AIGA 2007 MEETING

PACKAGED GASES SAFETY

30-31 August 2007
PATTAYA, THAILAND

Asia Industrial Gases Association

ISO CYLINDERS
DESIGN AND MANUFACTURE

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AIR LIQUIDE – Paris (France)

INTRODUCTION

1. Structure of ISO/TC 58
2. P and O Members
3. List of cylinder design standards

- ✓ Seamless steel
- ✓ Seamless aluminium
- ✓ Seamless stainless steel
- ✓ Welded steel
- ✓ Welded stainless steel
- ✓ Welded aluminium
- ✓ Composite
- ✓ Non-refillable
- ✓ Tubes - Drums

INTRODUCTION

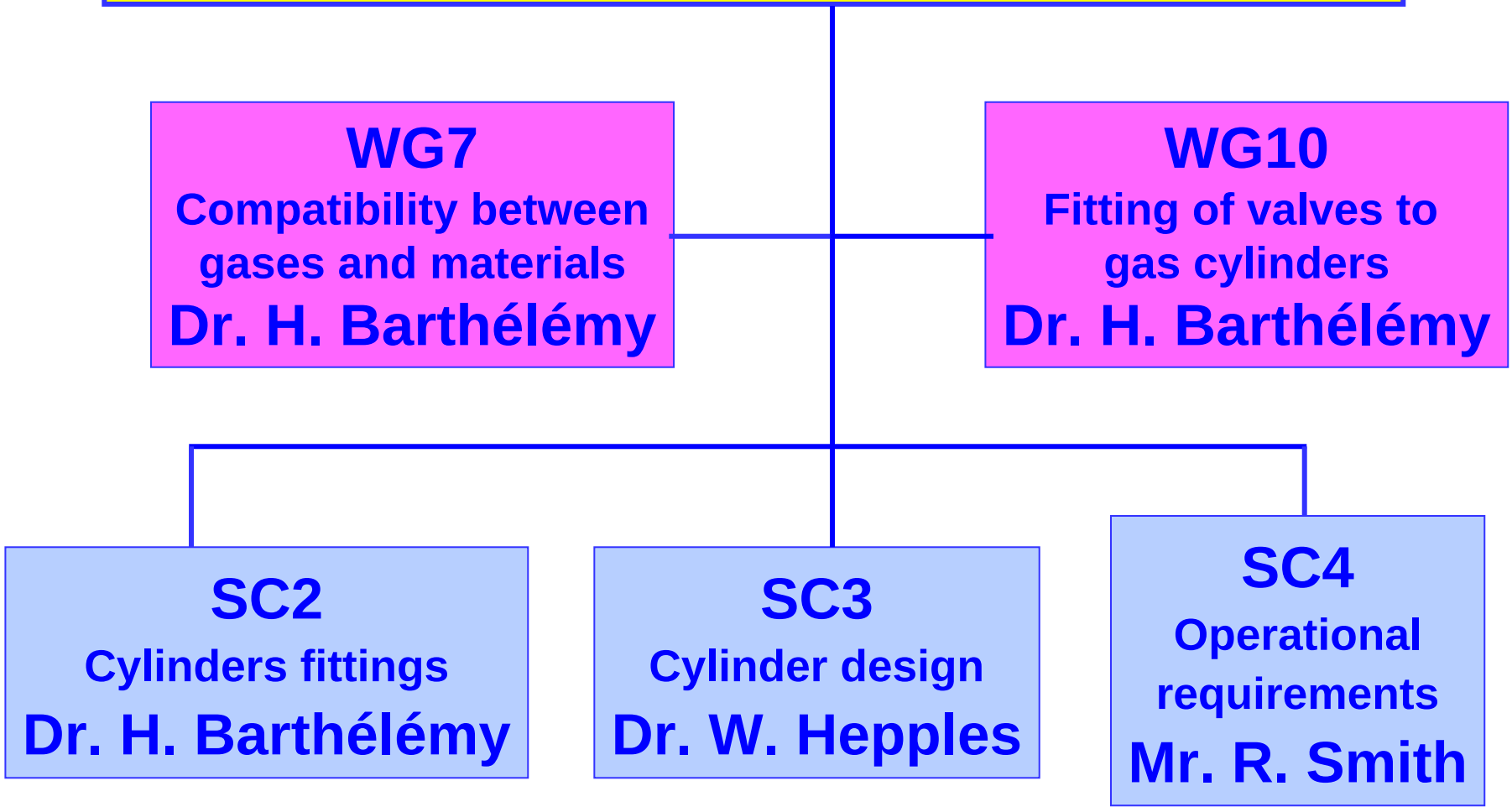
4. Cylinder design (Formula – Specific requirement for high strength steel and aluminium)

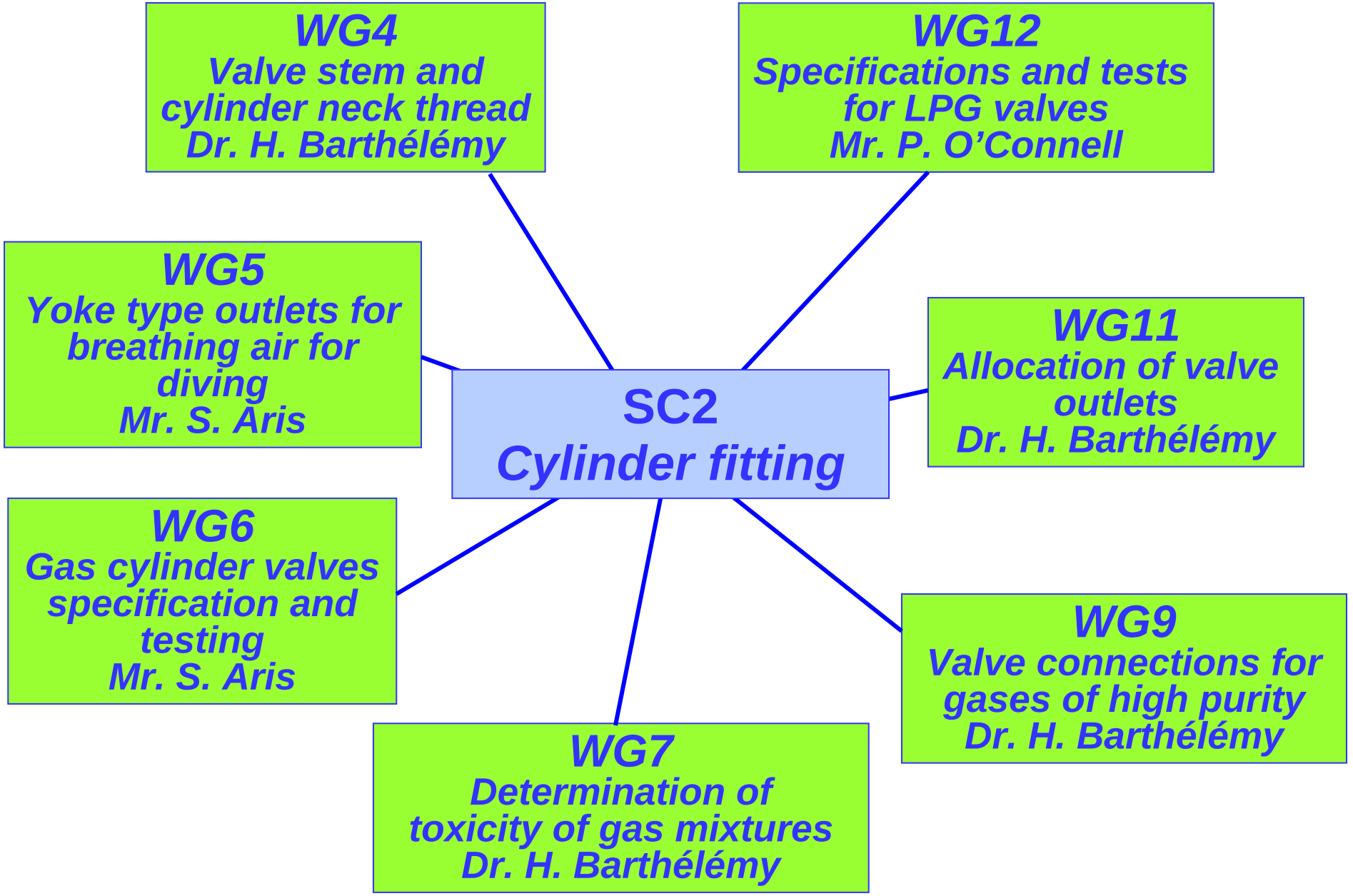
5. Materials – Gas/Material compatibility – Hydrogen Compatibility – Oxygen compatibility

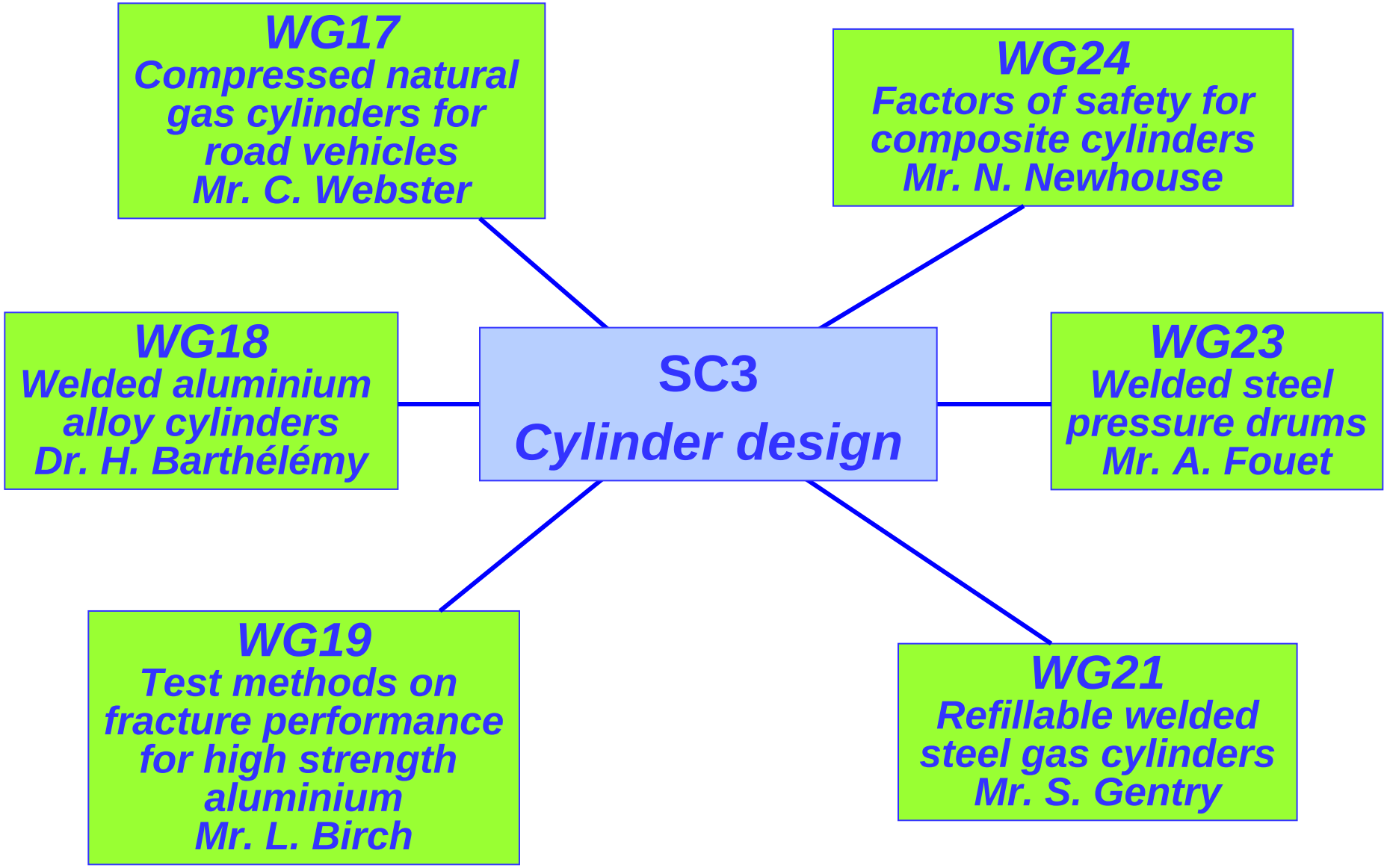
6. Use of ISO standards (UN – Europe – North America – Other countries

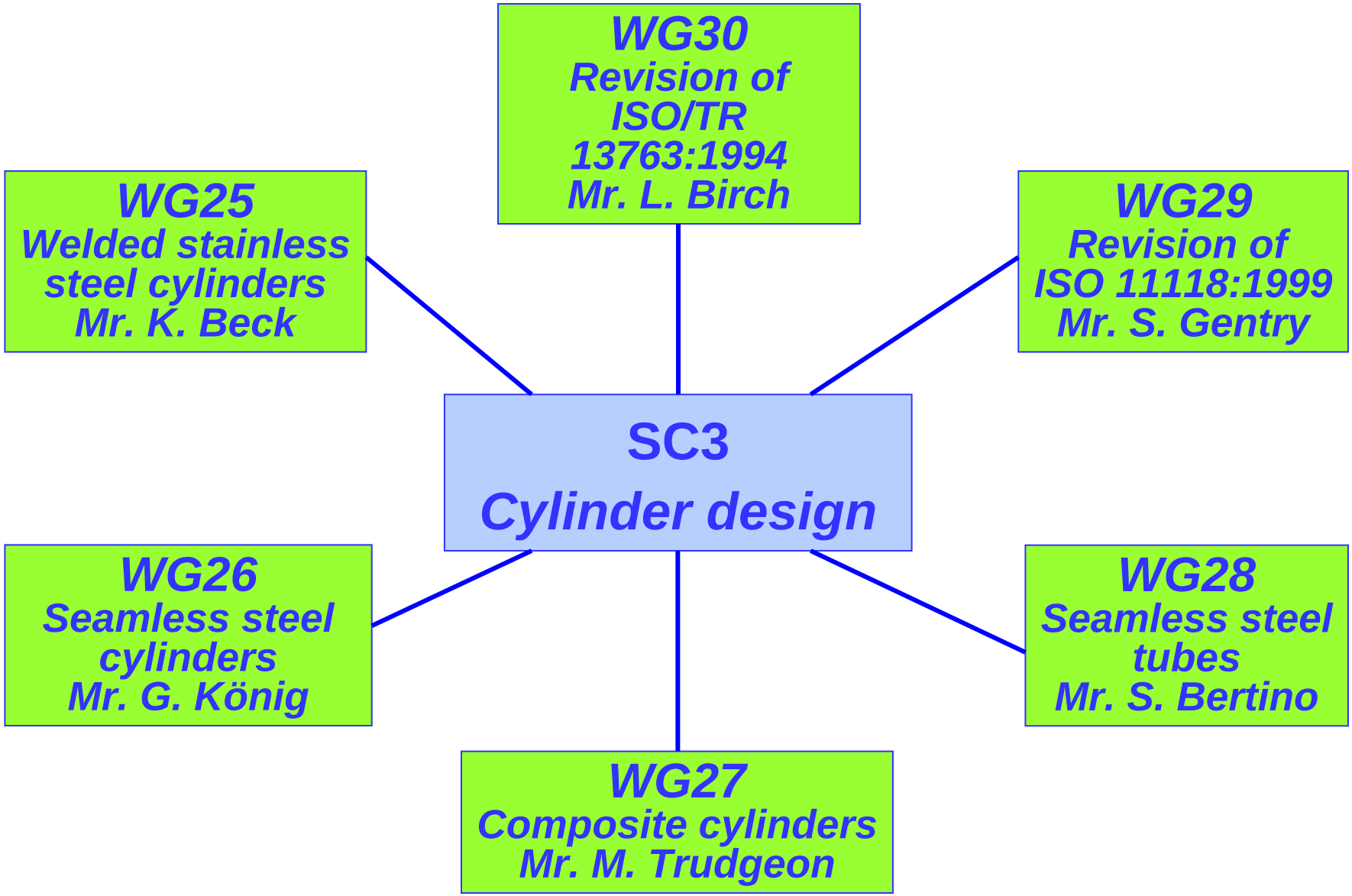
7. Conclusions

1. STRUCTURE ISO/TC 58 – Gas cylinders
Dr. C. Jubb




WG4
Valve stem and cylinder neck thread
Dr. H. Barthélémy
WG12
Specifications and tests for LPG valves
Mr. P. O'Connell
WG5
Yoke type outlets for breathing air for diving
Mr. S. Aris
SC2
Cylinder fitting
WG11
Allocation of valve outlets
Dr. H. Barthélémy
WG6
Gas cylinder valves specification and testing
Mr. S. Aris
WG9
Valve connections for gases of high purity
Dr. H. Barthélémy
WG7
Determination of toxicity of gas mixtures
Dr. H. Barthélémy


WG17
Compressed natural gas cylinders for road vehicles
Mr. C. Webster
WG24
Factors of safety for composite cylinders
Mr. N. Newhouse
WG18
Welded aluminium alloy cylinders
Dr. H. Barthélémy
SC3
Cylinder design
WG23
Welded steel pressure drums
Mr. A. Fouet
WG19
Test methods on fracture performance for high strength aluminium
Mr. L. Birch
WG21
Refillable welded steel gas cylinders
Mr. S. Gentry


WG30
Revision of ISO/TR 13763:1994
Mr. L. Birch
WG25
Welded stainless steel cylinders
Mr. K. Beck
WG29
Revision of ISO 11118:1999
Mr. S. Gentry
SC3
Cylinder design
WG26
Seamless steel cylinders
Mr. G. König
WG28
Seamless steel tubes
Mr. S. Bertino
WG27
Composite cylinders
Mr. M. Trudgeon

2. P AND O MEMBERS

P	O	MEMBER BODY	P	O	MEMBER BODY
	X	ARGENTINA (IRAM)		X	CROATIA (DZNM)
X		AUSTRALIA (SAA)		X	CUBA (NC)
X		AUSTRIA (ON)		X	CZECH REPUBLIC (CSNI)
	X	BARBADOS (BNSI)	X		DENMARK (DS)
X		BELGIUM (IBN)	X		ECUADOR (INEN)
	X	BRAZIL(ABNT)		X	EGYPT (EOS)
	X	CAMEROON (CDNQ)	X		FINLAND (SFS)
X		CANADA (SCC)	X		FRANCE (AFNOR)
	X	CHILE (INN)	X		GERMANY (DIN)
x		CHINA (CSBTS)		X	GREECE (ELOT)
	x	COLOMBIA (ICONTEC)		X	HONG KONG, CHINA (ITCHKSAR)

P	O	MEMBER BODY	P	O	MEMBER BODY
	X	HUNGARY (MSZT)		X	LUXEMBOURG (SEE)
X		INDIA (BIS)	X		MALAYSIA (DSM)
	X	INDONESIA (BSN)		X	MOLDOVA, REP. OF (MOLDST)
X		IRAN, ISLAMIC REPUBLIC OF (ISIRI)		X	MONGOLIA (MNCSM)
	X	IRELAND (NSAI)		X	NETHERLANDS (NNI)
X		ITALY (UNI)	X		NEW ZEALAND (SNZ)
X		JAMAICA (JBS)		X	OMAN (DGSM)
X		JAPAN (JISC)		X	PAKISTAN (PSI)
X		KENYA (KEBS)	X		PHILIPPINES (BPS)
x		KOREA, REPUBLIC OF (KATS)		X	POLAND (PKN)
	X	LITHUANIA (LST)		X	PORTUGAL (IPQ)

P	O	MEMBER BODY	P	O	MEMBER BODY
	X	ROMANIA (ASRO)		X	TANZANIA, UNITED REP. of (TBS)
	X	RUSSIAN FEDERATION (GOST R)		X	THAILAND (TISI)
	X	SAUDI ARABIA (SASO)		X	TRINIDAD AND TOBAGO (TTBS)
	X	SERBIA (ISS)		X	TUNISIA (INNORPI)
	X	SINGAPORE (PSB)		X	TURKEY (TSE)
	X	SLOVAKIA (SUTN)		X	UKRAINE (DSTU)
	X	SLOVENIA (SMIS)	X		UNITED KINGDOM (BSI)
X		SOUTH AFRICA (SABS)		X	URUGUAY (UNIT)
X		SPAIN (AENOR)	X		USA (ANSI)
X		SWEDEN (SIS)		X	VENEZUELA (FONDONORMA)
	X	SWITZERLAND (SNV)		X	VIETNAM (TCVN)

3. LIST OF CYLINDER DESIGN STANDARDS

SEAMLESS STEEL

EN ISO 9809 : 1999 **Seamless steel**

Part 1 : tensile strength < 1 100 Mpa

Part 2 : tensile strength > or equal to 1 100 Mpa

Part 3 : Normalized steel

Part 4 : R_m value of < 1 100 MPa

3. LIST OF CYLINDER DESIGN STANDARDS

SEAMLESS ALUMINIUM

EN ISO 7866 : 1999 — **Seamless aluminium Design, construction and testing**

WELDED STEEL

ISO 4706 : 1989 — **Welded steel**

Part 1 : Test pressure 60 bar and below

Part 2 : Test pressure > 60 bar

3. LIST OF CYLINDER DESIGN STANDARDS

WELDED STAINLESS STEEL

ISO FDIS 18172 — **Welded stainless steel**
Part 1 : Test pressure 6 MPa and below

Part 2 : Test pressure > 6 MPa

WELDED ALUMINIUM

ISO 20703 : 2006 — **Welded aluminium**
Design, construction and testing

3. LIST OF CYLINDER DESIGN STANDARDS

COMPOSITE

ISO 11119 : 2002 **Composite**

Part 1 : Hoop wrapped

Part 2 : Fully wrapped with load-sharing metal liners

Part 3 : Fully wrapped with non load-sharing metallic or non-metallic liners

3. LIST OF CYLINDER DESIGN STANDARDS

NON-REFILLABLE

ISO 11118 : 1999
Non-refillable cylinder

3. LIST OF CYLINDER DESIGN STANDARDS

TUBES

ISO 11120 : 1999 **Refillable seamless steel Design construction and testing**

3. LIST OF CYLINDER DESIGN STANDARDS

DRUMS

ISO/CD 21172 **Part 1 : Capacities up to 1 000 liters**

Part 2 : Capacities up to 3 000 liters

3. LIST OF CYLINDER DESIGN STANDARDS

VEHICLE TANKS

ISO 11439 : 2000 **Natural gas as a fuel for automotive vehicles**

ISO/DIS 15869 **Hydrogen vehicle tanks**

4. CYLINDER DESIGN - FORMULA

$$a = \frac{D}{2}\left(1 - \sqrt{\frac{10\,F\,R_e - \sqrt{3}\,p_h}{10\,F\,R_e}}\right)$$

Where the value of F is the lesser of $\frac{0.65}{R_e / R_g}$ or 0.85

Re/Rg shall not exceed 0,90

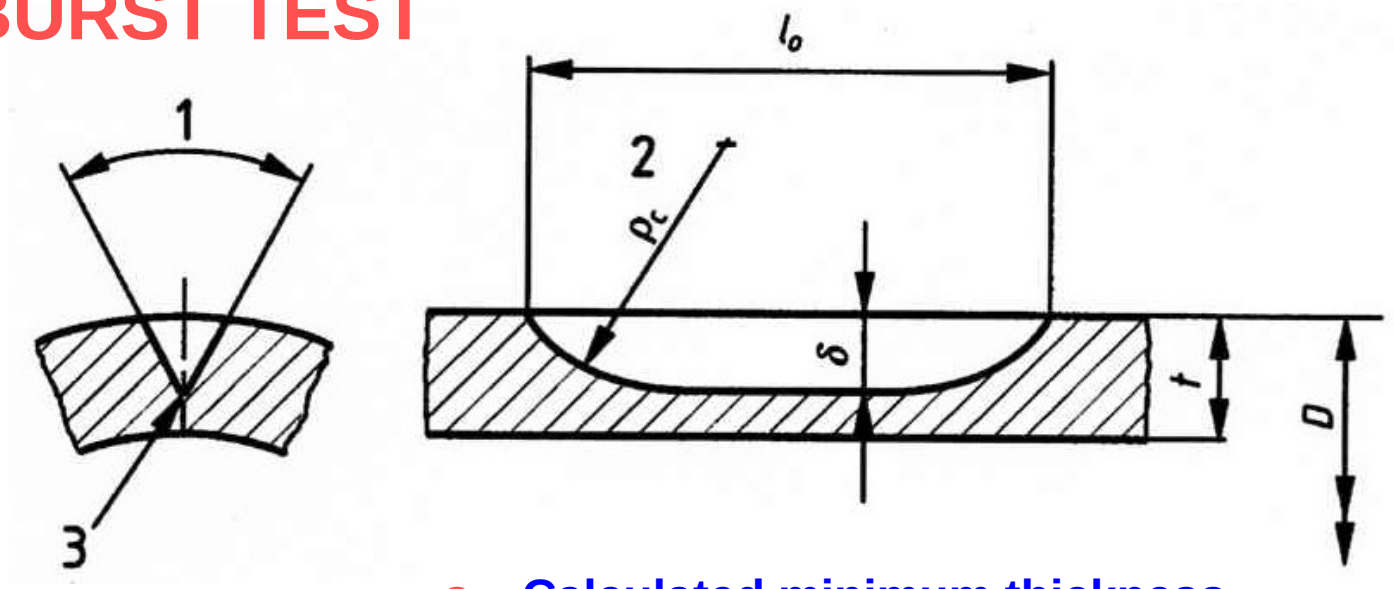
The wall thickness shall also satisfy the formula

$$a \geq \frac{D}{250} + 1$$

With an absolute minimum of a = 1.5 mm

4. CYLINDER DESIGN - SPECIFIC REQUIREMENTS FOR HIGH STRENGTH STEEL AND ALUMINIUM

FLAW BURST TEST



1. 45° angle of flaw
2. Run out radius
3. Flaw root radius

a Calculated minimum thickness
D Outside diameter of the cylinder
l_o Surface length of artificial flaw

P_c Run out radius
t Actual thickness of the test specimen
δ Depth of artificial flaw greater than 60 % of t

5. MATERIALS

- **ISO 11114 Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents**

  Part 1 : Metallic materials

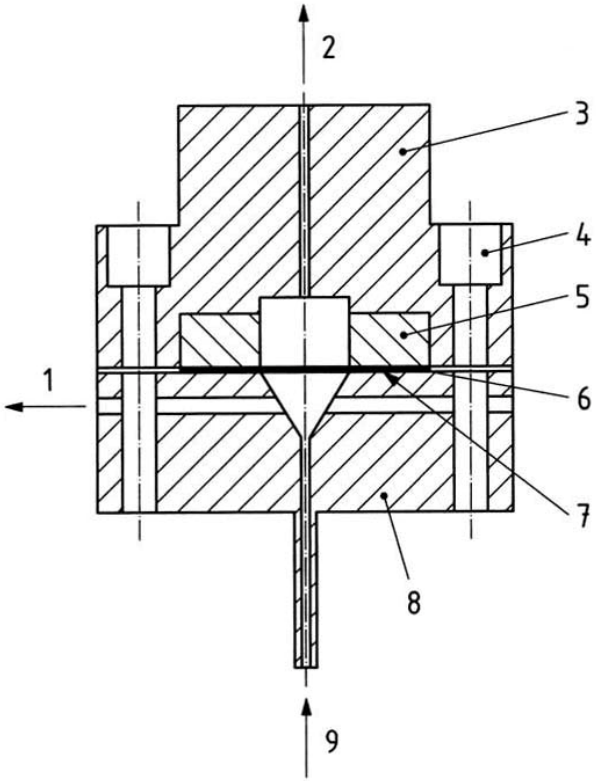
  Part 2 : Non-metallic materials

  Part 3 : Autogenous ignition test in oxygen atmosphere

  Part 4 : Test methods for selecting metallic materials resistant to hydrogen embrittlement (Recently published, contains 3 methods)

5. MATERIALS

➢ ISO 11114-4 – Disc test (Method A)

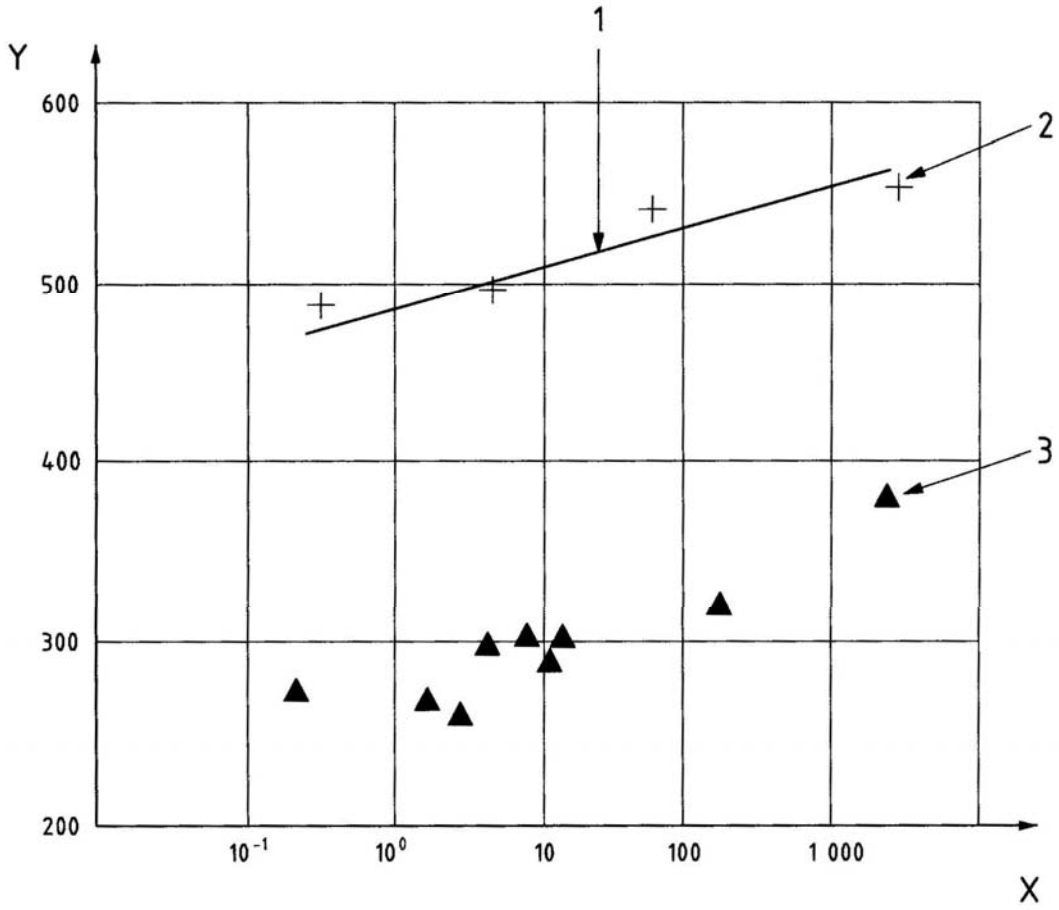


1. Port for evacuation and flow adjustment
2. Discharge port
3. Upper flange
4. Bolt hole
5. High-strength steel ring
6. Disc
7. O-ring
8. Lower flange
9. Gas inlet

Note: This method can also be used to perform H_2 pressure cyclic testing

Test installation (test cell)

5. MATERIALS



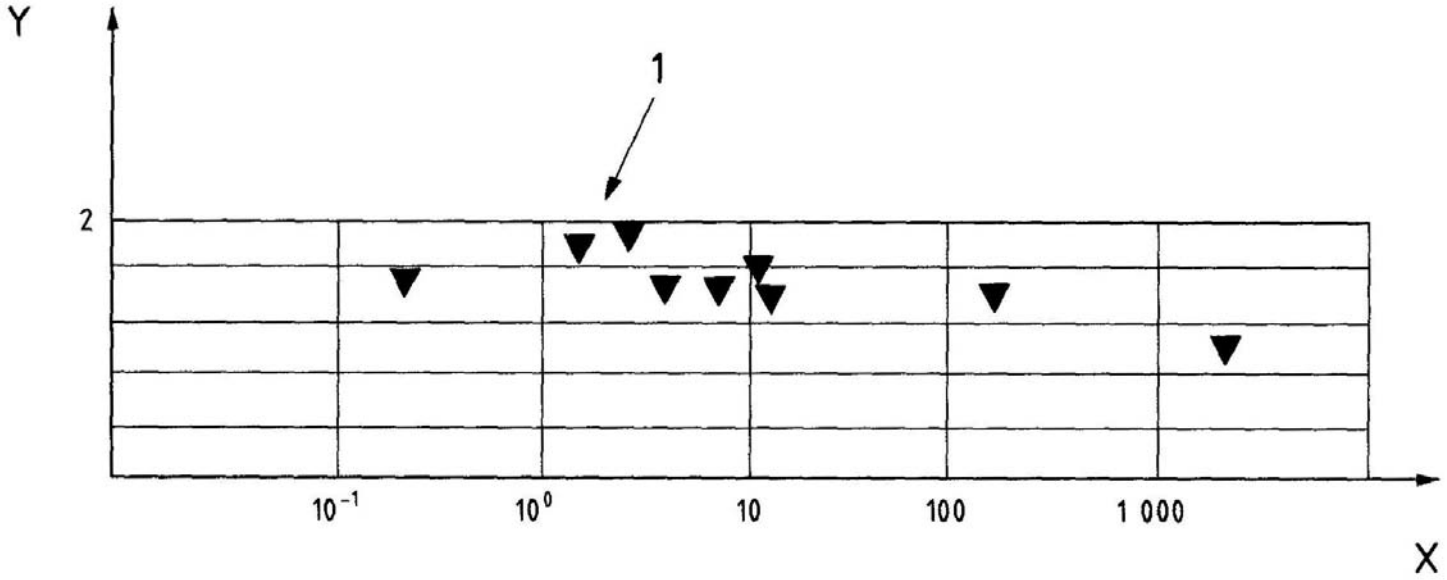
X. Pressure rise rate (bar/min)

Y. Corrected rupture pressure (bar)

1. Regression curve
2. Helium corrected rupture pressures ($P_{r'He}$)
3. Hydrogen corrected rupture pressures ($P_{r'H2}$)

Examples of hydrogen and helium corrected rupture pressure as a function of the pressure rise rate

5. MATERIALS



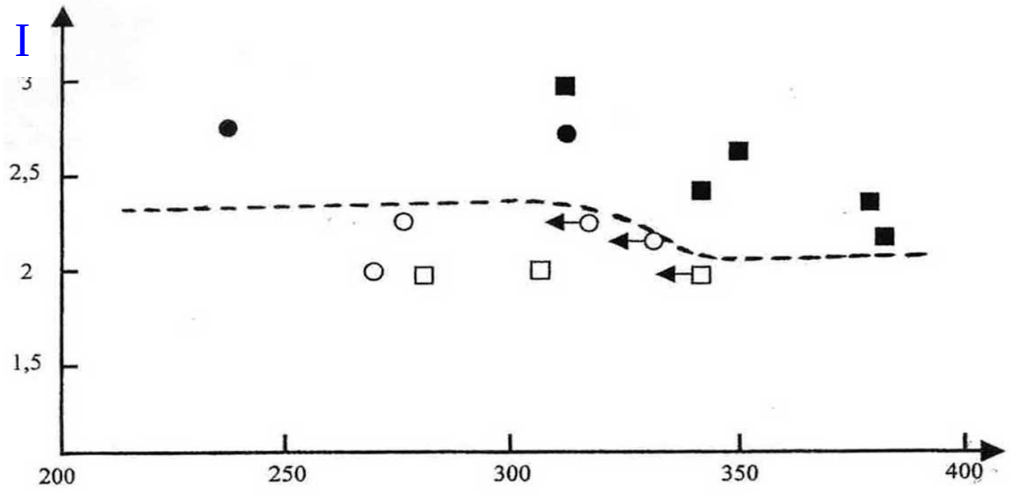
X. Pressure rise rate (bar/min)
Y. $P_{r'He}/P_{r'H2}$

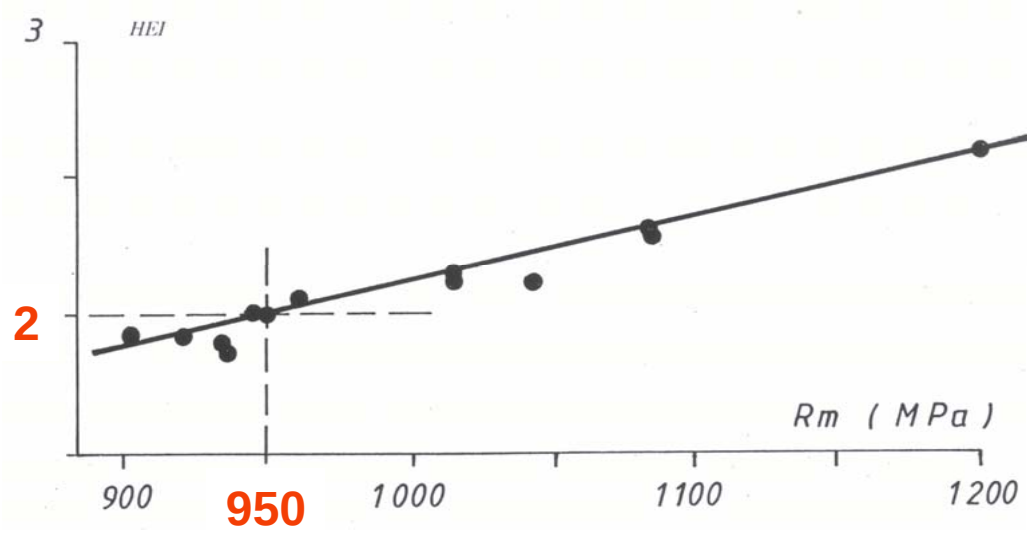
1. Hydrogen embrittlement index

Examples of the ratio $P_{r'He}/P_{r'H2}$ as a function of the pressure rise rate

5. MATERIALS

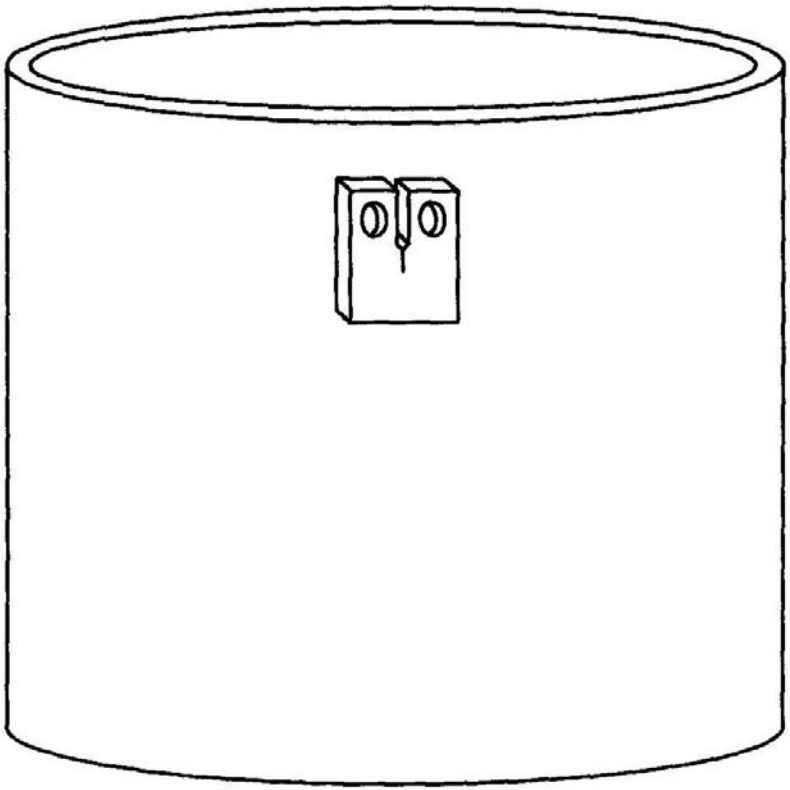
Embrittlement indices (I) of reference materials versus maximum wall stresses (σm)





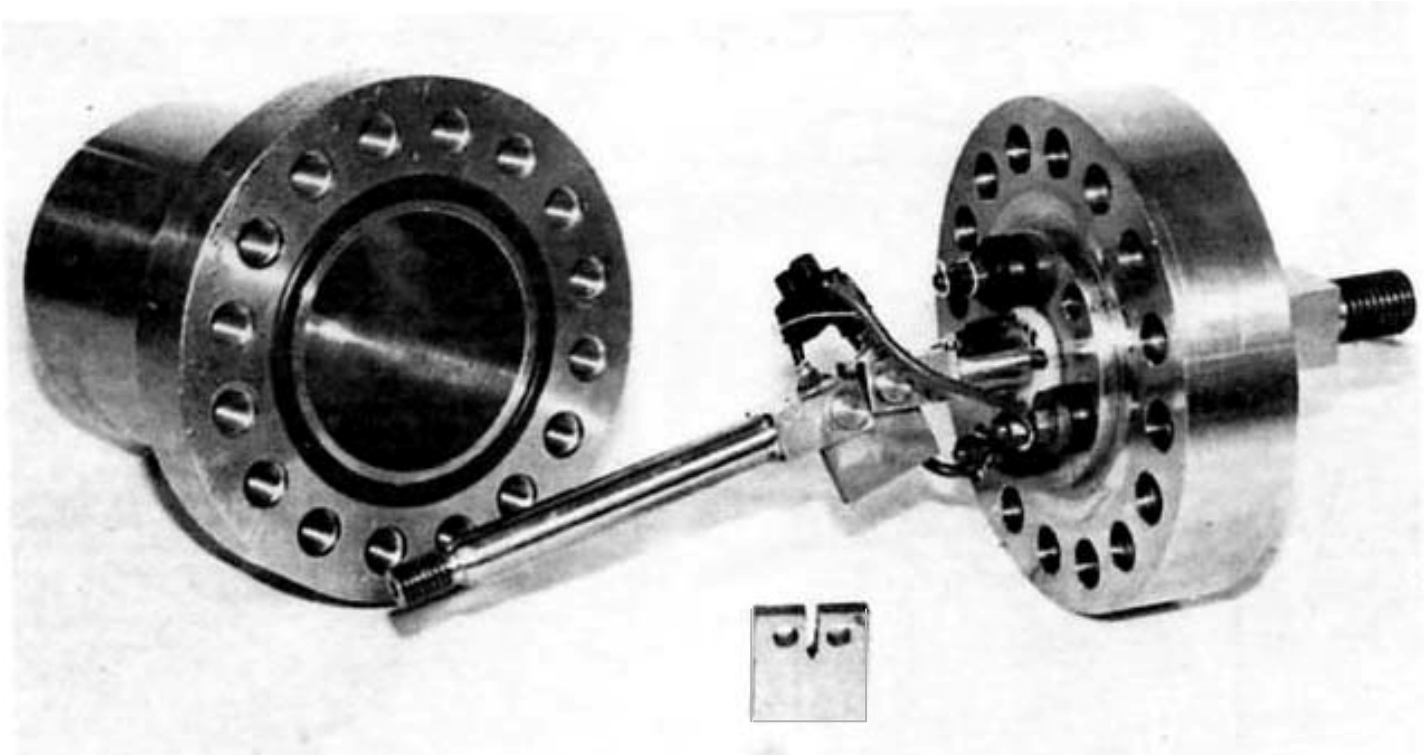
5. MATERIALS

ISO 11114-4 – Fracture mechanic test (Method B) – Test specimen



Compact tension test piece : type and orientation

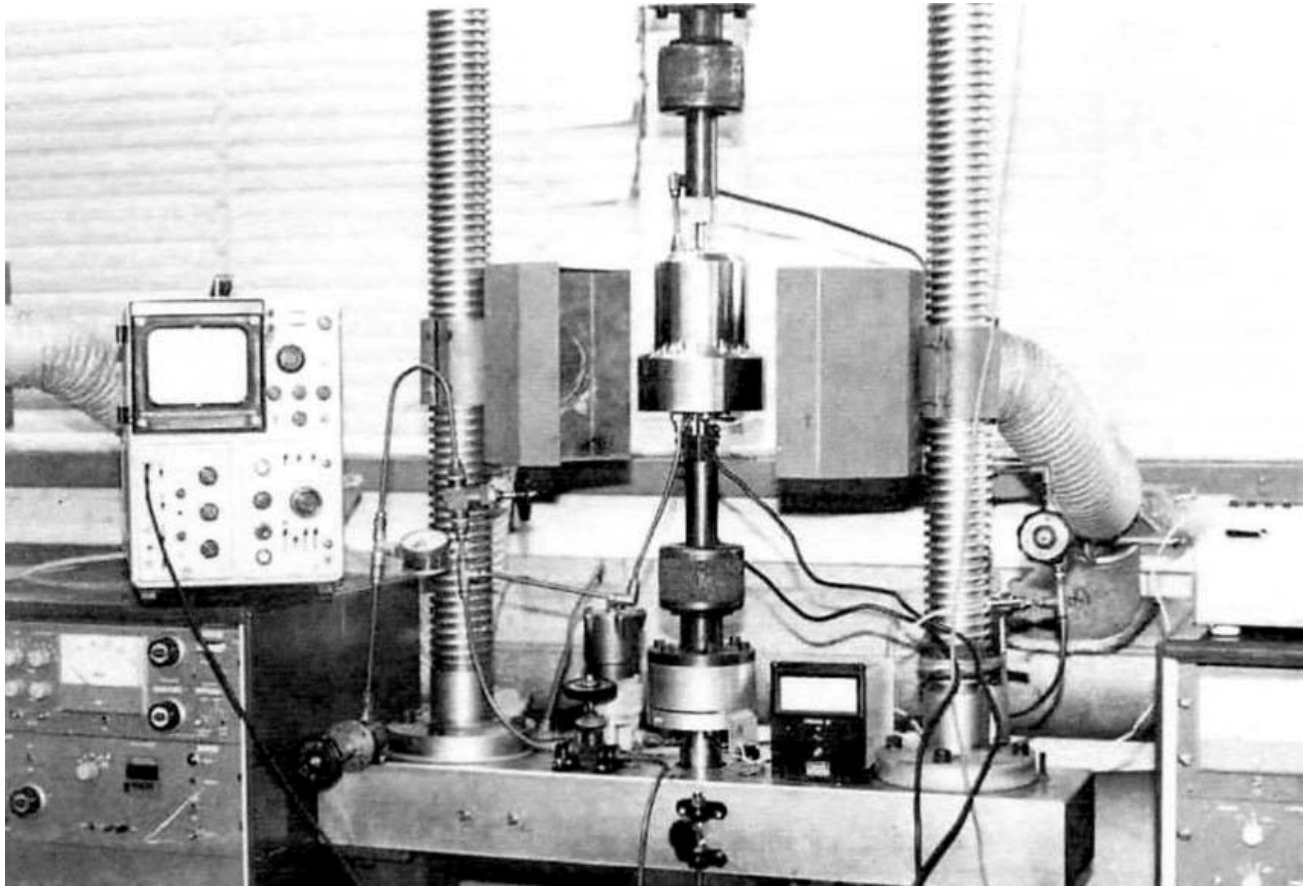
5. MATERIALS



Stainless steel chamber, showing loading bars and specimen

Note: It is important to evacuate air and moisture

5. MATERIALS



Servo-hydraulic test machine

5. MATERIALS

ISO 11114-4

- Test method to determine the resistance to hydrogen assisted cracking of steel cylinders (Method C)
- Principle: pre-cracked specimen loaded in air and put in H_2 for 1 000 hours
- Not retained in the EN 11114-4 version because specimen are not loaded in air

Note: 50 ppm O_2 (or less) greatly diminishes the H_2 embrittlement effect

6. IN WHICH COUNTRIES ARE ISO STANDARDS USED ?

- ISO standards referred in the UN Model regulations
- EUROPE introduced these standards in the ADR/RID
- USA (CANADA) referred in the HM 215
- Used in other countries (Australia, South Africa, etc.)
- Asia ?

7. CONCLUSIONS

- GOOD ISO STANDARDS ARE AVAILABLE FOR CYLINDER DESIGN
- COVER ALL TYPE OF CYLINDERS (SEAMLESS, WELDED, COMPOSITE, etc.)
- SHOULD BE THE TOOL TO HARMONIZE CYLINDER DESIGN