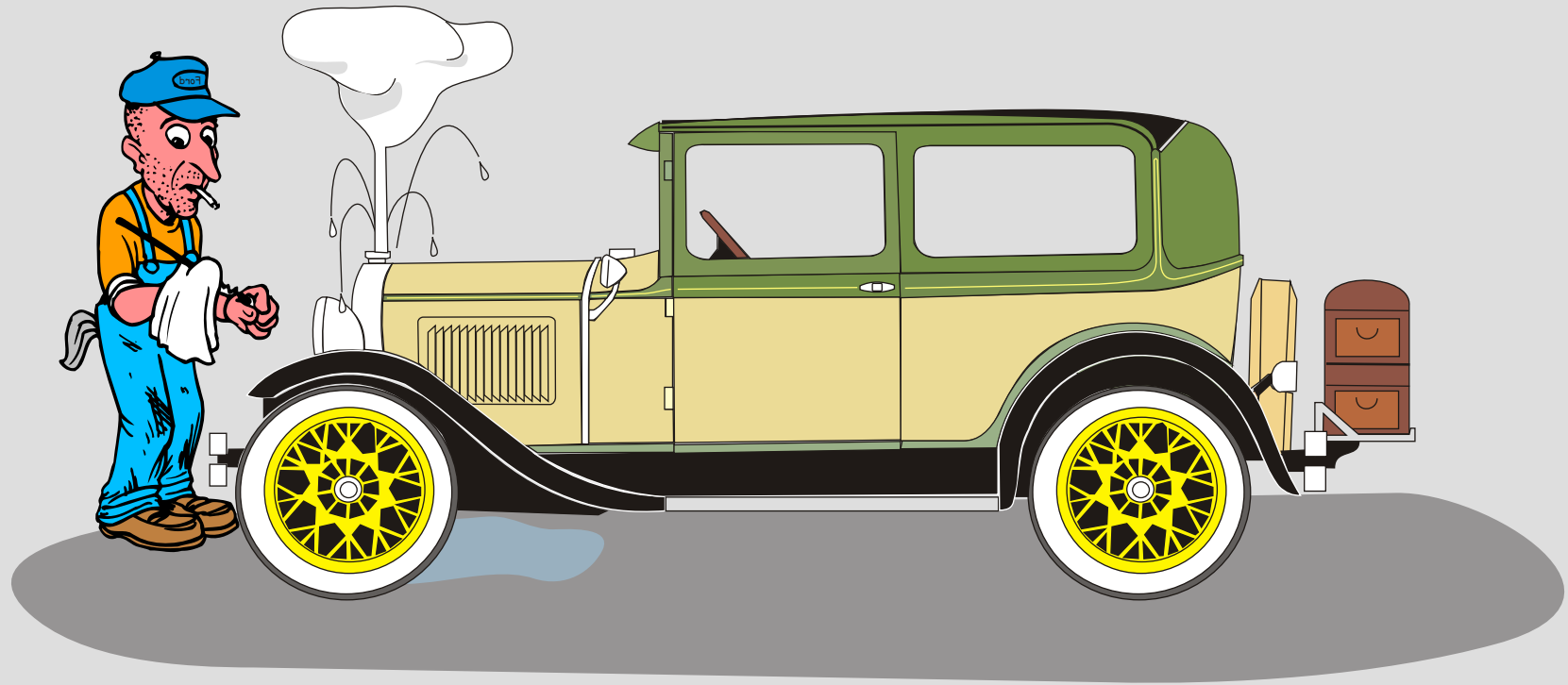




Cooling System Seminar

By: Andy Wiedeman

Member of the Rocky Mountain A's
As Presented at the Cooling Seminar

Feb. 25, 2012

In Franktown, Colorado



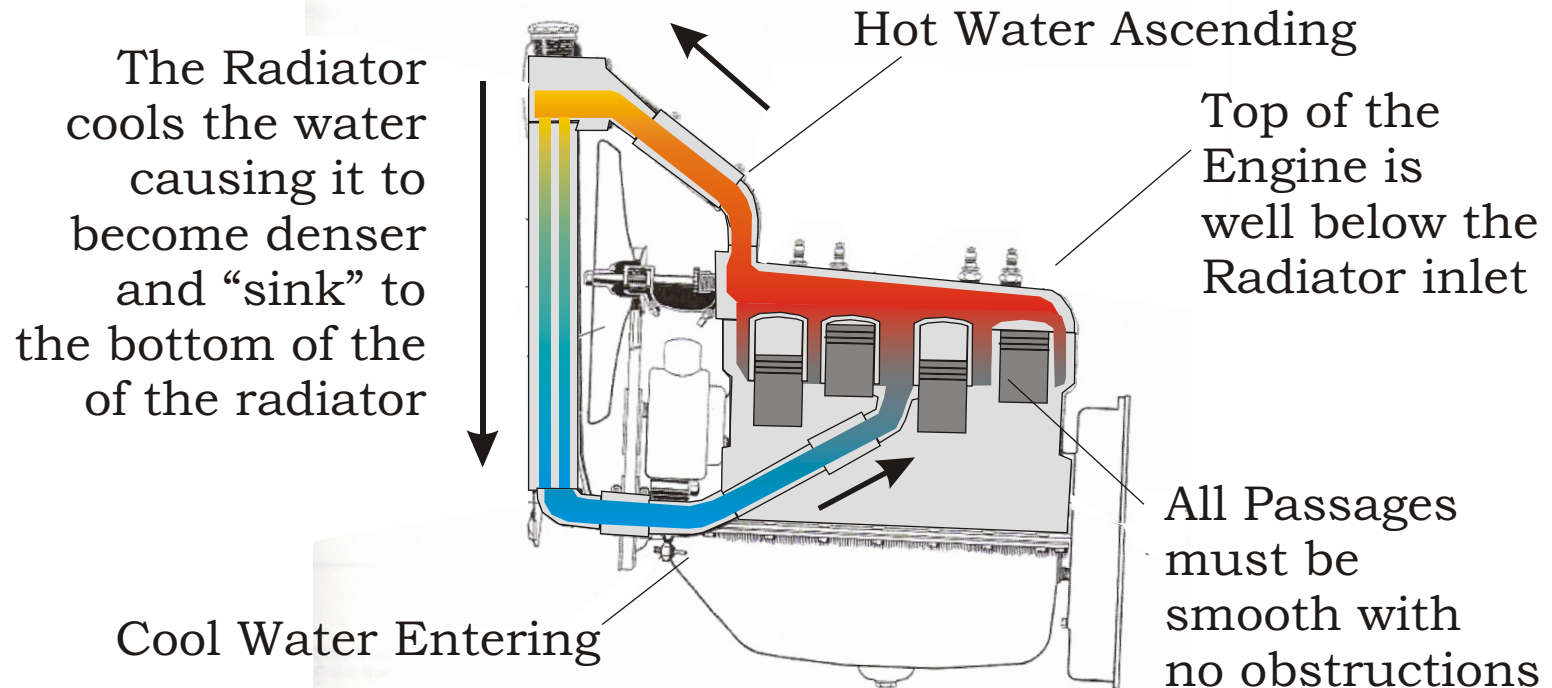
A Short History of Cooling the Model A Engine

- As horsepower increased water cooling was introduced using a water pump to force coolant through the engine
- Manufacturers wanted simpler means for cooling
- Designers wanted a non-pumped cooling system to avoid failed pumps ... The pumpless Thermo-Syphon system evolved ... A debate ensued pump or “no pump”
- Henry Ford adopted the thermo-syphon for the “T”
- Most manufacturers continued to use the water pump
- The Model A modified the “T” system to use BOTH !



The Thermo-Syphon Cooling of the Basic Model A System

- The Model A engine cooling system evolved from the earlier Model T Thermo-Syphon design



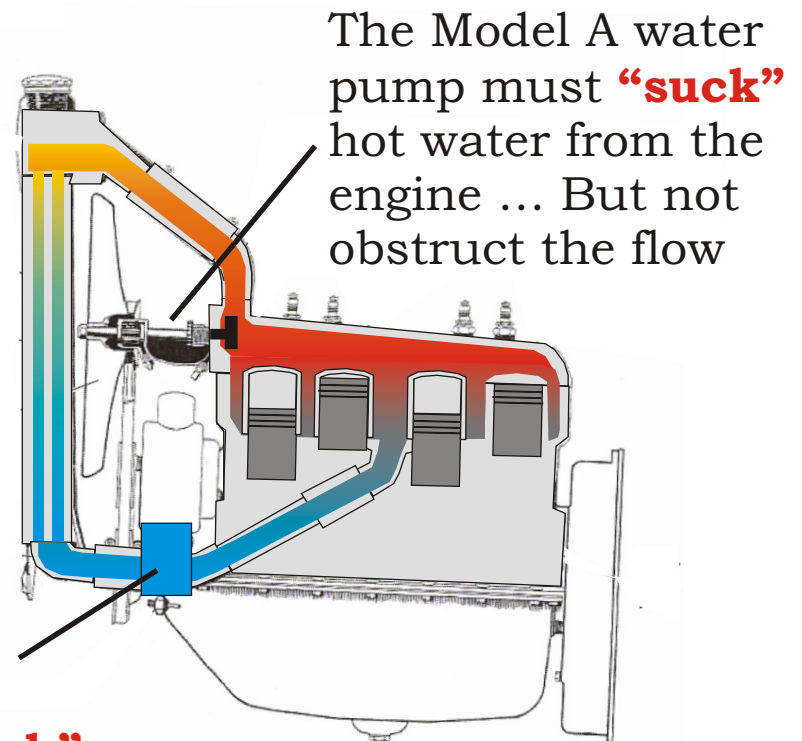
- The 1930-1931 Model A's have a raised radiator inlet to get additional Thermo-Syphon cooling action.



So what's with the Model A Water Pump?

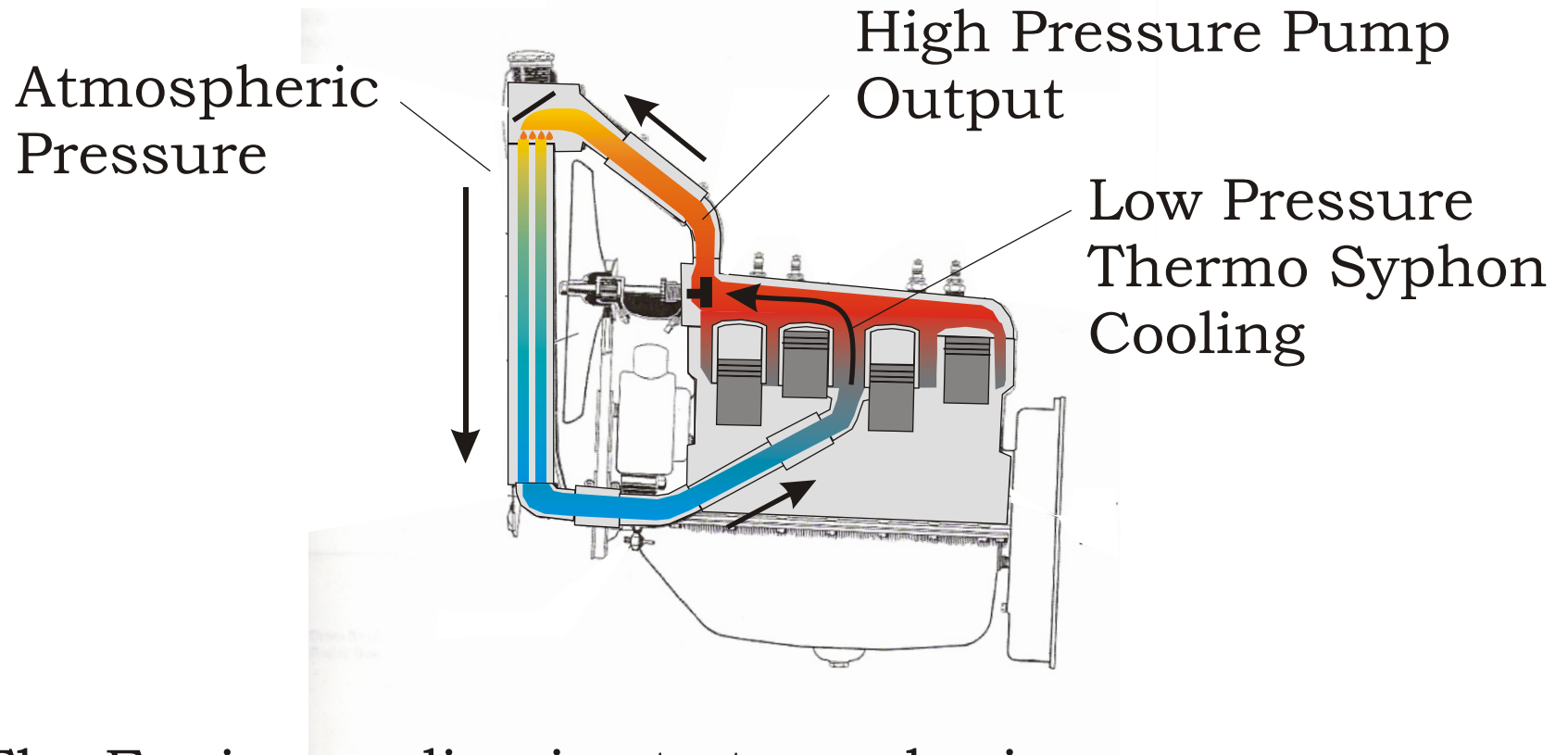
- The engineers of the Model A added a water pump the early 5 impeller pumps gave way in 1930 to a 3 impeller design (Replacement pumps are 3 impeller blades for all years)
- The pump is used at high engine speeds to increase the water flow and maintain a more even temperature.
- Basic cooling is still the Thermo-Syphon system

Most Manufacturers of the time put the water pump here to use gravity to feed the pump and **"push"** the water through the engine at a higher rate of flow than the Model A





Pump Aided Thermo Syphon Cooling



- The Engine cooling is at atmospheric pressure the water pump aids coolant flow at high speeds



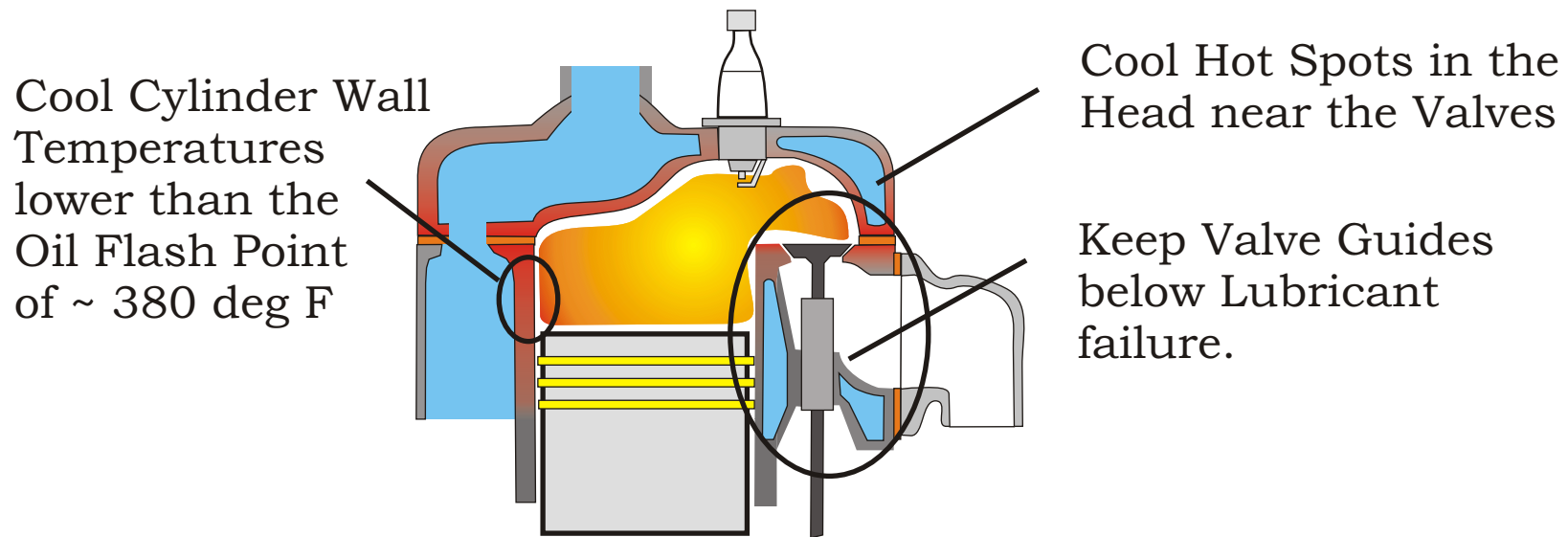
How do the various Designs Compare ?

	Early Autos	Model T	Model A	Modern Autos	Comments
Cooling Design	Pump Forced Water	Thermo Syphon No Pump	Thermo Syphon Pump aided	Pump Forced Coolants	The Model A is mostly a Thermo Syphon System (Last to Use it)
Coolant Flow	Up to 100 gal per min	Varies with heating 0 to 25 Gpm	36 to 38 Gpm	100 Plus gal per min	The Model A pump “sucks” water from the engine
Pressurized	NO	NO	NO	YES Usually to 1 Atmosphere (15 psi)	Pressurization Increases the margin to boiling by raising the BP
Flow Regulated	YES	NO	NO	YES with Thermostat	Thermostats raise engine temp fast in winter for more efficiency
Typical “hot” Operating Temperature	Boiling	Varies 150 to 200 deg F	Typically 190 deg F	195 to 220 deg F	The Model A has much less margin for boiling at high altitudes
Design Coolant	Distilled WATER	Distilled WATER	Distilled WATER	Antifreeze Mixtures with Additives	Modern cars are designed for using the less efficient Antifreeze coolant



What is Actually being Cooled ?

- The principle elements that are being cooled are the cylinder wall oil lubricant and the valve seat area.

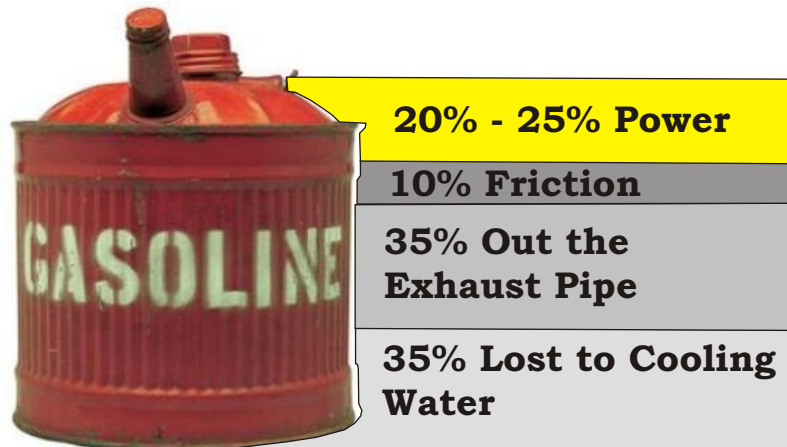
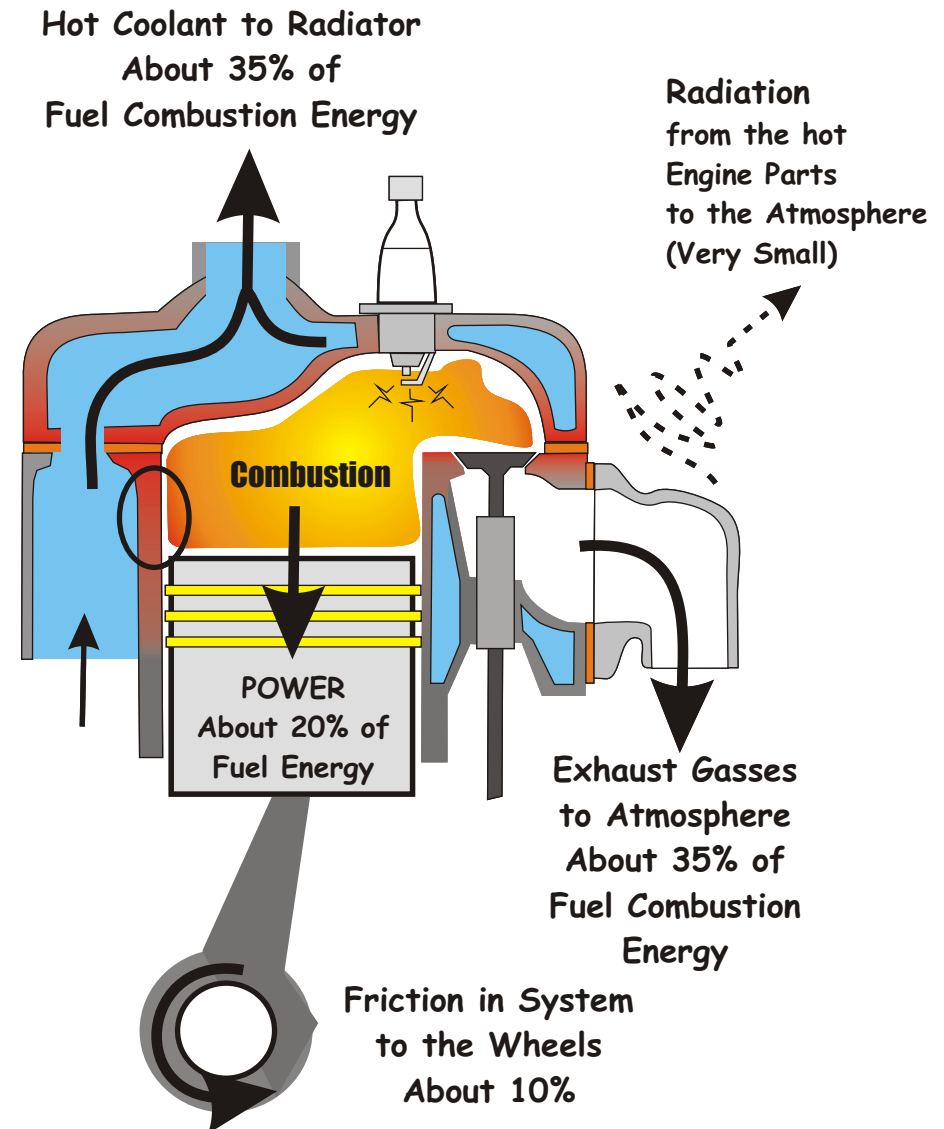


- There must be a “Balance” between cylinder wall temp and engine efficiency ... thus the designers set the Cylinder Wall Temp as high as possible to get the most out of the engine & keep the coolant from boiling



Energy Balance in the Model A Engine

- The Cooling System in the Model A must remove about 35% of the energy burned in each gallon of gasoline consumed
- The overall efficiency of most gasoline engines is about 20% to 25%

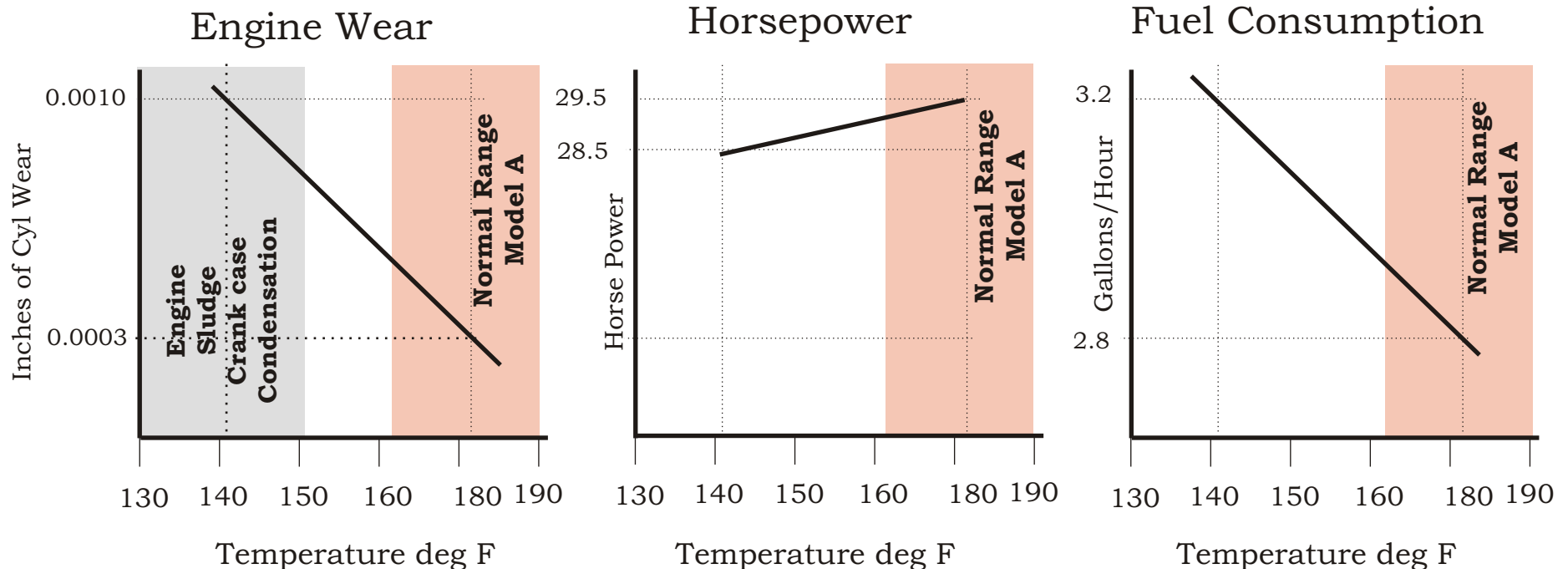




Can the Engine be too Cool ?

“ The best temperature to secure efficient operation is one on which considerable difference of opinion exists ... It is very important that the engine not get too hot, and at the same time is equally as vital that the cylinder should not be robbed of too much heat ”

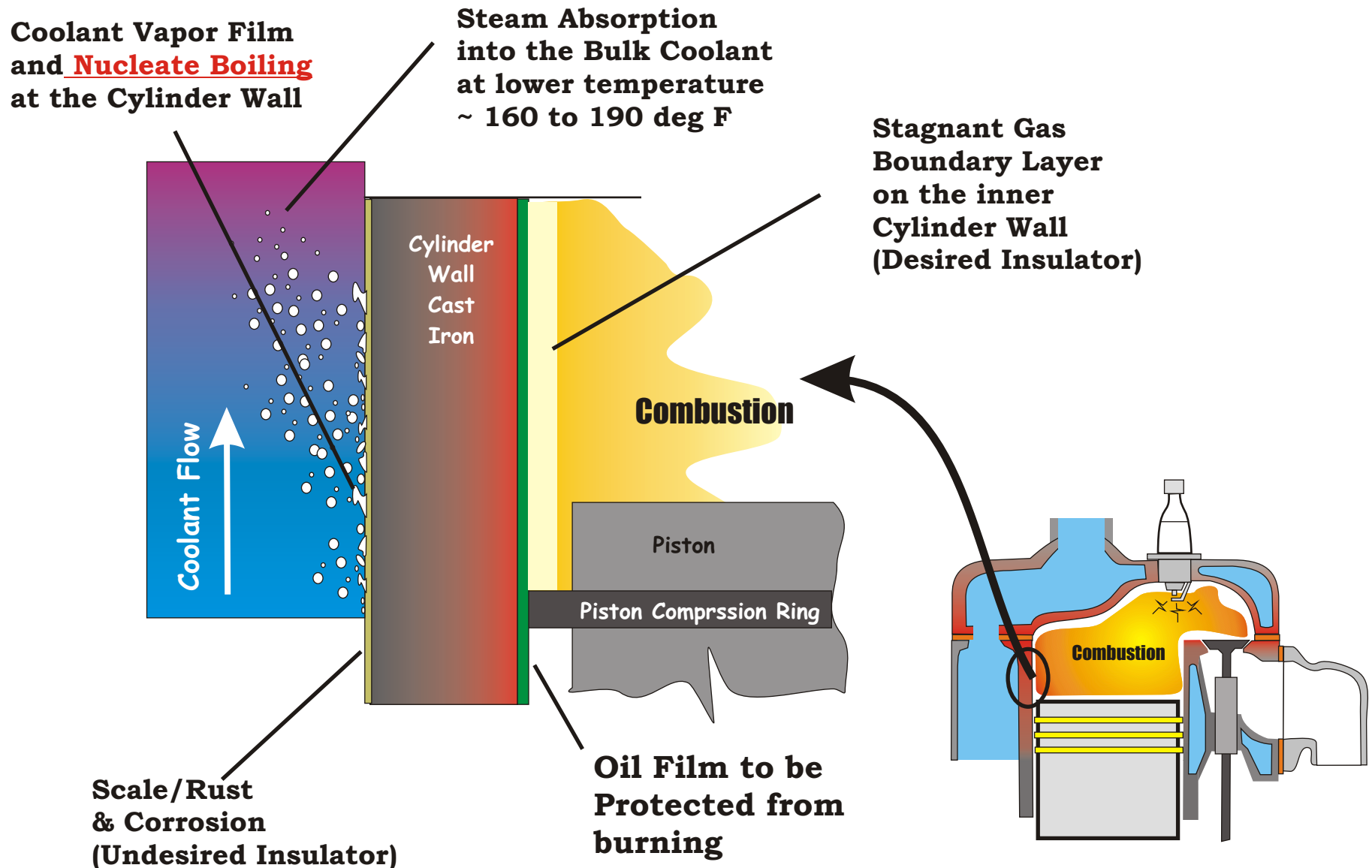
Victor Page - 1931
writing about the Model A



Tests Performed in 1950's - 60 hours of continuous operation by Continental Motors as shown in Stockel's Automechanics Fundamentals. Not a Model A Engine

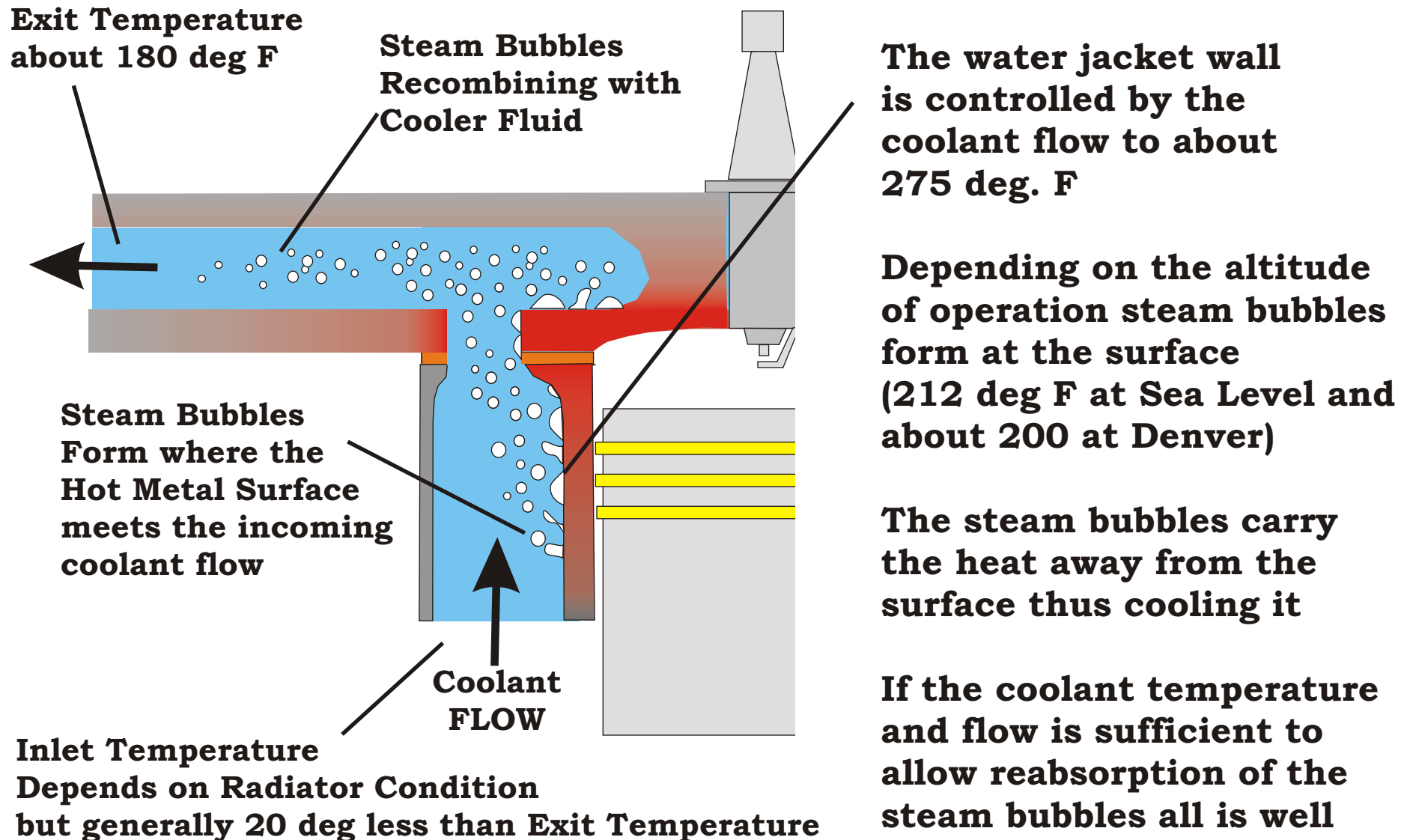


Heat Transfer at the Critical Cylinder Wall



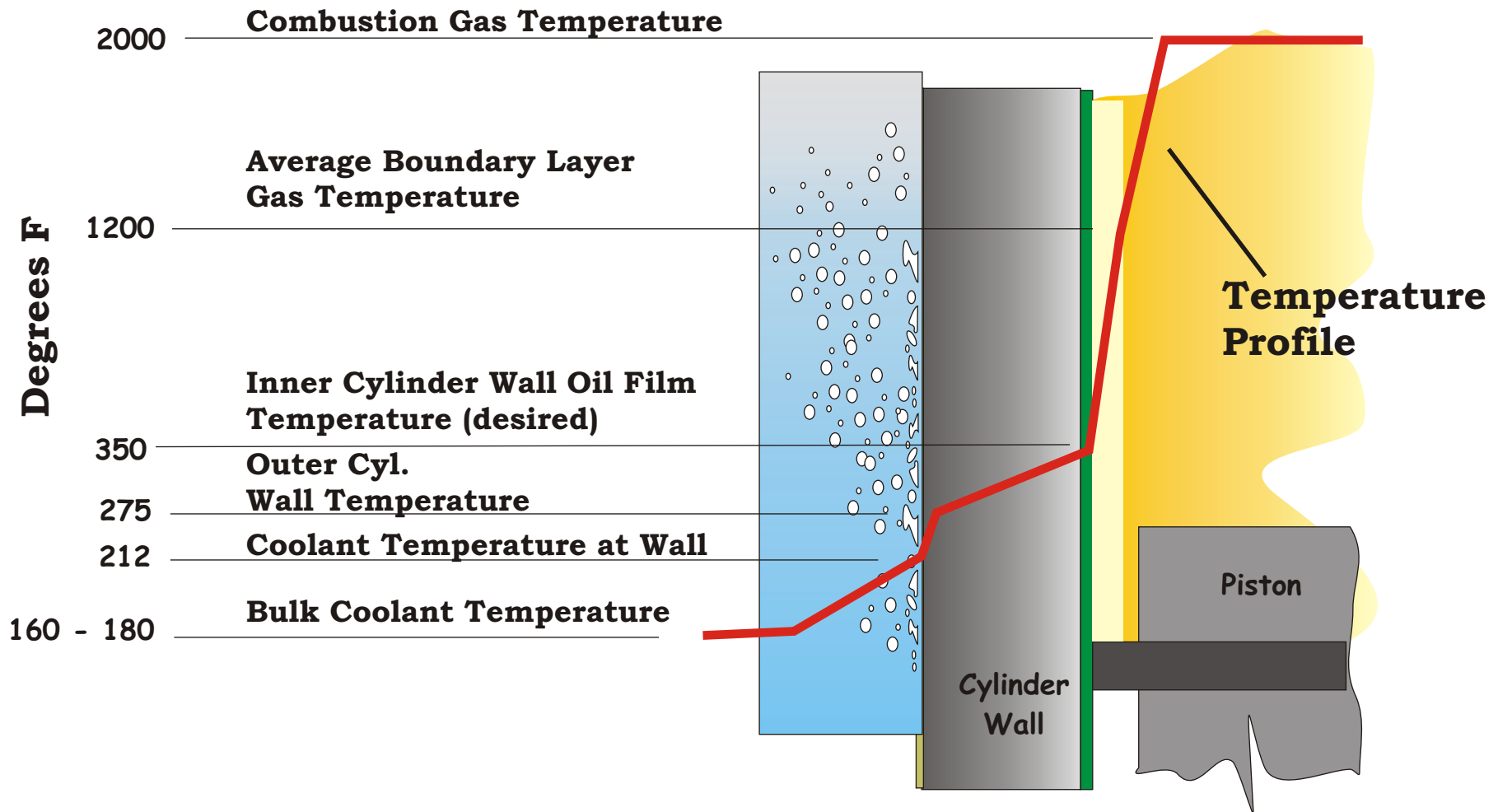


What do we mean by Nucleate Boiling ?





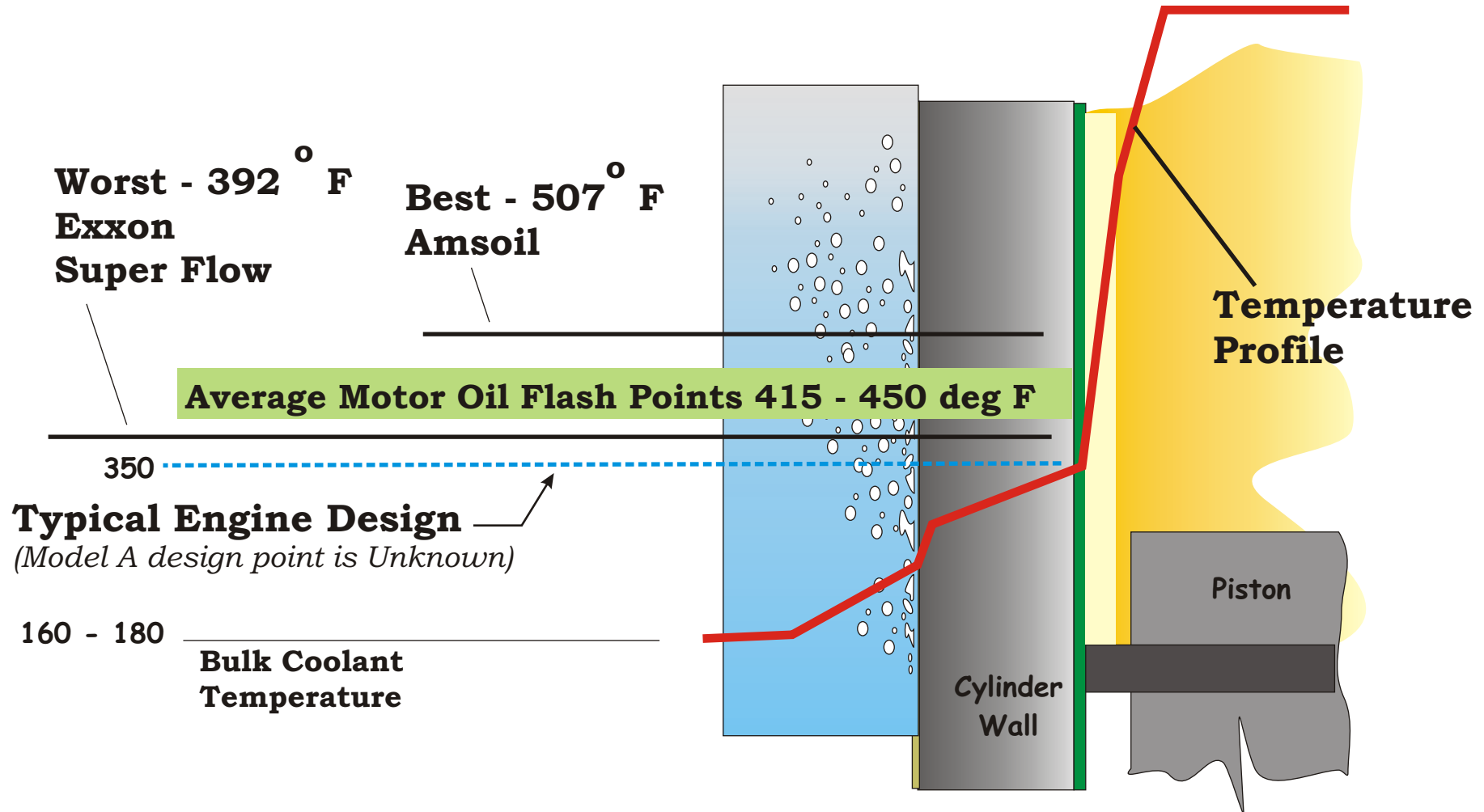
Temperature Profile of the Model A Cylinder Wall



EXAMPLE Average TEMPERATURES - MODEL A FORD CYLINDER WALL
At Sea Level



Motor Oil Flash Points Vary with Producers

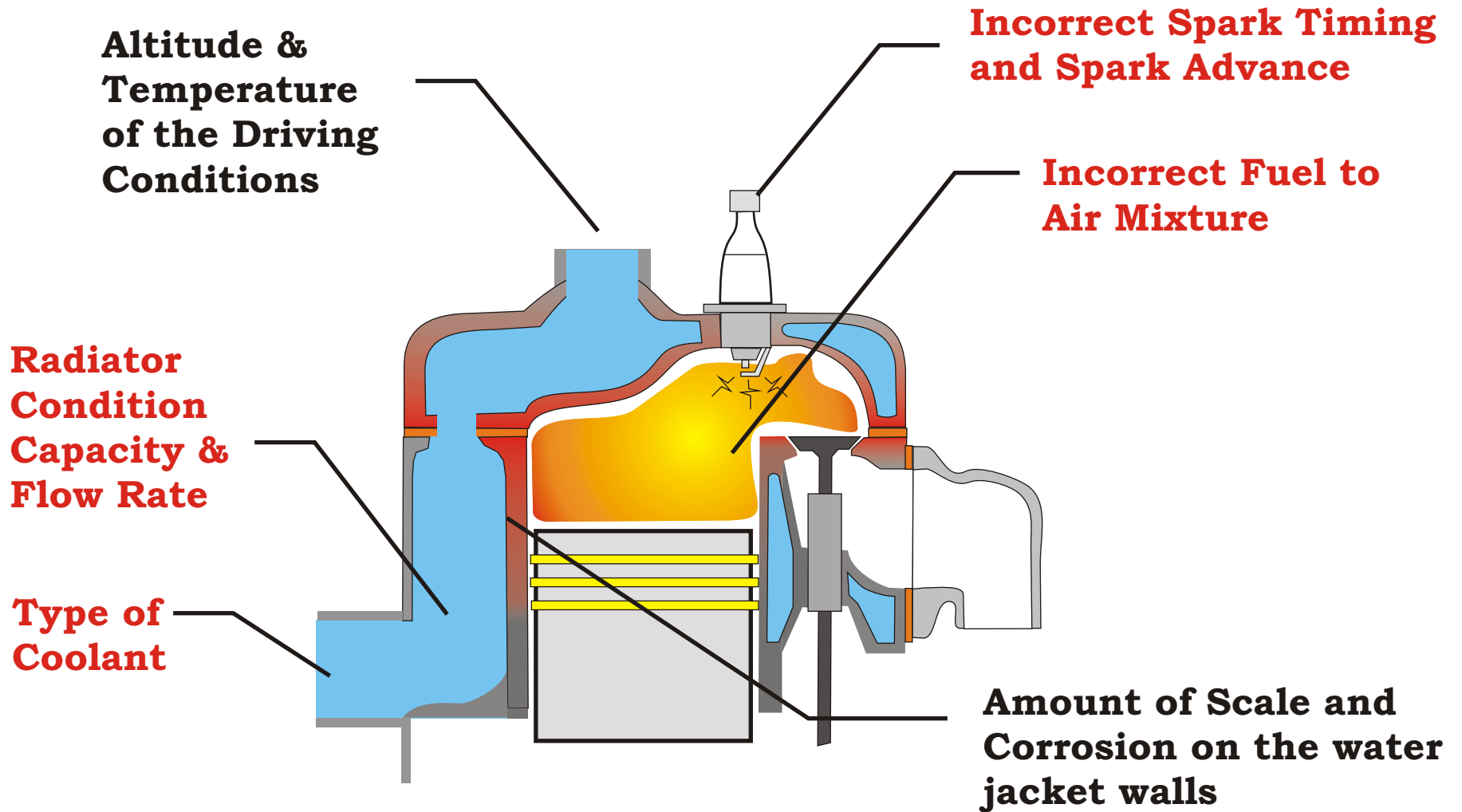


Design Margin can be as low as 40 deg F or as high as 157 deg F
For Average Oils is is about 80 deg F

At Sea Level (flash point testing by MicaPeak Labs 2005)



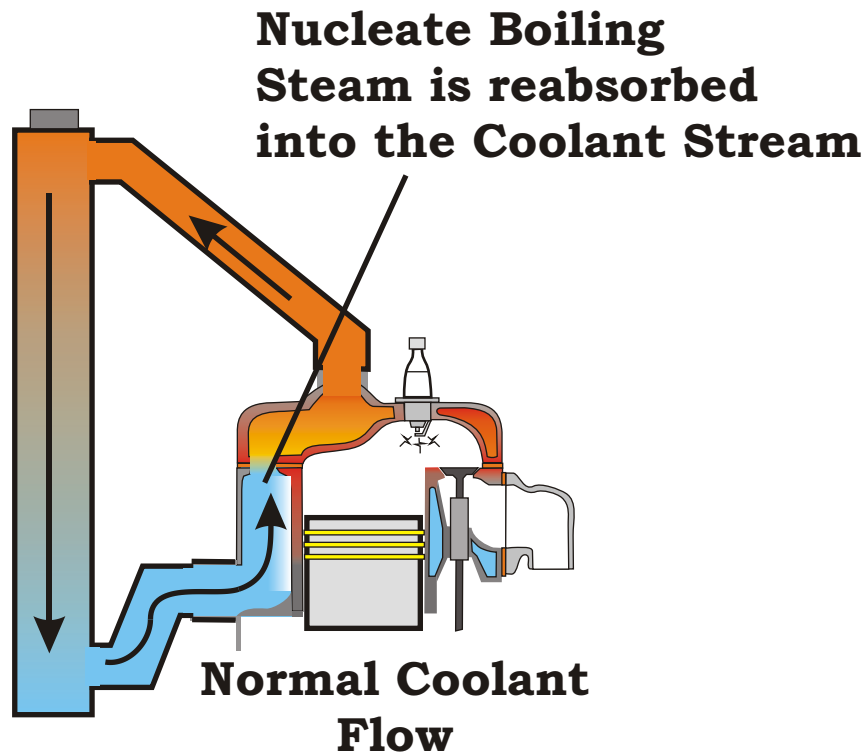
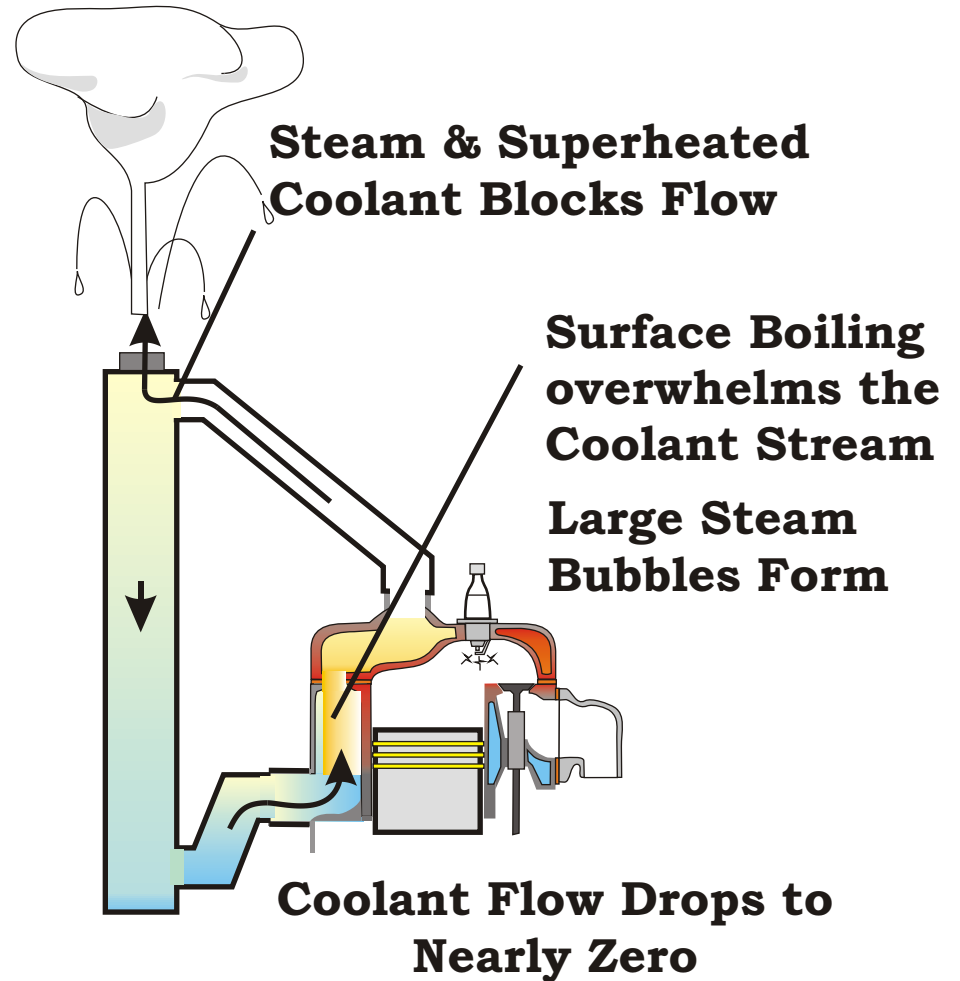
Conditions Leading to Cooling Failure



Red Text are Conditions over which we have Control



Cooling Failure



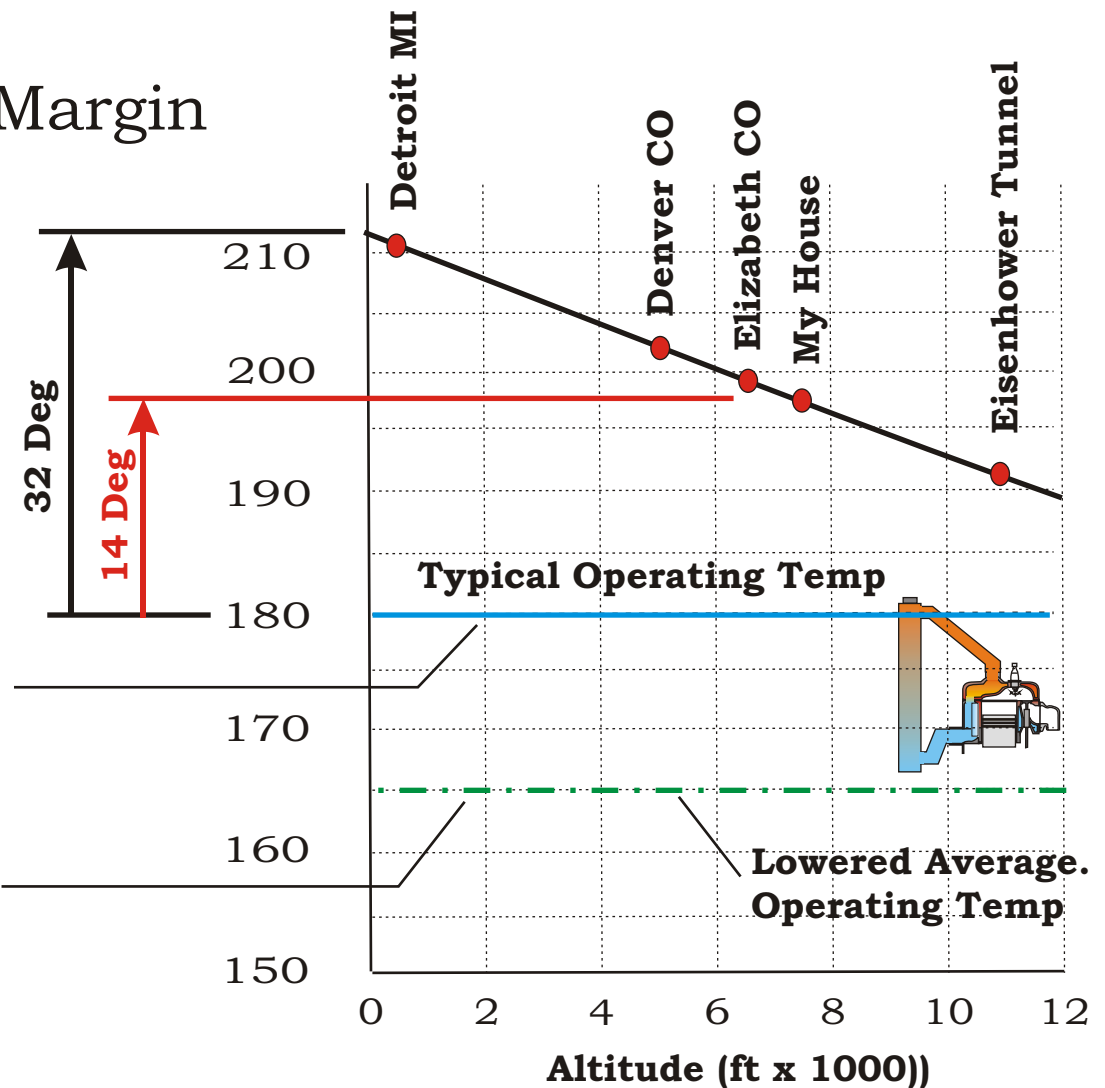
- Minor failure - delayed trip up to ½ hour or more
- Major failure - Blown head gasket, cracked block
Warped head, cracked radiator
Burned Pistons, scored cylinder walls



Cooling Margin and Strategies

- About 50% of Margin Lost due to Altitude
- Strategies to Improve Margin

- Ensure Engine is Timed Correctly. Adjust Mixture
- Flush Radiator Often
- Ensure no obstructions in the water flow paths
- Use highest efficiency coolant
- Improve coolant efficiency
- Use a four core radiator for higher capacity

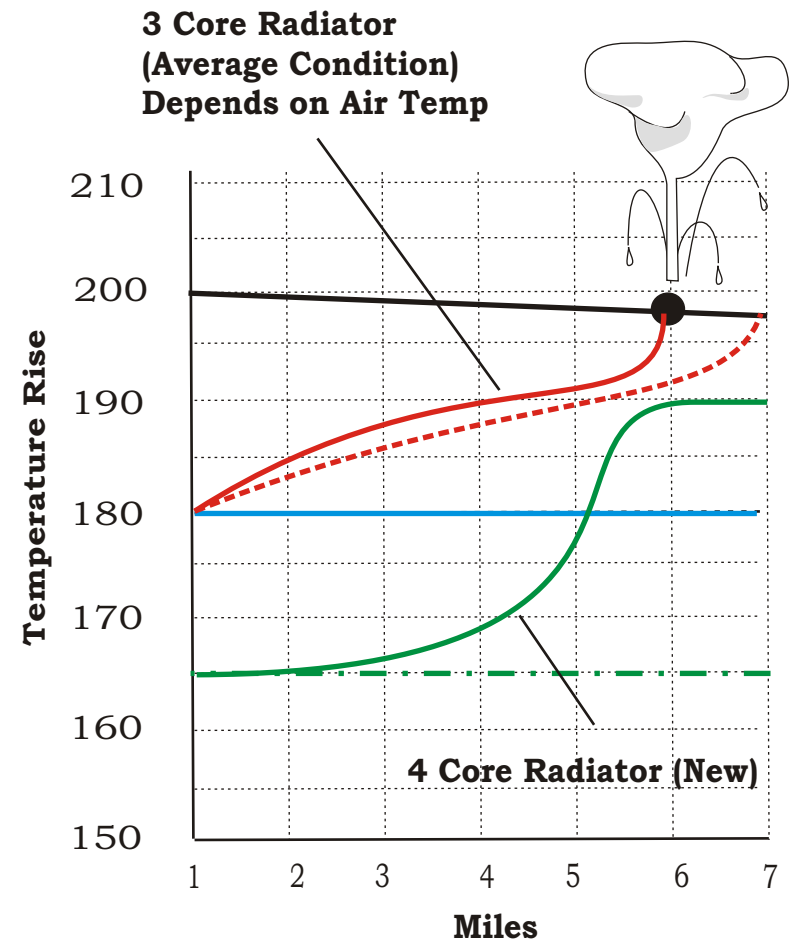


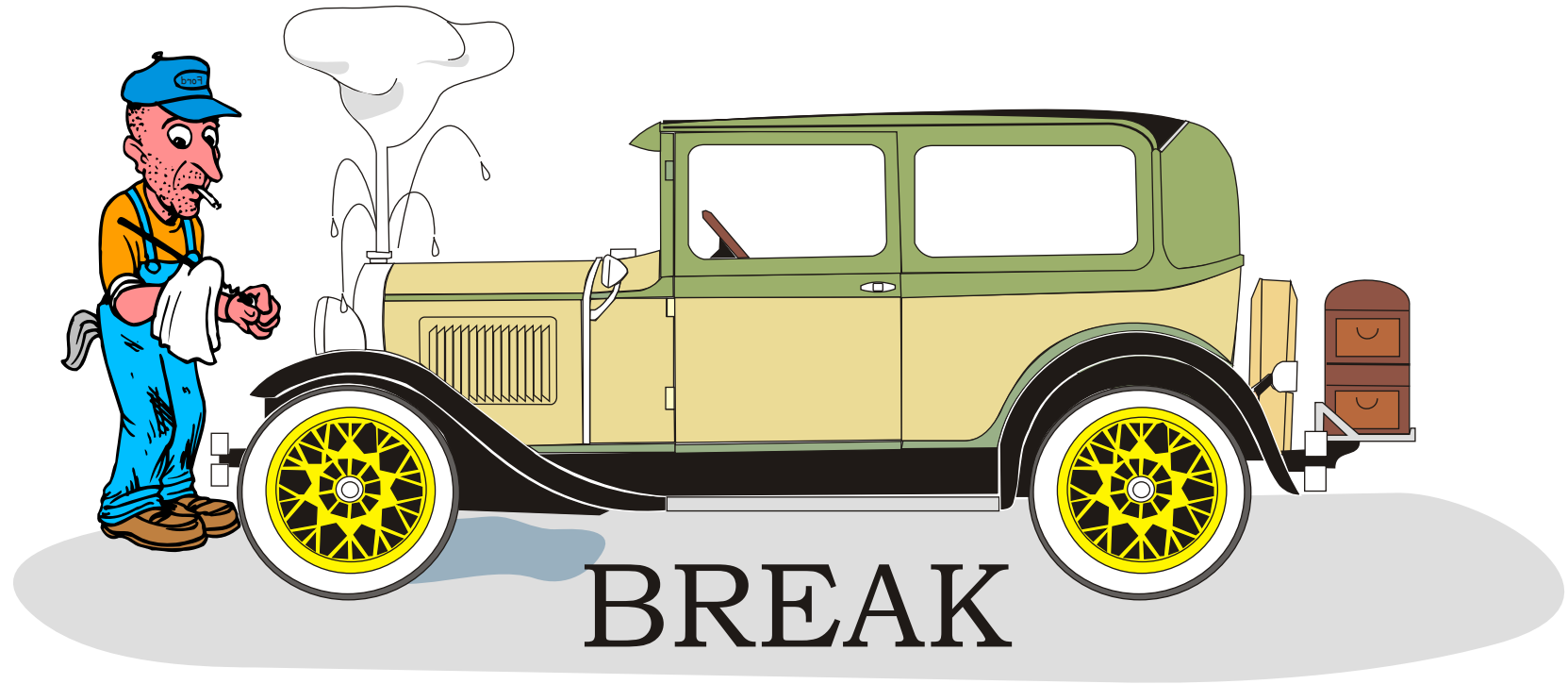


My Experience with Improvement of Radiator

- Sedalia to My Garage - 1610 ft in 7 miles
- Engine exit temperature stabilizes at 190 deg F *
- Measured over 75 times

* With 4 core radiator





Next

- What Cooling Fluids to Use
- How to Improve on Water as a Coolant



COOLANTS

What Choices Do We Have?

- Plain Ol H_2O
 - Used since the beginning of the automobile industry
 - In 1928 to 1931 was used to design the Model A cooling system
 - Free or nearly so
- Modern Ethylene or Propaline Antifreeze Coolants
 - Ford recommended use only in Winter from 1930 on
 - Modern Antifreeze Coolants introduced in 1950's
 - Modern Automobiles designed to use them year round from 1960's
- Water with an Additive to improve cooling
 - The racing crowd wanted better cooling
 - Redline Oil and others developed surface tension reducers



COOLANT Properties

		Importance
SPECIFIC HEAT	ABILITY TO ABSORB HEAT Affects Reabsorption of Steam The higher the value the better	VERY HIGH
LATENT HEAT	ABILITY TO TRANSFER HEAT Affects Extraction of Heat The higher the value the better	VERY HIGH
SURFACE TENSION	ABILITY TO MOVE STEAM BUBBLES Low values mean smaller steam bubbles at the metal boundary	HIGH
BOILING POINT	TEMP at NUCLEATE BOILING High BP means higher metal temp - Lower is better	Medium
SCALE COMBAT	ABILITY TO STOP SCALE BUILDUP Scale and corrosion of the water jacket form an insulator	Medium



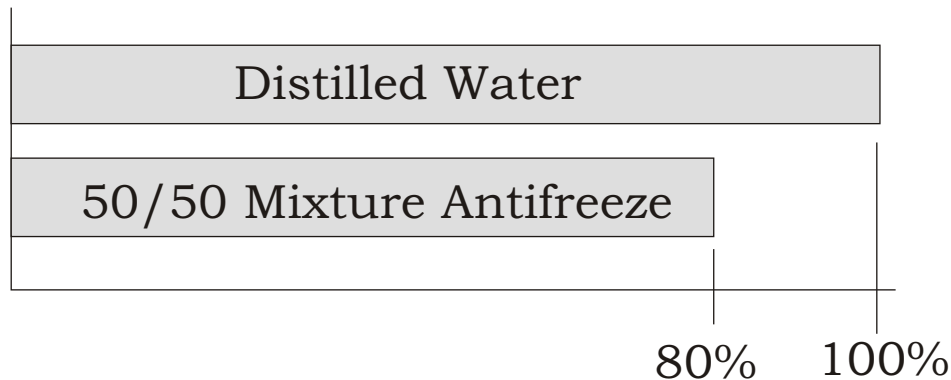
COOLANT Performance

	SPECIFIC HEAT	LATENT HEAT	SURFACE TENSION	BOILING POINT (1)	SCALE COMBAT	FREEZE PROTECT
Distilled Water	1.00	540 cal/gm	58 dynes/cm ²	200 deg F	NO	NO
Antifreeze 50/50 with water	0.80	375 cal/gm	51 dynes/cm ²	213 deg F	YES	YES
Distilled Water with a Surficant (WaterWetter)	1.00	540 cal/gm	28 dynes/cm²	200 deg F	YES	NO
(1) at Elizabeth CO (2) Surficant means Surface tension reducer	HIGH VALUE BEST Reabsorbs Steam Bubbles into coolant flow	HIGH VALUE BEST Extracts Heat from the Cylinder wall by vaporization	LOW VALUE BEST Lower value means small bubbles that break away easier	LOW VALUE BEST Point at which nucleate boiling begins	Water is the most corrosive use Distilled to reduce scale	Only Anti Freeze will protect in Winter

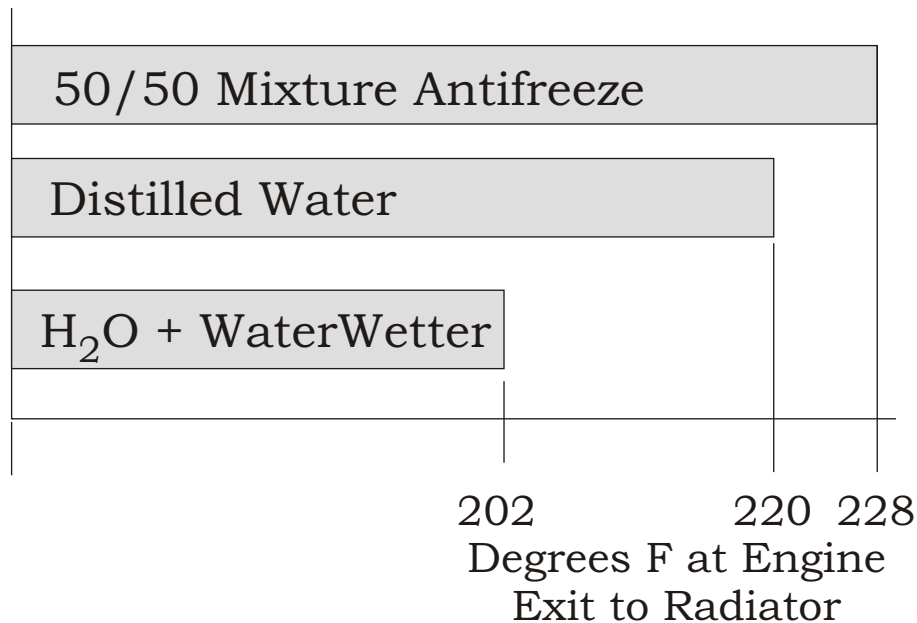


COOLING PERFORMANCE

Coolant type Comparison



Basis: Engineering Tests
Coolants for system designs
www.engineeringtoolbox.com
(Notes that flow must be increased)



Basis: Dynamometer Tests
Malcom Garrett Racing Engines
Chev 350 Cast Iron Block
Thermostat @ 160 deg F
Run @ 7200 RPM for 3 hours
Engine Coolant Measured at
end of each test run.

Note: Performance in
a Model A Ford with an
unpressurized cooling
system is unknown



COOLANT Tradeoff

Antifreeze versus Plain Water

- Modern Antifreeze Coolants have less cooling capacity
 - Higher Nucleate Boiling Temp REDUCES margin for Oil Flash Point
 - 20% Lower specific heat LOWERS the ability to reabsorb steam
 - 30% Lower latent heat LOWERS ability to extract heat from cyl wall
- Antifreeze has less cooling but a higher boiling point (washes out?) NOT really, the antifreeze will raise the cylinder wall temperature because of its high BP

THE BOTTOM LINE - Plain Water is better

- Modern Antifreeze Coolants have other benefits
 - Year round use
 - Corrosion Protection
 - Higher Bulk Boiling Temperature in Colorado +12 deg F

THE BOTTOM LINE - Antifreeze is better



What Water to Use

- When using Water as a coolant or as a mixture with Antifreeze be sure to **USE DISTILLED** (not just deionized) water ... **Definitely NOT tap water.**
- Tap and Well water in the Colorado Front Range is high in Alkaline content, calcium, magnesium, iron, and flourides. Minerals deposit in the engine
- Water at 190 deg F is 30 times more corrosive than at 70 deg F causes scale buildup clog radiator
- Add WaterWetter to combat corrosion



Why Do Modern Auto Manufacturers Mandate Antifreeze Coolants ?

- Long Warranty Periods MANDATE corrosion protection
- High use of Aluminum in engines for weight reduction requires much more corrosion protection
- Modern automobiles **are designed** to use the lower performance antifreeze coolants
 - Forced circulation at 100 gallons/min plus by efficient water pumps
 - Pressurized cooling system raises boiling point for high altitude
 - Non Thermo-Syphon system design allows thermostat use
 - Customer demand for less maintenance



Can we IMPROVE on Water to get the Antifreeze Benefits ?

- The answer is **YES** with some additional maintenance
- Water ADDITIVES on the market offer better cooling and corrosion protection
 - WATER WETTER by Red Line Oil
 - PURPLE ICE by Royal Purple Oil
 - ENGINE ICE
- These additives **DO NOT** provide winter antifreeze
 - **REQUIRES two changes of coolants each year**
 - SAVE the winter Antifreeze and use it for many years
- Water Wetter **DOES** provide corrosion protection
- Water Wetter **DOES** provide better heat transfer than plain old water and much better than antifreeze

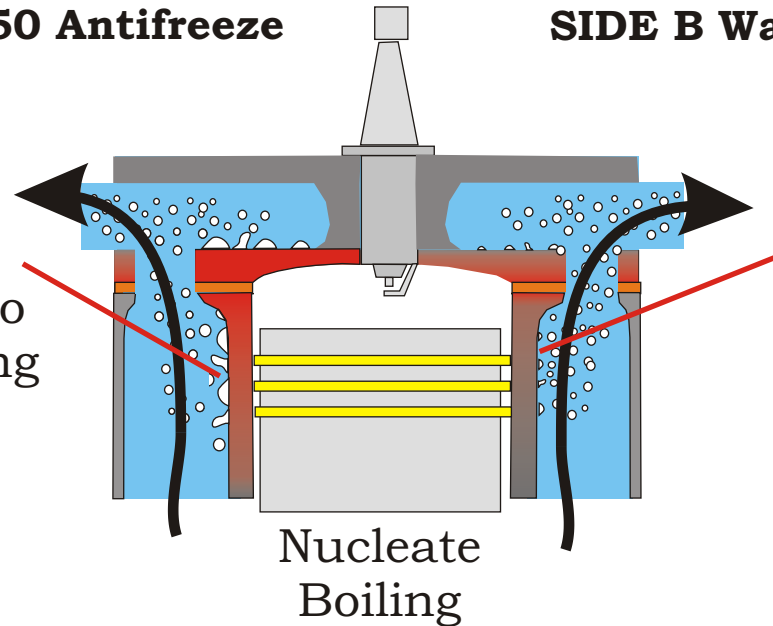
Disclaimer
I have not researched
other products than
Water Wetter



How Does Water Wetter Work ? How Good Is it ?

SIDE A Water or 50/50 Antifreeze

High Surface Tension makes large steam bubbles that can coalesce into a vapor barrier raising engine temperature



SIDE B Water + Water Wetter

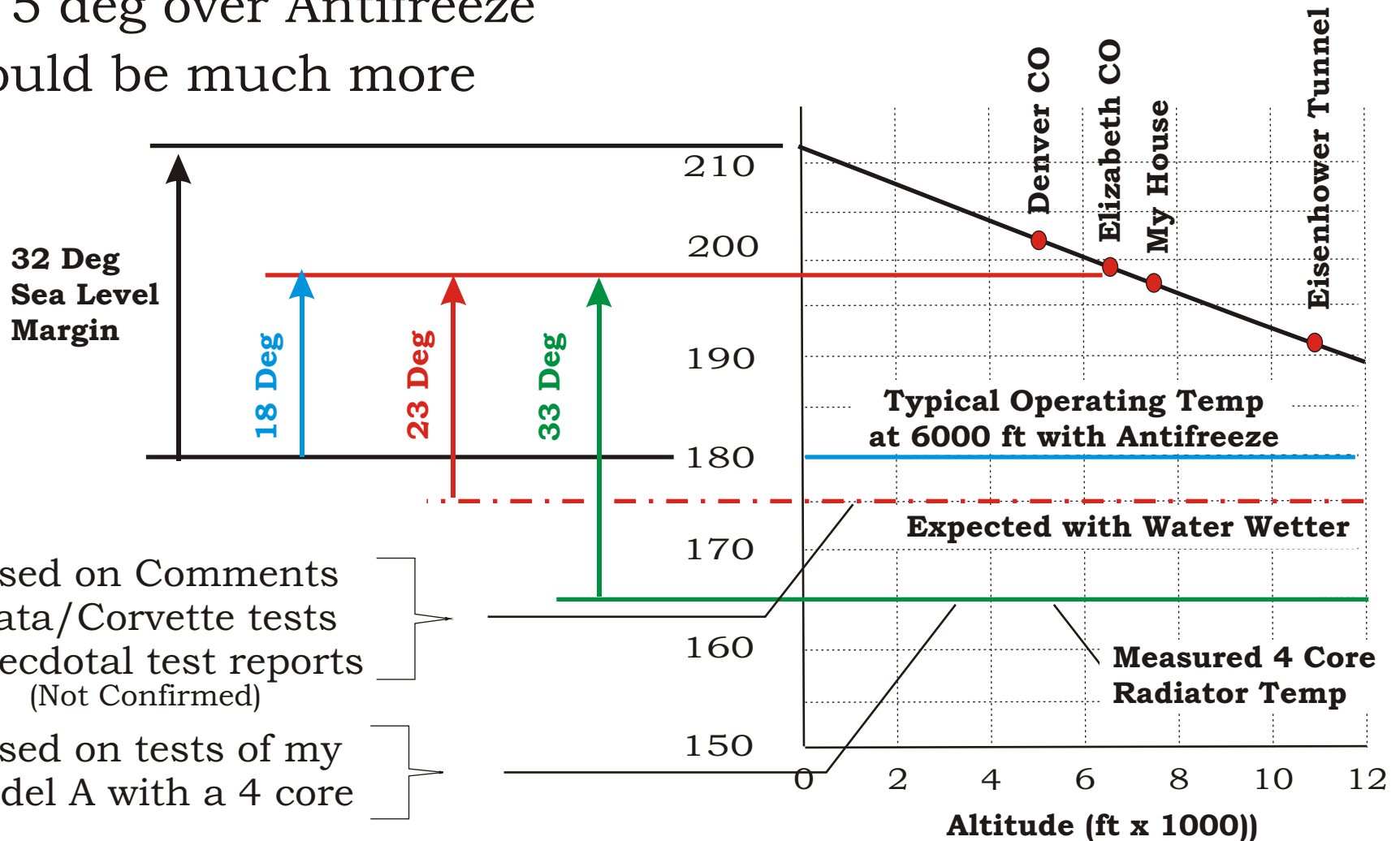
Reduced Surface Tension allows small steam bubbles to carry away heat from cylinder wall small steam bubbles are absorbed into coolant flow easier

PERFORMANCE (Engine coolant temp at exit to radiator)	
Red Line Claim	“ Up to 20 degrees lower operating temperature”
Import Tuner Mag 1993 Miata test	“10 deg in mixed driving - 13 deg sustained driving”
Anecdotal Tests	Commenter’s averaged about 5 to 8 deg lower
MODEL A Tests	TBD - to be conducted next summer



Cooling Margin Improvement with Water Wetter

- Expected **Minimum** Improvement ~ 5 deg over Antifreeze
- Could be much more



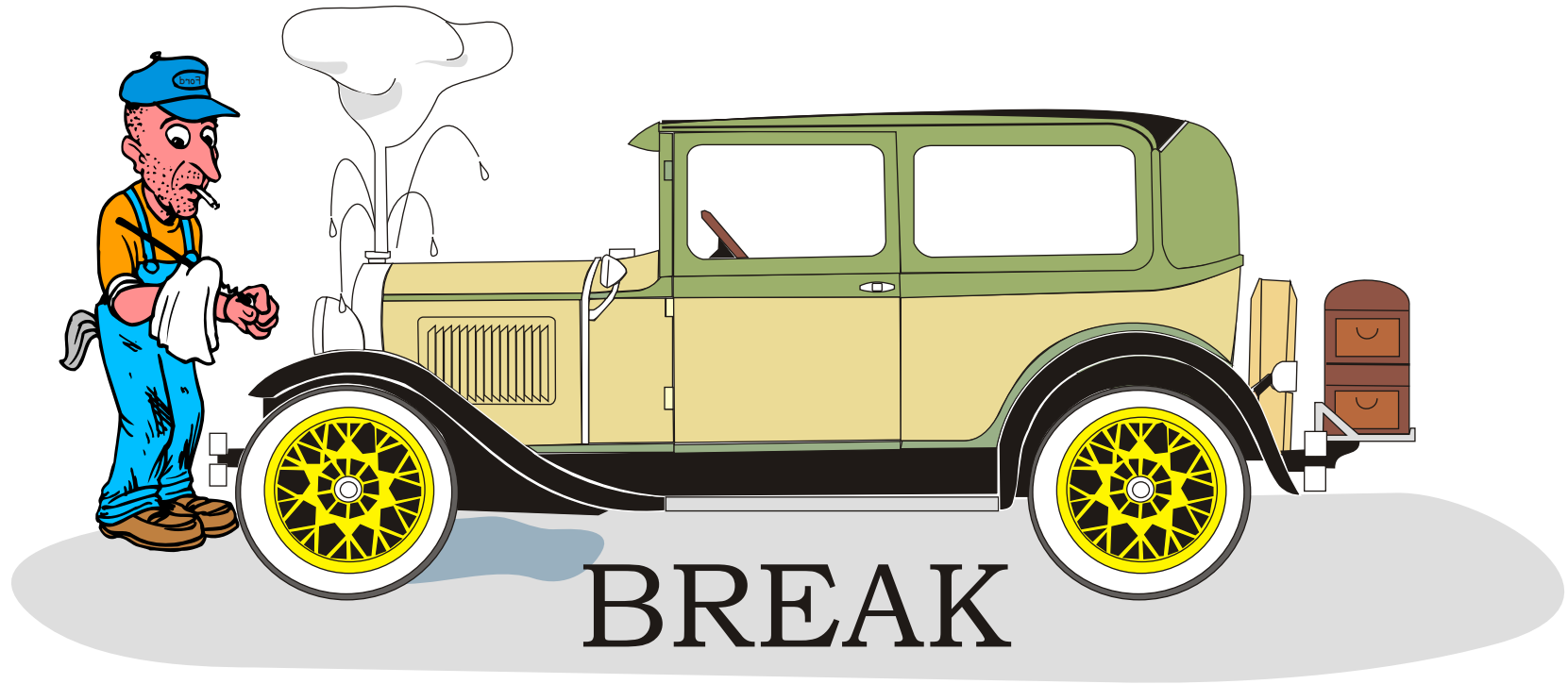


Why Not Add Water Wetter to Antifreeze ?

- Red Line claims OK to add Water Wetter to Antifreeze
(yields an overall performance about same as plain water)

... BUT

- Internet Forums and some Car Clubs claim it causes a brown slime, gunk, and deposits in the engine
 - I contacted Red Line and here is their response
 - It is due to silicate dropout because users did not change their antifreeze regularly not a Water Wetter problem
 - It is due to oxidation from leaking head gaskets not Water Wetter
- However they also said ...**
- In a Model A you should use it with water not antifreeze
 - Where there is smoke there is fire ... I go along with the Rolls Royce Club in the UK and **DO NOT** think it is a good idea to mix it with antifreeze.

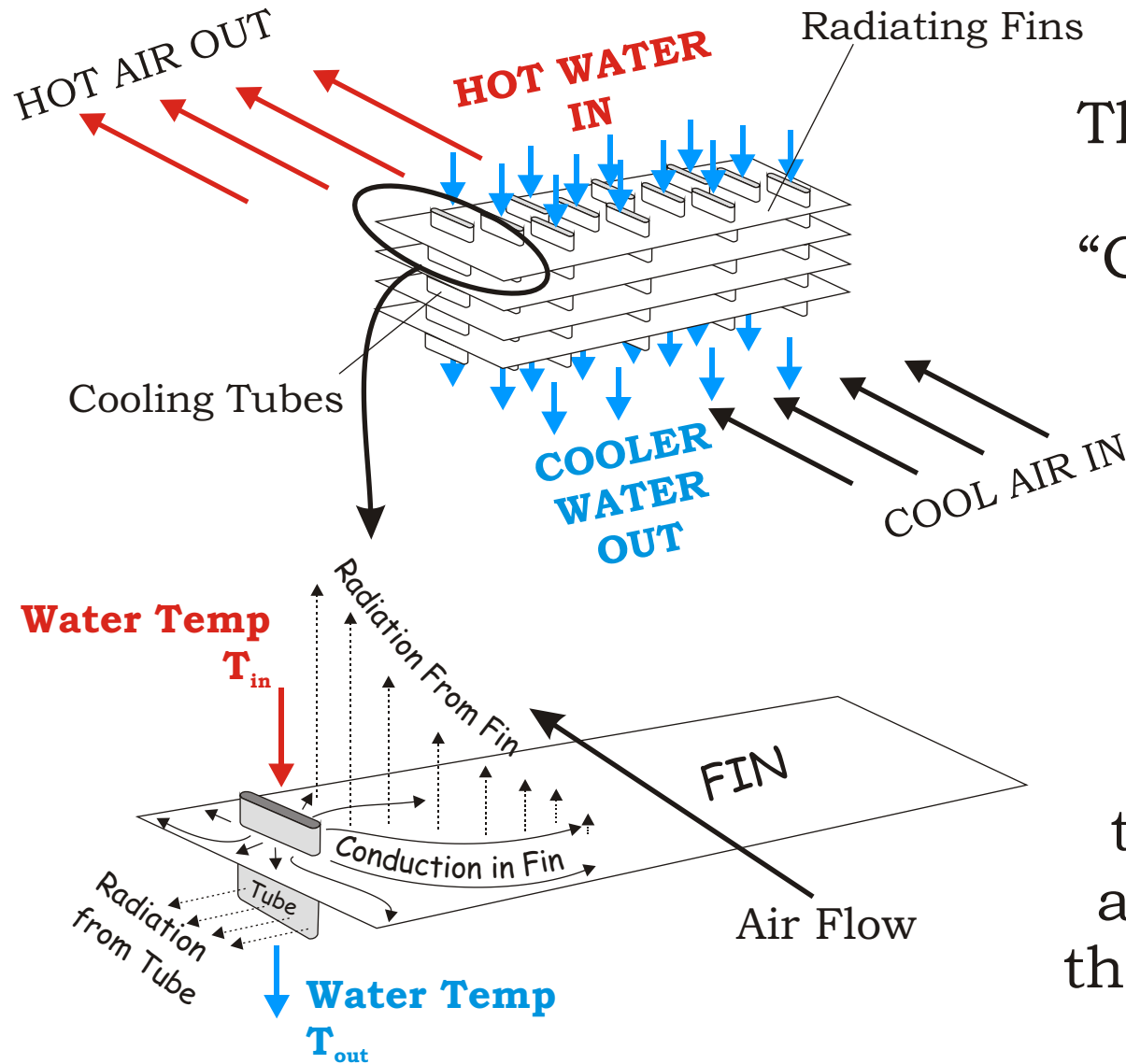


Next

- Radiator Performance
- Thermostats - a help or a hindrance ?



HOW RADIATORS WORK

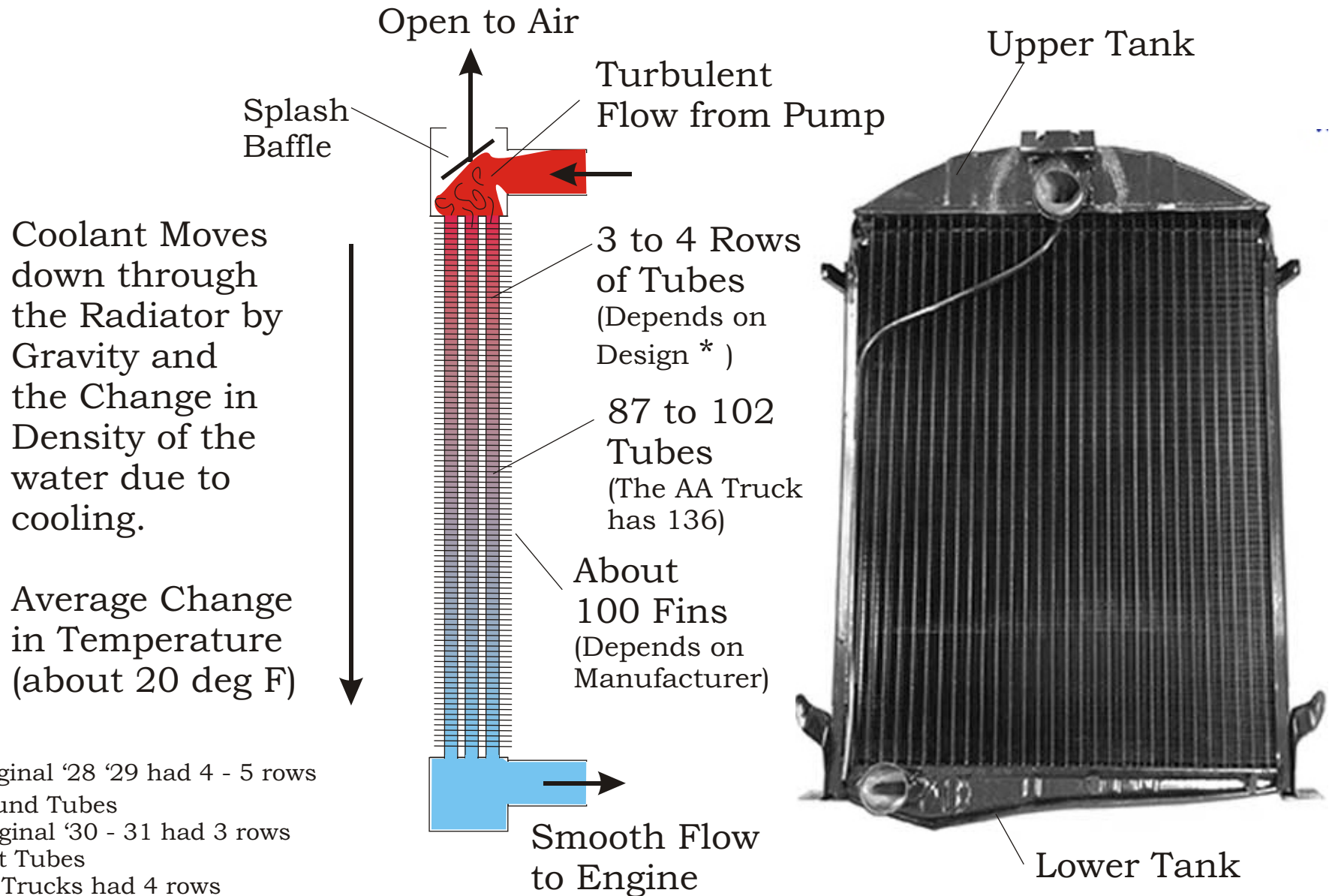


The Model A Radiator
is a
“Compact Fin & Tube
Heat Exchanger”

Heat Exchange
is by
Conduction from
the Tube to the Fin
and **Radiation** from
the Fin to the Air Flow



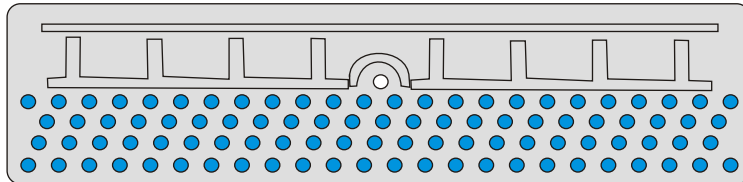
The MODEL A RADIATOR



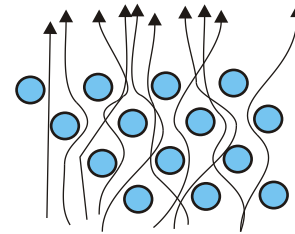


RADIATOR Types

Round Tube Radiators *



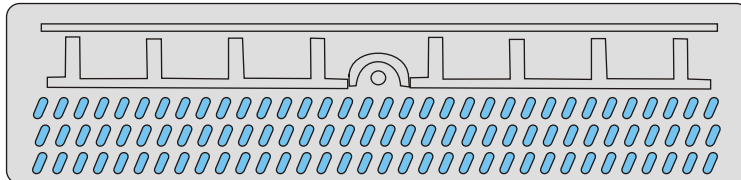
Year	Manufacturer	Rows	Tubes
28-29	Ford	4	94
29	Flintlock	4	100
29	McCord	5	87



1928 - 1929 Air Flow
Turbulent - Random
Inefficient. Round
Tubes have poor heat
conduction to fins

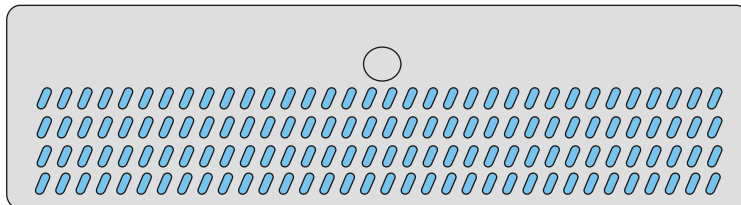
* After 1930
Replacement
Radiators for
1928 - 1929
Models were
Flat Tube
Designs

Flat Tube Radiators

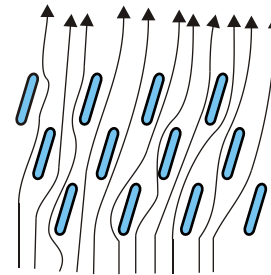


Year	Manufacturer	Rows	Tubes
30 - 31	Ford	3	102

Commercial Truck Radiators



Year	Manufacturer	Rows	Tubes
30 - 31	Ford	4	136



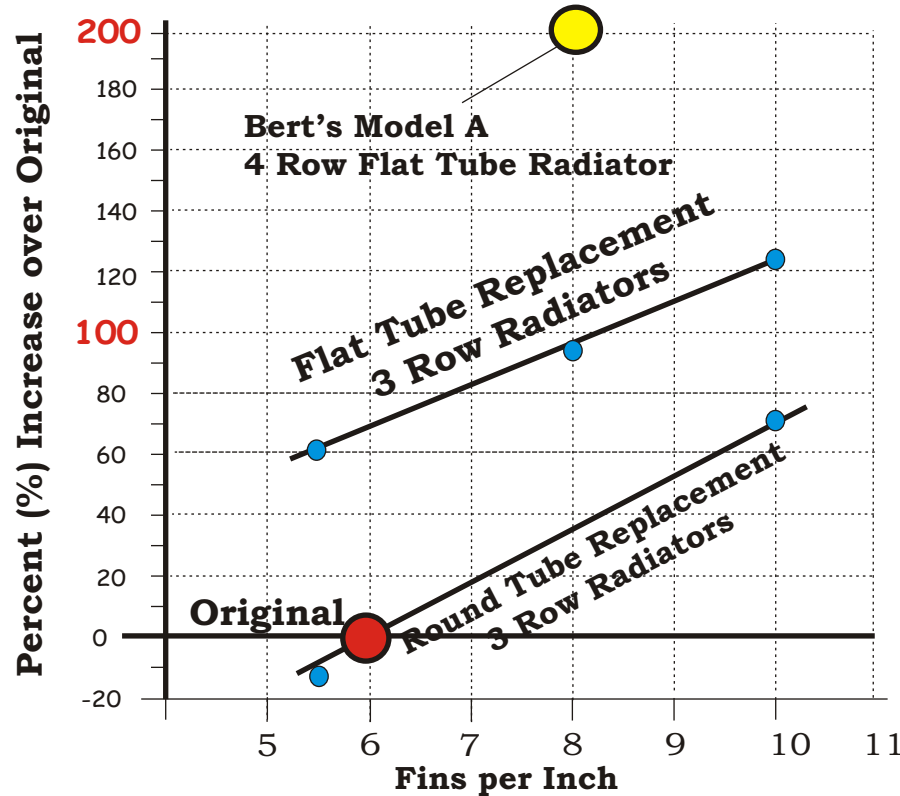
1930 - 1931 Air Flow
Streamlined - More
Efficient. Flat Tubes
increase conduction
to fins.

Most Model A
Radiators that
are available
today are 3 row
Flat tube
A common
upgrade is to
use a 4 row
AKA "4 core"
radiator based
on the 30 - 31
AA Truck
Radiator

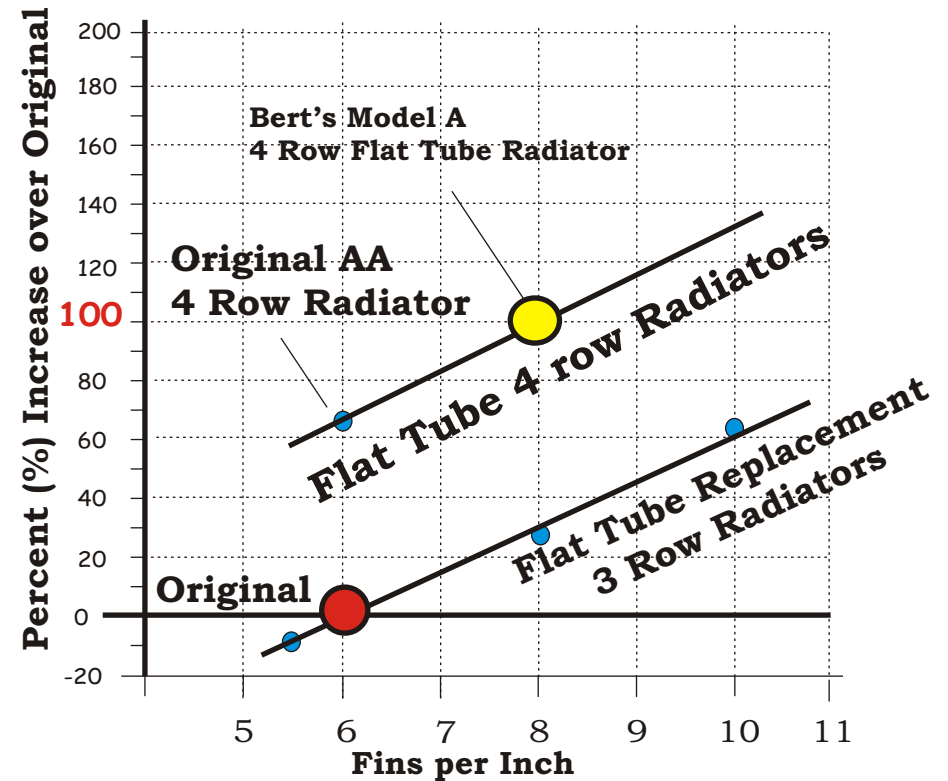


REPLACEMENT RADIATOR Efficiency

1928 - 1929



1930 - 1931



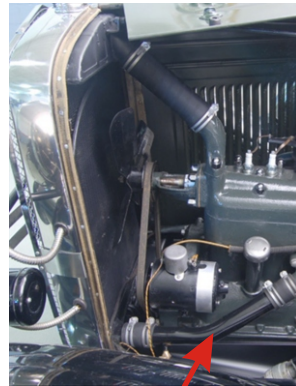
- Radiator Efficiency Depends on the # of Fins per Inch
- Mail Order Parts Vendors offer a wide variety of radiators with various fin/inch and tube configurations



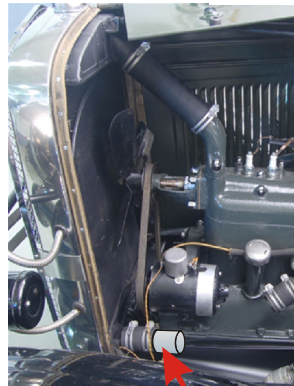
A Simple RADIATOR Test



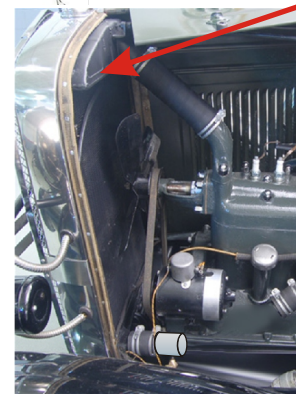
Drain Coolant
from System



Remove Metal
Water Pipe



Fit a Plug into
Lower Hose



Fill Radiator
with 1 ½ Gal
of Water *

Fill to just
below inlet
from engine
Leave cap off



Remove Plug
and Record
Time to Drain

A **Three Core Radiator**

should drain in less
than 4 seconds if it
is in good repair.

Replace or Repair
Radiator if more
than 5 seconds

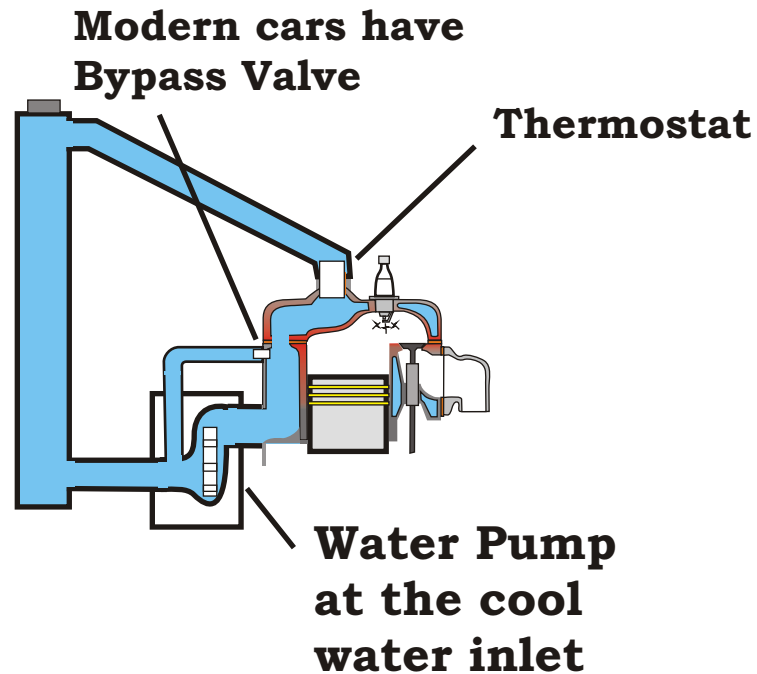
* The Capacity of the
Model A Coolant
System is about
3 Gallons
About ½ of it is in
the Radiator at any
given time ... Less for
28 - 29 ... More for AA
trucks



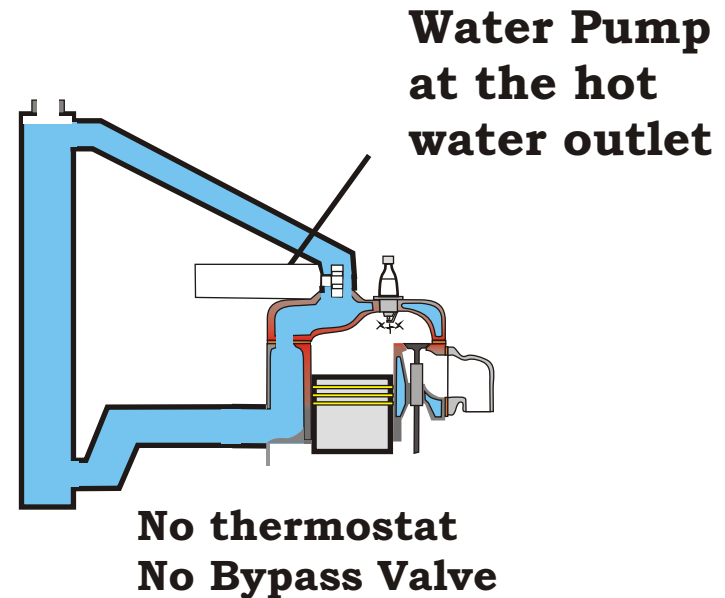
Thermostats

Do we need 'em ?

- Thermostats are used in Modern Cars to maintain an even engine temperature and give a quick warmup
- The Model A Ford was designed without a thermostat



Modern Engine

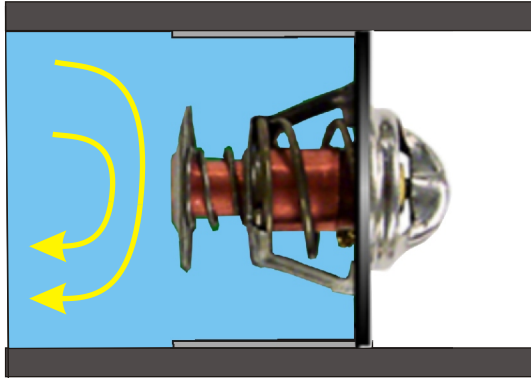


Model A Ford Engine

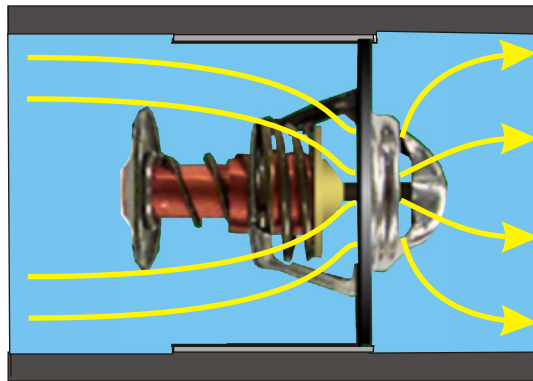


Thermostats

What do they do ?



A Thermostat remains closed until a temperature set point is reached (e.g. 160 deg F)



The Thermostat then opens in proportion to the temp of the coolant until a maximum is reached usually 20 - 25 deg F above the set point

- Thermostats regulate the bulk coolant temperature over a range of about 20 deg F by restricting the flow rate into the top of the radiator



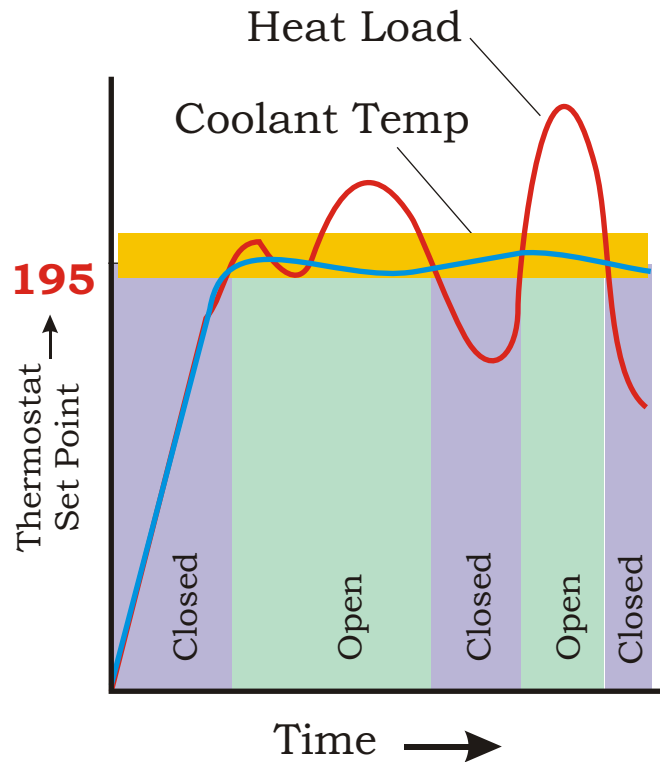
Were there Thermostats in the 1930's

Short Answer: YES

- Thermostatic control of engine coolants have been used since before the Model T
- In the early history of auto manufacturing a debate raged between pumped circulation with thermostats and thermo-syphon systems without.
- Henry Ford with his motto of **simplicity** came down on the side of the thermo syphon system and used it on the T and on the A
- Until the advent of pressurized systems thermostats were designed as a brass bellows containing a liquid which changed to a gas at a particular temperature
- After coolant systems were pressurized thermostats were designed with an expanding wax pellet.

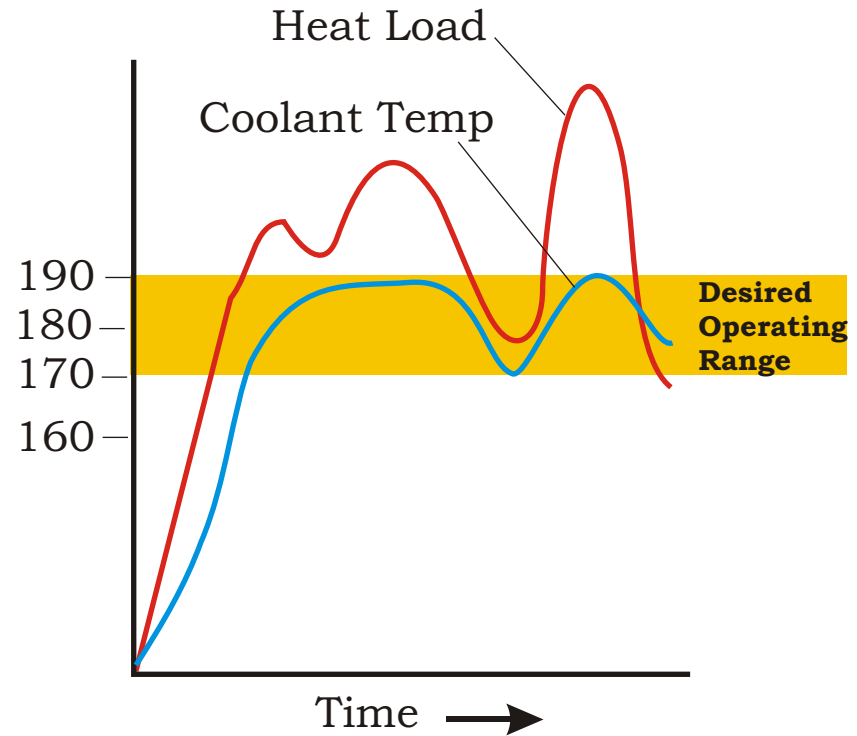


Modern Car Vs Model A Temperature Regulation



MODERN CAR WITH TS

Engine Coolant Temp at Inlet to Radiator controlled to a narrow operating range by opening and closing of the Thermostat (TS)

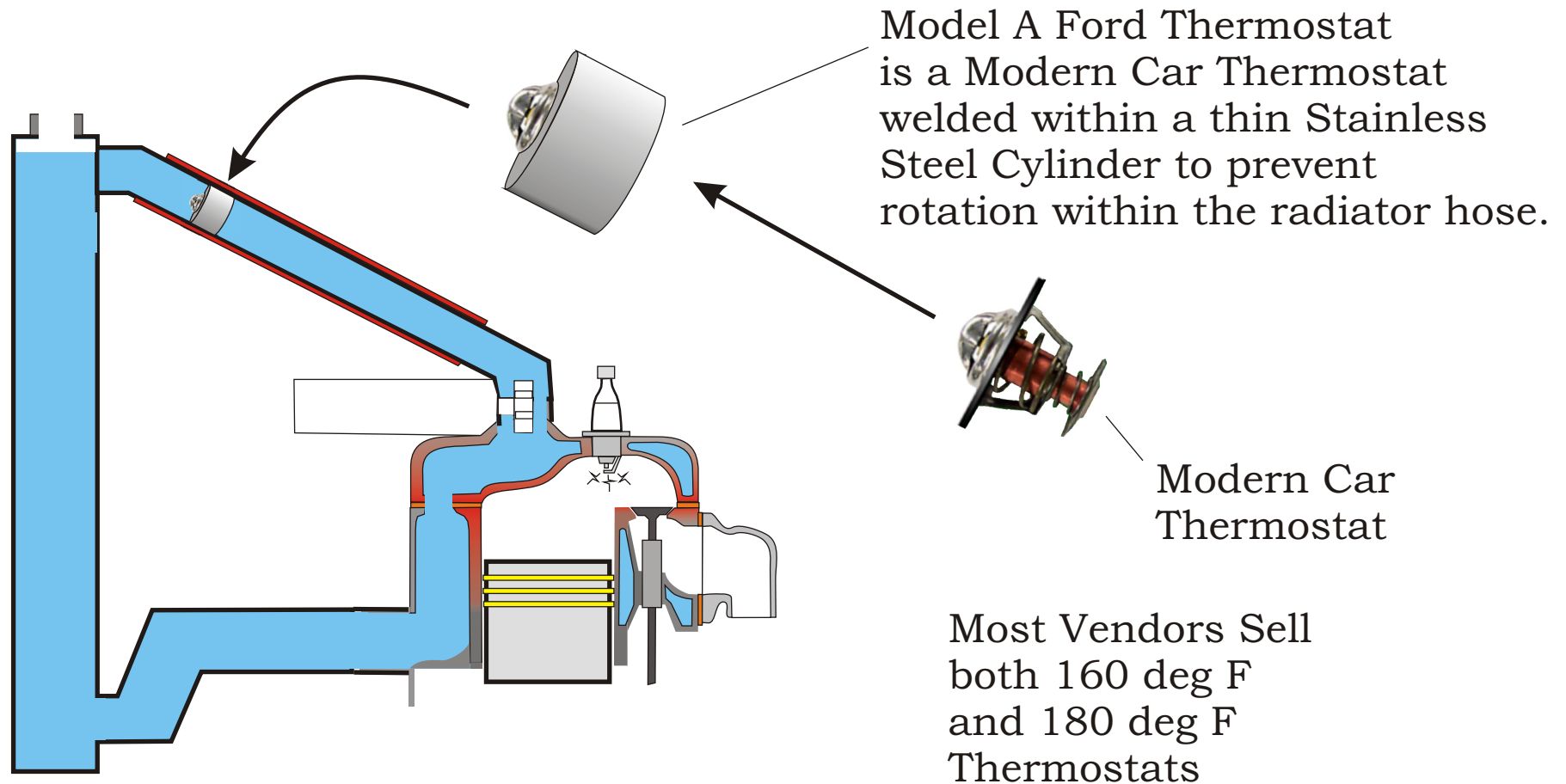


MODEL A WITHOUT TS

Engine Coolant Temp at Inlet to Radiator controlled by the Thermo Syphon action of the Model A cooling system



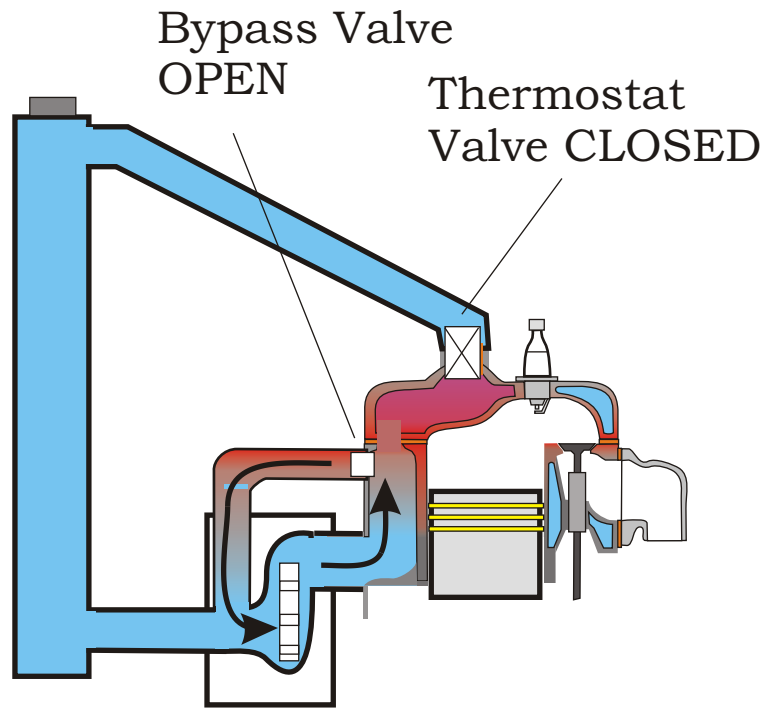
Model A Ford Parts Vendors Sell Thermostats



- **WARNING:** 180 deg F Thermostats are not fully open until 200 deg F which is the boiling point at Denver

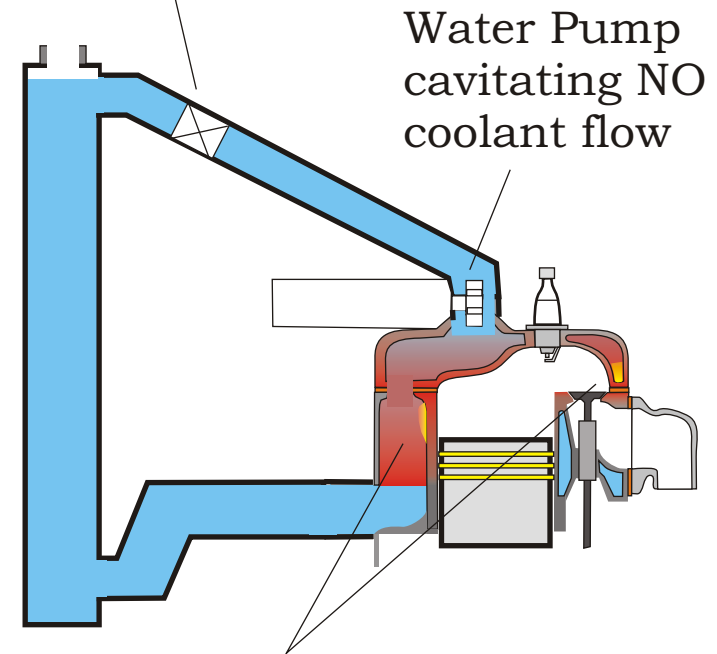


The Model A is NOT designed for the use of a thermostat



MODERN CARS have a **BYPASS** valve which allows circulation of coolant when the radiator is not being used to prevent local hot spot formation. Heated water is forced to the thermostat

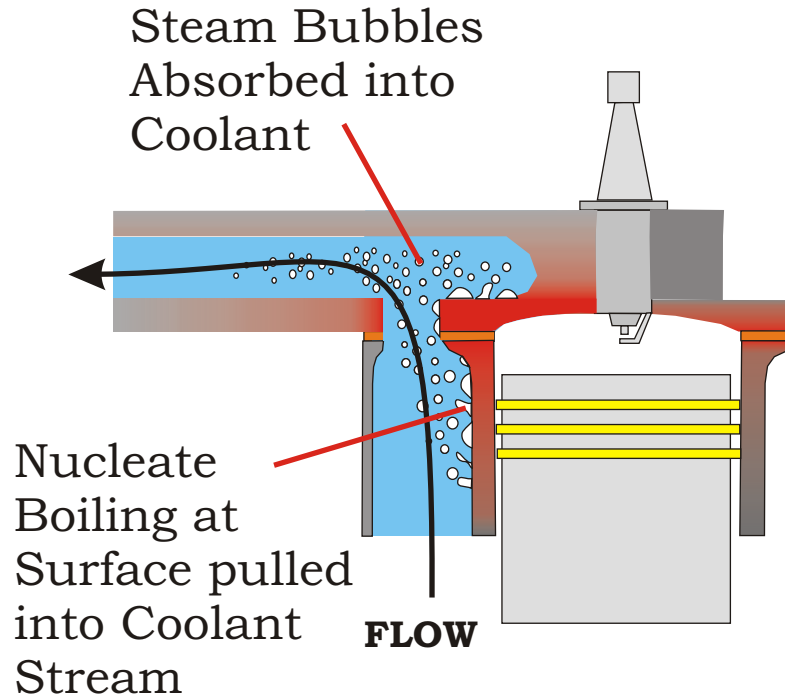
Thermostat
Valve CLOSED



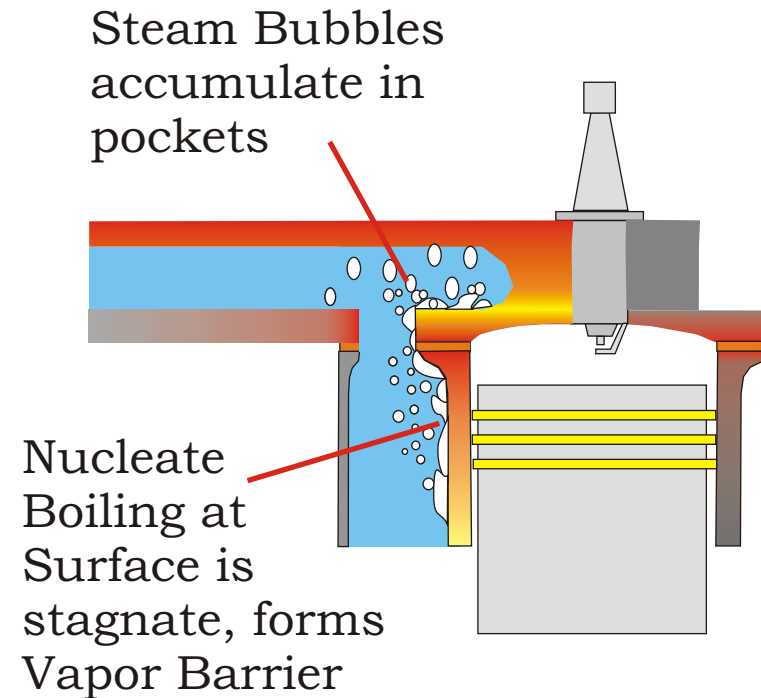
The **MODEL A** water pump cannot circulate coolant when the thermostat is closed. **Hot Spots develop** locally until the coolant heat at the inlet to the radiator reaches the set point. Heated water is not forced to the thermostat



Hot Spot Formation in a Model A with a Thermostat



**Modern Car with
Thermostat Closed
Coolant Flow with Bypass Valve
Until Thermostat Opens**

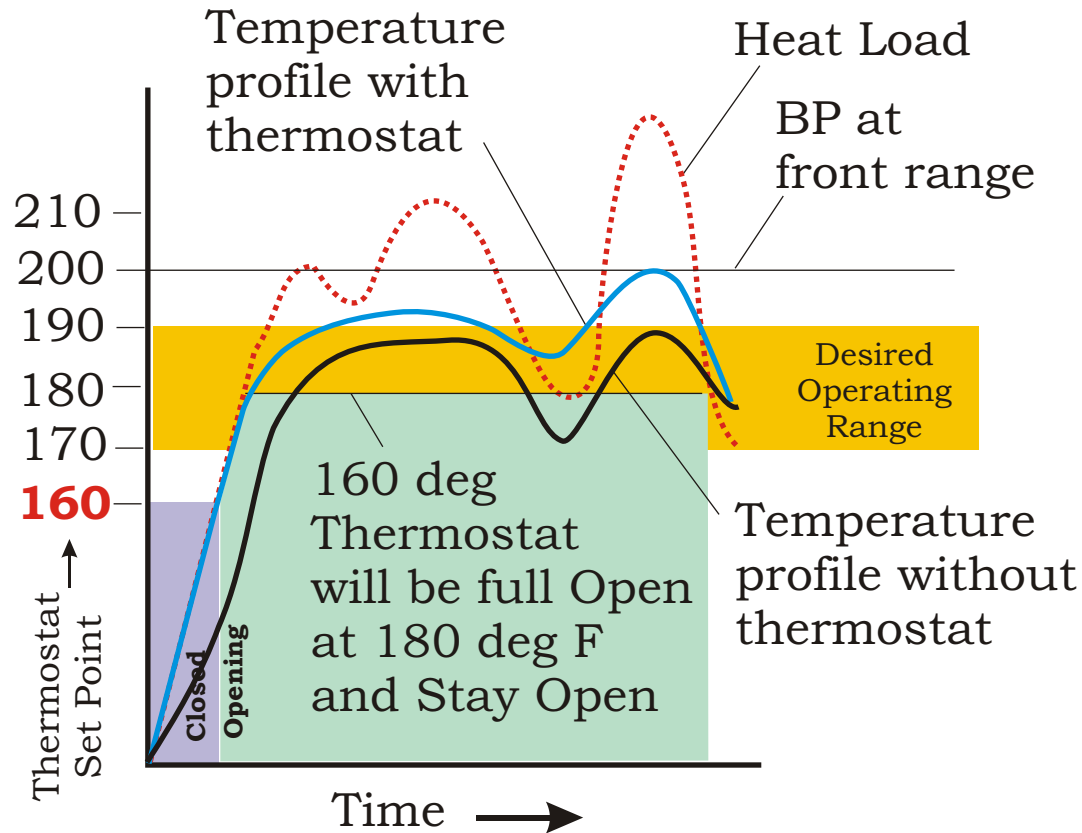


**Model A with
Thermostat Closed
No Flow
Until Thermostat Opens**



Temperature Profiles With and Without Thermostat

Average Varying Heat Load



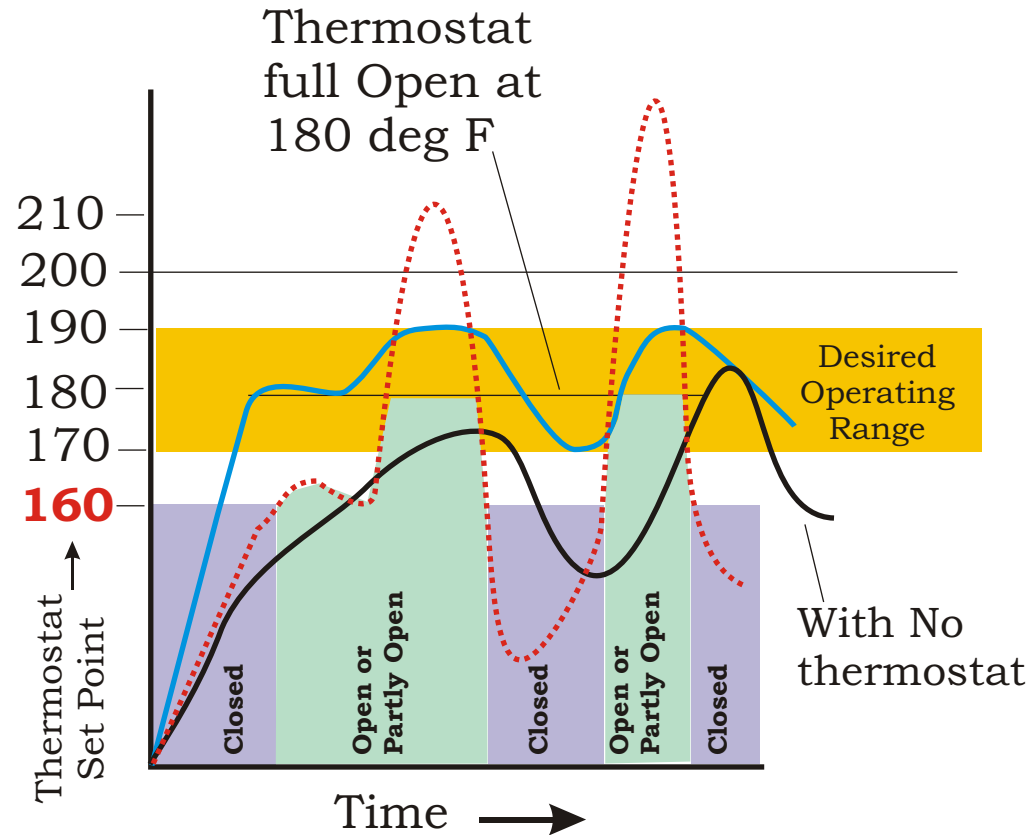
MODEL A
with Thermostat

- The use of a thermostat will allow heat up faster from cold start times
- Running temperatures will be higher due to the obstruction in the flow at the inlet to the radiator
- During the time the thermostat is closed the water pump will cavitate and not circulate water in the water jackets causing local hot spots which can cause damage
- No real advantage for use of a thermostat



Temperature Profiles With and Without Thermostat

Wildly Varying Heat Load



PROS

- Wildly varying heat load causes the thermostat to open and close often to provide a higher and more even temp
- Better engine performance

CONS

- 160 deg F thermostat is wide open at 180 deg. Further cooling control is dependent on Thermo Syphon ... Temp may exceed boiling point
- Operating the engine for an extended time with the TS closed stops coolant flow and creates Hot Spots which can potentially damage the engine



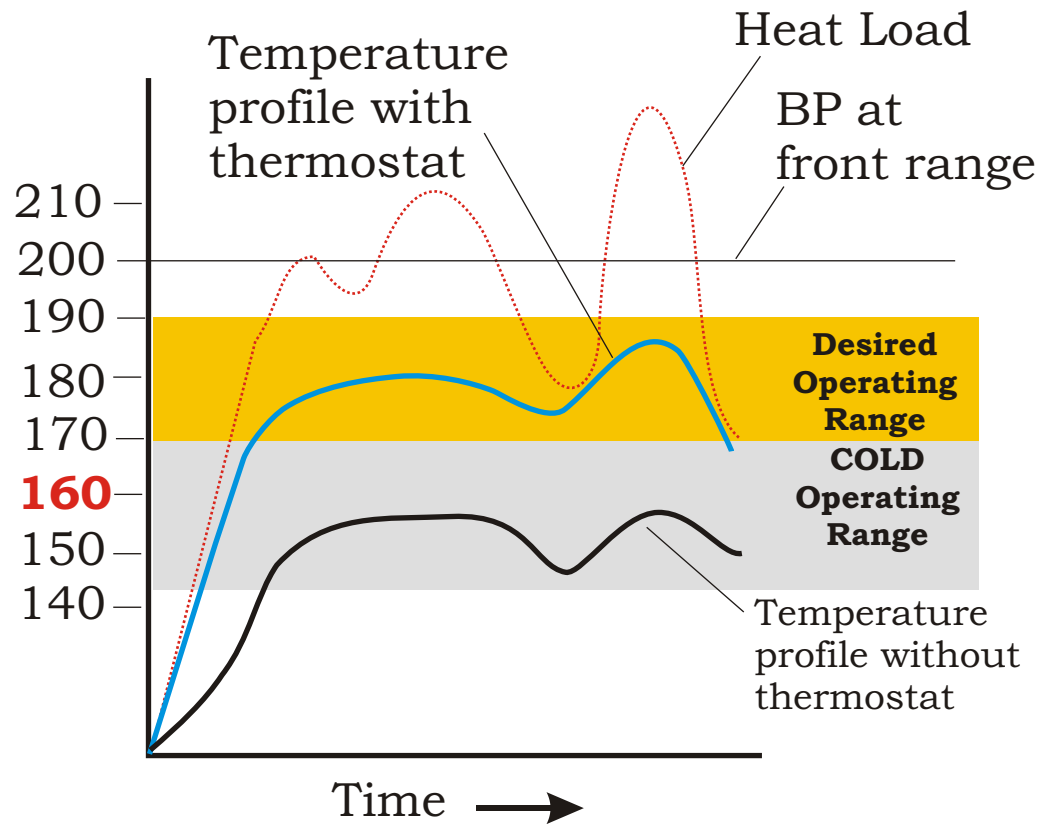
Temperature Profiles With and Without Thermostat

Cold Blooded Model A

Conclusion

If your Model A is operating in a cold range of 140 - 160 deg F a thermostat can raise the overall temperature

- Gives better performance
- Much shortened warmup
- Thermostat will cycle closed or partially closed much of the time - issue: Hot Spots
- Same effect can be had by covering up a portion of the radiator - especially in the winter



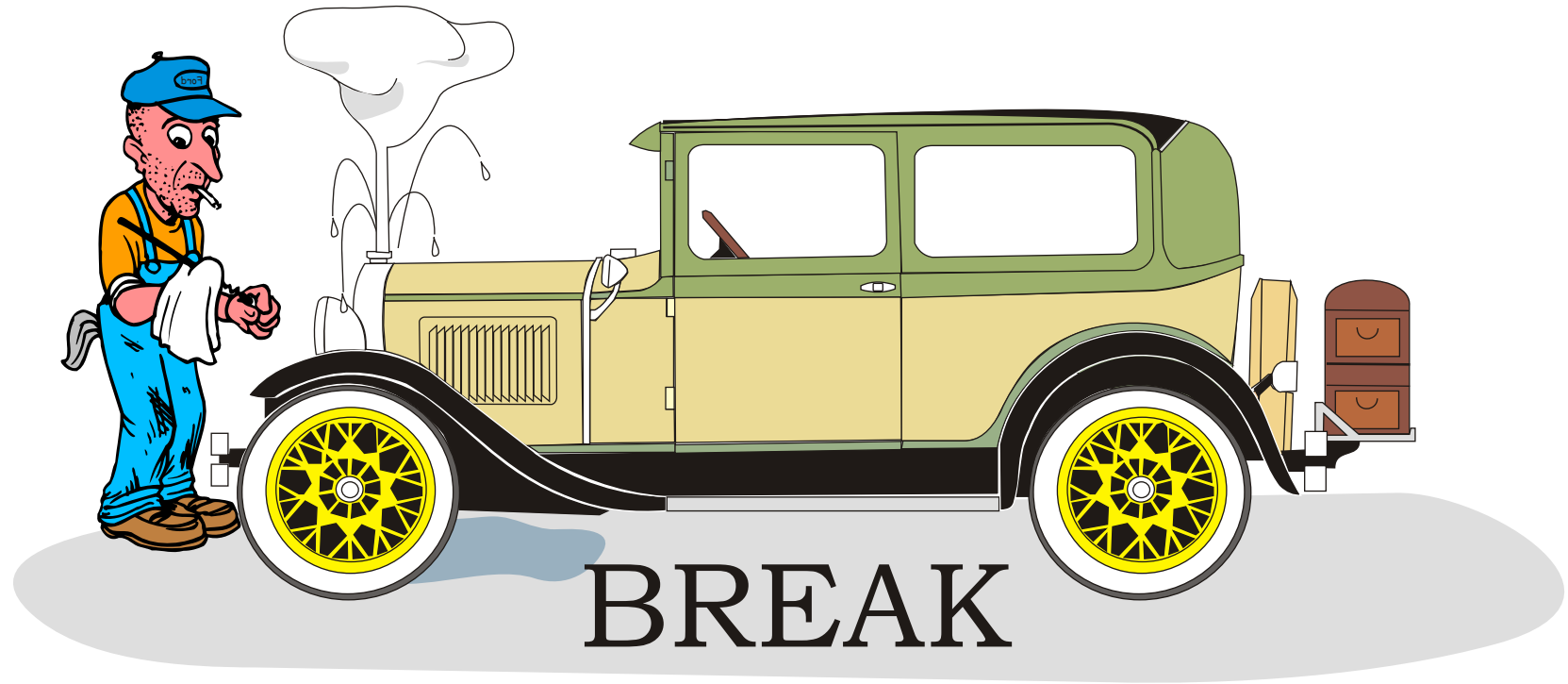
Cold Running MODEL A



Use A Thermostat ?

Conclusion

- It depends ... Some cars benefit others suffer
- The Safest Approach is to not use a thermostat
- There are better ways to squeeze that last horsepower out of the Model A Engine
- For winter driving you can run hotter by covering up 3 to 5 inches of radiator fins in the engine compartment to raise the bulk temperature without a thermostat
- Under most conditions the thermostat is wide open
- If your thermostat is cycling on and off worry about Hot Spots developing with potential engine damage
- WARNING: 180 deg F Thermostats are not fully open until 200 deg F which is the boiling point at Denver



Next

- Measuring Temperature
- Cooling System Maintenance

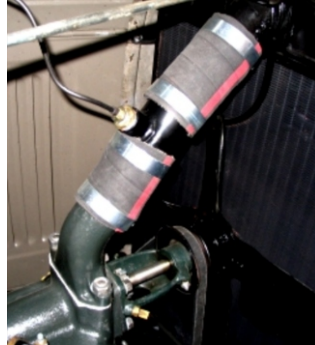


Temperature Indicators

TEMPERATURE GAUGE



Receiver Unit



Sender Unit

WILL ACCURATELY
TELL YOU THE
ENGINE COOLANT
TEMPERATURE

Indication of temperature
continuous and accurate

Dual gauges are for Oil
pressure and water temp

MOTOMETER



TELLS YOU THE
RELATIVE VAPOR TEMP
OF THE AIR ABOVE
THE COOLANT

Not calibrated in deg F
Usually reads between
two lines on the case. A
rapid jump to "Danger"
shows steam & boiling



Maintenance Methods

- 1931 Ford Instruction Book recommends “occasionally”
 - Open petcock on radiator, put hose in filler
 - Let water run until it comes out clear
- MAFCA Recommends FlushRadiator every 2000 miles
 - Does not specify method of flushing or what to use
 - Run engine for 10 minutes before draining
- DYKES Recommends FlushRadiator every Spring
 - Disconnect inlet and outlet hoses
 - Run tap water through radiator and engine
- MODERN Car forums
 - Drain Fluid then pour in a Radiator Cleaning Fluid
 - Run car until HOT then drain and flush with water



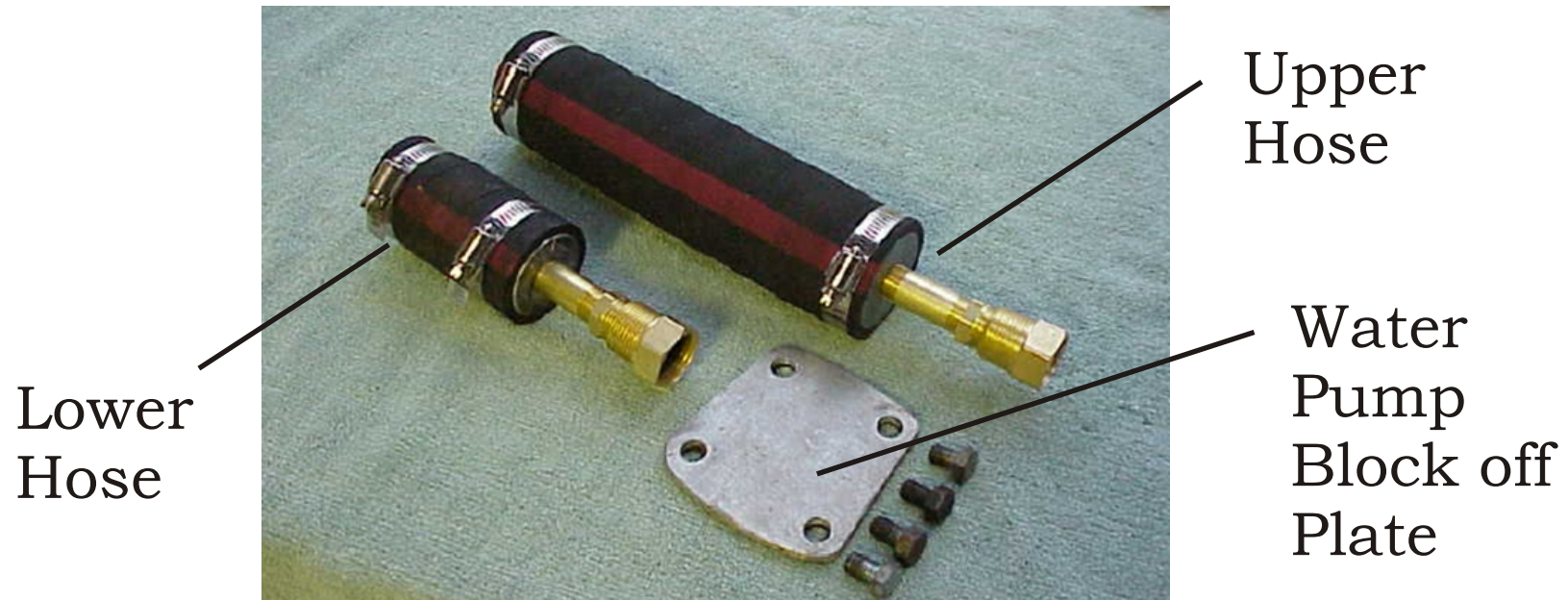
Scale and Crud Removal

- DYKES Motor Manual 1929
 - Use hot water with 1 cup of Washing or Baking soda (Washing Soda is Sal Soda) to 2 gallons water
 - Start Car and Run for 15 min with spark retarded
 - Drain and flush with water. Back Flush
 - For hard deposits - use 1 quart Muratic Acid to 5 gal water circulated slowly at idle for 5 minutes.
- Other CRAZY formulas from Model A Websites
 - One pound Sal Soda to Model A radiator & Engine drive for 1 hour - drain and refill
 - Contents of 3 or 4 two liter Coke bottles plus water Run 4 hours. Drain & fill with water run 15 min then drain and refill.



Back Flush Technique

- Back Flushing can remove crud from plugged pockets



- After cleaning using your “preferred method” you should Back Flush the engine.



Recommended Cooling System Reading

- Dykes Automobile Encyclopedia - 1929
- The Model A Ford - Victor Page - 1931
- Auto Mechanics Fundamentals - Stockel - 1969
- Automotive Mechanics - Crouse - 1970
- Model A Ford Troubleshooting - Les Andrews - 2000
- Internal Combustion Engines - Rajput - 2005
- Heat Transfer in Engines - Kirkpatrick - 2010

Website Information

- What Coolant to Use - www.rockymountainmodelclub.org
- Coolant Seminar - www.rockymountainmodelclub.org
- WaterWetter Info - www.redlineoil.com