# Ebullient Engine HRSG

## Throttle-less Spark Ignited Engine

OVERVIEW

FEB. 20, 2014

PRESENTED BY

BENZ AIR ENGINEERING, CO., INC.

BENZ AIR ENGINEERING

# Addressing California's Grid Nightmare

# Agenda

- Why only 1 CHP < 5mw was installed in So Cal in 2013?
- The Ebullient Engine
- California's Impending Power Grid Catastrophe – The "Duck Chart"
- Fabrica Installation
- Summary
- Benz Air Company Background

Appendix A. Reference Technologies

# Only One CHP System < 5 mw in So Cal 2013
# 22 cents/kw-hr



- Utility Interconnection – Solved or addressed
  - Supplemental Review
    - Additional variable cost
    - Minimum of 20 day up to 2 year delay
- Air Permitting – Solved or addressed
  - Additional point source requiring new air permit
    - New source review including public comment
    - 6 month delay
  - Stringent NOx and CO Requirements
    - 0.07lbNOx/mw-hr or 3.3ppmNOx @ 15%O2
- Utilization of Waste Heat-
  - Hot Water Has Limited Use
    - Seasonal Variations – Demand Opposite Electrical Demand
    - 300kw Hot Water CHP kicks out 70gpm of 180F water – There's only so many swimming pools to heat!

# All CHP systems have to produce all heat as Steam

- High Value Steam from Ebullient Cooled Engine
  - Supplements DA Steam in Facilities with Steam Processes
    - Additional CHP Credit from Replacing Boiler Steam
  - Use for Cooling in Absorption Systems
  - Nucleate Cooling Allows Higher Continuous Engine Output –
    - Far Higher Energy Density – Big Block V-8 outputs 300kws versus 100kw for Hot Water Unit.
    - 3 gpm of low pressure Steam versus 70 gpm of hot water.
- Engine Integrated with an Existing Steam Boiler
  - Engine Exhaust Replaces Boiler Re-circulated Flue Gas
    - NOx and CO reduced in Boiler Combustion
    - Engine Exhaust Heat Recovery Supplements Boiler Fuel
  - No Need for a New Air Permit
    - There is No Additional Emission Point Source
    - So Long as Boiler + Engine Fuel < Boiler Rated Heat Input
- Simplified Interconnection for Fast Track Utility Approval
  - Induction Generator through UL1741 Regenerative VFD
  - 10 day Approval Process Rule 21
  - Variable Generator Output from 30% to 100% Load at Peak Efficiency

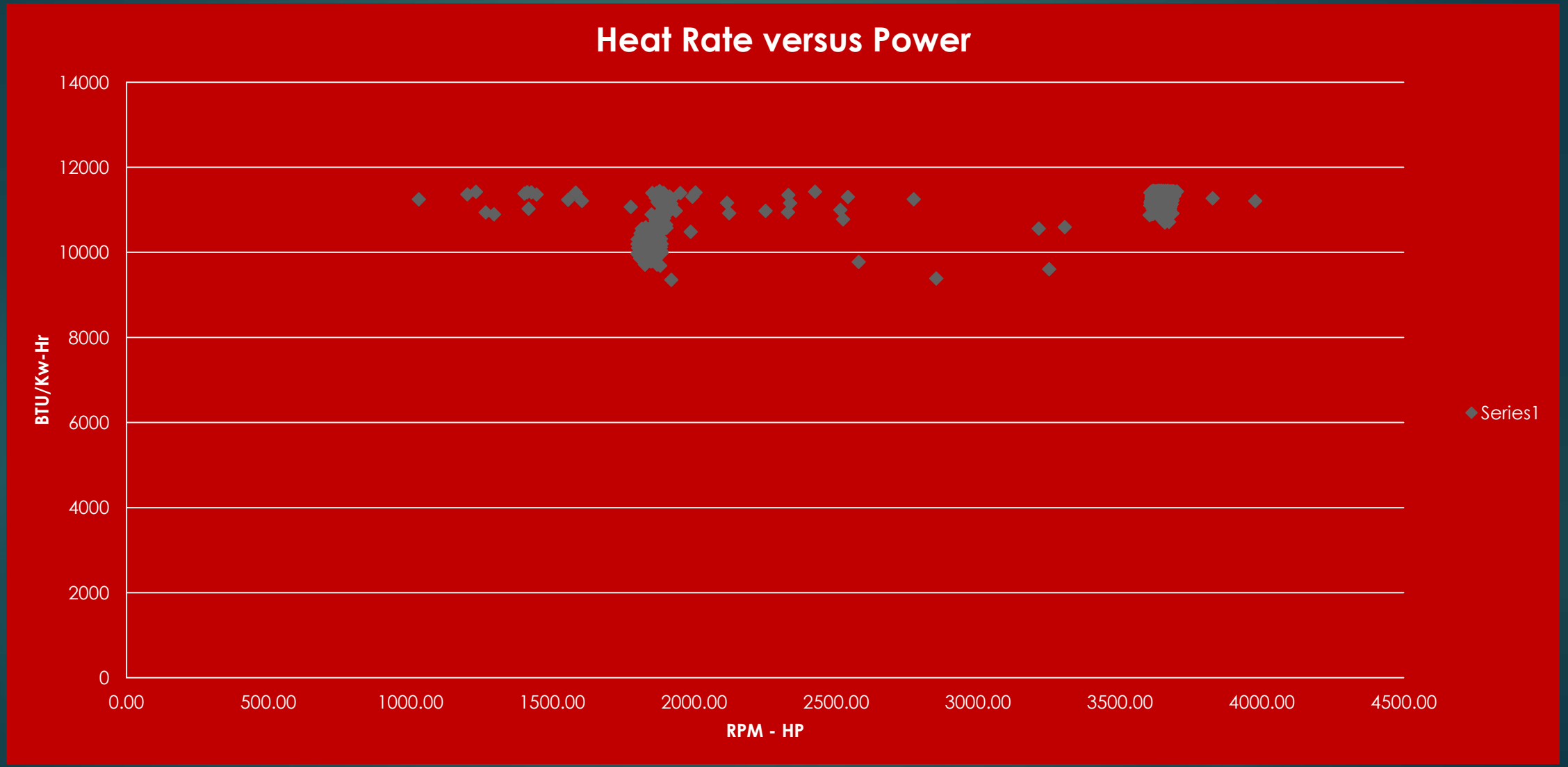
# Design and Testing Ebullient Engine

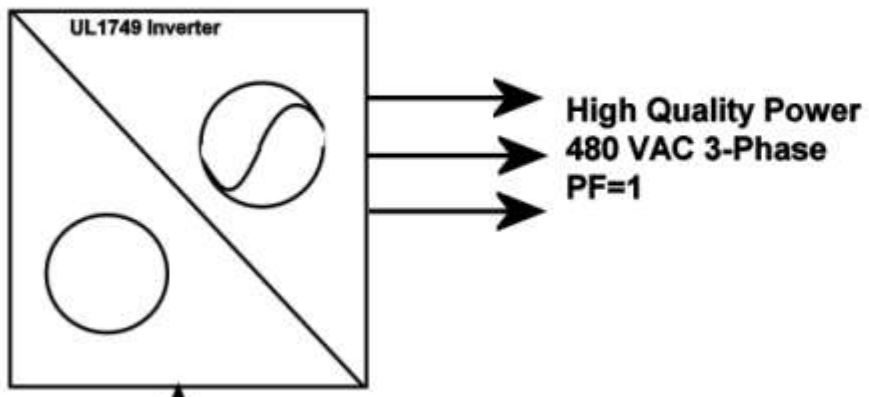
# Ebullient Cooled Versus Conventionally Cooled Engine Temperatures

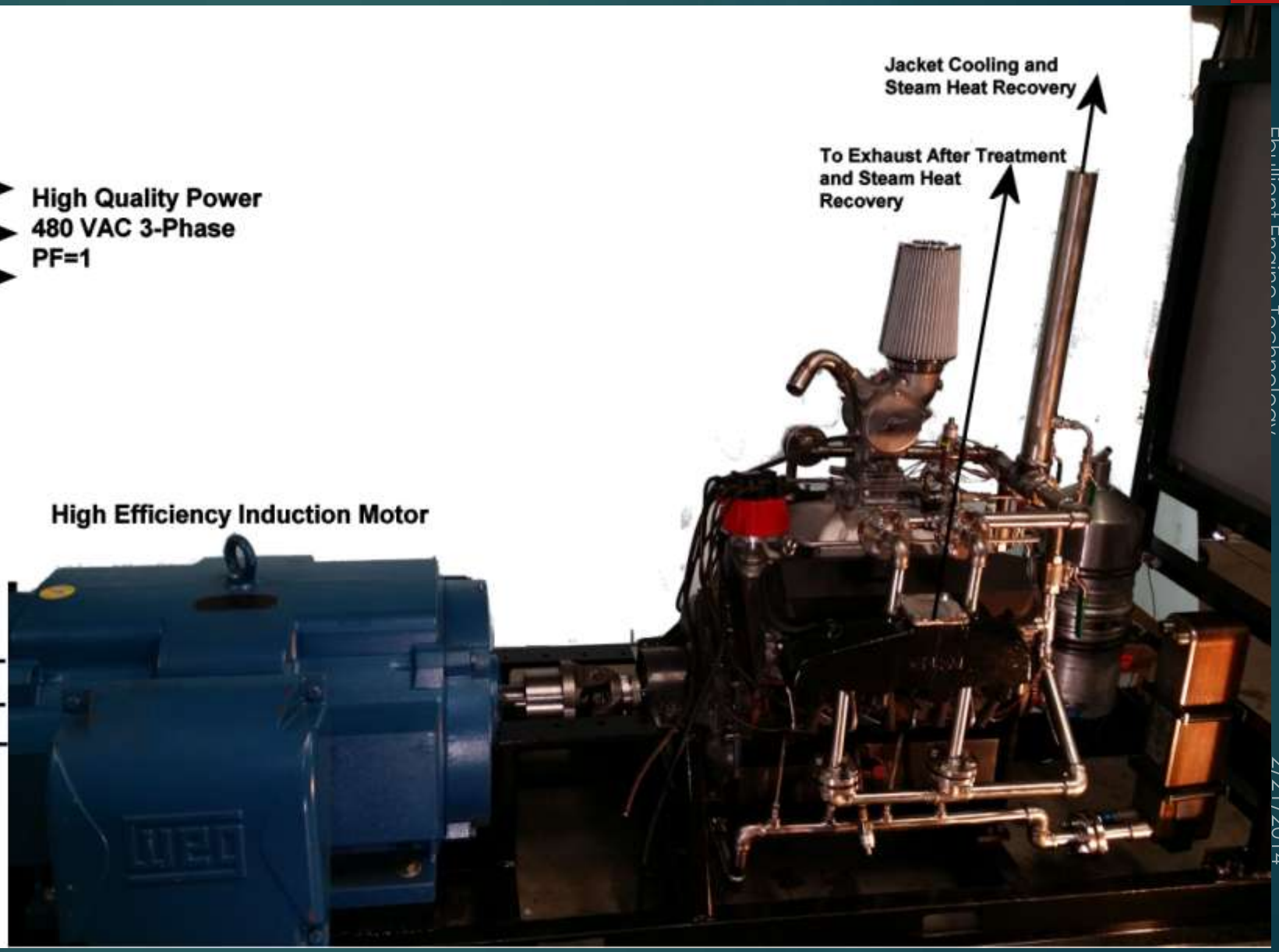
Cylinder Temperature Distribution


| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Exhaust Valve Temp Baseline | 362.70 | 323.09 | 336.49 | 334.63 | 314.44 | 325.97 | 323.43 | 326.35 |
| Exhaust Temps Baseline | 1452.55 | 1447.64 | 1394.73 | 1433.48 | 1390.91 | 1367.95 | 1363.19 | 1437.38 |
| Ebullient Exhaust Temps | 1361.10 | 1380.81 | 1340.25 | 1385.03 | 1420.73 | 1373.89 | 1394.96 | 1385.16 |
| Ebullient Valve Temps | 379.98 | 392.76 | 387.57 | 394.38 | 389.54 | 389.30 | 385.39 | 388.96 |

# Throttle-Less Engine for Constantly Low Heat Rate

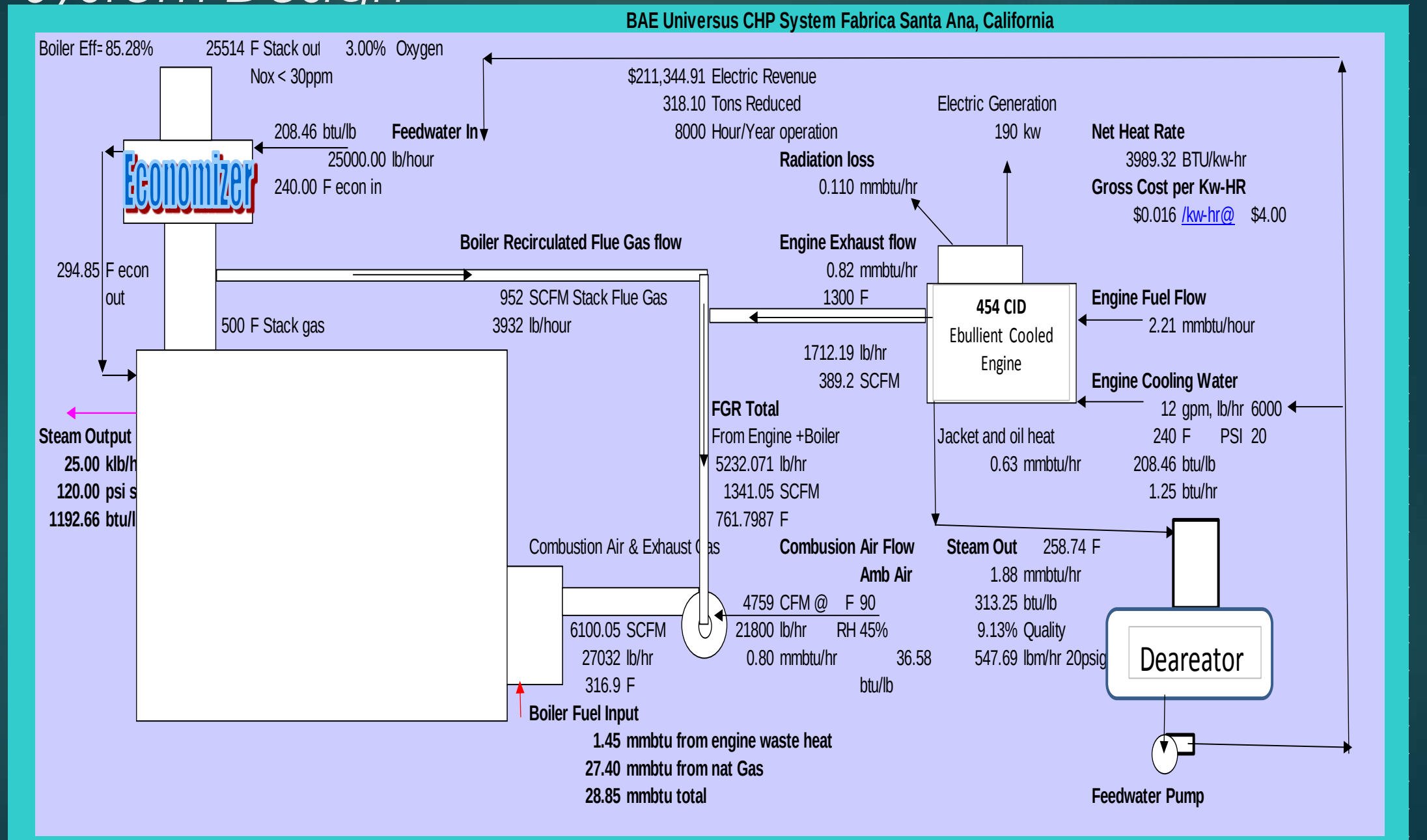



UL1749 Inverter
High Quality Power
480 VAC 3-Phase
PF=1
Direct Current Bus
Variable Frequency Drive
3-phase
Variable Frequency
Power


Jacket Cooling and
Steam Heat Recovery
To Exhaust After Treatment
and Steam Heat
Recovery
High Efficiency Induction Motor

# CHP System Design

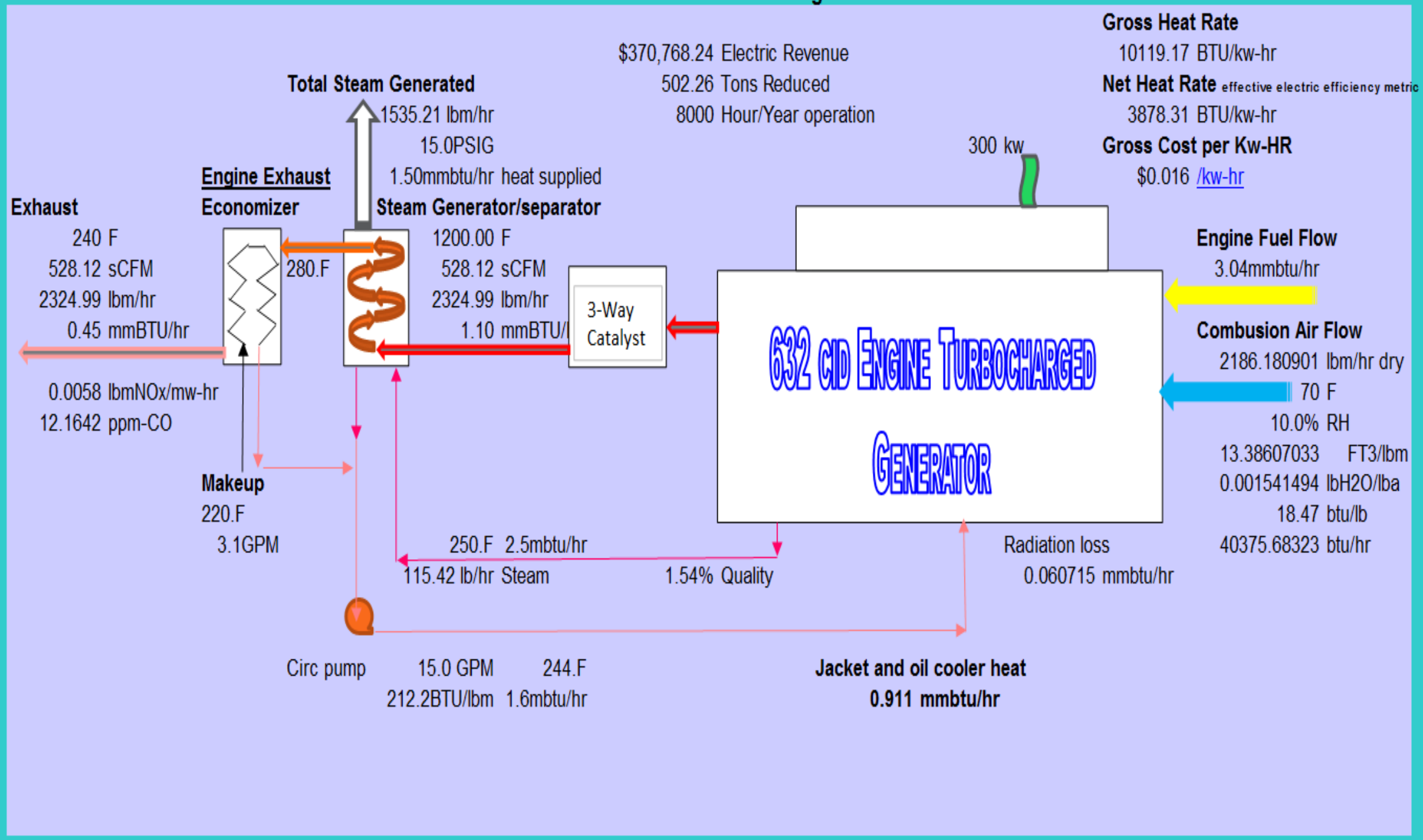




# Next Generation 632 CID Engine

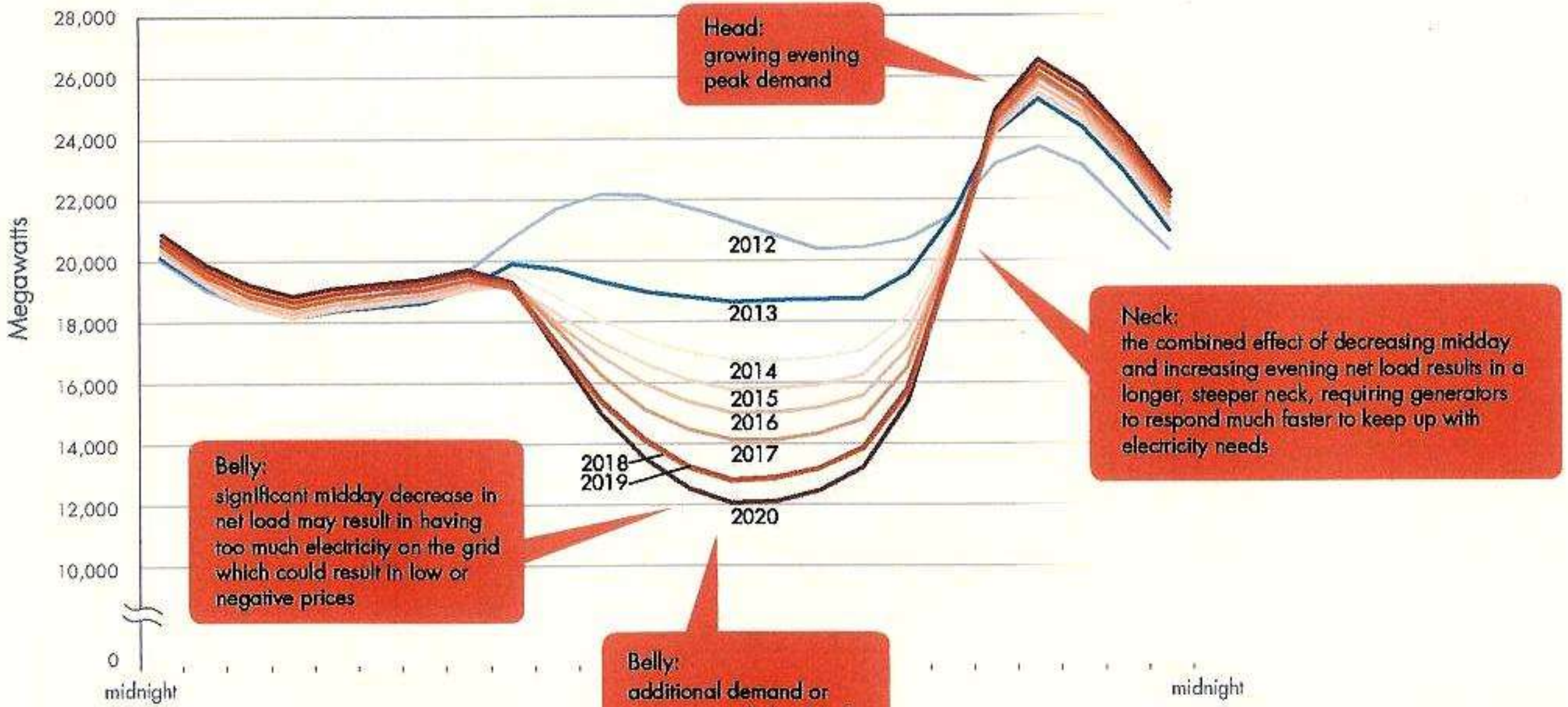
- Bigger Bore & Stroke for up to 400Kw
  - Higher Compression Ratio (<12:1)
  - Heat Rate < 10000btu/kw-hr
  - Integral Piston Cooling system
  - Roller Valve components,
  - Same Big Block GM Configuration as 454cid
  - Turbo Charging for higher power and exhaust temperation.
    - A turbo is cheaper than a heat exchanger?
  - Ceramic Coating of Internals to Minimize Heat Loss.
  - Off the shelf availability.
- Development of Micro Stand Alone Steam Cogeneration Plant
  - Small Boiler Replacement Alternative for Providing 25psig Steam at up to 2500lb/hour @400kw
  - Ultralow Emission Control - <3ppm NOx and CO
    - Steam Recirculation
    - Digital Air Fuel Ratio Control
  - Switchable from Non Island to Island Standalone Blackstart Capability
  - Packaged Absorption System for 150tons of Cooling

# Standalone Ebullient Engine CHP

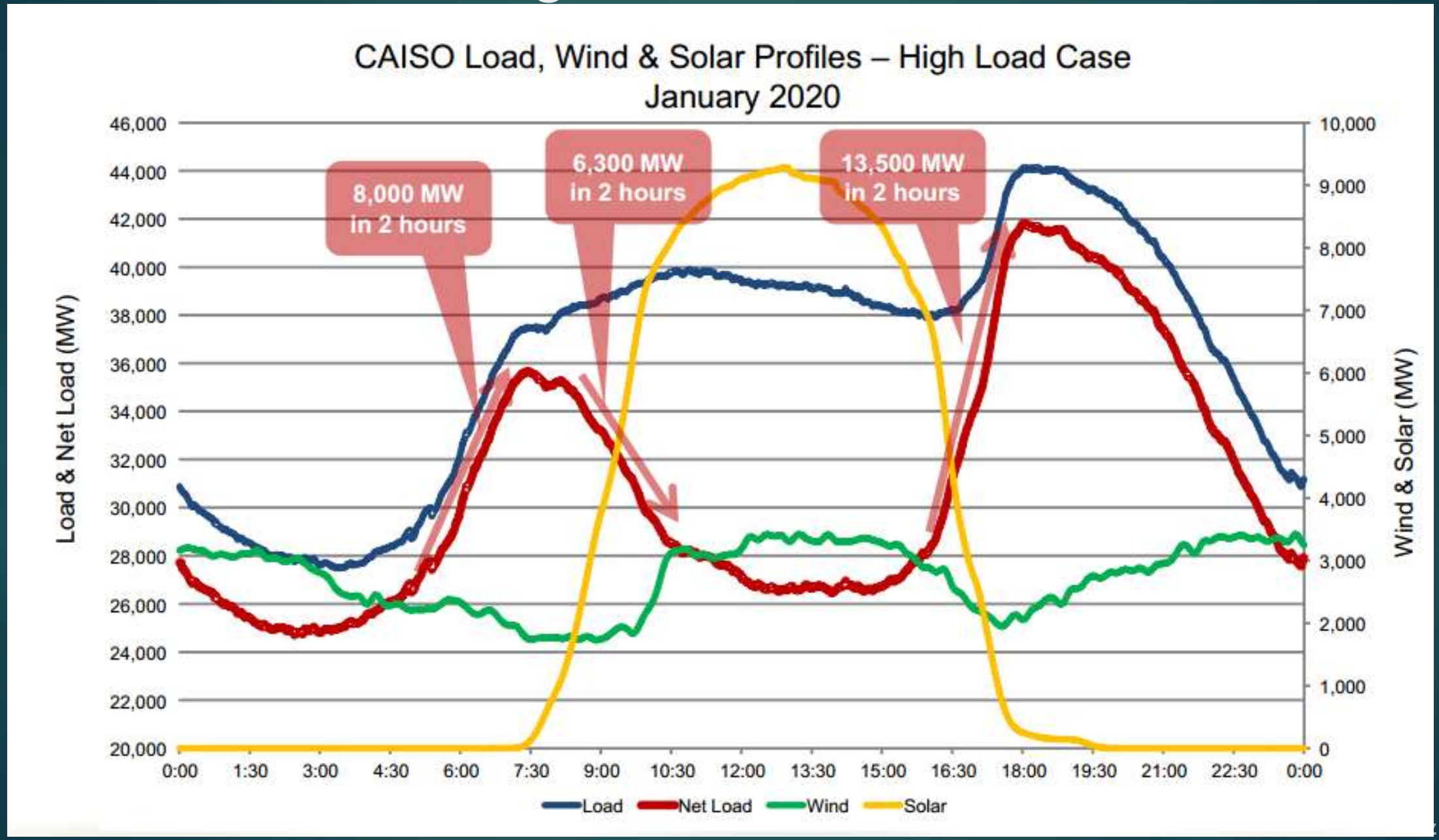


# A Total Change in the Business Case for CHP

- Consistent Reliable Generation ---------- Forget it
- Durability ---------- Sucks
- Spark Spread ---------- The Utility will Kill you


28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
0
Megawatts
midnight
midnight
Head:
growing evening
peak demand
2012
2013
2014
2015
2016
2017
2018
2019
2020
Neck:
the combined effect of decreasing midday and increasing evening net load results in a longer, steeper neck, requiring generators to respond much faster to keep up with electricity needs
Belly:
significant midday decrease in net load may result in having too much electricity on the grid which could result in low or negative prices
Belly:
additional demand or storage may help absorb excess generation in overgeneration conditions

# Renewables wreaking Havoc on California's Grid.



# Solution to "Duck Chart"

- Battery Storage – A Pipe Dream
- Hydro Storage – Already tapped out.
- Compressed Air – Come on?

## Natural Gas CHP for Demand Response

- Ebullient Engine HRSG w/Absorption Chiller
  - Constant Heat Rate Regardless of Output.
  - Startup and full load within 2 minutes.
- Electrical Chillers, boilers during oversupply
- Ramp up Engine and Absorption Chillers during undersupply.

# Summary

- Installation and demonstration of engine, exhaust of which replaces industrial boiler recirculated flue gas.
- Setup and installation of the UL1741 drive and testing wide open throttle to determine maximum ramp rate
- Impact of boiler emissions having an engine integrated within the boiler, the control volume including boiler and engine
  - Determining the limits of boiler load to engine output ratio
- Design and specification of turbocharger for increasing power output
  - Effect of head metal temperatures with increased boost at stoichiometric
- Black start and standby generation of induction generators
- Steam driven water chilling
- Steam injection for NOX control
- Local uses of steam for reformation of natural gas
  - Hydrogen production on site
  - Hydrogen injection for NOX emission reduction
  - Hydrogen injection for Power boosting
  - Ammonia production on site

# Contact Information

Robert Benz 209-602-1019

Rocco (Rick) Belmonte 203-885-6426

Benz Air Engineering, Co., Inc.
4061 Silvestri Lane, Bldg. 103
Las Vegas, NV 89120

702-597-4805

www.benzair.com

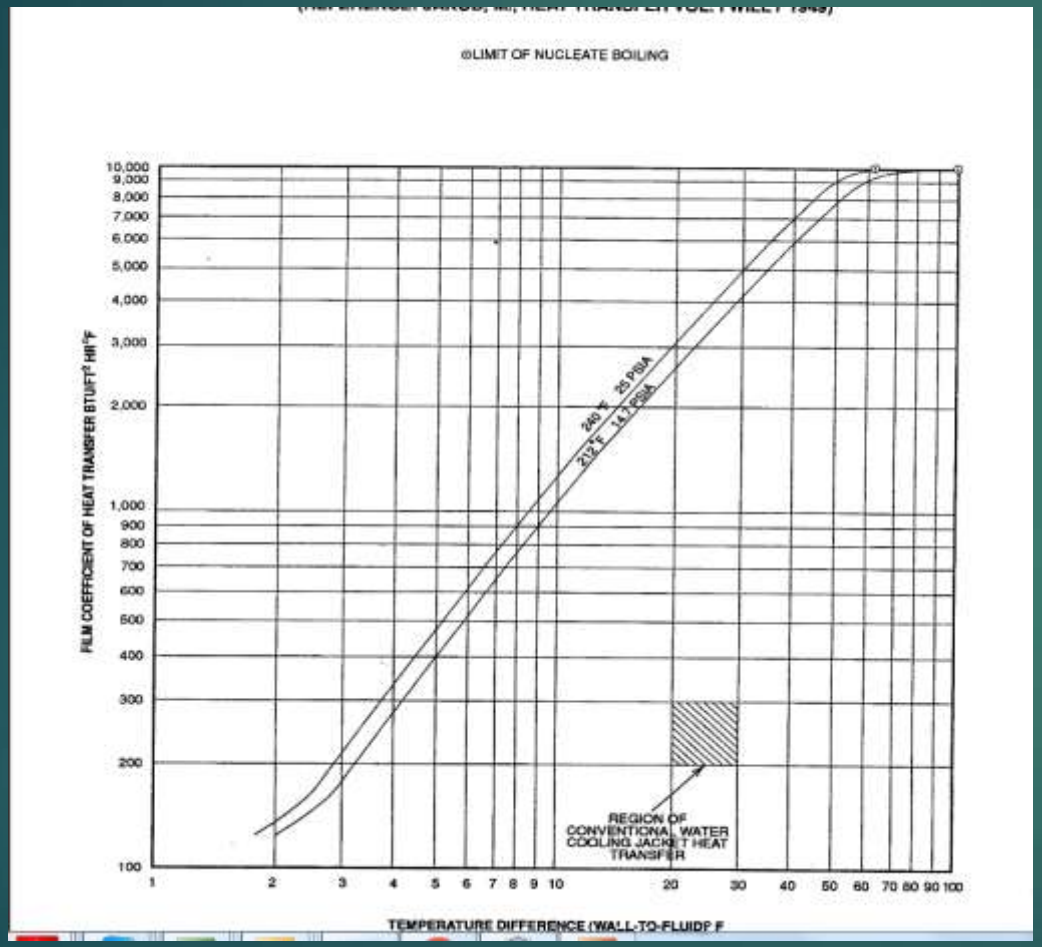
# APPENDIX A. REFERENCE TECHNOLOGIES

- Nucleate Boiling Heat Transfer
- Nucleate Heat Transfer Film Coefficient
- Ebullient Cooling Flow Patterns
- Engine Absorption Cooling Example

# Nucleate Boiling Heat Transfer 'Nucleate Cooling'

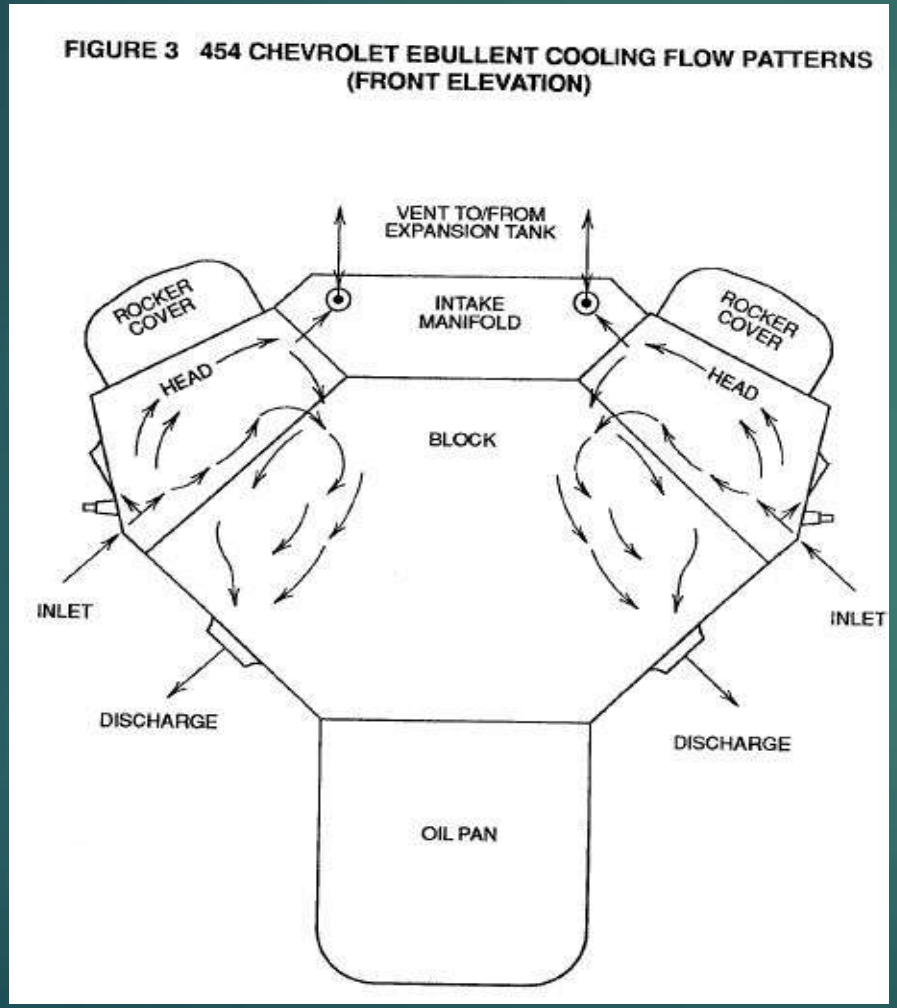
- 25 times the heat transfer rate of water convection
- Cooler Metal Temperatures with Hotter H20
- Uniform Head and Block Temperatures
- High Value Steam
- Low Parasitic Power – 1/10$^{th}$ Coolant Flow of Typical Engine
- Fast Starting
- Higher Margin in Cooling Capacity
  - Typical engine cooling is limited to 180F outlet water.
  - Constant temperature of Nucleate Cooling lacks any Limitation.

# Nucleate Heat Transfer Film Coefficient




- Note  tremendous difference in heat transfer rate for a given temperature difference between metal and coolant.
- That difference needs to be minimized for durability. – thermal stresses.

# Ebullient Cooling Flow Patterns




- Note reversal in direction of coolant circulation, top hot has priority for cooling capacity
- Once through flow

# Engine Absorption Cooling Example