

Apex Advanced Technologies Overview of Advanced Lubrication/Binder Technology

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Technologies

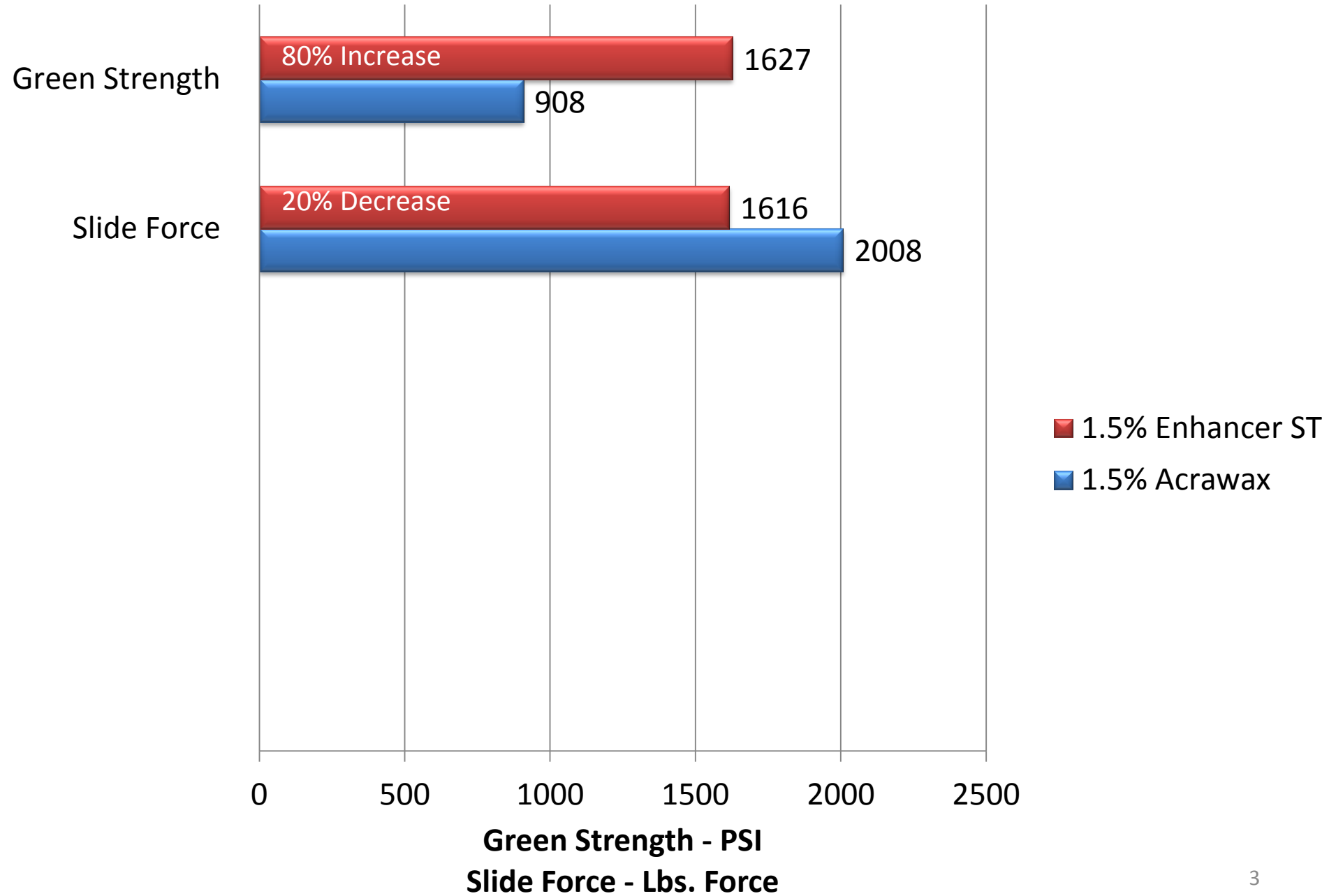
**Have you ever thought it would be
great if:**

- **A Lubricant could improve green strength and be a good lubricant at the same time**

Enhancer St

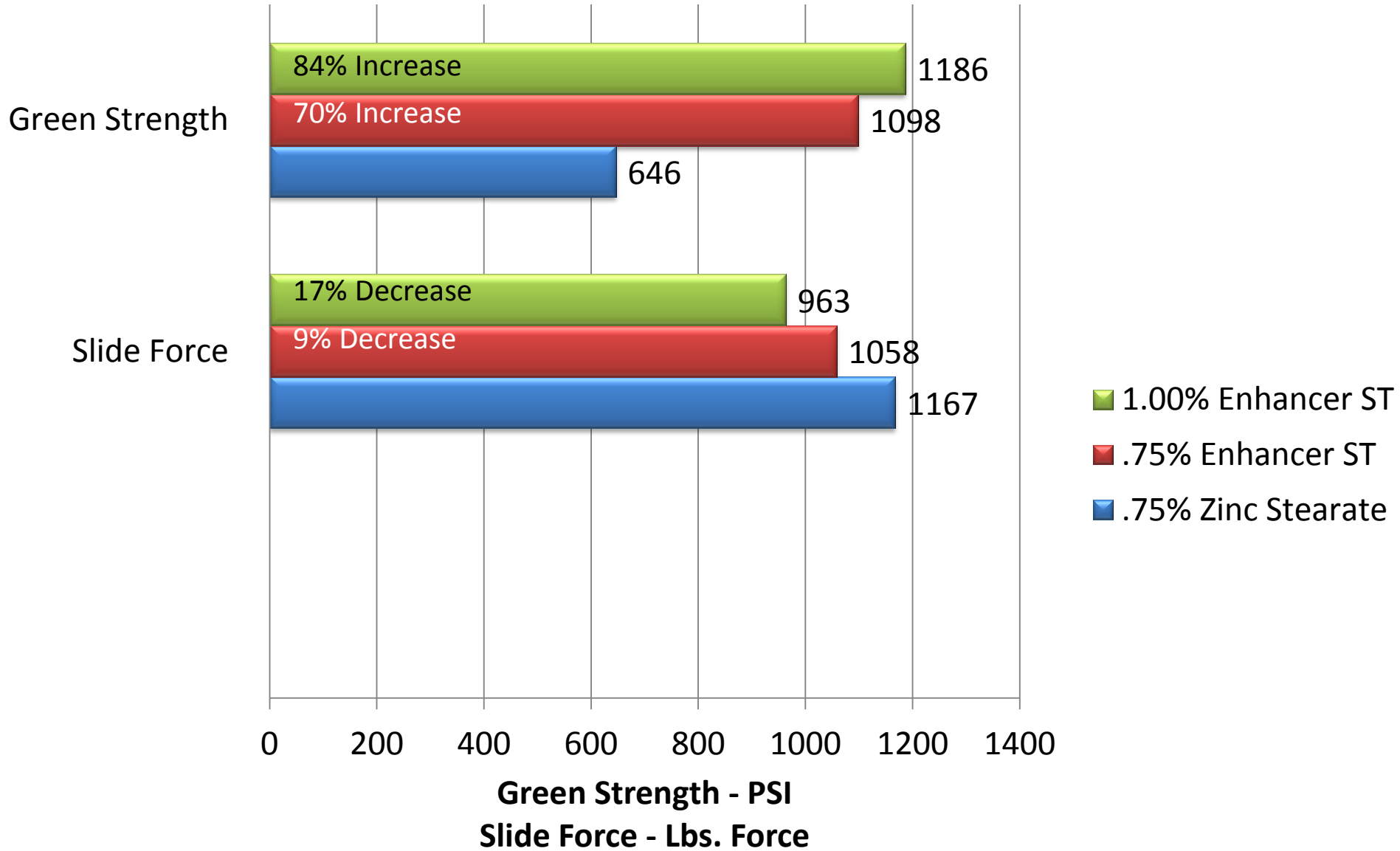
- **Modified polymer, surface treated with a lubricant**
- **Works 5.5 to 6.9g/cc range**
- **Lubricant portion allows for slippage/polymer for metal particle interlock**

Ametek 316L Stainless Steel



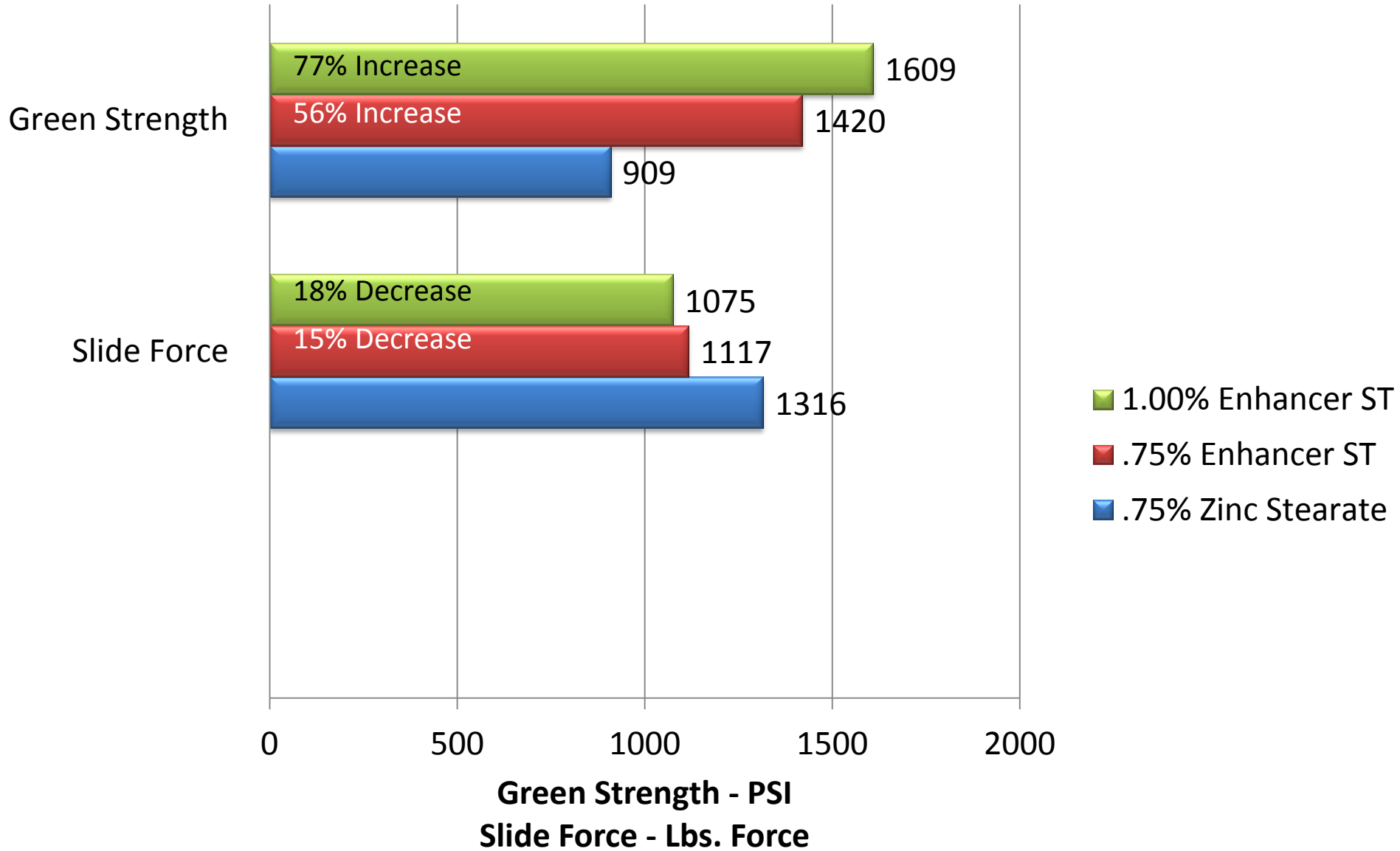
FC 0208 with Atomet 1001

Density: 6.2 g/cc



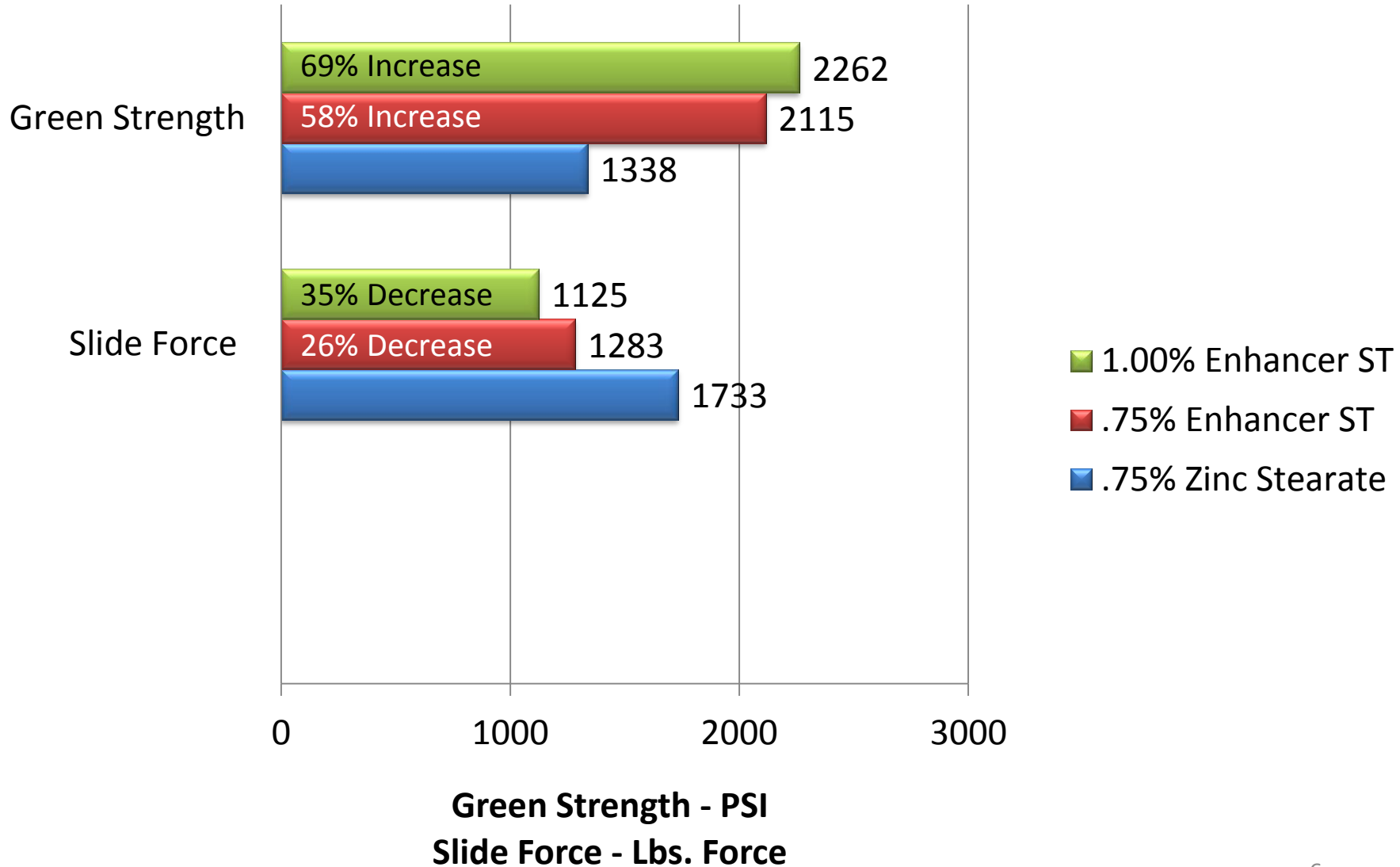
FC 0208 with Atomet 1001

Density: 6.4 g/cc

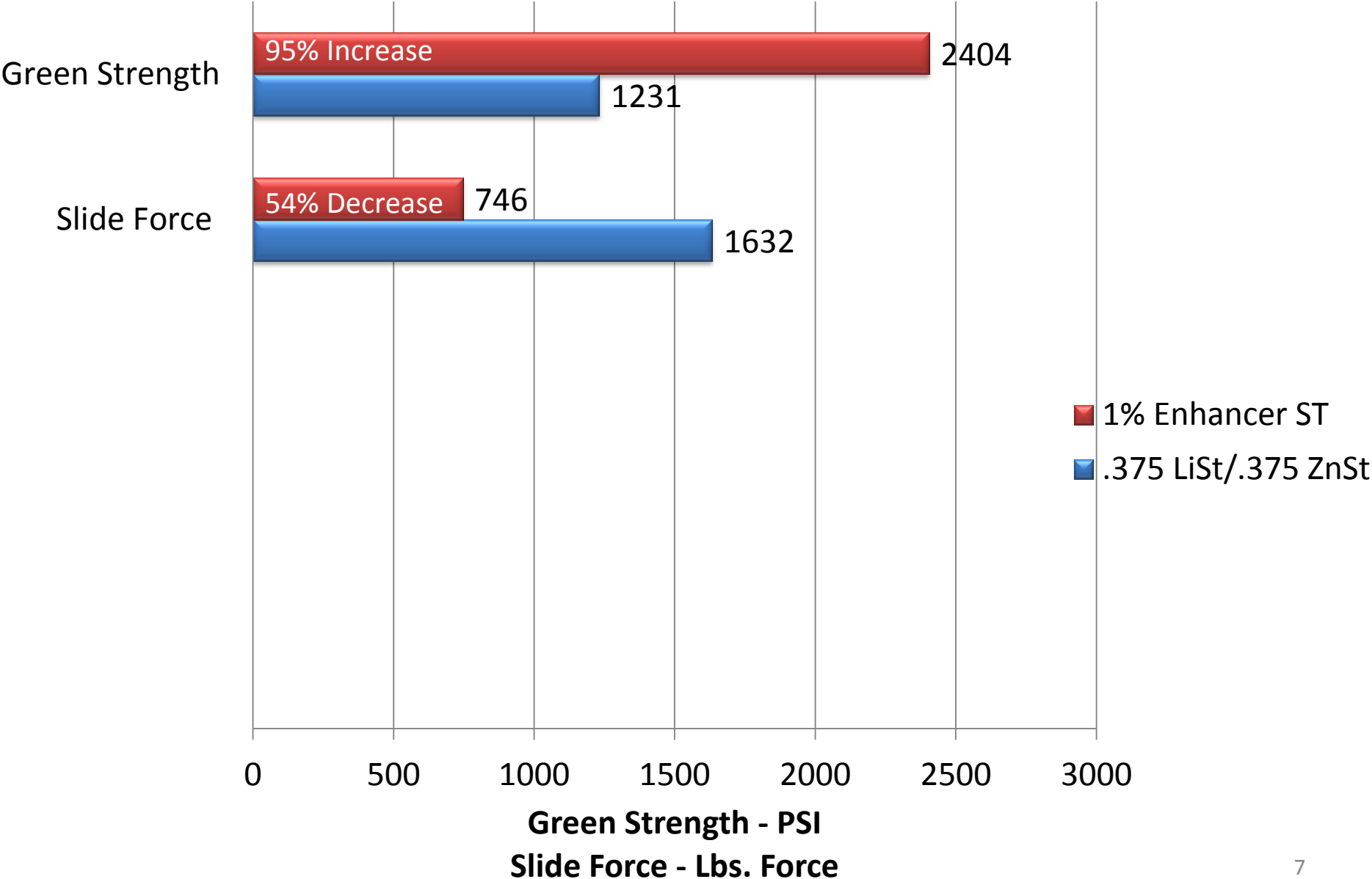


FC 0208 with Atomet 1001

Density: 6.7 g/cc



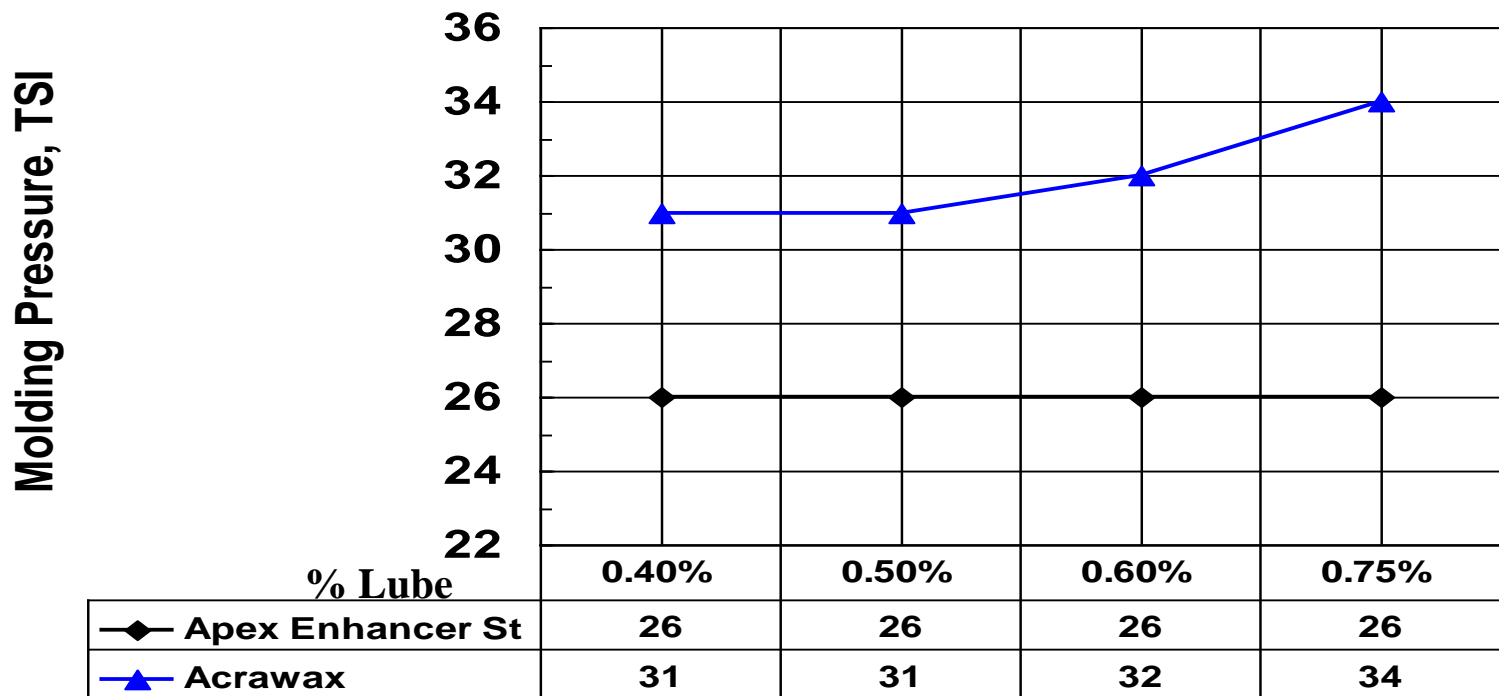
Copper U.S. Bronze Cu194 to Maximize Green Strength



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MATERIAL = FC-0208 (Density = 6.7 g/cc)

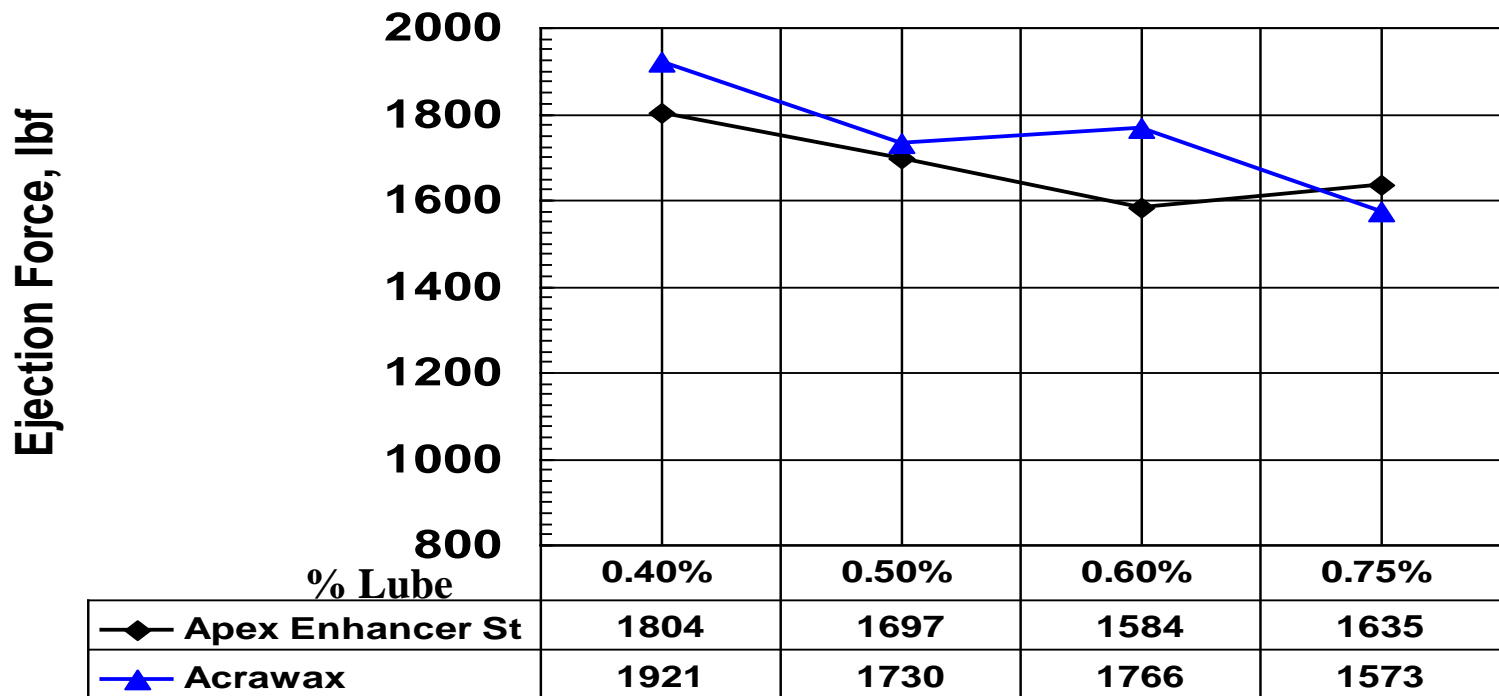
Molding Pressure / % Lube Curve



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MATERIAL = FC-0208 (Density = 6.7 g/cc)

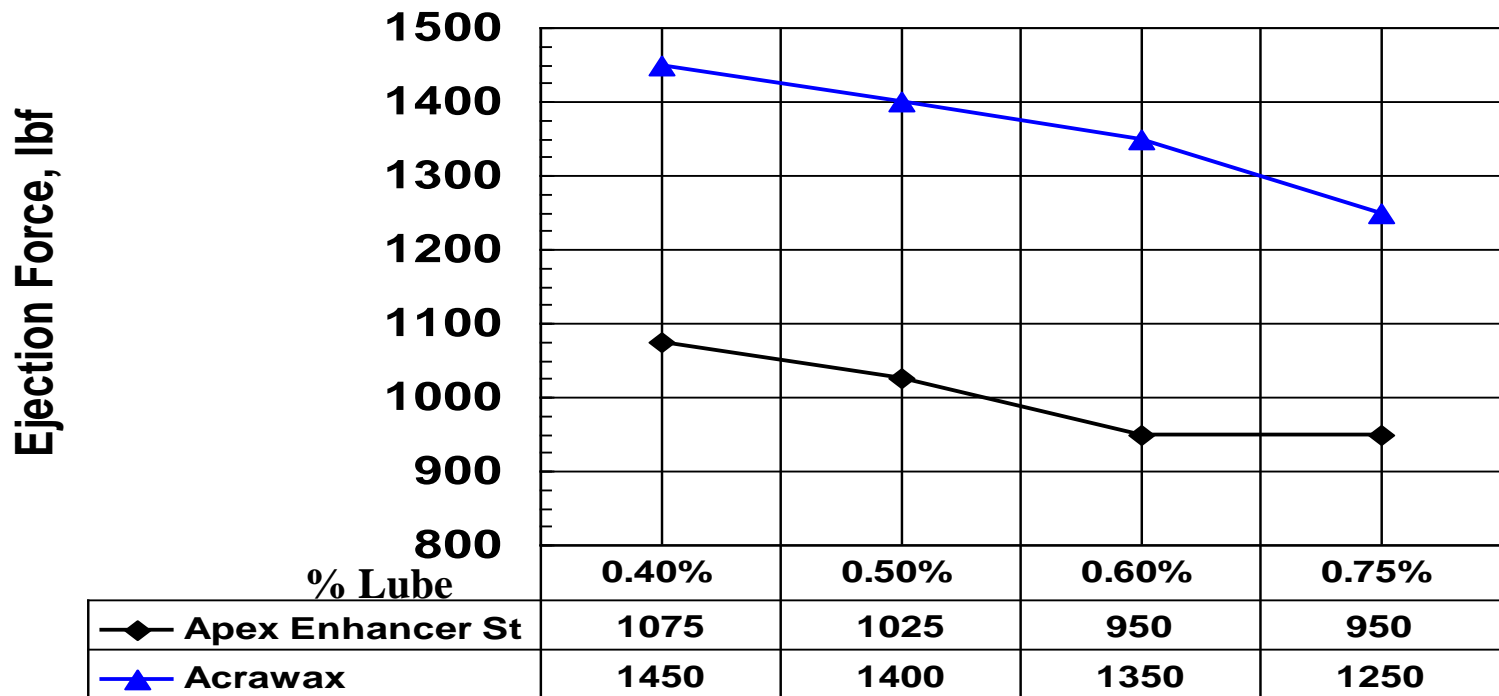
Peak Ejection / % Lube Curve



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MATERIAL = FC-0208 (Density = 6.7 g/cc)

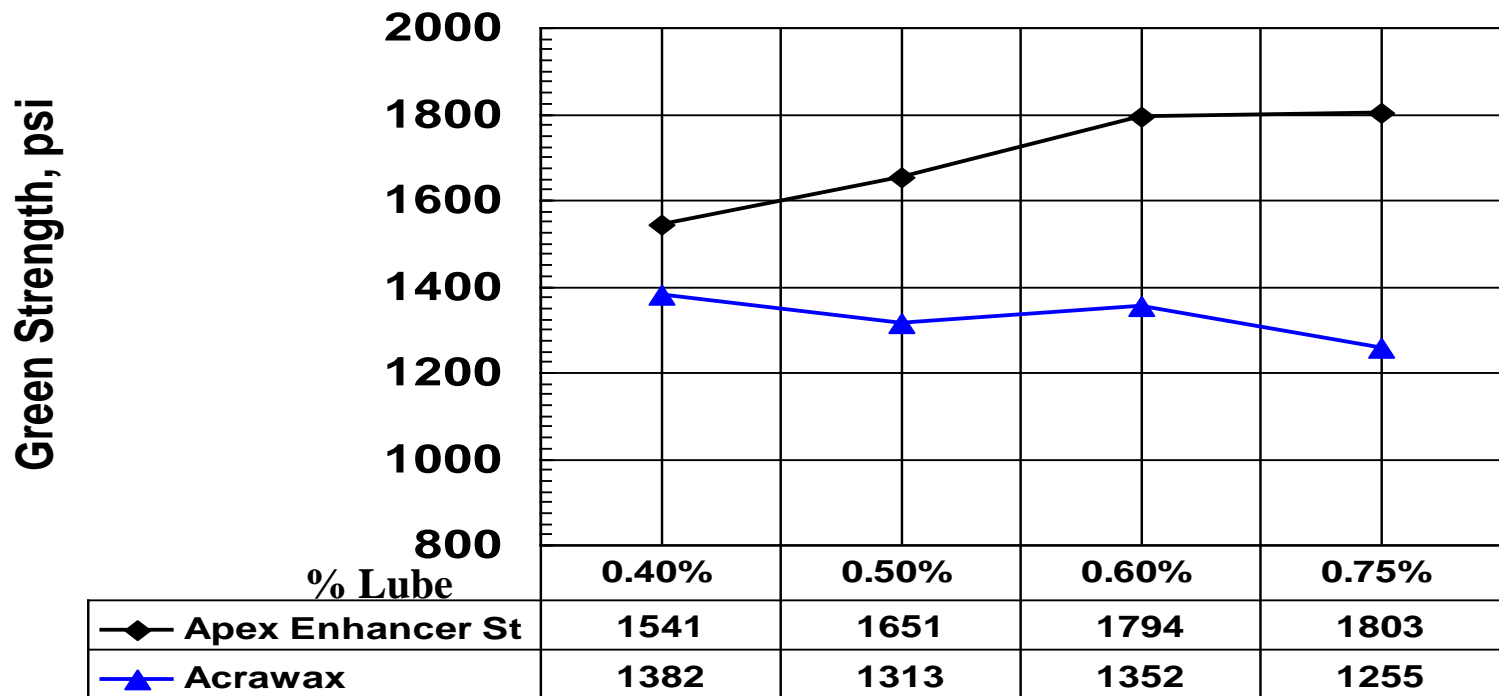
Slide Ejection / % Lube Curve



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MATERIAL = FC-0208 (Density = 6.7 g/cc)

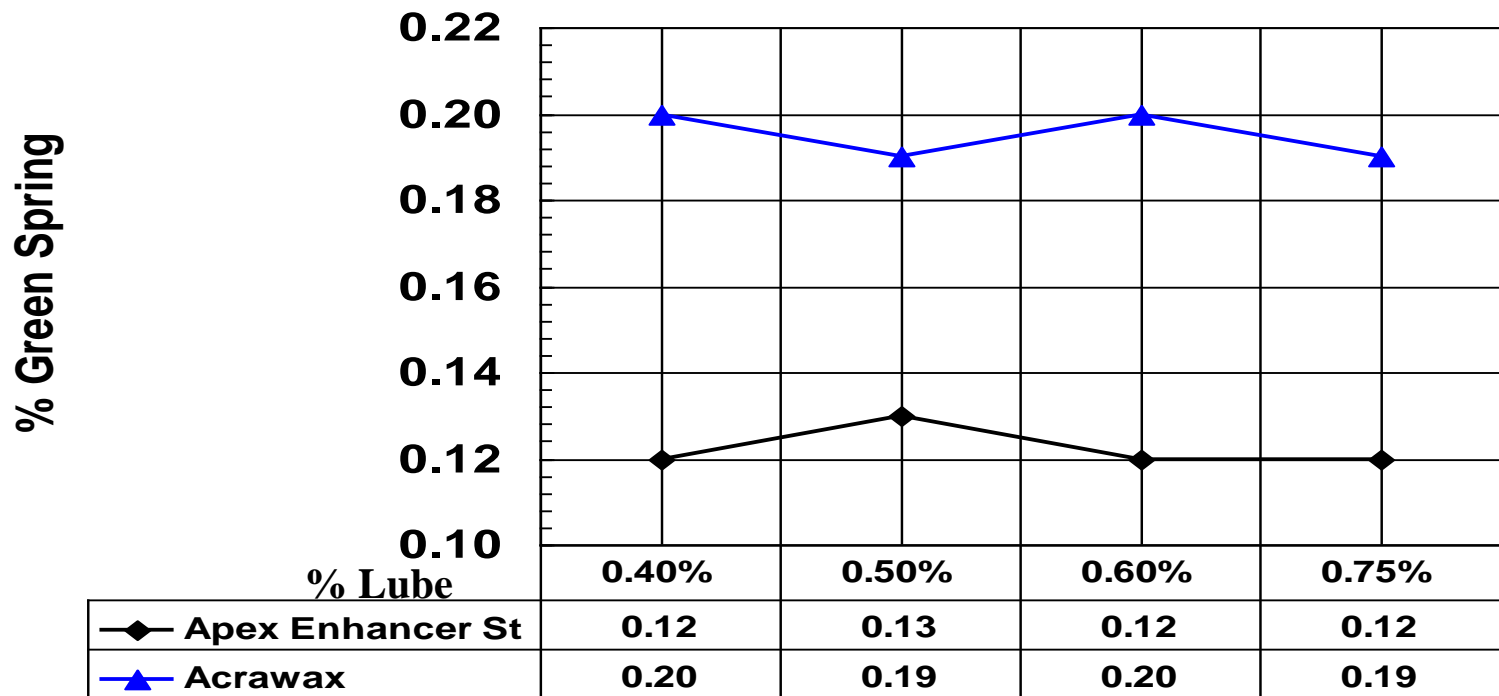
Green Strength / % Lube Curve



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MATERIAL = FC-0208 (Density = 6.7 g/cc)

% Green Spring / % Lube Curve



Have you ever thought it would be great if:

- **A Lubricant could make high density parts without complications of hot/warm compaction and without additional equipment cost?**

Apex Superlube®

- **Lubricant transforms in the press to a viscous liquid, 0.1 g/cc increase over hot/warm compaction**
- **Low use rate, the compressibility of base metal with additions control final part green density, calculate formulas with predictability**

Have you ever thought it would be great if:

- **A Lubricant could make large/complicated parts with the same ease of making small parts?**

Apex Superlube®

- **Lubricant transforms in the press to a viscous liquid, parts ride on film of liquid during ejection, low ejection forces, calculated formulas, compaction TSI reduced by as much as 27%**
- **Parts as large as ~4.1 kg**

Have you ever thought it would be great if:

- **A Lubricant could make Fe3P (0.45% P) parts or other highly abrasive mix with minimal die wear, ejection problems and at high density, without gradients and distortion after sintering?**

Apex Superlube®

- **Lubricant transforms in the press to a viscous liquid, parts ride on film of liquid during ejection, low ejection forces, calculated formulas, compaction TSI reduced, used in conjunction with Apex Enhancer St**
- **Parts as large as 0.45Kg ,parts as high as 7.3 g/cc green density**

Have you ever thought it would be great if:

- A Lubricant could make parts that have no density gradients and eliminate taper, weak points and distortion upon sintering?

Apex Superlube[®]

- Lubricant transforms in the press to a viscous liquid, semi- hydrostatic formula possible by calculation, 7.1g/cc or greater necessary for gradient elimination
- Example part 7.17g/cc 55mm tall 0.45%P composition sintered to 7.4 with no distortion

Have you ever thought it would be great if:

- **A Lubricant could be used to make copper infiltrated parts, that are stronger, use significantly less copper, have less distortion after sintering and can achieve higher densities than normal copper infiltrated parts?**

Apex Superlube®

- **Lubricant transforms in the press to a viscous liquid, semi-hydrostatic formula possible by calculation, 7.1g/cc or greater necessary**
- **Copper follows small pores from lubricant movement**
- **Iron is substituted for copper yielding higher density in the green part**

Cost Effective Copper Infiltration

- 6.6g/cc conventional to 7.4g/cc verses Apex 7.15 to 7.4 g/cc 69% savings in the copper usage
- 6.8g/cc conventional To 7.4g/cc verses Apex 7.15 to 7.4g/cc 58% saving in copper usage

Have you ever thought it would be great if:

- **A Lubricant could be used to make Nickel based parts and not have blistering problems on the parts after sintering?**

Apex Superlube®

- **Apex Superlube® has a decomposition temperature range that is significantly wider than conventional lubricants**
- **Typical formulations use less overall lube content less gas to come out of the part**
- **Apex Superlube® leaves open pores at the surface to allow gas to come out of the part without blowing holes**

Have you ever thought it would be great if:

- **A Lubricant could be used to eliminate staining on the surface of parts?**

Apex Superlube®

- **Apex Superlube® has a decomposition temperature range that is significantly wider than conventional lubricants**
- **Typical formulations use less overall lube content less gas to come out of the part**
- **Apex Superlube® does not leave pools of melted lubricant on the surface of the part during sintering, which is the fundamental cause of staining.**

Have you ever thought it would be great if:

Manganese could be used make harder, stronger P/M parts?

Apex Superlube[®] HPA/Mn/ 0104

- **HPA/Mn/0104 effective method to add Mn to P/M formulations to increase hardenability. 0.5-0.75% effective**
- **No interference with compressibility**
- **Works on all furnaces except Endo gas**
- **Increase hardenability on heat treated parts**
- **Lower alloy content on sinter Hardened formulations**

Have you ever thought it would be great if:

You could make near full density parts that could compete with forgings, castings, and machining?

Apex Superlube[®] NFD technology

- **Densities above $\geq 97\%$ of theory**
- **Net shaped hard steel alloys, S.S, Electromagnets**

Near full density Process Overview

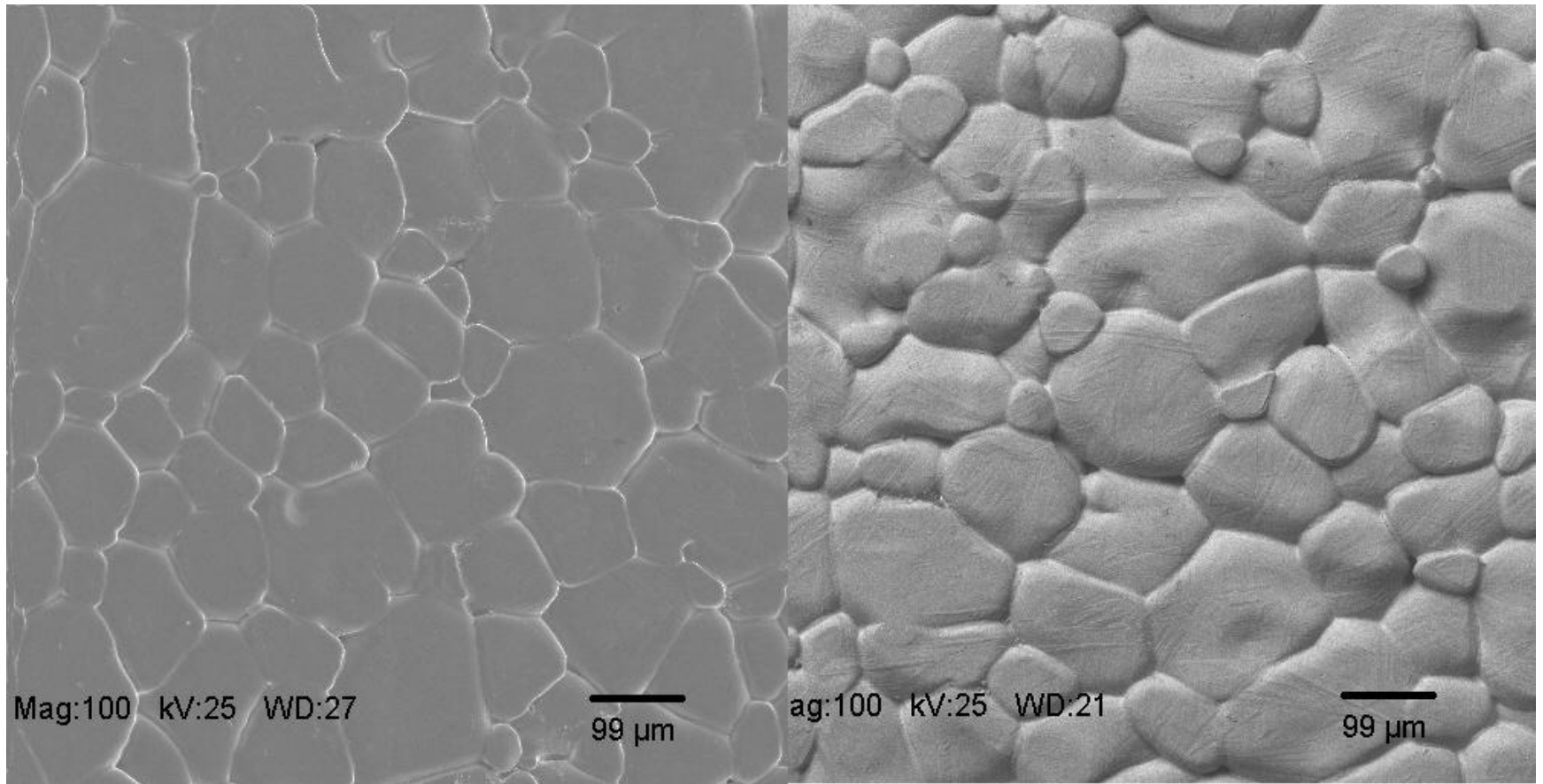
- **Standard water atomized powder, pre-alloyed and straight iron**
- **Special additive/lubricant master batch**
- **Conventional blending, standard tooling and conventional pressing**
- **Part pressing controlled to mass**
- **Compaction range ≥ 50 TSI**
- **Modified de-binding, controlled temperature, time, and atmosphere**

Process Overview Cont.

- **Modified sintering heat up rate and/or high temperature**
- **Sintering atmosphere can be low % hydrogen or vacuum**
- **Heat treating similar to conventional wrought**
- **Sintered densities >96%; up to 99+**



Particle Alignment



Stainless Steels Near full density

• Material	G.D	S.D.	Corrosion 5% salt
• 316L	6.76	7.8	0% 744 Hr
• 17-4Ph	6.23	7.6	0% 744 Hr
• 409CB	6.58	7.55	0% 744 Hr

Electromagnetic

- 45 P up to 7.72g/cc
- 80P up to 7.8g/cc
- 1.5 Si up 7.5g/cc

Summary

- **Apex Superlube[®] and Enhancer St can solve numerous costly problems**
- **There can be large cost savings by substituting Iron for Copper in Copper infiltration**
- **Apex Superlube[®] can out perform hot/warm compaction with no capital investment and at lower cost**
- **New markets can be addressed, P/M can compete with MIM, forging and casting**

Summary

- **Large parts can be made with lower TSI**
- **Low density parts can be made crack free**
- **Mn can be added to the P/M part makers tool chest**
- **Gradients can be eliminated**
- **Blistering and staining can be eliminated**