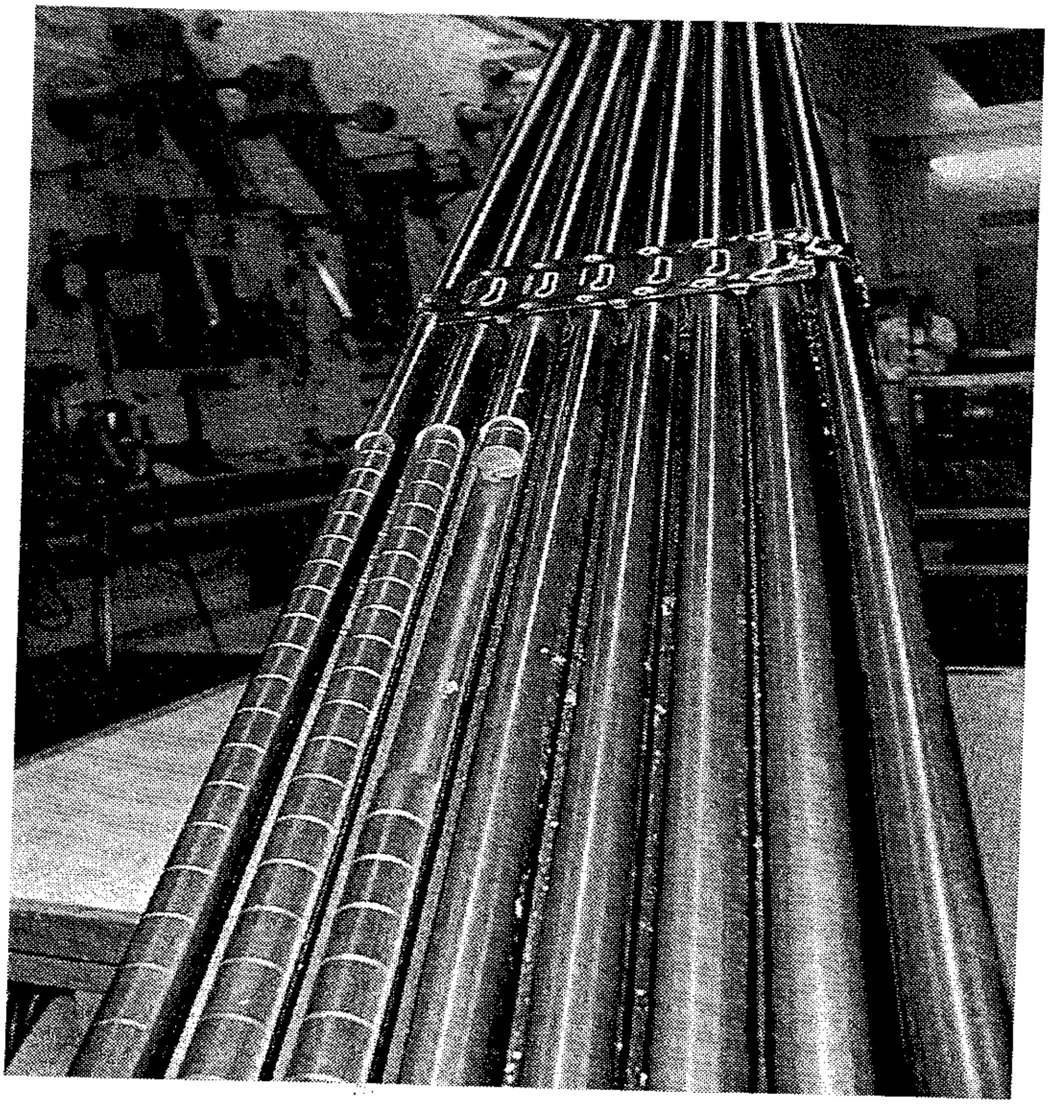
EWG "Hot Laboratories & Remote Handling" 21-23/5/'98 Windscale - UK

PAUL SCHERRER INSTITUT

27

Optimisation of the process for the determination of Fission Gas Release

from reactor fuel pins



P. Schleuniger. A. Hermann

Structural Materials and Corrosion

Introduction

In the framework of non-destructive PIE (Post - Irradiation - Examination) work at PSI, we are performing fission gas release measurements on irradiated fuel pins from Swiss BWR and PWR reactors.

The investigations consists of measuring the gas pressure, taking gas samples, calculating the free gas volume in the fuel pins, determining the gas composition using mass spectrometry, and calculating the fission gas release.

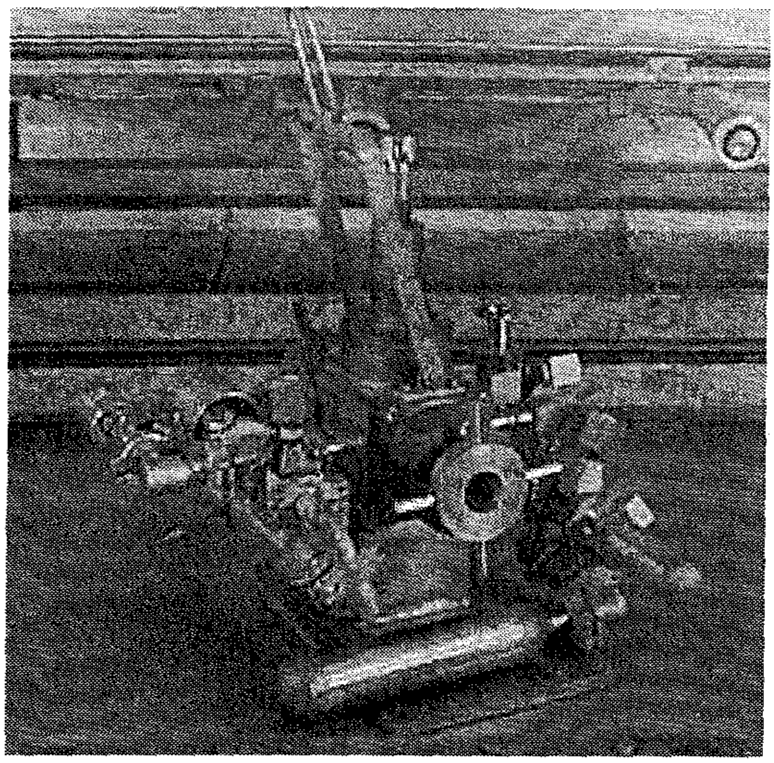
The goals of these gas release measurements are:

- **Developing advanced fuel pins for high burn - up and high power density**
- *Understanding the swelling behaviour of the fuel*
- **Determining the gas release of fuel pins**
- *Characterising the proportion of fissile isotopes in the gas*
- **Compiling a database for gas release modeling**
- *Checking the leakage of fuel pins*
- **Determining the total free volume of the fuel pin and the internal operating gas pressure**

Measurement technique

The fuel pin is pushed into the gas release station chamber, sealed on both sides with flat rubber seals and finally mechanically punctured with a steel needle. The gas is released into the gas chamber, while the pressure is recorded on a plotter. Following, the gas samples are collected for mass spectrometry. Afterwards, the free volume in the fuel pin is determined, and the amount and internal pressure of the fission gas finally calculated.

In - cell gas release station

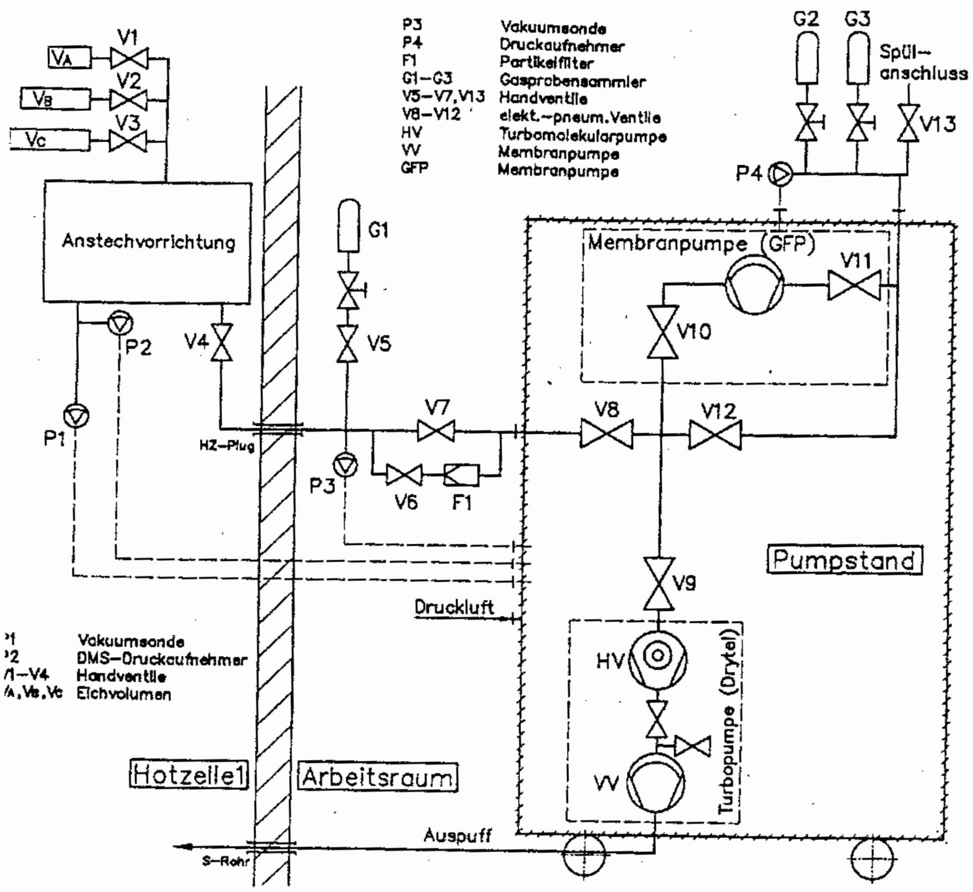


Technical data

Puncturing method:	Mechanical needle
Pin diameter:	8 - 14 mm
Dead volume:	≈ 190 cm^3
Volume of calibration chambers :	85.4. 345.8. 563.2 cm^3 ±0.1cm^3
Total leakage rate	1x10^{-6} mbar l/s
Pressure detection (strain gauge)	0-1000 mbar (error< 0.05%)
Vacuum gauge:	1000 to 1x 10^{-3} mbar

Optimisation of the gas release station

Layout

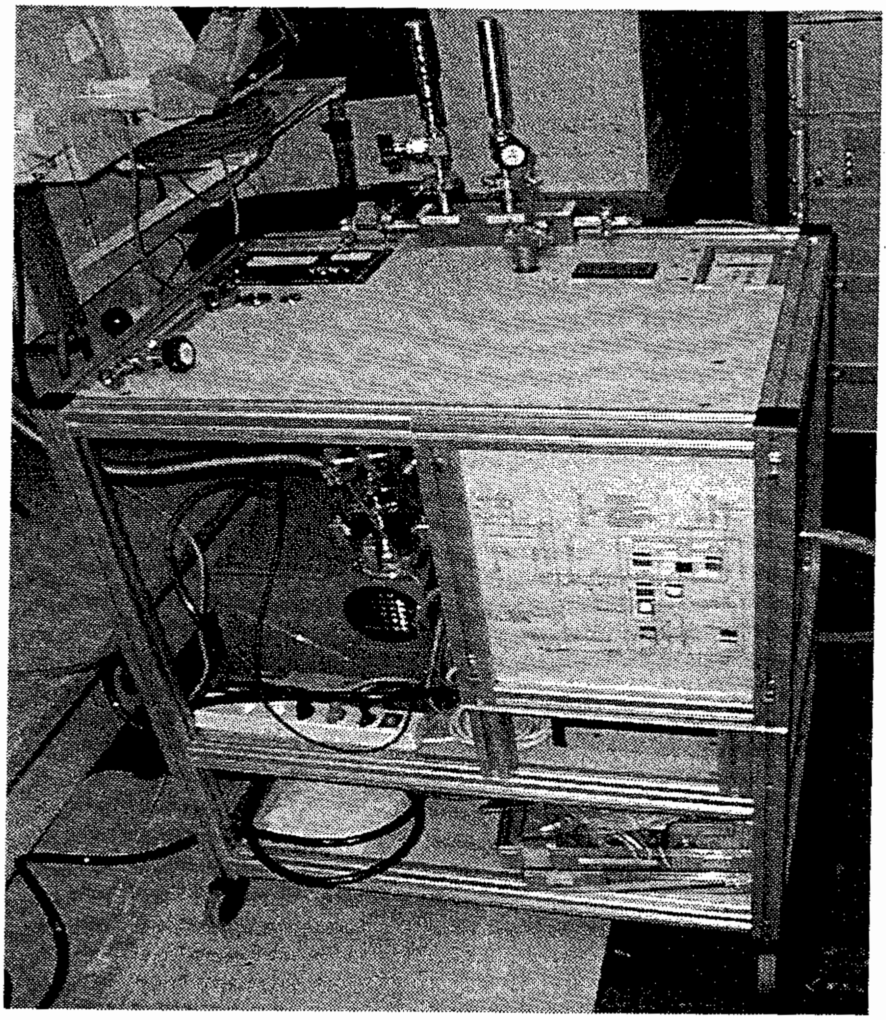


Improvements

Old version	New version
- Oil diffusion pump	- Turbo molecular pump
- Mercury Toepler pump	- Membrane pump (gas sampling)
- Gas phials made of glas	- Gas phials made of steel
- Mercury U-tube	- Electronic pressure gauge
- Electronically operated valves	- Pneumatically operated valves

Pumping facility

Pumping station



Technical data

Components	Performance	Leakage rate
Turbo molecular pump	1x 10^{-6} mbar at 4 l/s (He)	
Membrane pump	2 mbar at 3.3 m^3/h	< 5x 10^{-4} mbar l/s
Gas phials	50 cm^3 (including valve)	< 4x 10^{-9} mbar l/s (He)
Pirani gauge	1000 - 10^{-6} mbar	
Pressure gauge	0- 1000 mbar ±0.8%	(piezoresistive)
Pneumatic valves	1x 10^{-7} mbar up to 5 bar	
Puncturing unit with pumping station	1x 10^{-3} mbar at fuel pin (total volume 3000cm^3)	4x10^{-6} mbar l/s (4x10^{-3} mbar l/s) **

** (pumping station with membrane gas collecting pump)

Results

Extract from the standard tube certification

2 Gasfüllen und Eichstab verschliessen

Füllgas (Zertifiziert)	4474		Füllgas-Druck absolut bei 20°C	1.5	bar
Schweissprogramm-Nr.	32		SE-Offset (exzentrisch)	0,4	mm
SE-Seitenabstand	0,6	mm	SE-Winkel	90	Grad

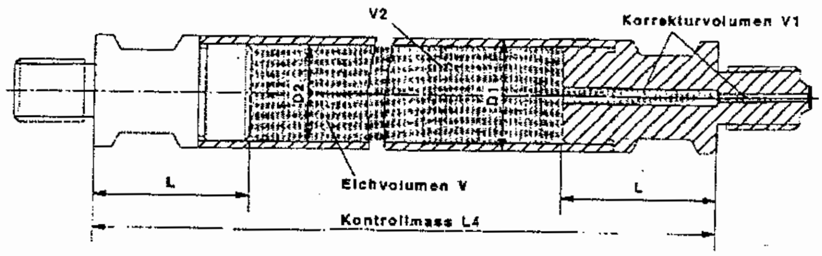
3 Eichstab kontrollieren

He-Leaktest bei Füllgas He	OK / ~~nicht OK~~		Röngtenuntersuchung-Nr.	KAL-Q3	
Innendurchmesser D2 (aus Zeichng.)	9.26	mm	Kontrollmass L4 ausmessen	200,2	mm
Volumen V2 berechnen	11.46	cm^3	Korrekturvolumen V1	0.0215	cm^3
Eichvolumen V berechnen	11.48	cm^3	Toleranz Eichvolumen ΔV_{max}	0,08	cm^3

$$V_2 = \frac{\pi \cdot D_2^2}{4} \cdot (L_4 - 2 \cdot L)$$

$$V = V_1 + V_2$$

$$\Delta V_{max} = \frac{\pi \cdot 2 \cdot D_2 \cdot \Delta D_2}{4} \cdot (L_4 - 2L) + \frac{\pi \cdot D_2^2}{4} \cdot 2 \cdot \Delta L$$



Results obtained with the new gas release station

determination of the dead volume in the puncturing unit

Average over 6 measurements: 183.3 cm^3 ± 0.30cm^3

Determination of the free volume in the standard tube

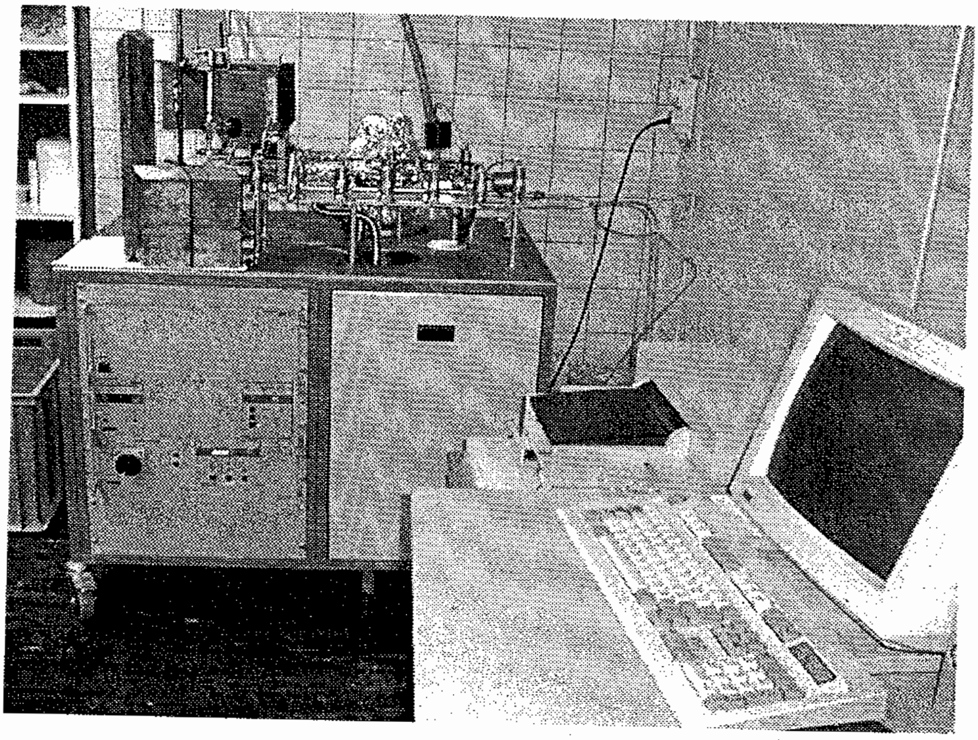
Average over 6 measurements: 11.44 cm^3 ± 0.37cm^3

Calculation of the gas pressure in the standard tube

Calculated gas pressure: 1.4 bar

Gas analysis

Mass spectrometer



Comparison between internal and external results of gas measurements on a standard tube

Gas component	Calibration gas 702 [Vol. %]	PSI tube Q3 [Vol. %]	Difference %(relative)	external Analysis tube Q6 [Vol. %]	Difference % (relative)
Krypton	0.98 ±0.03	0.24	-75	1.73	76
Argon	1.18 ±0.03	0.92	-22	1.09	-7
Xenon	14.31 ±0.51	3.54	-75	20.83	45
Helium	72.77±0.73	19.60	-70	65.9	-9
Nitrogen	8.47±0.18	59.53	603	8.21	-3
Oxygen	1.73±0.09	15.75	810	1.73	0
CO_2	0.565±0.016	0.42	-8	0.506	0
Sum	100	100		100	

Fission gas ratio:

He/Xe	5.09	5.54		3.16	
Xe/Kr	14.6	14.75		12.04	

Measurements with the new gas sampling station

Amount of air in the gas samples [%]

Project:	Gas sample 1	Gas sample 2	Gas sample 3*	Gas sample 4	Gas volume [ml]	Gas pressure [bar]	time between puncturing and analysis [days]
PWR program 1	0.181	0.097	0.800	0.481	1665.6	74.8	0
PWR program 1	0.000	0.092	0.238	0.213	1518.9	71.3	1
PWR program 1	0.930	0.047	0.239	0.410	1072.7	42.5	7
PWR program 1	0.133	0.047	0.182	0.410	791	29.7	5
PWR program 1	0.000	0.000	0.045	0.000	954.6	38.4	8
BWR program 2	0.000	0.000	0.539	0.000	244.5	12.5	14
BWR program 2	0.627	0.154	0.128	0.095	246.5	13.3	10
BWR program 2	0.047	0.035	0.361	0.256	155.6	7.7	20
BWR program 2	0.029	0.243	0.301	0.109	157	6.8	21
BWR program 3	0.037	0.031	0.330	0.490	153	7.1	28
BWR program 4	0.083	0.031	**2.232**	0.132	633.5	21.5	42
BWR program 4	0.020	0.017	**1.588**	0.266	382	14	32
BWR program 4	0.073	0.040	0.538	0.196	782.4	21.1	19
PWR program 2	0.013	0.027	0.133	0.067	875	56.6	14
PWR program 2	0.024	0.008	0.193	0.155	1050.5	56.6	18
PWR program 2	0.010	0.001	0.091	0.051	1011.5	53.3	21
BWR program 5	0.029	0.093	0.105	0.382	223.6	13.2	61
BWR program 5	**48.80**	0.133	0.159	0.215	176.4	8.6	19
BWR program 5	0.138	0.218	0.228	0.000	257.5	13.1	49
BWR program 5	0.380	0.045	0.040	0.000	154.6	7.2	34
Sum	2.756	1.359	8.470	3.927			
Average	**0.140**	**0.064**	**0.480**	**0.231**			

* gas collected using membrane pump

Up to now we have punctured 20 reactor fuel pins and have collected 80 gas samples. Only 3 samples exhibited air leakage.

Conclusions

The new gas extraction system has:

- proved safe to operate

- produced consistant gas samples

- shown good operational stability

- suitability to a range of pin diameters

- achieved exceptional accuracy

- in - cell electronic components which are essentially unaffected by radiation

Future prospects

We are planning future investigations into:

- the behaviour of the gas mixture in the sampling process (e.g. possible changes in gas composition)

- the influence of the membrane gas sampling pump

- pressure equilibration in full - length fuel pins during gas sampling and for void volume determi nation

- the elimination remaining risk of leakage at the pumping station

- measurement process integration into our quality management