Low-Cost Microchannel Heat Exchanger

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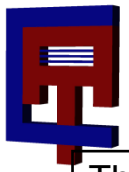

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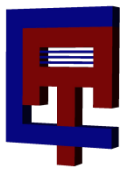
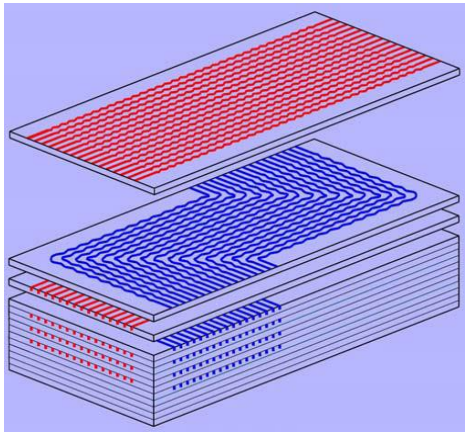
Project Objectives

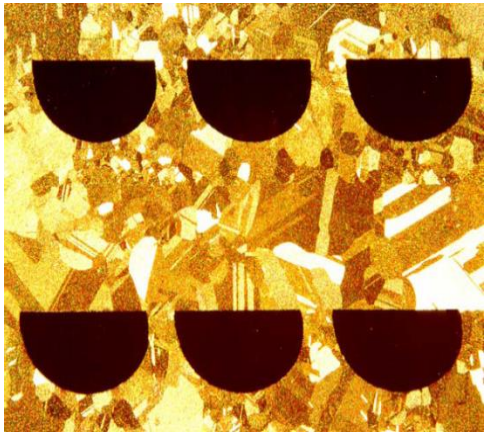
- Define and test low cost microchannel heat exchanger fabrication process
- Produce prototype heat exchangers for electronics cooling and high pressure waste heat recovery power system applications
- Test integrity and confirm high performance of prototypes
- Define capital and operating cost savings

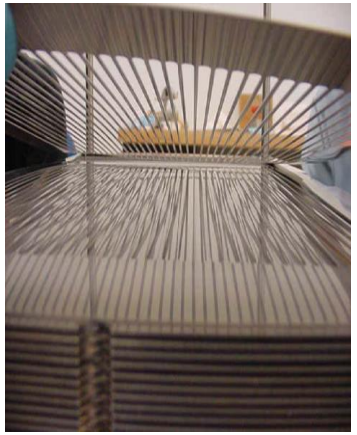


Current Microchannel Heat Exchanger (MCHEX) Manufacturing Approach

- Microchannels provide large surface areas and high heat transfer rates (order of magnitude higher than conventional HEXs) in very small volumes
- Current etching and micromachining manufacturing is too costly for most applications



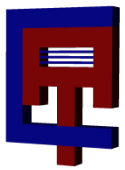




Lower Cost Manufacturing Approach

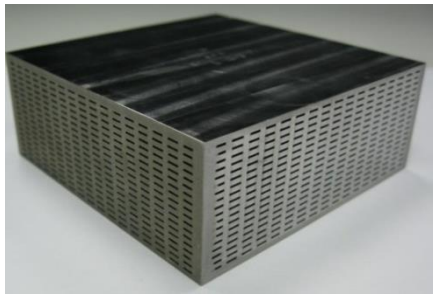
- Uses standard low cost part configurations
- Minimizes part count
- Utilizes simple limited tolerance machining step
- Stacks parts to achieve different capacities
- Applies minimum cost bonding approach
- Leverages existing bonding capabilities of contract manufacturer

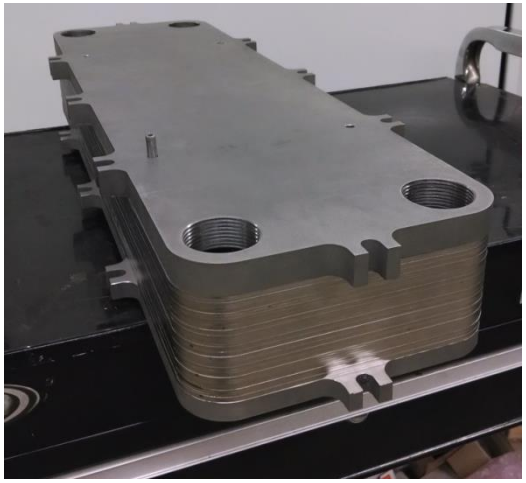
Use existing relationship with manufacturer to accelerate project and commercialization



MCHEX Product and Applications

Low cost and compact MCHEX has design flexibility and many applications





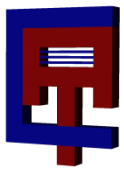
- Gas/gas, liquid/liquid, gas/liquid fluids
- 50 Watts to multiple Megawatts capacities
- Counter-flow and cross-flow configurations
- Aluminum, copper, stainless steel, high temperature alloys, corrosion resistant alloys construction
- Oil and gas platform processes, separators, LNG processing, chillers, heat pumps, fuels reforming, waste heat power systems and electronics cooling applications
- Many new and evolving residential, commercial and industrial systems can beneficially use the MCHEX
- Current heat exchanger markets have large total available markets

MCHEX Markets and Deployment

Industries where MCHEX 60% lower cost and 80% lower volume will be valued

Industry	Types of Applications	Worldwide Market ($MM)	MCHEX Markets ($MM)
Chemical	Air separation, reactors/heat exchangers	2,488	236
Fuel Processing	Refinery, fuels reforming	2,018	191
HVAC and Refrigeration	Chillers, heat pumps, condensers	2,337	221
Food Processing	Dehydration	989	94
Power	Waste heat power system recuperators	1,877	178
Total		9,712	919

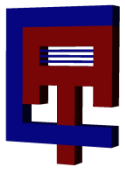
Deployment requires licensing of strategic partner to manufacture, market, sell and service MCHEX



MCHEX Measure of Success

Implementing MCHEX in just waste heat recovery power systems will have beneficial industry and public impacts

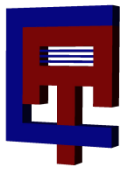
Savings	Value
Fuel Energy	0.25 Quads
Fuel Cost	$1.0 Billion
GHG Emissions	6.36 Million Tons
Sulfur Emissions	1.1 Million Lbs
NOx Emissions	19.0 Million Lbs



MCHEX Project Management and Budget

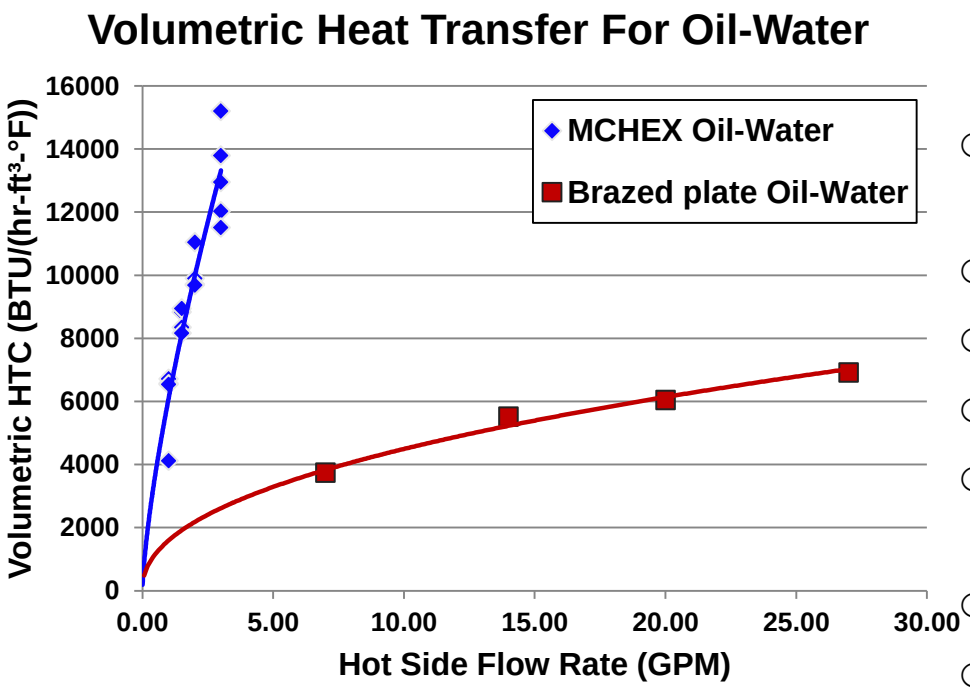
- Two year project to be completed in June 2014
- Complete electronics cooling application tests
- Complete high pressure application integrity and performance tests
- Define performance and cost advantages over conventional approach

Cost	Total Project Budget
DOE Investment	$1,120,000
Cost Share	
Project Total	



MCHEX Results and Accomplishments

Multiple benefits quantified



- Fabricated electronic cooling and high pressure MCHEX units to prove manufacturing approach
- Tests showed 400% higher heat transfer rates
- 80% reduction in volume
- 5,000 psi pressure capability
- High effectiveness > 90%
- 80% lower estimated external heat loss
- 60% estimated lower cost
- Complete remaining tests and refine cost analysis