POWER MODS FOR THE NEWBIE AND VETERAN TDI'ER

A Guide to TDI Performance Enhancement Strategies

TDIMeister

Introduction

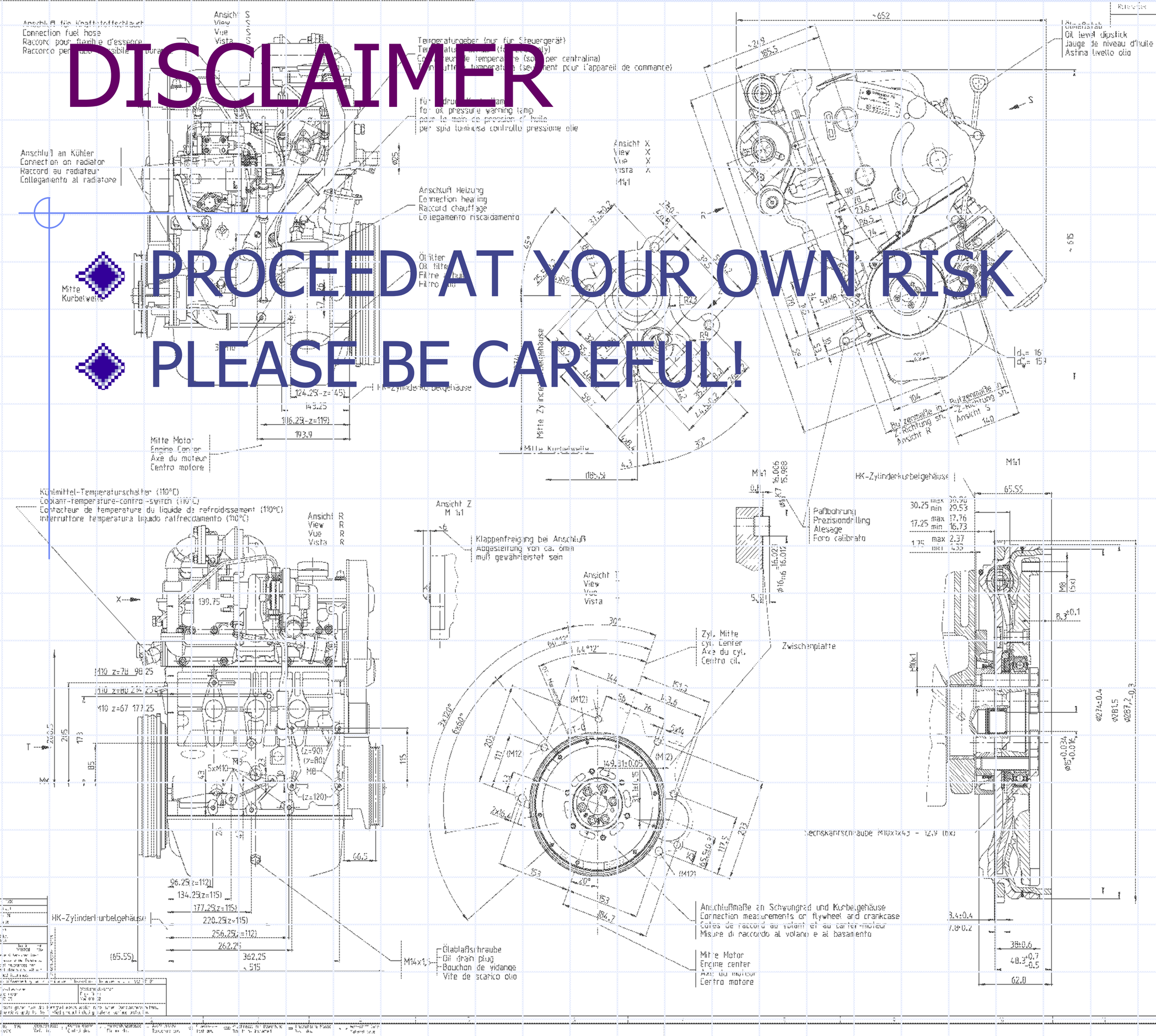
- Presenter background
  - Bachelor of Engineering Science (Mechanical), University of Western Ontario
  - 5+ years experience in Automotive Engineering specializing in Powertrain / Engine Design
  - Powertrain development experience (EPA, General Electric Diesel locomotives, GM, Ford)

Topics

- Disclaimer
- TDI Engine Performance 101
- Tuning considerations
- Dangers of Tuning
- Overview of various tuning strategies
- Suggested Order of Mods (Stage 1, 2, etc.)
- Summary
- Q&A
- Conclusion

DISCLAIMER

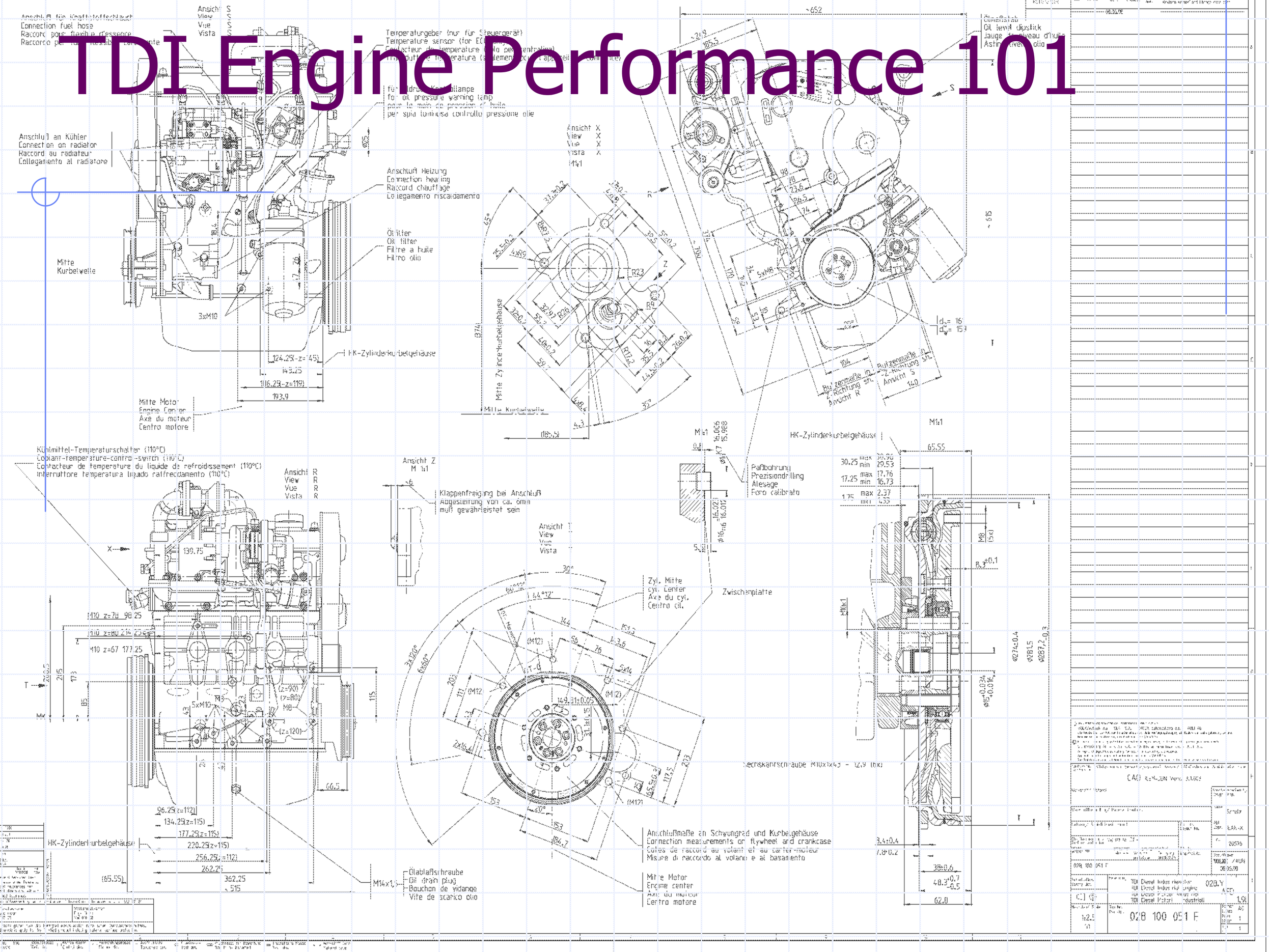
- PROCEED AT YOUR OWN RISK
- PLEASE BE CAREFUL!



TDI Engine Performance 101

- Formula: AIR + COMPRESSION + FUEL + EXPANSION = POWER
- Key #1: Burn maximum amount of fuel, correctly timed, as completely as possible
- Key #2: Air is vital, but secondary
  - Diesels always operate lean of stoichiometric
  - "Ideal fuel/air ratio for max power", is when the engine can burn as rich a mixture as possible without much of it going up in smoke (i.e. "smoke limit")
  - This "smoke limit" will always occur well lean of the stoichiometric air-fuel ratio (approximately 20-30% of excess air for a wide range of Diesel engines.

TDI Engine Performance 101



Tuning Considerations

- Increasing horsepower output can be achieved in several ways
  - Increase fuelling level
    - Lengthen injection duration (keeping hose turned on longer)
    - Increase injection rate (using a bigger hose or higher source pressure)

Tuning Considerations

- All engineered, manufactured products are designed to withstand defined stress in service
- Failure modes and their prediction are still relatively inexact sciences and involve extensive statistical and empirical methods (a lot of guessing and applying rules-of-thumb)
- Factors of safety are applied to give a sufficient margin to prevent failure under normally anticipated operating conditions
- Tuning for more performance invariably increase mechanical and thermal stresses

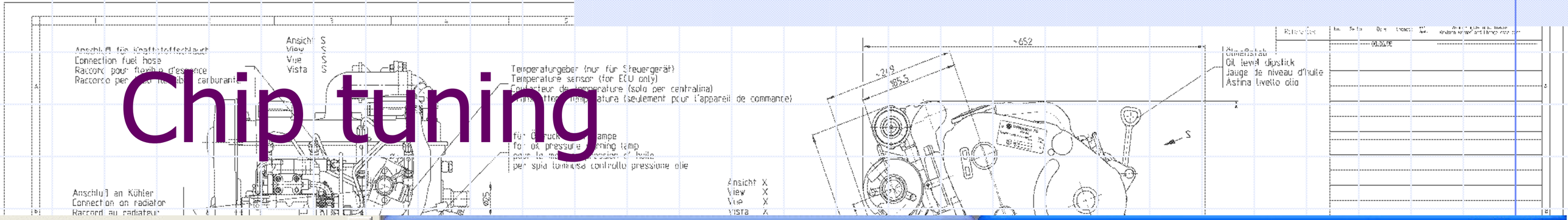
Tuning Considerations

- Margins of safety are diminished
- Failure becomes more imminent
- Because of the uncertainly in failure prediction, and the huge number of contributing variables, some engines will fail under less loadings than others.
- Individual, anectodal reports of failure or non-failure is not sufficient!
- Take home lesson: Don’t expect a tuned engine to last as long as a stock one
- Power, Reliability, Cost, Emissions: Choose two.

Chip tuning

- WHAT: A "chip" that stores data about a large number of engine operating parameters as a function of RPM, load (TPS), etc.
  - "Tuning" involves altering parameters such as fuel injection quantity, injection timing, requested boost, and "response characteristic" of TPS to these parameters.
- HOW: A chip tuner sets arbitrary values of the above parameters, which are stored as hexadecimal values and can be graphically plotted, giving rise to the term "maps."
- WHY: The ECU relates inputs it receives from the engine and the environment (TPS, injector needle lift, injection pump voltage, crank RPM sensor, IAT, MAP, etc.) and "looks up" the maps.
  - The maps determine the output (e.g. injection quantity, timing, etc.) based on the inputs and the matching point on the maps.

Chip tuning



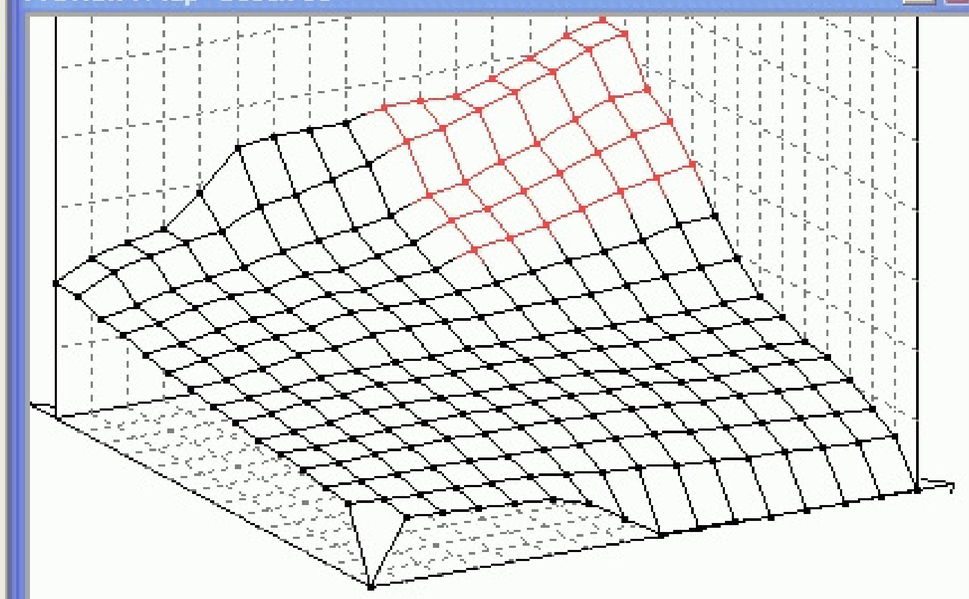
Projects, Versions & Maps:

M.	Adress	Name
	00000	Hexdump
	My maps	
	Potential maps	
	01302	Map "Bosch 16"
	013FA	Map "Bosch 16"
	01520	Map "Bosch 16"
	015F8	Map "Bosch 16"
	019C4	Map "Bosch 16"
	01D6E	Map "Bosch 16"
	02080	Map "Bosch 16"
	0217C	Map "Bosch 16"
	0235E	Map "Bosch 16"
	02644	Map "Bosch 16"
	027E2	Map "Bosch 16"
	03B9C	Map "Bosch 16"
	03CBE	Map "Bosch 16"
	03F10	Map "Bosch 16"
	03FEE	Map "Bosch 16"
	041D0	Map "Bosch 16"
	0452E	Map "Bosch 16"
	04A64	Map "Bosch 16"
	04FAC	Map "Bosch 16"
	054FE	Map "Bosch 16"
	0567A	Map "Bosch 16"
	057E6	Map "Bosch 16"
	0627C	Map "Bosch 16"
	065A8	Map "Bosch 16"
	066E8	Map "Bosch 16"
	067A0	Map "Bosch 16"
	06B85	Map "Bosch 8"
	06B86	Map "Bosch 16"
	075D2	Map "Bosch 16"
	075DE	Map "Bosch 8"
	076D4	Map "Bosch 16"
	077E4	Map "Bosch 16"
	078FC	Map "Bosch 16"
	07A8E	Map "Bosch 16"
	07B86	Map "Bosch 16"
	07E0E	Map "Bosch 16"
	07F32	Map "Bosch 8"
	07F40	Map "Bosch 8"
	07F48	Map "Bosch 8"
	10187	Map "Bosch 8"
	39302	Map "Bosch 16"
	393FA	Map "Bosch 16"
	3951A	Map "Bosch 16"

VW (Original), 021JB, Hexdump

```
8 04 41 05 E0 05 9A 06 9A 06 9A 0
```

Preview : Map "Bosch 16"

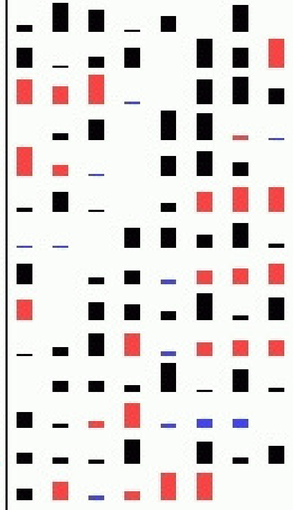


```
6 00 C6 00 C6 00 C6 00 C6 00 C6 0
6 03 60 04 60 04 60 04 60 04 60 0
0 04 D6 03 D6 03 AE 04 C0 04 FD 0
1 05 C1 05 C1 05 E0 03 E0 03 D5 0
0 05 9A 06 9A 06 9A 06 9A 06 FE 0
3 05 86 05 5F 06 A3 07 A3 07 A3 0
1 04 1A 05 4B 05 DE 05 E9 06 28 0
8 08 1B 04 1B 04 23 05 72 05 18 0
E 08 7E 08 7E 08 25 04 25 04 36 0
F 07 72 08 72 08 72 08 72 08 38 0
A 05 A2 06 B6 07 67 08 67 08 67 0
2 04 AD 05 2B 06 C8 06 B6 07 50 0
0 08 69 04 10 05 FB 05 54 06 C9 0
6 08 46 08 46 08 7D 04 68 05 4A 0
E 07 3B 08 3B 08 3B 08 3B 08 B8 0
C 06 BF 06 66 07 19 08 19 08 19 0
7 05 4A 06 8E 06 B6 06 2C 07 F8 0
8 07 F3 04 B7 05 4A 06 71 06 98 0
A 07 8A 07 8A 07 F3 04 B7 05 4A 0
7 06 68 07 5D 07 5D 07 5D 07 2E C
```

Text 2d 3d

VW (Importierted Version), 021JB, Hexdump

```
8 0B AC 0D 88 13 EC 13 00 00 04 0
4 04 F5 04 41 05 75 05 B5 05 F6 0
2 07 97 07 97 07 A3 03 1C 04 74 0
1 05 69 05 A9 05 F2 05 66 06 B6 0
7 08 A7 08 93 03 F0 03 7C 04 C8 0
D 05 E1 05 3A 06 A6 06 22 07 8B 0
9 09 63 03 EF 03 7C 04 D4 04 28 0
9 06 86 06 E6 06 5E 07 D3 07 3F 0
7 03 D7 03 6C 04 E8 04 40 05 99 0
6 06 0E 07 6F 07 D7 07 74 08 DD 0
F 03 5C 04 DC 04 4C 05 99 05 CD 0
8 07 F7 07 58 08 EE 08 D8 0A 51 0
0 04 CD 04 37 05 81 05 C9 05 21 0
9 07 43 08 32 09 1A 0B 91 0D 51 0
8 04 24 05 79 05 CD 05 29 06 EB 0
4 08 71 09 A3 0B 91 0D 00 00 23 0
4 05 69 05 C5 05 09 06 E2 06 9A 0
7 09 1A 0C 91 0D 00 00 E3 02 03 0
D 05 B1 05 12 06 F3 06 A6 07 FB 0
9 0C 14 0E 00 00 D2 02 DB 03 8C 0
5 05 05 06 FC 06 EA 07 2D 09 24 0
4 0E 00 00 B2 02 CF 03 78 04 00 0
9 06 11 07 50 08 B6 09 D6 0A CC 0
0 00 AE 02 B3 03 70 04 D4 04 31 0
8 07 7A 08 2D 0A 75 0B 81 0C B2 0
2 02 8B 03 50 04 EC 04 25 05 BD 0
F 08 C8 0A 32 0C 7D 0D 87 0F 87 0
B 03 40 04 F4 04 24 05 C5 05 2A 0
5 0B D1 0C 29 0E 49 10 49 10 00 0
F 04 D8 04 0C 05 C1 05 3A 06 94 0
A 0D 57 0E E8 10 E8 10 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
0 08 00 08 00 08 00 08 00 08 00 0
```



Text 2d 3d

Chip tuning

- PROS:
  - Most aftermarket chips undetectable to ECU scan tools
  - Large choice of products from different vendors with different performance levels / operating characteristics
  - Large power gains for expense
- CONS:
  - Involves opening up the ECU; permanent (soldered on PCB)
  - Potential drivability issues on some chip/vehicle combinations
- Performance Bang-for-Buck: VERY GOOD – EXCELLENT
- Verdict: A must for the performance seeking TDI'er. But choose carefully.

Tuning boxes, “Evry” Mod

- WHAT: a circuit of which one or more potentiometers are the main components (or just a single resistor/potentiometer) is installed in-line on the wiring harness from the ECU to the injection pump.
- HOW: The actual voltage signal input that the pump “sees” is conditioned or “strengthened” from the signal coming from the ECU.
- WHY: The voltage signal is directly related to how far the injection quantity control collar solenoid moves. More voltage → collar moves further → higher fuel quantity. However, there is a limit to how high of a voltage can be tolerated before triggering “limp-mode.”

Tuning boxes, "Evry" Mod

- PROS:
  - Tuning boxes can be readily disconnected
  - Extremely inexpensive (Evry)
- CONS:
  - Drivability issues on some cars
  - Moderate performance increase
- Performance Bang-for-Buck: MEDIOCRE - GOOD
- Verdict: (Tuning box) -- An fine mod for the weak-hearted, or for a leased vehicle that must be easily brought back to stock.

Fuel Injectors / Nozzles

- WHAT:
- HOW:
- WHY:

Fuel Injectors / Nozzles

- PROS:
  - Modification undetectable at a glance
  - Relatively mature products
  - Large choice of sizes for different HP gains
- CONS:
  - Involves opening up the ECU
  - Permanent (soldered on PCB)
  - Choose sizes wisely based on desired power output, smoke tolerance, tinkering aptitude
- Performance Bang-for-Buck: GOOD – EXCELLENT
- VERDICT: A logical first- or second step performance mod.

Injection Pumps

- WHAT: Injection pump that pressurizes, delivers and distributes fuel to the cylinders for combustion.
- HOW: Upgraded pump have larger plunger diameters and/or different cam plate profiles
  - Larger diameter plungers increase static hydraulic pressure
  - More rapid acceleration of the cam plate also increases dynamic pressure rise due to propagation of pressure waves
- WHY: Fuel flow can only be increased in one of three basic ways:
  - Increased injection duration
  - Increased injector orifice diameter
  - Increased injection pressure
- Upgrading the pump increases injection pressure

Injection Pumps

- PROS:
  - Moderate power increase for TDIs that have already have other fuelling mods performed
  - Higher injection pressures yield power increase with proportionately minimal smoke penalty
- CONS:
  - Relatively expensive
  - Labour to install pump
  - Products still not yet mature (pump head upgrades)
  - Timing belts may have to be replaced at shorter intervals
- Performance Bang-for-Buck: MEDIOCRE – GOOD
- Verdict: A mod for those who have pretty much done all other fuelling mods. A necessary finishing touch for ultimate performance.

Airflow Mods

- WHAT: Examples – Free-flow air filters, re-routed/cold-air intakes, intake pipes (pre-/post turbo), cylinder head porting, aftermarket free-flow exhausts
- HOW:
- WHY:
  - Reduces engine pumping losses

Airflow Mods

- **PROS:**
  - Reduces engine pumping losses for slight performance / efficiency benefit
  - Increases performance potential per given smoke output
- **CONS:**
  - Small- or no tangible HP increase from airflow mods alone
- Performance Bang-for-Buck: Poor
- Verdict: Limited performance gain for expense, but more airflow never hurts.

Turbochargers

- WHAT: Obvious
- HOW:
- WHY:

Turbochargers

- PROS:
- CONS:
- Performance Bang-for-Buck:
- Verdict:

Intercoolers

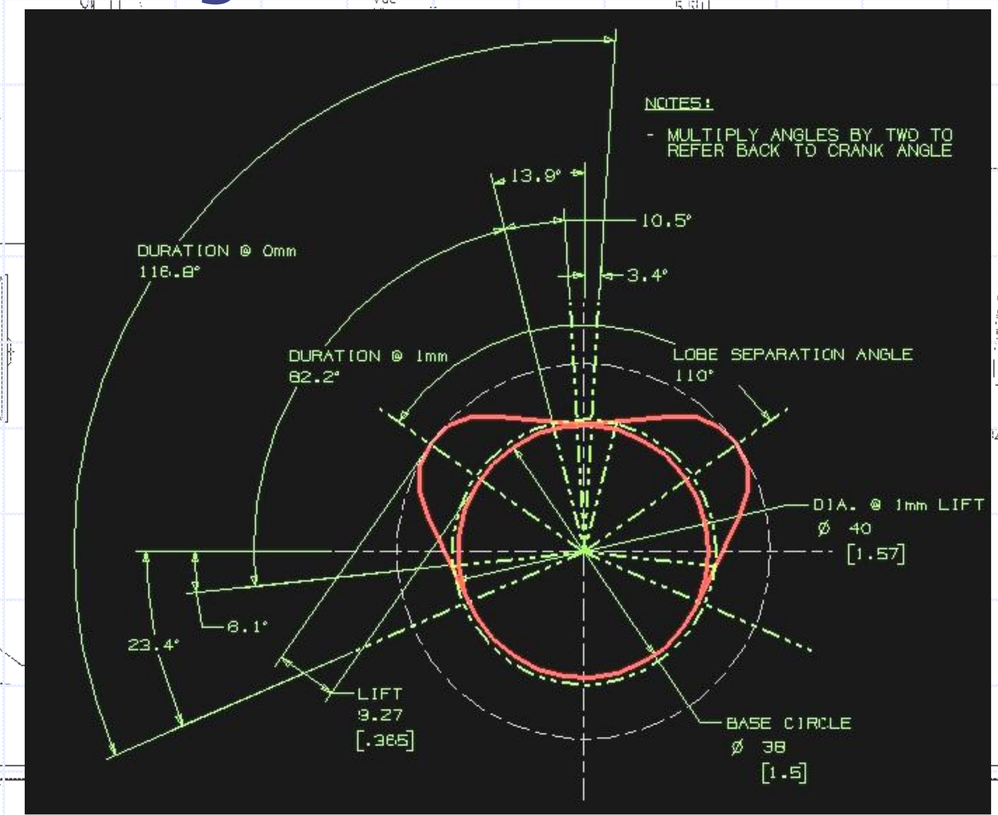
- WHAT:
- HOW:
- WHY:
- PROS:
- CONS:

Camshafts

- WHAT: Obvious
- HOW: Controls timing of the opening and closing of the valves, and the amount to which the valve lifts from the seat and for how long
- WHY: Valve timing has a big effect on the driveability, output, power delivery characteristics and emissions of the engine

Camshafts

- PROS:
  - Can tailor power curve
- CONS:
  - Unproven tangible HP increases in TDI (from cam alone)
  - Product development if TDI cams by vendors still at infancy
- Performance Bang-for-the-Buck: POOR



Nitrous / Propane / etc.

- WHAT: Chemical oxidizer (N2O) or gaseous hydrocarbon fuel
- HOW:
- WHY:

Nitrous / Propane / etc.

- PROS:
  - Very noticeable power gains (especially propane)
  - Near elimination of smoke on highly tuned engines (Nitrous)
  - Secondary intercooling benefit
- CONS:
  - Potentially dangerous increase in cylinder pressures, and mechanical / thermal stresses
  - Relatively rudimentary control system (ON or OFF; user-triggered or throttle pedal threshold)
  - Most propane systems lack safety regulation
- Performance Bang-for-Buck: GOOD
- VERDICT: For the adventurous, the frontier seekers and the rich

Suggested Stage 1 of Tuning

- Non-PD TDIs
  1. Injectors/nozzles and/or chip
     - OEM Euro 110HP or 150HP 5-cylinder TDI injectors; Bosio Sprint/Powerplus 357/520
     - Automatic TDIs can upgrade to injectors from manual cars as a first step
     - Chip: Upsolute, Rocketchip, Wetterauer, Speedtuning USA, Unitronic, etc.
- PD TDIs
  1. Tuning box or chip (coming soon)

Suggested Stage 2 of Tuning

- Non-PD TDIs
  1. Injectors/nozzles:
     - OEM Euro 110HP or 150HP 5-cylinder TDI injectors; Bosio Sprint/Powerplus 520/502/764
  2. Chip:
     - Upsolute, Rocketchip, Wetterauer, Speedtuning USA, Unitronic, etc.
- PD TDIs
  1. Upgraded injectors (from PD130/150)

Suggested Stage 3 of Tuning

1. Injectors/nozzles:
   - OEM Euro 150HP 5-cylinder TDI injectors; Bosio Sprint/Powerplus 520/502/764
2. OEM 11mm pump
3. Chip: Upsolute, Rocketchip, Wetterauer, Speedtuning USA, Unitronic, etc.
4. Optional: Upgraded intercooler, turbocharger; thicker head gasket

Beyond Stage 3

1. Injectors/nozzles and/or chip
   - OEM Euro 150HP 5-cylinder TDI injectors; Bosio Powerplus 502/764; Bosio Race 520
2. OEM 11mm pump with 12mm pump head
3. Custom chip programming
4. Upgraded intercooler
5. Upgraded turbocharger: Garrett VNT-20; GT20
6. Reduced compression pistons
7. Optional: manifolds (intake and exhaust); cam; nitrous; head work; upgraded con rods

- **Define an important parameter in Diesel engine design called the *air utilization rate*. In its most simplistic definition, it is the inverse of the equivalence ratio expressed as a percentage. If an engine is operating at stoichiometric (and is able to completely burn all of said fuel), logically it would have a 100% air utilization rate. An engine operating at an equivalence ratio of 1.2, would have an air utilization rate of 83%.**

- **A lot of factors influence how much fuel a Diesel engine is able to burn for a given amount of air. Air motion in the combustion chamber (swirl), bowl geometry, injection pressures and nozzle configuration / spray pattern -- all of which affect fuel-air mixing rates**

- **Smoke and NOx emissions rise significantly when you approach the max. air utilization rate, which is evidenced by the clouds of smoke. Also, the fact that you can increase power output by as much as 20-30% (implying approximately 20-30% more fuel) without significantly altering the airflow, says that there is a lot of margin to add fuelling before you run into the max. air utilization rate.**

- **Air utilization is mainly a function of the internal engine design, and NOTHING of what you do peripherally with modifications (chipping, tuning boxes, increasing boost, different turbos, larger injectors, installing intercoolers, cams, etc.)**

- **Putting in more air will only *support* combusting more fuel, but the ratio of the two will always remain proportional to each other within a fairly narrow range.**