19187-Phase Change Micro-Barrel Jacket Liquid Cooled Machine Gun Barrel For Continuous Fire

By:

Howard D. Kent, ADG, LLC.

Third Offset Weapons For Robotic & Remote Turret Applications:

Robots & Remote Turrets Do Not Need Standard Infantry Weapons…They Have No Hands To Change Barrels, To Load Ammunition Belts, Or To Clear Weapon Jams. In Order To Accommodate Future Weapon Systems, Firearms Need To Change Toward Adding These Capabilities Through Dedication In Form And Purpose.

This Presentation Is Dedicated One Element Of That Goal: Toward Eliminating The Need To Change Barrels Regardless Of Rate Of Fire Or Capacity Of Magazine.

Walking Tank Image By Patrick Gibbs

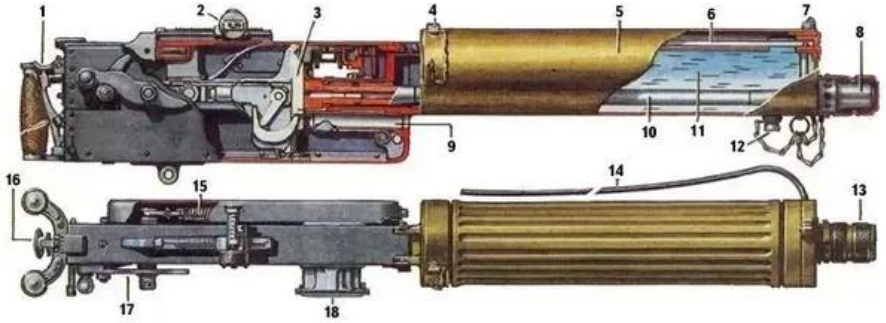
Contents:

Introduction:

We Have Suitable Existing Gas And Recoil Operated Infantry Weapons Which Can Be Optimized To Robotic Or Remote Turret Use And Externally Powered Guns Have Always Been Available For Use In Mounted Or Airborne Applications.

What They All Currently Lack Is A Single Barrel Which Can Be Fired Without Concern For Overheating, Heat Erosion, Bursting, Bullet Yaw, Or Anything Else.

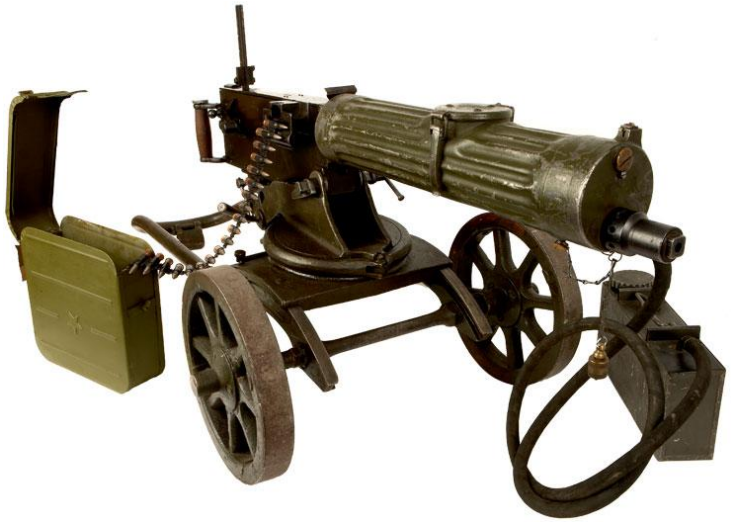
This Important Because While There Is Clearly Someone Aiming The Gun, There Is Nobody Behind The Weapon Running It In Case Of A Failure.



Review Of Water Cooled Weapons Of The Past

Quora Maxim Reference Graphic

Water-Cooled WW-I Era Heavy Machine Guns From Russia, England & Austria:



The Maxim Was The Original Water Cooled Machine Gun, With Others Following Immediately. Above From Left: The Russian 1910 "Tractor" Maxim, The British Vickers-Maxim And The Austrian Schwarzlose Machine Guns.

Deactivated Guns UK Photo Maxim, Vickers; SAR Photo Schwarzlose 07.

Browning Water-Cooled Machine Guns In 0.30 And 0.50 Caliber:

The latest type of recoil-operated Machine Gun designed by John M. Browning, used in the first World War and now standard equipment in U. S. Army and Navy.

RA PD 72730

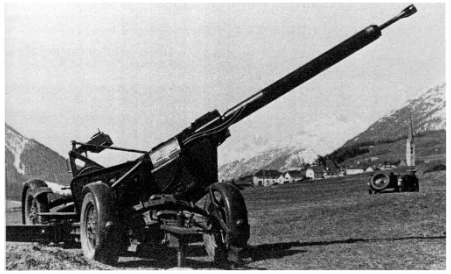
Figure 3 — Twin Cal. .50, Machine Gun, Pedestal Mount M46, With Water-cooled Guns

Browning Water Cooled Machine Guns Incorporated A Water Jacket That Placed The Barrel At The Bottom Of A "Boiler" Submerged In Coolant. The Liquid Produced Steam And Then Condensed It For Re-Use.

BrowningMGs.com Photo US Army, Guns.com Photo US Army, LoneSentry.com Photo US Army

Heavier Caliber Rapid Fire Single & Multi-Barrel Water-Cooled Weapons:

Adding Long Burst Firepower For Anti-Aircraft Batteries

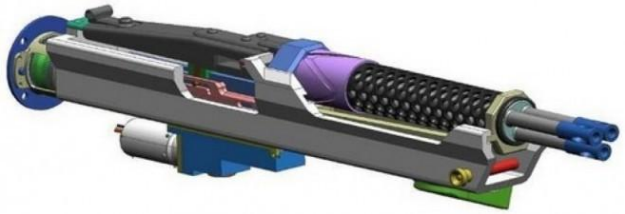
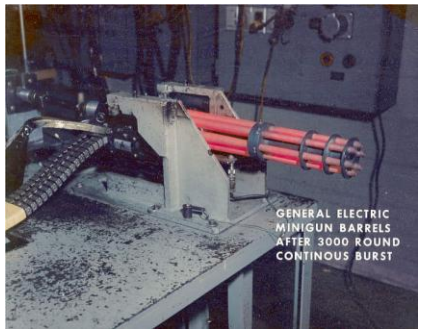


Clockwise From Upper Left: ZSU-23-4 SPAAG, Close Up Of 23-4 Showing Rust, WW-II Era Swiss 20mm Oerlikon, US Navy OTO 76mm Compact Gun, WW-II Era US Twin Bofors Water Cooled 40mm Cannon.

Janes Photo, Britmodeler.com Photo, Swiss Military Photo, USN Photos 76mm, 40mm

Other Solutions To Rapid Fire Air-Cooled Barrel Guns: More Barrels

NOTE: *The Proposed Solution Is Lighter Than Any Of These Designs…*





Above From Top Left: Rheinmetall Graphics Auto-Barrel Change MG And Close Up Of Auto-Barrel Change MG, GE Photo Of M-134, Swiss Military Twin 20mm Cannon IDR Photo, Asbestos Glove/Water M-60 Army Photo, Extra Barrels HK11/21 James Julia Auctions Photo, MetalStorm Photo 40mm Multi-Barrel Launcher.

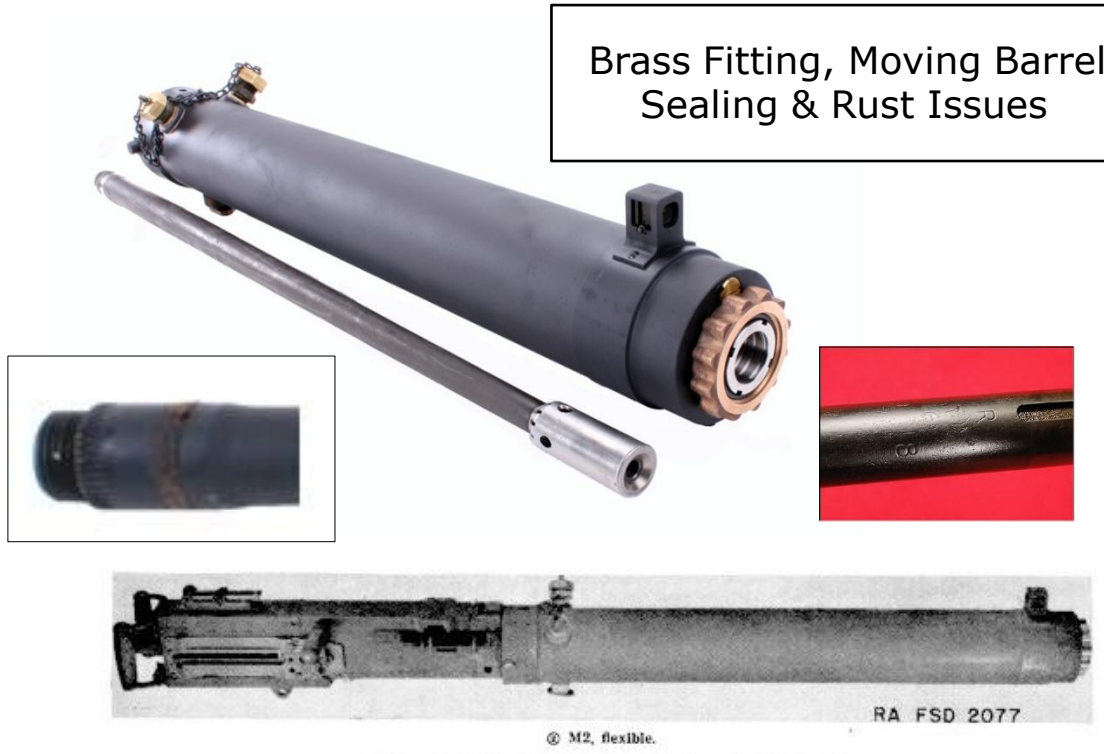
Justifying The Modern Phase Change Cooled Automatic Weapon

Futurism Robotic Hand Graphic

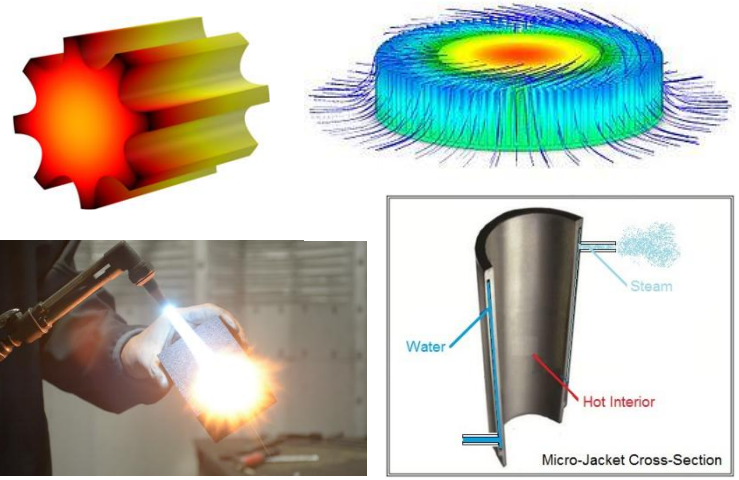
The Difference Between WW-I Era Models & The Current Phase Change Barrel Proposal:

Barrel Does Not Contact The Coolant…Graphite Foam Is The Transfer Media

Brass Fitting, Moving Barrel Sealing & Rust Issues



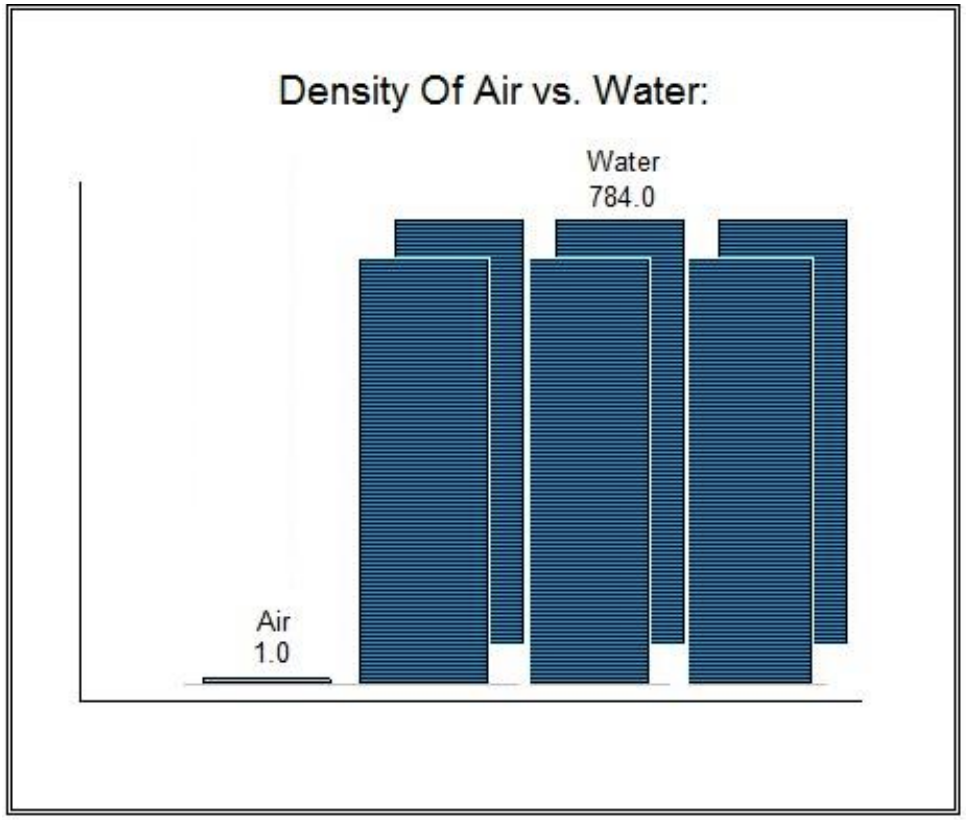
VS.

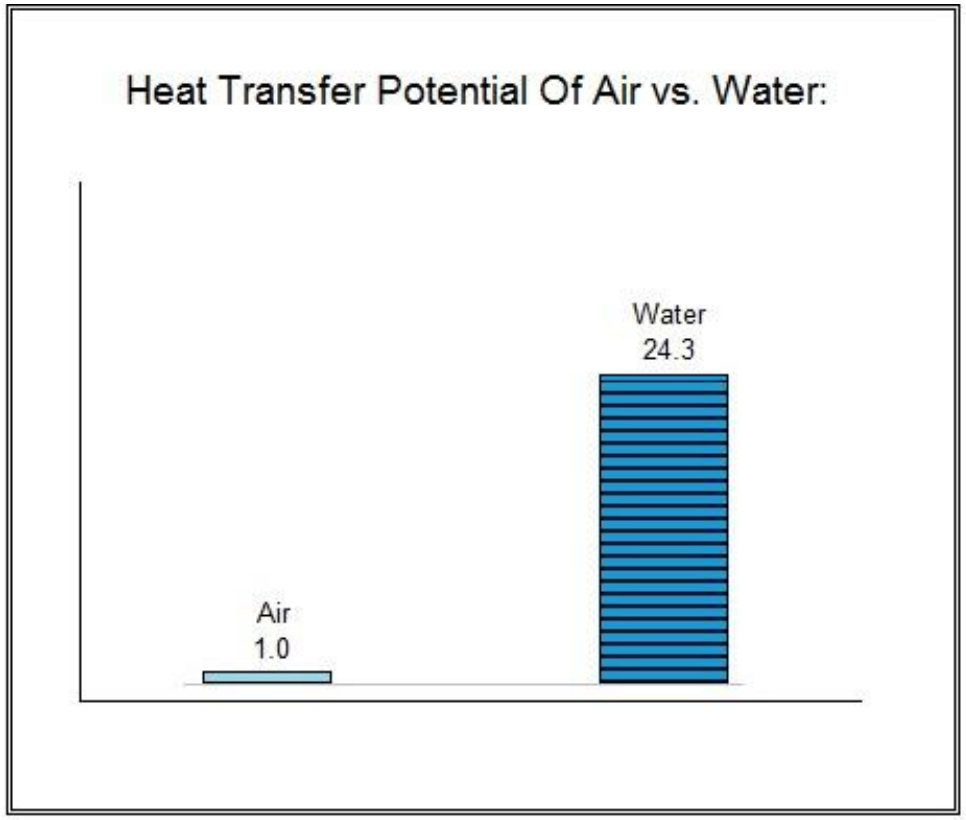


Graphite Heat Sink Around Barrel Transfers Heat Into Micro-Jacket

Above Left: BMG Parts Photo, US Army Ordnance Photo; Above Right: Comsol Thermal Simulations, Micro-Jacket Proposed Design, Graphite Foam Demonstrating Heat Sink Capability With Bare Hands And Blowtorch.

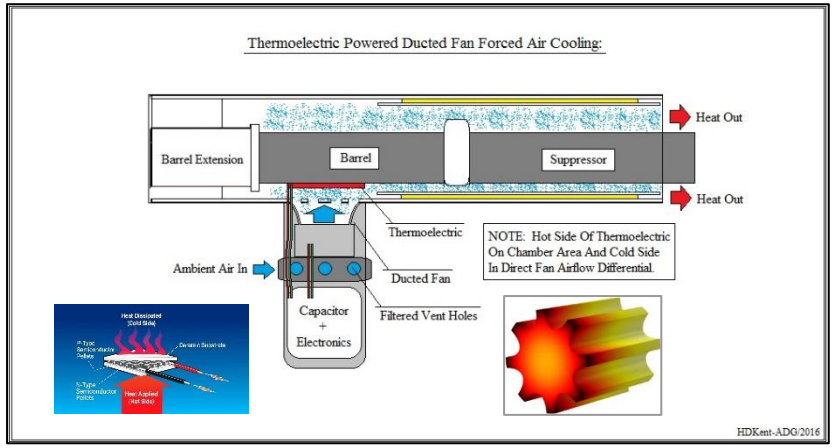
Properties Of Air vs. Water In Terms That Apply To Barrel Cooling:

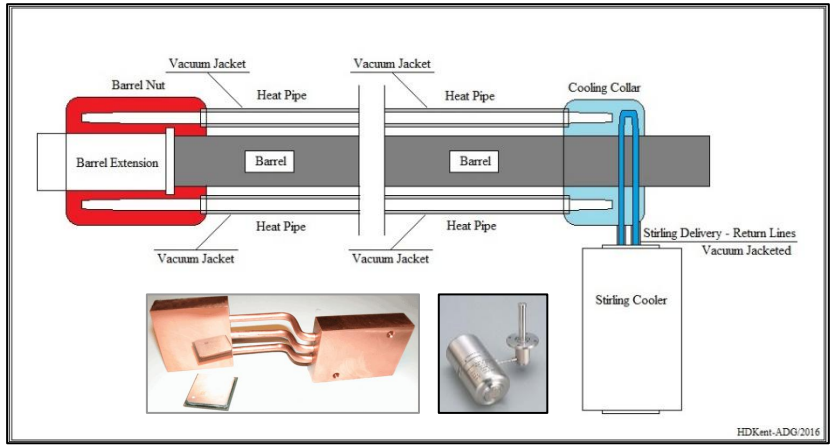


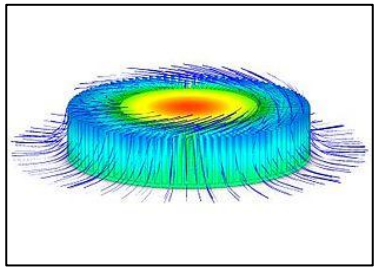


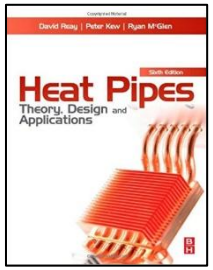
Above Left: Showing Greater Density Of Water vs. Air, Above Right: Showing Heat Transfer Ability Of Water.

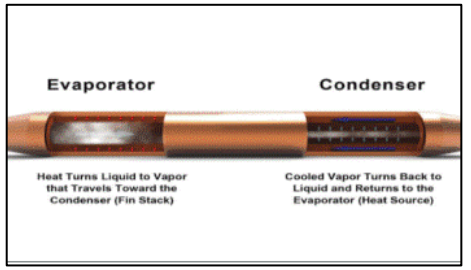
Even Advanced Air-Cooling Concepts Are Weak Compared To Liquid Phase Change:

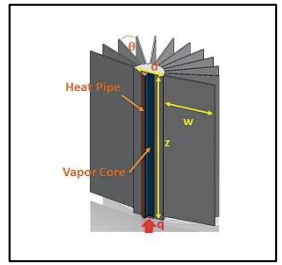






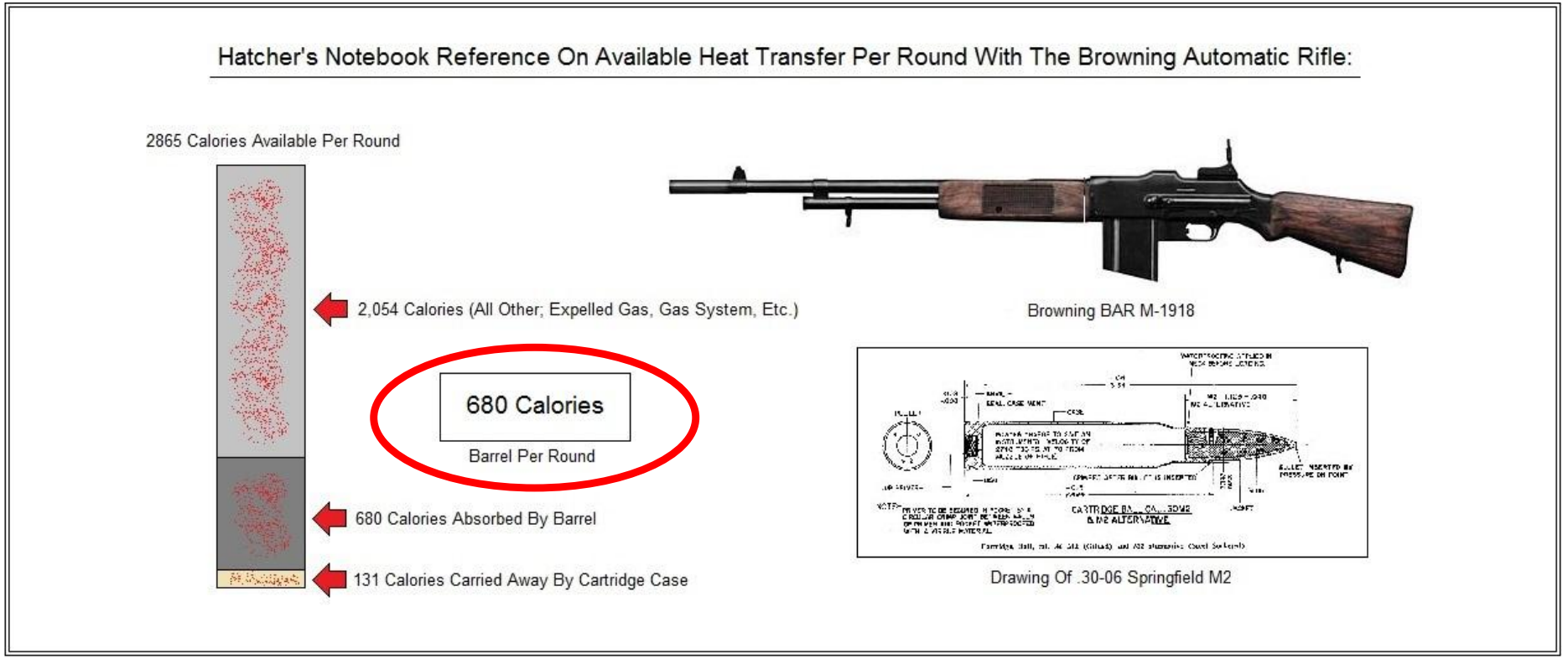






Clockwise From Top Left: Thermoelectric Self Powered Air Cooler, ACT Heat Pipe Driven Stirling Cryocooler, Radial Cooling Array, Thermacore Heat Pipe Example, Heat Pipe Product Catalog, Thermaltake Ring Fan, Comsol Simulation Of Airflow Over Heat Sink Array Showing Radial Dispersion Of Heat With Spiral Flow.

Early Research Into Automatic Weapon Heat Generation From Gen. Hatcher's Notebook:



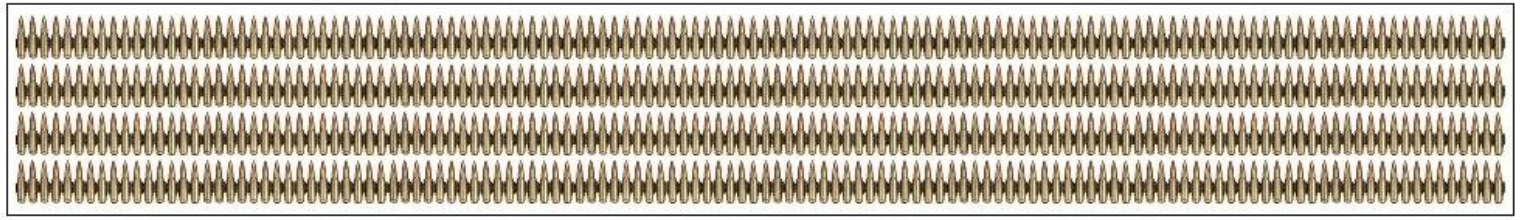
According To Gen. Hatcher; A Total Of 2,865 Calories Of Heat Were Generated By The BAR Per .30-06 M2 Round.

BAR 1918 Guns.com Graphic, US Army .30-06 M2 Graphic

40,000 Rounds vs. The Cooling Potential Of One Liter Of Water Turned To Steam:

27,200,000 Calories

Represents ***40,000*** Rounds Of Machine Gun Ammunition Total Calories Absorbed By Barrel



vs.

51,300,000 Calories

Winner!!!

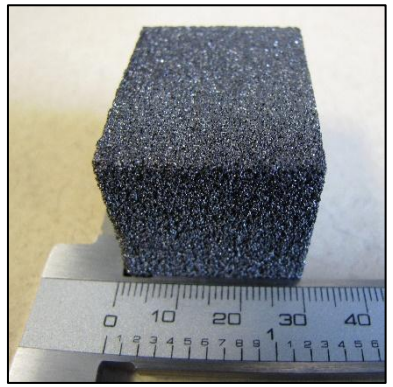
Represents 1 Liter Of 5C Temperature Water (41F) @ 540 Calories To Raise 1cc Of Water By 1 Degree C & An Increase Of 95C Required To Convert Water To Saturated Steam

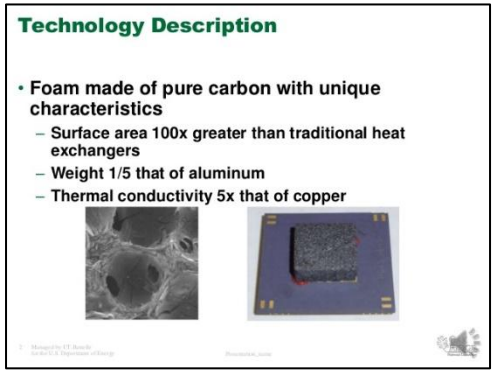
At Even 50% Cooling Efficiency, ***A Single Canteen Of Water Converted To Steam*** Could Maintain Barrel Temperatures At Acceptable Levels For >30,000 Rounds Of Continuous Fire.

Answer: @100% Efficiency = 75,441 Rounds

Components Of The Proposed Micro-Jacket/Heat Sink System

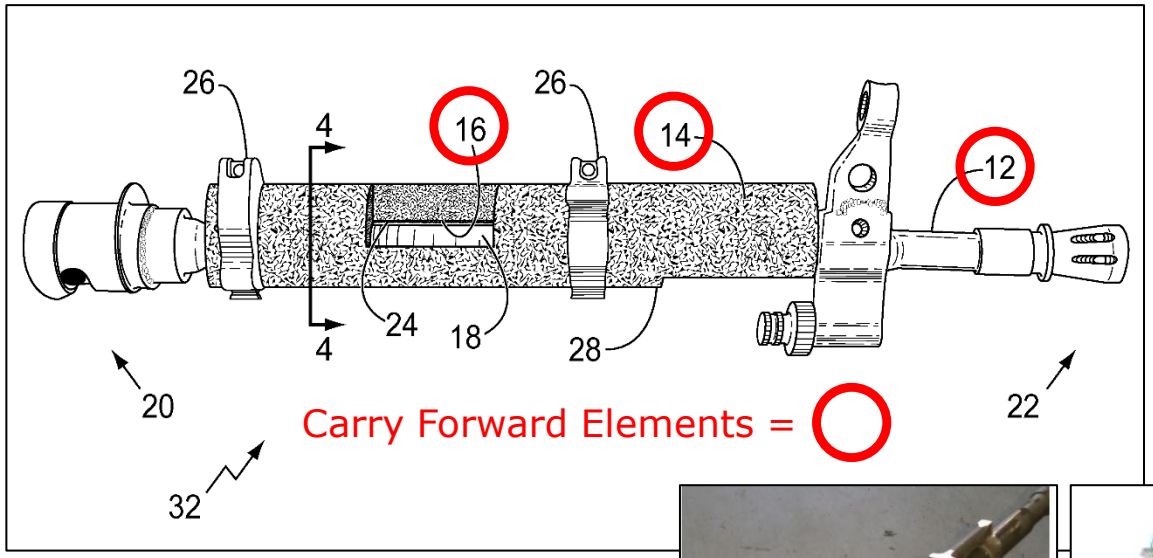
Graphite Foam Barrel Cooling Heat Sink Experiment: Mk48, 200 Rounds, <600F

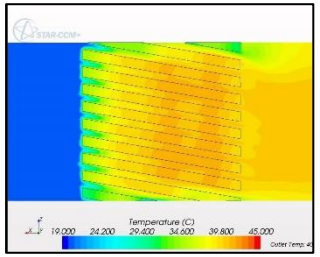


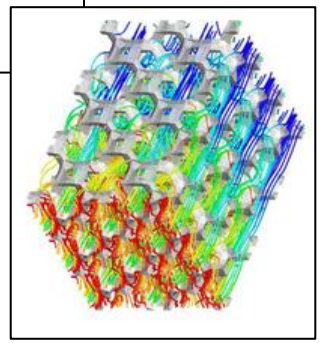


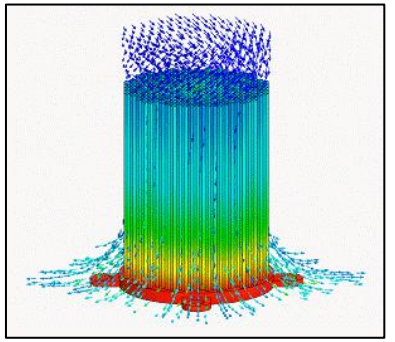
Clockwise From Above Left: Dr. James Klett Of ORNL And Graphite Foam, NEPCM Auburn University Open Cell Graphite Foam, C-Foam Photo, ICF Builders Graphite Photo, DOE Graphite Characteristics.

Graphite Foam Barrel Cooling Heat Sink Experiment: Mk48, 200 Rounds, <600F









ORNL Patent Drawing, ORNL Graphite Barrel Mk48 Trial Photo, Comsol Heat Flow Modeling Simulations (2), ORNL M-16 Graphite Enclosed Barrel Trial Photo, Star-CCM+ Graphite Heat Sink Flow Simulation.

Original ORNL Presentation Slide: Gun Barrel Cooling

The Problem

- Current machine guns get ***very*** hot during operation.
- After about 200 continuous rounds, the barrel must be changed.
- Barrel change out presents a problem to the operator as they are in a vulnerable position while it is occurring.

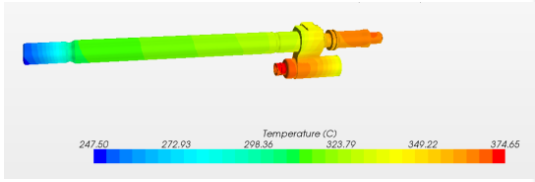
Solution?

- Rigid carbon/graphite materials can be used to design overwraps that cool the gun more efficiently than natural air cooling alone.

The Technology

Weapons test

M249 Short Barrel with Foam



Thermal imaging after 1000 rnds

Various Weapons

The Approach

- Machine a clam shell type overwrap to put on the barrel.
- Attach the overwrap to the gun and measure cooling effect.
- High conductivity will conduct heat and reduce temperatures, thus increasing operational capacity and extending barrel life.
- Utilize refractory surface coating or cooling jacket to protect foam from normal damage.

Unique Characteristics

- **Results initially modeled in Solidworks STAR-CCM+®.**
- **Actual Temperatures of barrel was significantly lower with the wrap than without the wrap applied:**

Weapon	Temperatures [°C]		Actual Temp Reduction
	bare	w/wrap	°C
M240B	480	404	76
M249	522	367	155
M2	447	392	55
M4	552	304	248
M4A1	408	245	163
Mk46	590	290	300
Mk48	715	480	235

Benefits

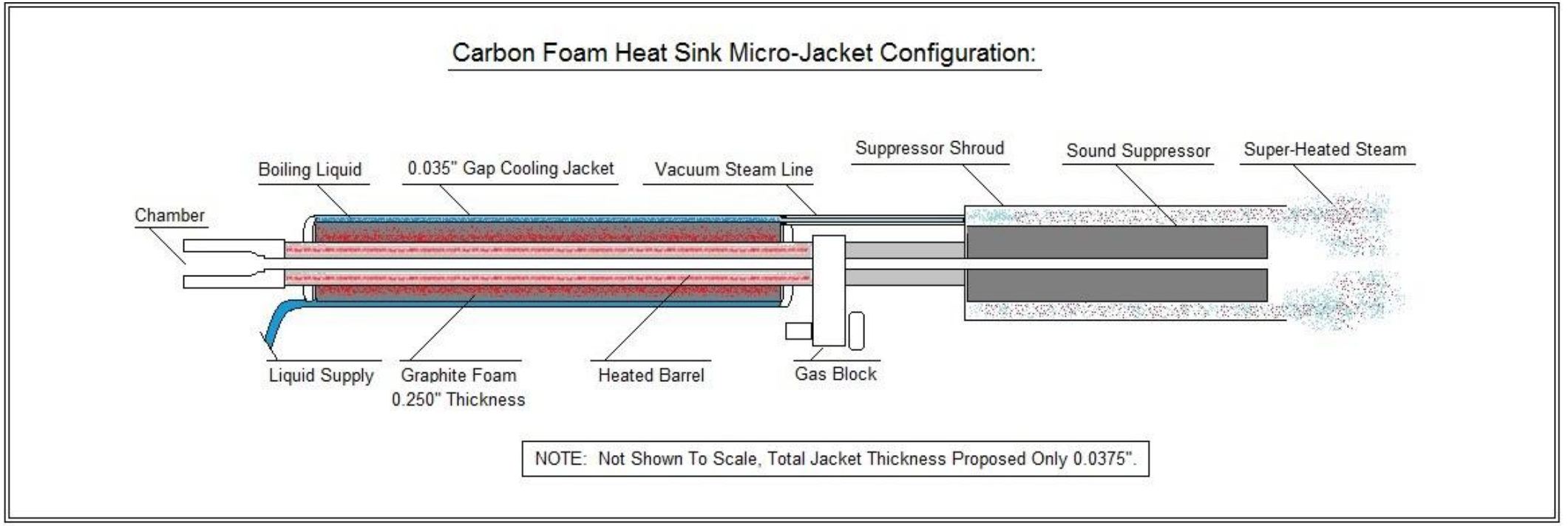
- **Recent test at ARDEC using WANAT protocol demonstrated that graphite based barrel wrap will remain cooler, and did not fail yaw test after 4100 rounds in 20 minutes.**
- **By dissipating heat from the gun barrel effectively, the life of the barrel due to reduced heat effects can be extended.**
- **By reducing temperatures, time between change out can be extended in continuous fire.**
- **If additional external cooling is provided, graphite foam performance is magnified due to continual heat outflow.**

Contacts

- **Dr. James Klett – ORNL – 865-574-5220**

General Configuration Of Proposed Machine Gun Barrel Cooling System:

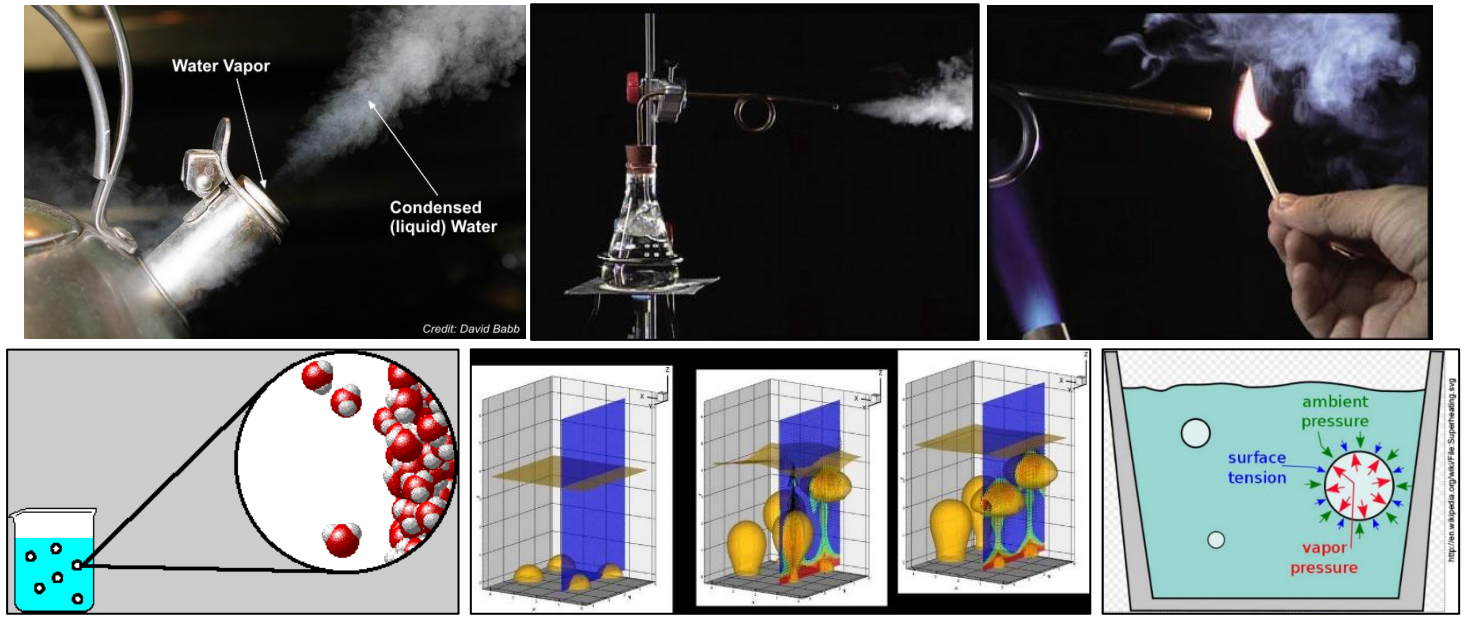
Liquid Cooled Integrally Suppressed Continuous Fire Weapon



Graphite Heat Sink Surrounds Barrel Which Draws Out Firing Residual Heat Into Thin Gap Liquid Cooling Jacket. Small Amount Of Water Produces Saturated Steam Which Is Injected Into Suppressor Shroud Thereby Providing "Steam Cooling" Of The Hot Sound Suppressor And Producing Invisible Superheated Steam As A Byproduct.

Some Properties Of Steam Generation & Super-Heating Which Are Applied:

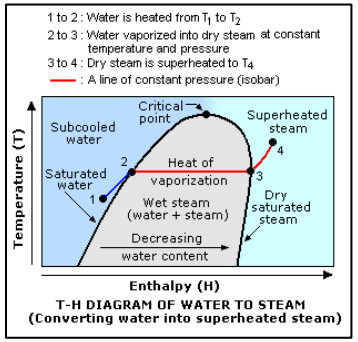
You Can See Water Vapor Saturated Steam, But Superheated Steam Is Invisible

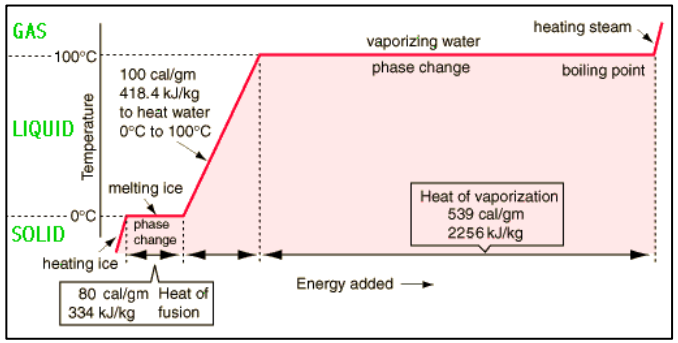


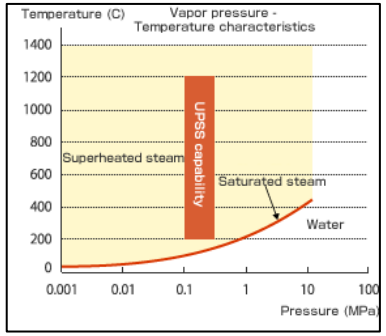
Clockwise From Upper Left: Annotte Teapot Photo, Sharp Science Photos Saturated vs. Superheated Steam, eCat Vapor Pressure Boiling Example, Scientific TSF Surface Nucleate Boiling Principles, HowToScience Boiling Graphic.

Superheated Steam Is Invisible & Carries More Heat Than Saturated Steam:

Hot And Dry Enough To Light A Match When Superheated



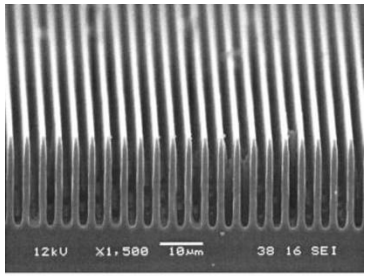


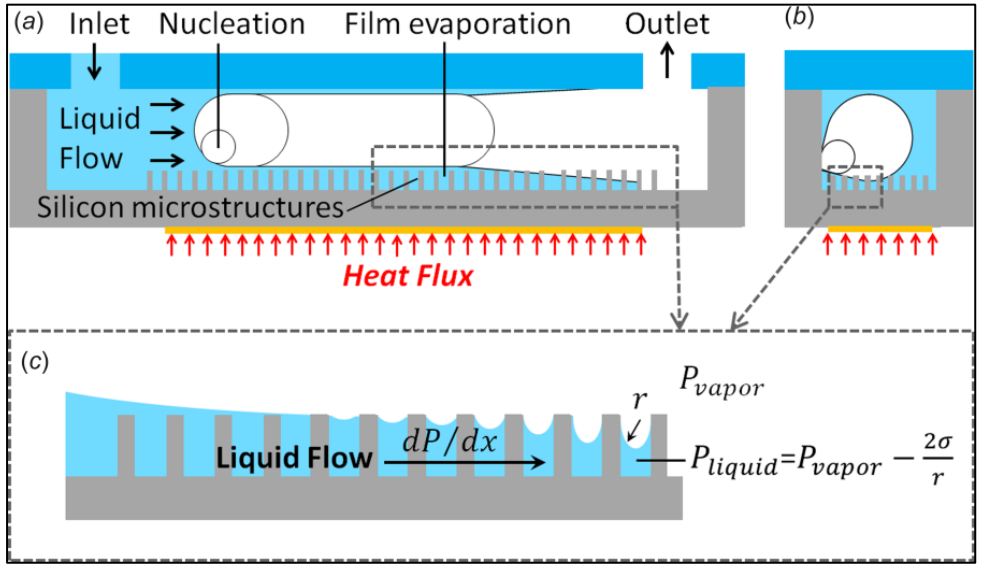


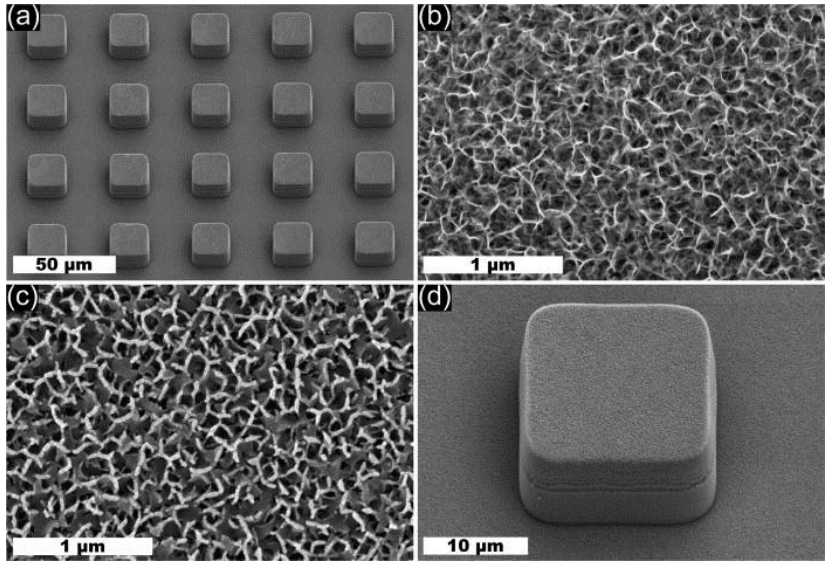
Clockwise From Upper Left: WonderHowTo.com Superheated Steam Photos (2), Flinn Scientific Photo, Tokuden Steam Pressure Graphic, Scientific Psychic Phase Change Graphic, Citizendium Steam Graphic.

Advanced Micro-Boiler Silicon Microstructure Internal Configuration:

Liquids Are Turned To Steam Directly In Micro-Etched Channels







From Left: Researchgate Silicon Micro-Structures Photo, ASME Silicon Micro-Structures Graphic, Researchgate Silicon Micro-Structures Photo. Illustrations Of Applique To Inner Wall Of Micro-Boiler Which Creates Steam.

Commercial Water Cooling Technology: Cooled Motors, Electronics & Intake Manifolds

Remarkably Driven By RC & Auto Racing, Plus The Electronic Gaming Industry





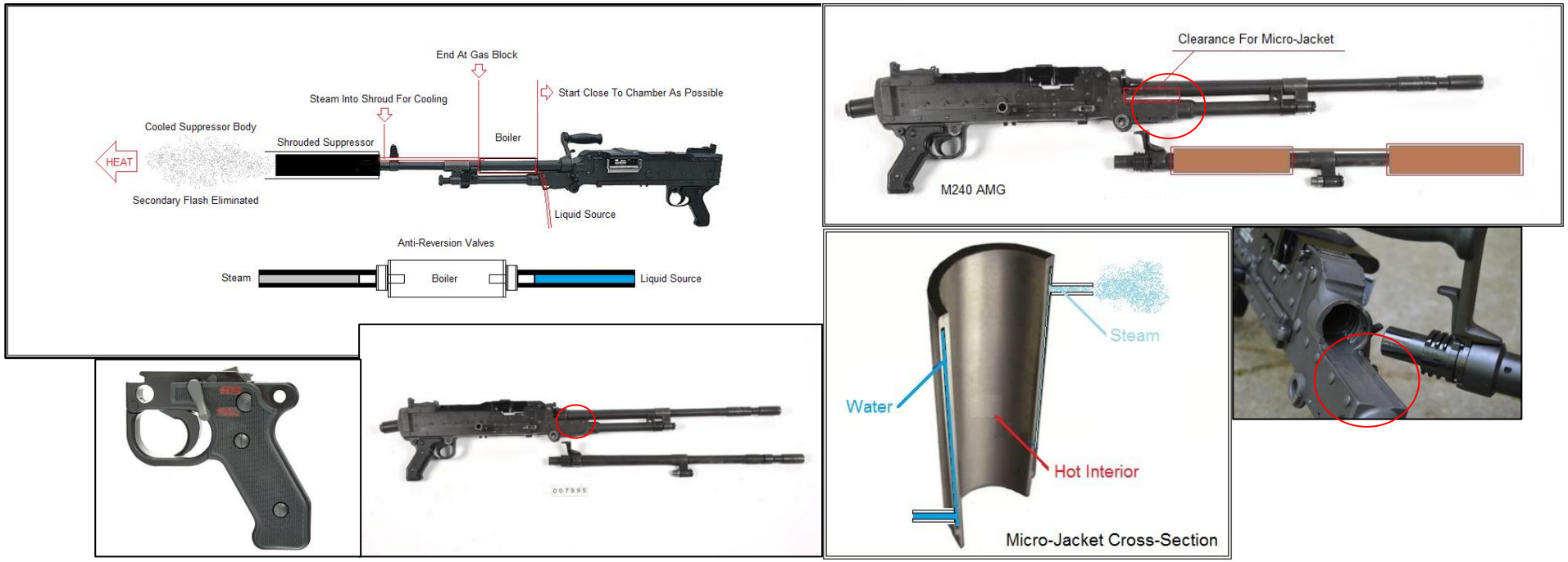


Clockwise From Upper Left: SDSHobbyUSA.net Photo, Turnigy Aquastar Motor Photo, HotRacing 36mm Photo, HRC 2028 Photo, NASIOC Motor Intercoolers Photo, PWR Automotive Water To Air Intercooler, Nordic Ice Automotive Water To Air Intercoolers, BW Barrel Charger Water To Air Intercooler, Ebullient PC Electronic Processor Water Cooler.

Modifications To An Existing Weapon To Integrate Design

Modification To Weapon Necessary For Installation Of Micro-Jacket Cooling System:

Guide Ramp Area For Manual Barrel Change Must Have Clearance Removed



Above Images Based On Fabrica Armas Licensed MAG, Clockwise From Upper Left: General Layout Of Cooling System With Anti-Reversion Valves, Clearance For Micro-Jacket, Ohio Ordnance Photo Of Clearance Needed, Micro-Jacket Cross Section And Original FA Image Area Requiring Relief, OOW Selective-Fire TG.

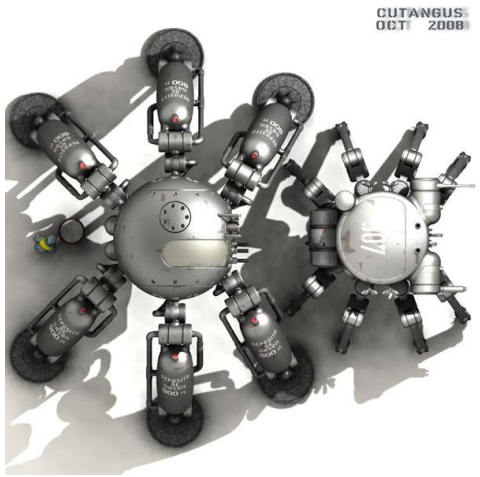
Modification To Weapon Necessary For Installation Of Micro-Jacket Cooling System:

SEG Integral Suppressor Design Provides Means Of Super-Heating Steam Produced

Commercial Development Team For Robotic & Remote Turret; **OOW, SEG, INSULON, SAI, TurnPoint, YETI**

An Advanced Design Demonstrator Virtually Off-The-Shelf…

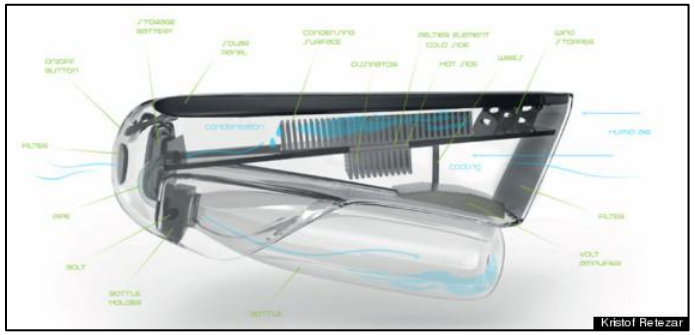
Enabling Technologies Which Advance The Concept

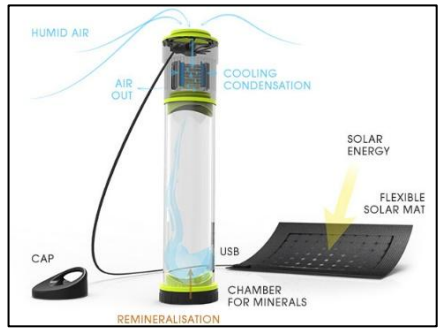


Enabling Technologies Which Advance The Concept:

Water Makers, Infusion Pumps & Thermostatic Valves

https://futurism.com/new-device-uses-sunlight-create-drinking-water-air/

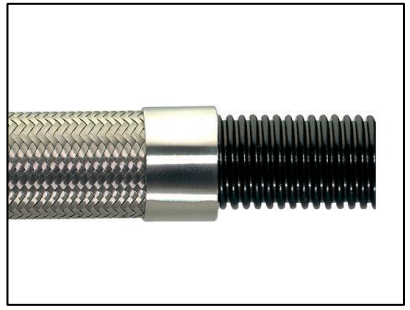


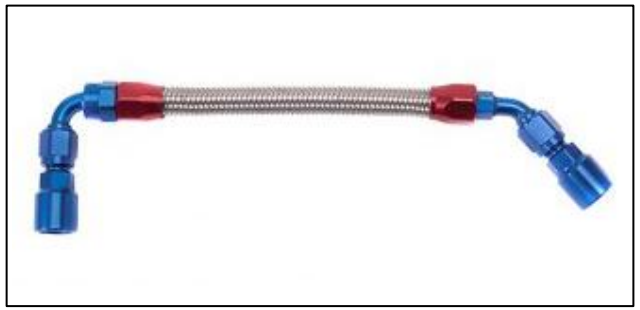


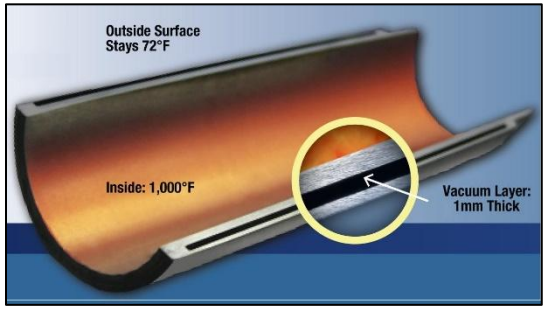
Fontus Water Maker Photos (3), ISTEC Moisture Sensor Valve, TCS Micro-Pump Photo, TurnPoint Breeze Programmable Medical Infusion Pump , G&A YETI Rambler Vacuum Insulated Thermos Bottles For Water.

Enabling Technologies Which Advance The Concept:

Aviation Quality "Plumbing" For Micro-Jacket Liquid Control







Clockwise From Upper Left: Direct Industry Stainless Braid, Raspberry Pi Watercooler, Parker Thermal Solenoid, Agency Power Brake Lines, CGI INSULON Cryo, CGI INSULON High-Temp As Micro-Jacket, DarkSide Racing Fuel Lines, Hydraulix Taper Lock Stainless Steel High Pressure QD Fittings

Enabling Technologies Which Advance The Concept:

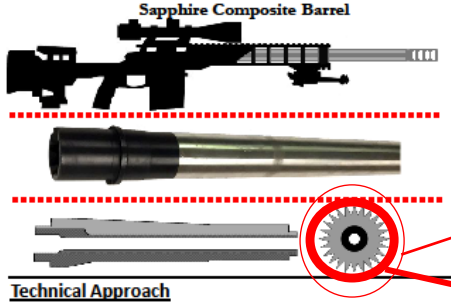
Integral Heat Sink Barrel Jacket Designs In Support Of The Micro-Boiler

GREY CASTLE GROUP, LLC

BAA Number: **17-S-4710**
Document ID: **TOS-R000-GREYCASTLEGROUP-QC7**
Proposal Title: **Sapphire LWLT Barrel (Light Weight/Low Thermal)**

2017 – Grey Castle Group – Proprietary Information
02/01/2017
Grey Castle Group, LLC

Sapphire Composite Barrel



Operational and Performance Capability - Summary

- 3 x to 4x Increase in Sustainable Rate of Fire (vs SBSW)
  - Enhanced Lethality and Accuracy Under Sustained Engagements Involving High Thermal Loads (vs SBSW)
- Thermal Management and Signature Reduction
  - 30% to 50% Increase in Heat Capacity
  - 300%+ Increase in Cooling Speed (Stealth/Low-Vis)
  - Less Exposure To FLIR (Potentially Life Saving)
- 85 % Increase in Barrel Stiffness vs (SBSW)
  - Enhanced Accuracy From Reduced Barrel Harmonics
  - Sound Dampening Inherent in Sapphire Material
- Increased Accuracy
  - 85% Increase in Stiffness vs (SBSW)(Steel Barrel of Same Weight)

Technical Approach

Current Standard Steel Barrel Issues: Accuracy/Structural Integrity Degrade as Thermal Load Increases; Point of Impact Shift Due to Thermal Fatigue; Increased Barrel Stiffness and Heat Capacity Requires Additional Steel/Weight. **The Solution: Sapphire Composite Barrel with** Inner Core Made From Standard Gun Barrel Steel; Mantle Made of Proprietary Sapphire Material; Acts Both As a Heatsink and Structural Reinforcement.
Estimated final barrel cost = <$800

Phase 1 Tasks:

- HIP Production of sleeved barrel (AR design complete in 5.56 and 7.62)
- Exterior machining for gas tube and prototype fitting to upper receiver
- Rifling interior and final assembly of test articles
- Range testing and validation

Phase 2 Tasks:

- Implement design adjustments
- HIP Production of selected barrel and caliber
- Exterior machining for gas tube and prototype fitting to upper receiver
- Rifling interior and final assembly of deliverables
- Range testing and validation with customer demonstration

Rough Order of Magnitude (ROM) and Schedule

Phase 1 - ROM $50,000; POP 4 months; Exit criteria: Four test articles at selected calibers for customer testing

Phase 2 - ROM $100,000; POP 6 months; Exit criteria: Finalized caliber/ barrel solution for customer demonstration.

Total POP: 21 months; Total Cost: $150,000

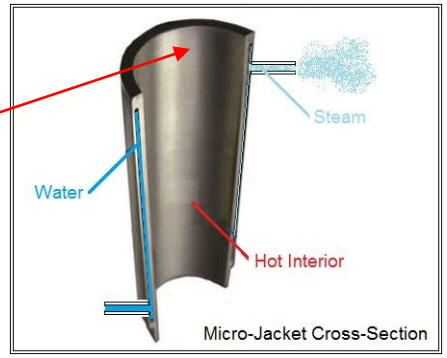
Products and Deliverables

Phase 1: MSRs; Initial Test Report; Performance Analysis Report
Phase 2: MSRs; Final Design Package; Final Test Report; User manual

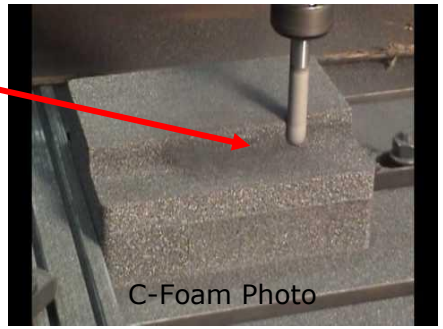
Corporate Contact Information

Grey Castle Group, Steve Brown, UNCC PORTAL, 9201 University City Blvd., Charlotte, NC 28223. Phone: (704) 533-5053
Email: sbrown@greycastlegroup.com

2017 – Grey Castle Group – Proprietary Information



Micro-Jacket Cross-Section


C-Foam Photo

Graphite Foam Shaped To High Surface Area Barrel Cross-Section Interfacing To Micro-Boiler

Enabling Technologies Which Advance The Concept:

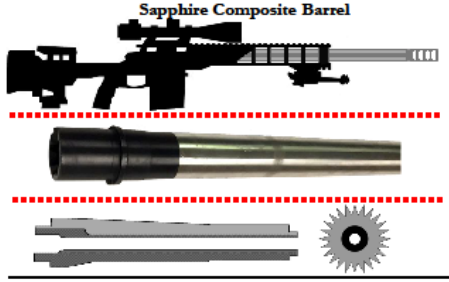
Integral Heat Sink Barrel Jacket Designs In Support Of The Micro-Boiler

GREY CASTLE GROUP, LLC

BAA Number: **17-S-4710**
Document ID: **TOS-R000-GREYCASTLEGROUP-QC7**
Proposal Title: **Sapphire LWLT Barrel (Light Weight/Low Thermal)**

2017 – Grey Castle Group – Proprietary Information
02/01/2017
Grey Castle Group, LLC

Sapphire Composite Barrel



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2017 – Grey Castle Group – Proprietary Information

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GreyCastle LLC Photos, Mohsehni et al Thermal Conductivity Graphic

Barrel Requires Liner With Non-Epoxy Heat Sink Material Jacket To Withstand Thermal Cycles

Conclusions:

- Water Cooling Has Much Greater Heat Transfer Potential Than Air Cooling
- A Modern Cooling Jacket Can Be Lighter Than Multiple Air Cooled QC Barrels
- The Amount Of Water Required For A Modern Cooling Jacket Fits In A Liter Thermos
- Cooled Robotic Or Remote Turret Weapons Can Be Made To Fire Continuous Bursts
- Improves Weapon Signature Reduction Endurance When Steam Cools Suppressors

Recommendations:

- Make Modifications Needed To Existing, Reliable Infantry Weapons For Unmanned Use: Charging, Firing & Port Clearing Automation, Cooling Jacket Clearances, et cetera.
- Purchase Existing Self Powered Weapons And Modify Them With Cooling Jackets For Competitive Trials With Modified Infantry Weapons; Considering Self Powered Efficiency vs. Many Common Battlefield Spares To Replace Damaged Weapons.
- Create A Situation Where Robotic Or Remote Turret Weapons Can Deliver A Continuous Stream Of Suppressive Fire Without Pause While Troops Maneuver Or Withdraw.
- Explore Expanded Magazine Capacities, Power Belt Assist Feed Mechanisms And Speed Loaders To Leverage Continuous Fire Capability For Robotic And Remote Turret Use.

Credits:

POC: Howard D. Kent, CEO, Phone: 818-314-8636, e-Mail: HDKent@socal.rr.com

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M-240/240-SLR Robotic

M-240 LW Selective Fire

POC: Lt. Robert Landies, USMC-Ret, VP, Phone: (440) 285-3481 x128, e-Mail: rlandies@ohioordnanceworks.com

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With Special Thanks To:

STS ARMS LLC.
FFL Class III – 07
Oregon Volunteer Testing Center

GUN IQ
Gun IQ International, LLC
POC: George E. Kontis, PE
Phone: 321-383-0987

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