EQUIPMENT ARMOR INC.

AN EXAMPLE OF **MISDIRECTION AND COMPLACENCY** IN THE MINING INDUSTRY

Tim Nickodemus
President
TERMINOLOGY

- **Monolithic Sheet** – A sheet of standard polycarbonate (PC).
- **Laminated Sheet** – Composite PC sheet consisting of multiple layers.
- **Lexan, Makrolon, Palguard** - trade names for PC.
- **Lexguard** - Trade name of laminated PC.
- **Fissures** – Microscopic breaks in molecular chains of PC.
- **Embrittlement** – Structural molecular weakening of PC.
- **Coating** – A mar or abrasion resistant hard coating that extends sheet life.
- **Equipment Armor Shield** – Composite monolithic PC assembly.
- **Sacrificial layer** – 1/8” sheet of high optic hard coated PC.
- **UL 752 Ballistic Rating** - Level 1 – 9mm, Level 2 – 357.
- **Mounting Brackets** – Brackets that bolt to machine bosses.
- **Sub-frame (black)** - mounts to brackets.
- **Shield Frame (yellow)** - mounts to the sub-frame and holds the Equipment Armor Shield.
AUGUST 2015 – A ½ LB. PIECE OF HAMMER STEEL PENETRATED A ¼ SHEET OF LEXAN MOUNTED ON AN EXCAVATOR RUNNING A 16,000 LB. HAMMER
PASSING THROUGH THE WINDSHIELD IN FRONT OF OPERATOR
AND OUT THE BACK GLASS
THE PROJECTILE AREA - 2”X1.5”X1.0”, WEIGHT - .5 POUND
IN SUMMARY:
THE FACTS, AND NOTHING BUT THE FACTS

- A ½ pound piece of hammer steel penetrated ¼” sheet of polycarbonate.
- It continued through the windshield and out the back glass missing the operator by inches.
- The projectile was found approximately 60 yards (180 feet) from the back of the cab.
- The projectile was traveling at a speed of 240 to 400 miles per hour.
- If the operator of the machine had been struck it would have resulted in a fatality.
OUR **MISDIRECTED FOCUS**

- Was To protect the windshield.

- Should have been protecting the operator from serious injury or death.

- Both the hammer (**NPK**) and tool (**Allied**) manufacturer gave **WARNINGS** on their products regarding shielding.
NPK HAMMER WARNING - • DO NOT OPERATE HAMMER WITHOUT AN IMPACT RESISTANT GUARD BETWEEN HAMMER AND OPERATOR. NPK RECOMMENDS LEXAN® OR EQUIVALENT MATERIAL, OR STEEL MESH.
ALLIED HAMMER POINT
THE OPERATOR MUST BE FULLY PROTECTED BY A PROTECTIVE SHIELD BETWEEN THE OPERATOR AND THE HAMMER.
NPK Service Department – “No standards”, but a $\frac{1}{4}''$ to $\frac{1}{2}''$ sheet of Lexan is known to work in protecting the windshield from flying rock.

Allied Construction Products Service Department – “No industry standards” but they recommend a bullet resistant Lexan.
Our complacency is presuming a sheet of polycarbonate will protect the operator from serious injury or death.
“SOLVE THE PROBLEM”

- GE Plastics Division (now SABIC)
- Mr. Joe Brown, Heavy Equipment Market Manager visited one of our local mines.
- “ABSOLUTELY NOT - Standard PC is not designed as a protective barrier from high velocity projectiles.”
  - Bullet Resistant - UL 752 Rating Levels 1 through 4.
  - The uniqueness of the application.
  - ROPS vs. FOPS.
PRODUCT RECOMMENDATIONS
The GE (SABIC) PC Engineering Group recommended:

- Lexguard MPC375 (3/8”) (UL752 - Level 1-9MM) for hammers up to 8000 lbs..
- Lexguard MPC500 (½”) (UL752 - Level 2 - .357) for hammers over 8000 lbs..
- A coated cover sheet to extend sheet life by 2 to 3 times over standard PC sheet.
- Cost was an issue - $3K to 5K per sheet.
BALLISTIC FIELD TESTING
MORE QUESTIONS THAN ANSWERS.

Actual Field Testing of GE (SABIC’s) recommendations.

- Test #1 – Standard monolithic vs. laminated Sheet
- Test #2 – Level 1 Testing – Composite Shield
- Test #3 – Level 2 Testing – Composite Shield
- Test #4 – Validate Testing Protocol
<table>
<thead>
<tr>
<th>Test</th>
<th>Date</th>
<th>Product</th>
<th>Base Thickness</th>
<th>Base Product</th>
<th>Cover Thickness</th>
<th>Cover Product</th>
<th>Caliber</th>
<th>Grain</th>
<th>Type</th>
<th>Distance</th>
<th>Temp</th>
<th>Humidity</th>
<th>PASS/FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/6/2015</td>
<td>Monolithic</td>
<td>1/2&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>73</td>
<td>76%</td>
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<td>158</td>
<td>JHP</td>
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<td>73</td>
<td>76%</td>
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<td>3</td>
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<td>N/A</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
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<td>73</td>
<td>76%</td>
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<td>MPC500</td>
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<td>N/A</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>73</td>
<td>76%</td>
<td>FAIL</td>
<td></td>
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<tr>
<td>5</td>
<td>11/6/2015</td>
<td>Monolithic</td>
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<td>N/A</td>
<td>9mm</td>
<td>124</td>
<td>FMJ</td>
<td>15 FT.</td>
<td>73</td>
<td>76%</td>
<td>FAIL</td>
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<td>N/A</td>
<td>9mm</td>
<td>124</td>
<td>FMJ</td>
<td>15 FT.</td>
<td>73</td>
<td>76%</td>
<td>FAIL</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>11/6/2015</td>
<td>MPC500</td>
<td>1/2&quot;</td>
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<td>N/A</td>
<td>9mm</td>
<td>124</td>
<td>FMJ</td>
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<td>76%</td>
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<td></td>
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<td>8</td>
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<td>MPC500</td>
<td>1/2&quot;</td>
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<td>N/A</td>
<td>9mm</td>
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<td></td>
</tr>
</tbody>
</table>

**TEST #1 - MORE RESEARCH NEEDED**
LEXGUARD – MPC 500 Laminate alone maintains no UL752 ballistic rating, but is used as a component in systems that include laminated safety glass and an appropriate air space to achieve varying ballistic ratings.
<table>
<thead>
<tr>
<th>Test</th>
<th>Base</th>
<th>Base</th>
<th>Cover</th>
<th>Cover</th>
<th>Caliber</th>
<th>Grain</th>
<th>Type</th>
<th>Distance</th>
<th>Temp</th>
<th>Humidity</th>
<th>PASS/FAIL</th>
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<td>9</td>
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<td>Monolithic</td>
<td>1/4&quot;</td>
<td>9mm</td>
<td>124</td>
<td>FMJ</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Fail</td>
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<tr>
<td>10</td>
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<td>Monolithic</td>
<td>1/4&quot;</td>
<td>9mm</td>
<td>124</td>
<td>FMJ</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Fail</td>
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<tr>
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<tr>
<td>12</td>
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<td>Monolithic</td>
<td>1/4&quot;</td>
<td>9mm</td>
<td>124</td>
<td>FMJ</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Fail</td>
</tr>
</tbody>
</table>

1. The first shot held but subsequent shots failed.

2. This test revealed that fissures were developing after the first shot.

TEST #2 – LEVEL 1 – COMPOSITE SHEET – 9MM FAILED
### TEST #3 – LEVEL 2 – COMPOSITE SHEET - .357 PASSED

<table>
<thead>
<tr>
<th>Plate</th>
<th>Date</th>
<th>Product</th>
<th>Thickness</th>
<th>Product</th>
<th>Thickness</th>
<th>Caliber</th>
<th>Grain</th>
<th>Type</th>
<th>Distance</th>
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<tbody>
<tr>
<td>13</td>
<td>11/8/2015</td>
<td>Monolithic</td>
<td>1/2&quot;</td>
<td>Monolithic</td>
<td>1/4&quot;</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Pass</td>
</tr>
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<td>14</td>
<td>11/8/2015</td>
<td>Monolithic</td>
<td>1/2&quot;</td>
<td>Monolithic</td>
<td>1/4&quot;</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Pass</td>
</tr>
</tbody>
</table>

1. ½” monolithic sheet was strong enough to use as a base for composite shields
2. Perhaps the hollow point was too soft to use in testing and we needed to use an actual piece of a hammer tool.
## TEST #4 – UL752 - LEVEL 2 TESTING PROTOCOL VERIFICATION

<table>
<thead>
<tr>
<th>Base Plate</th>
<th>Date</th>
<th>Product</th>
<th>Thickness</th>
<th>Cover Plate</th>
<th>Date</th>
<th>Product</th>
<th>Thickness</th>
<th>Caliber</th>
<th>Grain</th>
<th>Type</th>
<th>Distance</th>
<th>Temp</th>
<th>Humidity</th>
<th>PASS/FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>11/8/2015</td>
<td>MPC500</td>
<td>1/2&quot;</td>
<td>Monolithic</td>
<td>11/8/2015</td>
<td>MPC500</td>
<td>1/4&quot;</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Pass</td>
</tr>
<tr>
<td>16</td>
<td>11/8/2015</td>
<td>MPC500</td>
<td>1/2&quot;</td>
<td>Monolithic</td>
<td>11/8/2015</td>
<td>MPC500</td>
<td>1/4&quot;</td>
<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Pass</td>
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<tr>
<td>17</td>
<td>11/8/2015</td>
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<td>Monolithic</td>
<td>11/8/2015</td>
<td>MPC500</td>
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<td>0.357</td>
<td>158</td>
<td>JHP</td>
<td>15 FT.</td>
<td>54</td>
<td>47</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Test #1 – A composite shield is needed to “manage energy”.

Test #2 – Fissures developed after the first catastrophic incident leading to a failure.

Test #3 – Passed but the actual projectile was critical to real world testing.
INDEPENDENT TESTING OF 
THE COMPOSITE SHIELD

Testing protocol:

- Use **actual pieces of a hammer point** that have been cut to size.

- Shoot the sample projectiles at shields constructed of **composite monolithic, and laminated sheets**.

- Attempt to obtain **velocities between 240 mph and 400 mph**.
The Test Lab:

- We considered three test labs:
  - Sabic (GE) – Boston, MA.
    - Cannon designed to shoot forestry cutting head teeth - speeds limited to 230 mph.
  - Intertek – Architectural Testing – Springdale, PA
    - Cannon designed to shoot the “Dade County and Miami 2x4” for hurricane testing resulted in only 125 mph with our projectile.
  - Intertek – Ballistic Testing – York, PA
    - They designed and built a cannon to shoot our projectile achieving a speed of 300 mph in testing.
AIR CANNON

200 psi air tank with butterfly valve and 8 foot long 6” Cast Iron Barrel.
LASER SPEED METERS

Measures speed (FPS) of projectile by passing through the first meter and triggering the computer to measure time until the second meter is tripped.
Tested Three Plates

- Plate 1 – ½” Monolithic sheet.
- Plate 2 – Monolithic Base Composite shield.
- Plate 3 – Laminated Base Composite Shield.

THE TEST SUBJECTS
Plate 1 – The first two shots at 235 and 224 MPH showed impact points but no noticeable cracking. However, at the molecular level there were fissures developing throughout the plate.
On the third shot at 243 mph, the plate exploded.
The explosion of Plate #1 as a result of shot 3, documented the circular pattern prominent in fissure development throughout the testing.
PREPARING TO TEST THE SHIELD/BLAST PLATES, SECURING THE FRAME

An actual Equipment Armor Shield Frame was used for the testing. It was attached to a wooden/metal buck system for support.
PLATE #2
MONOLITHIC COMPOSITE PLATE

Test Results

- Shot 1 – 406 fps, 276mph
  - Results – Pass – Cover plate penetration.
- Shot 2 – 256 fps, 175mph
  - Results – Pass.
- Shot 3 – 379 fps, 258mph
  - Results – Pass.
- Shot 4 – 369 fps, 252mph
  - Results – Pass – Cover plate penetration.
PLATE #3 LAMINATED COMPOSITE PLATE

Test Results

- **Shot 1** - 376 fps, 256 mph
  - Results – Pass.

- **Shot 2** – 250 fps, 175 mph
  - Results – Pass.

- **Shot 3** – 325 fps, 222 mph
  - Results – Cover plate breakout – physical representation of fissures.

- **Shot 4** – 356 fps, 243 mph
  - Results – Pass – Visual representation of fissures.

- **Shot 5** – 438 fps, 299 mph
  - Results – Pass – Visual representation of fissures.
Plate 2 showed the greatest amount of base plate deflection with Shot #4 at 252 mph.

Plate 2 did not show the amount of fissuring on the cover plate that was shown by Plate 3.

Plate 3 did not show significant base plate deflection.

Plate 3 showed fissuring in the cover plate at each impact plus an actual break out on Shot #3 at 222 mph.
FINAL SHIELD RECOMMENDATIONS

- 1/8”, 1/4”, and 1/2” polycarbonate sheet alone is inadequate to prevent catastrophic events from occurring.
- A composite shield is capable of providing catastrophic incident protection.
- Given the difference in base plate deflection from 175 mph to 300 mph, a composite shield is capable of withstanding impact up to 400 mph.
- The life of a composite shield would be limited by embrittlement and fissuring.
CURRENT VALIDATION – ON ALL MATERIALS PURCHASED
UL752 - BALLISTIC TESTING
LEVEL 1 9MM AND LEVEL 2 .357
THE DEVELOPMENT OF THE EQUIPMENT ARMOR PROTECTION PACKAGE

Frame Development Considerations

- Size of shield needed and contour of cab.
- Rops vs. Fops.
- Welding versus bolting.
- Number of bosses and the weight they can support.
THE “ORIGINAL” EQUIPMENT ARMOR SHIELD FRAME.

THE INHERENT PROBLEMS WITH VERSION #1 WERE IN THE APPLICABILITY OF THE FRAME:

1. WELD ON ONLY DESIGN.
2. VIOLATION OF ROPS CERTIFICATION.
3. APPLICABLE TO OLDER CABS ONLY (FOPS).
VERSION #2 THE DEVELOPMENT OF THE EQUIPMENT ARMOR PROTECTION PACKAGE

1. Custom mounting brackets bolt directly to Cab Bosses.

2. Maintains integrity of ROPS Certification.

3. Sub Frame with adjustable mounted Hinges, T-Locks, and Locking Pin, bolting directly to the mounting brackets.

4. Shield frame mounts on three barrel hinges for ease of service.
“THE EQUIPMENT ARMOR PROTECTION PACKAGE”

1. Gussets on all corners front and back of shield frame and sub frame.

2. Wider shield frame opening to allow for sacrificial layer.

3. Doubler plate on bottom of sub-frame to provide greater support.

4. Additional holes on sub frame to allow for more bracketing options and sub frame wrap application.

5. The Equipment Armor shield Frame opens and closes like a door allowing for easy access to the windshield for cleaning.
HOW STRONG IS IT?

Three Examples of IMPACT!!!
1. Outer layer Penetration
2. Boulder Impact on Frame
3. Bucket Impact on Frame
ACTUAL SHIELD OUTER LAYER BREAK THROUGH.

Occurred on a rental machine. This is the lower center of the windshield just above the frame. The projectile was headed directly toward the operators lower torso.
A BOULDER FELL OFF THE HIGH WALL, BOUNCED OFF A BERM AND SLAMMED INTO THE LOWER BOOM SIDE OF THE SHIELD
THE SHIELD FRAME SUFFERED MINOR BENDING.
THE SUB-FRAME AND BRACKETS TOOK A BULK OF THE IMPACT.
The cab retained its original structure and the operator was secure.
A FIVE YARD BUCKET ON A CAT 345 SLAMMED INTO THE SHIELD WHEN THE HYDRAULICS MALFUNCTIONED DURING MAINTENANCE.
THE SHIELD ABSORBED THE ENERGY. STOPPING THE BUCKET WITHOUT INJURY TO THE OPERATOR OR DAMAGE TO THE CAB.
Starting in March of 2016 through October 1, 2018
Examined data from 63 machines:
13 machines or 21% - 3 to 8 months (High Volume Quarry)
39 machines or 62% - 9 to 15 months
8 machines or 13% - 16 to 21 months
3 machines or 5% - 22 to 28 months
Note: High volume quarries with 3 to 8 month shield life are being converted to the sacrificial layer program. Utilizing the sacrificial layer shield life can realistically be expected to reach 24 months before visibility becomes an issue.
Notes

- Equipment Armor Protection Package cost includes Frame Package, Custom Brackets, Sub-Frame Wrap, and installation at Dealer List of $5555.00 for Komatsu and $6000.00 for CAT. (20% mark up)

- A standard volume quarry would replace 1/4" or 1/2" polycarbonate sheet 2 x year

- Shield replacement is estimated at 1 year intervals with 62% of machines in the field running 9 to 15 months before replacement.

- Replacement costs for 1/4" or 1/2" Polycarbonate sheet include $500 in labor per change and $250 for the 1/4" sheet and $500 for the 1/2" sheet for standard polycarbonate.

- Estimated frame cost of $2500 is for an inhouse fabricated metal frame which the polycarbonate sheet would fasten to.

- Machine down time is estimated at 1000 tons per day at $2.50 per ton cost = $2500 per day for a ten hour day or $250 per hour.

- A high volume quarry would replace their 1/4" or 1/2" polycarbonate sheet 4 x year.

- The Sacrificial Layer is an 1/8" high optics hard coated sheet sitting in front of the shield. It is replaced every four months and can prolong the shield life up to two full years.
<table>
<thead>
<tr>
<th>Equipment Armor Protection Package Cost - Standard Volume Quarry</th>
<th>Year 1</th>
<th>Year 2-6</th>
<th>Total</th>
<th>Annual</th>
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<tbody>
<tr>
<td>Komatsu - Year 1 reflects cost of Equipment Armor Package Installed</td>
<td>$ 5,555</td>
<td>$ 1,800</td>
<td>$14,555</td>
<td>$ 2,425</td>
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<tr>
<td>Machine Down Time - 4 hours installation.</td>
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<td>$ 2,250</td>
<td>$ 375</td>
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<td>Total Cost</td>
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<td>$ 2,050</td>
<td>$16,805</td>
<td>$ 2,801</td>
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<td>Caterpillar - Year 1 reflects cost of Equipment Armor Package Installed</td>
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<td>$ 1,800</td>
<td>$15,000</td>
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<tr>
<td>Machine Down Time - 5 hours installation.</td>
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<td>$ 250</td>
<td>$ 2,500</td>
<td>$ 416</td>
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<tr>
<td>Total Cost</td>
<td>$ 7,250</td>
<td>$ 2,050</td>
<td>$17,500</td>
<td>$ 2,917</td>
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<table>
<thead>
<tr>
<th>Standard Volume Quarry - 1/4&quot; Polycarbonate</th>
<th>Year 1</th>
<th>Year 2-6</th>
<th>Total</th>
<th>Annual</th>
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<tbody>
<tr>
<td>Total PC Costs per year installed - Reflect $2500 frame cost plus annual PC Cost</td>
<td>$ 4,000</td>
<td>$ 1,500</td>
<td>$11,500</td>
<td>$ 1,917</td>
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<tr>
<td>Machine Down Time - 4 hours installation - 4 hours annual service time 2x year</td>
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<td>$ 2,000</td>
<td>$ 12,000</td>
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<tr>
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<th>Year 1</th>
<th>Year 2-6</th>
<th>Total</th>
<th>Annual</th>
</tr>
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<td>$ 2,416</td>
</tr>
<tr>
<td>Machine Down Time - 4 hours installation - 4 hours annual service time 2x year</td>
<td>$ 2,000</td>
<td>$ 2,000</td>
<td>$ 12,000</td>
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<td>Total Cost</td>
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<td>Annual</td>
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<td>-----------------------------------------------------------------</td>
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<tr>
<td><strong>1. Equipment Armor Protection Package Cost - High Volume Quarry</strong></td>
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<tr>
<td>Komatsu - 6 Years - Add for 2 Sacrificial Layers ($5555+$708)</td>
<td>$6,263</td>
<td>$8,202</td>
<td>$14,465</td>
<td>$2,411</td>
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<tr>
<td>Machine Down Time - 4 hour installation - 3 hour annual service time.</td>
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<td>$3,750</td>
<td>$5,250</td>
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<tr>
<td>Total Cost</td>
<td>$7,763</td>
<td>$10,452</td>
<td>$18,215</td>
<td>$3,286</td>
</tr>
<tr>
<td><strong>Caterpillar - 6 years - Add for 2 Sacrificial Layers ($6000+708)</strong></td>
<td>$6,708</td>
<td>$8,202</td>
<td>$14,910</td>
<td>$2,485</td>
</tr>
<tr>
<td>Machine Down Time - 5 hour installation - 3 hour annual service time.</td>
<td>$1,750</td>
<td>$3,750</td>
<td>$5,500</td>
<td>$917</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$8,458</td>
<td>$11,952</td>
<td>$20,410</td>
<td>$3,402</td>
</tr>
<tr>
<td><strong>2. High Volume Quarry - 1/4&quot; Polycarbonate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total PC Costs per year installed - Reflect $2500 frame cost plus annual PC Cost</td>
<td>$5,500</td>
<td>$15,000</td>
<td>$20,500</td>
<td>$3,417</td>
</tr>
<tr>
<td>Machine Down Time - 4 hours installation - 4 hours annual service time 4x year</td>
<td>$4,000</td>
<td>$20,000</td>
<td>$24,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$9,500</td>
<td>$35,000</td>
<td>$44,500</td>
<td>$7,417</td>
</tr>
<tr>
<td><strong>3. High Volume Quarry - 1/2&quot; Polycarbonate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total PC Costs per year installed - Reflect $2500 frame cost plus annual PC Cost</td>
<td>$6,500</td>
<td>$20,000</td>
<td>$26,500</td>
<td>$4,417</td>
</tr>
<tr>
<td>Machine Down Time - 4 hours installation - 4 hours annual service time 4x year</td>
<td>$4,000</td>
<td>$20,000</td>
<td>$24,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$10,500</td>
<td>$40,000</td>
<td>$50,500</td>
<td>$8,417</td>
</tr>
</tbody>
</table>
SAVINGS SUMMARY

Low Volume Quarry
- $1000 over ¼” standard polycarbonate
- $1500 over ½” standard polycarbonate

High Volume Quarry
- $4000 over ¼“ standard polycarbonate
- $5000 over ½” standard polycarbonate
WHERE DO WE STAND TODAY

- Over 200 units in the Field
- Locations in Pennsylvania, Maryland, Virginia, North and South Carolina, Georgia, and Tennessee.
- Customers include: Carolina Sunrock, Komatsu Rents, Lehigh Hanson, Linder Equipment, Luck Stone, Martin Marietta, Haile Gold Mine, Hedrick Industries, Tractor Equipment, and Vulcan Materials
- Industries served: Aggregates/Mining, Metal Recycling/Shearing, Heavy Mulching/Clearing.
QUESTIONS?