THE DECADE OF DEPLETED URANIUM

ASAF DURAKOVIC

M.D., D.V.M., MSc, Ph.D., F.A.C.P.

Professor of Medicine, Radiology and
Nuclear Medicine

URANIUM MEDICAL RESEARCH CENTRE

Washington, DC, USA

Richmond Hill, Ontario, Canada

A. Durakovic, P. Horan, L. Dietz

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Uranium Medical Research Centre

Washington, DC, USA

Richmond Hill, Ontario, Canada

Department of Earth Sciences

Memorial University of Newfoundland

St. Johns, Newfoundland, Canada

An Update of the Quantitative Analysis of Uranium Isotopes in British, Canadian, and United States Gulf War Veterans

Patients, Materials, and Methods

Twenty-Seven British, Canadian, and United States veterans presenting with complex non-specific clinical symptomatology of the **Gulf War Illness** had their 24hrs urine samples quantitatively determined for ^{234}U, ^{235}U, ^{236}U, and ^{238}U by the method of mass spectometric analysis at Atlantic Universities Radiogenic Isotope Facility.

St. Johns, Newfoundland, Canada

The Objective of the Study

To determine the quantities and ratios of uranium isotopes in the urine and organs of the Gulf War Veterans exposed to depleted uranium (DU) by the inhalational route of internal contamination.

Radiochemical Analysis

- The urine samples were collected and transported under controlled circumstances in sealed plastic vials, weighed into savillex-teflon screw-cap jars (15ml) and evaporated to dryness at 80-100 degrees C.
- All samples were repeatedly evaporated three times after the addition of 4ml of double distilled concentrated nitric acid.

- Each sample was separated into an isotopic concentration and isotopic dilution fraction, by adding 3.1N hydrochloric acid to each sample.

- Half of each sample was transferred to the savillex-teflon jar (7ml) & accurately weighed.

Mass Spectrometry

- Uranium was separated and collected in both fractions after ion exchange preparation with DOWEX analytical grade AGL-X8 ion exchange resins with a modified HBr technique.

- The isotopic composition was measured by a multi-collector Finnigan mass spectrometer using secondary electron multiplier (SEM) detector and ion counting system.

- The uranium blank control has been determined to by 0.45 picograms and 960U standard, measured by the same procedure.

Atlantic Universities Radiogenic Isotope Facility

(AURIF)

The Atlantic Universities Radiogenic Isotope Facility (AURIF) was created in 1989 to analyze geological samples for radiogenic isotopic tracers studies. Since its inception, AURIF has analysed samples for numerous scientists worldwide. The combined research experience of the scientific personnel in AURIF in dealing with the U/Pb isotopic system spans over 30 years with more than 5000 U/Pb analyses completed. Data from this lab has been published in peer- reviewed journals for more than 9 years.

Humans ingest or breathe in uranium. Sources are:

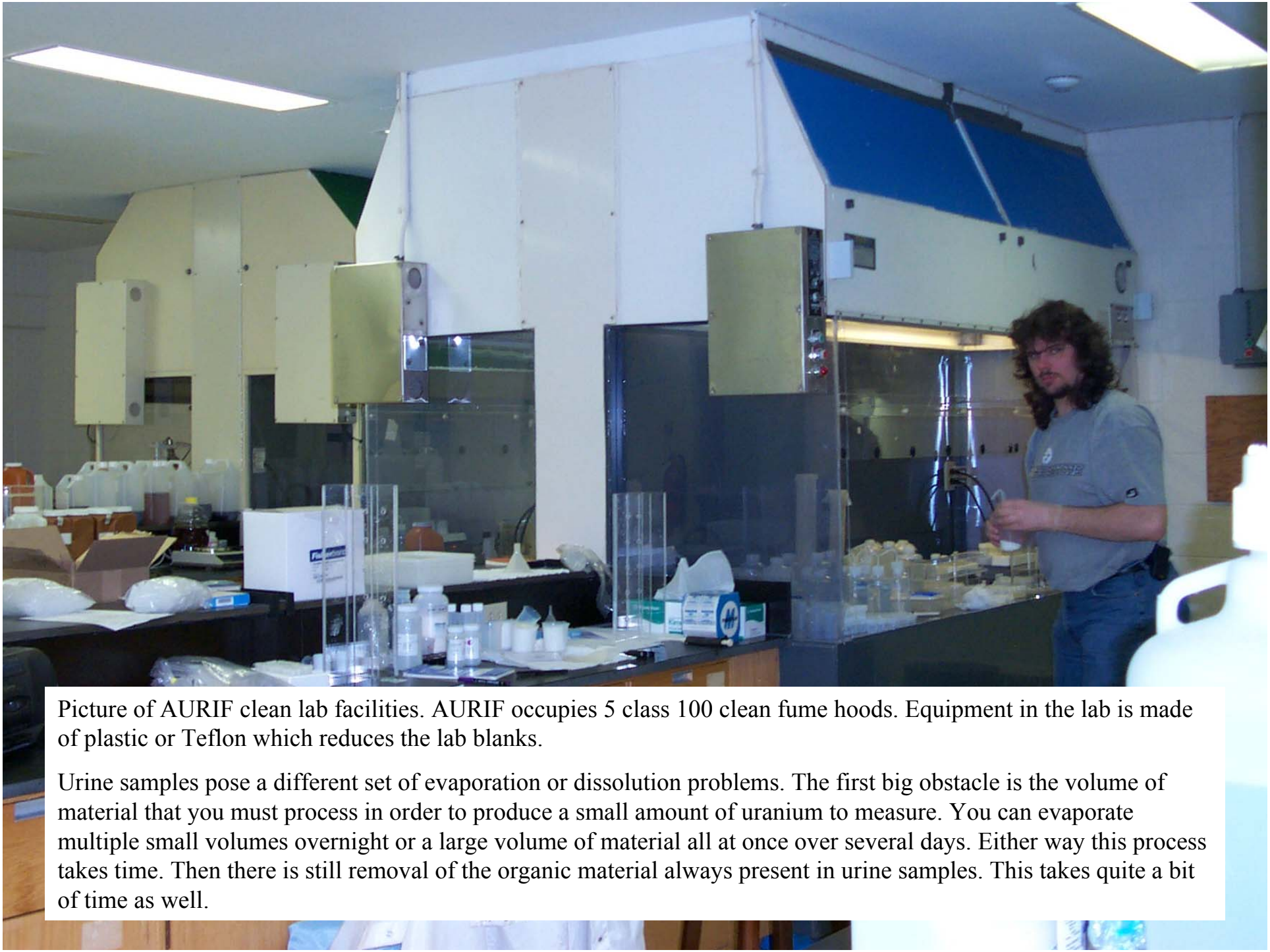
1) Drinking water which is filtered through the ground
2) Eating vegetables grown in our gardens
3) Breathing in dust and dirt on windy days

Hypothetical measurement of urine specimen:

$^{238}U/^{235}U = \sim 137.88$

Every person will have trace amounts of naturally occurring uranium in their system. We absorb it through the vegetable we eat and through the water we drink which is filtered through the soil and rocks that we live. We can also get small amounts by inhaling or ingesting dirt and dust blowing around in the breeze. So if I measured someone's urine specimen from my family, I would see this naturally occurring $^{238}U/^{235}U$ ratio of approximately 137.88.

Environmental soil and dust samples can be handled in the same way as whole rock powders. Small amounts of dust or soil can be weighed out accurately and dissolved using a HF/HNO_3 acid mixture. Tissue samples can also be treated in a similar fashion using acid attacks to dissolve the materialbut usually just HNO_3 is required. The major difference between rock powders and environmental or biological samples is the large amount of organic material that is present in the latter. This organic material must be destroyed using conc HNO3 or it will affect the ion exchange chemistry.



Picture of AURIF clean lab facilities. AURIF occupies 5 class 100 clean fume hoods. Equipment in the lab is made of plastic or Teflon which reduces the lab blanks.

Urine samples pose a different set of evaporation or dissolution problems. The first big obstacle is the volume of material that you must process in order to produce a small amount of uranium to measure. You can evaporate multiple small volumes overnight or a large volume of material all at once over several days. Either way this process takes time. Then there is still removal of the organic material always present in urine samples. This takes quite a bit of time as well.

Depleted Uranium : DU for short

"left-over" product during the enrichment process for nuclear fuel rods or nuclear weapons.

DU shrapnel measured in AURIF lab

$^{238}U = 99.7945\%$, $^{235}U = 0.2026\%$, $^{234}U = 0.0012\%$.

Key ratio of interest: $^{238}U/^{235}U = 491.87 \pm 0.16$ (2σ absolute)

The nuclear industry refines mined U_3O_8 and removes the majority of ^{235}U and ^{234}U for use in nuclear fuel rods. This enrichment process creates a "left over" form of uranium with substantially less ^{235}U and increased ^{238}U abundance as seen in this slide. This "left over" uranium is referred to as depleted uranium. The $^{238}U/^{235}U$ ratio measured from one particular piece of shrapnel is 491.87 ± 0.16 ($2\ \sigma$). I already mentioned one use of DU as ballast in airplanes manufactured before the mid –1980's. Another use of DU has been in shell casing for military armaments. The shells are very hard and will easily pierce armour. Upon impact, the DU in the shell casing ignites and burns causing massive damage.

HBr Ion Exchange Chemistry

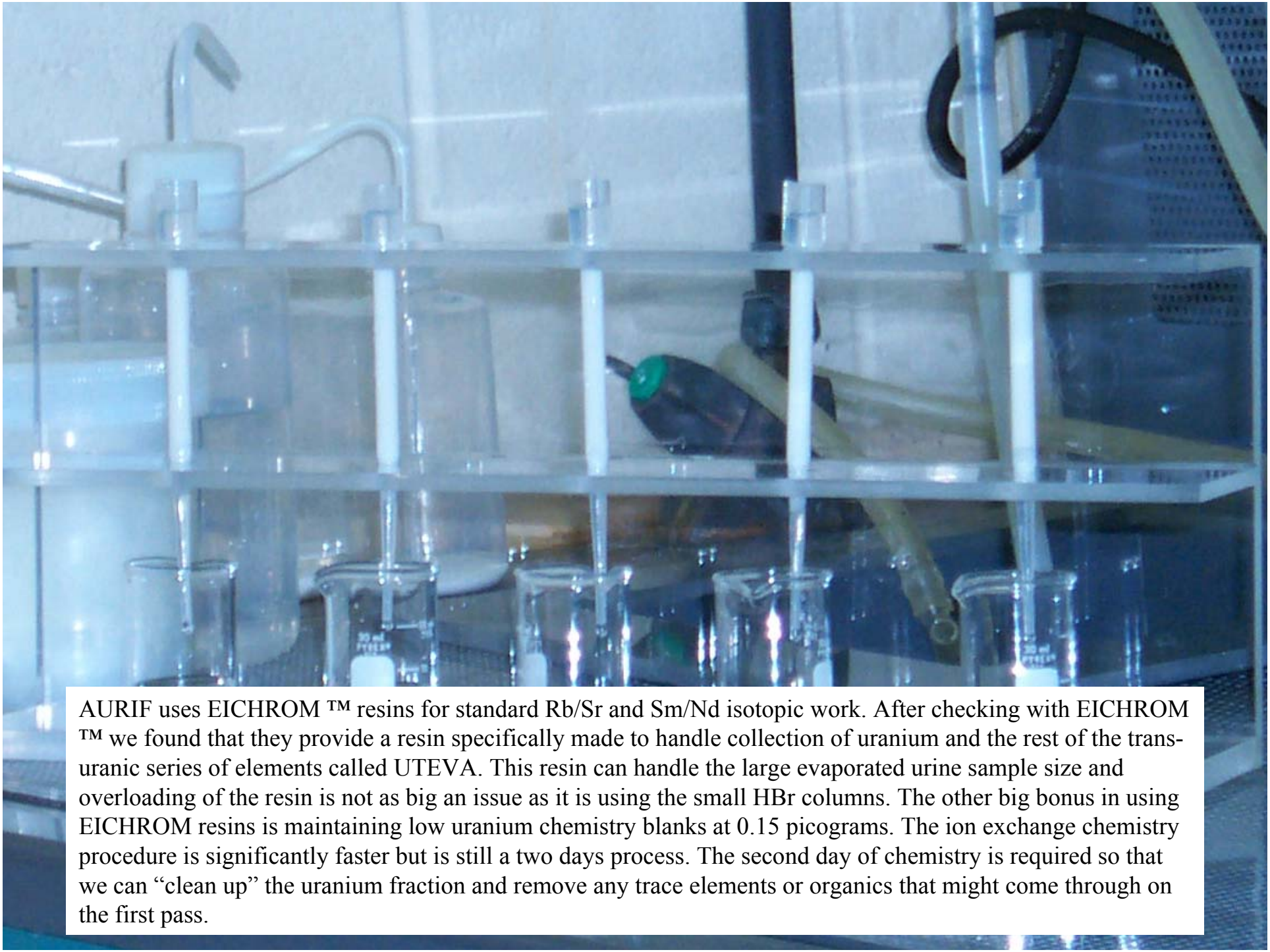
Manhes G., Minster J.F., Allegre C.J., 1978: Comparative uranium – thorium- lead and rubidium – strontium study of the Saint Severin amphoterite: consequence for early solar system chronology. Earth Planetary Science Letters, 39: 14-24.

EICHROM ™ UTEVA Ion Exchange Chemistry

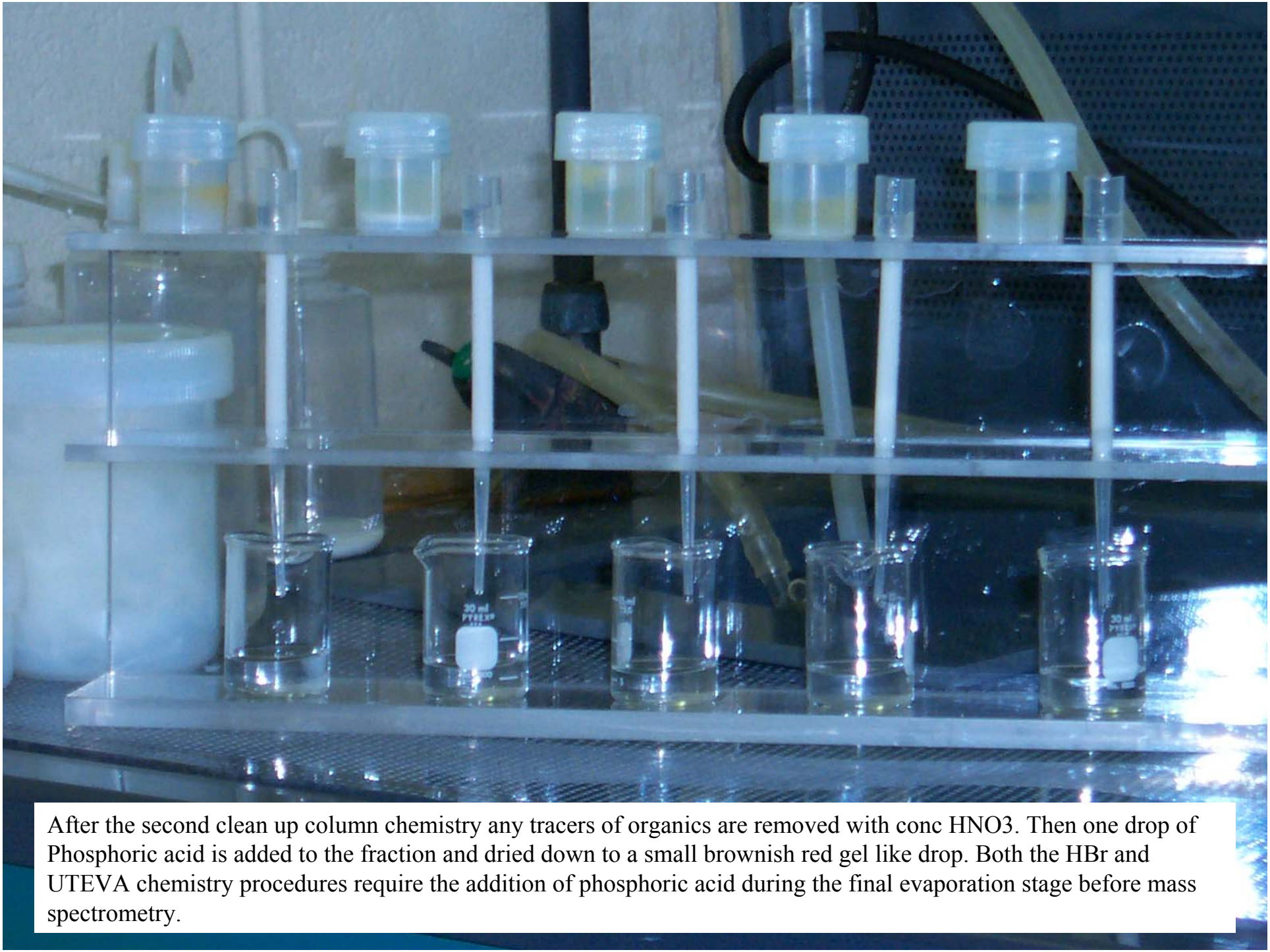
Eichrom Industries, Inc, 1999: Analytical Procedures ACU 02, Rev. 1.2

The next step in the process is the ion exchange chemistry. In the beginning of the project, a modified HBr technique was employed to separate the uranium from the remaining elements in the samples. This is a long two-day process, which is used routinely for the dating of minerals such as titanite or monazite. The HBr procedure was modified in order to compensate for the volume of urine evaporated but it didn't work very well. Uranium recovery was low compared to recovery when dealing with rock samples. We feel this is most likely due to the overloading of the ion exchange sites in the resin and as a result sample is lost. So another type of ion exchange chemistry needed to be found.

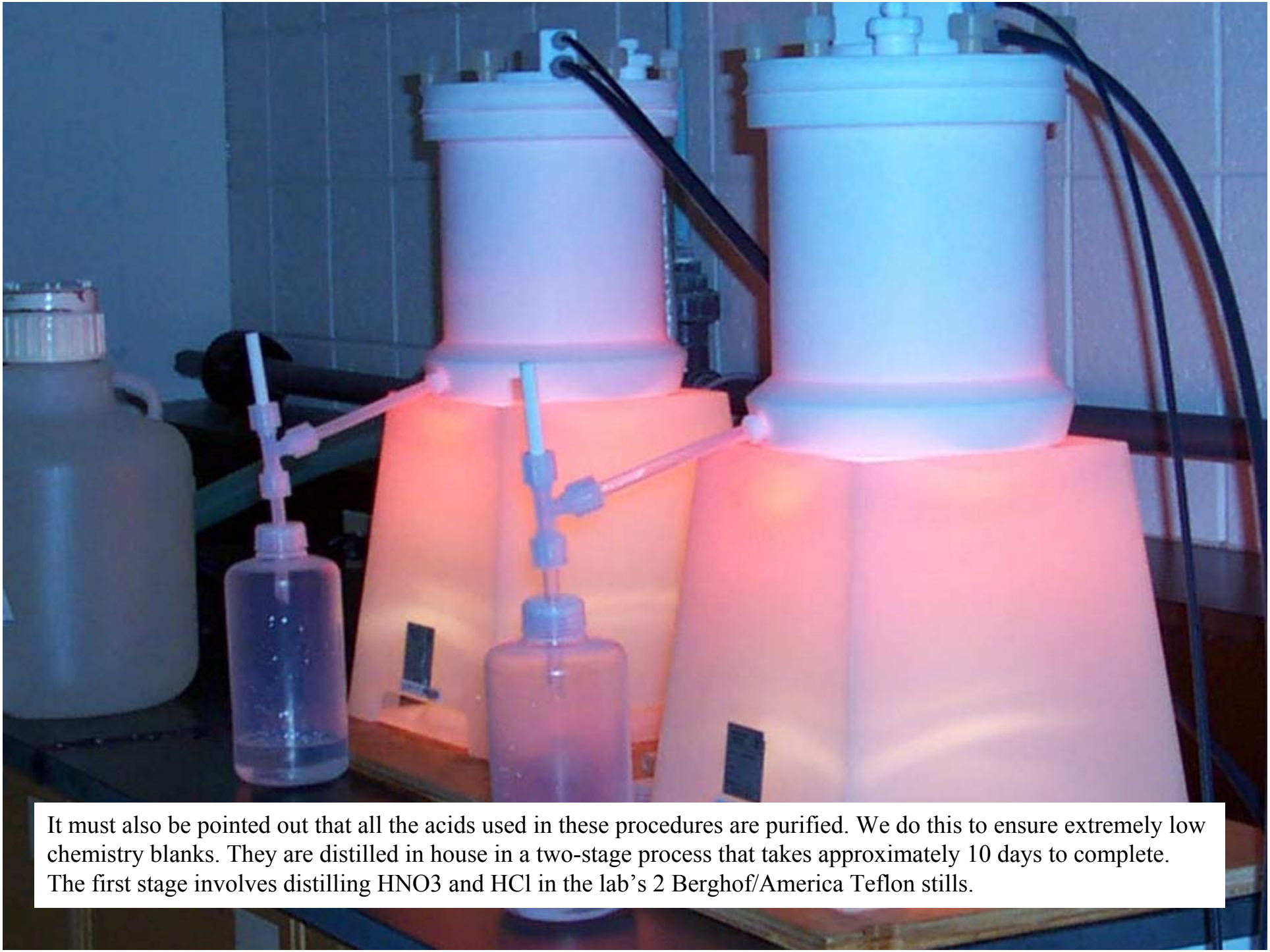
Picture of columns set up for HBr ion exchange chemistry.



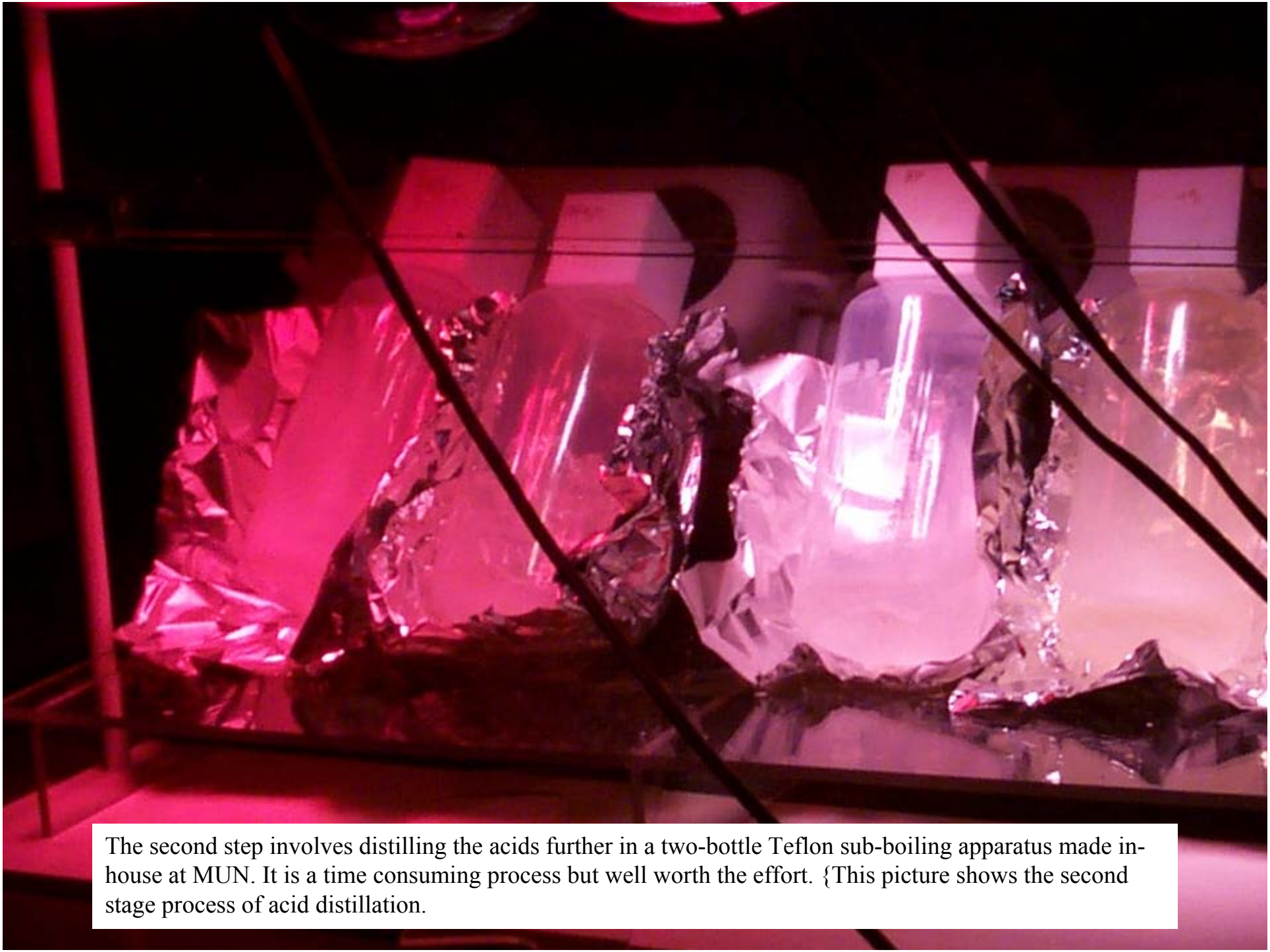
AURIF uses EICHROM ™ resins for standard Rb/Sr and Sm/Nd isotopic work. After checking with EICHROM ™ we found that they provide a resin specifically made to handle collection of uranium and the rest of the trans-uranic series of elements called UTEVA. This resin can handle the large evaporated urine sample size and overloading of the resin is not as big an issue as it is using the small HBr columns. The other big bonus in using EICHROM resins is maintaining low uranium chemistry blanks at 0.15 picograms. The ion exchange chemistry procedure is significantly faster but is still a two days process. The second day of chemistry is required so that we can “clean up” the uranium fraction and remove any trace elements or organics that might come through on the first pass.



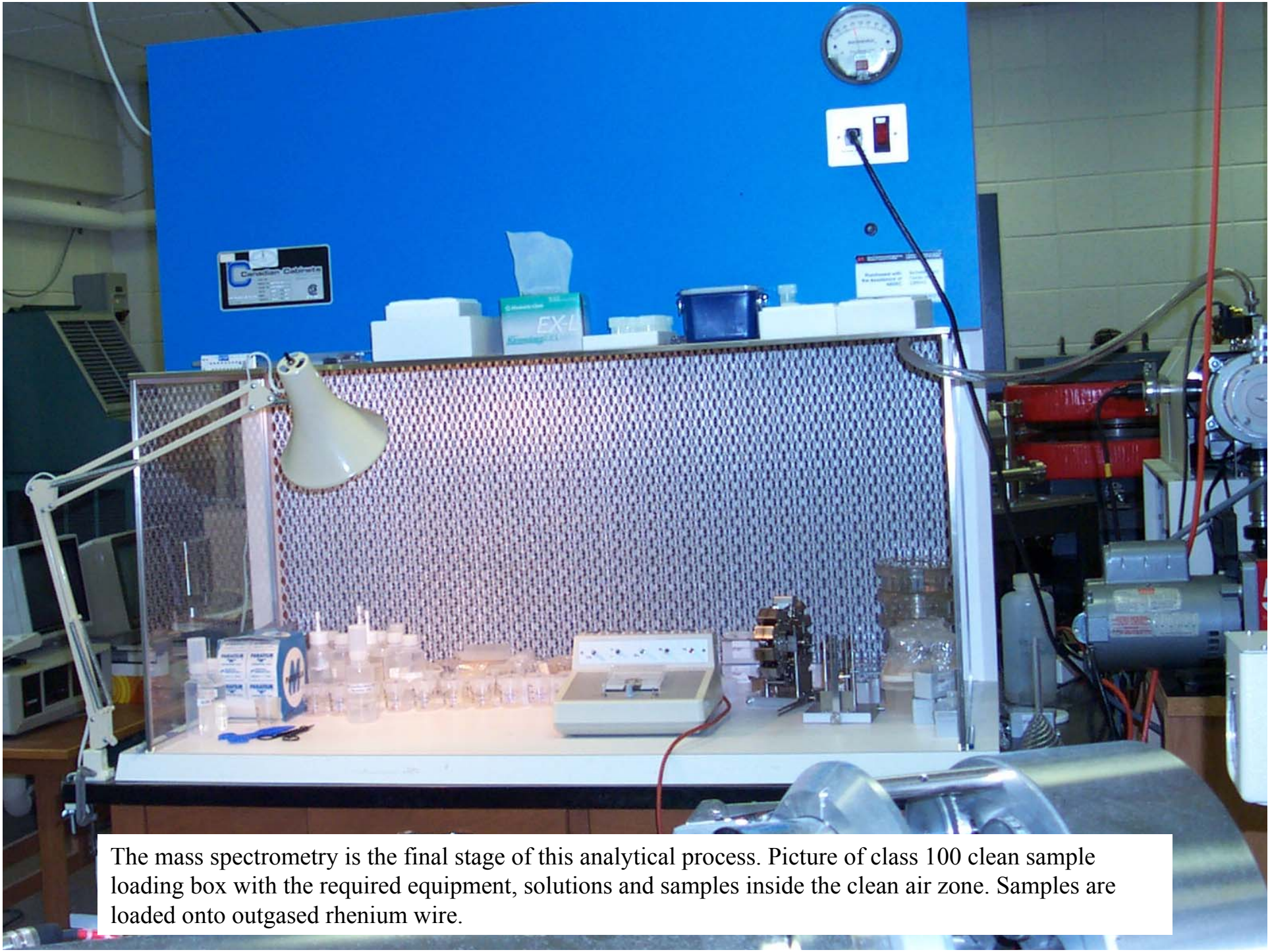
After the second clean up column chemistry any tracers of organics are removed with conc HNO3. Then one drop of Phosphoric acid is added to the fraction and dried down to a small brownish red gel like drop. Both the HBr and UTEVA chemistry procedures require the addition of phosphoric acid during the final evaporation stage before mass spectrometry.



It must also be pointed out that all the acids used in these procedures are purified. We do this to ensure extremely low chemistry blanks. They are distilled in house in a two-stage process that takes approximately 10 days to complete. The first stage involves distilling HNO3 and HCl in the lab's 2 Berghof/America Teflon stills.

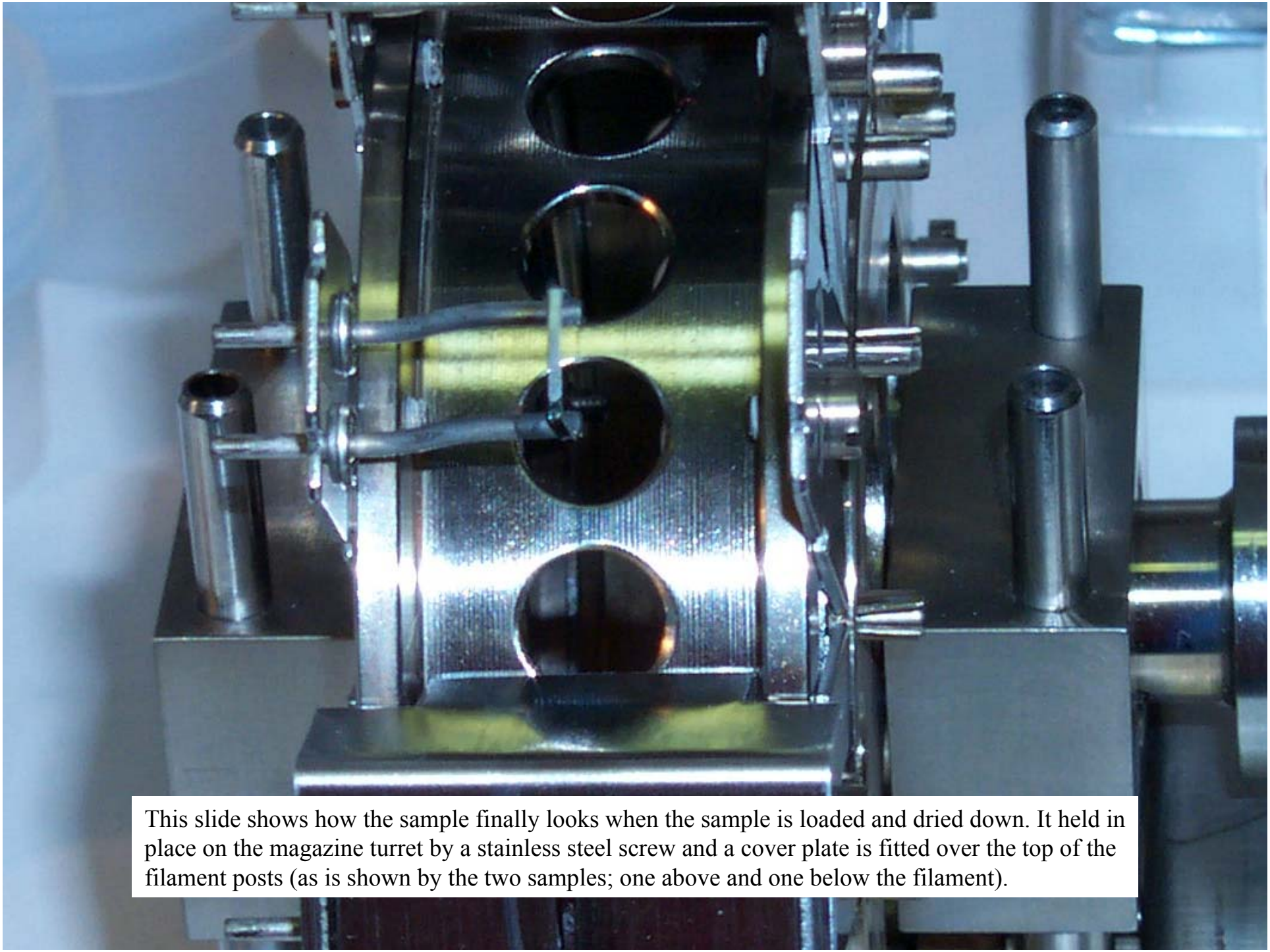


The second step involves distilling the acids further in a two-bottle Teflon sub-boiling apparatus made in-house at MUN. It is a time consuming process but well worth the effort. {This picture shows the second stage process of acid distillation.



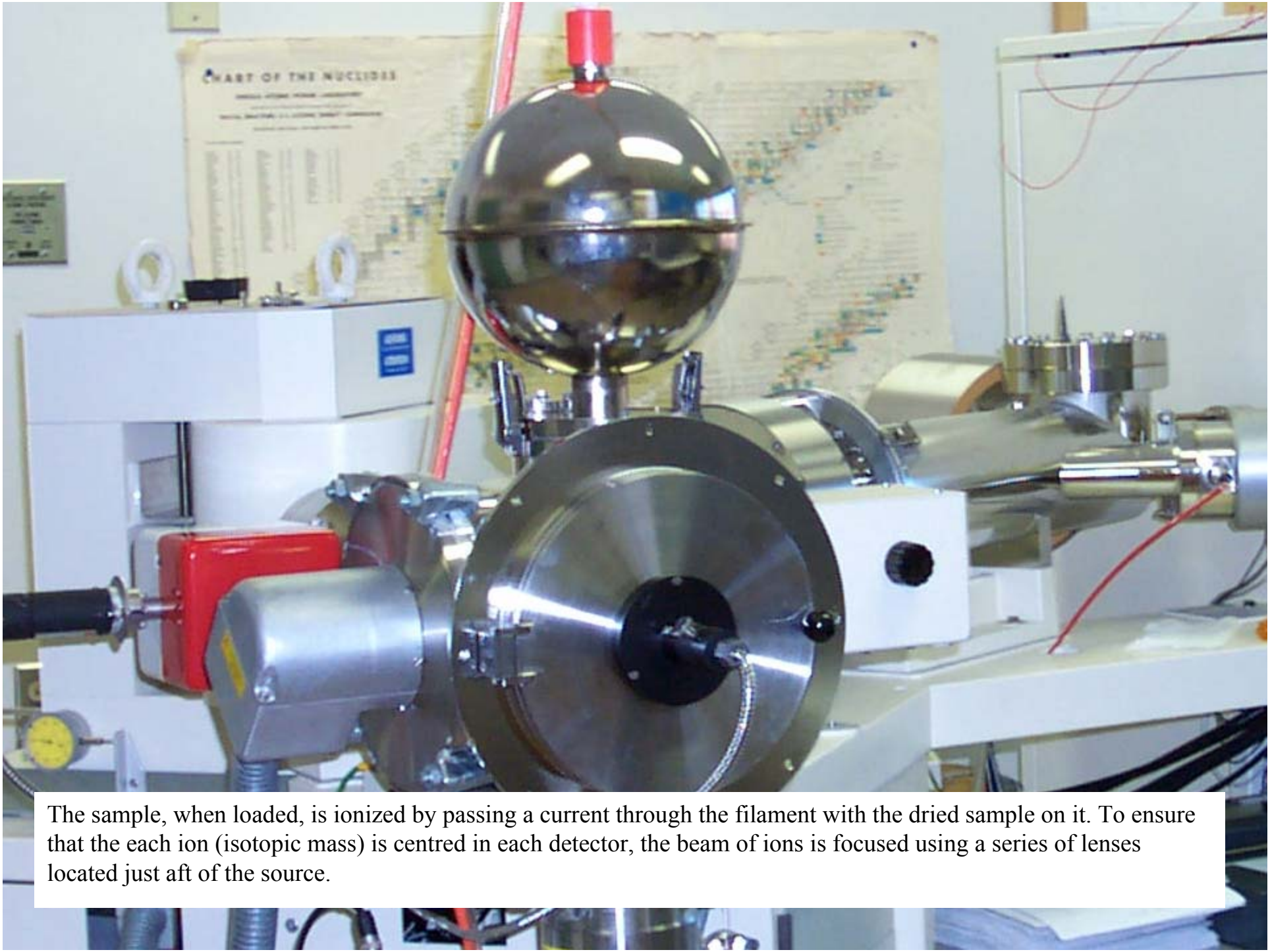
The mass spectrometry is the final stage of this analytical process. Picture of class 100 clean sample loading box with the required equipment, solutions and samples inside the clean air zone. Samples are loaded onto outgased rhenium wire.

The samples and standards are loaded with a silica gel/phosphoric acid combination, which will enhance uranium ionization and provide a stable beam of ions once heated. This is a picture of what the uranium sample looks like just prior to loading on the filament. This is what is left after ~4 days of sample preconcentration and ion exchange chemistry. The sample is dried down to a drop of gel like residue using phosphoric acid. We then run the sample as an uranium oxide.



This slide shows how the sample finally looks when the sample is loaded and dried down. It held in place on the magazine turret by a stainless steel screw and a cover plate is fitted over the top of the filament posts (as is shown by the two samples; one above and one below the filament).

AURIF uses a Finnigan MAT 262V solid source thermal ionization mass spectrometer with 8 faraday detectors and one secondary electron multiplier – ion-counting system.



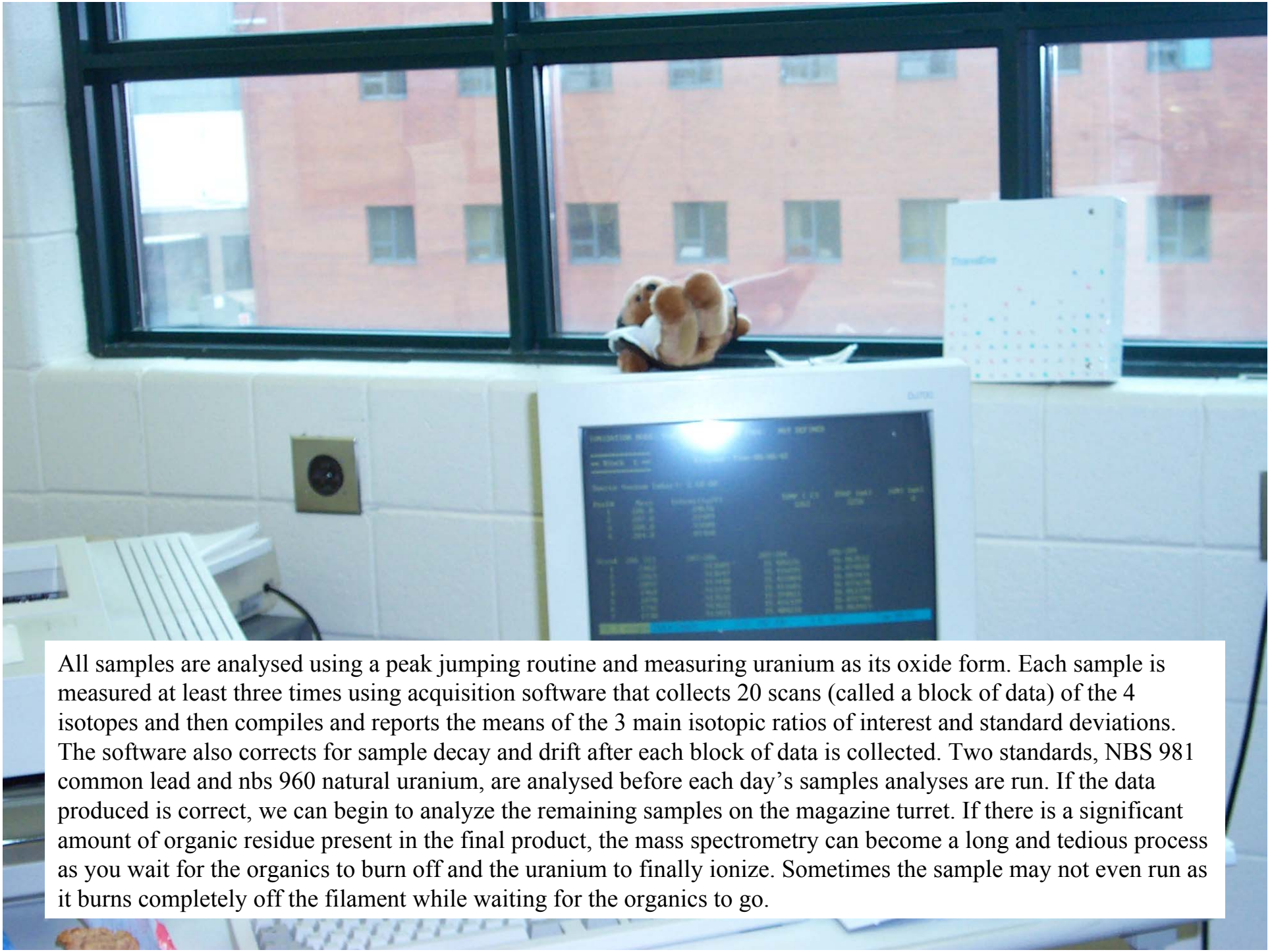
The sample, when loaded, is ionized by passing a current through the filament with the dried sample on it. To ensure that the each ion (isotopic mass) is centred in each detector, the beam of ions is focused using a series of lenses located just aft of the source.

The mass spectrometer has a large electromagnet that facilitates the separation of charged particles or ions.

Illustration of mass separation with the Finnigan electromagnet

Courtesy of Finnigan MAT

As the beam of ions pass out through the “line of sight” or beam valve, it encounters a strong magnetic field created by the large electromagnet. Since the beam contains ions of different masses, it splits into individual beams, one per isotopic mass present in the sample. So for uranium, one beam enters the magnetic field and produces individual ^{238}U, ^{235}U and ^{234}U (and even sometimes ^{236}U if present in the sample).



All samples are analysed using a peak jumping routine and measuring uranium as its oxide form. Each sample is measured at least three times using acquisition software that collects 20 scans (called a block of data) of the 4 isotopes and then compiles and reports the means of the 3 main isotopic ratios of interest and standard deviations. The software also corrects for sample decay and drift after each block of data is collected. Two standards, NBS 981 common lead and nbs 960 natural uranium, are analysed before each day's samples analyses are run. If the data produced is correct, we can begin to analyze the remaining samples on the magazine turret. If there is a significant amount of organic residue present in the final product, the mass spectrometry can become a long and tedious process as you wait for the organics to burn off and the uranium to finally ionize. Sometimes the sample may not even run as it burns completely off the filament while waiting for the organics to go.

For Natural uranium we have:

^{238}U - 99.2745% abundance and ^{235}U - 0.7200% abundance

238U/235U = ~137.88

For Depleted uranium we have:

^{238}U - 99.7945% abundance and ^{235}U - 0.2026% abundance

$^{238}U/^{235}U = 491.87 \pm 0.16$

When someone has been exposed to DU, there is a shift in the ratio from 137.88 towards the DU ratio of 492. This is the marker that shows exposure to DU.

We see in this slide the ratios for natural and depleted uranium. When a person has been exposed to DU, this $^{238}U/^{235}U$ ratio shift towards the ratio 492. This is the marker or fingerprint, if you will, that shows exposure to depleted uranium. There is no other way of shifting the $^{238}U/^{235}U$ ratio above the natural value of 137.88.

Mass spec ratios

Soldier#	**238U/235U**	**2 sigma**	234/238	2 sigma	236/238	2 sigma
1	**231.3256**	**0.0238**	0.000031	0.000005	0.000063	0.000018
2	**229.0800**	**0.0106**	0.000032	0.000004	0.000058	0.000004
3	**140.2946**	**0.1109**	0.000097	0.000001	0.000086	0.000022
4	**138.0957**	**0.0736**	0.000059	0.000005	0.000011	0.000003
5	**139.5594**	**0.0681**	0.000077	0.000012	0.000072	0.000010
6	**137.8191**	**0.3725**	0.000074	0.000008	0.000018	0.000007
7	**147.7830**	**0.1097**	0.000033	0.000065	nd	nd
8	**191.2613**	**0.1702**	0.000066	0.000004	0.000092	0.000005
9	**152.9657**	**0.5039**	0.000050	0.000004	nd	nd

Errors are 2 sigma absolute

This slide shows key data from some of the soldiers in the testing program. As you can see we have a varied representative group showing showing some soldiers with higher $^{238}U/^{235}U$ ratios and some soldiers with natural $^{238}U/^{235}U$ ratios.

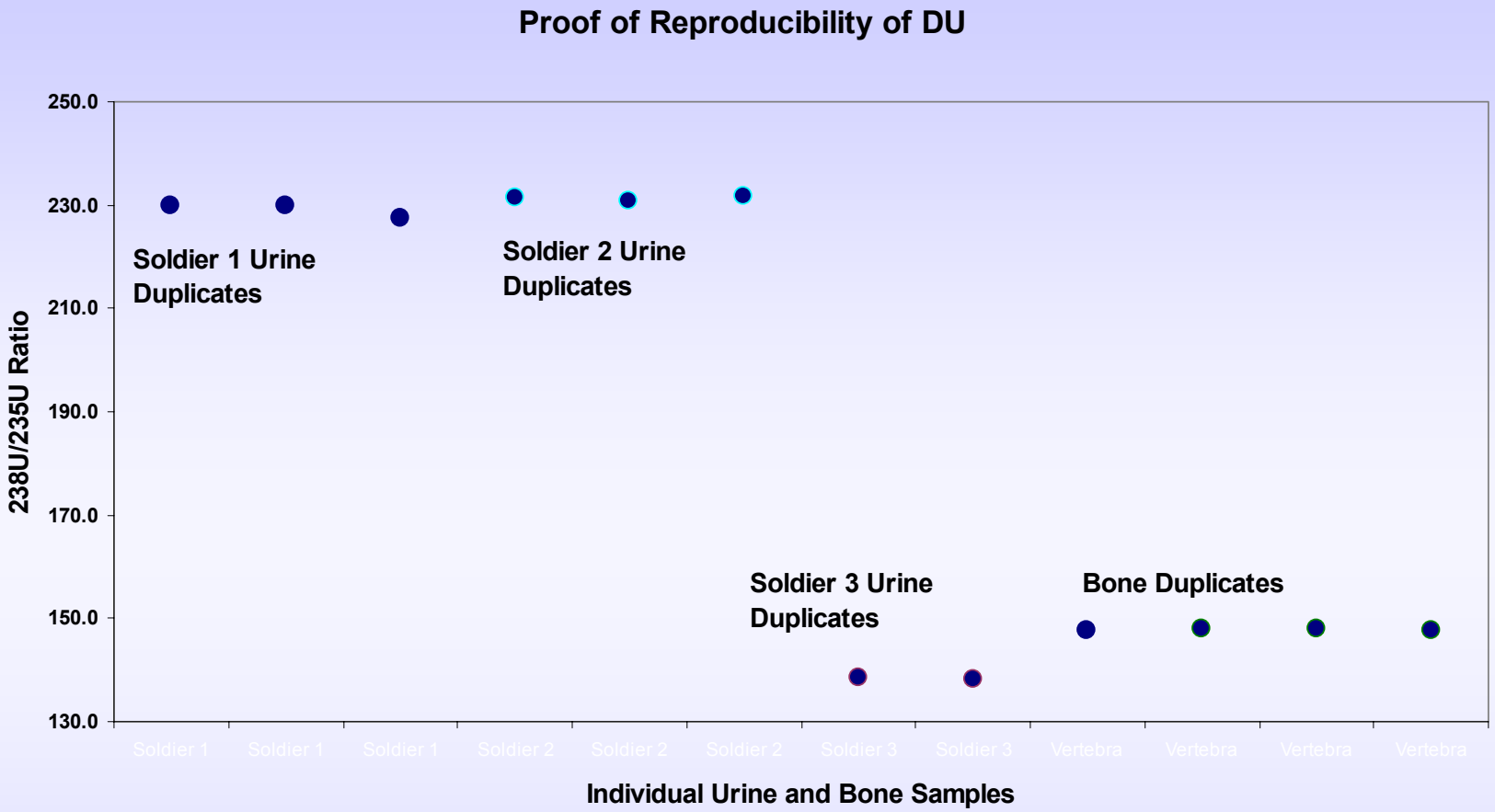
Results of autopsied bone fragments from deceased Canadian veteran

Sample#	**238U/235U**	**2 sigma**	234/238	2 sigma	236/238	2 sigma
Vertebra	**147.6721**	**0.190**	0.000057	0.0000360	0.000013	0.000002
Vertebra	**147.8660**	**0.413**	0.000052	0.0000005	0.000009	0.000002
Vertebra	**148.0673**	**0.562**	0.000052	0.0000007	0.000009	0.000001
Vertebra	**147.7731**	**0.352**	0.000051	0.0000014	0.000009	0.000002
Sample#	**U238%**	**U235%**	U234%	U236%		
Vertebra	**99.3205%**	**0.6726%**	0.0056%	0.0013%		
Vertebra	**99.3222%**	**0.6717%**	0.0051%	0.0009%		
Vertebra	**99.3232%**	**0.6708%**	0.0051%	0.0009%		
Vertebra	**99.3219%**	**0.6721%**	0.0051%	0.0009%		

This slide shows the results for the bone analyses from a deceased Canadian veteran. As you can see the bone sample shows a shifted 238U/235U ratio indicating the presence of DU.

Results of DU shrapnel analyzed at MUN

Sample#	**238U/235U**	**2 sigma**	234/238	2 sigma	236/238	2 sigma
Shrapnel	**491.8681**	**0.1571**	0.000012	0.000001	0.000017	0.000002
Sample#	**U238%**	**U235%**	U234%	U236%		
Shrapnel	**99.7945%**	**0.0017%**	0.2026%	0.0012%		



This slide show the proof of reproducibility of DU analyses. Each one of these analyses are complete duplicates starting with a fresh aliquot of urine or a new bone fragment. The 2 sigma absolute errors have been plotted along with the sample but in most cases you can't see them as they are so small.

Conclusions:

1) Modified HBr two day process chemically inefficient.
2) UTEVA faster and more efficient, problem with organics.
3) UTEVA modified so that is now a two day process but still better than HBr chemistry
4) New two day co-precipitation technique in development which eliminates the ten days required to evaporate one litre of sample. Looks very promising in the early stages. Blanks remain low.

When AURIF began analyzing urine and biological samples, it quickly became apparent that new chemistry techniques were need to speed up the evaporation and ion exchange chemistry. Originally, a series of 5 urine samples would take over 3 weeks to a month to process through the chemistry phases and wait for mass spectrometry. This may have been acceptable for a small research project of approximately 15-20 samples. For larger projects and especially for a project of this sensitivity a faster analytical procedure was needed. The 10 – 14 day 1L evaporation period has been reduced to 2 days with the use of the co-precipitation of uranium using calcium phosphate

Best Analytical Tools for this type of analysis:

1) TIMS : thermal ionization mass spectrometry;

measure all 4 uranium isotopes in extremely small samples peak jumping with the ion counting system,

2) ICP hexapole multicollector (plasma source);

measure all 4 uranium isotopes using both faraday and ion counter detectors, quick analytical measurement times ~5-10 minutes producing similar quality data as TIMS.

3) Ion exchange chemistry : there is no escaping this aspect.

TIMS and ICP multicollector mass specs are the two best analytical tools for this type of analyses. Both have the ability to analyse the lesser isotopes ^{234}U and ^{236}U in this type of sample. Due to the low levels of uranium in the majority of the urine samples, most if not all of the other currently available analytical techniques are not able to measure the lower abundance ^{235}U let alone ^{234}U and ^{236}U. This is obviously quite critical in order to determine the presence of DU. The beauty of the "new" ICP multicollector mass spec is the quick analytical time required to get the equivalent amount of data from TIMS. The added bonus is the ability to measure all 4 of the uranium isotopes simultaneously using both faraday and ion counters at the same time.

One point I must make is that regardless or what instrument you use, you will have to pass the samples through ion exchange chemistry in order to pre-concentrate and purify the uranium. If not then there are too many interferences such as organic materials present in the samples that will cause problems while analyzing on the mass spec.

Original Results of Urine Analysis

- DU present in 13/27 samples

$^{238}U > 99.45\%$

$^{235}U < 0.52\%$

- The average ratio

$^{238}U / {}^{235}U > 208.4$

- The results confirm the definitive presence of

$^{234}U > 0.0066\%$

and

$^{236}U > 0.0039\%$

Table 1: Quantitative Data for Individual Samples

No.	Patient	U 238	U 235	U238/U235	Sigma
1	G.B.	99.2782	0.7145	139.0	1.3
2	B.B	99.2742	0.7076	140.3	0.2
3	R.B.	99.2782	0.7145	139.0	1.3
4	L.B.	99.2738	0.7180	138.3	0.5
5	D.B.	99.2701	0.7233	137.5	0.5
6	P.C.	99.2570	0.7210	137.7	0.5
7	C.C.	99.2738	0.7113	139.6	0.4
8	R.G.D.	99.3154	0.6758	147.0	0.7
9	J.G.	99.7565	0.2339	426.6	3.7
10	W.H.	- - -	- - -	- - -	- - -
11	J.H.	- - -	- - -	153.0	0.1
12	M.K.	99.2762	0.7152	138.8	0.8
13	C.P.L.	99.2702	0.7200	137.9	0.5
14	G.L.	- - -	- - -	- - -	- - -
15	K.I.M.	99.4280	0.5663	175.6	1.7
16	T.N.	99.2963	0.6925	143.4	3.4
17	C.O.	99.2811	0.7135	139.1	0.9
18	A.P.	99.3456	0.6495	153.0	0.3
19	T.R.	99.5564	0.4346	229.1	1.3
20	P.R.	99.2742	0.7189	138.1	0.8
21	S.R.	99.5603	0.4304	231.3	1.6
22	F.S. (A)	99.4876	0.4945	201.2	5.9
23	F.S. (B)	99.2693	0.7189	138.1	1.7
24	V.S.	99.7113	0.2830	352.4	1.5
25	M.D.T	- - -	- - -	- - -	- - -
26	R.W.	99.3025	0.6825	145.5	1.4
27	A.W.	99.3862	0.4966	200.1	1.2

Table 2: Summary of Quantitative Data for Individual Samples

	U 238	U 235	U238/U235	Sigma
Negative	99.2726	0.7166	138.6	0.8
Std. Dev.	0.00625	0.0046	0.862	
Std. Error	0.00188	0.0014	0.260	
Positive	99.4561	0.5248	208.4	1.42
Std. Dev.	0.1598	0.1575	87.51	
Std. Error	0.0461	0.0455	24.27	
Totals	99.3728	0.6119	178.1	1.18
Std. Dev.	0.1469	0.1483	72.51	
Std. Error	0.0306	0.0309	14.80	
P-Value	0.00109	0.00073	0.00699	

Table 3: Quantitative Data for Positive Samples

No.	Patient	U 238	U 235	U238/U235	Sigma
3	R.B.	99.2782	0.7145	139.0	1.3
8	R.G.D.	99.3154	0.6758	147.0	0.7
9	J.G.	99.7565	0.2339	426.6	3.7
11	J.H.	- - -	- - -	153.0	0.1
15	K.I.M.	99.4280	0.5663	175.6	1.7
16	T.N.	99.2963	0.6925	143.4	3.4
18	A.P.	99.3456	0.6495	153.0	0.3
19	T.R.	99.5564	0.4346	229.1	1.3
21	S.R.	99.5603	0.4304	231.3	1.6
22	F.S. (A)	99.4876	0.4945	201.2	5.9
24	V.S.	99.7113	0.2830	352.4	1.5
26	R.W.	99.3025	0.6825	145.5	1.4
27	A.W.	99.3862	0.4966	200.1	1.2
Totals		99.4561	0.5248	208.4	1.42
Std. Dev.		0.1598	0.1575	87.51	
Std. Error		0.0461	0.0455	24.27	

Table 4: Quantitative Data for Negative Samples

No.	Patient	U 238	U 235	U238/U235	Sigma
1	G.B.	99.2782	0.7145	139.0	1.3
2	B.B	99.2742	0.7076	140.3	0.2
4	L.B.	99.2738	0.7180	138.3	0.5
5	D.B.	99.2701	0.7233	137.5	0.5
6	P.C.	99.2570	0.7210	137.7	0.5
7	C.C.	99.2738	0.7113	139.6	0.4
12	M.K.	99.2762	0.7152	138.8	0.8
13	C.P.L.	99.2702	0.7200	137.9	0.5
17	C.O.	99.2811	0.7135	139.1	0.9
20	P.R.	99.2742	0.7189	138.1	0.8
Totals		99.2726	0.7166	138.6	0.91
Std. Dev		0.00625	0.0046	0.862	
Std. Error		0.00188	0.0014	0.260	

Table 5: Ratio of Uranium Isotopes

	U 238	U 235	U238/U235	U235/U238
Natural Uranium	99.2739	0.7200	137.88	0.0073
Shrapnel (DU)	99.7945	0.2026	492.60	0.0020
Urine	99.3728	0.6119	178.1	0.0062

Table 6: Isotopic Ratio in Individual Samples

No.	Patient	235/238	Sigma	234/238	Sigma	236/238	Sigma
1	G.B.	0.007195	0.000034	0.000069	0.000005	0.000004	0.000003
2	B.B	0.007130	0.000090	0.000100	0.000002	0.000090	0.000020
3	R.B.	0.006628	0.000143	0.000080	0.000012	0.000072	0.000006
4	L.B.	0.007230	0.000037	0.000057	0.000003	0.000006	0.000002
5	D.B.	0.007280	0.000034	0.000065	0.000003	0.000011	0.000004
6	P.C.	0.007264	0.000018	0.000128	0.000006	0.000094	0.000013
7	C.C.	0.007170	0.000020	0.000080	0.000010	0.000070	0.000010
8	R.G.D.	0.006805	0.000032	0.000070	0.000007	0.000019	0.000006
9	J.G.	0.002345	0.000020	0.000035	0.000003	0.000059	0.000007
10	W.H.	- - -	- - -	- - -	- - -	- - -	- - -
11	J.H.	0.006535	0.000004	0.000066	0.000004	0.000092	0.000005
12	M.K.	0.007205	0.000041	0.000080	0.000004	0.000007	0.000003
13	C.P.L.	0.007255	0.000026	0.000075	0.000004	0.000023	0.000003
14	G.L.	- - -	- - -	- - -	- - -	- - -	- - -
15	K.I.M.	0.005696	0.000055	0.000041	0.000006	0.000026	0.000009
16	T.N.	0.006970	0.000175	0.000100	0.000044	0.000013	0.000009
17	C.O.	0.007188	0.000044	0.000052	0.000010	0.000003	0.000001
18	A.P.	0.006540	0.000010	0.000050	0.000002	0.000000	0.000000
19	T.R.	0.004366	0.000025	0.000032	0.000002	0.000058	0.000003
20	P.R.	0.007241	0.000039	0.000059	0.000005	0.000011	0.000003
21	S.R.	0.004323	0.000030	0.000031	0.000002	0.000063	0.000006
22	F.S. (A)	0.004981	0.000146	0.000046	0.000012	0.000123	0.000033
23	F.S. (B)	0.007242	0.000090	0.000080	0.000077	0.000047	0.000030
24	V.S.	0.002838	0.000012	0.000016	0.000001	0.000043	0.000002
25	M.D.T	- - -	- - -	- - -	- - -	- - -	- - -
26	R.W.	0.006870	0.000065	0.000116	0.000003	0.000037	0.000011
27	A.W.	0.004992	0.000016	0.000081	0.000007	0.000042	0.000010

Table 7: Summary of Isotopic Ratio for Individual Samples

	235/238	Sigma	234/238	Sigma	236/238	Sigma
Negative	0.007218	0.000049	0.000077	0.000007	0.000040	0.000013
Std. Dev.	0.000045		0.000022		0.000045	
Std. Error	0.000014		0.000007		0.000014	
Positive	0.005376	0.000072	0.000059	0.000013	0.000050	0.000008
Std. Dev.	0.001561		0.000030		0.000034	
Std. Error	0.000433		0.000008		0.000009	
Totals	0.006176	0.000061	0.000066	0.000011	0.000042	0.000008
Std. Dev.	0.001467		0.000027		0.000039	
Std. Error	0.000299		0.000006		0.000008	
P-Value	0.000564		0.060110		0.125050	

Table 8: Quantitative Data for ^{234}U and ^{236}U

No.	Patient	U 234	U 236
1	G.B.	0.0069	0.0008
2	B.B	0.0096	0.0085
3	R.B.	0.0079	0.0071
4	L.B.	0.0057	0.0006
5	D.B.	0.0065	0.0011
6	P.C.	0.0127	0.0094
7	C.C.	0.0077	0.0072
8	R.G.D.	0.0070	0.0019
9	J.G.	0.0037	0.0060
10	W.H.	- - -	- - -
11	J.H.	- - -	- - -
12	M.K.	0.0080	0.0007
13	C.P.L.	0.0075	0.0023
14	G.L.	- - -	- - -
15	K.I.M.	0.0041	0.0016
16	T.N.	0.0099	0.0013
17	C.O.	0.0051	0.0003
18	A.P.	0.0049	0.0000
19	T.R.	0.0032	0.0057
20	P.R.	0.0058	0.0011
21	S.R.	0.0031	0.0062
22	F.S. (A)	0.0046	0.0123
23	F.S. (B)	0.0076	0.0028
24	V.S.	0.0016	0.0043
25	M.D.T	- - -	- - -
26	R.W.	0.0115	0.0036
27	A.W.	0.0058	0.0045

Table 9: Summary of Quantitative Data for ^{234}U and ^{236}U

	U 234	U 236
Negative	0.0076	0.0032
Std. Dev.	0.0021	0.0035
Std. Error	0.0006	0.0010
Positive	0.0058	0.0045
Std. Dev.	0.0030	0.0033
Std. Error	0.0009	0.0010
Totals	0.0066	0.0039
Std. Dev.	0.0027	0.0034
Std. Error	0.0006	0.0007
P-Value	0.0682	0.1967

Table 10: Gravimetric Data for Individual Samples

No.	Patient	U pg/g	U pg/24hr
1	G.B.	5.01	10196.99
2	B.B	- - -	- - -
3	R.B.	- - -	- - -
4	L.B.	- - -	- - -
5	D.B.	- - -	- - -
6	P.C.	7.33	12149.63
7	C.C.	- - -	- - -
8	R.G.D.	13.07	1290.24
9	J.G.	- - -	- - -
10	W.H.	8.55	960.00
11	J.H.	- - -	- - -
12	M.K.	4.01	35.94
13	C.P.L.	0.20	545.44
14	G.L.	1.49	141.90
15	K.I.M.	2.77	14111.26
16	T.N.	- - -	- - -
17	C.O.	- - -	- - -
18	A.P.	- - -	- - -
19	T.R.	- - -	- - -
20	P.R.	15.21	7604.85
21	S.R.	77.96	268225.11
22	F.S. (A)	163.02	10780.19
23	F.S. (B)	162.49	10745.42
24	V.S.	- - -	- - -
25	M.D.T	0.0150	1.60
26	R.W.	- - -	- - -
27	A.W.	2217.04	11426.01

Table 11: Summary of Gravimetric Data for Individual Samples

	U pg/g	U pg/24hr
Negative	32.38	6879.71
Std. Dev.	63.94	5314.25
Std. Error	26.10	2169.53
Positive	494.77	75409.84
Std. Dev.	964.90	112434.73
Std. Error	431.51	50282.34
Totals	209.64	34057.00
Std. Dev.	585.90	71715.11
Std. Error	156.59	19166.67
P-Value	0.16031	0.11574

Table 12: Autopsy Specimens

	U 238	U 235	U238/U235
Lung	99.2348	0.6932	143.20
Liver	99.2792	0.7082	140.20
Bone	99.3220	0.6718	147.80

Table 13: Uranium Concentration in Man

	Daily Urinary Excretion (in mg)	Estimated Body Content (in mg)
UK	0.380	100
USA	0.154	80

UK – Hamilton E.I.: Nature 227, 501-502. 1970

USA – Welford G.A., Baird R., Fisenne I.M.: Annual Bioassy and Analytical Chemistry Conf. Bethesda MD, 1970.

Mechanism of Decorporation from the Target Organ

Isoionic Heteroisotopic Exchange

Conclusion

The results demonstrate a significant presence of DU in the urine of Gulf War Veterans nine years after inhalational exposure and warrants further investigation.

When a book hits the head and a hollow sound is heard, it is not always the fault of the book.

Schopenhauer