Low force update, October 2010

Agenda

- Clarified items
- Service experience 12K98ME-C + 10K98ME-C
- Not clarified items
- Risks
- Introducing as “standard” & remaining tasks

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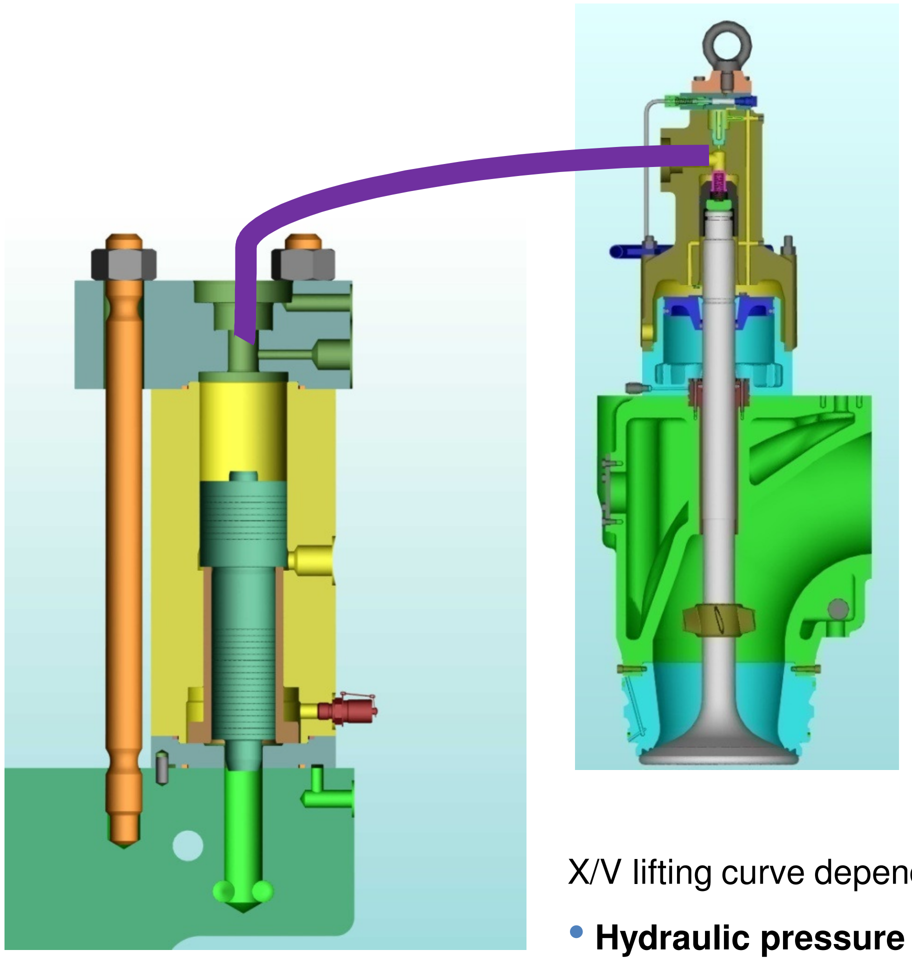
Low force principle
MC exhaust valve applied on ME engine



X/V lifting curve depends on:

- **Hydraulic pressure**
- **Air spring pressure**
- **Engine load**
- **Engine rating …**

Design elements:

- **Modified actuator: Low force**
- **Standard MC exhaust valve**
- **Reduced air pressure**
- **Valve lift feed back signal: air pressure sensor instead of cone and inductive sensor**
- **Cooling oil orifice in actuator**

"Seems simple; but isn't so simple"

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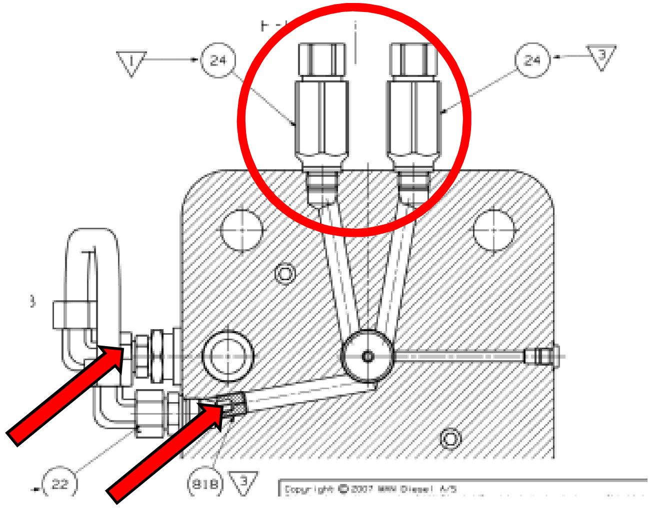
Clarified items

- ✓ **Actuator step I**
- ✓ **Air supply reduction station**
- ✓ **Overshoot: “long horn” damper …(OK ?)**
- ✓ LP oil supply: 2 X non-return valve
- ✓ Bolts / studs / trust piece
- ✓ Cone assembly
- ✓ Air pressure sensor (“orifice problem”)
- ✓ Alarm – “Too low air pressure” inside air spring
- ✓ Cooling oil: hardened orifice + non-return valve
- ✓ Others: found metal chips, pressure gauge broken etc.…



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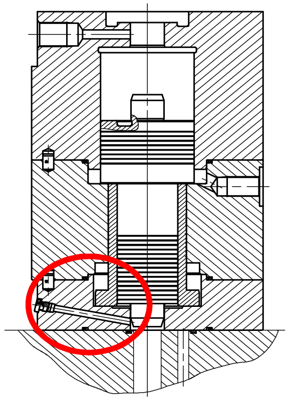
Overview
Actuator Step I case

Measured step I impact velocities with "new 300 bar" design:

Increased damper/hydraulic force ratio: R = 1.37 ~ 1.78

According to FEM analysis < ~ 1.5 m/s in impact velocity is safe (fatigue stress)

(Initial design K98ME LF300 impact velocities were up to about 7 m/s !)



Load [%]	S65ME-C	L70ME-C	Version#1 S90ME-C LF	BASLE Express K98ME LF	TestRig T35 K98ME LF	
~19				0.79		
25	0.8		0.79		~ 0.6 - 0.9	
~ 40				0.99		
75		0.8 - 0.9				
100	~1.1 - 1.2		1.15 *)		1.3	
100					1.6	Heated inlet oil (55 degC)

*) Note: Final version of S90ME-C step#1 will have lower impact velocity

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Damper efficiency, step I

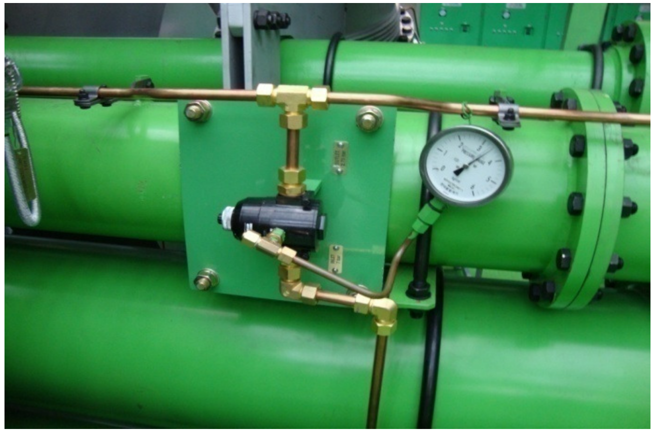
Inefficient damper, some theories…

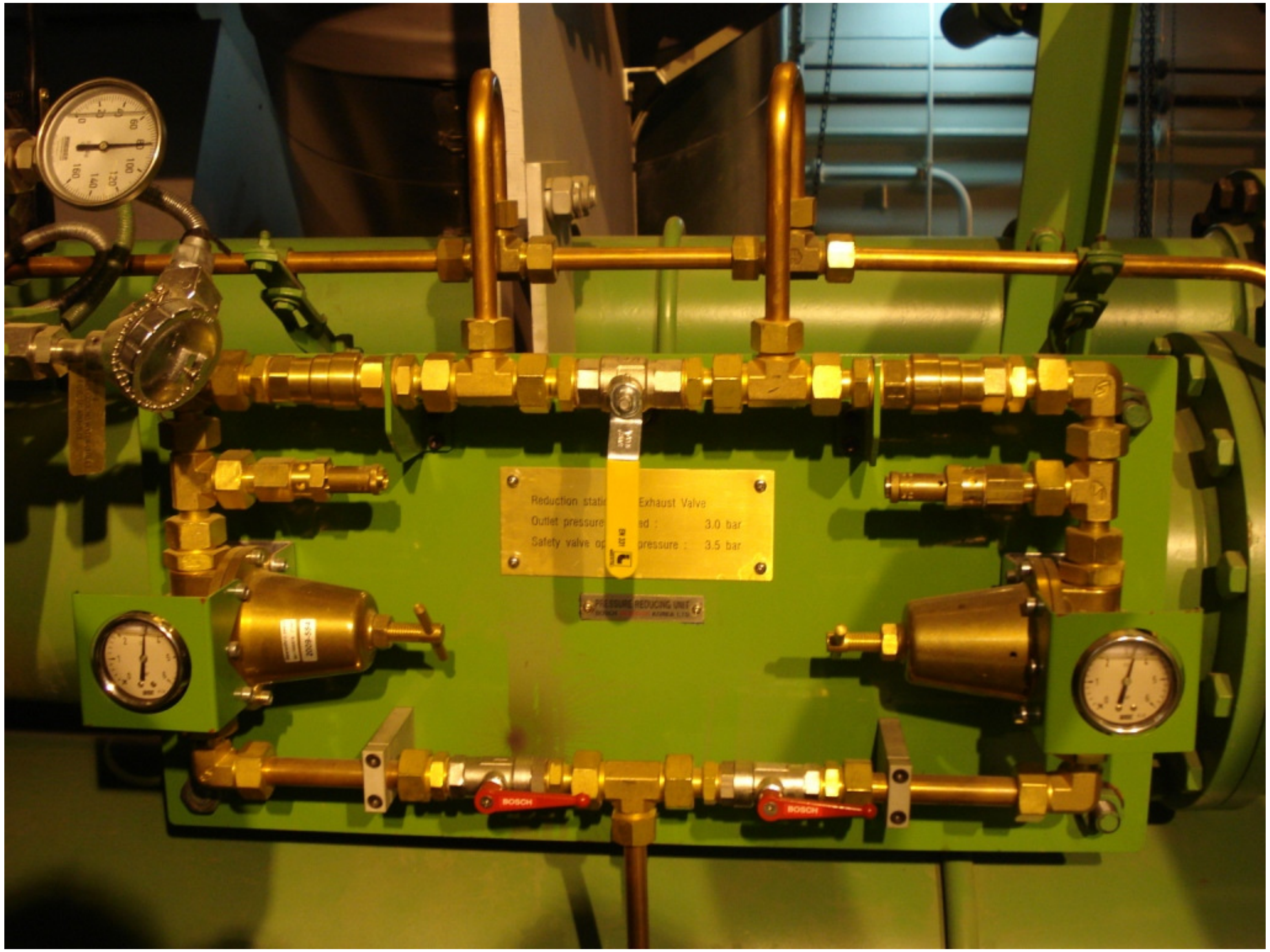
- Air content in oil – effects effective bulk modulus *and* viscosity
- High oil temperature → low viscosity
- Large leakages
- Poor oil filling of damper chamber - lack of self-supply of oil
- Entrance of air into damper (actuator) locally
- Deformations due to pressure (increased clearances)
- “Cheated” by false measurements ?
- Other reasons for breakage of step#1, 300bar: too slender walls…
- **Too small damper area compared to accelerating forces**

Air supply reduction station

Revised design12K98ME Vienna Express

Initial design





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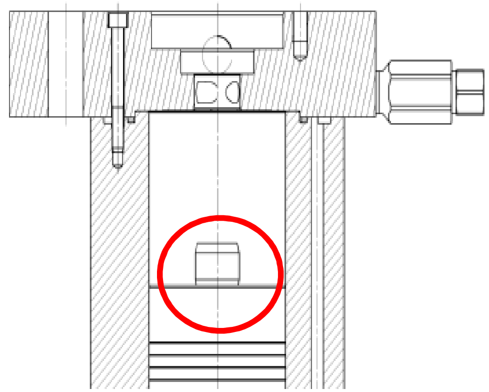
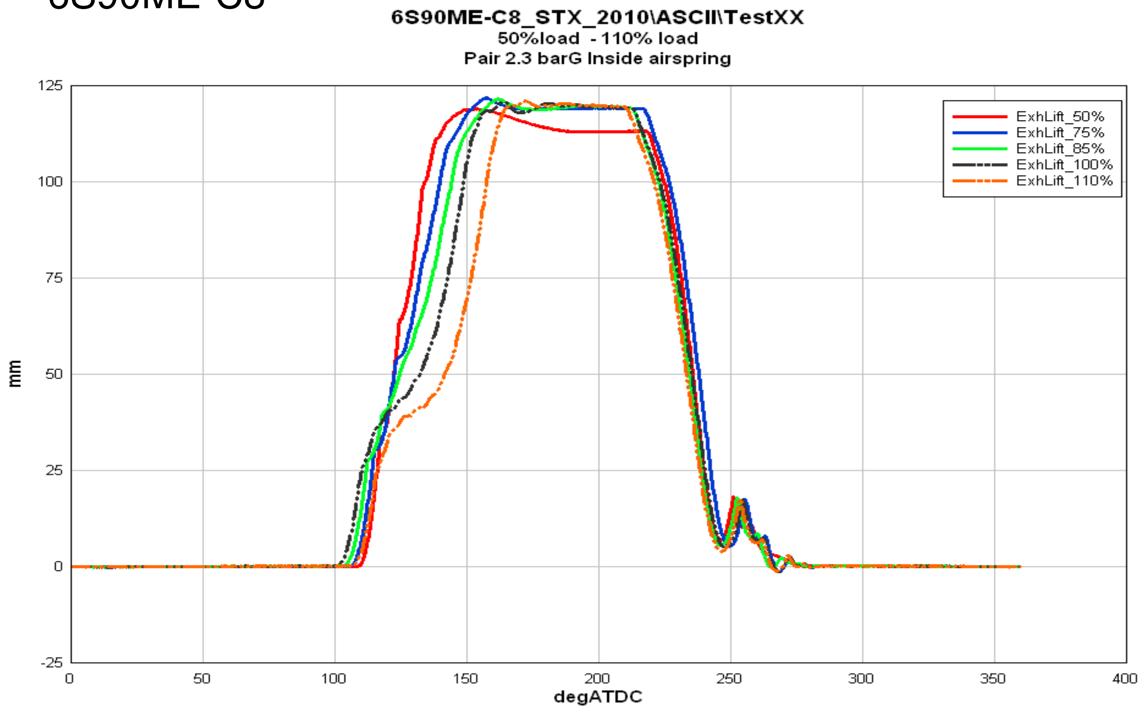
Exhaust valve overshoot

- **K98ME with “long horn”: OK**
- **S90ME-C8 no overshoot at all (underpowered stepII).**

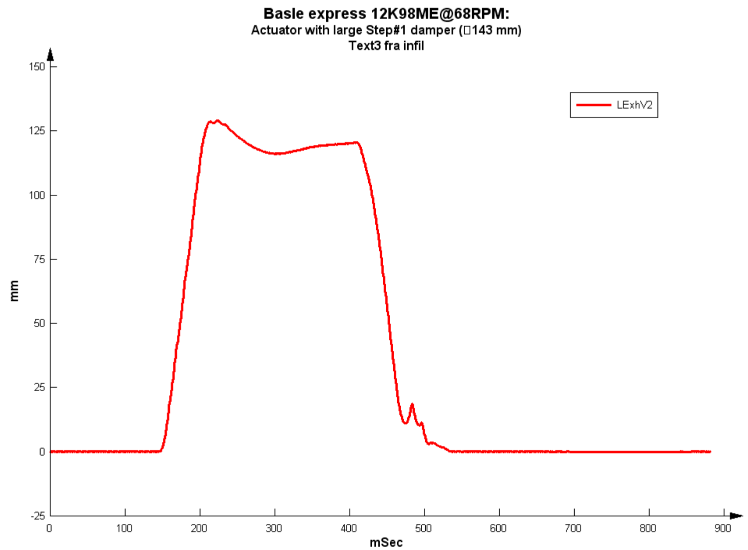
(awaiting new tests November 2010)



6S90ME-C8



Basle, 12K98ME-C@68 RPM



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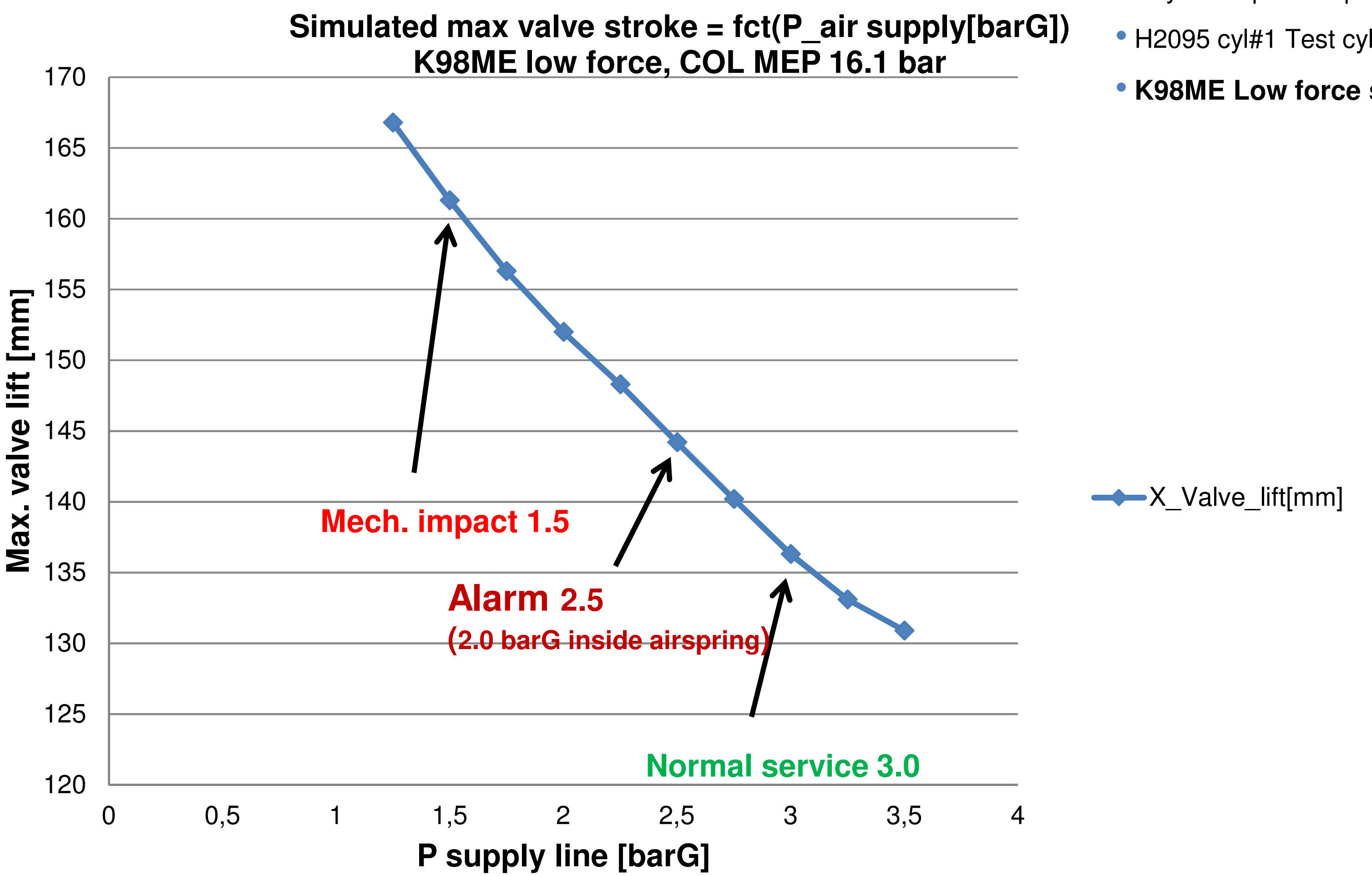
Valve stroke vs. air supply pressure: K98ME



- Koyoto Express trip#1 : Smax =138mm
- H2095 cyl#1 Test cylinder: Smax=144 mm
- **K98ME Low force standard: Smax=160 mm**

K98ME low force valve (@ 100%load)

Exhaust valve overshoot

- **“Long horn” stepII damper**
- **Relief holes in exhaust valve oil cylinder**
- **Enough “room” in air spring (and combustion chamber)**
- [Apply alarm: “Too high air pressure”, however not implemented]

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Service experience & Unclarified items

- Cavitation in actuator piston / cover
- Safety valve durability & ”accuracy” & COL level
- Sensitivity to hydraulic pressure curve & engine load, engine de-rating
- Exhaust valve position measurement. Indirect / direct ?
- 3 bar air spring or 7 bar airspring pressure

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Low force, “List of reference”

In service (with load restriction !!)

- **3 X 12K98ME + 3 X10K98ME (300 bar)**

  hereof 2 cylinders with new actuator design – 2 steps rest is with blocked step#1 and large stepII

  Basle Express now (23th October 2010) fully equipped with 2-step actuator – latest design

- 1 cylinder K98ME Osaka Express (200bar): **To be ended and rebuild ASAP**

Delivered

1 X 6S90ME-C8 about 35-40 more S90ME-C to be delivered soon

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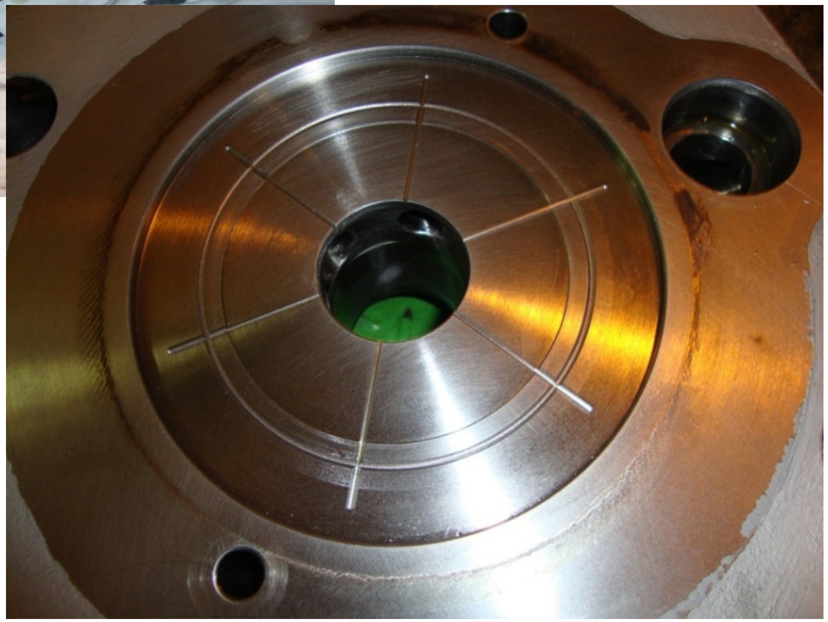
Service experience:
New K98ME LF 300 bar actuator

BASLE EXPRESS 12K98ME: 2. August 2010 Inspection of new actuator (large damper). Approx. 5 weeks in service (709 hours).

Top damper

and topcover



Step#1

Basle Express unit#1
Pusan 23/24 October 2010 : 17 weeks in service

Important areas:

COL level was also checked, 3 cylinders: OK

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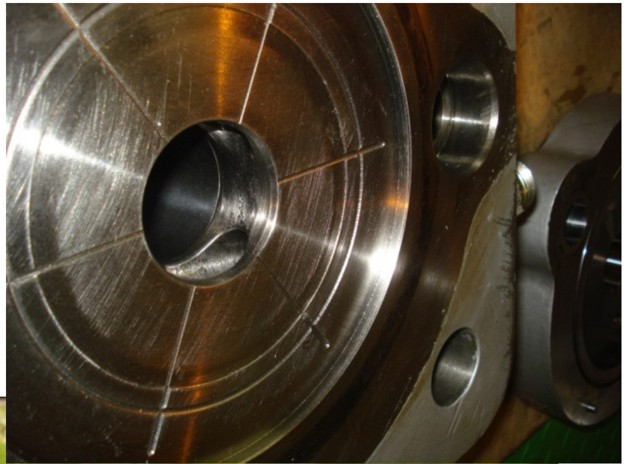
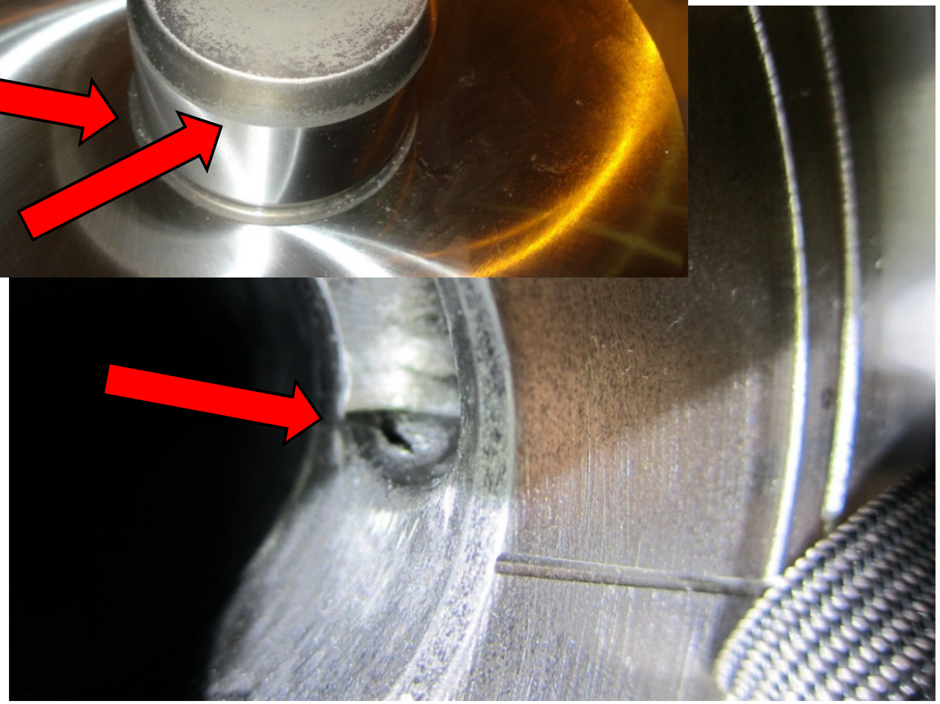
SOFIA express 10K98ME service experience

As per 1st of September 2010 Approx. 600 running hours

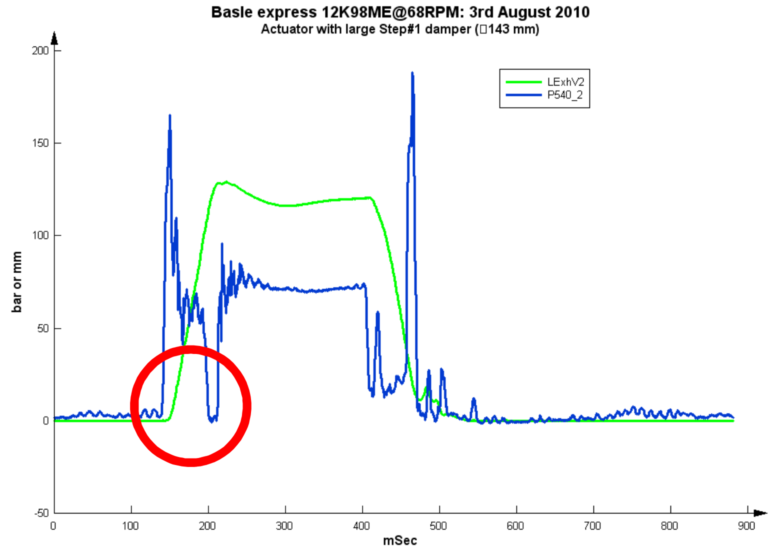
Fine !





Cavitation countermeasures

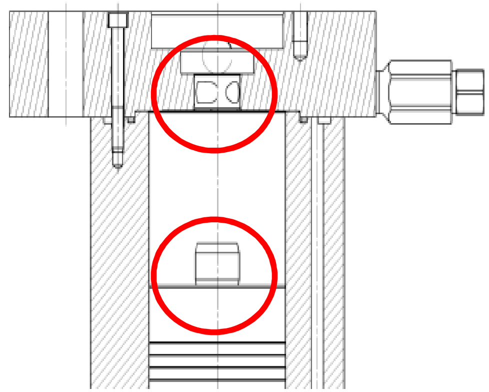
Cavitation in actuator top damper / cover top



- Use of modulated opening of X/V by new SW from LDT/LDE

Complicated "specialist" task. Instrumentation and measurements necessary

- Damper "nose" and/or cover in tool steel



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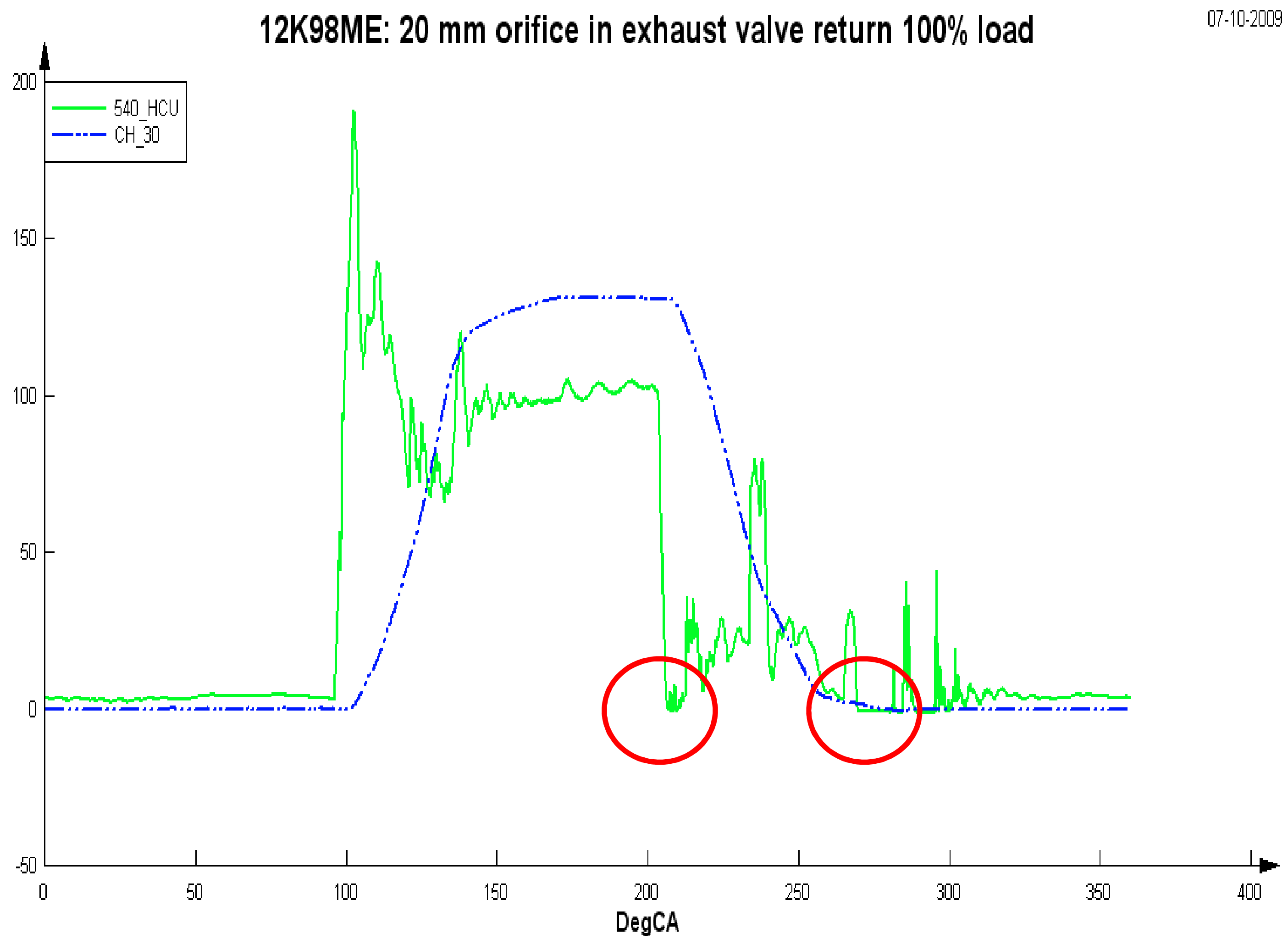
ME exhaust valve:
Pressure in actuator top. ALSO cavitation….

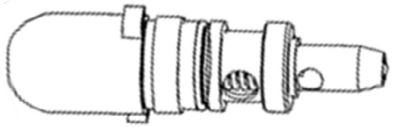
ME exhaust valve:



12K98ME tests at HHI (may 2007)

Safety valve in air spring

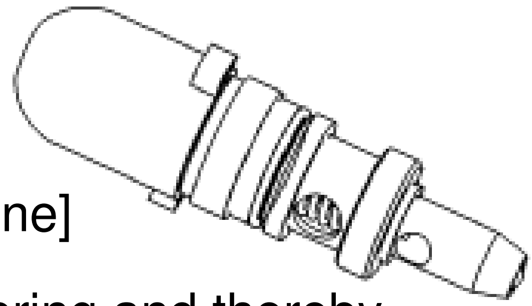
Safety valve will operate more or less continuously – otherwise compression ratio in air-spring (== X/V lift) will vary too much due to incoming oil



Safety valves starts to open

Safety valve & COL oil level

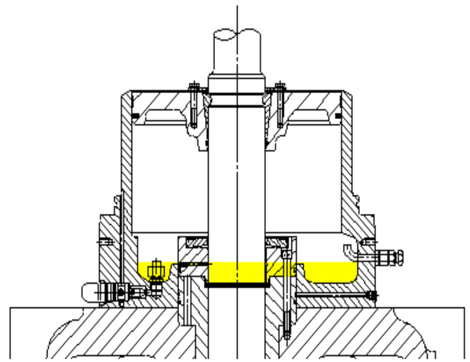
Now, the safety valve plays a new significant role:



It participate in decision of exhaust valve stroke

[since actuator excess force (MC and ME classic) now is gone]

COL oil amount decides effective compression ratio in air-spring and thereby valve stroke.



- **Durability ?** ("Water hammering" is a *theoretical* possibility)
- **Accuracy of adjustment ?**
- **Apply alarm "Air pressure too high" ? (:14 bar, + 5 liter COL)**

We (HH +EDP) will acquire and dissect two pieces of SFV

which have been operating in service (in low force application)

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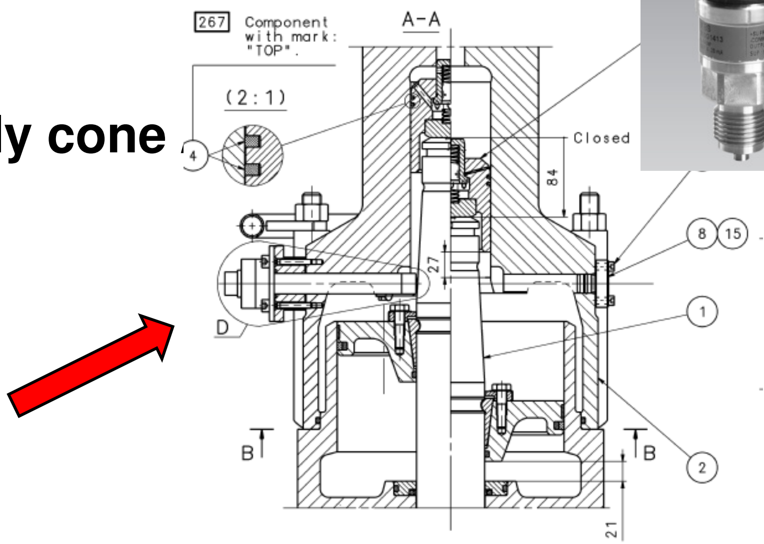
Spring air pressure feedback sensor

- No reports of failing sensor (??)
- Indirect measurement, not failsafe
- Inaccurate figures of X/V stroke and behavior appear due to un-linearity in air-spring pressure

(linear gain factor is used)

- Dept. LDE have expressed wishes to apply cone inductive sensor on this application also.



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Sensitivity of exhaust valve

Applying "low force" will increase exhaust valve sensitivity since "excess" forces not are present anymore. This means <u>more attention</u> are necessary to:

- **Actuator pistons main dimensions (LDF)**
- **Critical damper is now actuator stepII top damper (before opening damper in ME exhaust valve) (LDF)**
- **Load dependent hydraulic pressure curve (LDF)**
- **Adjustment of spring air pressure supply (3 bar solution)**
- **Adjustment of safety valve**

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3 bar or 7 bar air spring pressure ?

7 bar low force exhaust valve – reduced air piston diameter:

- **Less sensitive due to inaccurate air pressure**
- **Cost down**
- **However, can probably not be used on MC engine (?)**

“standard” exhaust valve will be in two versions (?)

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Main RISKS

- **Cavitation damage**

  When HALO engines increase to higher load, what will happen ?

- **Safety valve: malfunctioning / bad adjustment**

- **Unexpected overshoot ? ➔ heavy contact airpiston/spindle guide**

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Introducing “Low force” as standard

A. Continue unchanged concept: indirect measurement and ~ 3 bar spring air

B. Cone applied to spindle: direct measurement

C. Smaller air piston: 7 bar air spring

D. Both B+C: Cone based direct measurement + 7 bar spring air

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