Improvement of Fission Gas Analyzer

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Contents

1.Background

Reactor Fuel Examination Facility

A view of the facility

Operation room

OverView

- RFEF is one of the largest hot laboratories in Japan.
- RFEF performs PIEs on LWR spent fuels and materials to evaluate the safety and reliability.
- Safety research on the high burnup fuel is carried out as part of the PIEs at RFEF.

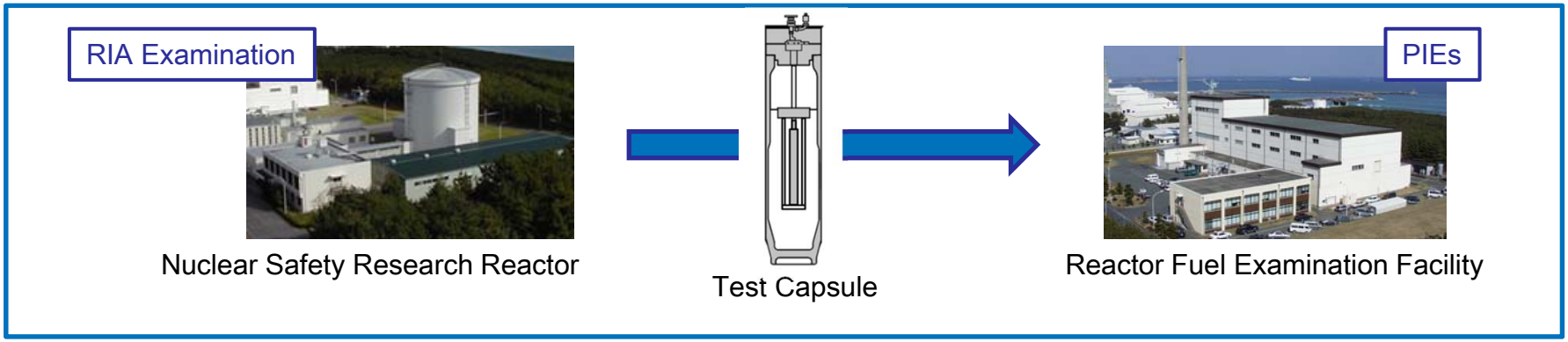
http://www.jaea.go.jp/english/04/ntokai/hot/hot_03.html

1.Background

Burnup of nuclear fuel has been be extended for the beneficial utilization.

➢ High burnup fuel must be evaluated to keep their safety.

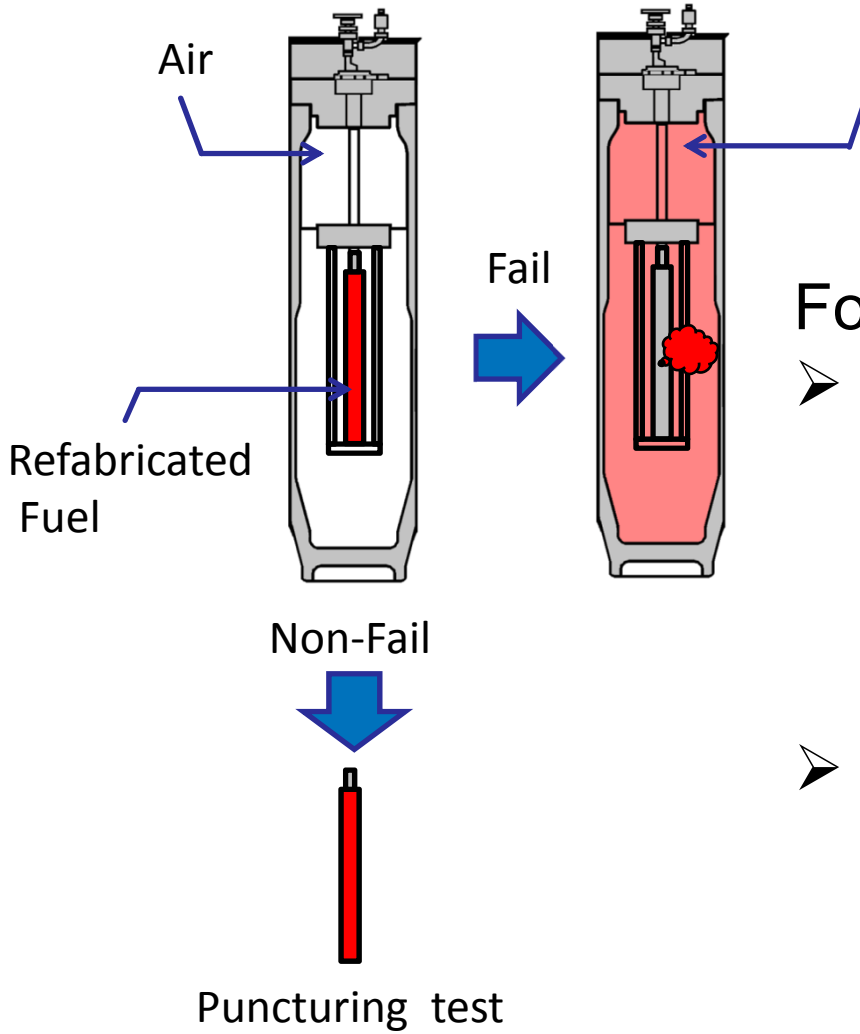
Fuel behavior during RIA condition is studied as a part of the safety research of High burnup fuel.



GC and the GC-MS were used to measure the volume and the isotopic ratio of Kr and Xe.

1.Background

FP gas is collected after RIA examination.



For the failed fuel

- FP gas is diluted by the large amount of air.
  - Dilution of Kr
  - N_2 affect to the Kr measurement

- Gas analyzer has been improved in two approaches, hardware and software.

2. Hardware approach

1.Background

2. Hardware approach
- 2.1 Improvement of apparatus
- 2.2 Evaluations
- 2.3 Results

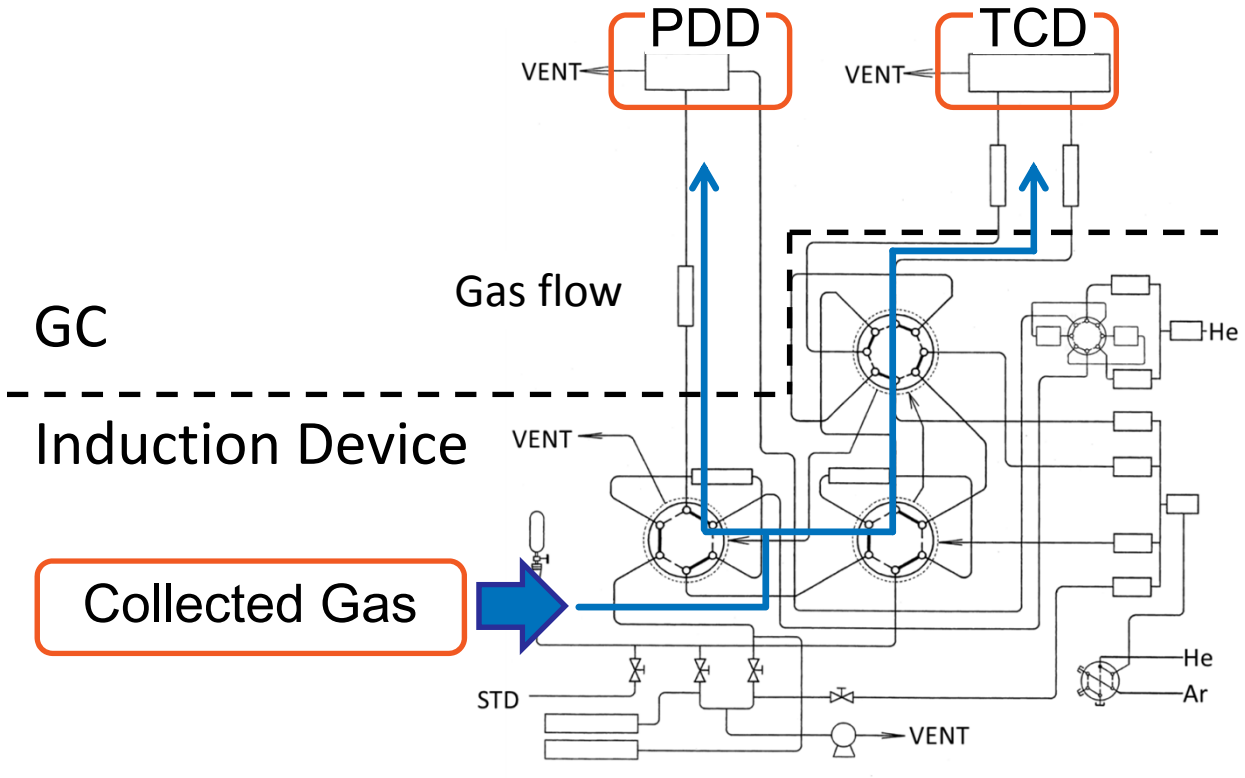
3. Software approach
- 3.1 Peak analysis
- 3.2 Evaluations
- 3.3 Results

4. Summary

2.1Improvement of apparatus

For the measurement of dilute Kr gas.

- High sensitivity detector PDD has been added.

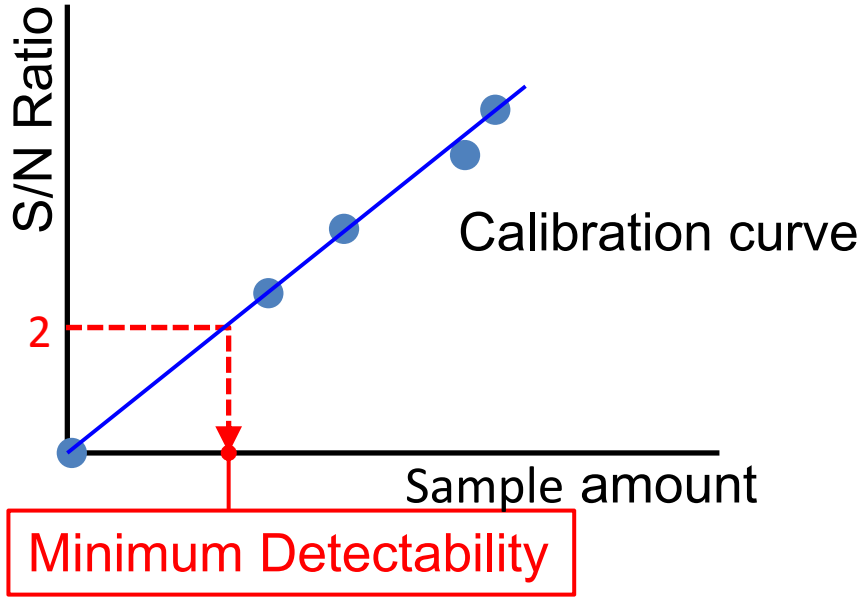


Schematic Diagram of the Fission gas Analyzer

2.2 Evaluations

Determination of the Minimum Detectability[1]

- Standard gas of 0.5 Kr% is measured.
- Varying gas volume and calibration curve of S/N ratio is calculated.
- Determine the Minimum detectability from calibration curve on S/N = 2.



[1] IUPAC Analytical Chemistry Division 9.2.4.4

2.3 Results

Results of the determinations

Component	Detector	Minimum Detectability (ppm)
Kr	TCD	5.27×10^{-1}
	PDD	1.05×10^{-3}

Minimum Detectability of TCD and PDD.

PDD has 500 times higher sensitivity compared with TCD.

3. Software approach

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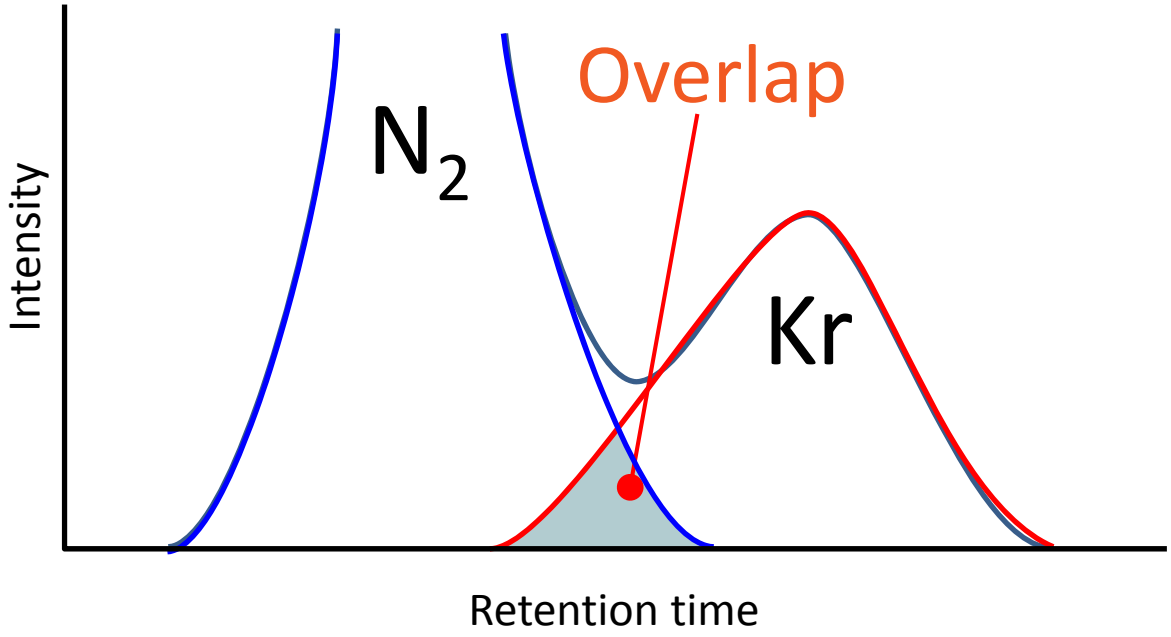
4. Summary

3.1 Peak analysis

For the Peak overlap of Kr and N_2

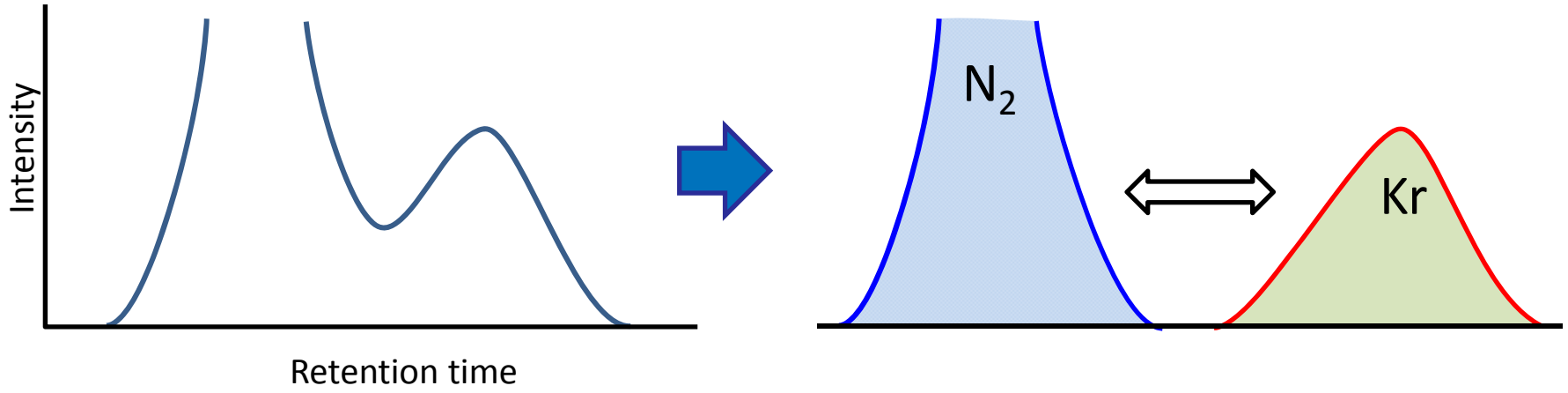


This overlap was caused by the closed retention times of the Kr and N_2.

- Peak overlap of Kr and N_2 affects measurement accuracy of Kr.

3.1 Peak analysis

Separate overlapped peak



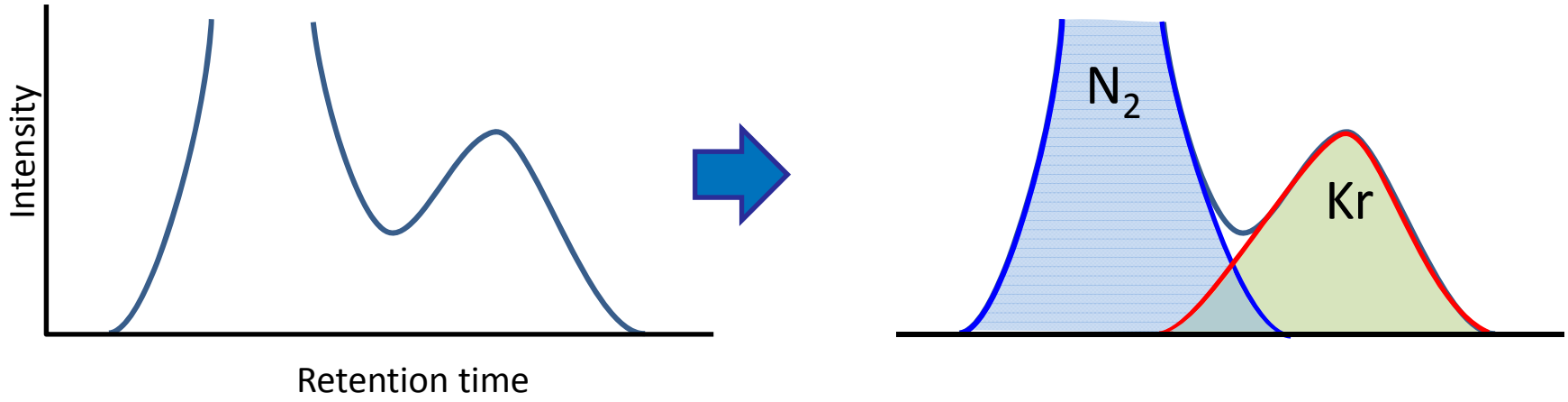
Optimization of measurement condition

- Longer measurement time
- Large amount of gas

➢ Prevent these problems

3.1 Peak analysis

Peak analysis



Deconvolute the overlapped peak

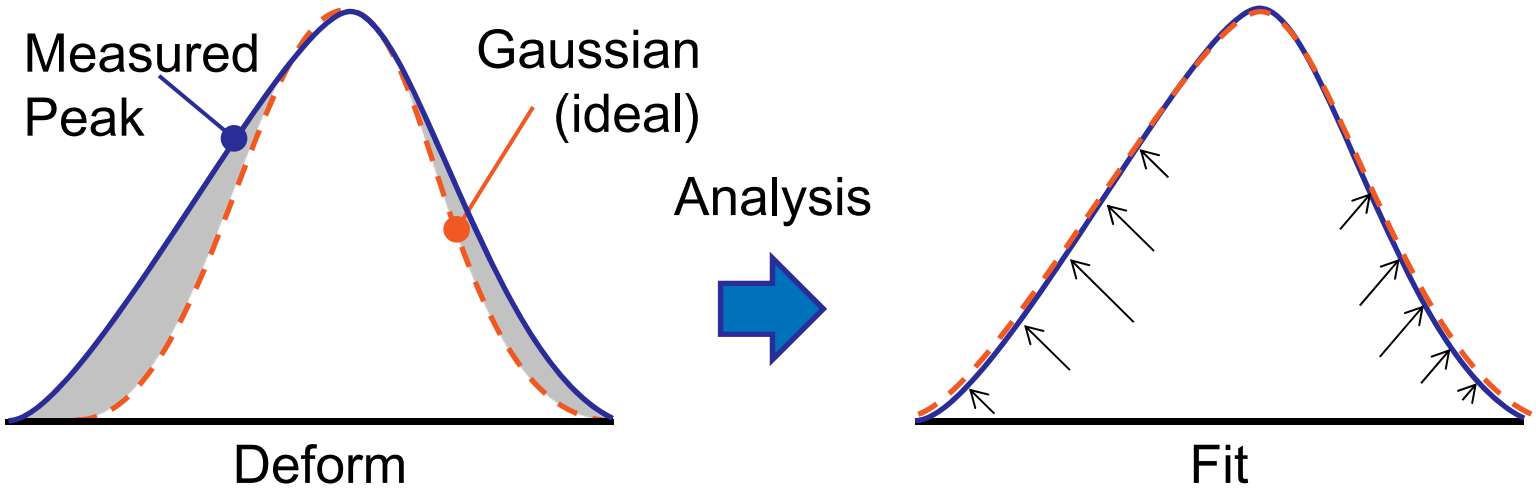
- Saving measurement time
- Applicable for limited amount of gas

➢ Peak analysis was applied to overlapped peaks.

3.2 Evaluations

Peak function

- Peak shape is the Gaussian distribution in the ideal condition.
- Deformed from the ideal shape as leading and tailing.



Four different types of Gaussian Functions were compared to figure out the best fit function.

[2] S. Walsh, D. Diamond. Talanta. 42 (1995) 561

3.2 Evaluations

Peak function used for the evaluation.

Exponentially **M**odified **G**aussian Function[3],[5]

Empirically **T**ransformed **G**aussian Function[4],[5]

Generalized **E**xponentially **M**odified **G**aussian Function[3],[5]

Polynomial **M**odified **G**aussian Function[3],[5]

- Each Sum of Squared Residuals was obtained by analysis of measurement peaks and estimated peaks.

- The best fits are obtained by minimizing the SSR.

[3] P.Nikitas J Chromatogr. A 912 (2001) 13
[4] J. Li. Anal. Chem. 69 (1997) 4452
[5]J. Li. J Chromatogr. A 952 (2002) 63

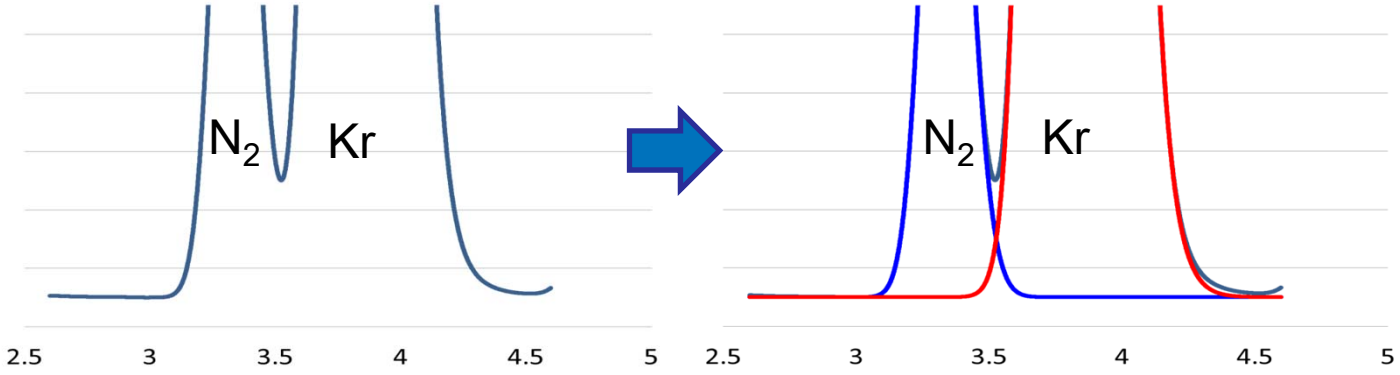
3.3 Results

Results of evaluation

- ETG function gave the minimum SSR values.

Function	EMG	ETG	GEMG	PMG2
SSR	4.7E+10	3.74E+9	4.37E+10	1.46E+12

Example of deconvolute Kr and N_2.



- Overlapped peaks of Kr and N_2 are deconvoluted with ETG Function.

4. Summary

Gas analyzer has been improved in two approaches, hardware and software.

Hardware approach

- PDD reached 50 times higher minimum detectability of Kr than TCD.

Software approach

- Overlapped peaks of Kr and N_2 are deconvoluted with ETG function.

Increasing of measurement accuracy is expected for the gas analysis of failed fuel on the RIA examination.