THE ENGINE PEOPLE

ANY PART AT ANY TIME ALL OVER THE WORLD

MECHANISM OF HIGH TEMPERATURE CORROSION AT FOUR STROKE-ENGINES.

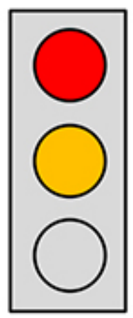
Speaker: Uwe Pränger

Hot Corrosion – The Triggers

Main triggers to initiate and/or to favor Hot Corrosion in Engine Operation

- Vanadium, Sodium and Sulfur in the Fuel

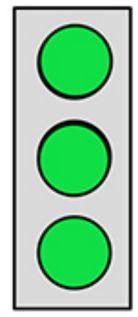
- Salty ambient Atmosphere (carry-over of Sodium)



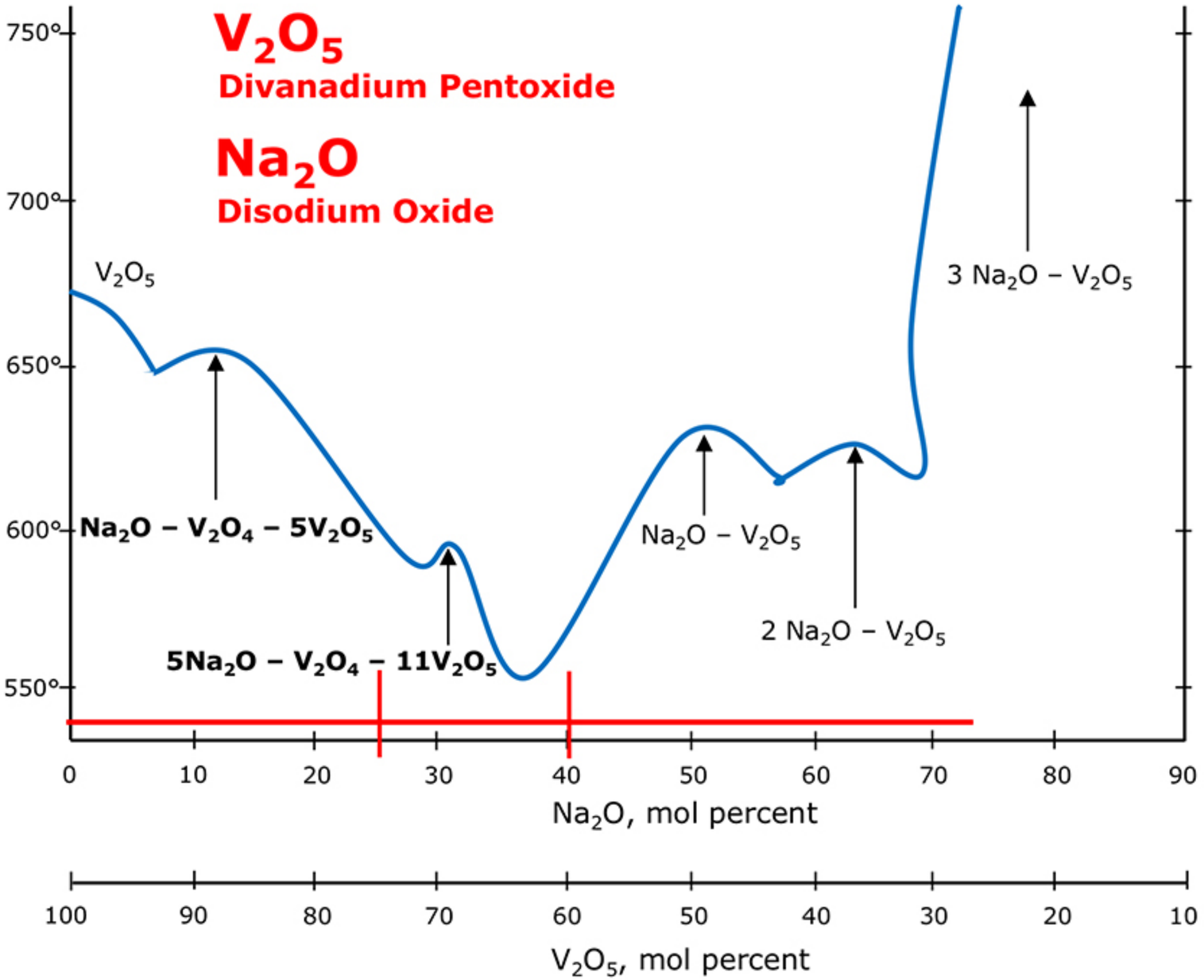
- Continious engine operation at too high temperatures

- Injection equipment/adjustment not in order

- Fuel and/or luboil separation not properly operated



Hot Corrosion – chemic- and thermal basics



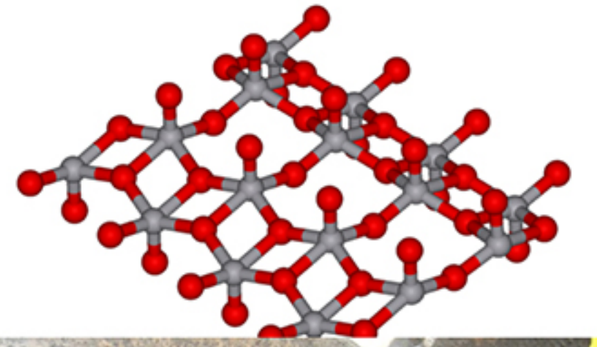
Content of V_2O_5 can be calculated under below Formula:
c = (TV/V1) ×1000 (unit: g/l)

2. The determination of vanadium pentoxide content in the supernatant fluid or the in the tail liquid
Accurately take test solution 10 ~ 20 ml to 250 ml beaker. The next procedures are the same as the first one. When calculating, V1 is not 2ml but the real volume of the sample.
3. The determination of the purity of vanadium pentoxide
Accurately weigh 0.2 grams of sample, add it to 250 ml beaker, add 10 ml of 1 + 1 sulfuric acid, melt it in electric furnace. When the sample is completely dissolved, cool it a little, add a small amount of water, cool to room temperature, put it into a 100 ml volumetric flask and dilute it to scale, shake, absorb 10 ml of solution to make the test. The next procedures are the same as the first one.
The purity p of vanadium pentoxide is:
p = (TV/m) ×(100/10)
4. The determination of V2O5 in green ore or slag
Weigh accuately 0.5-1 g of sample(depending on the content of vanadium pentoxide), place it at 30 ml of corundum crucible (or silver crucible), add 4 grams of sodium peroxide, mix them with a glass rod, cover it with a small amount of sodium peroxide, put it into 700 ℃ muffle furnace, melt it until the color turns to fuchsia (takes about 5 minutes), take it out, cool to dark red, then place it into 250 ml beaker with 90 ml of hot distilled water in it. When the obvious heat exchange is over, wash out ……..

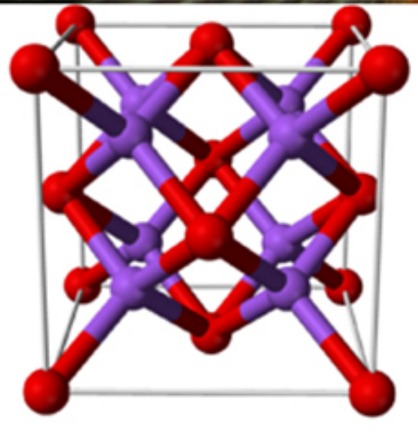
The content x of V2O5 is as follows:
x = (TV/m)

Hot Corrosion – chemic- and thermal basics

Divanadium Pentoxide V_2O_5



Disodium Oxide Na_2O



Hot Corrosion – chemic- and thermal basics

Chemical composition	Melting point C°
V_2O_5	670
$Na_2O - V_2O_5$	682
$2Na_2O - V_2O_5$	643
$Na_2O - V_2O_4 - 5V_2O_5$	535
$5Na_2O - V_2O_4 - 11V_2O_5$	535

= > crystalisation

$$Na_2O \cdot 6V_2O_5 <=> Na_2O \cdot V_2O_5 \cdot 5V_2O_5 + ½\ O_2$$

<= melting

= > crystalisation

$$5Na_2O \cdot 12V_2O_5 <=> 5Na_2O \cdot V_2O_5 \cdot 11V_2O_5 + ½\ O_2$$

<= melting

Oxygen Pump

Published by Pollmann (1) und Wagner (2)

Hot Corrosion – how it works...

- **forming of the salts: Sodium Sulfate, Disodium Oxides, Nickel Sulfide and Divanadium Pentoxide.**

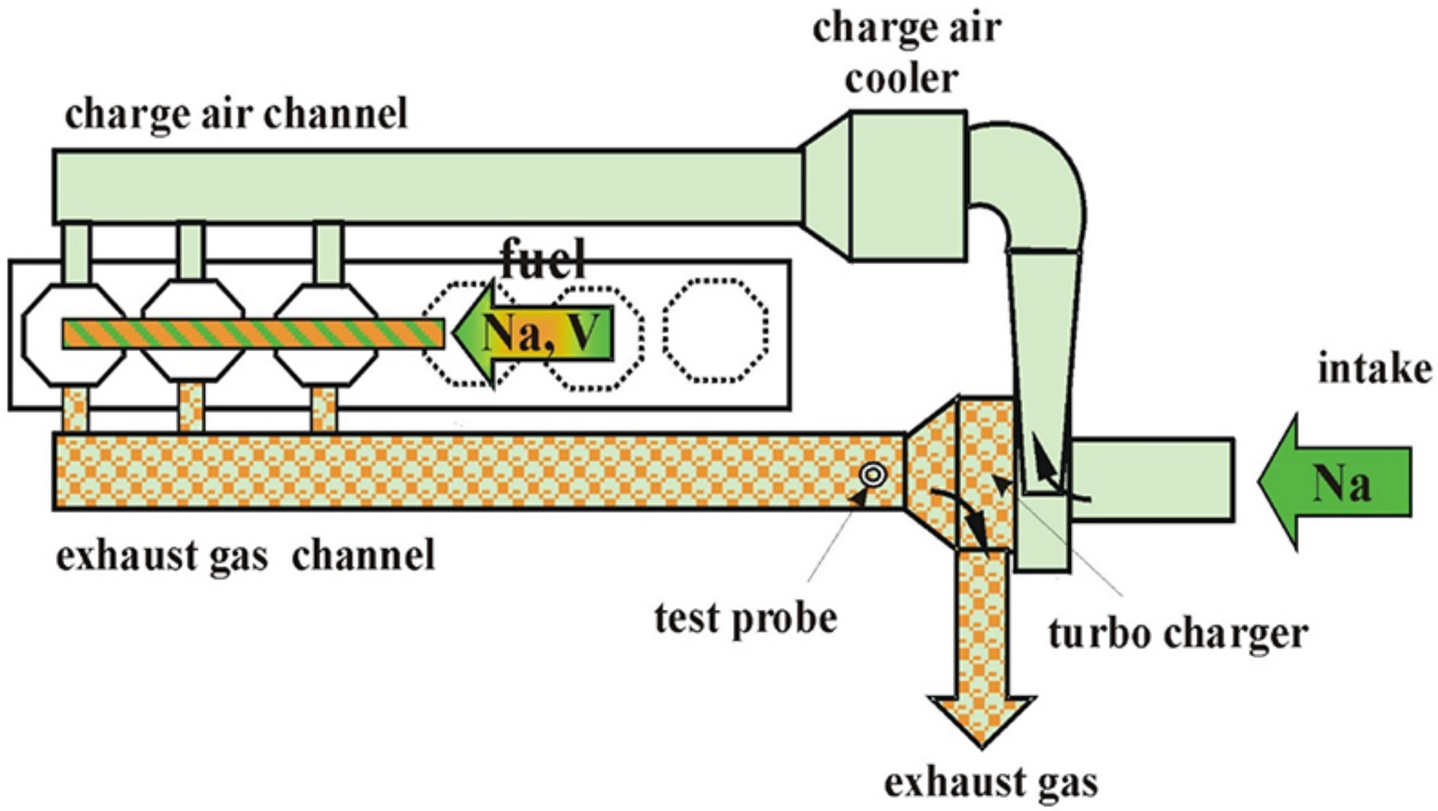
- **these salts are condensing on the combustions bowl after ignition**

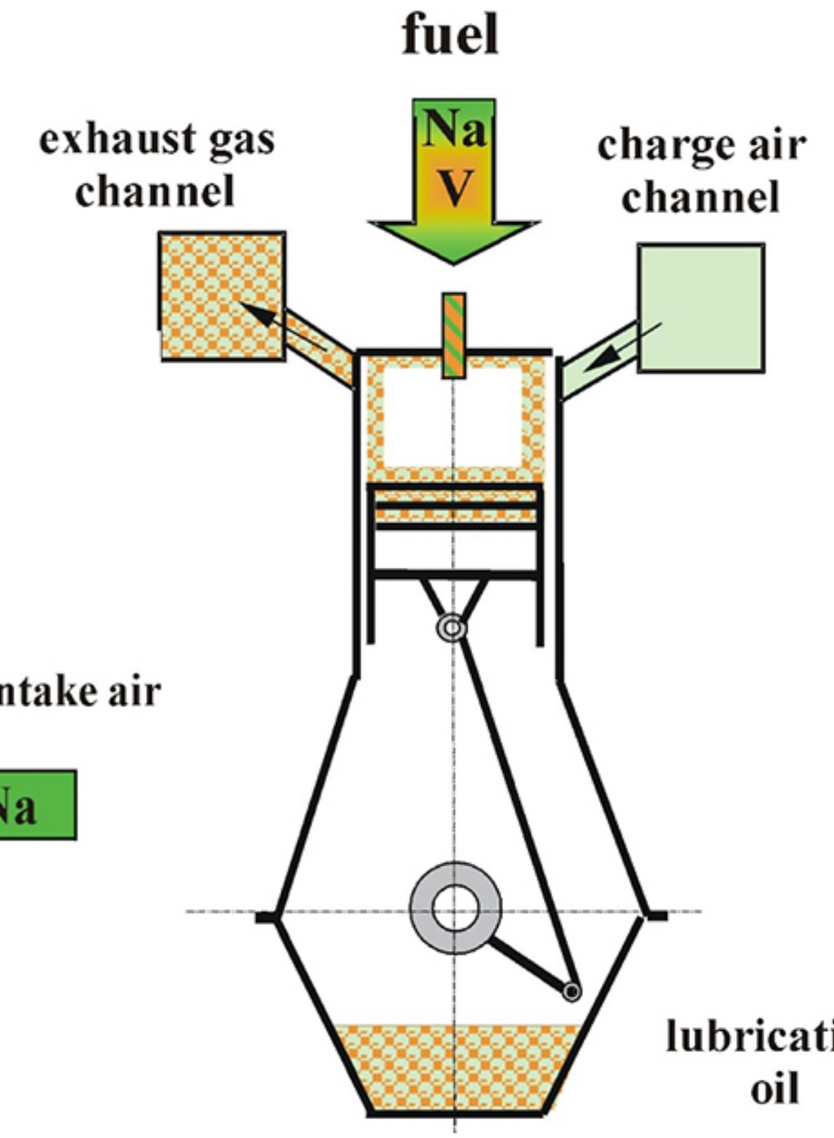
- **rising temperature after ignition will melt the salts and those melted salts are absorbing surrounding oxygen.**

- **and now an oxygen pumping effect starts towards the piston surface, which destroys the piston crowns surface by corrosion.**

Hot Corrosion – Depots of Na and V in engines

Na input (fuel & charge air)
V input (fuel)
Na depot
Na + V depot





Hot Corrosion – Depots of Na and V in engines

Testrun with SKL 6VDS 24/24

Fuel: HFO in accordance to ISO 8217

- Vanadium 322 mg/kg
- Sodium (Na) 56 mg/kg

Separation: HFO and Luboil under optimal conditions

Running hours:

48h

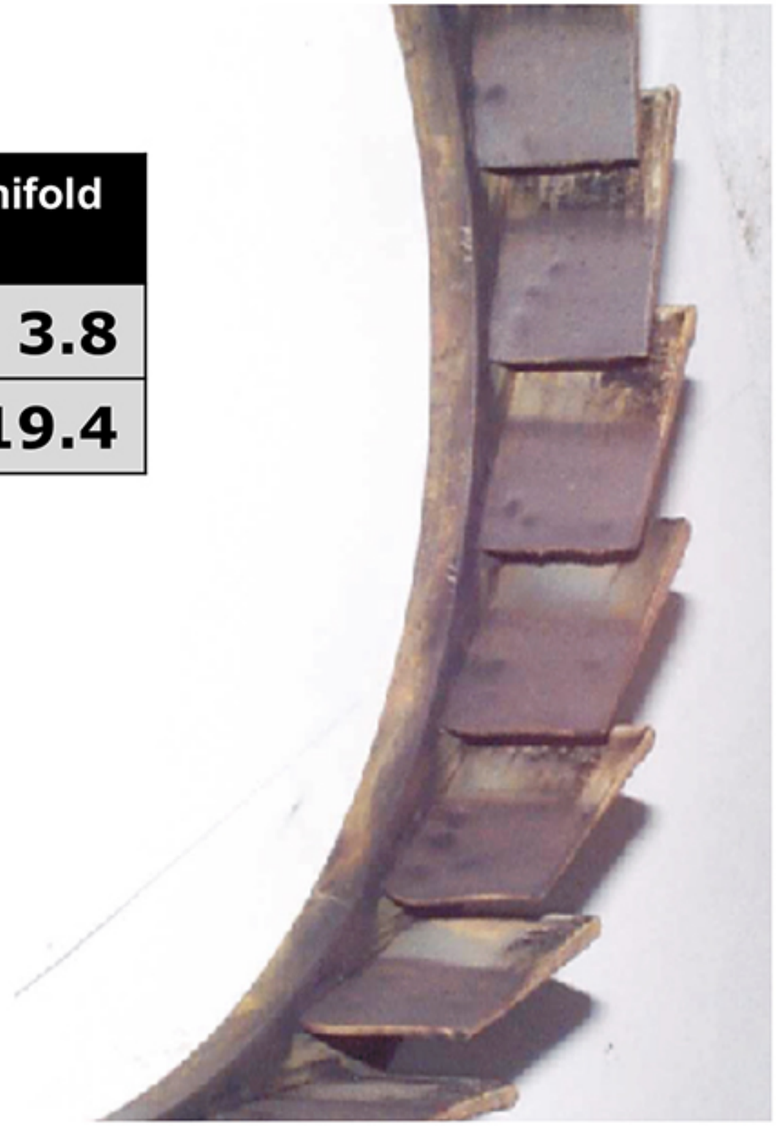
Elements	Fresh oil prior to test mg/kg	Used oil after test mg/kg
Na	**9**	**49**
V	**0**	**24**

Hot Corrosion – Depots of Na and V in engines

Testrun with SKL 6VDS 24/24

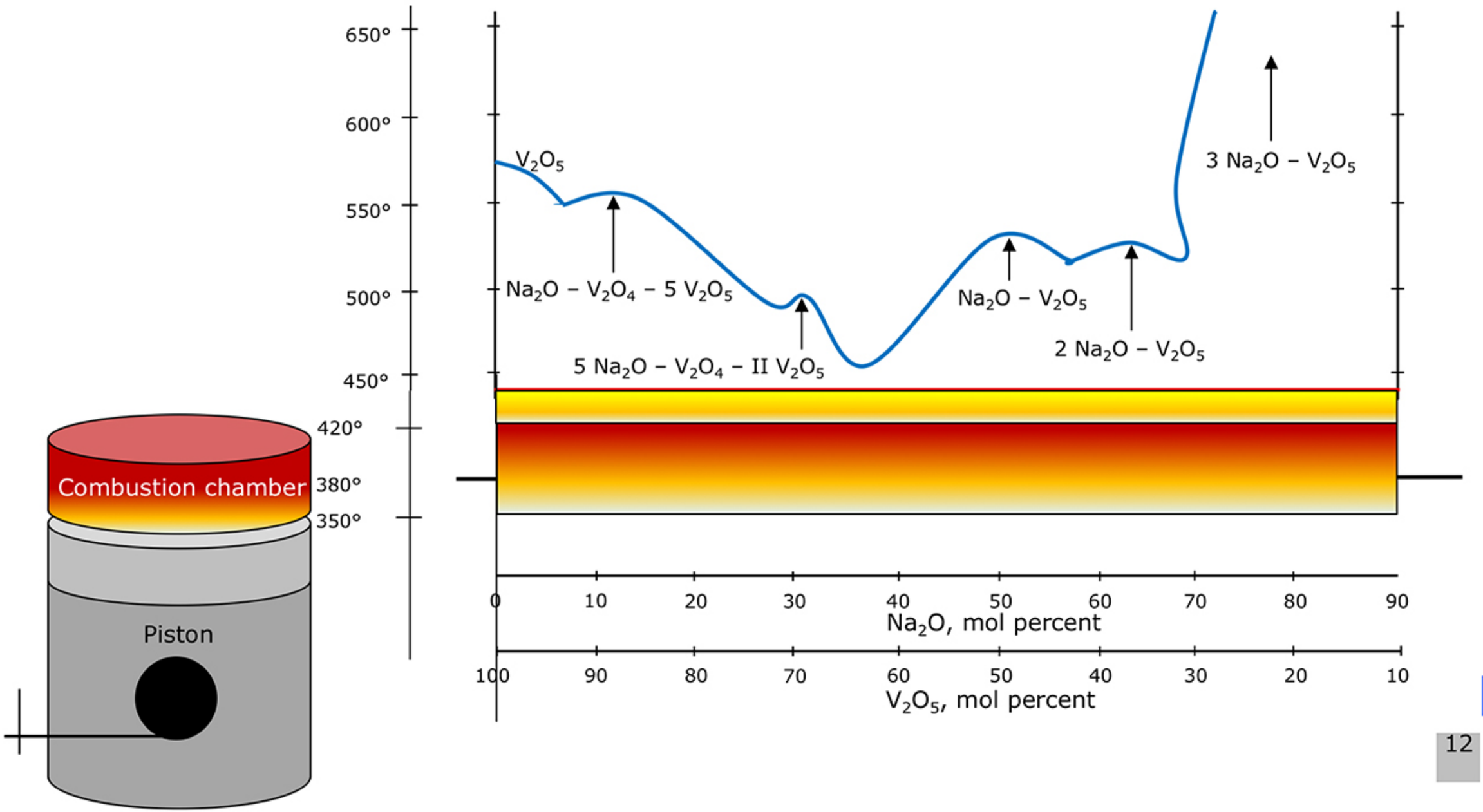
Analyses of deposits at turbocharger

Elements	Nozzle ring % (m)	Turbine Blade % (m)	Exhaust manifold % (m)
Na	**3,9**	**1,9**	**3.8**
V	**16,8**	**13,8**	**19.4**



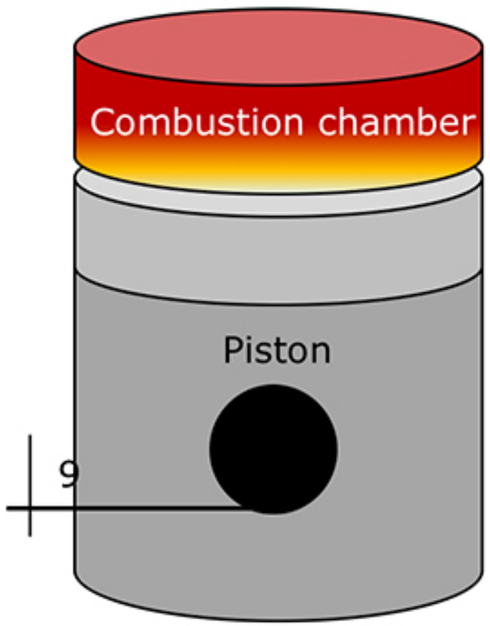
Hot Corrosion – how it works...

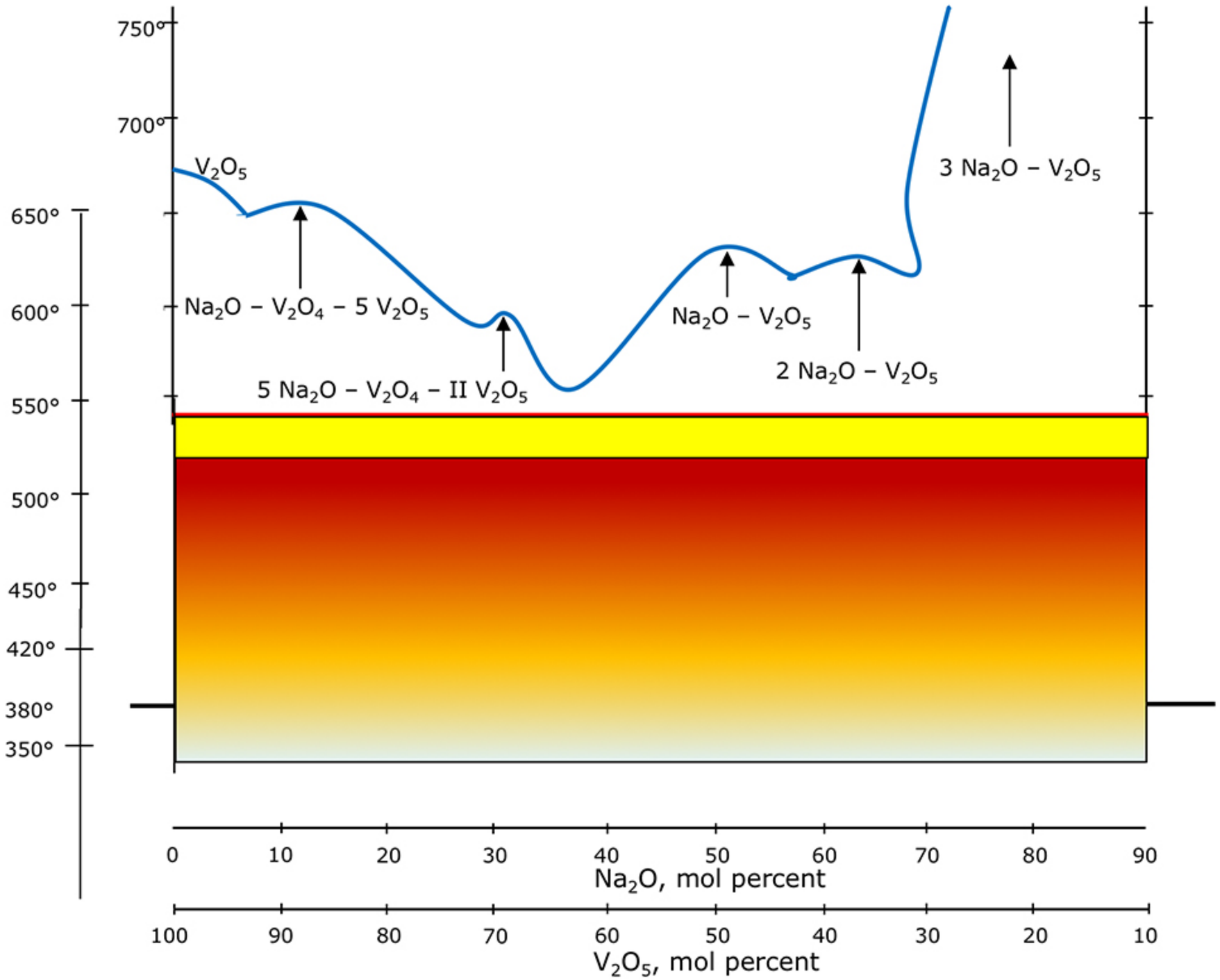
If Sulfur came into the picture as well, a content of 2% will reduce the Reactiontemperature up to 100°C.



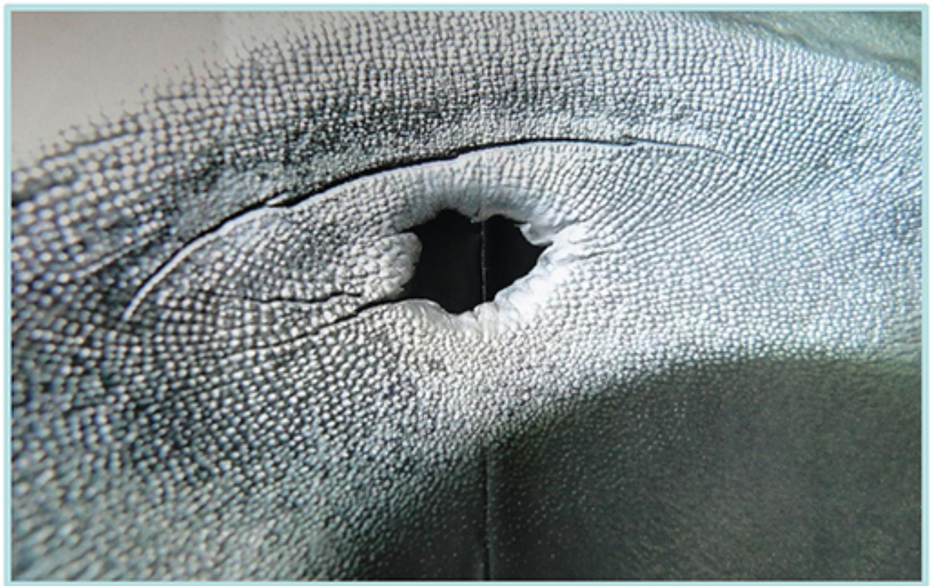
Hot Corrosion – how it works...

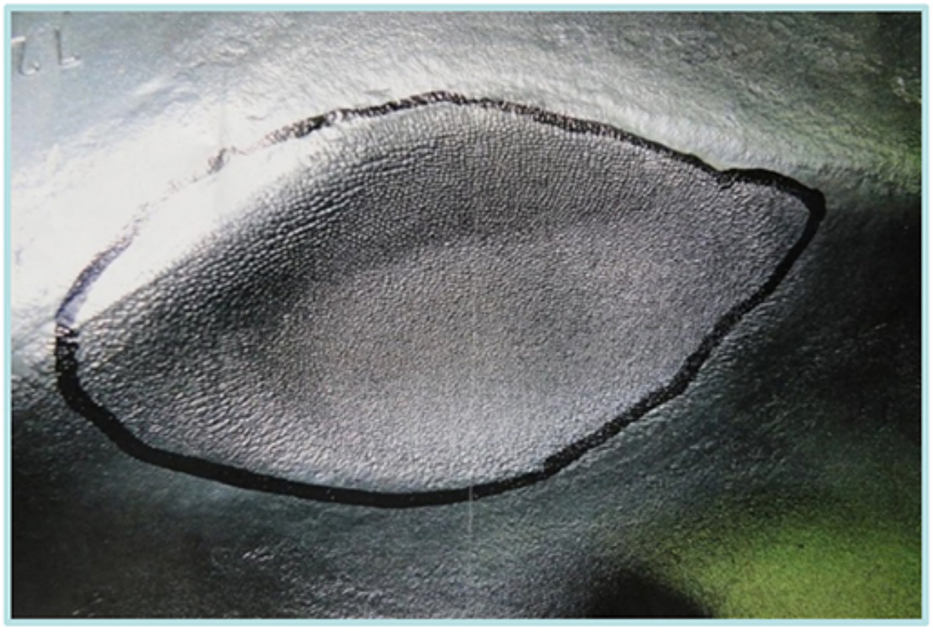
A 2% content of Sulfur will cause an increase of the firing temperature up to 80°C.





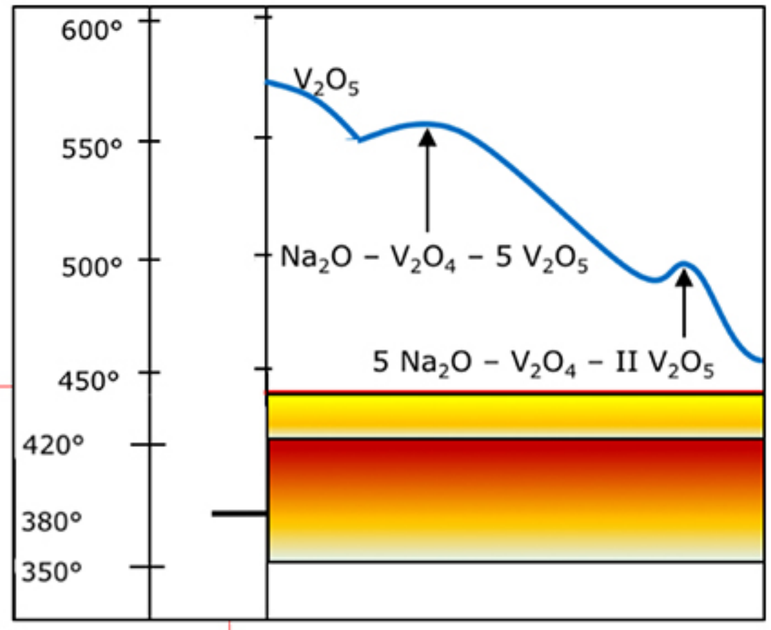
Hot Corrosion .....has many faces

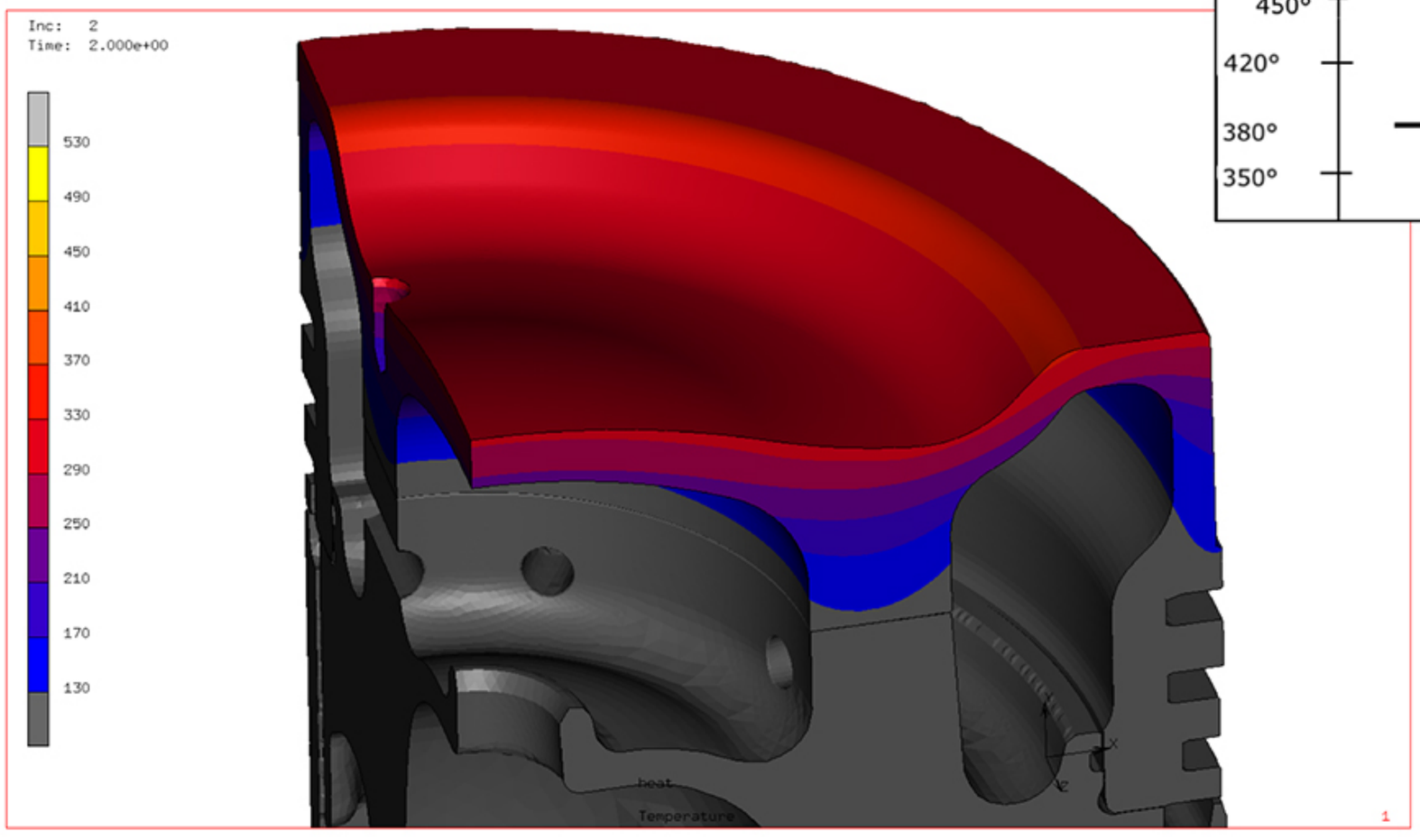




Hot Corrosion

- **cooling chamber without carbon residues**
- **full engine load**



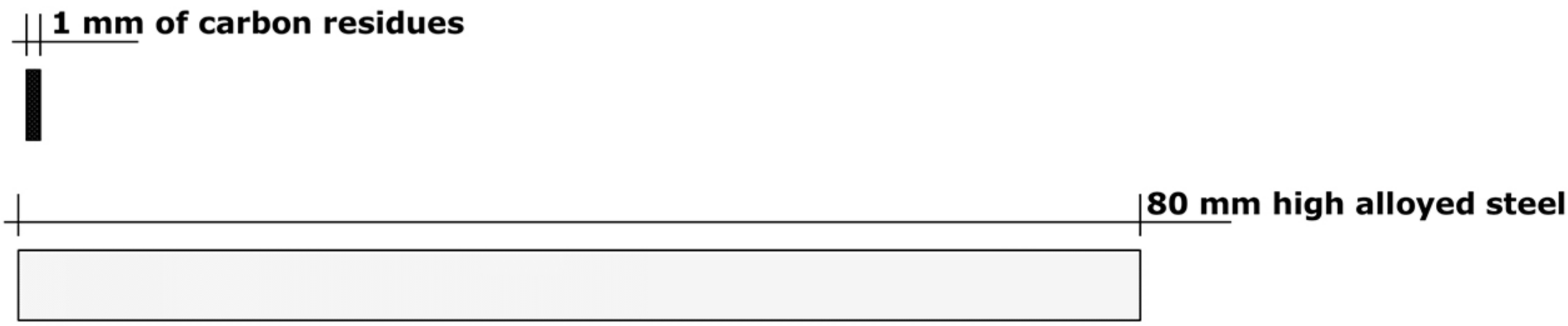


Hot Corrosion

Thermal insulating effect of carbon residues in the cooling chamber of a piston crown

- **Carbon residues have a 50- to 400-times worse thermal conductivity than high alloyed steel**
- **Carbon residues are a remarkable thermal insulator.**
- Empirical formula:

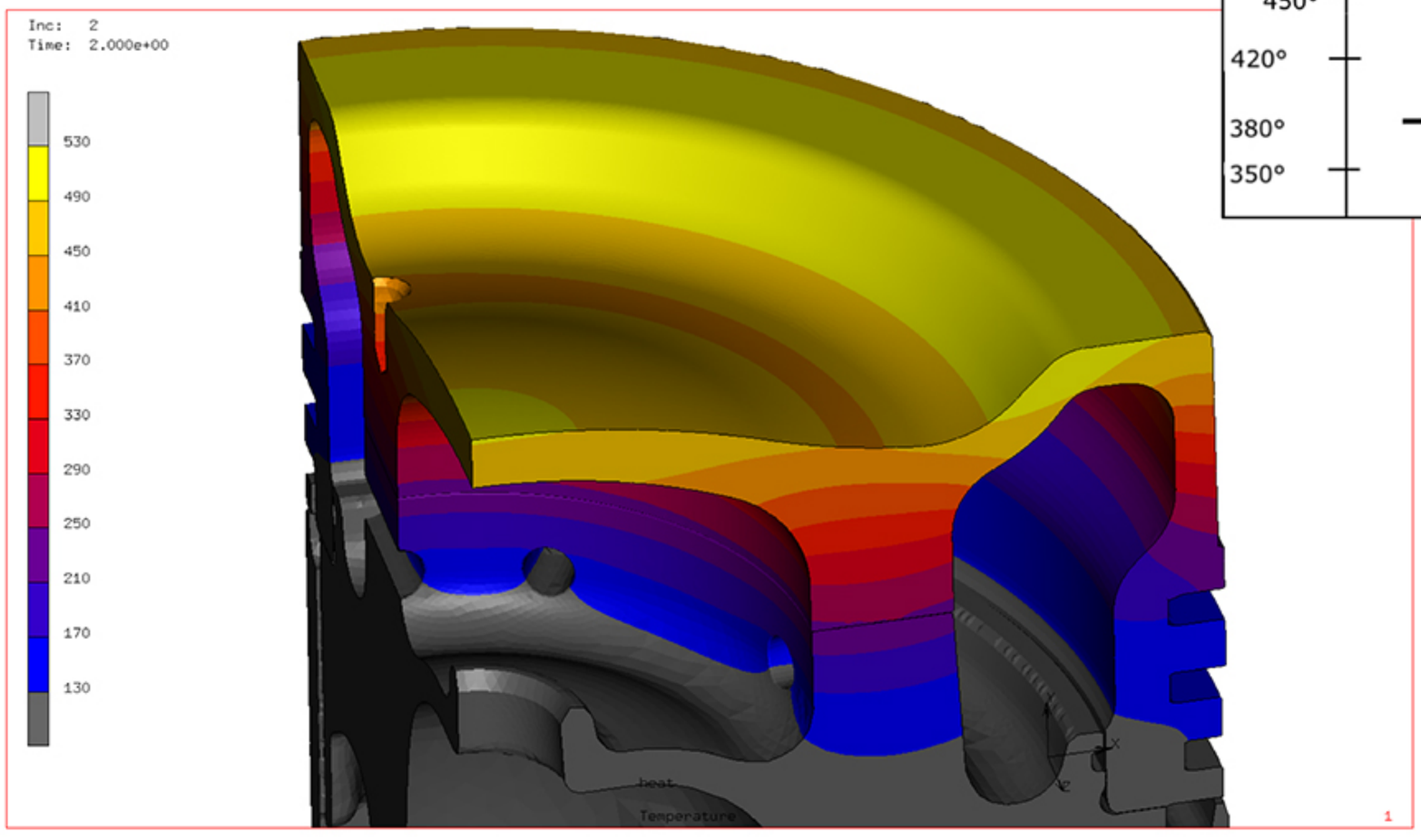
1 mm oil deposit on surface is equal to 80 mm thickness of steel (rule of thumb):
deposits: 0.1…0.8 kcal/m h °C = 0.12…0.93 W/m K
steel (31CrMoV9): 43.0 W/m K

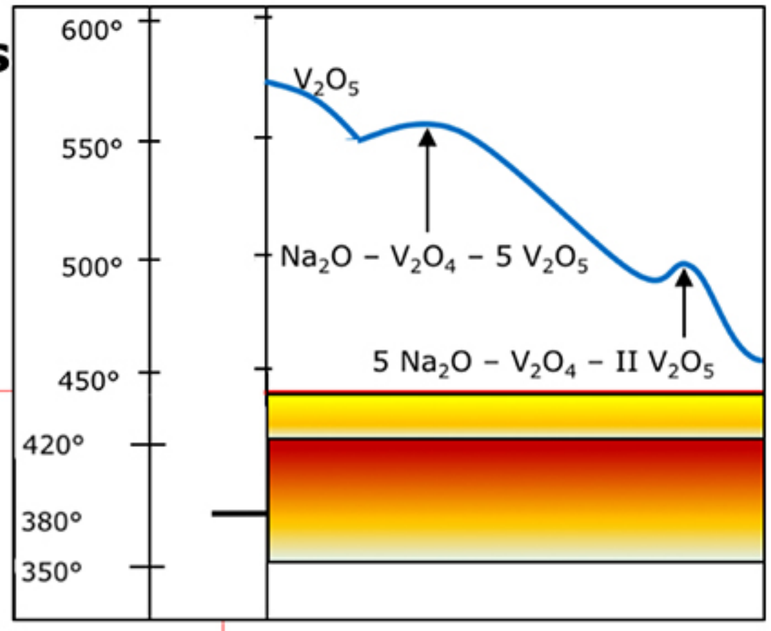


Source:
Hilfsbuch für Mineralöltechniker: Stoffkonstanten und Berechnungsunterlagen von A.F. Orlicek, H. Pöll

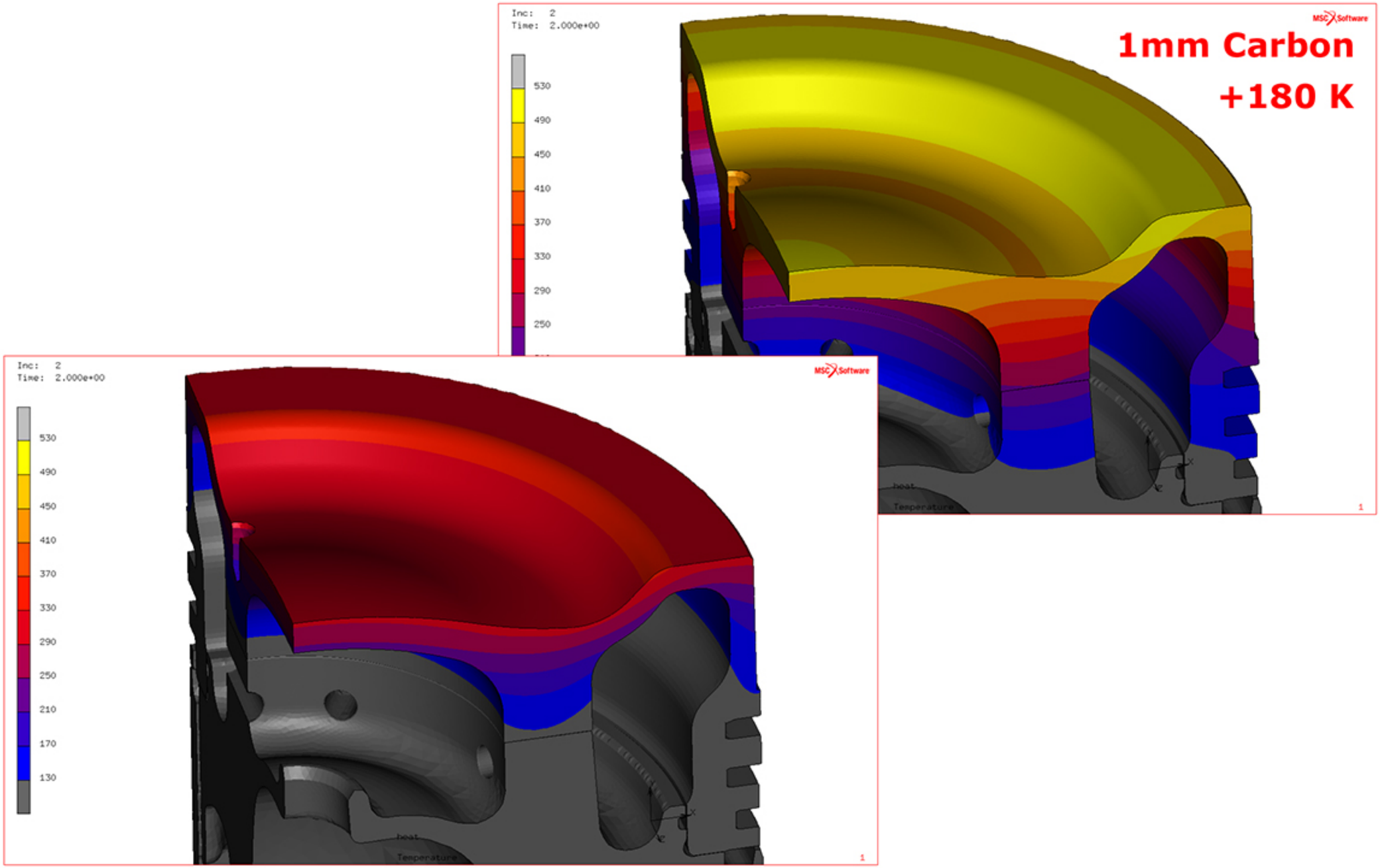
Hot Corrosion

- **cooling chamber with 1mm carbon residues**
- **full engine load**





Hot Corrosion



Hot Corrosion

Options to avoid/reduce Hot-Corrosion at the piston crown

- **Improve and continuously hold piston crowns surface temperature as low as possible with:**

  Regulary carbon cleaning service

Hot Corrosion

Recommendations to avoid/reduce Hot-Corrosion

- Use uncritical fuel with a low content of Vanadium and a uncritical low ratio of V/Na. (Na/V<25% with Na<100 mg/kg)

- Prevent continuous piston crown surface temperatures higher than 420° C.

- Prevent exhaust gas temperatures higher than 500°C

- Decrease the Na entry by the fuel to the lowest possible level due to proper maintained and well operated separators.

- If – in a salty ambient atmosphere – a high Na carry-over is an issue, the installation of a demister after charge air cooler will reduce the problem remarkable.

Thank you very much for your kind attention

Literature

(1) S.Pollmann

Mineralogisch-kristallografische Untersuchungen an Schlacken und Rohrbelägen aus dem Hochtemperaturbereich ölgefeuerter Großkessel.

Mitteilung der VGB (1965), H.95, S. 1-18

(2) E.Wagner

Diss. Hannover 1964

(3) S.Bludszuweit

Sodium in the Intake Air

Final Report 1999