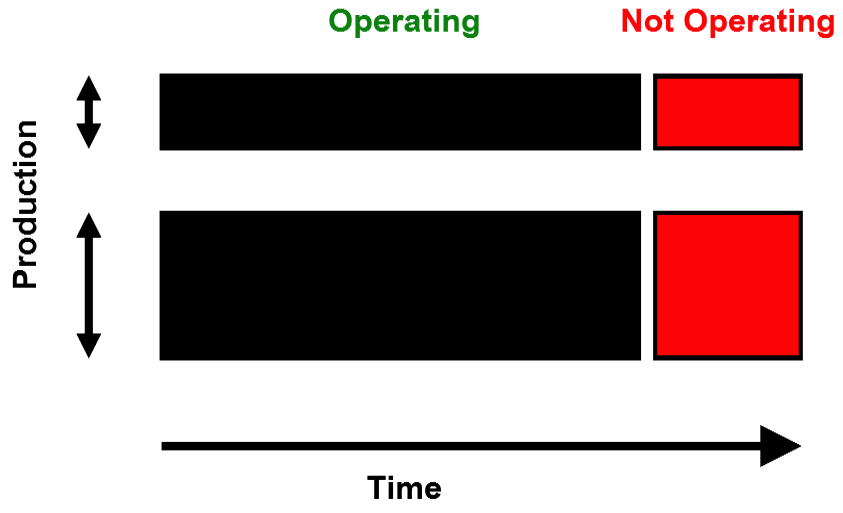
47

HAGLER SYSTEMS

PotashCorp

Increase Production & Efficiency



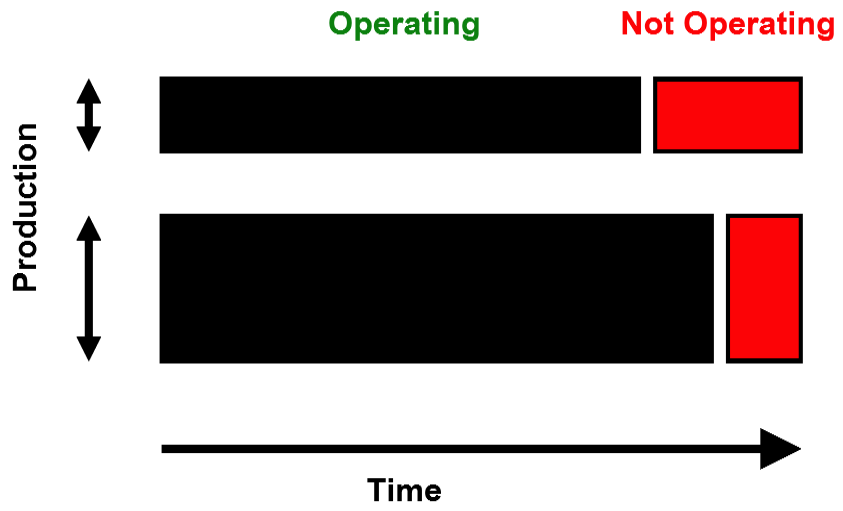
17 OCT 06

48

HAGLER SYSTEMS

PotashCorp

Increase Production & Efficiency



17 OCT 06

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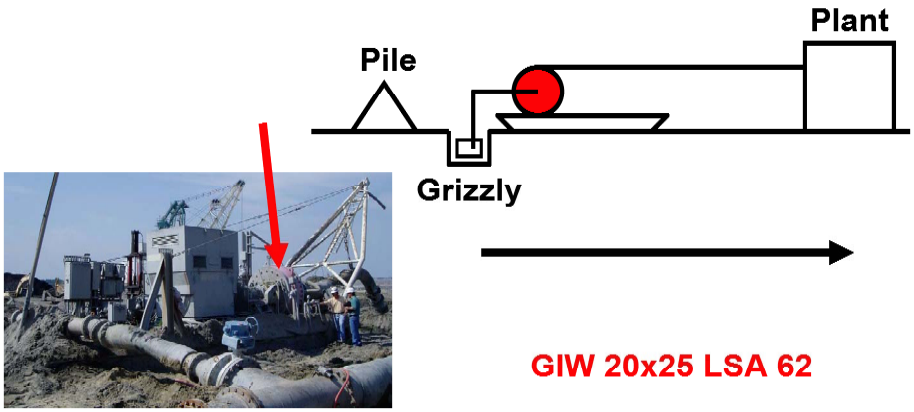
HAGLER SYSTEMS

PotashCorp

New Sled Pump

Improved Suction Performance



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50

HAGLER SYSTEMS

PotashCorp

Matrix Pump Sled 266-105

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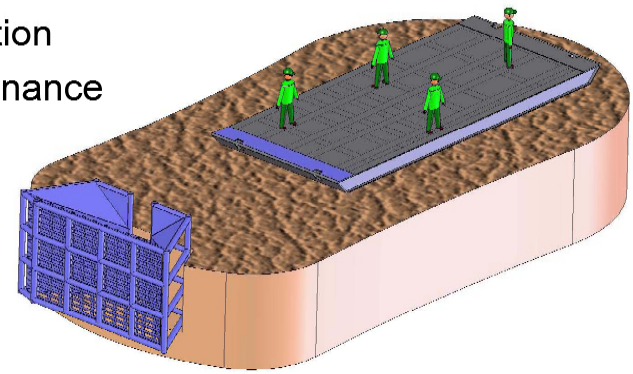
HAGLER SYSTEMS

PotashCorp

Matrix Pump Sled

- Concerted effort to maximize ease of:
  - Access
  - Operation
  - Maintenance



17 OCT 06

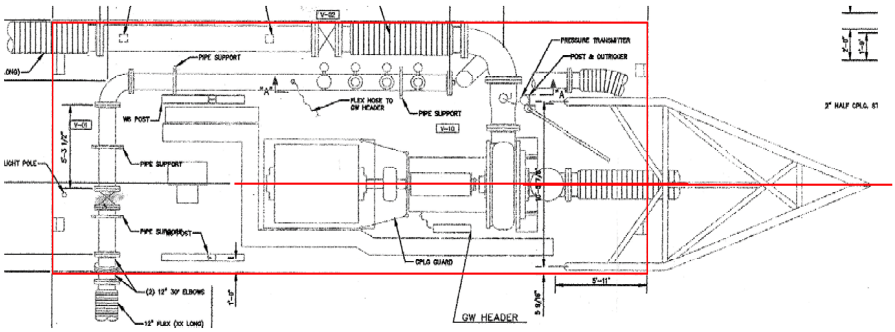
52

HAGLER SYSTEMS

PotashCorp

Pump and Motor

- Centrally located
  - Better weight distribution



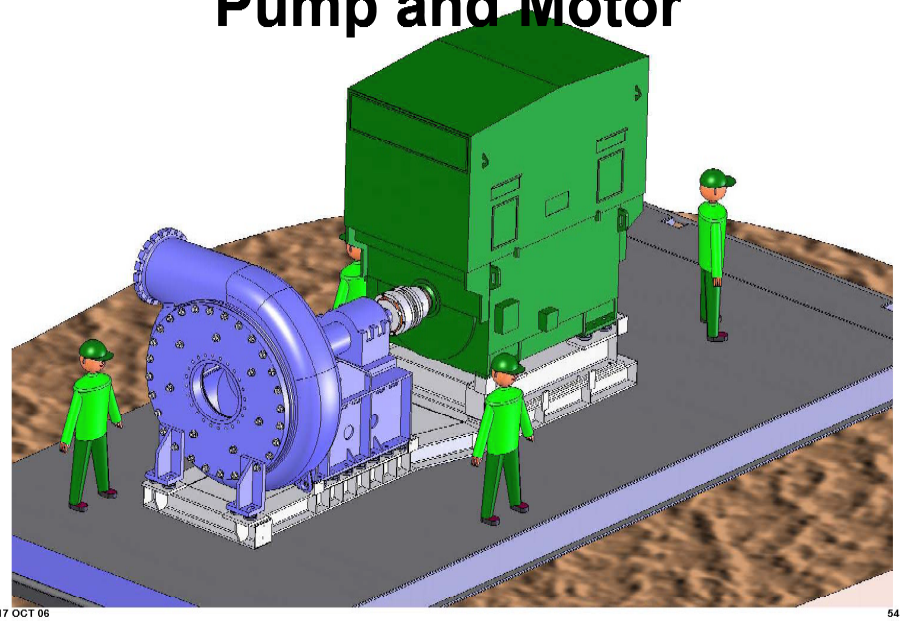
17 OCT 06

53

HAGLER SYSTEMS

PotashCorp

Pump and Motor



17 OCT 06

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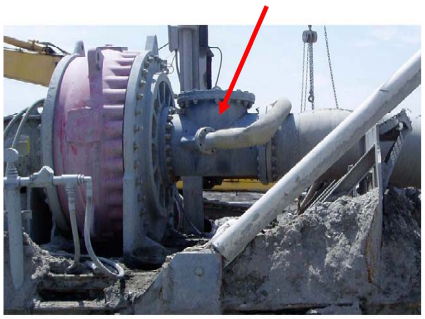
HAGLER SYSTEMS

PotashCorp

Discharge Piping

- Top Horizontal Pump
  - Much easier to prime
  - No burp / recirc system required

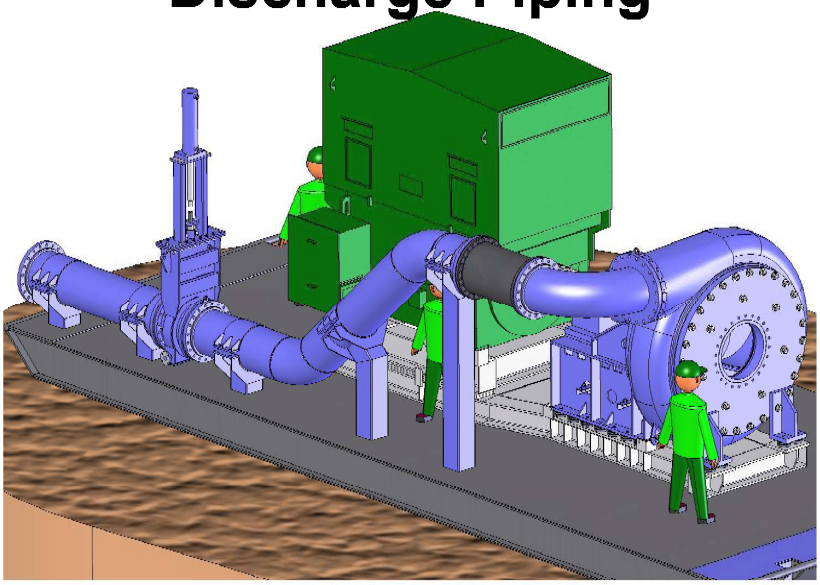


17 OCT 06 55

HAGLER SYSTEMS

PotashCorp

Discharge Piping

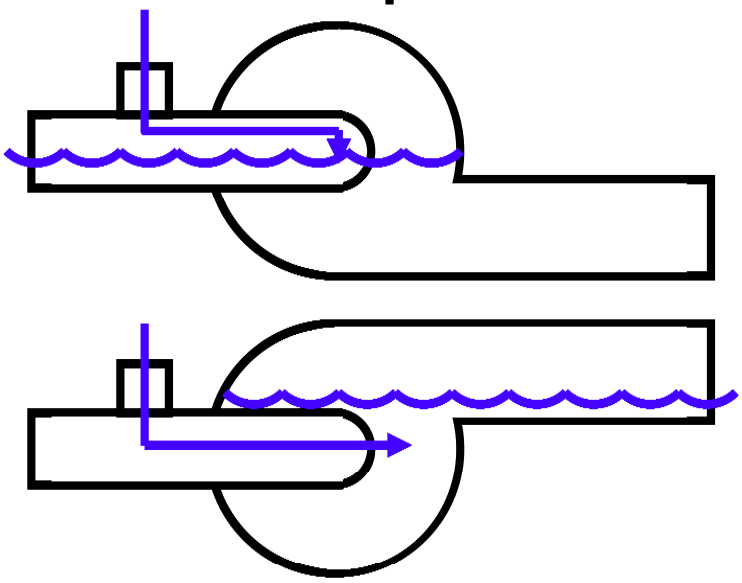


17 OCT 06 56

HAGLER SYSTEMS

PotashCorp

Bottom vs. Top Horizontal



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HAGLER SYSTEMS

PotashCorp

Suction Piping

- Minimize pipe friction losses

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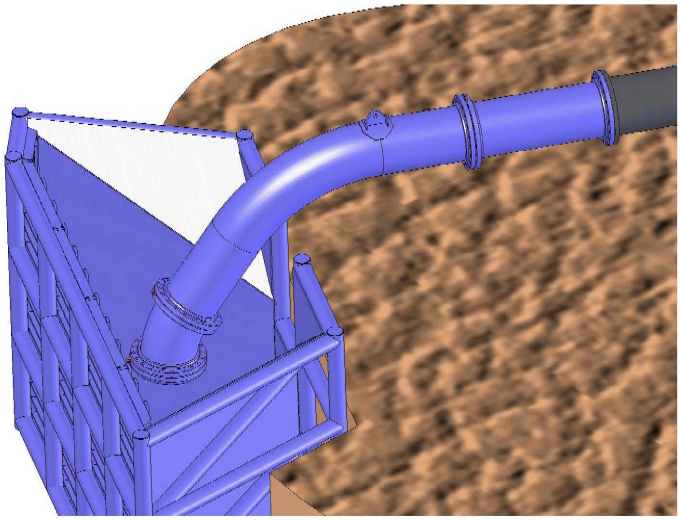
HAGLER SYSTEMS

PotashCorp

Suction Piping



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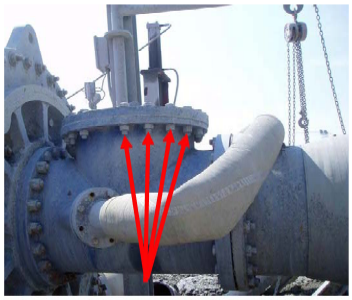
59

HAGLER SYSTEMS

PotashCorp

Clean-Out

- Quick open and close
- Large opening
- Come-a-long anchor points



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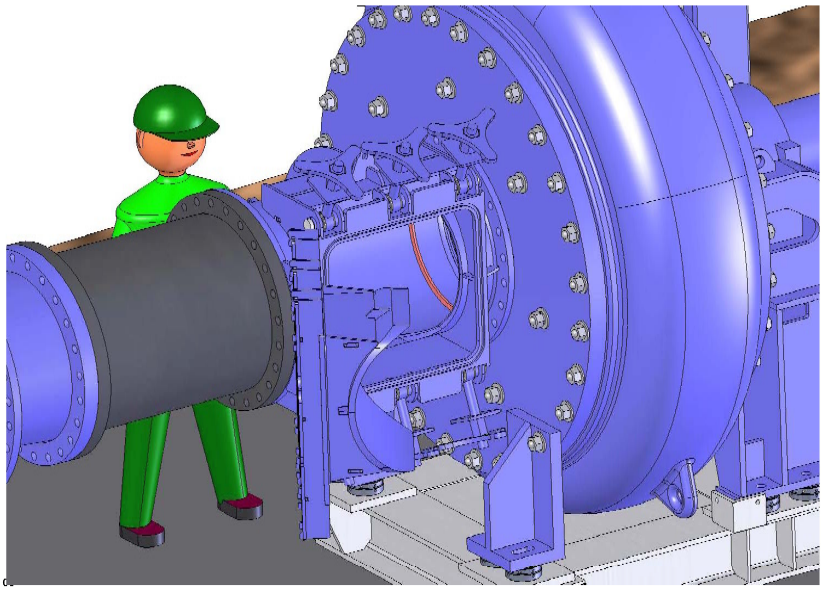
60

HAGLER SYSTEMS

PotashCorp

Clean-Out



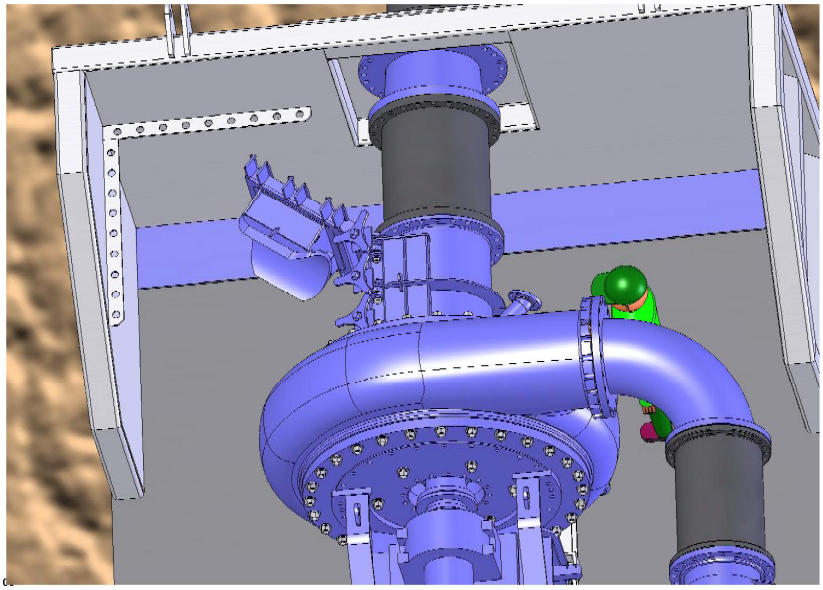
17 OCT 0

61

HAGLER SYSTEMS

PotashCorp

Clean-Out



17 OCT 0

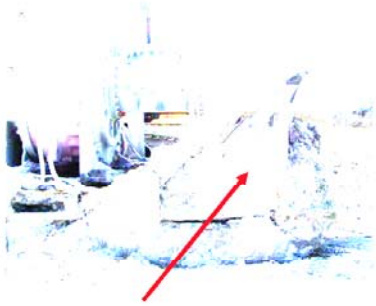
62

HAGLER SYSTEMS

PotashCorp

Front Bulkhead

- Reduce dirt accumulation
- Solid anchor points for piping
- Keep A-Frame out of work area



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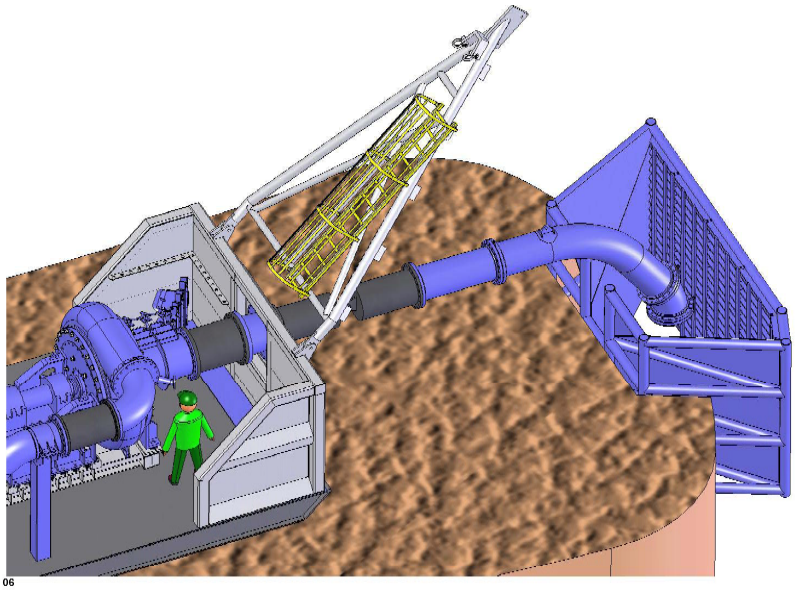
HAGLER SYSTEMS

PotashCorp

Front Bulkhead



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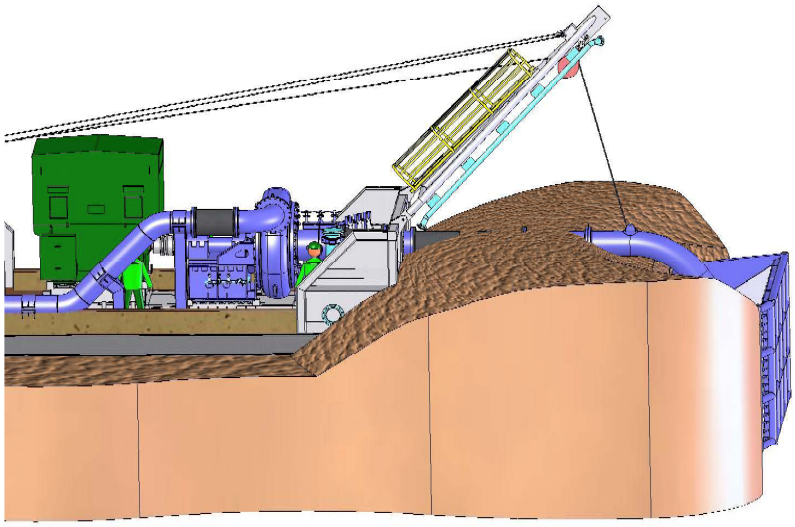
HAGLER SYSTEMS

PotashCorp

Front Bulkhead



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HAGLER SYSTEMS

PotashCorp

Water System

- Compact arrangement
- More direct routing

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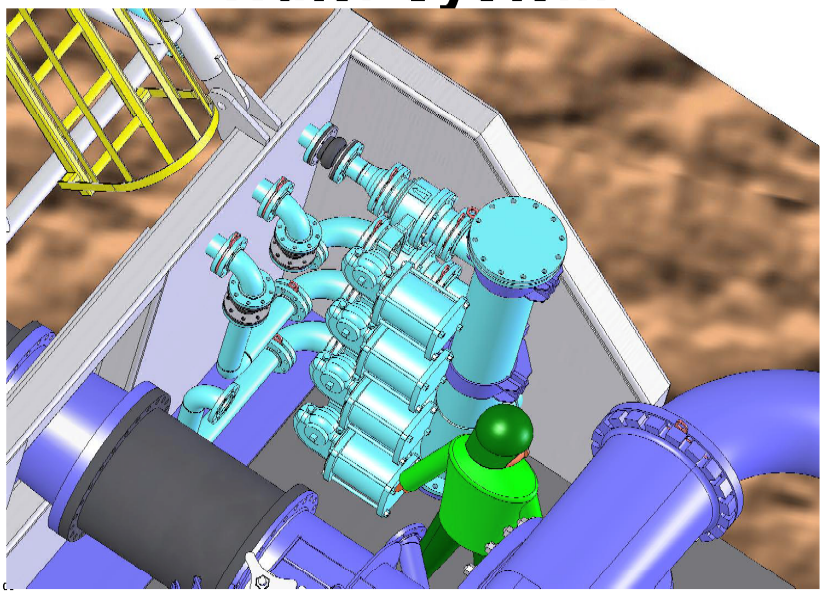
HAGLER SYSTEMS

PotashCorp

Water System



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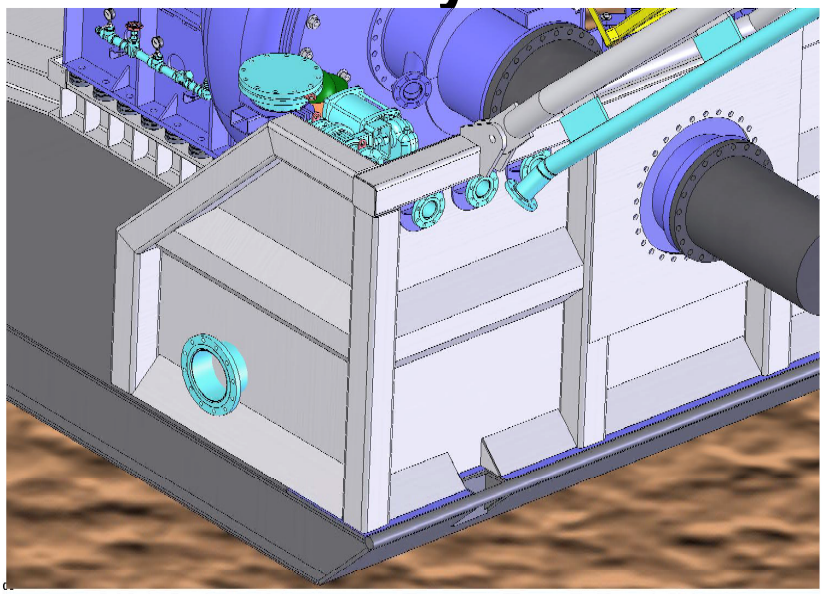
HAGLER SYSTEMS

PotashCorp

Water System



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HAGLER SYSTEMS

PotashCorp

Rear Bulkhead

- Reduce dirt accumulation
- Protected area for equipment & panels

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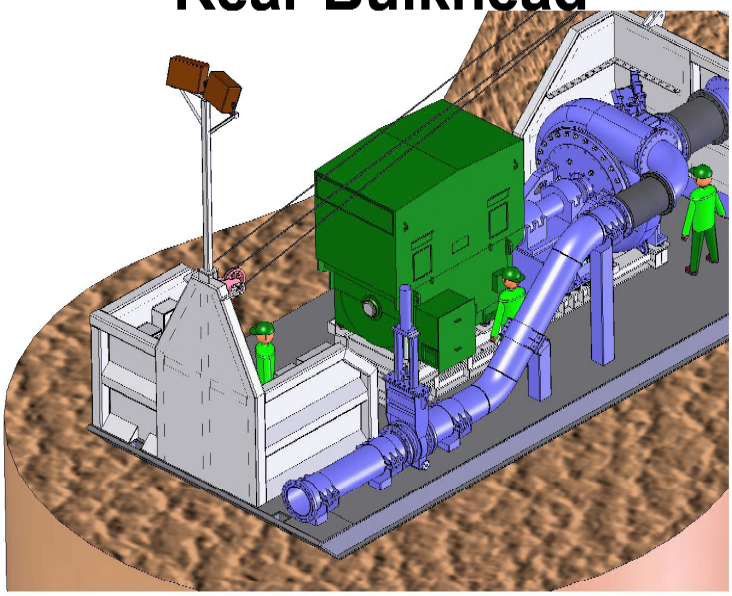
HAGLER SYSTEMS

PotashCorp

Rear Bulkhead



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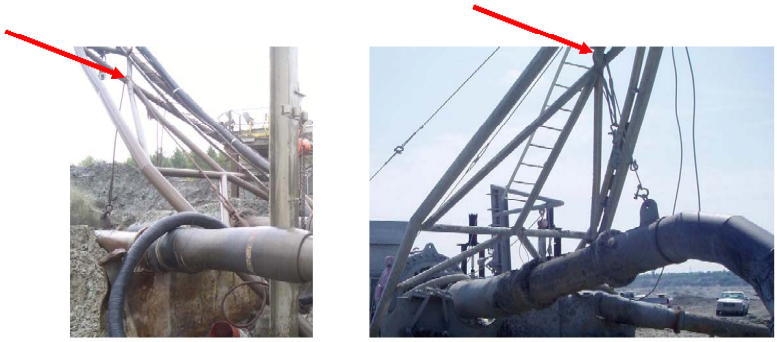
70

HAGLER SYSTEMS

PotashCorp

Winch System

- Less time required to raise and lower suction pipe



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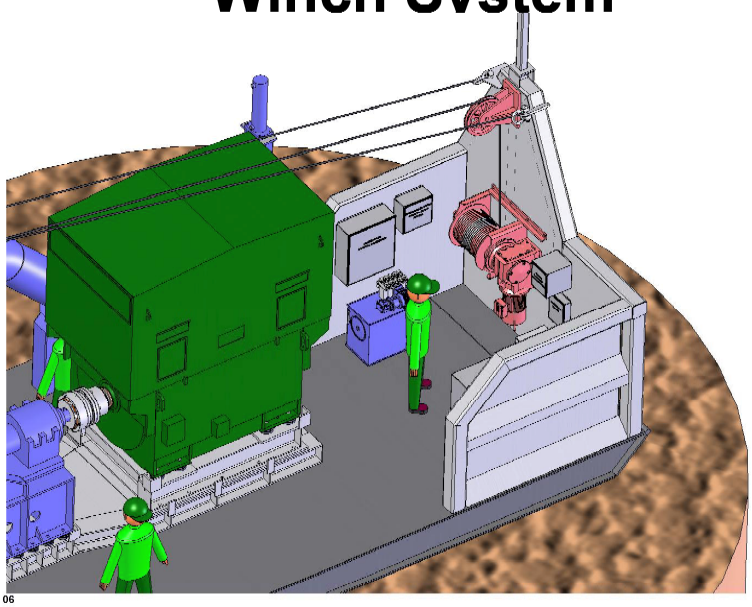
HAGLER SYSTEMS

PotashCorp

Winch System



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HAGLER SYSTEMS

PotashCorp

Hydraulic and Electrical

- Protected area for panels
- Ease of access, operation, maintenance

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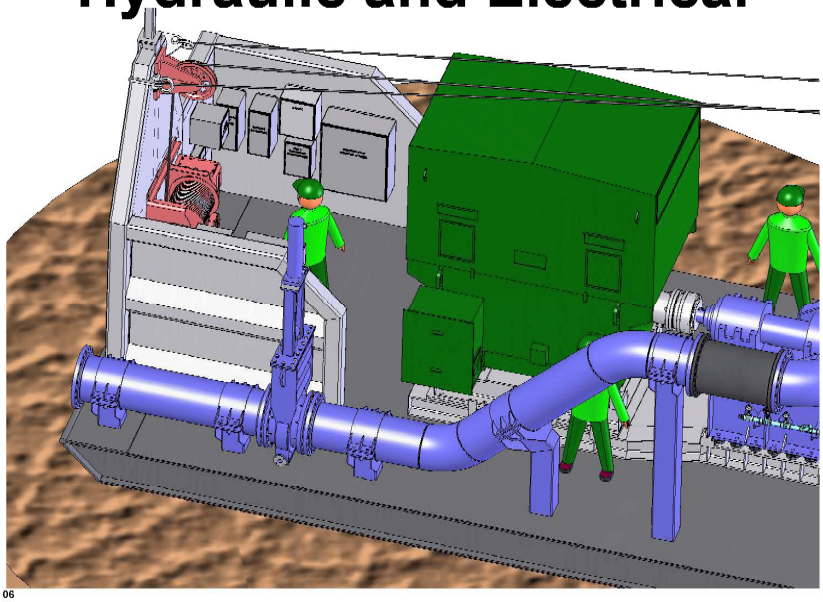
HAGLER SYSTEMS

PotashCorp

Hydraulic and Electrical



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HAGLER SYSTEMS

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Dirt Accumulation on Sleds a Common Problem

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HAGLER SYSTEMS

PotashCorp

Weight

- New pump, motor, and sub base add ~22,000 lbs.

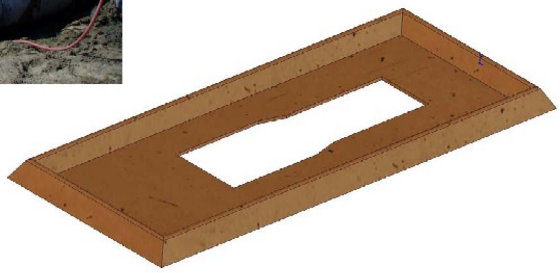
- Front and rear bulkheads add ~8,500 lbs.
  - Can "pay" for themselves by reducing dirt accumulation

17 OCT 06 76

HAGLER SYSTEMS

PotashCorp

Est. 27,161 lbs. Dirt on Sled



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HAGLER SYSTEMS

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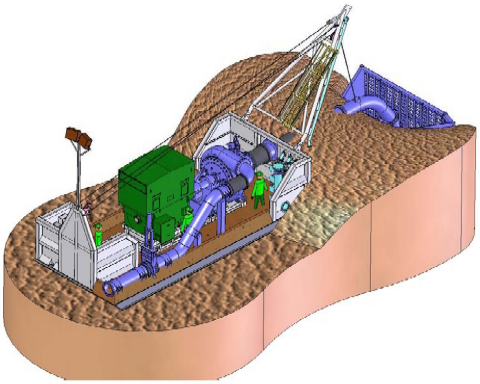
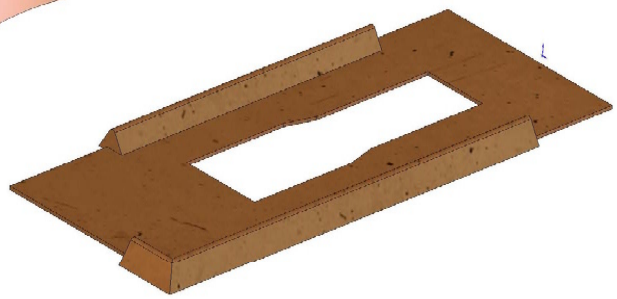
Est. 19,440 lbs. Dirt on Sled





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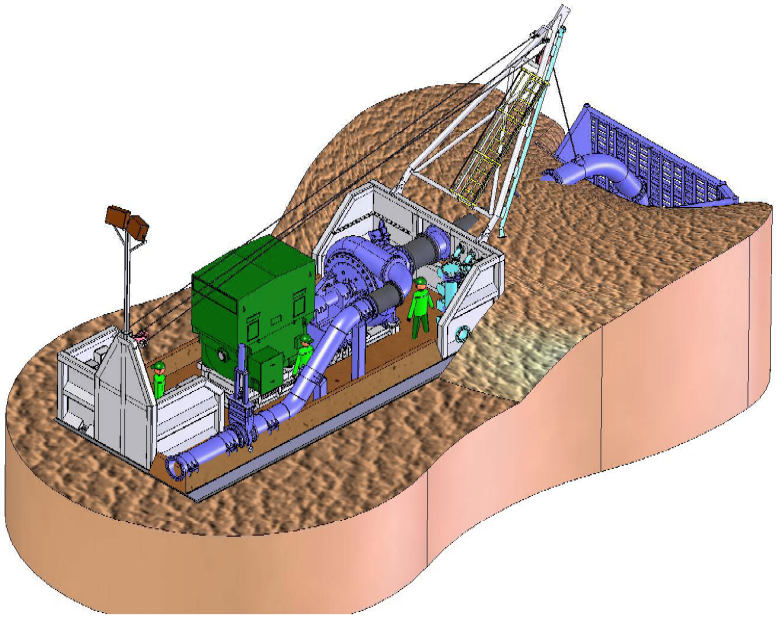
HAGLER SYSTEMS

PotashCorp



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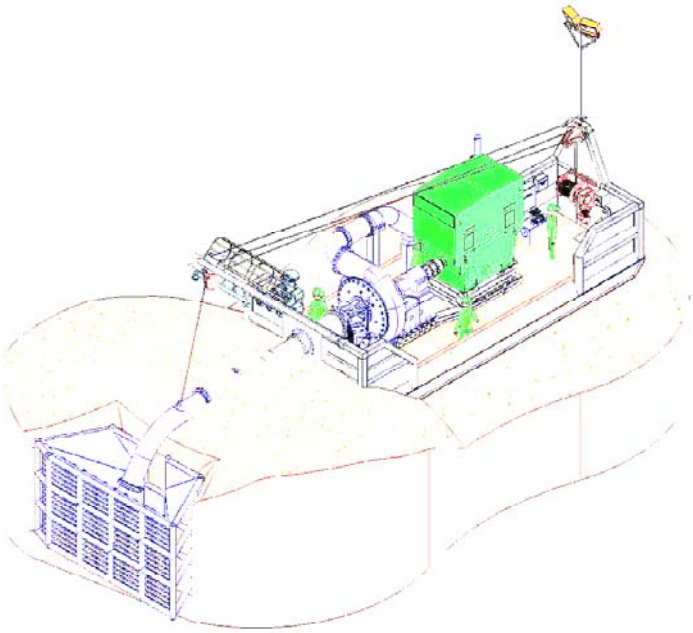
HAGLER SYSTEMS

PotashCorp



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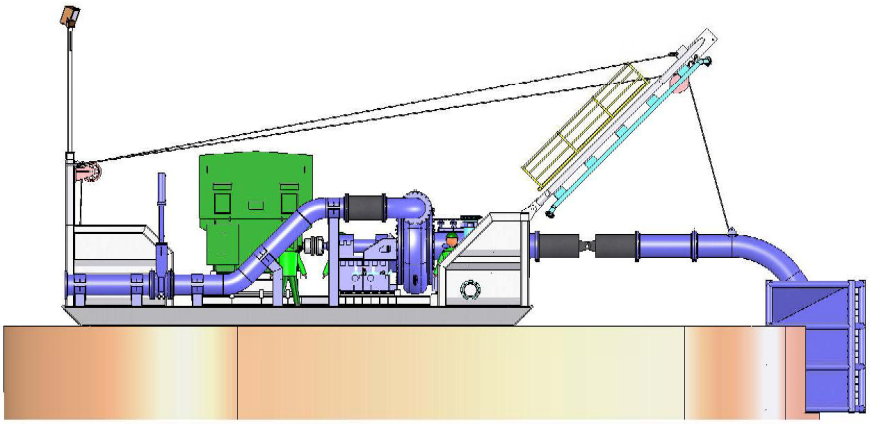
HAGLER SYSTEMS

PotashCorp



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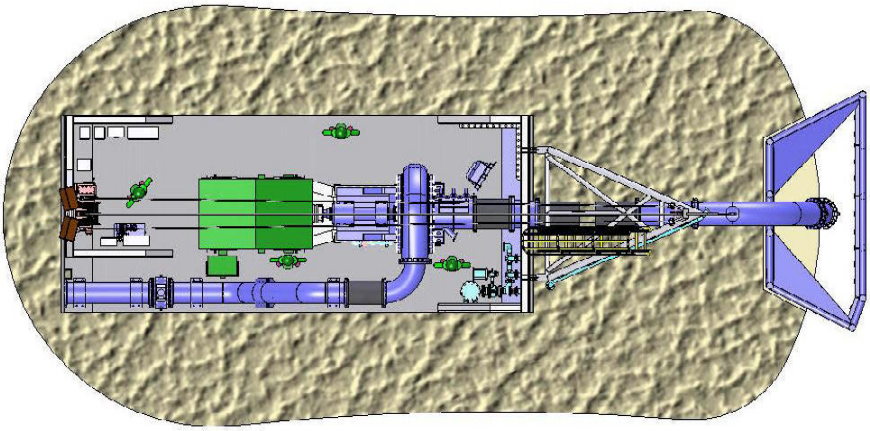
HAGLER SYSTEMS

PotashCorp



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Appendix J

TYPE D MATRIX WINGATE PUMPING EVALUATION

Wingate Dredge Evaluation-50%-20in

```
                                    SLYSEL
                             Version 20070618/  -10101     GIW Industries, Inc.
Item # : two                                               Grovetown, GA  USA
Reference: Wingate Creek Mine                              Date: Jun-21-2007
Application: Production Dredge                             Time: 10:29:34

System Analysis
                           Settling Slurry Information
Fluid Temperature (F) ....    70.0   Viscosity (lbf-s/ft^2) ....0.0000205
Fluid specific gravity ...   0.998   Gravity (ft/s^2) ...........   32.17
D50 (microns) ............    510.   D85 (microns) ..............   1200.
Particle Shape Factor ....   0.260   % of Fine particles < 74 microns  0.
Solids S.G. ..............    2.65   Slurry S.G. ................   1.450
Concentration by WEIGHT ..   50.0%   Concentration by VOLUME ....   27.4%
Coefficient of mechanical-sliding friction = .40

Conduit Information
Section    Roughness    Dia.  Pipe Len  Rise  Total K  Disch
            "E" ft       in       ft     ft    Value    psi
-------------------------------------------------------------------------------
Suct  # 01 0.000050     20.0     25.0    0.0    2.0     0.0
Disch # 01 0.000050     19.0   1200.0   72.0    2.0     0.0
Disch # 02 0.000050     19.0   5150.0   35.0    2.0     0.0
Disch # 03 0.000050     19.0   3500.0   35.0    2.0     0.0

Static Head Information for a Dredge
A negative number indicates a position below the pump centerline
and a suction pipe below the water level.
Vertical distance from the:  up(+)/down(-)
     Water surface to suction pipe inlet    (ft) ........  -92.0
     Pump centerline to suction pipe inlet  (ft) ........  -20.0
     Effective suction depth                (ft) ........   43.4
     Pump centerline to final discharge     (ft) ........  142.0
     Suction Elevation      (ft Above Sea Level) ........  100.0

System Evaluation
  Minimum Friction Point | Deposit Data  | Deposit Data (Worst Case,D50=500)
  For The Given Sections | @D50,Cw=50.0% |    @Cw=50.0%        @Cw=28.6%
           ft/s     GPM  | ft/s    GPM   |  ft/s      GPM    ft/s      GPM
-------------------------------------------------------------------------------
Suct  # 01  5.3   5140.8 | 10.1   9882.8 |  10.2    9982.2   14.2   13908.3
Disch # 01 12.3  10914.0 | 10.0   8820.8 |  10.1    8909.7   14.4   12724.1
Disch # 02 13.3  11797.7 |  9.7   8601.5 |   9.8    8688.2   13.9   12274.4
Disch # 03 13.1  11620.9 |  9.7   8614.8 |   9.8    8701.6   13.9   12301.9
Recommended Minimum Flow:  15000.  GPM
All Head loss values are in ft of slurry
Static Head (ft) =    98.6

The operating point of the system is  12634.5 ( GPM  ) and head of  552.5 (ft)
Throughput:  2292.0 tons/hr

 1  Assembly 9220D     20  x20  WBC 50(49)    C H14-  /  / 3ME13- 5/ 8
             Test Basis: T112 -93     Design Imp Dia(in):   49.000
   Maximum available HP:    1500.     Actual Imp Dia(in):   48.000
               Pump RPM:     481.  Motor Characteristics: Synchronous
    Solids Effect(Head):    7.48%     Solids Effect(Eff):    5.23%
    Head (ft of slurry):   155.1        Pump Efficiency :    71.6%
   NPSHR (ft of slurry):     9.4         Pump Power (HP):  1001.9
```

```
 2  Assembly 7450D     18  x20  WBC 54        C H11- 1/ 2/ 3ME11- 1/ 4
            Test Basis: T118 -85     Design Imp Dia(in):   54.000
  Maximum available HP:    1500.     Actual Imp Dia(in):   52.000
              Pump RPM:     505.  Motor Characteristics: Synchronous
   Solids Effect(Head):    6.96%     Solids Effect(Eff):    4.87%
   Head (ft of slurry):   228.1        Pump Efficiency :    75.4%
  NPSHR (ft of slurry):    10.5         Pump Power (HP):  1400.0

 3  Assembly 3195D     18  x18  WBC 46        C H11- 1/ 2/ 3ME11- 1/ 4
            Test Basis: T118 -85     Design Imp Dia(in):   46.000
  Maximum available HP:    1250.     Actual Imp Dia(in):   46.000
              Pump RPM:     505.  Motor Characteristics: Synchronous
   Solids Effect(Head):    7.77%     Solids Effect(Eff):    5.44%
   Head (ft of slurry):   169.3        Pump Efficiency :    78.0%
  NPSHR (ft of slurry):    12.6         Pump Power (HP):  1003.8
```

Flow (GPM)	System Resistance (ft)	Pump Head (ft)
10000.	557.9	573.7
11000.	550.2	566.0
12000.	549.5	557.9
13000.	554.7	549.3
14000.	564.9	540.1
15000.	579.6	530.3
16000.	598.2	519.9
17000.	620.4	508.9
18000.	646.0	497.2
19000.	674.7	484.8

COMMENTS:
System evaluation-50% solids
Per changes 06/18/2007
20" pipe

Wingate dredge evaluation-50%

```
                                   SLYSEL
                            Version 20070618/  -10101     GIW Industries, Inc.
Item # : one                                              Grovetown, GA  USA
Reference: Wingate Creek Mine                             Date: Jun-21-2007
Application: Production Dredge                            Time: 10:31:20

                          Settling Slurry Information
Fluid Temperature (F) ....    70.0   Viscosity (lbf-s/ft^2) ....0.0000205
Fluid specific gravity ...   0.998   Gravity (ft/s^2) ..........   32.17
D50 (microns) ............    510.   D85 (microns) .............   1200.
Particle Shape Factor ....   0.260   % of Fine particles < 74 microns  0.
Solids S.G. ..............    2.65   Slurry S.G. ................   1.450
Concentration by WEIGHT ..   50.0%   Concentration by VOLUME ....   27.4%
Coefficient of mechanical-sliding friction = .40

Conduit Information
Section    Roughness    Dia.  Pipe Len  Rise  Total K  Disch
            "E" ft       in       ft     ft    Value    psi
-------------------------------------------------------------------------
Suct  # 01 0.000050     20.0     25.0    0.0    2.0     0.0
Disch # 01 0.000050     19.0   1200.0   72.0    2.0     0.0
Disch # 02 0.000050     19.0   5150.0   35.0    2.0     0.0
Disch # 03 0.000050     19.0   3500.0   35.0    2.0     0.0

Static Head Information for a Dredge
A negative number indicates a position below the pump centerline
and a suction pipe below the water level.

Vertical distance from the:  up(+)/down(-)
     Water surface to suction pipe inlet    (ft) ........  -92.0
     Pump centerline to suction pipe inlet  (ft) ........  -20.0
     Effective suction depth                (ft) ........   43.4
     Pump centerline to final discharge     (ft) ........  142.0
     Suction Elevation      (ft Above Sea Level) ........  100.0

System Evaluation
  Minimum Friction Point | Deposit Data  | Deposit Data (Worst Case,D50=500)
  For The Given Sections | @D50,Cw=50.0% |    @Cw=50.0%        @Cw=28.6%
            ft/s     GPM  | ft/s    GPM   |  ft/s      GPM    ft/s      GPM
-------------------------------------------------------------------------
Suct  # 01  5.3   5140.8 | 10.1   9882.8 |  10.2    9982.2   14.2   13908.3
Disch # 01 12.3  10914.0 | 10.0   8820.8 |  10.1    8909.7   14.4   12724.1
Disch # 02 13.3  11797.7 |  9.7   8601.5 |   9.8    8688.2   13.9   12274.4
Disch # 03 13.1  11620.9 |  9.7   8614.8 |   9.8    8701.6   13.9   12301.9
Recommended Minimum Flow:  15000.  GPM
All Head loss values are in ft of slurry
Static Head (ft) =    98.6

 Flow    Total  NPSHA   Suct  # 01    Disch # 01    Disch # 02    Disch # 03
          TDH           Vel   Loss    Vel   Loss    Vel   Loss    Vel   Loss
( GPM  )  (ft)   (ft)   (ft/s) (ft)   (ft/s) (ft)   (ft/s) (ft)   (ft/s) (ft)
-----------------------------------------------------------------------------
 10000.  557.9  61.8   10.2    4.4   11.3   57.9   11.3  235.6   11.3  161.4
 11000.  550.2  61.2   11.2    5.0   12.4   57.4   12.4  230.8   12.4  158.4
 12000.  549.5  60.4   12.3    5.7   13.6   57.8   13.6  229.6   13.6  157.8
 13000.  554.7  59.6   13.3    6.5   14.7   59.0   14.7  231.3   14.7  159.3
 14000.  564.9  58.8   14.3    7.4   15.8   60.8   15.8  235.5   15.8  162.6
 15000.  579.6  57.8   15.3    8.3   17.0   63.2   17.0  242.0   17.0  167.4
 16000.  598.2  56.8   16.3    9.4   18.1   66.1   18.1  250.5   18.1  173.5
 17000.  620.4  55.7   17.4   10.5   19.2   69.6   19.2  260.8   19.2  181.0
 18000.  646.0  54.5   18.4   11.6   20.4   73.4   20.4  272.8   20.4  189.5
 19000.  674.7  53.3   19.4   12.9   21.5   77.7   21.5  286.3   21.5  199.2

COMMENTS:
System evaluation-50% solids
Per changes 06/18/2007
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Wingate dredge psi calc-50%-20in

SLYSEL
Version 20070618/ -10101

GIW Industries, Inc.
Grovetown, GA USA

Item # : three
Reference: Wingate Creek Mine
Application: Production Dredge

Date: Jun-21-2007
Time: 10:16:54

- Pump Spacing and Steady Head Distributions -

Length along pipe (ft)	Description	Head (ft-slurry)	Cavitation
0.0	Before 1th Conduit	43.4	OK
25.0	After 1th Conduit	37.2	OK
25.0	Suction of pump # 1	37.2	OK
25.0	Discharge of pump# 1	192.3	OK
25.0	Before 2th Conduit	192.3	OK
1225.0	After 2th Conduit	61.8	OK
1225.0	Suction of pump # 2	61.8	OK
1225.0	Discharge of pump# 2	289.9	OK
1225.0	Before 3th Conduit	289.9	OK
6375.0	After 3th Conduit	24.5	OK
6375.0	Suction of pump # 3	24.5	OK
6375.0	Discharge of pump# 3	193.9	OK
6375.0	Before 4th Conduit	193.9	OK
9875.0	After 4th Conduit	0.3	OK
9875.0	Plant Discharge	0.3	OK

Pump #	Suction PR. (psi)	Discharge PR. (psi)
1	23.35	120.74
2	38.80	182.01
3	15.40	121.72

COMMENTS:
System evaluation-50% solids-pressure
Per changes 06/18/2007
20" pipe