CARB Workshop Switching Fuel

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Changing over from MDO to HFO

From the Operation Manual for Sulzer Type engines:

SULZER RT-flex96C Operation 0270–1/A1

Operation

Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa

Continuous operation with heavy fuel oil is recommended for engines and plants provided for running on heavy fuel oil. Changing over from heavy fuel oil to diesel oil operation may only be undertaken when absolutely necessary for example by:

- Flushing the engine before maintenance works
- Heating plant switched off in the drydock
- Environmental requirements

To ensure safe changing over, consider the following items:

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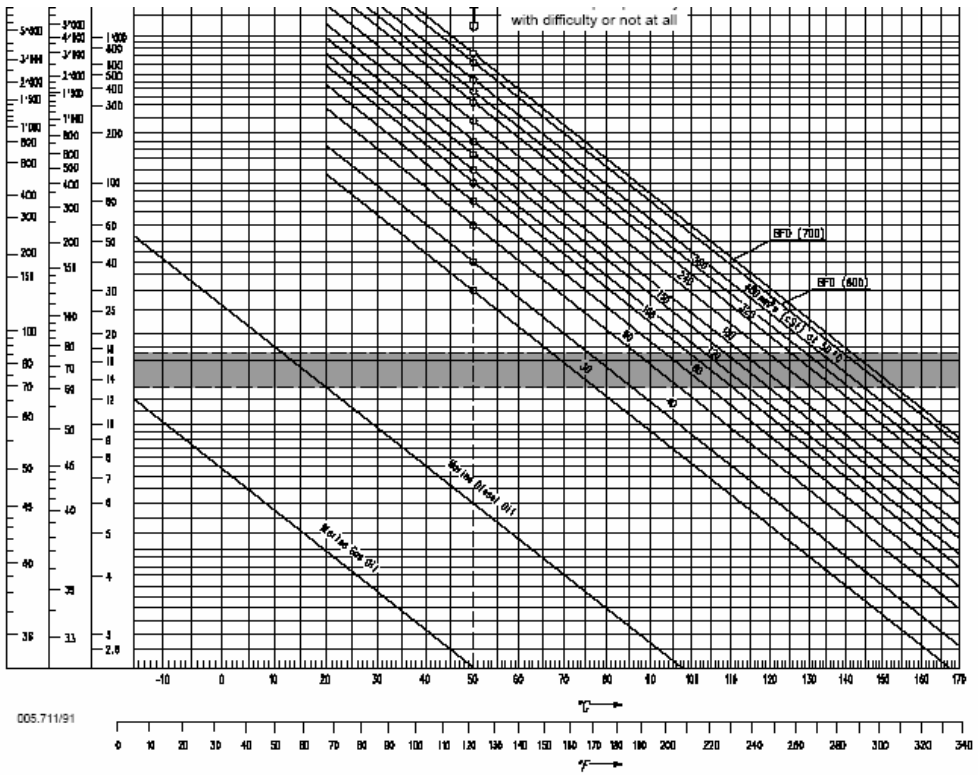
Changing over from MDO to HFO



Recommended viscosity before fuel pumps

The temperature necessary to ensure that the required viscosity of the fuel before inlet to the fuel pumps is reached can be seen on Viscosity-Temperature Diagram 0270–2. This temperature is hereafter referred to as the 'required preheating temperature'.

The preheating of the fuel is controlled by a viscosimeter.

Changing over from MDO to HFO

Plant side:

After changing over the three-way valve 21 the result is a mixture of diesel oil and heavy fuel oil in the mixing unit 24. The viscosimeter controls the end-heater 26 in such a way that the required viscosity (preheating temperature) of the mixture is maintained. This preheating should be done only **slowly** (temperature rise max. 15°C/min.). Sudden temperature changes can lead to seizing of the fuel pump plungers.

The heating for the fuel filter 27 as well as for the fuel delivery and return pipes should be kept on, at least until the 'required preheating temperature' (read off at the thermometer before inlet to the fuel pumps) is reached.

Check fuel pressure after low pressure feed pump and at fuel pump inlet (see Operating Data Sheet 0250–1).

Engine side:

- The trace heating on the engine (supply unit and fuel rail) must be turned on at the latest when changing over from diesel oil to heavy fuel oil in the plant. All covers of the rail unit must be closed.
- If the engine room is completely cold the trace heating shall be turned on about one hour before changing over.
- Before stopping the engine, changing over must be completely finished, avoiding a mixture of diesel oil and heavy fuel oil in the fuel rail which may cause viscosity problems during the next start.

It is recommended not to exceed 75% CMCR load during changing over and until the required preheating temperature has been reached.

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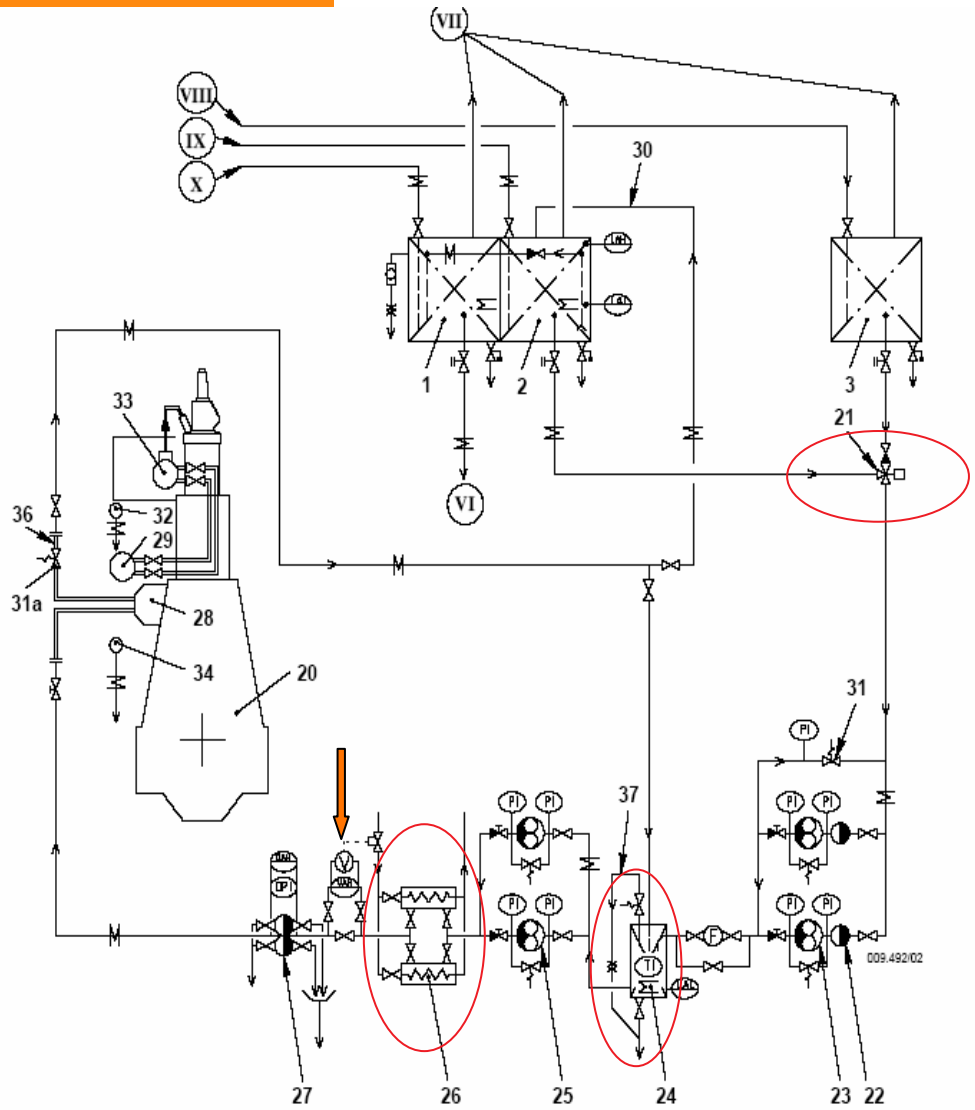
Changing over from MDO to HFO

1 Heavy fuel oil settling tank
2 Heavy fuel oil daily tank
3 Diesel oil daily tank
4 Heavy fuel oil separator supply pump
5 Heavy fuel and diesel oil supply pump
6 Suction filter
7 Heavy fuel oil preheater
8 Three-way valve
9 Self-cleaning heavy fuel oil separator
10 Self-cleaning heavy fuel oil / diesel oil separator
20 Main engine
21 Three-way valve
22 Suction filter
23 Low pressure feed pump
24 Mixing unit, heatable and insulated
25 Booster pump
26 End-heater
27 Fuel filter, heatable
28 Supply unit (fuel pumps)
29 Intermediate fuel accumulator
30 Bypass pipe
31 Pressure regulating valve
31a Pressure retaining valve
32 Fuel leakage rail unit
33 Fuel rail
34 Fuel leakage supply unit
36 Return pipe
37 Air overflow pipe

I to diesel oil storage tank
II from heavy fuel oil transfer pump
III Draining/de-watering
IV from diesel oil storage tank
V to separator sludge tank
VI to heavy fuel oil separator
VII to vent manifold
VIII from diesel oil separator
IX from heavy fuel oil separator
X from the transfer pump

Flow indicator
Heated & insulated pipes
Insulated pipes
Pressure regulating valve
Sight glass
Viscosimeter

PI Pressure gauge
TI Thermometer
DAH Differential pressure alarm high
DPI Differential pressure indication
LAL Fluid level alarm, low
LAH Fluid level alarm high
VAH Viscosity alarm high



Changing over from HFO to MDO

Changing over from heavy fuel oil to diesel oil

Plant side:

To change over from normal heavy fuel oil service to diesel oil, the three way valve 21 has first of all to be repositioned accordingly. This results in a mixture of heavy fuel and diesel oil in the mixing unit 24. The viscosity of the circulating mixture at a certain temperature drops quickly corresponding to the increasing share of diesel oil. After a short period the heating can be shut off.

Engine side:

- The trace heating on the engine (supply unit and fuel rail) must be shut off at the same time when changing over from heavy fuel oil to diesel oil in the plant.
- A complete change over takes appropriately longer if the engine is running at low load.

Attention! Running on diesel oil and with turned on trace heating is extremely dangerous for the engine!

- Before stopping the engine, changing over must be completely finished, avoiding a mixture of diesel oil and heavy fuel oil in the fuel rail which may cause viscosity problems during the next start.

It is recommended to change over from heavy fuel oil to diesel oil operation at less than 50% CMCR power.

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Engine Output / Engine speed

Propeller law, fix pitch propeller

Engine Output (%)	Engine rpm (%)
100	100
90	96
75	91
50	79
40	74
30	67

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Effect on Engines

2-stroke engines

LSHFO + high BN

- LSHFO + 70BN => risk for hard calcium carbonate deposits on piston crown land => SSW.

HFO + low BN

- HFO + 40BN => risk for corrosion.

Mitigation

- Different lubricant for > and < 1.5 % S.
- Tribopack:
  - APR against high BN.
  - Liner wall temperature optimised along full stroke, reduced sensitivity for low BN.
- Changes in feed rate justified in some cases.

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Effect on Engines

4-stroke engines

LSHFO + high BN

- LSHFO expected to have low amounts of ash constituents (vanadium, sodium, nickel) => deposits unlikely, especially with APR.
- LSHFO with high ash content + high SLOC => risk for deposits.

HFO + low BN

- Risk for corrosion.

Mitigation

- Suitable BN (not too high, definitely not too low).
- Fuel and lubricating oil flexibility to avoid unsuitable combinations.
- Monitor BN.

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Effect on Engines

Fuel type	Fresh oil BN	BN condemning limit
HFO	30-55	20
LSHFO	30-40	20
HFO+LSHFO	30-55	20
HFO+LSHFO+LFO	30-55	20
HFO+LSHFO+LSLFO	30-55	20
DMC	30-40	20
LFO+LSLFO *	15-30	-50 %
LSLFO **	10-30	-50 %

Depending on the fuel sulphur content and lubricating oil consumption the optimum BN can be selected from the upper or the lower end of the BN range.
* For LFO qualities meeting the DMX / DMA specification, minimum BN of lubricating oil is 10.
** Also for LSLFO having a low sulphur content of 0.01 …0.2 % a lubricating oil with BN of minimum 10 is needed to ensure adequate alkali reserve to neutralize acid oxides of sulphur as well as nitrogen.

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Effect on Engines

2- and 4-stroke engines

Engine type	Minimum fuel injection viscosity, cSt
Wärtsilä 20	1.8
Wärtsilä 26	2.0
Wärtsilä Vaasa 32/32LN	2.0
Wärtsilä 32	2.0
Wärtsilä 38	2.0
Wärtsilä 46	2.8
Wärtsilä 64	2.8
Sulzer S20	3.0
Sulzer Z40, ZA40, ZA40S	2.0

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Low injection viscosity 4-stroke engines

Normally not a problem, however when operating on too low viscosity:

1. **Injection equipment.** Cavitation and lower structural damping, in worst case increased wear of components and increased risk for seizure of fuel injection pump elements.
2. **Engine performance, minor predictable effects.** Increased leak between the plunger and the barrel leads to changes in the running parameters, such as delay in the dynamic injection, prolonged injection, lower max pressures, lower NOx emissions, higher soot and CO2 emissions, higher exhaust gas temperatures, higher fuel consumption, and higher amounts of leakage fuel. The fuel leakage is typically a controlled process, where the leaking fuel is conducted to a fuel leakage tank onboard.
3. **Engine performance, less predictable effects.** In exceptional cases increased vaporisation of lighter fuel fractions, reduced injection pressures and injected quantities, increased pressure oscillation, risk for cavitation damages in injection pumps, pipes and nozzles. Risk for loss of capability to produce full power, and possibly stalling, black-out or similar and also starting problems. In some fuel injection pump models there may be a risk for fuel leakage into the cam box and therefore into the lubricating oil, especially when the pumps are worn.
4. **Combination with low density.** The combined effect of low viscosity and low density needs to be considered.

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Low injection density

Energy content of the fuel, effect on automation settings:

1. **4-stroke:** Reduced energy content per stroke of fuel pump, reduced output at any fuel rack position. Depending on the 4-stroke engine type, the actual difference between LFO and HFO can typically be approx. 6…15 %, considering also the leakage due to low viscosity. Further aggravated due to wear in the injection pumps.
2. **2-stroke:** On 2-stroke engines in general pump index limitations are not an issue. During normal circumstances the torque limiter and charge air limiter have sufficient margin. However, during exceptional conditions, such as a combination of an old engine with worn injection pumps, inappropriate adjustments, extreme weather and distillate fuel these limiting devices may limit the available power. It may be prudent to check the engine in case operation in rough sea areas on distillate fuel is foreseen (especially in case of small container ships).
3. **Generator engines (4-stroke):** 110 % output may not be available.
4. **Engines driving FP-propellers (2- and 4-stroke):** The issue is related to max power, but perhaps even more to governor setting in the part load area
5. **Engines driving CP-propellers (2- and 4-stroke):** Not an issue. If necessary, the load control system automatically reduces the pitch of the propeller.

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Low lubricity

Based on Wärtsilä's experience lubricity is not considered a problem for 4-stroke fuel injection components as long as the sulphur content is above 100 ppm (= 0.01 %) S-content.

At the time of writing documented experience about fuels with lower sulphur content than 100 ppm is not available. However, in extreme cases a lubricity additive can be added to very low sulphur fuel by a fuel manufacturer / marketer.

For 2-stroke engines it has not been considered an issue by itself.

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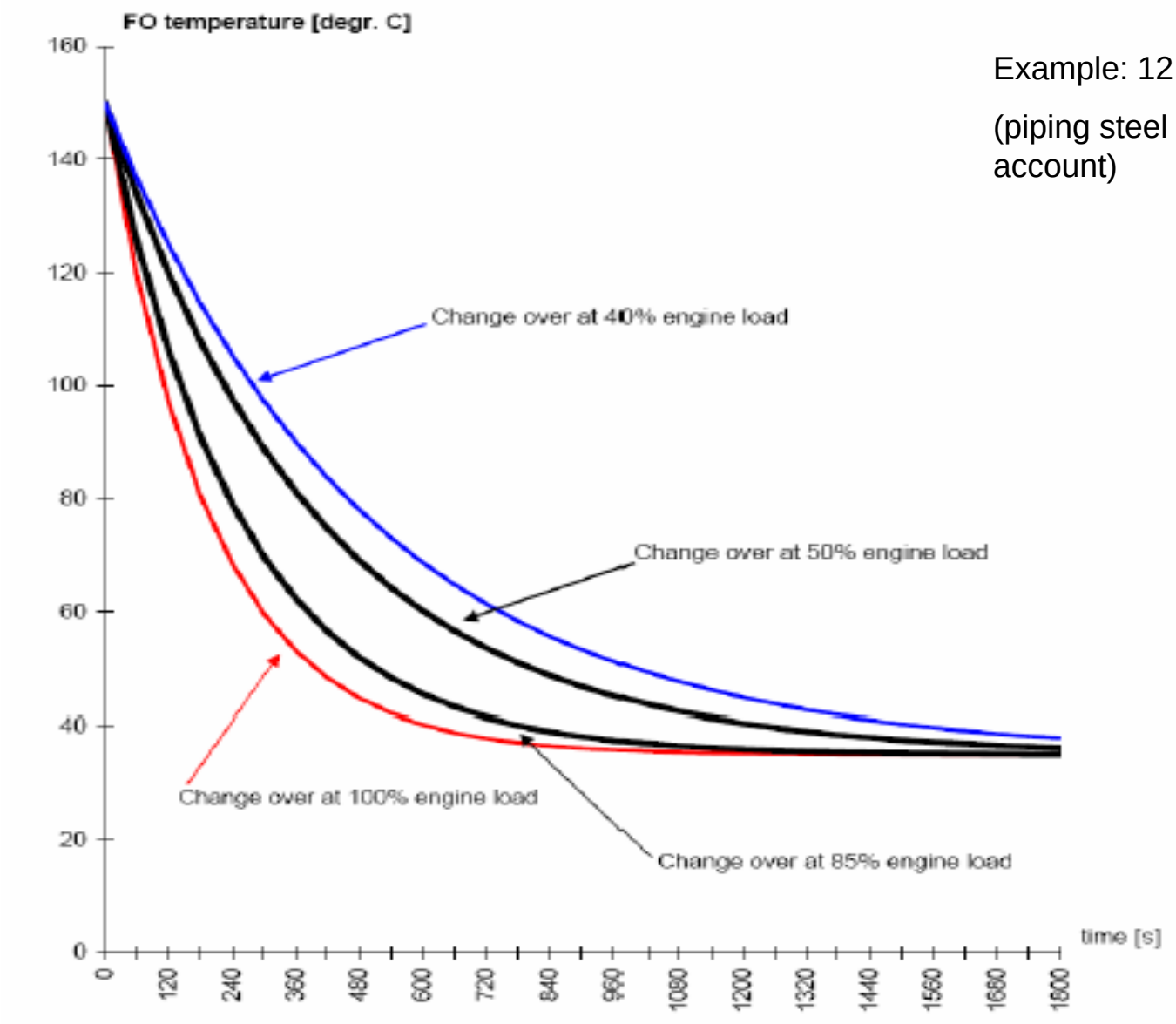
Fuel temperature at engine inlet



Example: 12 RTA96C engine

(piping steel mass taken into account)

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Time between overhaul

Generally speaking lower sulphur content in the fuel gives longer times between overhaul of a diesel engine. For 4-stroke engines Wärtsilä has developed separate definitions for a good HFO quality. This is called HFO1, while a conventional HFO as per the poorest quality of ISO 8217 is called HFO2. The better HFO may give somewhat longer TBOs for certain 4-stroke engine components, provided that all properties are within the specification. E.g. bad ignition quality may offset the other good qualities.

For 2-stroke engines no such distinction is made.

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Oil-fired boilers

Risks when operating HFO oil-fired boilers on low viscosity distillates

1. Damages to fuel pumps
2. Gassing of fuel within heated piping
3. Smoking and local heating of boilers
4. Flame backlash and ignition problems and deposits in rotary cup burners
5. Gassing when applying steam for atomizing
6. Ignition failures

Source:

DNV, "Regulations for the Prevention of Air Pollution from Ships, Technical and Operational Implications", 21 February 2005.

The source also proposes technical solutions to mitigate the identified risks.

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Preparation for Low Sulfur Check-List

SYSTEMS
HFO settling tanks
HFO service tanks
HFO bunker tanks
LFO tanks
HFO separators
LFO separators
HFO/LFO blending unit
LFO cooler
Fuel return line to LFO service tank
HFO/LFO switch-over arrangements
Cylinder oil storage / daily service tanks (2-stroke)
Fuel filter differential pressure monitoring
DIESEL ENGINES
Anti-Polishing Rings (2-stroke)
Tribopack (2-stroke)
Check of fuel rack adjustment
ME speed governor
Start fuel limiter
Load increase rate (2-stroke)

OPERATIONAL GUIDELINES / TRAINING
Selection of lubricants (for ordering)
Cylinder oil change at SECA border (2-stroke)
Cylinder oil feed rate (2-stroke)
Analysis of piston underside drain oil (2-stroke)
Flash point and viscosity analysis of lube oil (4-stroke)
Minimum LFO viscosity when ordering
Maximum LFO temperature
HFO/LSHFO switch-over procedures
HFO/LFO switch-over procedures
Onboard fuel compatibility tests

Develop guidelines for

- Items to check, adjust, install

When evaluating several alternatives, the check list can be a rather complex matrix

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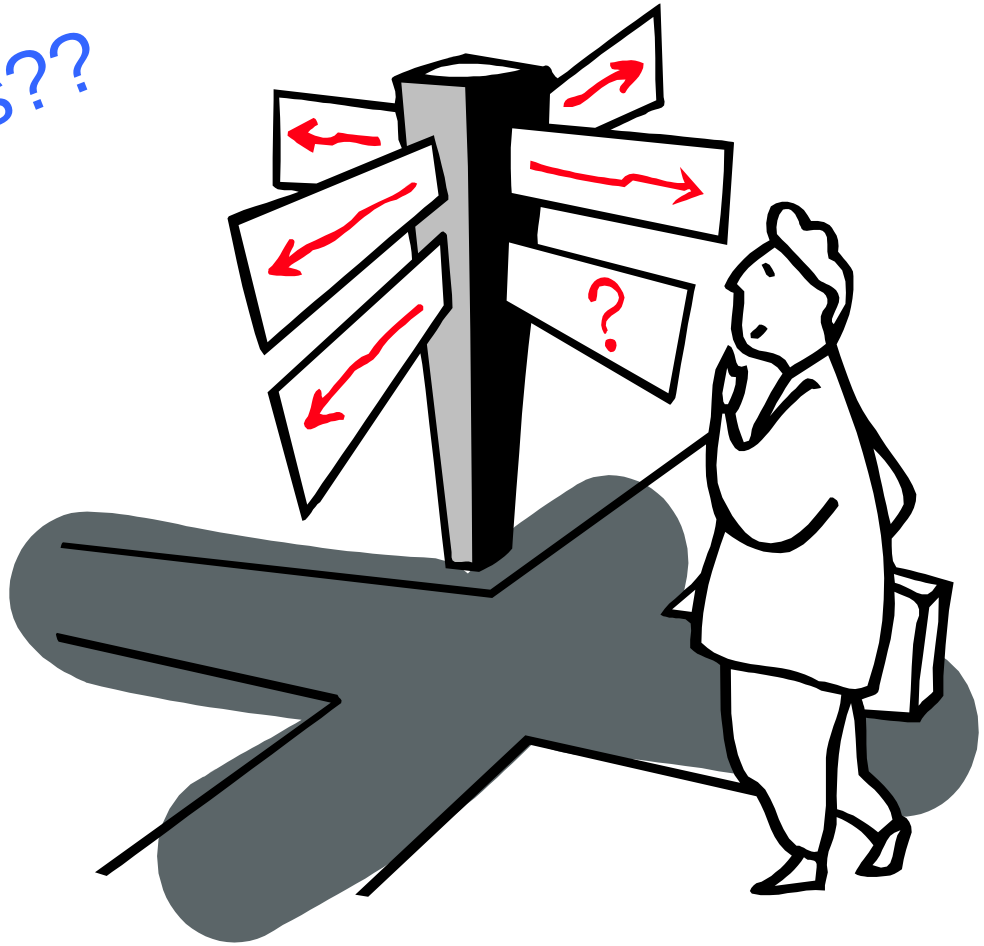
? Next steps ?

?? Questions??



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