VAST™ HiFlo™ & HiFloPlus™ Slotted/Filter Liners

VAST Power Systems, Inc.

VAST Power Systems, Inc. seeks to commercialize its HiFlo and HiFloPlus patented slotted/ filter liner technologies invented by Dr. David Hagen, its Chief Scientist. These liners incorporate a radically new approach to controlling sand while extracting oil or gas through perforated pipes ("slotted liners") in well bore holes. Horizontal extraction wells use slotted liners to recover, tight oil ("shale oil"), crude oil, sand/shale-bedded natural gas, or coal bed methane. VAST's liners provide major improvements in this existing multi-billion dollar slotted liner global market. They provide game changer benefits for the rapidly expanding market niche of high temperature thermal liners to extract heated bitumen from oil sands, heated kerogen from oil shale, or heated heavy oil.

VAST's HiFlo™ & HiFloPlus™ slotted/filter liners provide game changer performance and economic benefits over conventional slotted and premium liners:

- Higher performance with thinner and/or cheaper steels.
  - 300% to 700% of the net filter area of slotted liners.
  - 500% of collapse strength of conventional slotted liners.
  - >75% lower axial force up to 330°C, avoiding plastic yield and buckling.
- Double the product's net operating profits from higher revenues with lower costs.
- Targets the greater than $20 billion global liner market over the next 20 years.
- $1.2 billion net on $2.2 billion gross sales for an 8% global market share with 20 plants.
- Projected annual Rate of Return (ROR) of more than 100% per year for VAST HiFlo™ liners.
- Higher annual ROR for VAST HiFloPlus™ liners. These benefits are detailed as follows.

Figure 1 shows the 300% to 720% of "Net Open Area" of VAST's HiFlo™ and HiFloPlus™ liners compared to conventional slotted liners. These key advantages in liner permeability lower the flow resistance ("skin effect") into the liner. This enables faster hydrocarbon fluid flow into the pipe from the surrounding resource – while still excluding most of the sand. Even a 0.2% higher recovery provides a $366/ foot ($1,200/meter) of pipe net present benefit.[1] Recovering the product faster drives a higher Rate of Return (ROR). VAST offers 300% and 720% more Net Open Areas in its HiFlo™ liners (~7.5%), and HiFloPlus™ liners (~18%) compared to conventional slotted liners (~2.5%) - for the same sand size filtering capacity. Yet they are more rugged and eliminate the expensive and failure prone wedge wire and filter hole support systems in conventional high flow and premium filter liners.

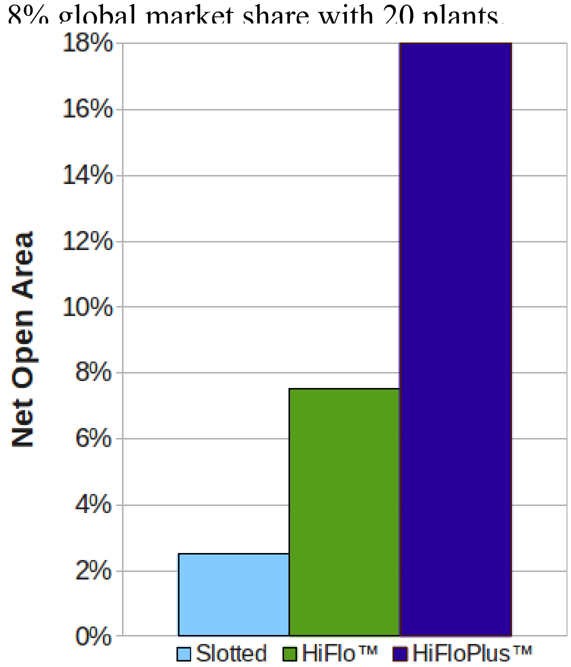

Figure 1: Increase in Net Open Area.

1 Net Present Value from increase in bitumen recovery at a bitumen price of $45/barrel with effective liner life of 10 years at a real discount rate of 10%/year. Peak liner recovery of 1 bbl/day/m. Average recovery 60% of peak.

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Figure 2 highlights how VAST's liner designs are 500% stronger in radial collapse (crush) strength than traditional slotted liners. Its HiFlo and HiFloPlus designs are lighter or use less expensive steel for the strength required for a particular down hole site. This reduces liner cost and increases project profitability. VAST's manufacturing system is designed to make 120,000 meters/year of liner (20 m/hour or 1.1 ft/min for 6,000 hours/year). This would annually supply ~ 100,000 bbl/year of bitumen recovery in oilsands. VAST's liners promise higher returns on investment even if priced below equivalent premium liners.

Figure 3 shows VAST's strain relief liners provide at least a 500% higher bending flexibility without damage.

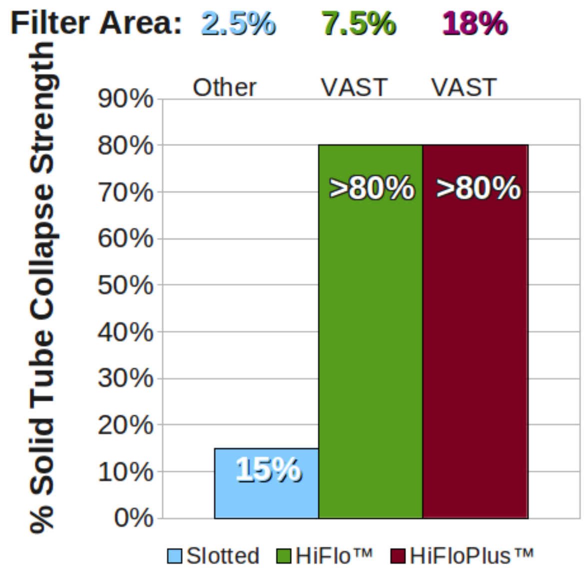

Figure 2: Higher tube strength

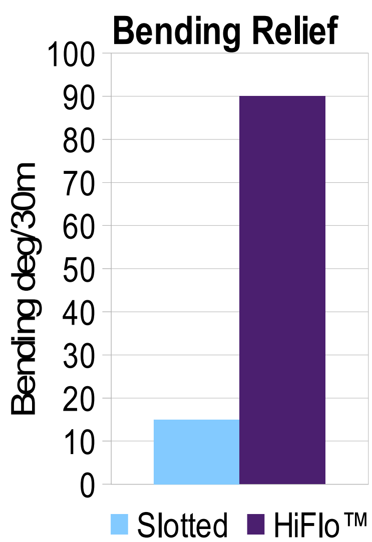

Figure 3: Greater Bending Relief

Conventional slotted liners are constrained by plastic strain (unrecoverable expansion) to a bending rate of 15 deg/ 30 m (98 ft) or a bending radius of about 115 m (375 feet) for 7" (178 mm) OD tubing. This constrains how sharp a "dogleg" bend can be used in inserting slotted tubes underground. VAST's 7" HiFlo™ liners enable bending rates up to 90 deg per 30 m (100 ft). This increases the resource capture efficiency in oil sands and/ or reduces the well pad area required. This increased flexibility accommodates resource shifting, reducing conventional *in situ* collapse failures.

Figure 4 shows two VAST liner designs with torsional strengths of about 20% and 45% of a solid tube.

The simpler Design A can be used to deliver high performance liners with torsional strength probably exceeding threaded connections and similar to slotted liners.

The higher performance of Design B provides the higher torsional strength desired to rotate liners as they are inserted into a well bore.

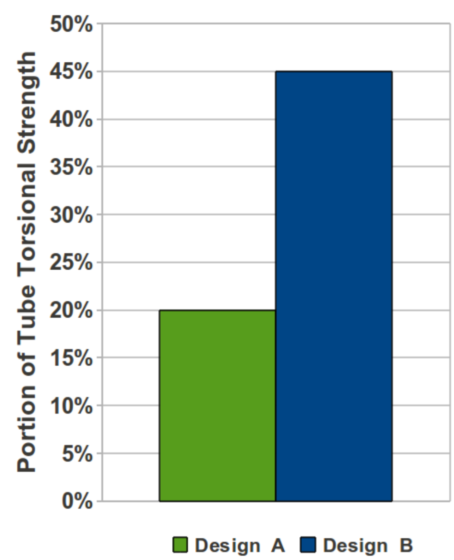

Figure 4: Greater Torsional Strength.

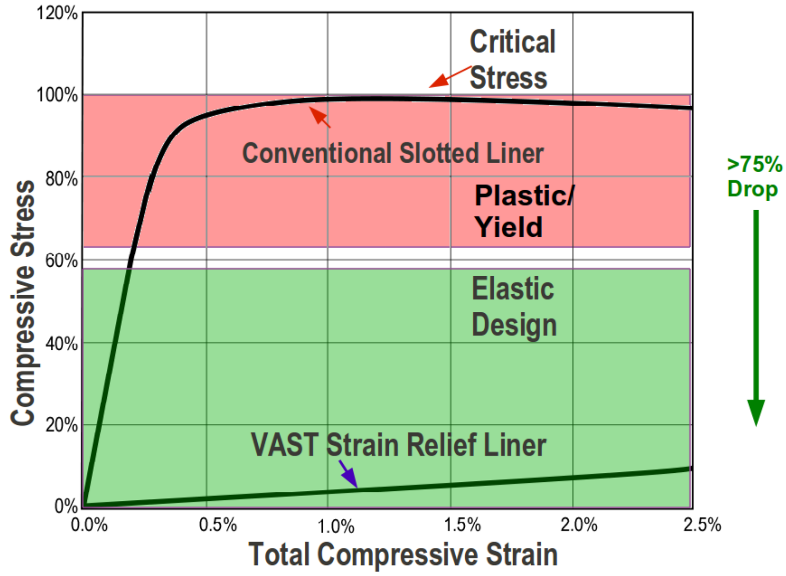

Figure 5: Inexpensive Strain Relief.

Figure 5 shows the VAST filter liner's game changer reduction in axial force from thermal expansion (strain relief). To reduce viscosity sufficiently to recover bitumen, high temperature steam at 290°C to 330°C is injected into oilsands resources. This causes nine to twelve feet (3-4 meters) expansion in typical 2,000 ft to 4,000 ft (600 m to 1200 m) long slotted liners. Conventional liners operate under severe compression with permanent deformation (plastic yield) just below the critical stress which would cause liner collapse. Alternatively they require expensive expansion joints. Conventional liners often require higher strength steels to prevent collapse, especially at greater well depths.

VAST's strain relief liner provides more than 75% reduction in axial compressive stress, by providing strain relief for thermal axial expansion. VAST strain relief liners readily tolerate more than 2.5% axial compressive strain and yet remain within the elastic design range (recoverable deformation). These strain relief liners enable operation to 330 °C or higher with higher collapse strengths, while using thinner and/or less expensive steels. VAST has two US patents and another in preparation plus international applications.

Figure 6 shows ExxonMobil's 2016 worldwide liquid hydrocarbon ("oil") market expection. In this scenario, global demand for liquid fuels is conservatively assumed to only grow 1.5%/year. (BP projects 1.7%/year growth to 2030. US oil use grew 9%/year for 80 years. China has been growing 9%/year for the last decade.) The International Energy Agency estimates depletion of liquid fuel production in known projects at ~7%/year (ranging from 3% in large oil fields to 10% in deep offshore projects). Consequently, the industry projects needing at least 63 million bbl/day of new liquid fuel production by 2031. These unidentified projects include developing untapped proven reserves, Enhanced Oil Recovery of depleted reserves, and yet to be discovered light oil resources, heavy oil and oil sands (bitumen), and natu-

ExxonMobil 2016

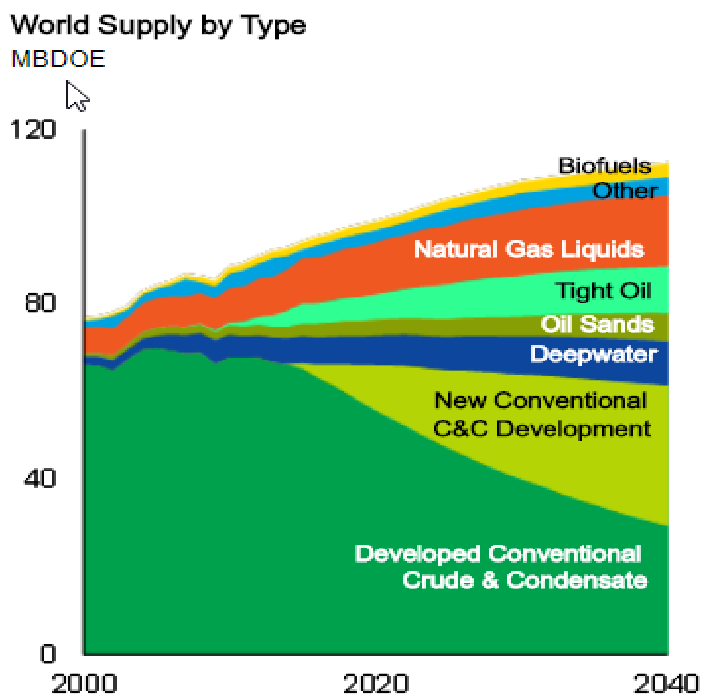

Figure 6: World Hydrocarbon Production

ral gas liquids, biofuels, and other alternative fuels.

In *Oil 2018*, the International Energy Agency sees oil demand increasing 7 million bbl/day to 105 mb/d by 2023. IEA expects the number of cars on the road to double by 2050. However, discoveries of new crude oil, condensate and natural gas liquids in 2017 were only 4% of global consumption! IEA warned that the 51% drop in global oil investment in 2015-2016, with little recovery since. The global spare capacity cushion falling to only 2.2% of demand by 2023 raises oil shortage risks.

Such tight supply will put strong upward pressure on fuel prices. Production cuts led by Saudi Arabia and OPEC with Russia have already pushed oil prices back up from $27/bbl to $75/bbl despite US tight oil production rising. Saudi Arabia is reportedly seeking to return prices up to $80/bbl to $100/bbl.

ExxonMobil (2018) shows conventional crude oil plus deep water production plus oil sands liquids supply peaked in 2005, declining 10% by 2040. Only tight oil boost liquids up 20% by 2040. BP only sees oil growth to the mid 2030s. Shell's Global Supply Model to 2100 combined price models with fitting numerous Hubbert-like curves. Shell saw so little oil growth potential that it has refocused on producing natural gas resources and then to making and selling electricity.

Future liquids supplies will likely be tight and increasingly more difficult to obtain. Improving recovery will become increasingly important. The projected future 20 year fuel production is expected to require at least 75 million meters (m) of slotted liner (assuming 1.2 m liner per bbl/day hydrocarbon production.) This indicates a 20 year cumulative market for liners for liquid fuels of at least $20 billion gross at an average liner price of $270/m.

Potential sources of new hydrocarbon supply include resources of about 6 trillion barrels of oil sands, oil shale, and heavy oil in place. About one trillion barrels (~17%) may be recoverable, similar to the one trillion barrels left of conventional light oil. An increasing portion of future fuel production will require thermal liners to recover heated bitumen from oil sands and heavy oil.

With superior performance and lower manufacturing costs, VAST projects installing ten liner plants over eleven years from years five through fifteen each ramped up to 85% of design production over two years. This would be followed by another ten plants in the following five years. These plants would produce a cumulative total of 12 million m of liner in years 5 through 20, with each plant reaching ~120,000 m/year. In this scenario, VAST nominally captures 16% of this 73 million m >$20 billion global liner market during the 20 year life of its current patent applications.

In addition, there are further rapidly growing liner markets for natural gas, shale gas, and coal bed methane. Exxon projects major growth in natural gas, overtaking coal by 2030 as the world's second largest source of energy. Much of this growth in natural gas production will provide further opportunities for VAST's slotted and filter liners. This demand for natural gas etc. is in addition to the financial projections above for petroleum liners.

Figure 7 summarizes the economic benefits of VAST liners. With three times the net filter area (~ 7.5%), VAST projects its HiFlo™ liners to sell at a 2011 industry competitive price of $370/m -- $100/m more than conventional slotted liners. VAST estimates its manufacturing and operating costs are ~$40/m lower (under 2010 prices & costs). If there were a price war, VAST could profitably sell its liners for less than the cost of the oil field tubulars purchased by competitors. This $140/m operating profit advantage gives about 2.2 times the operating profit of conventional liners. With seven times the net filter area of slotted liners, VAST's HiFloPlus™ liners are projected to command substantially higher prices, even if priced less than existing premium liners. With but modest increases in manufacturing costs, VAST's HiFloPlus™ liners should earn yet higher profits.

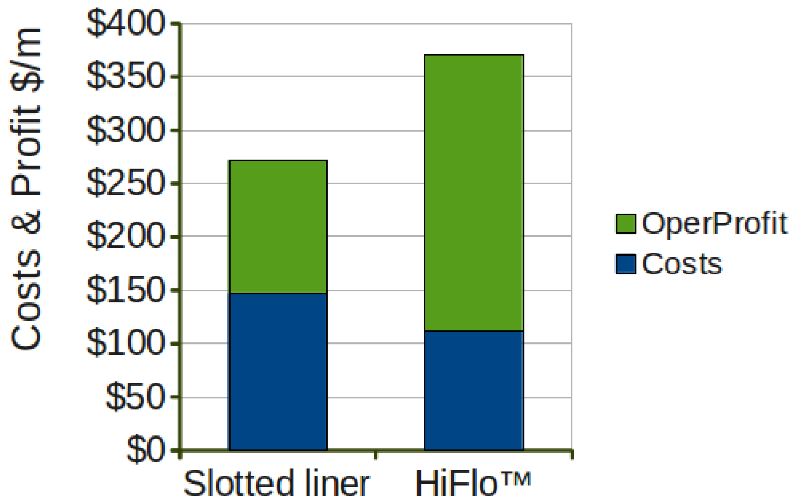

Figure 7: Higher Revenue, Lower Production Costs.

Figure 8 schematically summarizes the scheduled investments to create this manufacturing system. This starts with phased applied Research and Development to test and develop initial and prototype manufacturing methods. The resulting prototype liners would then undergo testing, certification, and demonstration. Contract pilot production would then lead to the capital expenditures for a full plant.

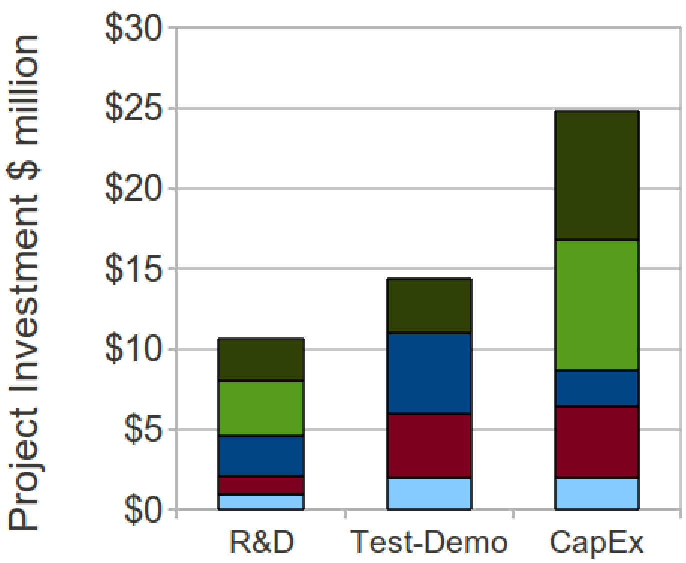

Figure 8: Phased Project Investment.

This investment is expected to lead to the first full plant roll out in 3-4 years. Each HiFlo™ liner plant is projected to earn a net operating profit of $23 million/year/plant (on $197/m profit after royalty before taxes). VAST projects about 46% annual Rate of Return (ROR) to investors on a staged investment of $50 million for the first full greenfield HiFlo™ liner plant. This includes covering all costs of R&D through startup, plus $14 million for contingency (30%) and 3 months' working capital.

Subsequent HiFlo™ plants are projected to give an annual rate of Rate of Return of about 106%. The projected 20 plants would nominally earn investors ~$3.6 billion net profits (after royalties) on gross revenues of ~$6.5 billion at 2010 prices and costs. Utilizing or leasing existing facilities would reduce these capital costs. Further development of premium HiFloPlus™ liners are projected to earn yet higher profits and returns.

Proposed Next Steps:

Financial & Technical Presentations: VAST proposes to provide financial and/or technical presentations of public information. Full technical and financial presentations can be provided under suitable bilateral confidentiality and non-disclosure agreement. (A third patent is in preparation.)

Staged R&D Plan: VAST has planned a staged risk reducing R&D plan. This conducts full Finite Element Analysis (FEA), using the 3D (CAD) models being developed. They will be verified with third party consultants. VAST will work with manufacturers to conduct lab scale and then prototype level development and tests of its breakthrough manufacturing methods.

Prototype Tooling and Equipment: Next VAST plans to develop and test prototype tooling and the custom equipment for material and liner handling. Key lead fabrication vendors have been selected and machine design challenges with potential solution paths identified.

Liner Delivery Partner: Identify a suitable partner to modify current equipment to handle the delivery and insertion of VAST liners.

Contract/Pilot Production: Preliminary pilot production could be conducted under contract to existing manufacturers, using the prototype tooling and equipment. Pilot production will provide initial quantities of liners for certification and initial demonstration.

Testing, Certification and Demonstration: With pilot production liners, VAST plans to have its prototype liners tested by third parties to independently verify our software models. Then follows initial demonstration of commercial in ground utilization and formal certification testing.

Full Commercial Production: VAST projects that commercialization of its HiFlo™ liners may take 3-4 years to full commercial production depending on demonstration and certification.

Roll Out Rate: VAST projects installing one plant per ~14 months in years 5 through 15. It then projects installing two plants per year for the next five years, leading to 20 plants installed in year 20. These liner manufacturing plants would nominally supply ~12 million meters of liners, capturing a 16% niche in the projected liquid fuel liner market of 73 million m over the next twenty years. In addition, VAST's liners will likely be sold into further markets for sand control, including the natural gas, shale gas, and water supply markets.

VAST's Current Objective: VAST seeks appropriately capitalized and experienced oil patch firms and investors to join with VAST and its technology development partners to launch and commercialize the VAST Slotted Liner™. Financial arrangements may include a joint technology development venture or licensing. VAST has further technical details and financial models describing these technologies and supporting these advantages which can be presented under a bilateral confidentiality and nondisclosure agreement.

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