UPC

Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa

LABSON

General Assembly

Meeting PROHIPP (period 37-48 month)

26-27 May 2008
Vic (Catalonia-Spain)

PRO HIPP

Sixth Framework Programme

WP1 & 6

(Work performed from 37 to 48 month)

Objectives:

WP1

Objectives

Specify the design requirements for hydraulic cylinders using a new methodology design by category DBC

Cylinder Categories Concept & Methodology

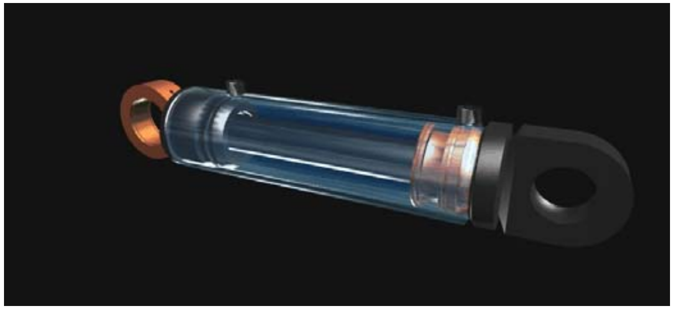
WP6

T6.1.1 Field testing. Objectives

Efforts were directed towards performance testing of cylinder for assembled machines in order to establish

Expected Load History (normalized spectra)

Design by Category



Methodology

Category concept

- It proposes to **define the physical conditions that might arise in any category for design purpose**, and should not be used to limit the areas of operation due to the variety of physical conditions likely to be met in different application

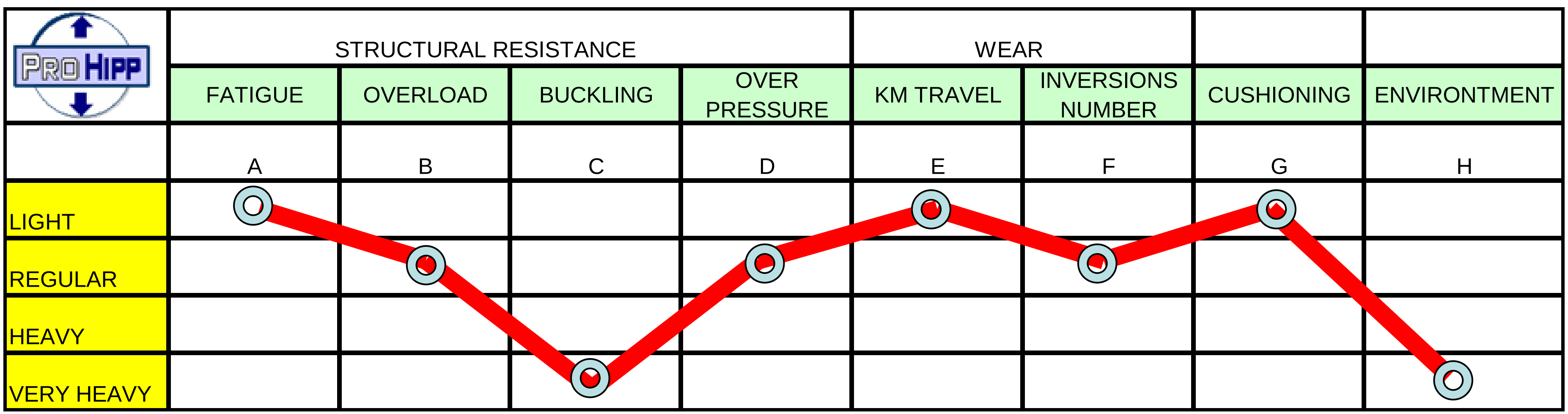
Hydraulic cylinder category levels

- LIGHT
  - Equipment rarely subject to maximum load and frequently to very little load
- REGULAR
  - Equipment quite often subject to maximum load and frequently to very little load
- HEAVY
  - Equipment frequently subject to maximum load and frequently to medium load
- VERY HEAVY
  - Equipment frequently subject to maximum or near maximum load.

(*) The word “load” is used in general sense

- For **each cylinder category** ***<u>a code</u>*** **is assigned** for cylinder design in order to insure an **overcome of a specific laboratory testing protocol**.

Example:



Category concept

- The problem is to find which category of design is the appropriate for an specific application, taking in mind:

  -*actual load*

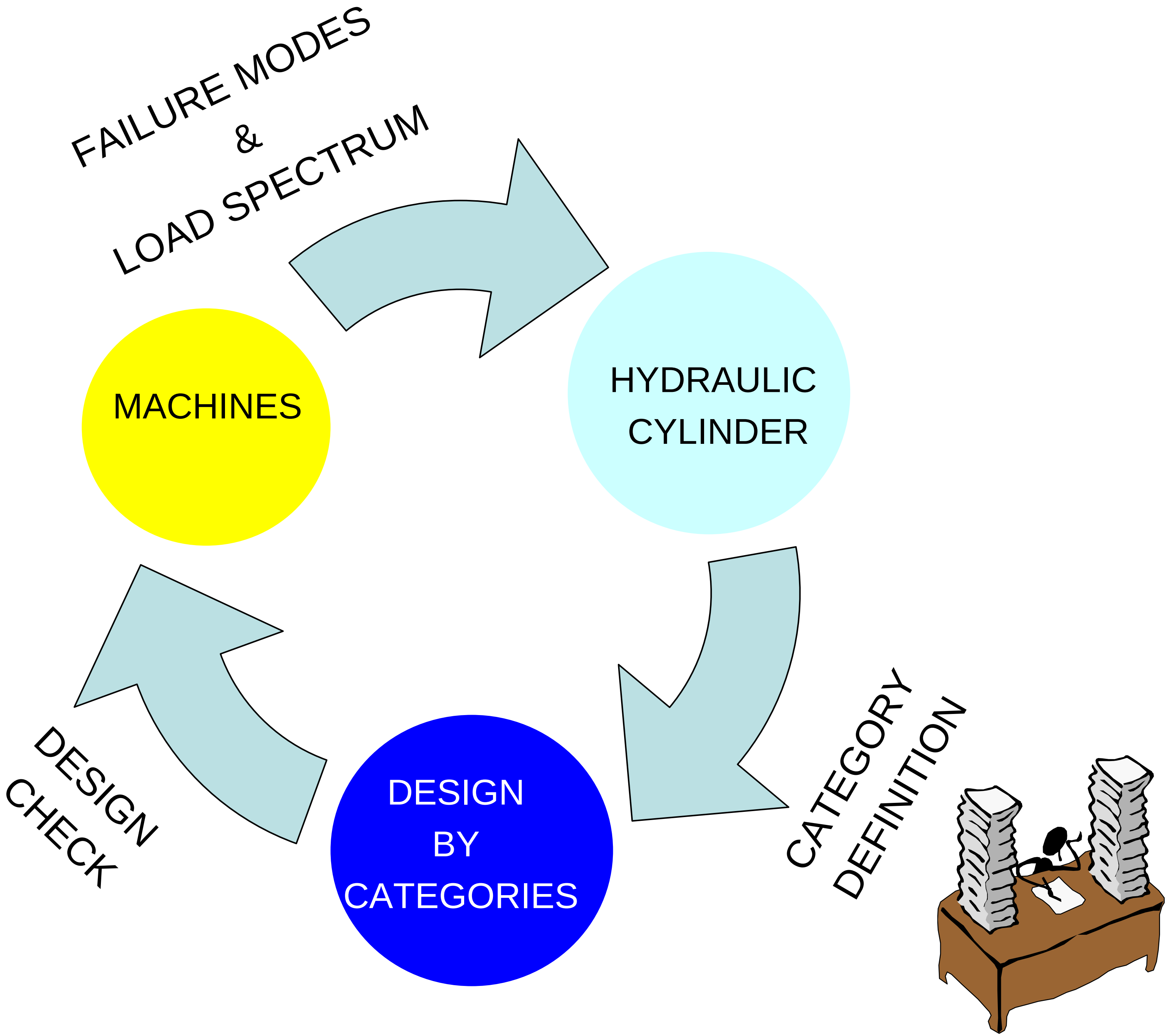
  (represented by his pressure cycle spectrum)

  -*safety considerations*

  (is not the same a power steering cylinder than a door operator cylinder)

  -*intended real in field life*

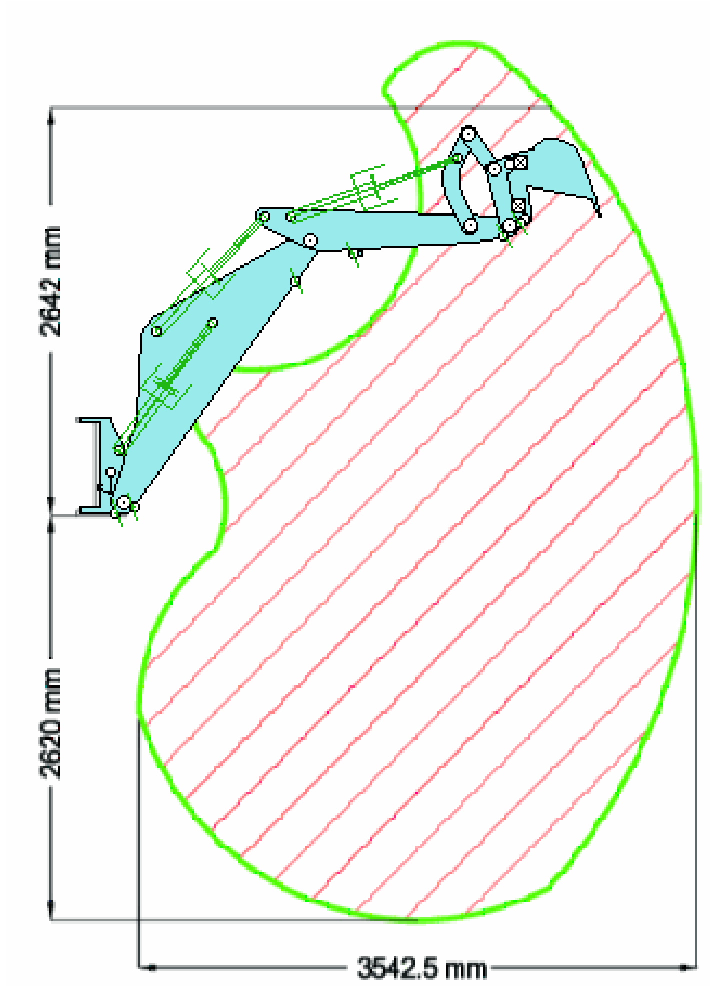
(*) Clearly this goal is a long way off

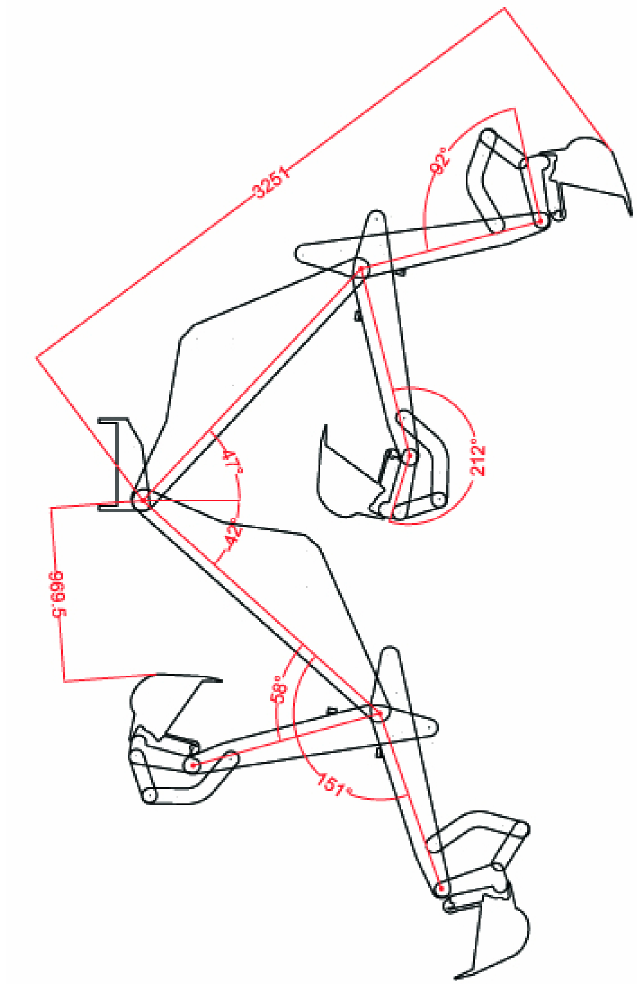

FAILURE MODES
&
LOAD SPECTRUM
MACHINES
HYDRAULIC CYLINDER
CATEGORY DEFINITION
DESIGN BY CATEGORIES
DESIGN CHECK

Machine types	Machine size			Partners involved	Number
	Small	Medium	Large		
Backhoe	Terraco BMH 275 R(John Deere) Leon	JBC	O&K	Hidrar Roquet Labson	5
Roadway cleaner		Belafer		Hidrar Labson	1
Loader mining	LK1 LK1N LK1D	LK2 LK2AC LK2ACDW	LK4C	Fadroma	7
Dumper trucks	STR190	Idealrok 260	Idealrok320 STR320	Sempere Labson	4
Lift truck	fork lift Nissan			Roquet	1
Lift container truck		Tucaman		Hidrar Labson	1
Platforms	lift ACL platform	garage ACL platform		ACL Labson	2
Scissors platform	mini ACL platform	OMEGA platform		ACL Hytres	2
Farm loader	VANO Loader	BMH4000 (John Deere)	BMH6000 (John Deere) BMH6680 (John Deere)	Hidrar Roquet Labson	4
Press	paper shear press Press thermoforming she	metal shear press metal bending press		Hidrar Adira Labson	4
Tree Shaker	Agric1	Uma		Agric Labson	2
Solar pannels			Guascor	Hidrar Roquet Labson	1
Others		Zuidberg farm loader apero Stripping machine (Catapulta) Grate cleaner turbine straw separator cast iron casebox manipulator		Hytres Hidrar F Roda Roquet Labson	1 1 1 1 1
16	**14**	**18**	**7**	**39**	

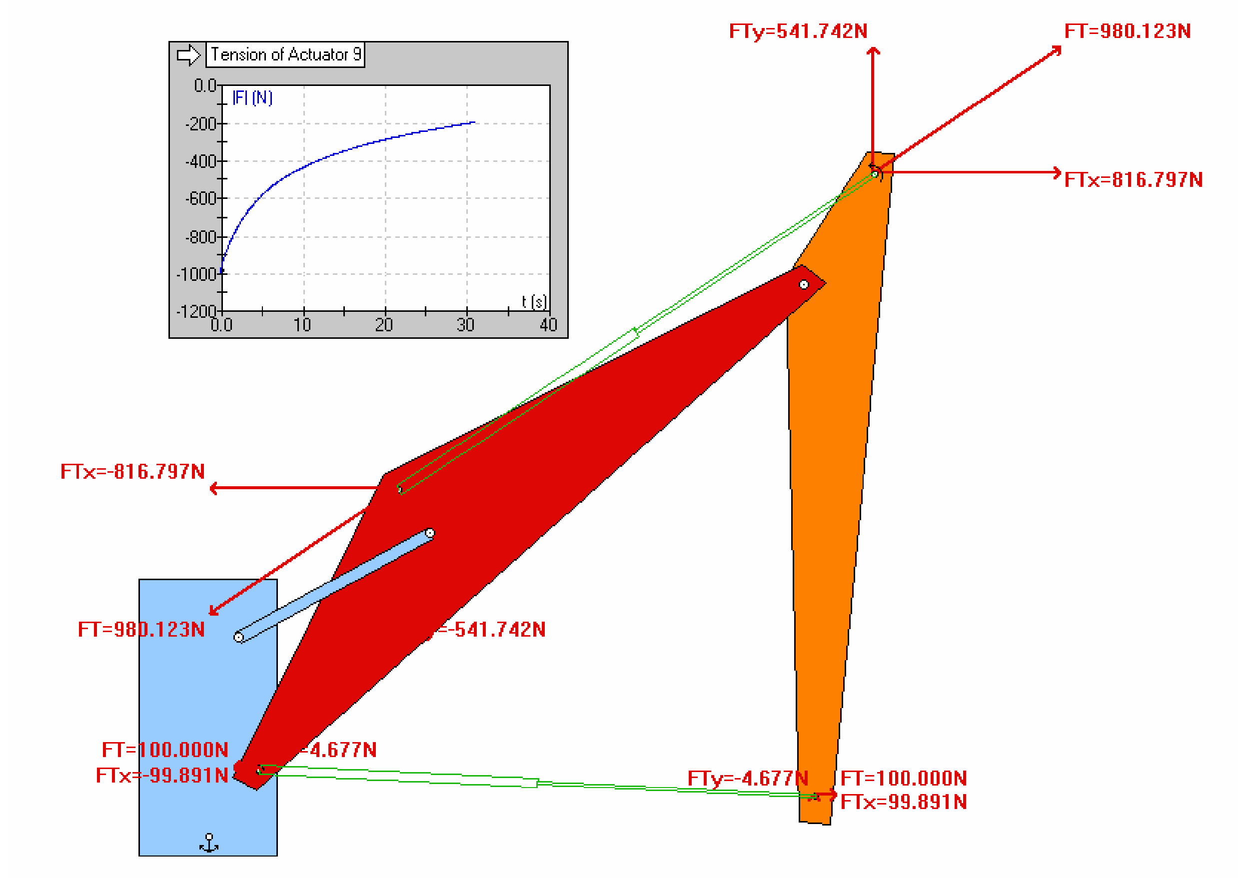
1st STEP: Mechanism description (2D)

-Geometry
-Cylinder working cycles
-velocity



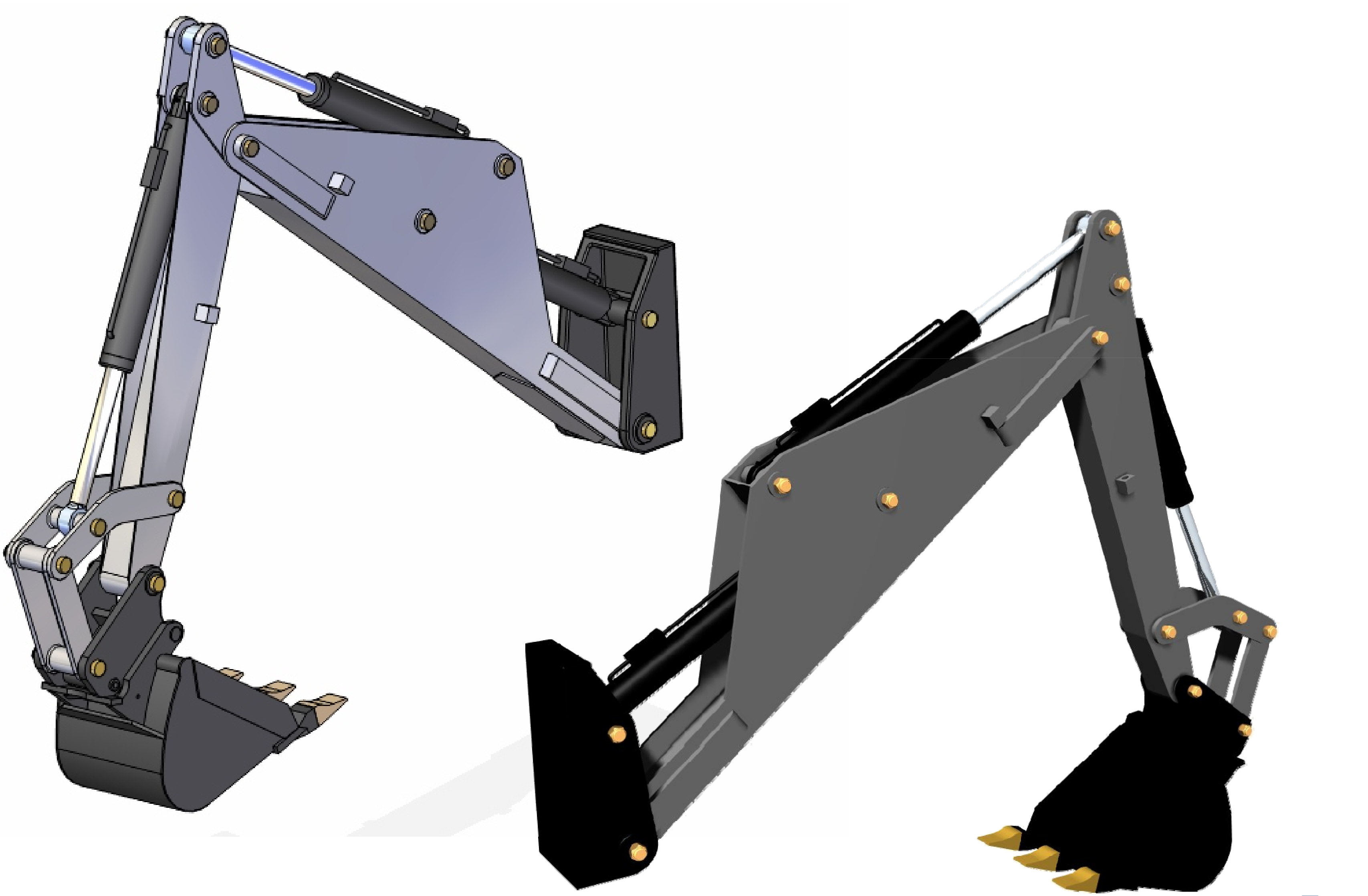


1st STEP: Mechanism description (2D)



-Geometry
-Cylinder working cycles
-load

1st STEP-bis : Mechanism description (3D)



Kinematic and dynamic anàlisis by LABSON

2th STEP:

The proposed approach in fatigue life prediction **is to relate the fatigue life of a hydraulic cylinder**, subjected to a random load, **to laboratory fatigue experiments of simple one subjected to a constant-amplitude load**: so-called *S-N* data. Therefore it is necessary to define equivalent 'load cycles' and assume a damage rule: that is, a method to measure the damage caused by each simple cycle.

In practice one often uses the *Palmgren-Miner* linear damage, and load cycles defined using the *Rainflow method.*

In most cases this is the best available method, the accuracy of the approach is often good. The method is mostly used at the design stage, when the accuracy of fatigue lifetime predictions are less important but the experiments have to be relatively cheap.

Experimental field testing (Ex: Mini-backhoe)

2th STEP:

a) One cycle
b) Continuous working cycles

Pictures realized by Hidrar

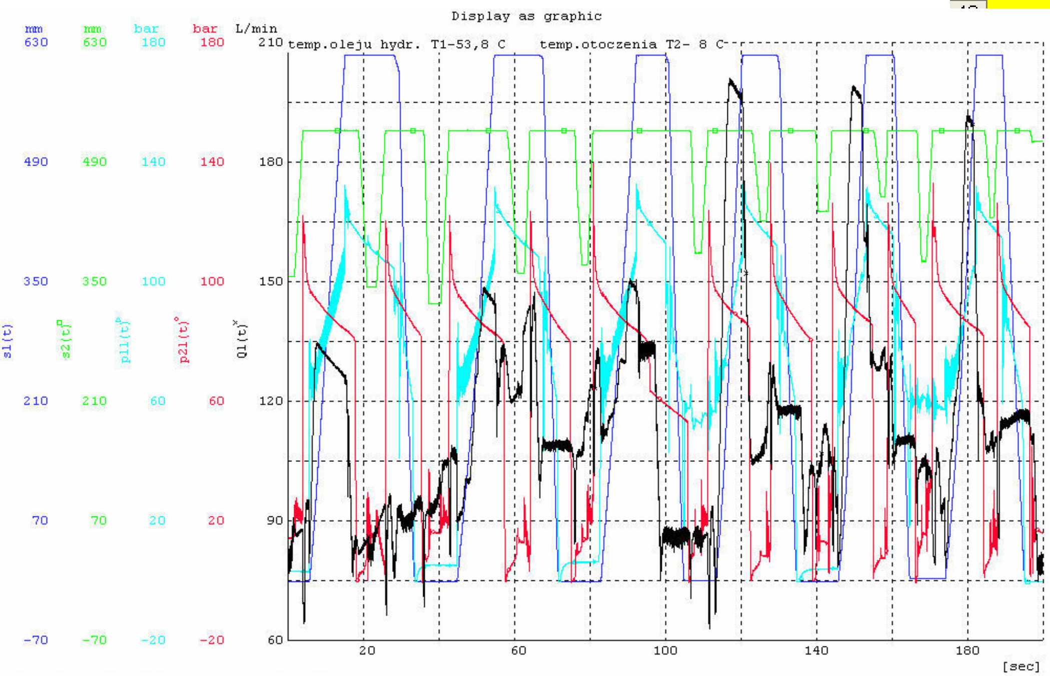
Field test (continuous working cycles)

Measured parameters:

- Pressure in piston chamber
- Pressure in rod chamber
- Hydraulic oil temperature
- Ambient temperature
- Piston displacement
- Hydraulic oil cleanness
- Hydraulic oil flow

	A	B	C	D	E	F
1	Seweral working cycles of mining loader LK1 with rated load					
2	\Name of source file: 20060202_LK1_obciazniki_wysiegnik__8 <new>					
3	\Recording from 02,02,2006 16:02 POMIAR 8					
4	hydraulic oil temperature T1= 45 C					
5	ambient temperature T2= 8 C					
6	\Channels: 5					
7	\Scanning rate: 10 ms = 0,010 sec					
8	\Variable 1: s1(mm) displacement of boom cylinder's rod (left)					
9	\Variable 2: s3(mm) displacement of boom cylinder's rod (right)					
10	\Variable 3: p11(bar) pressure in piston chamber of boom cylinder (left)					
11	\Variable 4: p12(bar) pressure in rod chamber of boom cylinder (left)					
12	\Variable 5: Q1(L/min) oil flow					
13						
14	t [s]	s1 [mm]	s3 [mm]	p11 [bar]	p12 [bar]	Q1 [L/min]
15	0	0,292	-0,3	5,78	-0,612	80,438
16	0,01	0,292	-0,3	5,723	-0,612	79,981
17	0,02	0,292	0	5,665	-0,612	81,436
18	0,03	0,292	-0,3	5,723	-0,612	81,146
	0,04	0,292	-0,3	5,723	-0,612	81,146
	0,05	0,292	0	5,665	-0,612	81,064
	0,06	0,292	0	5,78	-0,612	80,33
	0,07	0,292	-0,3	5,723	-0,612	80,061
	0,08	0,292	-0,3	5,723	-0,612	80,831
	0,09	0,292	-0,3	5,723	-0,612	81,27
	0,1	0,292	-0,3	5,723	-0,612	80,859
	0,11	0,292	0	5,78	-0,612	80,859
	0,12	0,292	0	5,665	-0,612	80,941
	0,13	0,292	-0,3	5,78	-0,612	80,941
	0,14	0,292	0	5,665	-0,612	80,195
	0,15	0,292	0	5,723	-0,612	81,064
	0,16	0,292	0	5,723	-0,612	80,424
	0,17	0,292	-0,3	5,723	-0,612	80,424
	0,18	0,292	-0,3	5,78	-0,612	81,298

Arkusz1 / Arkusz2 / Arkusz3



Data base by Fadroma

CYCLE COUNTING

Methods:

-Level-crossing counting
-Peak counting
-Simple range counting

limitation:
no consideration
effects sequence

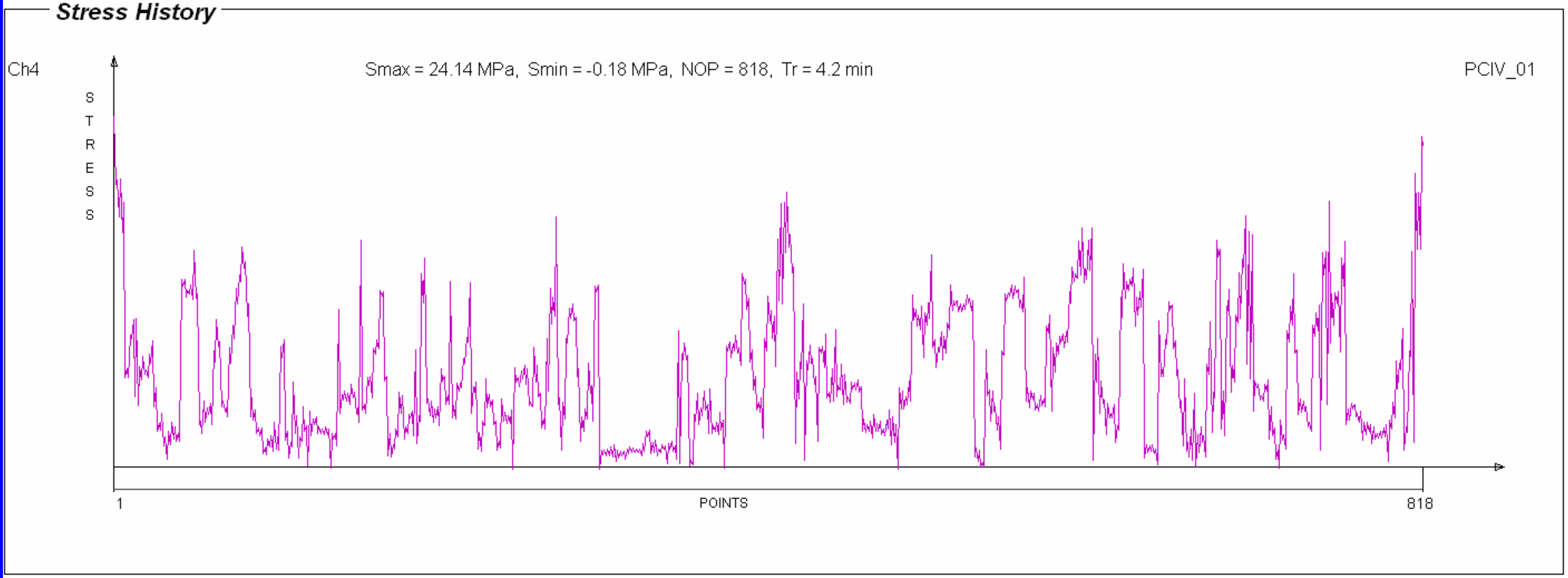
-Rainflow counting
original method - pagoda roofs (Matsuishi and Endo)
range-pair counting
racetrack method
Hayes method, etc

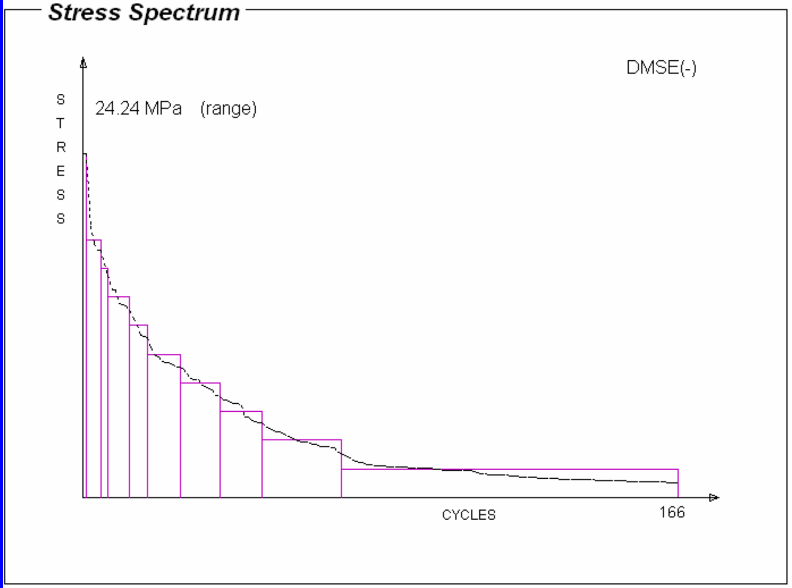
-Standards
ASTM standard (Rainfow counting method)
CEN prEN 13445-3 (Reservoir cycle countinf method)

Proposed method

Software developed by IFTR- Life SN soft.
Software developed by Pedro ROQUET
Software comercial : DIADEM

Software developed by IFTR





Stress Spectrum Information

Level	Range [MPa]	Cycles
1	24.24	1
2	22.22	0
3	20.2	0
4	18.18	4
5	16.16	2
6	14.14	6
7	12.12	5

Spectrum levels: 12 Omitted cycles: 243

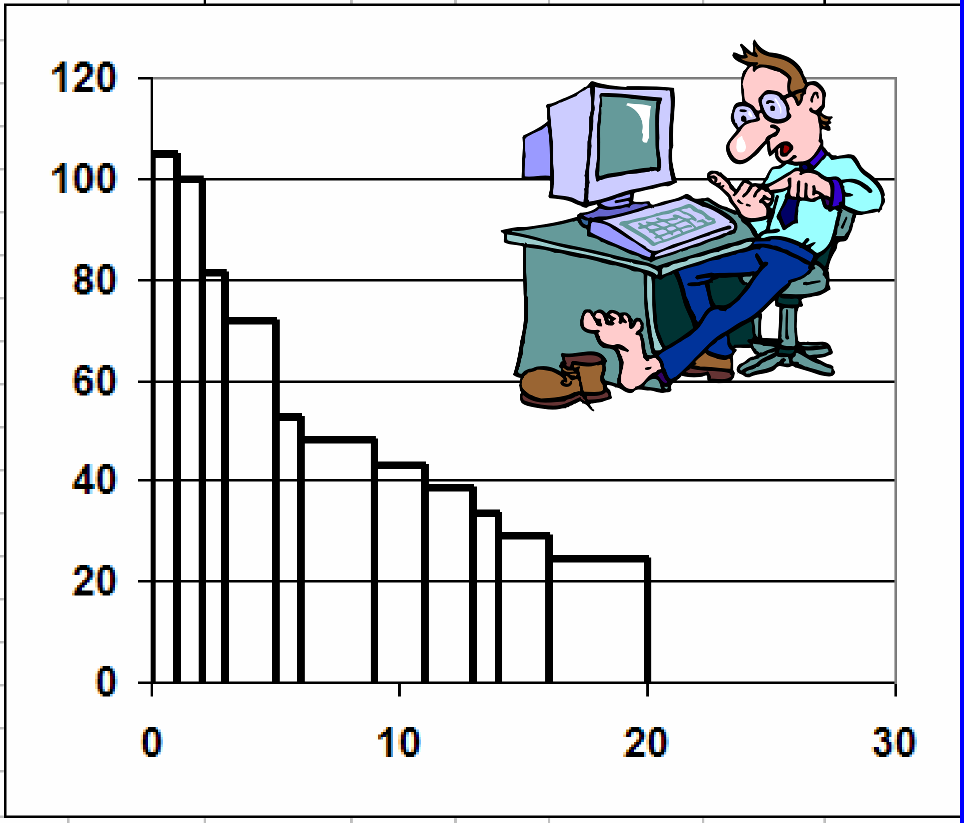
Software developed by Pedro ROQUET

v1

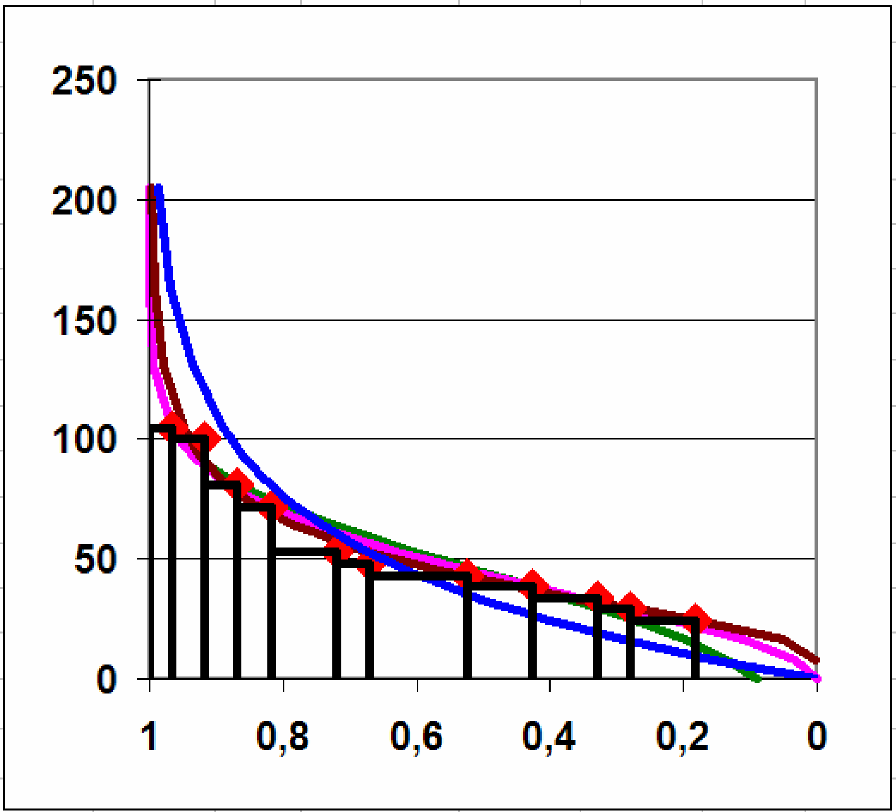
STATISTICAL DISTRIBUTION ASSOCIATED WITH A LOAD SPECTRA

machine | date
cylinder
work performed
comments

	level	pressure	cycles	F(x)(*)	R(x)
max	1	104,73	1	100%	0%
	2	100,00	1	97%	3%
	3	95,28	0		
	4	90,55	0		
	5	85,83	0		
	6	81,11	1	87%	13%
	7	76,38	0		
	8	71,66	2	82%	18%
	9	66,93	0		
	10	62,21	0		
	11	57,48	0		
	12	52,76	1		28%
	13	48,03	3		28%
	14	43,31	2		33%
	15	38,58	2		48%
	16	33,86	1		57%
	17	29,13	2		67%
min.(*)	18	24,41	4		72%



Statistical distributions comparative analysis



Exponential distribution: s/Weibull

ajuste natural (x1)

lambda:	0,021
average:	47,5

from Henry

Weibull distribution		correct.
Beta:	1,81	
ñu:	53,2	0,51
average:	47,5	0,45

Normal distribution	
average	44,4
stnd. Dev.	33,2
Vx (s/m)=	0,75

log Normal	ln(x)	(x)
average	3,72	41,1
stnd. Dev.	0,57	25,5
Vx (s/m)=	0,15	0,62

distribution ploted: all the 4

exponential (blue) weibull (pink)

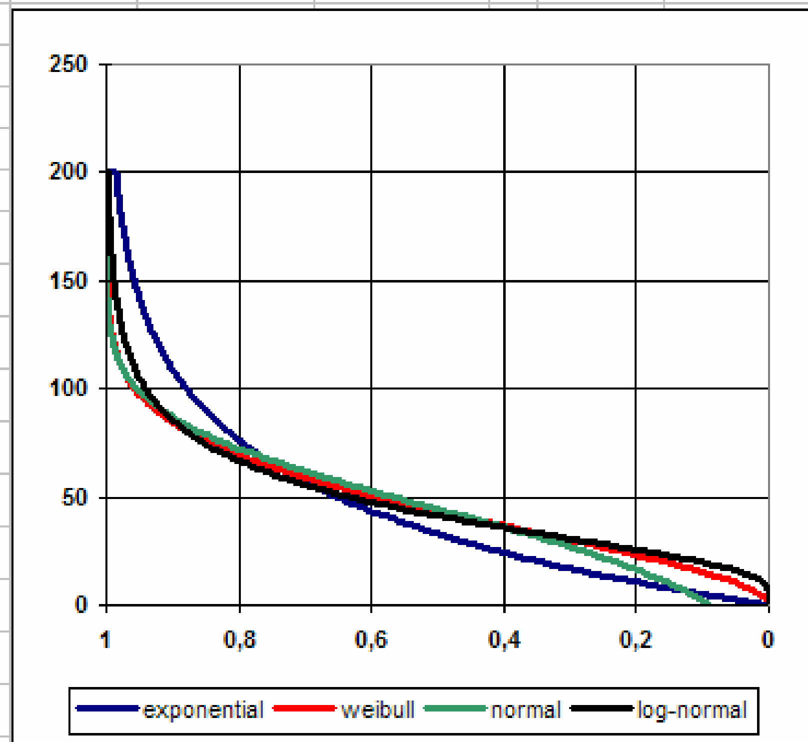
ormal (green) log.normal(brown)

Equivalent life in laboratory

Cylinder C1
Piston chamber

				Design cycles	Design pressure	
Design Pressure	200	bar	log-normal	119.493	200	bar
Relieve valve	200		weibull	103.854		
Desired life	10	years	normal	114.534		
working days	200	days / year	exponential	178.758		
hours per day	8					
% of the working hours	50					
"m" of S-N curve	3					
cycles/minute	15					
D	2					

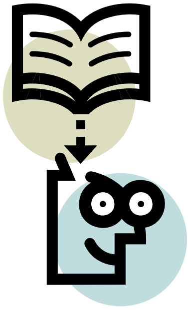
weibull	$\beta(\alpha)$	1,81
	$\eta(\beta)$	53,20
log -normal	μ(ln)	3,72
	σ(ln)	0,57
	μ(x)	41,3
	σ(x)	25,57
exponential	μ	47,5
	λ	0,021
normal	μ(x)	44,4
	σ(x)	33,2



Remember, until now, we have:

- A list of failure mode (critical points)

-A standard spectrums (load and displacement)



This knowledge
is important for

Fatigue life predictions
DBA,

It is necessary, but not sufficient

WE NEED TO INTRODUCE THE RISK CONCEPT

4th STEP

Failure Mode

↓

Effect
Severity: 1-10

↓

Causes
Occurrence: 1-10

↓

Controls
Detection: 1-10

↓

RPN = Severity X Occurrence X Detection

1-1000

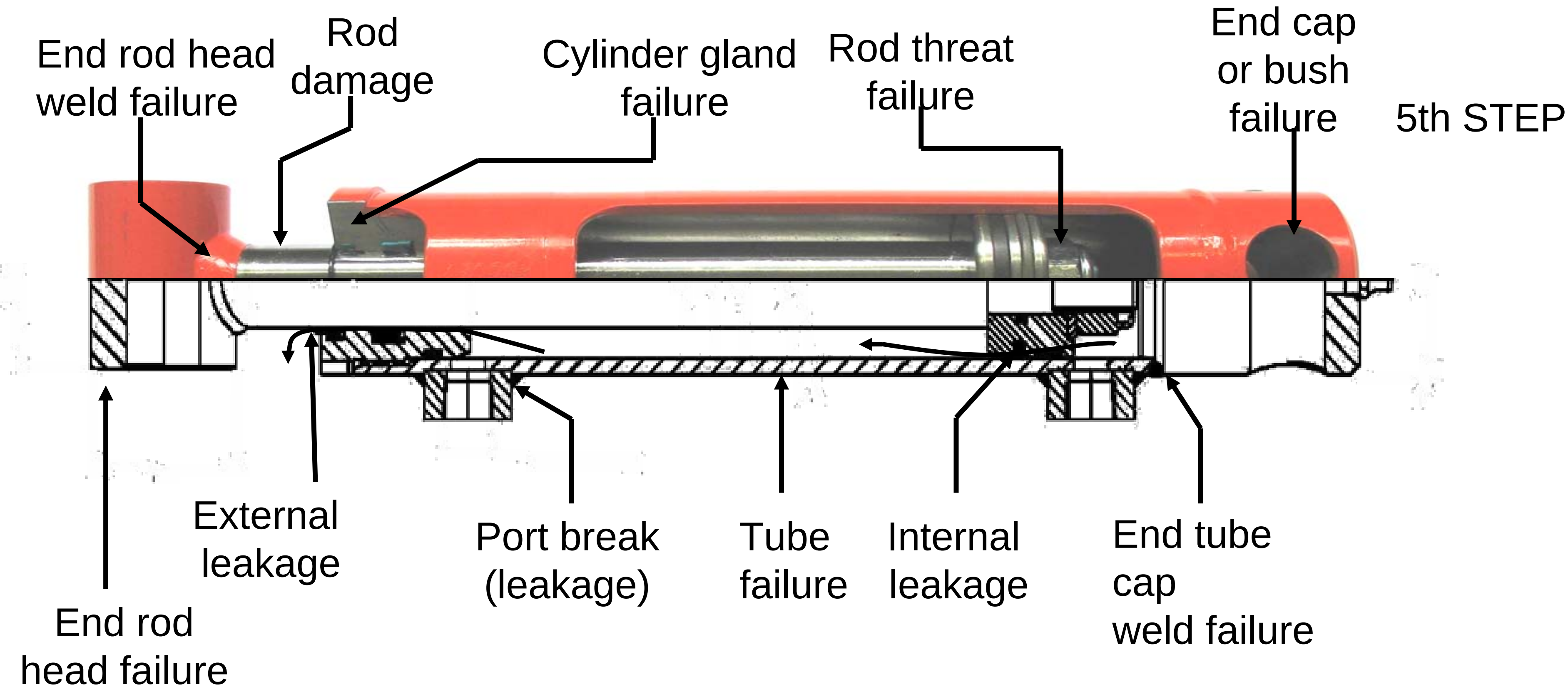
In all hydraulic cylinder applications we need to define a RPN

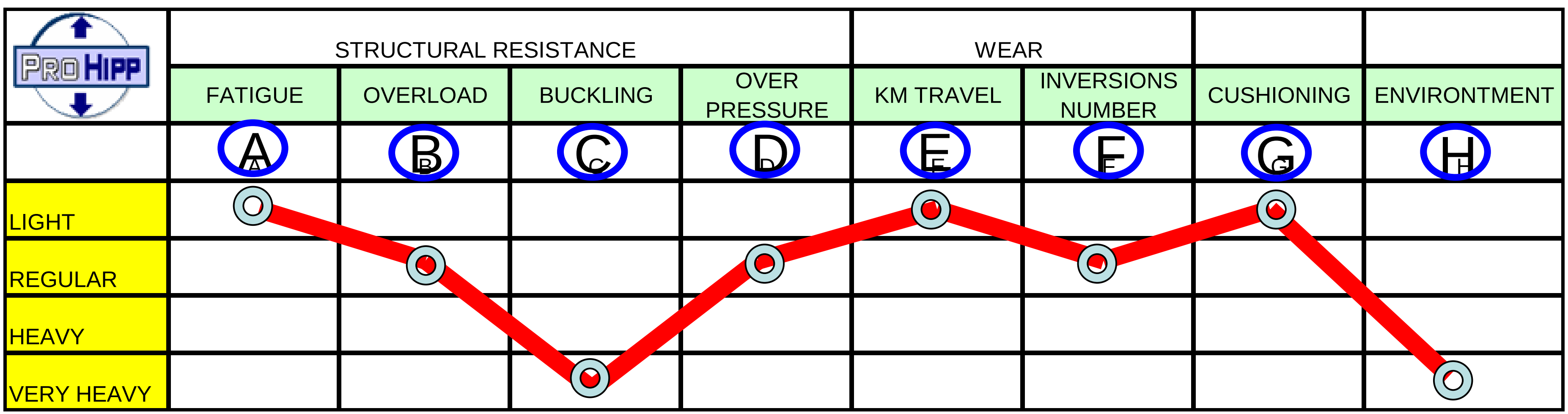
The RPN is a measure of *design risk*

RISK PRIORITY NUMBER (RPN)

The RISK PRIORITY NUMBER (RPN) is the product of the SEVERITY (S), OCCURRENCE (O), and DETECTION (D)

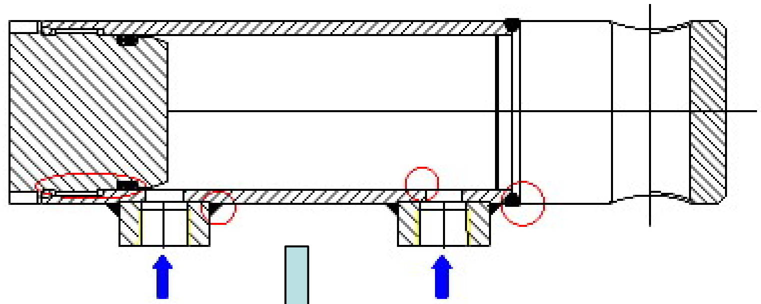
RPN = (S) x (O) x (D)

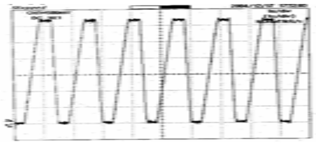




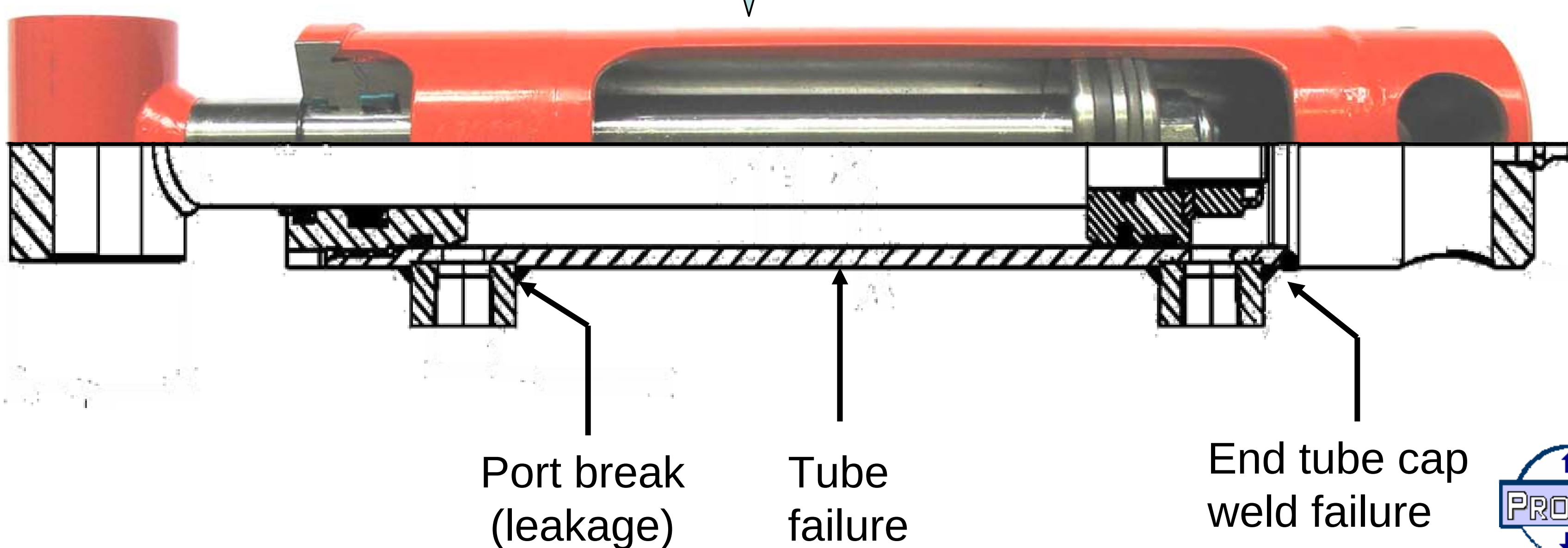
The RISK PRIORITY NUMBER increase the category level

A	FATIGUE		LIGHT	REGULAR	HEAVY	VERY HEAVY
	Test	Pressure	200 bar = 1 Nominal pressure			
		Cycles number	10.000	100.000	360.000	1.000.000





Fatigue pressure test

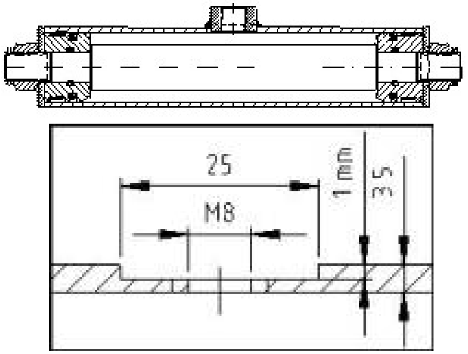


Laboratory testing

- static fatigue tests have been performed of a cylinder with a single oil port.

Date	Cylinder N°	Drawing N°	Ø Ext	Ø Int	Ø Rod	Stroke	Critical part broken	N° Cycles done	Max Test Presure	FI DE LA PROBA?
29/03/2007	PH-F-261	2652-3-4	57	50	30	-	OIL PORT	492170	200	SÍ

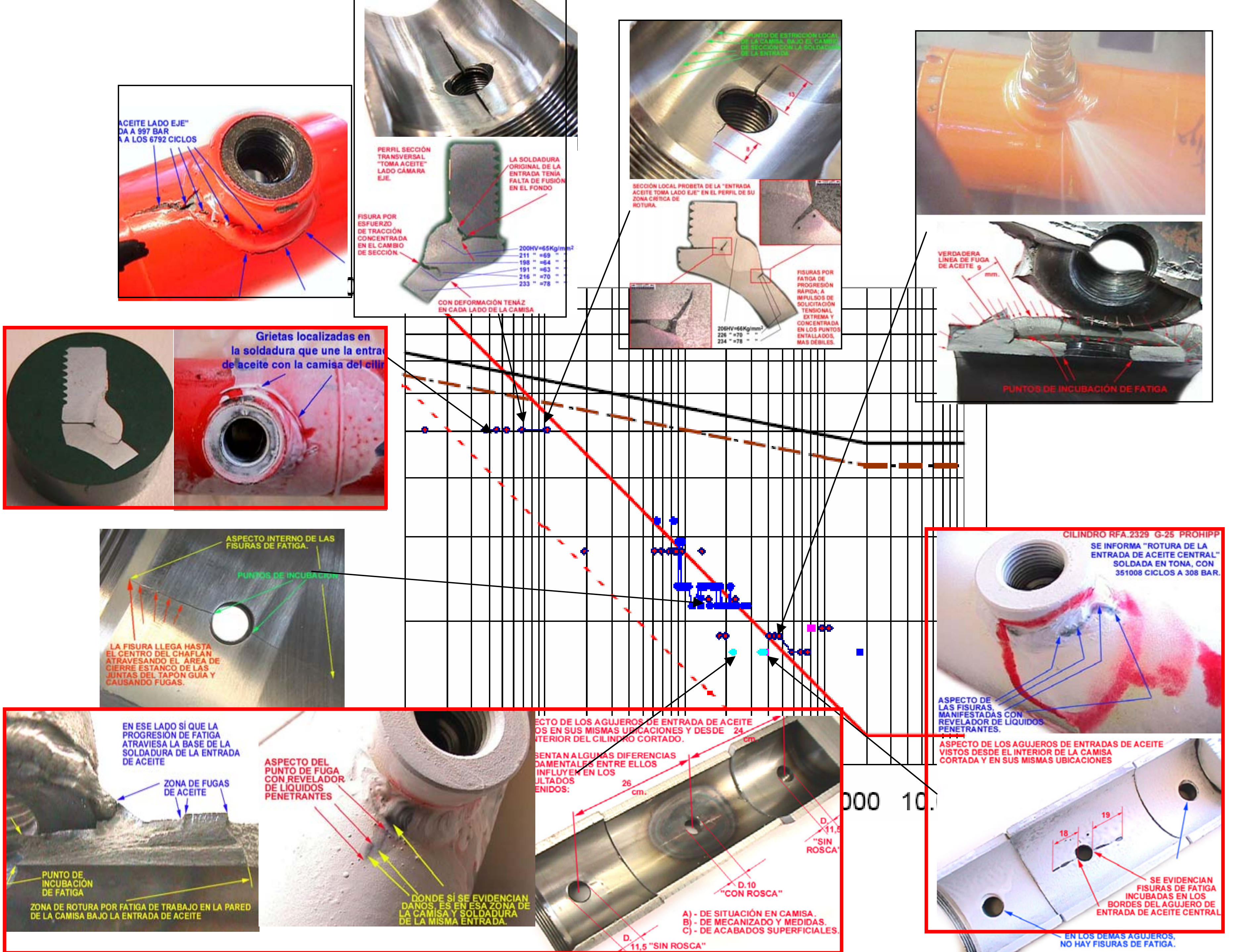
Date	Cylinder N°	Drawing N°	Ø Ext	Ø Int	Ø Rod	Stroke	Critical part broken	N° Cycles done	Max Test Presure
21/02/2007	PH-F-258	2652-3-4	57	50	30	-	OIL PORT	15816	554



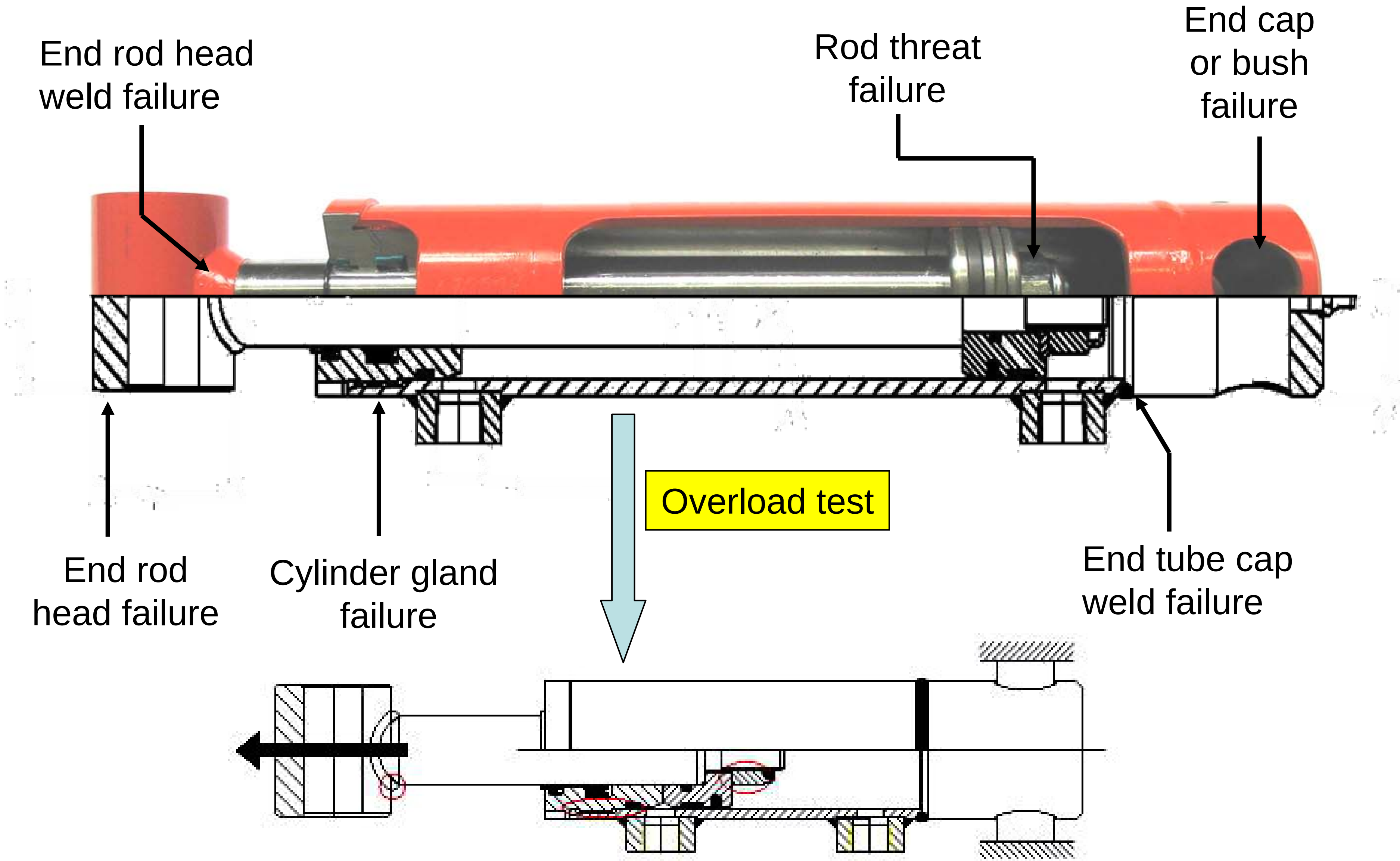
Date	Cylinder N°	Drawing N°	Ø Ext	Ø Int	Ø Rod	Stroke	Critical part broken	N° Cycles done	Max Test Presure	FI DE LA PROBA?
12/04/2007	PH-F-272	2652-3-5	52	45	30	-	OIL PORT	700716	200	SÍ

Date	Cylinder N°	Drawing N°	Ø Ext	Ø Int	Ø Rod	Stroke	Critical part broken	N° Cycles done	Max Test Presure
16/02/2007	PH-F-269	2652/3/5	52	45	30	-	OIL PORT	11624	554

Data base by Pedro ROQUET



ACEITE LADO EJE"
DA A 997 BAR
A LOS 6792 CICLOS
PERFIL SECCIÓN TRANSVERSAL "TOMA ACEITE" LADO CÁMARA EJE.
LA SOLDADURA ORIGINAL DE LA ENTRADA TENÍA FALTA DE FUSIÓN EN EL FONDO
FISURA POR ESFUERZO DE TRACCIÓN CONCENTRADA EN EL CAMBIO DE SECCIÓN.
200HV=65Kg/mm2
211 " =69 " "
198 " =64 " "
191 " =63 " "
216 " =70 " "
233 " =78 " "
CON DEFORMACIÓN TENÁZ EN CADA LADO DE LA CAMISA
SECCIÓN LOCAL PROBETA DE LA "ENTRADA ACEITE TOMA LADO EJE" EN EL PERFIL DE SU ZONA CRÍTICA DE ROTURA.
FISURAS POR FATIGA DE PROGRESIÓN RÁPIDA; A IMPULSOS DE SOLICITACIÓN TENSIONAL EXTREMA Y CONCENTRADA EN LOS PUNTOS ENTALLADOS, MAS DÉBILES.
206HV=66Kg/mm2
226 " =70 " "
234 " =78 " "
13
8
VERDADERA LÍNEA DE FUGA DE ACEITE 9 mm.
PUNTOS DE INCUBACIÓN DE FATIGA
Grietas localizadas en la soldadura que une la entrad de aceite con la camisa del cilin
ASPECTO INTERNO DE LAS FISURAS DE FATIGA.
PUNTOS DE INCUBACIÓN
LA FISURA LLEGA HASTA EL CENTRO DEL CHAFLÁN ATRAVESANDO EL ÁREA DE CIERRE ESTANCO DE LAS JUNTAS DEL TAPÓN GUIA Y CAUSANDO FUGAS.
EN ESE LADO SÍ QUE LA PROGRESIÓN DE FATIGA ATRAVIESA LA BASE DE LA SOLDADURA DE LA ENTRADA DE ACEITE
ZONA DE FUGAS DE ACEITE
PUNTO DE INCUBACIÓN DE FATIGA
ZONA DE ROTURA POR FATIGA DE TRABAJO EN LA PARED DE LA CAMISA BAJO LA ENTRADA DE ACEITE
ASPECTO DEL PUNTO DE FUGA CON REVELADOR DE LÍQUIDOS PENETRANTES
DONDE SÍ SE EVIDENCIAN DAÑOS, ES EN ESA ZONA DE LA CAMISA Y SOLDADURA DE LA MISMA ENTRADA.
ECTO DE LOS AGUJEROS DE ENTRADA DE ACEITE
OS EN SUS MISMAS UBICACIONES Y DESDE
NTERIOR DEL CILINDRO CORTADO.
SENTAN ALGUNAS DIFERENCIAS
DAMENTALES ENTRE ELLOS
INFLUYEN EN LOS
ULTADOS
ENIDOS:
24 cm.
26 cm.
D. 11,5 "SIN ROSCA"
D.10 "CON ROSCA"
D. 11,5 "SIN ROSCA"
A) - DE SITUACIÓN EN CAMISA.
B) - DE MECANIZADO Y MEDIDAS.
C) - DE ACABADOS SUPERFICIALES.
000 10.
CILINDRO RFA.2329 G-25 PROHIPP
SE INFORMA "ROTURA DE LA ENTRADA DE ACEITE CENTRAL" SOLDADA EN TONA, CON 351008 CICLOS A 308 BAR.
ASPECTO DE LAS FISURAS, MANIFESTADAS CON REVELADOR DE LÍQUIDOS PENETRANTES.
ASPECTO DE LOS AGUJEROS DE ENTRADAS DE ACEITE VISTOS DESDE EL INTERIOR DE LA CAMISA CORTADA Y EN SUS MISMAS UBICACIONES
18
19
SE EVIDENCIAN FISURAS DE FATIGA INCUBADAS EN LOS BORDES DEL AGUJERO DE ENTRADA DE ACEITE CENTRAL
EN LOS DEMAS AGUJEROS, NO HAY FISURAS DE FATIGA.



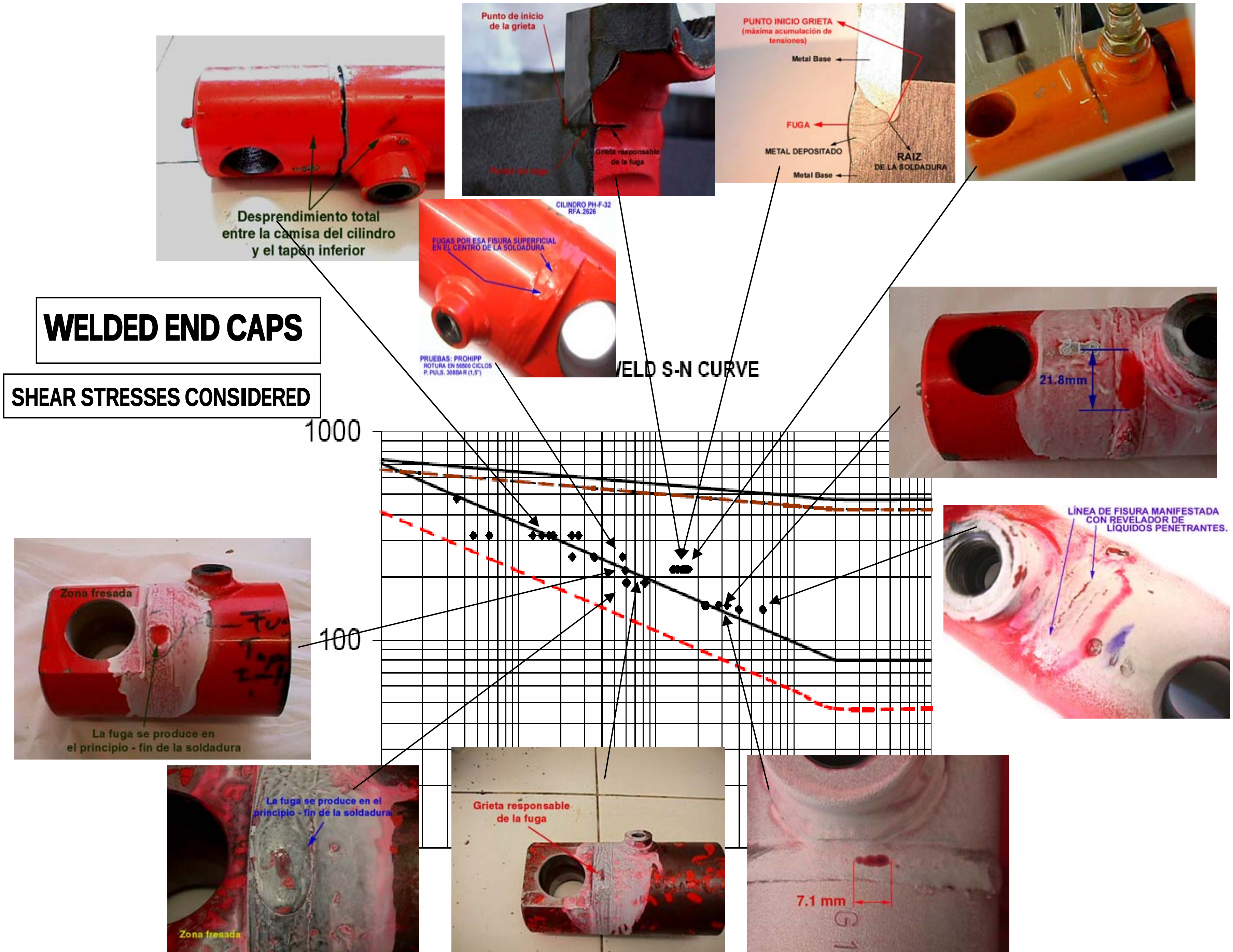
B	OVERLOAD	LIGHT	REGULAR	HEAVY	VERY HEAVY

Test

Equiv.Pressure	200 bar = 1 Nominal pressure			
Cycles number	10.000	100.000	360.000	1.000.000

WELDED END CAPS

SHEAR STRESSES CONSIDERED



Laboratory testing

- mechanical resistance test to external forces have been performed for the rod head and the rod ends.

PH-F-179
ROD HEAD BROKEN
125.675 CYCLES AT 308 BAR

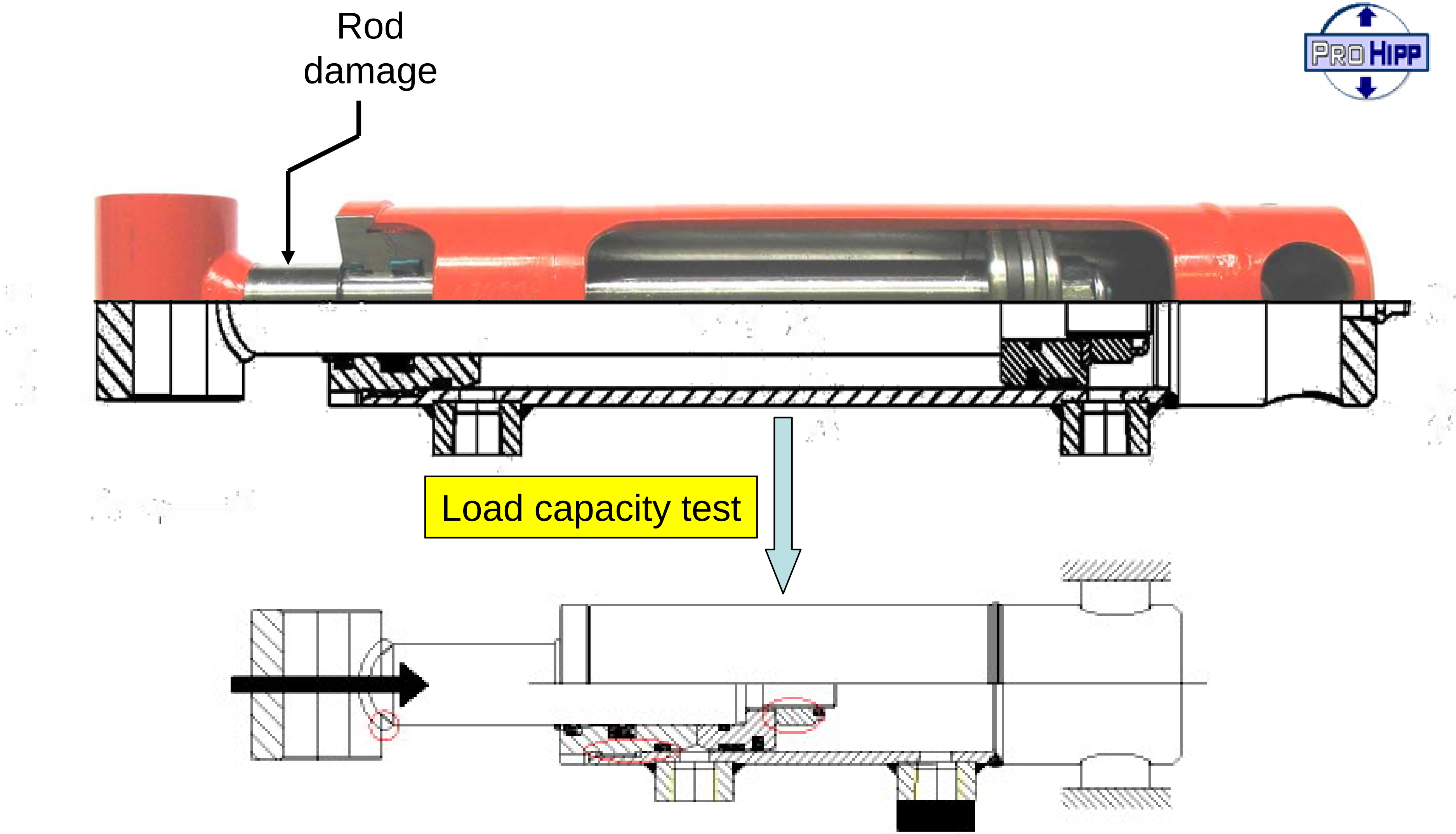
PH-F-158
ROD HEAD BROKEN
76.765 CYCLES AT 308 BAR

PH-F-158

PISTON END BROKEN

40.991CYCLES AT 308 BAR

Data base by Pedro ROQUET

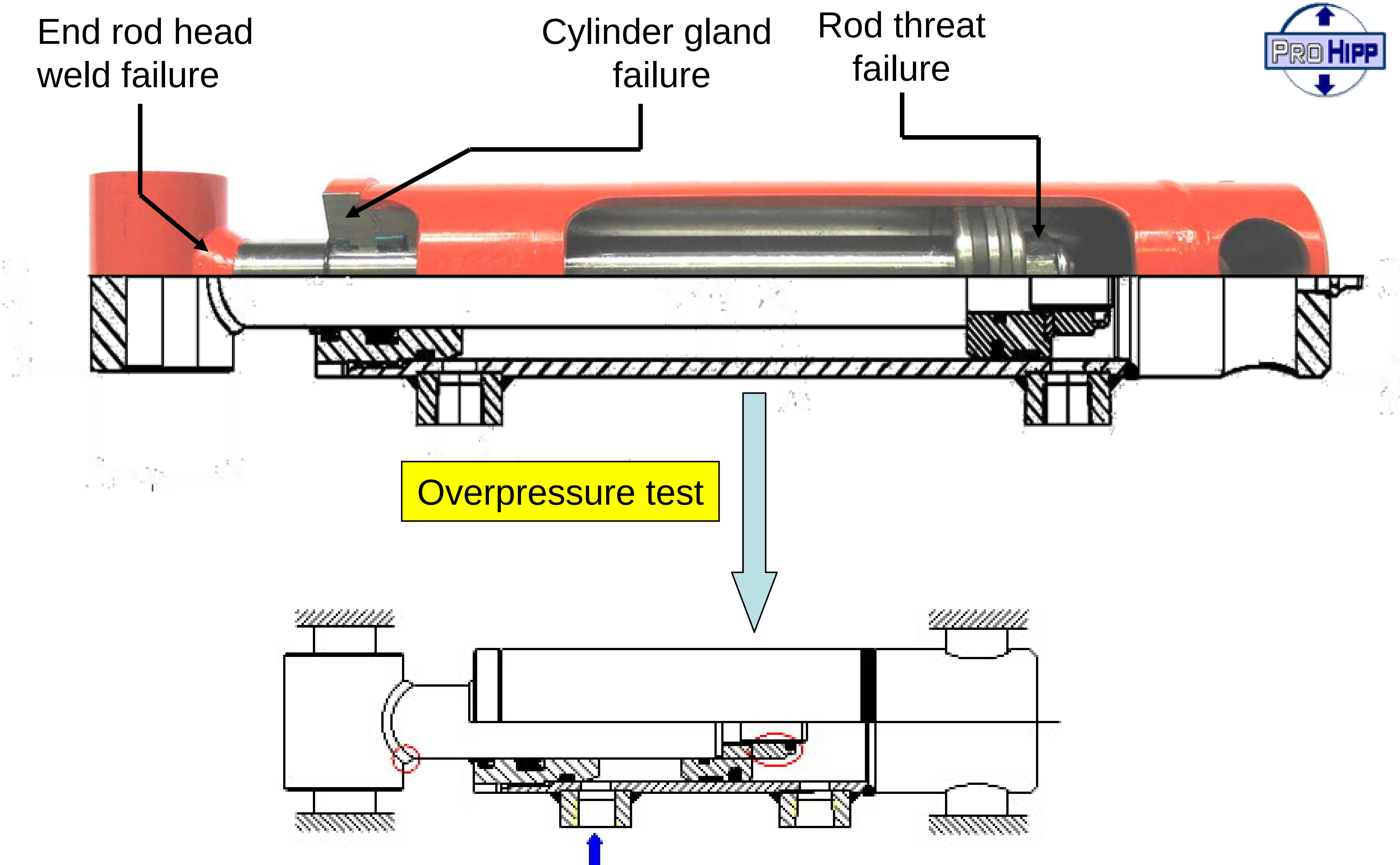


C	BUCKLING	LIGHT	REGULAR	HEAVY	VERY HEAVY

Test

Equiv.Pressure	200 bar = 1 Nominal pressure			
Limit Load Capacity	1,5 x Nominal Pressure	2 x Nominal Pressure	3 x Nominal Pressure	4 x Nominal Pressure

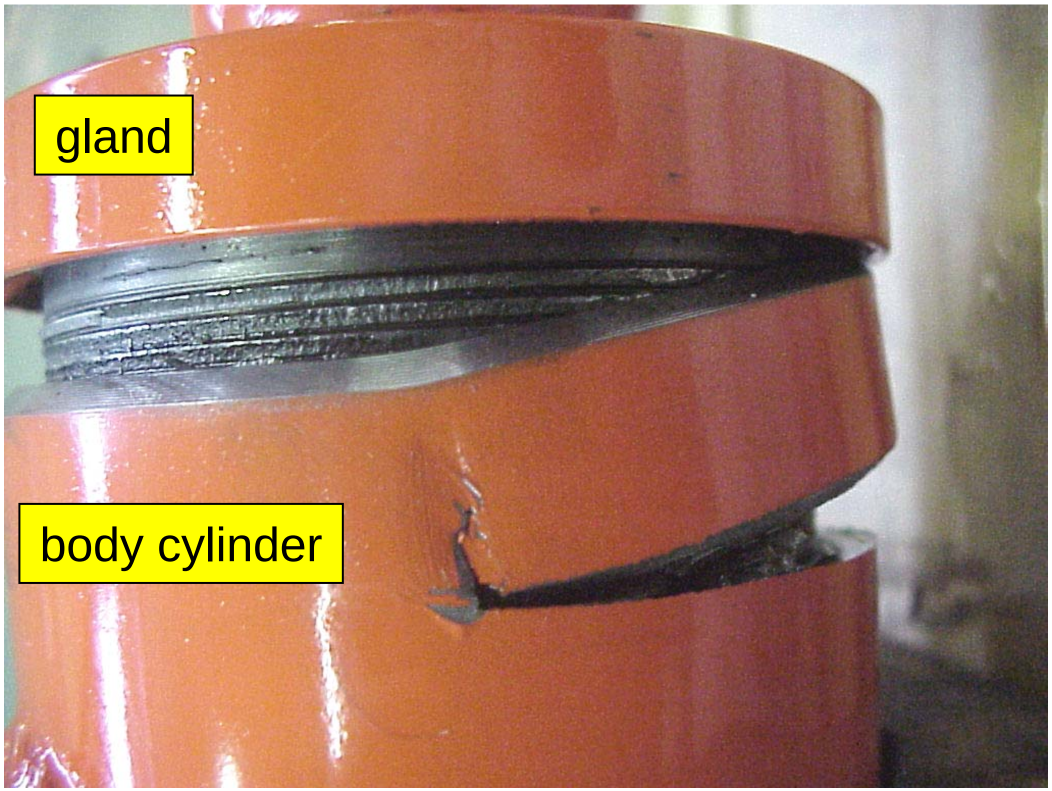
Photos by LABSON

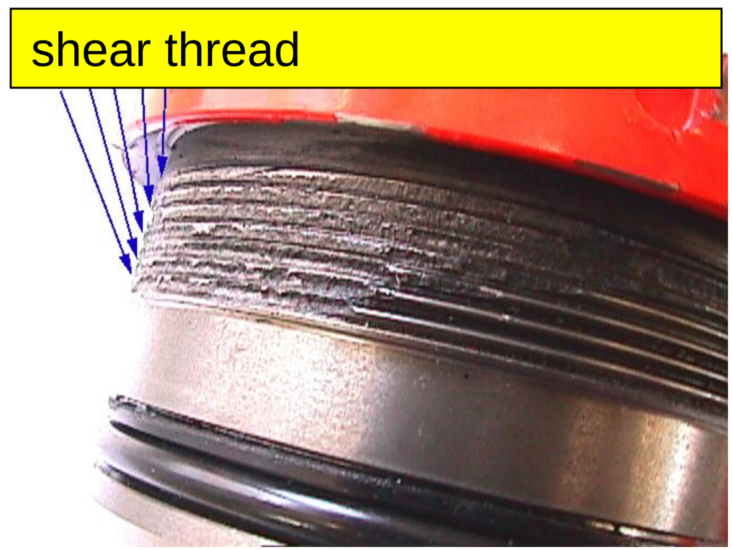


D	OVER PRESSURE		LIGHT	REGULAR	HEAVY	VERY HEAVY
	Test	Equiv.Pressure	1,5 x PN	2 x PN	2,5 x PN	3 x PN
		Cycles number	16	16	16	16

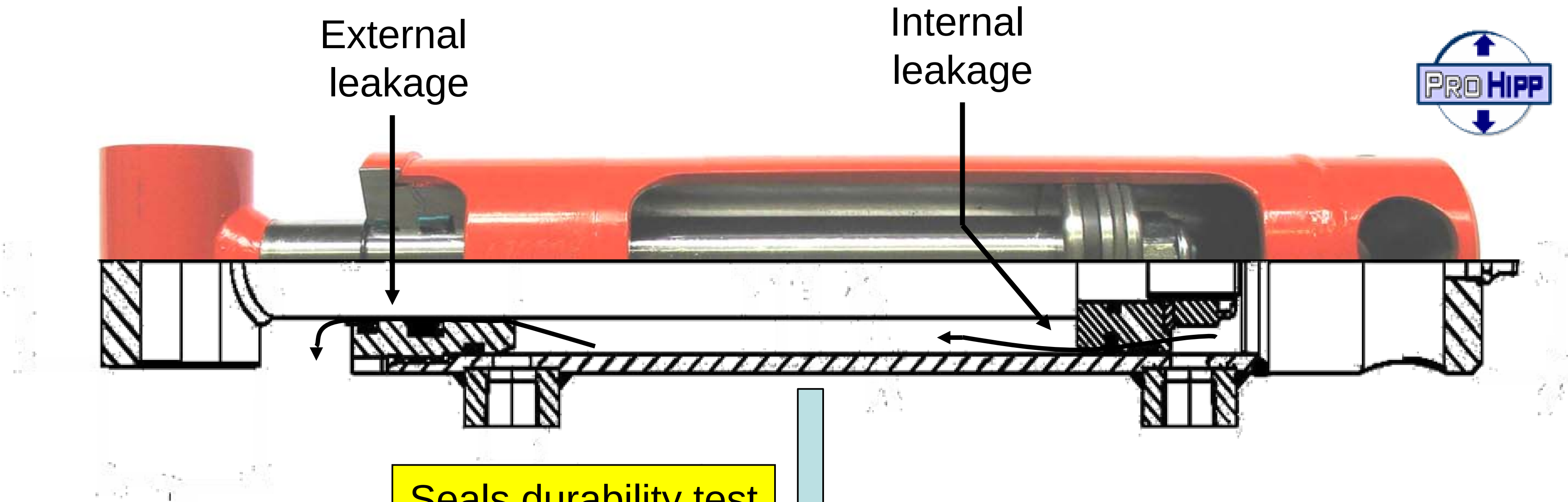
Gland failure (shear thread)

TEST
60.670 cycles
Pulsating Pressure
308 / 0 bar

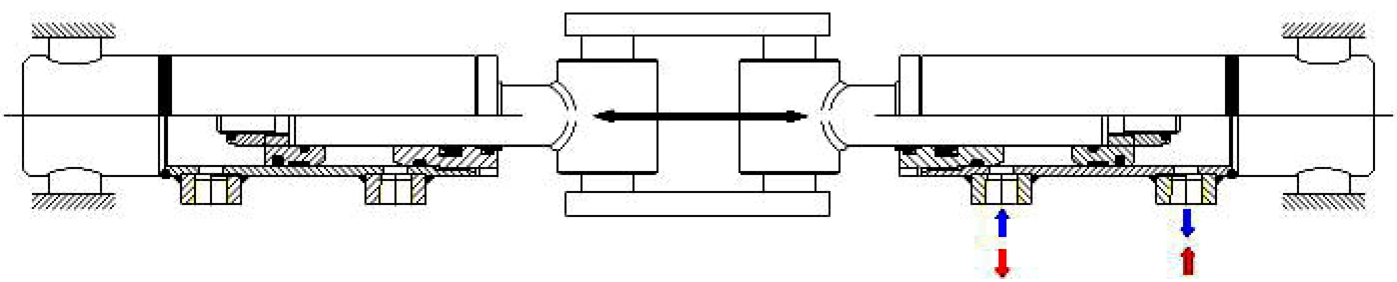




Photos by P ROQUET



Seals durability test



F	WEAR RESISTANCE		LIGHT	REGULAR	HEAVY	VERY HEAVY
	Seals (alternative test)	Pressure	250= 1,25 x NP	250= 1,25 x NP	250= 1,25 x NP	250= 1,25 x NP
		Total travel (km)	50 Km	100 Km	200 Km	300 Km
		Temperature	80 ºC	80 ºC	80 ºC	80 ºC

- Performing cycling tests of tubes honed by Honingtec

PHM-139-108 km.

PHM-95-300Km.

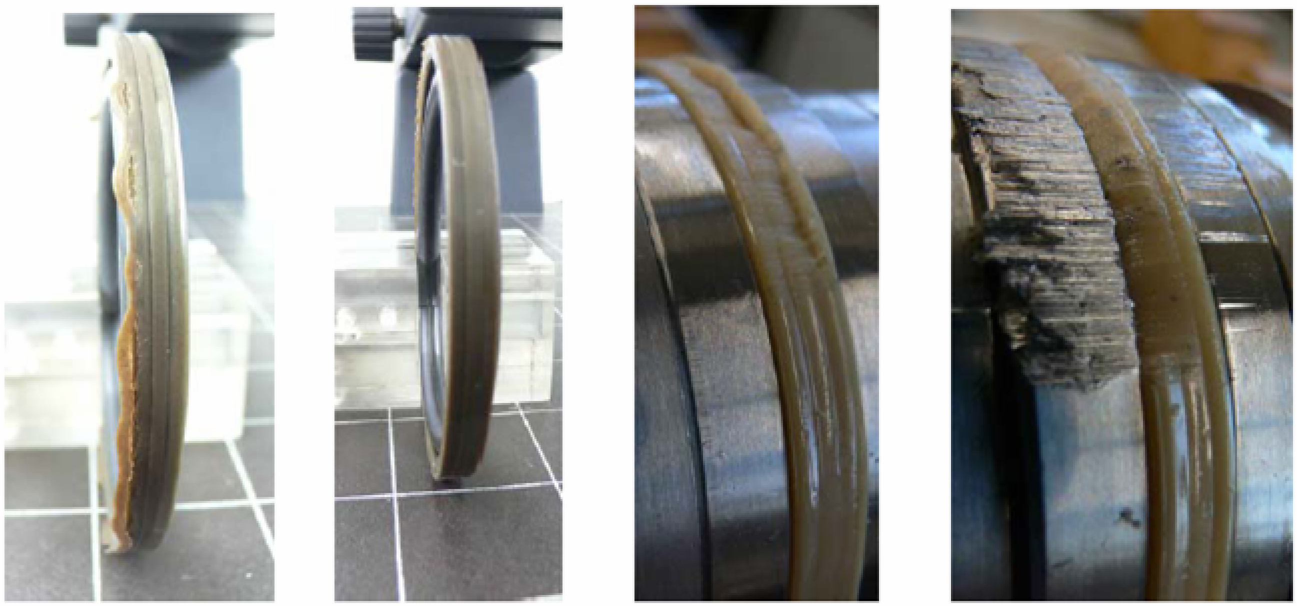
PHM-91-300Km.

PHM-92-300Km.

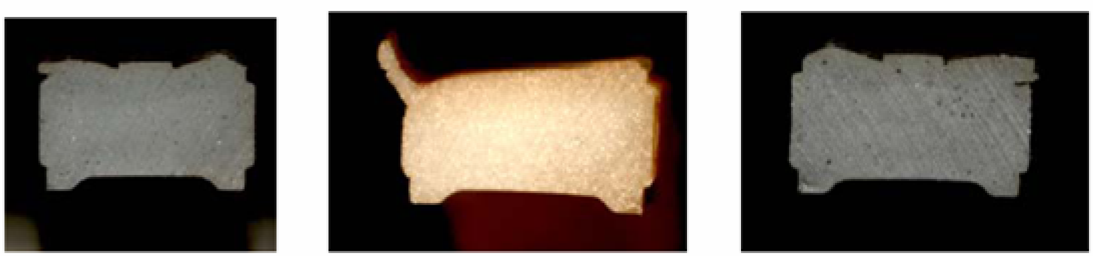
PHM-93-300Km.

by P ROQUET / HONINGTEC / Centre CIM / TRELLEBORG

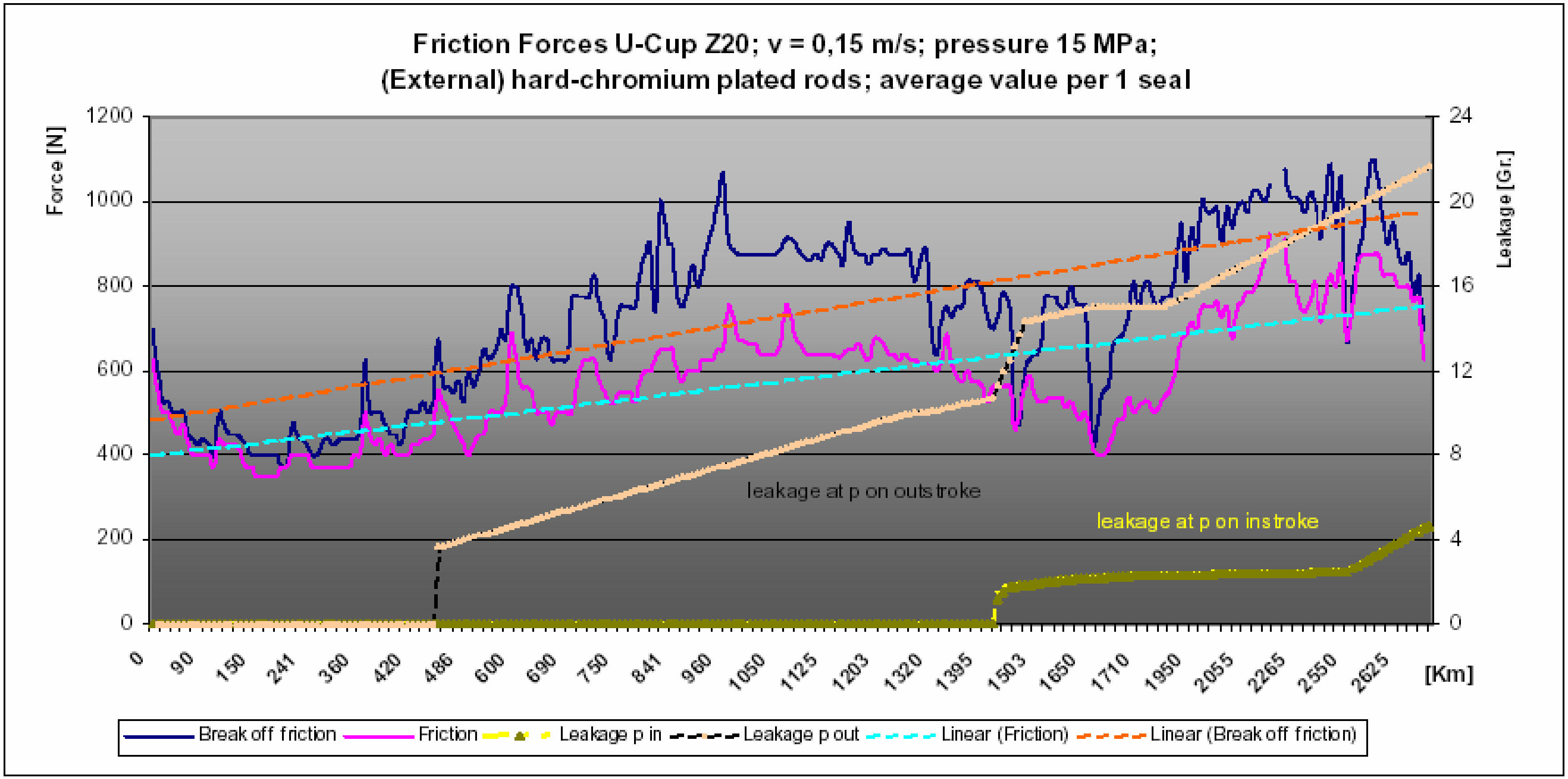
Seals in total view with partly remarkable wear / damage



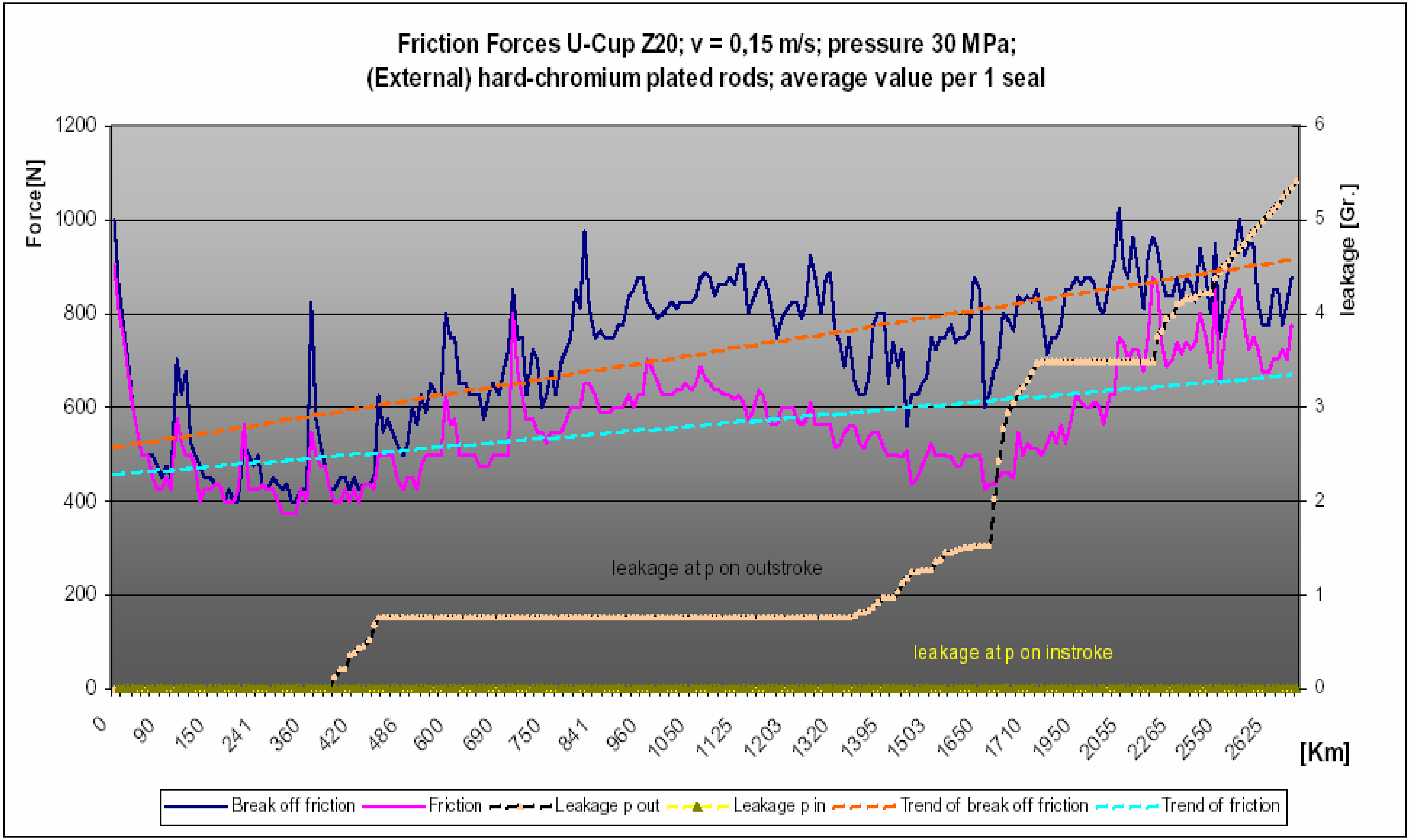
PU sealing element without pre-stressing element (showing extrusion and wear marks)



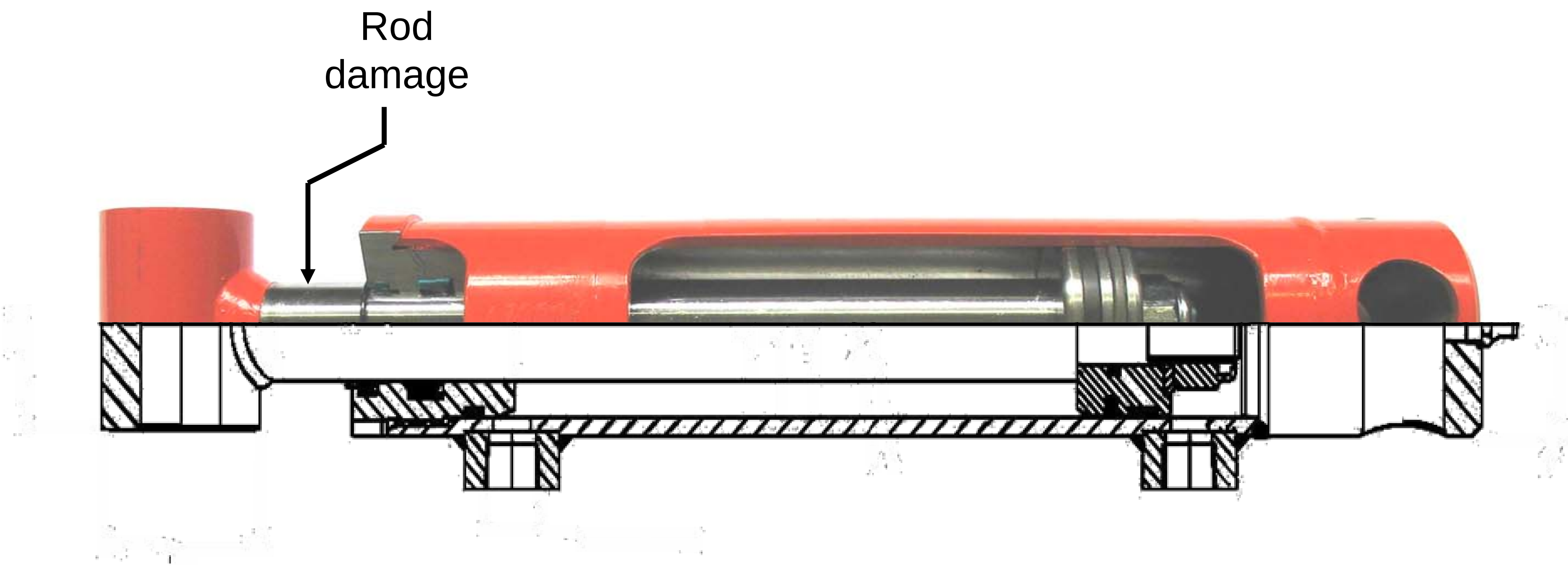
Photos by TRELLEBORG



Tests results by TRELLEBORG



Tests results by TRELLEBORG



H	CORROSION RESISTANCE	LIGHT	REGULAR	HEAVY	VERY HEAVY

Life index= hours in a mist chamber according standard ASTM B 117 equivalent to ISO 9227 (Neutral salt mist)
Failure mode: corrosin index according to ISO 4540

Rod	test type	NSS	NSS		CASS
Corrosion	Hours	72	200		64
Resistance	Rating	>9	>9		>9

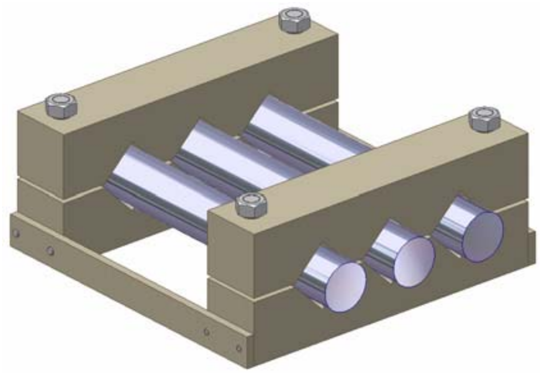
NSS-Neutral salt mist test
ASTM B 117 equivalent to ISO 9227

CASS-Copper Accelerated Acetic Acid Salt Spray Test Method
B0368-97R03E01

- “corrosion resistance test ” with different type of chrome plated, oxynitrocarburated and ceramic bars.

Test bar dimensions : **ø30 x 200**

Areas to test (Mines, sea areas, etc.):



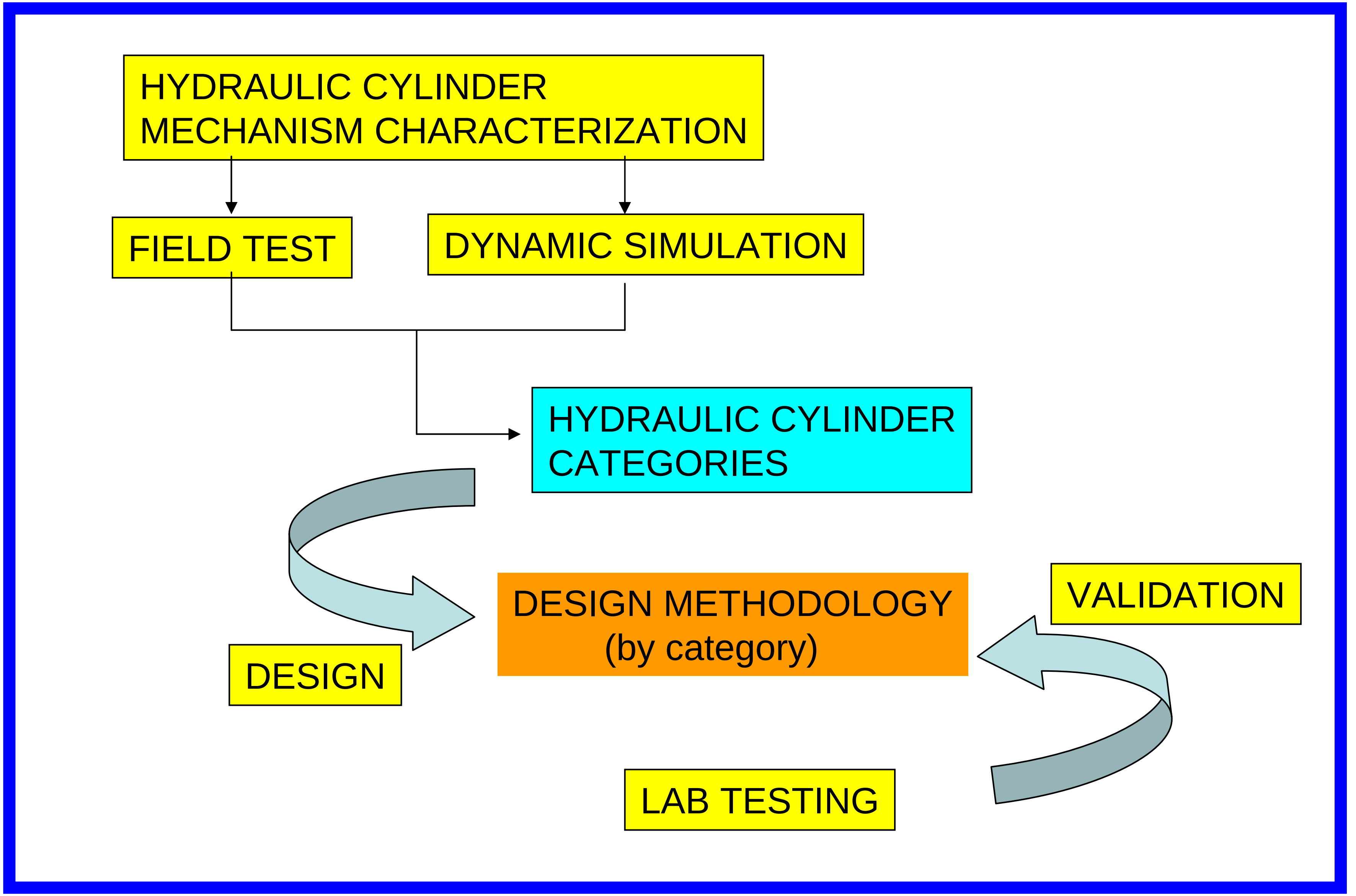
Coating types to be tested

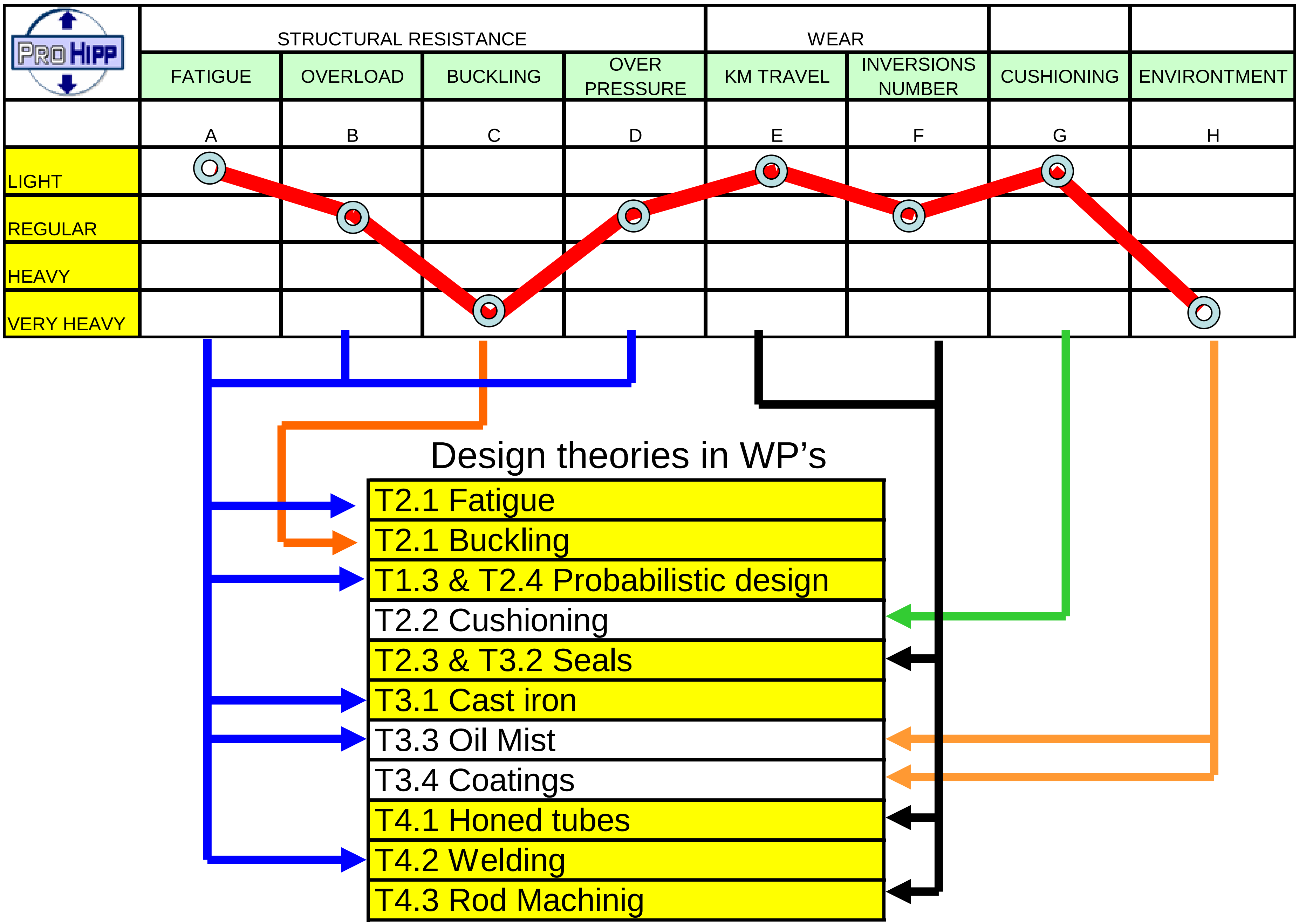
- Chrome plated

- Induction hardened Chrome plated

- Oxinitrocarburated

Photos by P ROQUET/ HEF / BCE


HYDRAULIC CYLINDER
MECHANISM CHARACTERIZATION
FIELD TEST
DYNAMIC SIMULATION
HYDRAULIC CYLINDER
CATEGORIES
DESIGN METHODOLOGY
(by category)
VALIDATION
DESIGN
LAB TESTING


ProHipp
STRUCTURAL RESISTANCE
WEAR
FATIGUE
OVERLOAD
BUCKLING
OVER PRESSURE
KM TRAVEL
INVERSIONS NUMBER
CUSHIONING
ENVIRONTMENT
A
B
C
D
E
F
G
H
LIGHT
REGULAR
HEAVY
VERY HEAVY
Design theories in WP's
T2.1 Fatigue
T2.1 Buckling
T1.3 & T2.4 Probabilistic design
T2.2 Cushioning
T2.3 & T3.2 Seals
T3.1 Cast iron
T3.3 Oil Mist
T3.4 Coatings
T4.1 Honed tubes
T4.2 Welding
T4.3 Rod Machinig