JRC 85595

ISSN 1977-5296

ESARDA

Bulletin

NUMBER 29
DECEMBER 1998

ISSN 0392-3029
Number 29
December 1998

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Designed by
J. Wells
EC, JRC, Ispra, Italy

Printed by
Arte Stampa Daverio (VA), Italy

ESARDA Bulletin

EUROPEAN SAFEGUARDS RESEARCH AND DEVELOPMENT ASSOCIATION

Contents

Neutron Position Sensitive Detectors: Development and Application to the Minimization of Uncertainties

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1. Introduction

In non destructive analysis, reduction of the measurement uncertainties is very important especially in the safeguards field where inspectors have to measure sometimes unknown sources. Our present work is focused on the reduction of spatial uncertainties that can be very high. Some examples show these uncertainties to be an order of magnitude /1/, /2/. Research and Development programs are in progress for the development of non destructive techniques for the characterization of wastes. They are being performed at CEA-CADARACHE, with the realization of several experiments to optimize performance of each measurement cell component (neutron fluxes, counting blocks and electronic, background reduction). Simultaneously, development is underway on complementary measurement systems and software allowing characterization of the package matrix and inner localization of the nuclear material.

This paper reports the development of position sensitive proportional detectors planned to be used to characterize the spatial distribution of the nuclear material in radioactive waste drums. The first part presents the specifications of one kind of prototype designed to be used in an existing low level waste measurement cell. Detection process, position encoding and electronics will be presented. First experimental results are shown.

The second part presents another kind of position sensitive detector based on charge division. General principles will be described. In order to optimize the electronics following the detection, we present the development of a new data acquisition card.

Finally, neutron measurements are widely used in non destructive analysis for Safeguards (total counting, multiplicity, etc.). Position sensitive detector should be able to improve our measurement strategy in order to reduce the uncertainties. Developments will be necessary, but the benefits of this kind of new technology could be very interesting.

2. Delay Line Detector

2.1. Description

The neutron position sensitive multiwire proportional counter under development was fabricated at the European Molecular Biology Laboratory, at Institut Laue Langevin in Grenoble /3,4/. This kind of detector is a gaseous detector. The position encoding of the particles is based on a delay line readout system. This localization technology is well known in X-ray detection (medical applications, plasma physics, solid state physics, astrophysics, etc.) /5/ and neutron diffraction experiments /6/. Our detector was designed to be placed in an existing low level waste measurement cell built to measure 118 litre drums /7/.

The active detection area of the position sensitive prototype was 100 mm x 960 mm. The detector consists of a 120 mm x 55 mm x 1000 mm aluminium pressure cell containing the detecting gas. Then, with a 15 mm thick polyethylene shell all around the detector, we are able to use it instead of a bank of seven conventional helium tubes in the cell measurement. The pressure cell is made of a special aluminium alloy chosen for its low absorption cross section for thermal neutrons. Calculations have shown that less than 5% of the incident particles are lost with a five mm thickness.

2.2. Detection

The detector consists of a pressure cell filled with detecting gas with a plane of wires (anodes) between two cathodes. The first one is the entrance window, the second is used for position encoding. A high electric field is applied between the anodes and the body of the detector.

The detection of thermal neutrons is based on neutron capture reactions /6/. In our case, the detecting gas is helium-3 which has a high absorption cross section for the thermal neutrons (~5300 barns for 0.025 eV energy). The reaction involved in neutron detection is the following:

$$ {}^{1}_{0}n_{th} + {}^{3}_{2}He \rightarrow {}^{1}_{1}H + {}^{3}_{1}T + 0.765\ MeV $$

Gas filled detectors rely on the phenomenon of gas multiplication to amplify the charge represented by the original ion pairs created within the gas by the passage of a charge particle. As the electrons and charged ions drift under the influence of the applied electric field, they collide with neutral molecules. If the applied field exceeds a critical value, electrons will be accelerated between collisions sufficiently for them to acquire the kinetic energy needed to ionize the next neutral atoms they encounter. An electron liberated by this secondary ionization process can, in its turn, be accelerated sufficiently to create further ionization. The phenomenon of gas multiplication therefore takes the form of a cascade of ionizing collisions. The electric field rises steeply in the immediate vicinity of the wire and the electrons enter the high field region as they are drawn to the anode. A Townsend avalanche occurs and provides a large amplification.

The use of pure helium-3 gives poor spatial resolution and a stopping gas has to be employed to reduce the centroid image. The stopping gas is generally a heavy gas which does not detract from the ionization effect in the helium-3. Typically, xenon or argon are used as a stopping gas. Polyatomic gas additives also have the effect of quenching the ultraviolet or visible light emitted from collisions between drifting electrons and gas molecules and hence prevent breakdown in the counter when it is operating with a high gas multiplication. Our detectors will work with a $^{3}He + CF_4$ mixtures /8/. The active thickness of the detector is about 30 mm.

2.3. Position encoding

As described on figure 1, the cathode used for the position encoding system is a plane consisting of linear copper strips orthogonal to the wires of the anode . In our applications, each strip is 5 mm wide and the gap between them is 1 mm wide. We use lumped delay lines of 50 Ω impedance with separate sections of inductances and capacitors, with a total delay of 200 ns.

When a signal reaches the anode wire, the capacitance coupling between anode and cathode plane results in a charge buildup on the cathode. The charge distribution in the strips of the cathode will be influenced by the arrival of an electric pulse anywhere on the wire. The effect on a given cathode strip will depend on the solid angle subtended by the element at the position where the neutron arrives. Since each element of the cathode is connected to an element of a delay line, the charge flows in opposite directions on the line giving two electric signals. Comparison of the time dependence of both signals at the end of each line allows us to determine the position of the incident particle. We should note that with delay lines, position data are digital which is very effective to avoid noise. Moreover, intrinsic spatial resolution of the detector is much smaller than the gap between each cathode strip (5 mm in our case). As a matter of fact, electric charges on the cathode are distributed on several strips. Then, position electronics will determine the position of the centre of gravity of induced charge.

2.4. Electronics and data acquisition

Electronic signals from each end of the delay line are pre-amplified (PA). This first stage of the signal processing electronics consists of low noise and high bandwidth preamplifiers that are located close to the detector. Further amplification of the signal is achieved by a timing filter amplifier (A). Then, a constant fraction discriminator (CFD) follows the amplifier to obtain accurate timing information independently of the pulse height. A gate and delay generator must be used on the Stop line to make a difference between the right and the left of the detector. In our preliminary experiments, Start and Stop lines are connected to a Time to Amplitude Converter (TAC) which generates an analog output pulse proportional to the measured time between Start and Stop. Analog output of the time converter module is connected to an Analog-Digital Converter (ADC) which is combined via a bus with a personal computer. Count rate capability in this data acquisition configuration is limited to some thousands of counts per second, because we used an ADC without buffer memory.

In a future configuration, we plan to use a Time Digital Converter (TDC). Then, the count rate capability of the acquisition will be close to a million events per second.

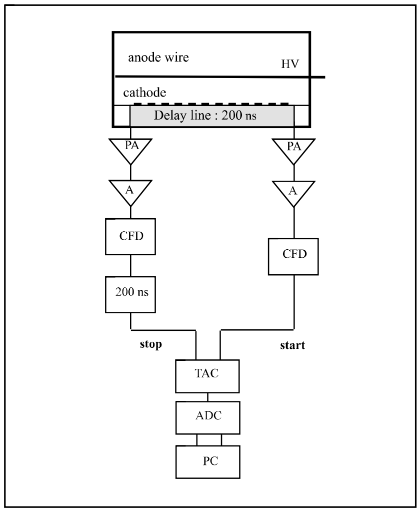

Figure 1: Schematic diagram of position encoding electronics

2.5. Preliminary results: spatial resolution measurement

Spatial resolution measurements were performed with a small size prototype detector (one wire, active detection area: 200 mm x 10 mm). We used a ^{252}Cf neutron source with an intensity of 10^5 n/s. Experiments are as presented in figure 2.

After preliminary tests on detection electronics, we measured the background of the detector. Position encoding tests were carried out to check any problem. Electronic spatial resolution was excellent.

Figure 3 shows the spatial resolution measurement with a 10 mm wide slit for a 2 atmosphere helium-3 pressure.

First results are very encouraging. We showed that neutron position sensitive detection based on delay line technology is easy to perform.

Finally, we plan to test the large size detector very soon.

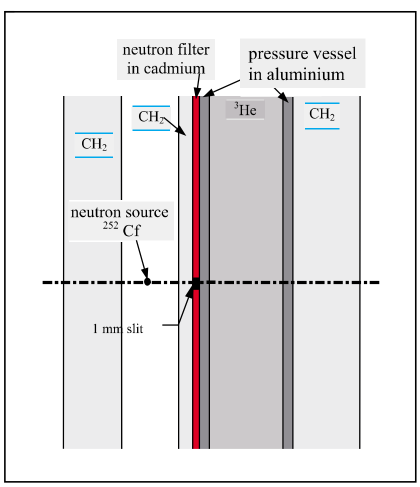

Figure 2: Plan view of the experiments defined for the study of the spatial resolution

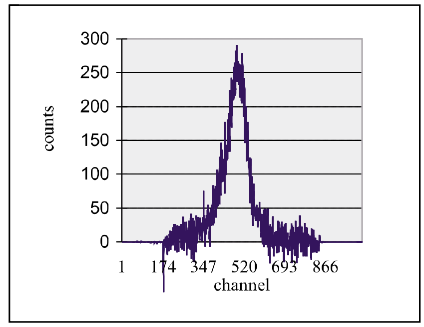

Figure 3: Measured spatial resolution. FWHM ≈ 26 mm

2.6. Application to waste drum measurements

One of the most important uncertainties of waste drum measurement is due to the inner localization of the nuclear material. A first step towards the reduction of uncertainty was to rotate the drum. Then, with detectors on cell measurement walls, the radial uncertainty can be reduced. This improvement is used on the more recent device /7/. However, the axial uncertainty is still very high. Some examples of cell efficiency show order of magnitude between the upper and the lower part of the drum. Cells were designed with a lot of individual helium-3 tubes to reduce the error, but, in this case, it is necessary to link each detector with a complete electronic set.

With a position sensitive detector installed following the axis of the drum, it will be possible to determine the location of nuclear material inside the waste drum. Shortly, this first measurement will be performed in our cell measurement /7/.

3. Charge Division Encoding Position Detector

3.1. Description

Position sensitive ^3He neutron detectors are made of cylindrical tube (40 centimeters useful length). The aspect is closed to the conventional tube except that the anode is formed with a resistive wire (some kilo ohms all along the wire) and both sides are connected. Two detectors are 2.54 cm diameter tubes developed by Eurisys Mesures.

3.2. Detection

Detection phenomena are strictly the same as those mentioned above (Townsend avalanche).

3.3. Position encoding

Position encoding is performed by charge division measurement. Each end of the resistive line is linked to a charge amplifier. As described on figure 4,

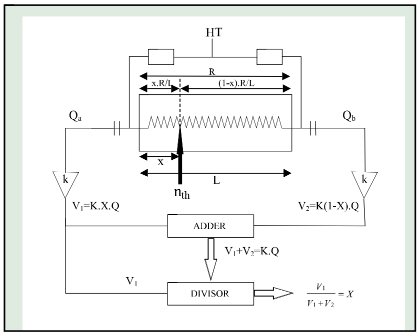

Figure 4: Principles of position encoding from charge division.

charges Q_a and Q_b are measured and converted to voltages through a charge amplifier. The neutron event x-position is obtained after a summation and a division: $x = V_1/(V_1+V_2)$, with:

x: position of the incoming neutron on the detector

k: charge amplifier gain

Q_a and Qb: charge from both extremities of the detector.

R: total resistance of the anode wire

L: total length of the detector

Preliminary tests on both detectors show some non-linearity problems on position response. Developments on new amplifier give better results. Preliminary measurements on voltage amplitude ratio were performed with digital oscilloscope.

In order to get an histogram of event positions, our laboratory is developing a new data acquisition module (module ADSCL).

4. Conclusion and Potential Applications to Safeguards

Our research programs show the feasibility of the large size neutron position sensitive detector. Numerous technical problems have been resolved. We showed that neutron position sensitive detection, based on delay line technology, is easy to realize.

Calculation results and preliminary tests demonstrate the possibility to determine the location of a neutron source.

It has been proven that the detection efficiency of the prototype is nearly the same as those of the bank (seven usual tubes) of the former experimental setup. Consequently, the new detector is position sensitive without losing detection efficiency which is very important in the case of low level measurement.

In the future, we will study the large size detector. After background and position encoding tests, we will determine the experimental spatial resolution versus the helium-3 pressure and the polyethylene thickness. After that, we will concentrate first on measurements of the location of the fissile mass inside the drum. Later, the behavior of the detector with active neutron measurement (bursts of 14 MeV neutrons from D-T neutron generator) will be studied.

In non destructive analysis for safeguards, the knowledge of the spatial distribution of the nuclear material in measured objects could be useful in order to reduce uncertainties. Position sensitive neutron detector can detect "hot spots" of nuclear material which could be on different type containers. In numerous configurations, the spatial information may give access to a new kind of data. As a matter of fact, we can get absolute value as, for example, total counting versus nuclear material mass (usual passive neutron measurement) and also relative value with the use of a rough collimator. Position sensitive detectors can be able to avoid some type of spatial scanning which is not easy to process on inspection. This type of detector is quite light and can be used by inspectors during their measurement campaign. Even, the development of large size detector could replace the use of numerous detectors on classical cell measurement.

Finally, we can see that the kind of detector has a strong potentiality in the safeguard applications. Research and Development should be undertaken in order to promote this kind of detector.

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Uncertainty Estimates for Neutron Coincidence Mesurements

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1. Introduction

A measurement result which will serve as a basis for a decision must be associated with an estimate of its uncertainty. For neutron coincidence measurements using the shift register technique the error estimation presented particular problems; the available algorithms /1/ did not lead to realistic uncertainties in most cases /2/.

In this report two approaches for the error estimation are compared for a realistic set of verification measurements. The two approaches are a global error estimate /3/ and an estimate based on the detailed measurement process /4/.

2. Use of the Error Estimate

In Safeguards the routine use of an error estimate is for qualifying an operator-inspector difference as significant or not: detection of an anomaly in the process of verification. The critical parameter for the decision is the estimated total uncertainty, $\sigma_t(m_t)$ of the "measured" amount of nuclear material.

If the uncertainty is underestimated an unnecessary large number of wrong decisions is taken on average. The effort to resolve such anomalies is expensive (time consuming) and frustrating for the inspector.

If the uncertainty is too large - this may seem preferable - real anomalies may not be detected. The same verification result could have been obtained with less effort: simpler instrument, less measurement time and (in case of a 2 instrument sampling) fewer measurements with the DA instrument.

Whereas for the above purpose an empirical estimate of σ_t is sufficient, there is good reason to develop also a detailed estimate where the different contributions to the overall uncertainty are separately accounted. If both estimates are consistent then there is good confidence in the modelling of the detailed error contributions.

The availability of a reliable detailed error estimate has the following advantages:

– The uncertainty can still be estimated if between calibration and verification there is a change in the measurement environment (background, measurement time, changing accuracy of the determination of the isotopic vector, etc.).

– The measurement process can be optimised with respect to the error contributions; e.g. neutron statistics and gamma (or mass spectroscopic) uncertainties should give about equal contributions to the overall uncertainty.

– The effect of the different contributions may be tested separately and serve for quality control of the measurement system; e.g. measurement repetition without sample repositioning allows to test the uncertainty caused by the counting statistics and the reliability of the related instrumentation.

Table 1: Data evaluation from measured quantities (symbol explanation in Table 1bis)

INSTRUMENT CONSTANTS

(1) $f = \exp(-p \cdot \lambda) \cdot (1 - \exp(-g \cdot \lambda))$

(2) $y = 1 - \frac{1 - \exp(-g \cdot \lambda)}{g \cdot \lambda}$

for $g \to t$: $y(g \cdot \lambda \to \infty) = 1$

RAW DATA TREATMENT

(3) $T_{dn} = \frac{T_m}{t} \cdot DT_{corr}^{025} \cdot \sqrt{k} \cdot \left[\exp\left(\frac{A}{4} \cdot \varphi\right)\right]$

(4) $\varphi = \frac{\beta \cdot \lambda}{2 \cdot n}$

(5) $DT_{corr} = \exp\left(\left(A + B \cdot \frac{T_m}{t}\right) \cdot \frac{T_m}{t}\right)$

(6) $EA_m = T_m^2 \cdot \frac{g}{t}$

(7) $R_m = [R + A]_m - EA_m$ [1)]

(8) $R_{dn} = \frac{R_m}{t} \cdot DT_{corr} \cdot k$

(9) $T = T_{dn} - B_T$

(10) $R = R_{dn} - B_R$

(11) $\beta = \frac{R}{T} \cdot \frac{2}{f}$

1) this modified algorithm reduces the uncertainty of R significantly, see factor FN in table 5 below; for the "traditional" expression: Rm=[R+A] – Am the factor is FN=2 instead of FN=1 for equation (7) above.

ACCIDENTALS - TOTALS TEST

(12) $d = \frac{A_m - EA_m}{A_m}$

(13) $\beta_d = \frac{R_m}{T_m} \cdot DT_{corr}^{075} \cdot \frac{2}{f}$

(14) $\sigma(d) = \frac{1 + \beta_d \cdot y}{\sqrt{A_m \cdot t \cdot DT_{corr}}}$

(15) exclude measurement if $d > 2 \cdot \sigma(d)$

3. Raw Data Treatment

From the measured quantities (totals, coincidences and accidentals) the refined data (the corrected totals and real rates) are evaluated, see table 1. If the accidentals-totals test fails the measurement is discarded. Conventional outlier tests for more than 3 measurements may be performed on T and R, for unknown mean value and known sigma /6/; see below for the sigma values.

There are two important differences from "standard" analysis:

(a) The deadtime correction of the totals shows an additional factor which depends on the fictitious count rate,

Table 1bis: Symbol explanation for Table 1

g	coincidence gate time [s]
p	predelay [s]
λ	neutron decay constant [1/s]
f	measured/total coincidences
y	variance factor
n	number of detector banks
t	measurement time [s]
T_m	measured totals
$[R+A]_m$	measured total coincidences
R_m	"measured" reals
A_m	measured accidentals
DT_{corr}	dead time correction factor
EA_m	expectation value for accidentals
A, B	dead time correction parameters
k	normalization factor
B_T	totals background rate
B_R	reals background rate
T_{dn}	totals rates (deadtime corrected and normalized)
R_{dn}	reals rates (deadtime corrected and normalized)
T	corrected totals rate
R	corrected reals rate
b	corrected beta value
d	normalized residual accidentals
β_d	preliminary beta value, may be used if step 11 is not available

which is a function of β and γ: both variables control the frequency of small pulse distances (not accounted for in the Poisson statistics). For a single counter bank (preamplifier) a typical value would be: $\varphi \approx 2500$ count/s; this is the limit at which high precision measurements may be influenced. The theory for the dead time correction was developed in /5/.

(b) Attention is drawn to step 6 (table 1). The average value of the reals is unchanged if the expectation value instead of the measured accidentals is used; however, the variance of the reals is drastically reduced, see chapter 6 below.

4. Evaluation of the Pu-Mass

Table 2 contains the uncertainty relationship of isotopic data.

The Pu-mass is obtained using the function f, see table 3, equation (1). It is important to note that the first 3 variables are statistically independent. It is a particularly important fact for the error calculation that T and R/T are not correlated /4/. I is the isotopic vector measured by mass spectroscopy or gamma techniques. The parameters $\hat{a}$ and $\hat{b}$ are the parameters of a linear calibration function (least squares fit).

The detailed algorithm is developed from the well accepted “point-model” (one energy, one space point approximation). As long as this model is strictly true the linear calibration function passes the zero point ($\hat{b}$=0). In other cases this calibration model should be applied to finite calibration ranges only.

The details of the algorithm are given in table 3, equations (1) to (7).

5. Error Models

The error model may be an empirical one or a detailed one. Depending on the planned application and on the knowledge of the inherent fluctuations, which

Table 3bis: Symbol explanation for Table 3

m_t	total mass of Pu
T, R/T, I	are statistically independent
T, R	deadtime + background corrected and normalized
$I = [i_{238}, i_{239},,,,]$	isotopic abundance vector
a, b	calibration constants
$\hat{A}_{240\ eff}$	^{240}Pu-eff coefficient [%]
R_{mc}	multiplication-corrected Reals
M	multiplication factor
α	characteristic “alpha” of Pu sample
$S_{\alpha,n}$	α-n source strength
S_f	spontaneous fission source strength

Table 2: Uncertainty relationship of isotopic data

(1)	$I\,(i_1, i_k, , i_6)$	Updated isotopic vector (independent components)
(2)	$E(e_1, e_k, ,, e_6)$	Relative error of isotopic vector components, depends on measurement method.
(3)	$Ca\,(a_1, a_k, , a_6)$	coefficients for a-n source strength
(4)	$Cf\,(f_1, f_k, , f_6)$	coefficients for spontaneous fission source strength
(5)	$C40\,(c_1, c_k, , c_6)$	coefficients for the ^{240}Pu-eff factor [g/g]
(6)	$S_{\alpha,n} = \sum_{k=1}^{6} i_k \cdot a_k$	α-n source strength of sample [n/s]
(7)	$S_f = 10.2 \sum_{k=1}^{6} i_k \cdot f_k$	spontaneous fission source strength of sample [n/s]
(8)	$\alpha = \frac{S_{\alpha,n}}{S_f}$	alpha value of sample (for multiplication factor)
(9)	$A_{240\ \ eff} = \sum_{k=1}^{6} i_k \cdot c_k \approx \frac{S_f}{10.2}$	^{240}Pu-eff coefficient [%]

$$10)\quad \sigma_{\%}^2\left(S_{\alpha,n}\right) = \frac{\sum_{k=1}^{6}\left(i_k \cdot a_k \cdot e_k\right)^2}{S_{\alpha,n}^2}$$

$$\sigma_{\%}^2\left(S_f\right) = \frac{(10.2)^2 \sum_{k=1}^{6}\left(i_k \cdot f_k \cdot e_k\right)^2}{S_f^2}$$

$$(11)\quad \mathrm{cov}_{\%}\left(S_{\alpha,n}, S_f\right) = \frac{10.2 \cdot \sum_{k=1}^{6}\left(i_k^2 \cdot a_k \cdot f_k \cdot e_k^2\right)}{S_{\alpha,n} \cdot S_f}$$

$$(12)\quad \sigma_{\%}^2(\alpha) = \sigma_{\%}^2\left(S_{\alpha,n}\right) + \sigma_{\%}^2\left(S_f\right) - 2 \cdot \mathrm{cov}_{\%}\left(S_{\alpha,n}, S_f\right)$$

Values of above defined vector components

Isotope	k	a_k	f_k	c_k	$E(e_k)$ % I	II	III
^{238}Pu	1	134	2.43	2.49	1.50	1.00	1.2
^{239}Pu	2	0.381	0	0	0.05	0.05	0.6
^{240}Pu	3	1.410	1.0	1.0	0.10	0.05	1.4
^{241}Pu	4	0.013	0	0	0.20	0.20	1.2
^{242}Pu	5	0.020	1.69	1.57	0.40	0.30	10
^{241}Am	6	26.9	0	0	0.20	-	4

with:
I: The relative error vector $E(e_k)$ is typical for mass spectroscopy (see 93 International Target Values: random errors)
II: Achievable errors using mass spectroscopy (TIMS+α) (see 93 International Target Values: systematic errors
III: Good MGA (Pu Isotopic Analysis Code) values

Table 3: Algorithms for Point Model (symbol explanation in table 3bis)

$$1)\quad m_t = f\left(T, \frac{R}{T}, I, \hat{a}, \hat{b}\right)$$

$$(2)\quad m_t = \frac{R_{mc} - \hat{b}}{\hat{a} \cdot A_{240\ \ eff}}$$

$$(3)\quad R_{mc} = \frac{T \cdot \rho_0}{M \cdot (1+\alpha)}$$

$$(4)\quad M = u + \sqrt{u^2 + \frac{R}{T} \cdot \frac{1}{k_{10} \cdot r_0}}$$

(5) $v = k_{10} \cdot (1+\alpha)$ (typically 3.0 to 3.6)
$u = (v-1)/(2 \cdot v)$

$$(6)\quad k_{10} = \frac{\overline{\nu(\nu-1)}^{I}}{\overline{\nu}^{I} - 1} \cdot \frac{\overline{\nu}^{Sf}}{\overline{\nu(\nu-1)}^{Sf}} = 2.062$$

(7) M = 1 for $\frac{\frac{R}{T} \cdot (1+\alpha)}{\rho_0} = 1$ $\quad \rho_0 = \frac{R_0}{T_0} \cdot (1+\alpha_0)$ Reference sample for M=1

with M=1+ε $\frac{R}{T}(1+\alpha) = \rho_0 \cdot (1 + \varepsilon \cdot (1+v))$

$$R = R_{mc} \cdot (1 + \varepsilon \cdot (2+v))$$

give rise to the final uncertainty, either model may be chosen.

5.1. Empirical Error Estimation /3/

If the calibration exercise is done in the same measurement environment as the verification measurement, the empirical model should be well suited. Same measurement environment means that the variable ranges of Pu-mass, isotopic vector and resulting count rates are the same and that also the measurement instrument (for the isotopic vector and for the neutrons) and procedures as well as the background conditions are unchanged. This includes also the condition that any other “calibration perturbing characteristics” (see /3/) play the same role during calibration and verification, such as possible mechanical instabilities, unaccounted variations in chemical composition (such as humidity or fluorine admixtures).

The calibration exercise with n different samples makes it possible to compute the calibration parameters (a,b), their variance matrix and the residual sum of squares divided by the degrees of freedom. The latter two items allow the estimation of the systematic and the random error components of a measurement, see table 4 equations (8) to (10).

The systematic error variance component originates from the uncertainty of the chosen calibration parameters.

The random variance component implicitly includes all the calibration perturbing variations which were also present during the calibration exercise. Obviously a detailed knowledge of the different contributors of variance is not required.

5.2. Detailed Error Estimation /4/

Based on the point model algorithms and on a detailed study of the statistics of the neutron counting process the error components are estimated, see table 5.

Table 4: Algorithms for the Empirical Error Estimation

8) $$\sigma^2_{\%}(m_t) = \sigma^2_{rand\%}(m_t) + \sigma^2_{syst\%}(m_t)$$

(9) $$\sigma^2_{syst\%}(m_t) = \frac{cov(\hat{a},\hat{a})}{\hat{a}^2} + 2\cdot\frac{cov(\hat{a},\hat{b})}{\hat{a}\cdot(R_{mc}-b)} + \frac{cov(\hat{b},\hat{b})}{(R_{mc}-b)^2}$$

(10) $$\sigma^2_{rand\%}(m_t) = \frac{1}{(R_{mc}-b)^2}\cdot\left\{\frac{1}{n-2}\cdot\sum_{i=1}^{n}\left(R_{mc,i}-\left(\hat{a}\cdot m_{t,i}\cdot A_{240\ eff,i}-\hat{b}\right)\right)^2\right\}$$

Table 5: Algorithms for the Detailed Error Estimation

(11) $$\sigma^2_{\%}(T) = \sigma^2_{\%,T}(R_{mc}) = \frac{1}{T^2}\left\{\frac{T_{dn}\cdot(1+\beta)}{t} + k\cdot\sigma^2(B_T) + \left(T_{dn}\cdot\frac{\sigma(k)}{2\cdot k}\right)^2\right\}$$

(12) $$\sigma^2_{\%}\left(\frac{R}{T}\right) = \frac{1}{R^2}\cdot\left\{\frac{\left(R_{dn}+FN\cdot T^2_{dn}\cdot g\right)(1+\beta\cdot y)^2}{t} + \left(k\cdot\sigma(B_R)\right)^2 + k\cdot\left(\left(\frac{R}{T}\right)\cdot\sigma(B_T)\right)^2 + \left(R_{dn}\cdot\frac{\sigma(k)}{k}\right)^2\right\}$$

(12a) For the “traditional” algorithm for the measured reals: FN = 2, for the revised one: FN = 1, see table 1 equation (7).

(13) $$\sigma^2_{\%,\frac{R}{T}}(R_{mc}) = \sigma^2_{\%}\left(\frac{R}{T}\right)\cdot FU^2$$

(14) with $$FU = -\frac{M-2\cdot u}{2\cdot(M-u)}$$

(15) $$\sigma^2_{\%,\alpha}(R_{mc}) = \sigma^2_{\%}(\alpha)\cdot FA^2$$

(16) with $$FA = -\frac{\alpha}{1+\alpha}\cdot\left(1+\frac{1}{2\cdot v\cdot(M-u)}\right)$$

RELATIVE ERROR OF MULTIPLICATION CORRECTED REALS

(17) $$\sigma^2_{\%}(R_{mc}) = \sigma^2_{\%,T}(R_{mc}) + \sigma^2_{\%,\frac{R}{T}}(R_{mc}) + \sigma^2_{\%,\alpha}(R_{mc})$$

RELATIVE ERROR OF ^{240}PU-eff

(18) $$\sigma^2_{\%}(m_{240eff}) = \left(\sigma_{\%}(R_{mc})\cdot FC\right)^2 + \sigma^2_{\%,cal}(m_{240eff})$$

(19) with $$FC = \frac{R_{mc}}{R_{mc}-\hat{b}}$$

and with $\sigma^2_{\%,cal}(m_{240eff}) = \sigma^2_{syst\%}(m_t)$ see table 4 equation (9)

(20) $$\sigma^2_{\%,Iso}(m_t) = FG^2\cdot\sigma^2_{\%}(S_{\alpha,n}) - 2\cdot FG\cdot(1+FG)\cdot\sigma_{\%}(S_{\alpha,n})\cdot\sigma_{\%}(S_f) + (1+FG)^2\cdot\sigma^2_{\%}(S_f,S_f)$$

(21) with $FG = FC\cdot FA$

RELATIVE ERROR OF TOTAL PU-MASS

(22) $$\sigma^2_{\%}(m_t) = \left\{\left(\sigma^2_{\%,T}(R_{mc}) + \sigma^2_{\%,\frac{R}{T}}(R_{mc})\right)\cdot FC^2 + \sigma^2_{\%,ISO}(m_t)\right\} + \left\{\sigma^2_{\%,cal}(m_{240\ eff})\right\}$$

The Relative Variance of the Totals

In the presence of correlated neutrons the counting statistics do not follow Poisson statistics (where the probability for a pulse t seconds after a given pulse is a constant, independent of t). The relative variance is given by the first term in the bracket of equation (11). The remaining terms depend on the background error and the uncertainty of the normalisation factor (see below).

The Relative Variance of the Reals/Totals

Basically the relative variances of the reals and of the reals over totals ratio are of equal size (table 5, first term in equation (12)). The 2nd and 3rd terms derive from the background data and the 4th term from the uncertainty of the normalisation factor (see below).

The contribution of this variance to the multiplication corrected reals (equation 13) is controlled by the factor FU (equation 14) which is obtained from table 3, equations (3) and (4), in the standard way.

The Relative Variance of the α-Value

As shown in table 2, the α-value of the sample is calculated as the ratio of the (α-n) and the spontaneous fission source strengths (equations (6), (7) and (8)). The variance of α is given by equation (12); both source strengths are correlated through the isotopic vector. The relative variance of contributes to the multiplication corrected reals (table 5, equations 15 and 16) through the factor FA (typical value: 0.5), which is obtained from table 3, equation (3), (4) and (5), in the standard way.

It is important to notice that the (α-n) source strength depends on the chemical composition. The values of the Ca-vector (table 2, definitions (3)) are valid only for stoichiometric PuO_2. Traces of humidity or fluorine would modify the coefficients.

The Relative Variance of R_{mc}

The estimated relative variance of the multiplication corrected reals, R_{mc} (equation (17) of table 5), is the sum of the 3 contributions given in equations (11), (13) and (15).

Usually, in applications with low background and mass spectroscopic isotope determination, the contribution of the totals, T, is smallest, the contribution of R/T is between one and 2 orders of magnitude larger, and the contribution of the isotopic vector is again 1 to 2 orders of magnitude larger.

The Relative Variance of the ^{240}Pu-eff Mass

The variance of ^{240}Pu-eff mass is shown in equation 18 of table 5: the R_{mc} contribution is modified by the base line shift to the regression line (factor FC) and the systematic calibration contribution is added, see table 4 equation (9).

The Relative Variance of the Total Pu-Mass

Basically the relative variance of the ^{240}Pu-eff mass must be increased by the relative variance of the ^{240}Pu-eff coefficient (see table 2 equation (9)); the latter is equal to the relative variance of spontaneous fission source S_f (equation (10) of table 2) and it is therefore correlated to the variance of α (equation 12 of table 2).

The contribution of the isotopic composition to the relative variance of the Pu mass is given in table 5 equations (20) and (21). The total relative variance of one Pu determination is given by equation (22). It consists of a random component (1st term) and a systematic component (2nd term). It is believed that all major error sources have been considered; under this assumption the empirical and detailed methods should agree and the random component of equation (22) must be equivalent to equation (10) of table 4.

6. Remarks on Specific Error Components

Measured Accidentals versus Expectation value

In the original applications of the correlation technique to safeguards verification the electronic stability of the measurement set-ups and their response to changes in the environment were quite critical; it was reported (by Böhnel) that relatively better results were obtained by replacing EA with the measured accidentals (table 1, equation (7)). Erroneously this procedure was maintained even though the measurement electronics and the background conditions were substantially improved. Under standard measurement conditions (A>>R) the variance of R reduces to 50% of its former value if the above quoted equation (7) is used /4/.

Normalisation Factor k

The uncertainty of the normalisation factor depends on the precision of the initial test of k. Normally an error of 0.5% is assumed for k. However, in practically all cases a variation of k is not observed. In this case k is unity and the uncertainty of k should be set to zero. It is not understood why the accuracy of the totals rates should be limited artificially to 0.25% (with more than 10 million counts collected).

Neutron Background

The neutron background radiation may contribute to the totals and to the reals background.

There is no problem to establish the totals background with the intended precision. The counts originate almost exclusively from external neutron sources. Therefore the background can be determined in the usual way, i.e. with an empty sample cavity.

The reals background, however, is a big problem. Normally the background sources are at a relatively large distance from the sample cavity; this reduces the probability of correlated counting events with an empty sample cavity to very low levels (compared to the totals). Still, then counting events can be well determined. However, there may be in addition an "internal" reals background which has as origin induced fissions caused by "background totals" in the sample. This background may change from sample to sample and it cannot be determined experimentally. A wrong reals background biases R, R/T and the multiplication factor.

Accurate results, therefore, can be obtained only with negligible internal reals background, i.e. with negligible totals background.

Multiplication Factor

The multiplication correction of the reals as shown in table 3, equations (3) to (7), performs satisfactorily under most circumstances, i.e. it linearizes the relation between the reals and the ^{240}Pu-eff. It is difficult to measure ρ_o but, it is the experience that the value is not critical, it may be adjusted. (M may differ from the actual source multiplication but still linearizes the relation (2)).

For very small samples (range of grams) it is not certain if the multiplication factor can be set to unity. This would be useful in cases where the factor $(1+\alpha)$ could be obtained from the measurement of the reals to totals ratio (table 3, equation (7)). For typical precision measurement /7/ the relative error of R and of R/T is between 0.13% and 0.24%, whereas for mass spectrometric determination $(1+\alpha)$ is around 0.4%.

It may be possible that a correction due to a fast fission factor would still be required /8/.

Uncertainty of the Isotopic Vector

The errors which are quoted for the components of the isotopic vector influence the random error quite strongly. The set of uncertainties used for the evaluations (table 2, E_I-vector) are consistent with the random errors quoted by the 93 International Target Values. Since these errors dominate the error evaluation (see below) realistic uncertainty values for the components of the isotopic vector are essential. Normally such error values are strongly rounded.

7. Results

The results of our comparative error calculation are shown in tables 6A, 6B, 6C and 7A, 7B, 7C. After a series of calibration measurement (same measurement environment as for the verification measurements) 10 verification measurements were performed (4 different Pu-batches, 2 different sample designs and 2 calibration functions). The neutron background for all measurements is negligibly low.

Table 6

Table 6A shows the declared and measured Pu masses, their relative difference and the results of the empirical error estimation model. The relative differences are also given in units of the random and the total error. If the differences are on average consistent with the errors, the standard deviation of these ratios should be close to unity, as shown in table 6A.

Table 6a: Comparison between empirical and detailed error estimates: empirical error estimates

Total Pu-Mass			Empirical error estimates				
Decl. [g]	Meas. [g]	Rel.Diff. (meas.date)	σ(cal) systematic	σ(ran) random	σ(tot)	Rel.Diff. / σ(ran)	Rel.Diff. / σ(tot)
11857.93	11627.70	0.68%	0.166%	0.546%	0.571%	1.248	1.194
11855.02	11794.88	-0.77%	0.171%	0.538%	0.565%	-1.433	-1.366
11865.40	11661.88	0.45%	0.167%	0.544%	0.569%	0.830	0.794
11809.59	11573.98	0.74%	0.165%	0.549%	0.573%	1.341	1.284
11591.96	11483.78	0.09%	0.274%	0.642%	0.698%	0.141	0.130
11563.97	11459.74	0.06%	0.277%	0.643%	0.700%	0.091	0.084
11559.83	11470.31	-0.07%	0.275%	0.643%	0.699%	-0.108	-0.099
11442.11	11317.89	0.21%	0.244%	0.488%	0.545%	0.427	0.382
15091.34	15227.78	-0.90%	0.166%	0.607%	0.629%	-1.485	-1.432
14629.94	14730.13	-0.68%	0.139%	0.627%	0.643%	-1.087	-1.061
			AVERAGE			-0.003	-0.009
			STANDARD DEVIATION			1.039	0.996

Table 6b: Comparison between empirical and detailed error estimates: detailed error estimates with t=900s

Detailed error estimates: using {E_I, σ(k)=0, t=900}							present method using E_{III}	standard method ref /1/
σ(T)	σ(R/T)	σ(Iso)	σ(ran)	σ(tot)	Rel.Diff. σ(ran)	Rel.Diff. σ(tot)	σ(tot)	σ(tot)
0.007%	0.118%	0.567%	0.580%	0.603%	1.175	1.130	1.35%	1.71%
0.007%	0.119%	0.568%	0.580%	0.605%	-1.329	-1.275	1.35%	1.71%
0.007%	0.118%	0.568%	0.580%	0.603%	0.779	0.749	1.35%	1.71%
0.007%	0.118%	0.567%	0.580%	0.603%	1.269	1.221	1.35%	1.71%
0.007%	0.117%	0.478%	0.492%	0.563%	0.184	0.161	1.34%	1.52%
0.007%	0.117%	0.478%	0.492%	0.564%	0.119	0.104	1.34%	1.53%
0.007%	0.118%	0.478%	0.492%	0.564%	-0.141	-0.123	1.34%	1.53%
0.006%	0.120%	0.614%	0.626%	0.671%	0.333	0.310	1.52%	1.74%
0.006%	0.119%	0.706%	0.716%	0.735%	-1.258	-1.225	1.46%	2.03%
0.006%	0.120%	0.706%	0.716%	0.730%	-0.952	-0.935	1.46%	1.98%
		AVERAGE			0.018	0.012		
		STANDARD DEVIATION			0.945	0.911		

Table 6c: Comparison between empirical and detailed error estimates: detailed error estimates with t=500s

Detailed error estimates: using {E_I, σ(k)=0, t=500}						
σ(T)	σ(R/T)	σ(Iso)	σ(ran)	σ(tot)	Rel.Diff. σ(ran)	Rel.Diff. σ(tot)
0.008%	0.159%	0.567%	0.589%	0.612%	1.156	1.113
0.008%	0.159%	0.568%	0.590%	0.614%	-1.307	-1.256
0.008%	0.159%	0.568%	0.590%	0.613%	0.767	0.738
0.008%	0.158%	0.567%	0.589%	0.612%	1.249	1.202
0.008%	0.157%	0.478%	0.503%	0.573%	0.180	0.158
0.008%	0.157%	0.478%	0.503%	0.574%	0.116	0.102
0.008%	0.158%	0.478%	0.503%	0.574%	-0.138	-0.121
0.007%	0.161%	0.614%	0.635%	0.680%	0.328	0.306
0.007%	0.160%	0.706%	0.724%	0.743%	-1.244	-1.213
0.007%	0.161%	0.706%	0.724%	0.738%	-0.942	-0.925
		AVERAGE			0.017	0.011
		STANDARD DEVIATION			0.931	0.899

Table 7: Detailed error estimates with a 20% reduction of error in the isotopic vector

Table 7a: Results with σ(k) = 0 and t = 900 s

Detailed variance estimates using: {$E_I \rightarrow 0.80 \cdot E_I$, σ(k)=0, t=900}						
σ(T)	σ(R/T)	σ(Iso)	σ(ran)	σ(tot)	Rel.Diff. σ(ran)	Rel.Diff. σ(tot)
0.0066%	0.118%	0.454%	0.469%	0.498%	1.452	1.369
0.0066%	0.119%	0.454%	0.470%	0.500%	-1.642	-1.543
0.0066%	0.118%	0.454%	0.469%	0.498%	0.963	0.907
0.0066%	0.118%	0.454%	0.469%	0.497%	1.568	1.479
0.0070%	0.117%	0.382%	0.400%	0.485%	0.227	0.187
0.0070%	0.117%	0.382%	0.400%	0.486%	0.146	0.120
0.0070%	0.118%	0.382%	0.400%	0.486%	-0.174	-0.143
0.0065%	0.120%	0.491%	0.506%	0.561%	0.412	0.371
0.0061%	0.119%	0.565%	0.578%	0.601%	-1.560	-1.500
0.0062%	0.120%	0.565%	0.578%	0.594%	-1.181	-1.148
		AVERAGE			0.021	0.010
		STANDARD DEVIATION			1.169	1.108

Table 7b: Results with σ(k) = 0 and t = 500 s

Detailed error estimates using: {$E_I \rightarrow 0.80 \cdot E_I$, σ(k)=0, t=500}						
σ(T)	σ(R/T)	σ(Iso)	σ(ran)	σ(tot)	Rel.Diff. σ(ran)	Rel.Diff. σ(tot)
0.0077%	0.159%	0.454%	0.481%	0.509%	1.417	1.339
0.0076%	0.159%	0.454%	0.482%	0.511%	-1.601	-1.509
0.0077%	0.159%	0.454%	0.481%	0.509%	0.939	0.888
0.0077%	0.158%	0.454%	0.481%	0.508%	1.530	1.447
0.0083%	0.157%	0.382%	0.413%	0.496%	0.219	0.183
0.0083%	0.157%	0.382%	0.413%	0.497%	0.142	0.118
0.0083%	0.158%	0.382%	0.414%	0.497%	-0.168	-0.140
0.0075%	0.161%	0.491%	0.517%	0.571%	0.403	0.364
0.0069%	0.160%	0.565%	0.587%	0.610%	-1.535	-1.477
0.0070%	0.161%	0.565%	0.587%	0.604%	-1.161	-1.130
		AVERAGE			0.019	0.008
		STANDARD DEVIATION			1.143	1.086

In table 6B the results from the detailed error estimation model are shown, i.e. the contributions from R, R/T and Iso-vector to the relative error of the Pu-mass. The combination of the three error contributions is the random error and must be compared to the random error of the empirical error estimation model. Since also here the standard deviation is close to 1 it should be concluded that the detailed calculation treated the main error sources in a reliable way and that no additional significant error sources exist.

The last two columns of table 6B show two additional detailed calculations for σ(tot). One is based on the present method (Detailed Error Estimation) but the isotope uncertainties of the MGA (Pu Isotopic Analysis Code) method are used (see table 2 E_{III}). The last column gives the results as obtained from “the standard method” /1/.

Table 6C shows that a reduction of the measurement time from 900 to 500s does not change the error in any significant way.

Table 7

In table 7A the effect is shown of a 20% reduction of all errors of the components of the isotopic vector. This leads to a 20% reduction of the random error. The set of errors which is used originally is shown in table 2 (as vector E_I).

In tables 7B and 7C also other combinations of modified parameters are displayed.

8. Summary

The good consistency of the set of real Operator-Inspector differences with both the empirical and detailed error estimates gives confidence into the proposed error algorithms. Since the algorithms are based on standard error calculus and on theoretical and simulation studies for the neutron statistics, this result suggests that there are no significant additional “calibration perturbing effects” in the analysed data set, such as mechanical instability, varying humidity, etc.

It is proposed to check also details of these error estimates by special evaluations of measurements, which are repetitive and/or which belong to one batch only (same isotopic composition) or to one calibration function (same item design and weight range).

It is also apparent that any detailed error estimate of neutron coincidence results, which does not account for the uncertainty of the isotopic vector components cannot give physically meaningful results:

- If the measurement conditions are ideal (negligible background, mass

Detailed error estimates using: {$E_I \rightarrow 0.80 \cdot E_I$, $\sigma(k)$=0.5%, t=500}						
σ(T)	σ(R/T)	σ(Iso)	σ(ran)	σ(tot)	Rel.Diff. / σ(ran)	Rel.Diff. / σ(tot)
0.237%	0.198%	0.454%	0.549%	0.574%	1.241	1.188
0.237%	0.199%	0.454%	0.550%	0.576%	-1.403	-1.340
0.237%	0.198%	0.454%	0.549%	0.574%	0.823	0.788
0.237%	0.198%	0.454%	0.549%	0.573%	1.340	1.283
0.234%	0.199%	0.382%	0.490%	0.562%	0.185	0.161
0.234%	0.199%	0.382%	0.490%	0.563%	0.119	0.104
0.234%	0.199%	0.382%	0.491%	0.563%	-0.142	-0.124
0.238%	0.201%	0.491%	0.582%	0.631%	0.358	0.330
0.241%	0.201%	0.565%	0.646%	0.668%	-1.394	-1.350
0.241%	0.201%	0.565%	0.646%	0.661%	-1.055	-1.032
		AVERAGE			0.007	0.001
		STANDARD DEVIATION			1.013	0.973

Table 7c: Results with σ(k) = 0.5% and t = 500 s

spectroscopic isotope determination), the “standard method” /1/ overestimates the error by up to a factor of three. (This was the situation where the inadequateness of the model was detected originally)

- For the combination of coincidence counting with the MGA method the “standard method” gives values which are only some 25% too large. (However, this agreement is purely accidental)
- In the case of very large backgrounds neither the error of the isotopics nor the error of the correlation statistics are the determining contributions. In this case no significant differences between the statistics of the real results and the “standard method” were noted.

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Internet - the New Pathway for Information

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1. Introduction

The Internet may be considered one of the most momentous innovations in the field of information and communication at the end of the 20th century. Based on precursor innovations like semiconductor development (integrated circuit, microprocessor), the Internet offers an integration of various technologies, and opens up perspectives for the convergence of telecommunications, computer and content industries. Having started with the demand for universal connectivity and reliable access for special purposes in a network structure, and developing towards the demand for ubiquituous connectivity, satisfactory privacy and security in communications, and global interaction for everyone, the Internet will bring forth a great variety of successor innovations.

2. History and Growth

The early origin can be seen in 1969 with a DARPA (Defense Advanced Research Projects Agency) contract to build a network supposedly invulnerable to nuclear attack. 1983 is mentioned for the introduction of TCP/IP (Transmission Control Protocol/ Internet Protocol), the basic information transport method of the Internet (network of TCP/IP nets). The following year, 1,000 host computers were already connected, and the mnemonic DNS concept (Domain Name System, name resolution into IP addresses) was introduced /1/.

The host number (devices or appliances with IP address, originally central mainframe computers hosting various services) increased from 10,000 in 1987 to 100,000 in just two years. Then, Internet (NSFNET, National Science Foundation) was still a domain of restricted communities, e.g. for research and education. U.S. federal policy decisions focused attention on connecting with other networks and supporting the research community world-wide. In 1992, the U.S. Congress opened the NSFNET to private companies for business and commerce (and in 1994 the US backbone was commercialized as a consequence).

That same year, the number of hosts reached 1,000,000 and in the subsequent year the WWW (World Wide Web) structure became publicly accessible (from CERN, European Laboratory for Particle Physics), supported by HTTP (HyperText Transfer Protocol), providing HTML Web pages (HyperText Markup Language) to be explored or navigated by means of a browser (e.g. early NCSA Mosaic, National Center for Supercomputing Applications). This time interval can be seen as the real starting point of the huge Internet innovation engine and, from the viewpoint of the past years, no standstill, consolidation or saturation can be observed yet.

3. Status, Nature and Usage

Nowadays, the Internet comprises roughly 200,000 networks ranging from site-oriented local-area networks (LAN) to globally spread wide-area networks (WAN), besides others like BITNET, UUCP, FidoNet, OSI. A Web server survey reveals 2,084,473 sites (servers) as of March 1998. Performed since 1987, an Internet domain survey identifies 29,669,611 hosts as of January 1998 (a growth of 50% within the last six months, of 84% for 1997, and of 70% for 1996) /2/.

The Internet has established itself as a world-wide information universe with some services already defined and others not yet predictable, open for individuals and enterprises as one of the prerequisites for the anticipated information society. The geographical distribution of users connected is given as about 70 million users in Canada and U.S.A, 20 million in Europe, 14 million in Asia and the Pacific Region, 7 million in South America and about 1.5 million in Africa and the Middle East /3/.

The nationality of the users as well as their cultural and social influences on the technology demand are of course important for further Internet development. The U.S. and Canada are clearly ahead with their dominant English language. An Internet lifestyle (participating in newsgroups and mailing lists, shopping in virtual company stores, etc.) appears to be developing comparable to global audiences for tv programmes. However, the pace of growth appears to be slowing down slightly in the U.S., possibly caused by problems with bandwidth limitations, insufficient modem speeds, trend weakening and hasty pace of technological development.

One of the parents of the Internet has expressed the view that (the Internet is at once a world-wide *broadcasting capability*, a mechanism for *information dissemination*, and a medium for *collaboration and interaction* between individuals and their computers without regard for geographic location(. From around 1973, the Internet expanded with electronic mail (e-mail), the favourite network application for about 20 years. Other services provided resource sharing such as electronic file transfer (FTP), access to remote computers (Telnet), and resource discovery like Gopher (document file system).

The idea of the WWW emerged around 1991 to implement hypertext structures on documents stored on networked computers and linked together in the form of a worldwide web. A definition describes the WWW (or W3) as a “distributed heterogeneous collaborative multimedia information system”. Information is stored in hypertext format at various sites (servers), and documents (Web pages) can be viewed at the user’s device (client). This service was the subsequent major force for the growing acceptance of the networked world.

Newsgroups and discussion groups (mailing lists) contributed to accelerating growth. A current directory mentions 89,382 mailing lists, about 30,000 USENET newsgroups, and some 25,000 IRC channels (Internet relay chat). The precision of all the numbers should not be overestimated but they obviously indicate the trend of growth.

4. Issues

Almost 30 years have passed since the Internet design originated, with its concept of information flow between a limited number of computers or workstations and a minority of elitist users. In the meantime, the nature of the Internet has changed dramatically, its purpose is the general supply of any kind of information and at the latest count there are over 100 million users. The packet-switching information transmission concept, the connectivity concept of computer networks, the PC (personal computer as client), and the WWW (World Wide Web) concept have been incredibly successful, but the introduction of multimedia content and the transformation of existing services (e.g. telephone, radio, computer, video) to the Web had not been envisaged. Therefore, technical and design enhancements, and regulatory and legal provisions are urgently required, and will promise extended future use of the Internet. Some topics are described in the following.

4.1. Technical

The growing amount of Web pages (at least 320 million according to a recent survey) and the increase in data demand and throughput have led to performance problems.

IP address

The early IP design introduced a 32 bit IP address (IPv4 - Internet Protocol Version 4) to route the data packets to their proper destination. In the meantime, a new protocol IPv6 (or IPng - IP next generation) has been proposed with a 128 bit address space (supporting expanded addressing, autoconfiguration, multimedia, network layer end-to-end security amongst others). The new header may optionally also contain information about encryption, authentication, priority and payment conditions. At present, tests are being carried out with a IPv6 testbed called "6bone".

Infrastructure

Different telecommunication lines, gateways and routers constitute the current Internet infrastructure. The "information superhighways" (e.g. glassfibre backbones with transmission rates of up to 622 Mbit/sec) may have to be accessed by means of telephone wires by individual users. TV cable networks, satellites, ISDN (Integrated Digital Services Network) and xDSL (version of Digital Subscriber Line, mainly ADSL at present) can temporarily help to ease performance problems but there is already a U.S. I2 (Internet2) project underway (for commercial use also) supported by the governmental vBNS (very high-speed Backbone Network Service).

Multicast

The functionality of the Internet can be used to provide information in a variety of communication modes, from the one-to-one concept (IP unicast) through one-to-many (IP multicast) to many-to-many. In order to avoid unnecessary traffic over TCP/IP networks, IP Multicast is an initiative to reach all members of a specified destination host group at the same multicast address. "Mbone" (multicast backbone on the Internet), an experimental enhancement for processing of multimedia content, has been approved by the IETF (Internet Engineering Task Force).

WWW improvement

The W3C (World Wide Web Consortium) supports W3 development by several projects. The HTTPng (HyperText Transfer Protocol next generation) project foresees a distributed and object-oriented architecture, which is more oriented towards the modern usage requirements of the Web. HTML is used for publishing hypertext on the World Wide Web (HTML 4.0 as the latest version). In order to define data formats for structured document interchange, XML (Extensible Markup Language) has been promoted by market contributors. Another consortium has been formed for the specification of VRML (Virtual Reality Modeling Language) to provide file format standards for 3D multimedia and shared virtual worlds on the Internet.

4.2. Organizational

The genuine Internet operation was pursued by a like-minded community. It was not much perceived among the public until 20 years had passed. In the last few years, the speed of technological development and the increasing number and diverging motivation of participating actors have led to difficulties with the "original open and flexible consensus-building process".

Domain name reform

IP addresses were centrally registered by the IANA (Internet Assigned Numbers Authority) and are distributed region-wise by (new) ARIN (American Registry for Internet Numbers), RIPE (Réseaux IP Européens) and APNIC (Asian-Pacific Network Information Center). The early DNS comprised six top-level domains (TLD): .com for commerce, .edu for education, .mil for military, .org for non-profit-organizations, .gov for government and .net for network service providers; and additionally, of course, the country-code domains (ccTLD) like .us, .de etc. InterNIC (International Network Information Center) administered "generic" TLDs (.com, .org, .net, .edu and .gov - for US government only) whereas national NICs now look after more than 200 ccTLDs.

In accordance with demand, the TLDs are nowadays rather unequally filled with IP addresses. For instance, .com leads with 8,201,511 hosts, followed by .edu with 5,283,568 hosts, then .net, .jp (Japan), .mil (US military, nearly as many as Japan), .us (U.S.A.), .de (Germany), .uk (United Kingdom) and .ca (Canada) etc. Obviously, the availability of useful names is particularly scarce in the .com domain. The growing participation of Internet users of any kind requires supplementary modification of the DNS (originating from 1984). Current proposals envisage 7 new (generic) gTLDs, namely .firm, .store/.shop, .web, .arts, .rec, .info and .nom.

Administration

Only a few bodies and institutions ("Internet community") were concerned about interoperability and standards issues, for instance, IAHC (Internet Ad Hoc Committee), IAB (Internet Architecture Board), IANA, IETF, W3C, InterNIC, ISOC (Internet Society) etc., working in the form of a "cooperative and mutually supportive relationship". Instead of being subject to a general authority, the global network was strongly influenced by the scientific and academic community and, later, by "normal" users, private individuals and businesses with increasing dominance.

For the future, many parties (governments, supranational organizations, multinational enterprises etc.) request more international competition in DNS funding, administration and name assignment. A US proposal is already under discussion, also in the EU (European Union), but there is still no international consensus about a solution. CORE (Council of Registrars, Geneva), a coalition of more than 200 international Internet actors, plans to compete in managing gTLDs instead of NSI (Network Solutions Inc., contracted by NSF and operating InterNIC).

4.3. Regulatory and Legal

Unlike the development of other information and communication services, the Internet is essentially user-driven, i.e. the content is generated by many active participants within the network following an "open and spontaneous organizational concept". In order to prevent misuse, national governments and international authorities now request formal agreements and legal structures for the supervision of the global network /4/.

Legal provisions

Particularly in the U.S.A., there have already been provisions for jurisdiction in the Internet like, for instance, the controversial Communications Decency Act (CDA), Internet Gambling Prohibition Act, Electronic Communications Privacy Act, Protecting Children from Internet Predators Act etc. National laws differ from country to country, and therefore jurisdictional conflicts may arise.

Regulatory aspects

According to the expanding private and commercial use of the Internet, an

increasing number of issues deserves attention beyond self-regulatory commitments:
- user identification and liability, data protection and integrity;
- company jurisdiction, trademarks, copyright, protection of intellectual property;
- labour law, consumer protection, terms and conditions of contract, harmful and illegal content.

In the following, several of the related technical terms are described.

Security

The acceptance of Internet use greatly depends on secure technical services, authentication services and personal privacy aspects. W3C security initiatives comprise the Platform for Privacy Preferences (P3P), the Digital Signature Initiative, the Platform for Internet Content Selection (PICS), and HTTP enhancement (provision of authentication scheme amongst others).

Privacy

W3C intends to set up individual privacy principles by its P3P project. Internet users should be able to specify their privacy preferences for information exchange with the variety of Web sites and to control the use of their personal information profile (e.g. “cookies”). Another way is the use of anonymous or pseudonymous web servers and remailing services.

Privacy can be achieved as well if content is not openly shared (e.g. password protected) with other participants of the public network. A new approach proposes VPNs (Virtual Private Network) as a secure way of global corporate WAN communication. Strong encryption and authentication provisions and data integrity checks are characteristic of this “extranet” solution. Another DARPA project is reported as ESP (Extranet for Security Professionals) that encrypts all data traffic and explicitly restricts access to qualified participants only.

Encryption

In order to keep digital data and electronic communications confidential, plain text is made “invisible” for unauthorized participants by various methods. Classical encryption operates with *keys*, other means are steganography (hiding of plain text in pixels of images) and “chaffing and *winnowing*” (mixture of garbage and plain text). Governmental authorities are concerned about legal key access, key escrow and key recovery.

Authentication

Information transmission for private or business use should not be disclosed (confidentiality), tampered with (integrity) and delivered only by the genuine source (authentication). In the latter case, the original sender may uniquely ensure its identity by particular means.

Digital signature

The authenticity of the source can be proven and the integrity of data verified by encryption and digital signatures. Digital signatures are based on “public key cryptography”, which requires some sort of key management and mutual trust between sender and recipient. P3P is also intended to support future certificate and signature opportunities. For feasibility reasons, certificates of the participants’ identity could be issued by official third-party Certification Authorities (CA). Of course, repudiation of a digital signature may happen, for instance in cases of so-called “undisclosed” delegation.

Content

Appropriate content classification is a major problem with respect to the incredible number of documents on the WWW. Search engines and hierarchical categorization rely on keywords, which may not properly describe a given content in every case. PICS is concerned with adding meta-information to documents, for instance copyright statements and usage information. Besides other means, it could be used to filter and reject Web pages with harmful or illegal content.

The mission of WIPO (World Intellectual Property Organization) is protection of industrial property (e.g. inventions, trademarks etc.) and copyright (i.e. multimedia authorship). Several groups are concerned about a weighted balance between intellectual property rights and free flow of information in Internet. Another example is the Digital Object Identifier system (DOI) being proposed for the identification of digital objects (in the interest of publishers).

Commerce

A general definition designates electronic commerce (e-commerce) as a set of activities that “covers any form of computerized buying and selling, both by consumers and from company to company”. Depending on institutional arrangements and technical infrastructure, e- commerce is expected to grow considerably. Privacy of consumers and security of transactions in the international marketplace need to be warranted by an effective multilateral policy framework. The Internet could serve as the basic medium for commerce in the context of an expected knowledge-based society.

5. Predictions

The Internet offers concepts and structures for the integration of services that will constitute much more than a technological paradigm in the future. Improvements in data processing speed and data storage capacities, bandwidth and information transmission enhancements and privacy and security solutions for information exchange will lead to a complex global information and communication infrastructure for any kind of user. Within the next few years, a number of emerging countries (e.g. Argentina, Brazil, Chile, China, Colombia, Greece, India, Indonesia, Malaysia, Mexico, Pakistan, Peru, the Philippines, Poland, Russia, Saudi Arabia, Thailand, Turkey, Venezuela, Vietnam etc.) are expected to participate significantly in the future use and growth of the global network.

In the 21st century, the skills of “human users” may be complemented by intelligent “information appliances” as part of the network, as well as “machine users” such as household devices or computer desks /5/. Internet could serve the same purposes for ubiquitous information provision as the electric grid does for power supply. At present, information appliances are defined as “low-cost, easy-to-use, digital consumer electronics devices providing access to the Internet or Internet-like services” /6/. Falling communication tariffs may further contribute to the development of the electronic marketplace. The envisaged information society can become reality, the more governments, enterprises, and private users perform advanced information processing via the Internet /7/.

6. Concluding Remarks

A considerable effort in international safeguards is devoted to the generation, confirmation and evaluation of information to enable well-founded decisions to be made on the potential diversion of nuclear material and the possible evidence of undeclared nuclear activities (verification of nuclear non-proliferation) /8/. The scope and extent of necessary information to be acquired, managed and analysed for safeguards have increased even more with regard to the new Model Protocol (INFCIRC/540) /9/. Based on the availability and accessibility of data (either from confidential or open sources, provided by humans or automated/smart instruments, acquired routinely or on an ad hoc basis), the use of the Internet, information appliances and a reliable security technology could serve to improve safeguards efficiency in an appropriate way.

The Internet (as an extranet for the safeguards control regime) can be envisaged to be more effective and less expensive than proprietary communication lines and devices for future safeguards data acquisition, data evaluation and decision-making. Varying levels of internetworking security could be represented through virtual private networks that may be defined as “temporary, secure connection over a public network, usually the Internet”. In the world of communications and transactions, the rise of the Internet and the dissemination of its services can be regarded as the innovative technological means in providing new dimensions of potential assistance and support.

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One year of ESARDA activities

Seminar on "Modern Verification Regimes: Synergies, Differences and Challenges"

Organized by ESARDA in the framework of its 20th Annual Meeting.
Helsinki 12-14 May, 1998

ESARDA Organizes every second year an Internal Meeting. The purpose of these meetings is to convene all Members of the ESARDA Working Groups and the management of the Association, to discuss issues of common interest. This year, ESARDA decided to discuss the possible synergies of Safeguards with other verification regimes, especially those related to mass-destruction weapons.

Nuclear non-proliferation is but one component of the international regime to prevent proliferation of weapons of mass destruction. That regime saw significant developments in 1997 with the coming into force of the Chemical Weapons Convention (CWC), the adoption of the full IAEA safeguards strengthening measures (programme "93+2"), the establishment of the Organization to monitor the Comprehensive Test Ban Treaty (CTBT) and the ongoing discussion on verification by the conference on the Biological Weapons Convention. All these instruments, together with those stemming from the nuclear disarmament initiatives (i.e. the disposition of surplus weapons material and Fissile Material Cut-off), depend on an effective independent verification regime.

In facing the challenge of verification, there is much to be gained from a technical dialogue and information exchange between the safeguards community and these other organizations. The seminar, which convened 100 technical experts and speakers from the safeguards area and from other verification agencies, aimed at fostering and encouraging this dialogue, with a view to:

1. inform the safeguards community about the approaches being adopted by other international verification agencies that could be used to support advances in international safeguards;
2. inform the wider verification community of the technologies and experience in safeguards verification which may have wider application and benefit;
3. stimulate exchange of concepts and technologies by providing an opportunity for technical interchange among experts in verification systems;
4. encourage a forward looking technical review of verification and to identify the challenges to research and development.

The Seminar was chaired by Denis Flory, Chairman of ESARDA. The plenary session, lasting one day, provided the opportunity for invited speakers to present the international context and the technical verification aspects of their systems. The session was opened by an address of the Director for Arms-Control, Non-Proliferation and Disarmament of the Finnish Ministry for Foreign Affairs, Mr. Kari Kahiluoto, and by an address of the Director-General of the Finnish Radiation and Nuclear Safety Authority, Prof. Jukka Laaksonen. The following presentations were given:

D. Flory (CEA, IPSN, Paris, France, and ESARDA Chairman): "Safeguards and ESARDA: Experience and Objectives"

J-P. Contzen (Special Adviser to European Commission and former Director General of the Joint Research Centre): "Verification is the Key to Treaties' Enforcement, but Technology is the Key to Verification"

J.L. Rolland (Director of the Verification Division of the Chemical Weapons Convention Organization, The Hague, Netherlands): "The Chemical Weapons Convention Verification Regime and Experience gained through the first Year of Implementation"

O. Thränert (Research Institute Friedrich Ebert Foundation, Bonn, Germany): "The current Status of Negotiations of the Biological Weapons Convention"

P. Stokes (Secretary of the Preparatory Committee of the Comprehensive Test-Ban Treaty Organization, Vienna, Austria): "Structure of the Comprehensive Nuclear Test-Ban Treaty and Verification Techniques"

W.D. Lauppe, G. Stein (Forschungszentrum Jülich, Germany): "Possible Implications of the IAEA Strengthened Safeguards System on Future Cut-off Verification"

V. Ostropikov, A. Panasyuk (MINATOM, Moscow, Russia): "Experience of the Russian Federation in the field of the Nuclear Material Control"

J.W. Tape (LANL, Los Alamos, NM, USA): "Modern Verification Regimes for Excess Nuclear Weapons Materials: A View from the US

A. Nilsson, J. Rautjaervi (IAEA, Vienna, Austria): "Introduction to IAEA Safeguards R&D and IS Programme 1999-2000"

In order to facilitate maximum interaction and to draw conclusions, the Seminar then formed into four Working Groups:

- Working Group 1: "Verification Concepts", chaired by B. Dufer (*IPSN, France*)
- Working Group 2: "Information Treatment", chaired by A. Nilsson (*IAEA, Vienna*) and M. Cuypers (*JRC, Ispra, Italy*)
- Working Group 3: "Measurement Techniques", chaired by R. Schenkel (*JRC, Karlsruhe, Germany*)
- Working Group 4: "Monitoring Techniques", chaired by B. Richter (*FZJ, Jülich, Germany*)

Each Working Group was charged with identifying similarities and synergies and, more importantly, the differences, the lessons to be learnt and the technical challenges for research and development. The Working Group discussions were interspersed with a total of 28 detailed specialist presentations. The seminar was concluded by a plenary session lasting half a day, in which the working groups reported their findings and conclusions. Proceedings of the Seminar are being published now.

Workshop on "Science and Modern Technology for Safeguards" jointly organized by ESARDA and INMM

Albuquerque, New Mexico, USA,
21-24 September, 1998

This is the second Workshop on the subject, the first one having taken place in Arona, Italy, on 28-31 October, 1996. A similar Workshop will be conducted in Japan in the year 2000.

The workshops on "Science and Modern Technology for Safeguards" aim at providing a forum for the presentation and discussion of selected fields of science and modern technology that have not, as yet, been considered or have not, as yet, been fully exploited by safeguards experts, with the objective of:

1. informing the safeguards community,
2. stimulating application to safeguards and
3. providing an opportunity for technical interchange among experts in the various technologies and in safeguards.

The Workshop held in Albuquerque, New Mexico, USA, September 21-24, 1998, was attended by over 100 participants. It was chaired by. C. Sonnier (Consultant to the US DOE, Albuquerque, NM, USA) and by G. Stein (Forschungszentrum Jülich, Germany).

The Workshop provided a full discussion on several near and far term scientific technologies that may be applied to safeguards. In addition, there were extended discussions on the social and political aspects surrounding the areas of Non-proliferation, International Safeguards, Regional Safeguards and other (non Safeguards) Inspection Regimes. In the opening plenary session, addresses were given by the INMM President, Mr. O. Amacker, and by the ESARDA Chairman, Mr. D. Flory, followed by invited presentation of Messrs. J. Rautjaervi (IAEA, Vienna, Austria), T. Sellers (SANDIA, Albuquerque, NM, USA), A.E. Whiteman (DOE, Albuquerque, NM, USA) and W. Gmelin (EURATOM Safeguards Directorate, Luxembourg).

The Workshop then formed into four Working Groups:

- Working Group 1: "Social and Political Aspects of Safeguards", chaired by H. Kurihara (*NMCC, Tokyo, Japan*) and J. Pilat (*International Institute for Safety Studies, London, UK*)
- Working Group 2: "Advanced Sensor Technology", chaired by K. Sanders (*Dept. of Energy, Washington, DC, USA*) and R.J.S. Harry (*Consultant to ECN, the Netherlands*)
- Working Group 3: "Survival in a Data-Rich Environment", chaired by M. Cuypers (*European Commission, Ispra, Italy*) and J. Kaniewski (*IAEA, Vienna, Austria*)
- Working Group 4: "Lessons from Non-Safeguards Inspection Regimes", chaired by D. Flory (*IPSN, Paris, France*) and J. Menzel (*OSIA, Dulles, VA, USA*).

35 technical papers were presented in the Working Groups, by invited experts: the participants were then asked to engage in a discussion of the prospective applications or implications of these topics to safeguards. This interaction helped inform the experts of opportunities for application of their area of expertise to safeguards, and helped inform the safeguards community of the applicability and limitations of each selected topic. The conclusions of the Working Groups were reported and discussed during a closing plenary session.

The participants agreed that the Workshop was successful and reached its objectives. Proceedings will be printed.

The planned Workshop of the Year 2000 will consider the following topics: Social and Political Aspects of Safeguards, Regional System Considerations, and Robotics/Microelectronics Technologies.

Workshop on "Quality Requirements for NDA in Safeguards"

Ispra, Italy, November 1998

The production of high quality measurement results requires appropriate technical and organisational measures to ensure their reliability, consistency and comparability. To reach these objectives, adequate Quality Assurance at the laboratory carrying out the measurements is necessary.

In the past, the ESARDA Non Destructive Analysis (NDA) Working Group has often considered the issue of Quality Assurance. Recently, the decision was taken by the Working Group to organise an International Workshop on this subject, with the aims of:

i) gaining insight into terminology, procedures, norms and legal issues,
ii) understanding how Quality Assurance is achieved,
iii) reviewing the scientific, technical and formal requirements for making quality measurements,
iv) exchanging experience with laboratories implementing - or having implemented - a formal Quality Management System, and
v) drawing conclusions and giving recommendations to NDA laboratories related to safeguards.

The workshop was held at the Joint Research Centre of the European Commission, at Ispra (Italy). During three days of presentations and discussions, 25 participants from R&D organizations, from certification and accreditation bodies and from safeguards authorities were able to draft a set of conclusions and recommendations to NDA laboratories. The papers presented, the conclusions and the recommendations will be published in the Workshop's Proceedings.

Other Information

Tripartite Seminar on "Nuclear Material Accounting and Control at Radiochemical Plants"

Obninsk, Russia, 2-6 November 1998

A Tripartite Seminar on "Nuclear Material Accounting and Control at Radiochemical Plants" was held in Obninsk, Russia on 2-6 November 1998. It was jointly organized by the Ministry of Atomic Industry - Minatom - of the Russian Federation, the European Commission and the US Department of Energy. The Seminar took place at the Russian Methodology and Training Centre of Obninsk, which was set up with the cooperation of the European Commission (the TACIS programme and the Joint Research Centre). It was attended by representatives from the United States, the European Union, and Russia. In particular, there were fifty-one participants from the Russian Federation, coming from thirteen facilities, from Minatom and from the Federal Safeguards Authority Gosatomnadzor. During the Seminar, Russian and foreign specialists gave thirty-seven presentations on the topic of nuclear material control and accounting (MC&A) at Radiochemical and Reprocessing Plants. These presentations dealt with the development and performance of MC&A systems and their basic components. Individual presentations covered:

1. General aspects of State MC&A systems; requirements, regulatory aspects, and discussion of the nuclear fuel cycle in Russia, particularly of reprocessing.
2. MC&A at the various stages of the radiochemical process.
3. Quantitative and qualitative aspects of measurements for MC&A at reprocessing plants, including methods of destructive and non-destructive assay, density and volume measurements, requirements for accuracy of measurements and measurement quality assurance.
4. Continuity of knowledge of measurement data, including use of tamper-indicating devices and of containment/surveillance systems.

The significant amount of questions and discussion after each presentation demonstrated the strong interest of the participants in the subject's matter.

This was the second NMC&A Tripartite Seminar at the RMTC, the first having been conducted in 1997 with the title "NMA&C in Fuel Fabrication Plants". A third Seminar dealing with Enrichment Facilities is planned for the year 2000.

Grand Opening Ceremony of the Russian Methodological and Training Centre (RMTC)

Obninsk, Russia, 4 November 1998

On November 4, a Grand Opening Ceremony was organized to celebrate the establishment of the Russian Methodological and Training Centre (RMTC) of Obninsk and recognize its training accomplishments in the field of nuclear materials control and accounting. The Ceremony was attended by numerous experts in Nuclear Materials Accountancy and Control coming from the Russian Federation, the European Union and the United States of America as well as representatives of the media (press and TV). Distinguished guests were: Mr. E. Adamov, Minister of Atomic Energy of the Russian Federation; the President of the Kaluga Region; Mr. M. Shubin, Mayor of the City of Obninsk; Mr. G. Adam, Member of the European Parliement; Mr. H. Allgeier, Director General of the Joint Research Centre of the European Commission; Mr. A. Dimitriev, Deputy Head of the Gosatomnadzor of the Russian Federation; Mr. P. Ek, representing the Swedish control Authority SKI , Mr. P. Gourlez, representing the French control Authority IPSN; Mr. K. Sheeley, Deputy Director of the Office of Arms Control and Non Proliferation of the US Dept. of Energy.

A detailed report of this event will be published in the next number of the ESARDA Bulletin.

It is worth to recall that, over the past three years, courses were established at the RMTC covering Nuclear Material Control and Accountancy in the entire spectrum of facilities of the nuclear fuel cycle, and that the relevant training facilities were completed. More than 40 courses are now taught annually, attended by over 1000 students from Russia, Lithuania, Ukraine, Kazakhstan.

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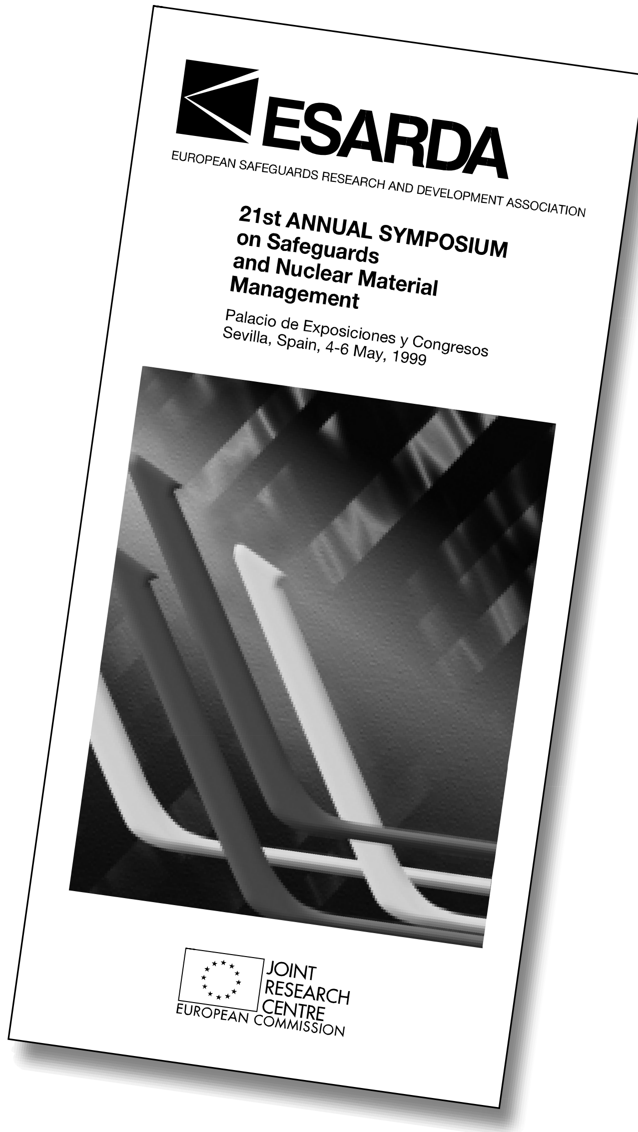
21st ANNUAL SYMPOSIUM on Safeguards and Nuclear Material Management

Palacio de Exposiciones y Congresos
Sevilla, Spain, 4-6 May, 1999

The 21st ESARDA Annual Meeting will be a Symposium on Safeguards and Nuclear Material Management; it will be held in the “Palacio de Exposiciones y Congresos”, at Sevilla, Spain.

The purpose of this Symposium is to offer an opportunity to exchange information between Research Organizations, Safeguards Authorities and Nuclear Plant Operators on new aspects of international safeguards and their implications for research and development activities.



Nearly 150 contributions will be given in different areas. The Symposium sessions will include:

Opening session
Other Verification Regimes
Technical consequences of the application of INFCIRC/540
Concepts and Views
National Safeguards Systems
Co-operatives Programmes
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Further information and registration forms can be obtained from:

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Issue No 3: April 1997

ESARDA

Working Group on Containment and Surveillance

COMPENDIUM

Containment and Surveillance Products

PREFACE

At a workshop held in Salamanca in 1992, by the ESARDA Working Group on Containment and Surveillance, it was concluded that the development of containment and surveillance (C/S) devices had now reached a stage where products or basic expertise were available to assist with the solution of many problems. It was felt that a compilation, which contained outline information on a range of C/S products would help the potential user to know where to obtain further information and thus to judge whether a particular device might meet the requirements of a specific application.

This compendium is not intended to be comprehensive but collects together contributions provided by the members of the Working Group.

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1. DESIGN VERIFICATION

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
1.1	DIVIP Design Information Verification using Image Processing Jan 1995	Verification of structures	Verification of safeguards-relevant plant structures or equipment. During Design Information Verification (DIV) activities of chemical processing facilities, a large number of vessels and associated pipework must be physically checked and compared to plant design drawings. Afterwards reverification and continuity of knowledge of verified structures have to be performed. The system DIVIP creates reference digitized images and compares images taken during reverification for identifying changes.	Verification in chemical processing facilities.	E. Bettendroffer. "Use of Image Processing for Design Information Verification", User manual.	IAEA task completed.
CONTACT: F. Sorel, JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789411, Fax +39-0332-789185						
1.2	DIVLa Design Information Verification using Laser Range Images Oct 1997	Verification of structures	Verification of safeguards-relevant plant structures or equipment. During Design Information Verification (DIV) activities of chemical processing facilities, a large number of vessels and associated pipework must be physically checked and compared to plant design drawings. Afterwards reverification and continuity of knowledge of verified structures have to be performed. The system DIVLa is based on a scanning laser range finder and reconstructs a 3D presentation from distance measurements. It creates reference data files and compares measurement results of reverification for identifying changes.	Verification in chemical processing facilities.	J.G.M. Gonçalves, V. Sequeira, F. Sorel. "Application of Virtualised Reality to Safeguards". Proceedings of the Symposium on International Safeguards - Session on Modern Technology for Safeguards, International Atomic Energy Agency, Vienna, Austria, October 1997. J.G.M. Gonçalves, V. Sequeira, F. Sorel. "Application of 3D Models to Training and Design Information Verification in Safeguards". Proceedings of the 38th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, Arizona, USA, 20-24 July, 1997. V. Sequeira. "Active Range Sensing for Three-Dimensional Environment Reconstruction". Ph.D. Thesis, Department of Computers and Electrical Engineering, IST-Technical University of Lisbon, Lisbon, December 1996. J.G.M. Gonçalves, V. Sequeira, F. Sorel. "From Distance Measurements To Tele-Presence And Virtual Reality Applications In Safeguards". Proceedings of the ESARDA-INMM Workshop on "Science and Modern Technology for Safeguards", pp. 151-157, Arona, Italy, October 28-31, 1996.	Prototype in laboratory.
CONTACT: J.G.M. Gonçalves, JRC, T.P. 270, I-21021 Ispra (VA), ITALY - Phone +39-0332-789416, Fax +39-0332-789185						

2. SEALS AND SEAL READERS

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
2.1	Ultrasound Reader 26.11.96	Sealing system	Final disposal casks of the POLLUX type are sealed by weld seams applied to the lid and the cask body. The microstructure of the cask material as well as of the weld seam provides for a unique fingerprint of the cask. Ultrasound backscattering techniques proved to be suitable for the identity and integrity verification of the casks by reproducible ultrasound scanning of the microstructure.	Identification and proof of integrity of final disposal casks of the POLLUX type based on the microstructure of the cask and weld seam material. Identification of any type of spent fuel cask based on a small part of the cask material structure.	E. Leitner, K. Rudolf, E. Wogatzki. "Identity and Integrity Verification on Spent Fuel Casks by Means of the Ultrasound Technique". ESARDA 25, 14th Annual ESARDA Meeting, 05-08 May, 1992, Salamanca, Spain, 1992, p. 55. K. Rudolf, R. Weh, U. Netzelmann, B. Richter, G. Giersch, D. van der Eecken. "Ultrasound Reader for POLLUX Cask Seals". 37th INMM Annual Meeting, 28-31 July, 1996, Naples, Florida.	Prototype Ultrasound Reader available.
CONTACT: K. Rudolf, GNS, Gesellschaft für Nuklear-Service mbH, Hollestr. 7a, D-45127 Essen, GERMANY						
2.2	Laser Reader 26.11.96	Sealing system	Final disposal casks of the POLLUX type are sealed by weld seams, the surface structure of which provides for unique fingerprints of the casks. Laser techniques proved to be suitable for the identity and integrity verification of the casks by reproducible laser scanning of the weld seam profile.	Identification and proof of integrity of final disposal casks of the POLLUX type based on a weld seam applied to the lid and the cask body.	D. Holm, W. Jüptner, U. Mieth, W. Osten, E. Leitner, K. Rudolf, E. Wogatzki. "Identification and Integrity Verification of Final Disposal Casks by Radiographical and Optical Techniques". BMBF/IAEA Joint Programme. Report 235, 1992. K. Rudolf, R. Weh, B. Richter. "Identity and Integrity Verification of Final Disposal Casks by Weld Seam Examination". ESARDA 26, 15th Annual Symposium on Safeguards and Nuclear Material Management, 11-13 May, 1993, Rome, Italy, p. 781.	Prototype of the Laser Reader under construction.
CONTACT: K. Rudolf, GNS, Gesellschaft für Nuklear-Service mbH, Hollestr. 7a, D-45127 Essen, GERMANY						
2.3	Improved Adhesive Surface Seal	Seal	Monitoring of the integrity of a containment/cask. Associating an identity with a container.	Short term application during PIV, e.g. storage area. Any closure of a containment/cask which can be secured with an adhesive. Any place within a facility where inspector access is possible.	B. Richter, M. Goldfarb. "Design and Production of an Improved Adhesive Seal for Application in IAEA Safeguards". BMBF/IAEA Joint Programme. Report No. 231, March 1992.	Implemented by IAEA. Commercial supplier: Spinhoff Siebdruck+Werbung. Rotter Bruch 16 D-52068 Aachen GERMANY Phone +49-241-504066 Fax +49-241-507926
CONTACT: B. Richter, Forschungszentrum Jülich GmbH, Programme Group TFF, D-52425 Jülich, GERMANY - Phone +49-2461-614884, Fax +49-2461-612496, E-mail: B.Richter@fz-juelich.de						
2.4	In-situ Readable Seal System (IRUSS)	Seal	Provides a comprehensive system for data acquisition, data analysis, data storage and production of IAEA safeguards inspection reports for ARC and VAK III seals.	IRUSS will replace the obsolete seal reader, known as the SPAR, currently used with the ARC seal. IRUSS will also be used at facilities where WAK III seals have been installed. A seal reader, known as the Seal Interface Unit (SIU), will contain hardware and software to operate seal reading heads and acquire seal signature data. A second system component, the Seal Interface Program (SIP), will provide the inspector interface via a notebook computer with the seal reader.	R.N. Nishimura (AECL), J.F. Brauneisen (AECB). "The In-Situ Readable Ultrasonic Sealing System". IAEA Symposium on International Safeguards, 14-18 March 1994. R. Shah and R. Westman (AECL), J.F. Brauneisen (AECB). "Software Development for the In-Situ Readable Ultrasonic Seal System (IRUSS)". Proceedings of the 33rd Annual Meeting of the Institute of Nuclear Material Management, 19-22 July 1992.	Delivery of a system prototype to the IAEA for acceptance testing is scheduled for early 1994.

				The final component of the system is an IAEA headquarters database program called the Seal Evaluation and Management Program (SEMP). HQ personnel can confirm field verifications and perform overall sealing system management. The software architecture using object-oriented programing techniques should permit the HQ database to be extended to other in situ-verifiable seals used by the IAEA.	"System Requirements Specification for the In-Situ Readable Ultrasonic Seal System (IRUSS)". IAEA Task Number E00458, IRUSS-PDRL-001, 1991 August 07 (Chalk River Laboratories Document Number IRUSS-GEN-1).	
CONTACT: R.N. Nishimura, Program manager, AECL Safeguards Program, AECL Research, Chalk River Laboratories, Chalk River, Ontario, CANADA K0J 1J0 - Phone +1-613-584-3311 ext 3665, Fax +1-613-584-1770 **J. Brauneisen,** Canadian Safeguards Support Program, Atomic Energy Control Board, 280 Slater Street, Ottawa, Ontario, CANADA K1P 5S9 - Phone +1-613-995-8062, Fax +1-613-995-5086						
2.5	MK5-CL Ultrasonic Clamping-Seal System Oct 1994	Mechanically attached in situ readable underwater/air ultrasonic seal.	Can be clamped on *dowel pins* or *pegs* used to center covers on containers. It provides a *locking* function without asking to be screwed in like a *Sealing-Bolt*. It embodies ultrasonically readable *identity* and *integrity* features. When removed, its integrity status changes but its identity does not. Can be read either in air or underwater.	In the *present version* and *size*, the *Clamping-Seals* can be applied to lock the *shock absorbers* of transport *PuO_2 containers* just after these ones have been filled up at the reprocessing plant. They would be with drawn at the fuel manufacture facility before opening and emptying the containers. It would be used because of its sturdiness and good behaviour in nuclear environment.	The *Clamping-Seal* is readable at HQ and on site by means of a *portable equipment* similar to the one used with *Sealing-Bolts*. It can be installed simply by hand if the accessibility for the inspector is good. It is removed by applying a few turns counterclockwise, either by hand or by means of a light spanner. Doing this will cause its integrity status to change. A special procedure is used to compare an instant reading (*signature*) to a *reference signature* acquired previously at delivery time by inspectors.	Under development in a collaboration with PNC/COGEMA. Available in 1995.
CONTACT: B.C. d'Agraives, JRC, TP 450, I-21020 Ispra (VA), ITALY - Phone +39-0332-789107, Fax +39-0332-785780						
2.6	MK4-R Ultrasonic Sealing-Bolt System Oct 1994	On site readable underwater ultrasonic seal.	Replaces one of the standard bolts closing the lid of a container. In addition to providing the same mechanical function, it embodies ultrasonically readable *identity* and *integrity* features. When removed, its integrity status changes but its identity does not. Can be read either in air or underwater.	In the *present version* and *size*, can be applied to any container's lid closed with standard bolts to be tightened with a nominal torque of at least 50 Nm. It is now commonly installed underwater on various types of *MultiElement Bottles* (MEB types: 1166, 1175, 1176 & 1196), at the BNFL site of Sellafield. It is suitable for a dozen of other MEB types. Its stay in a storage pond can extend up to 15 years.	The *Sealing-Bolt* is readable both at HQ or on site thanks to a *reading station* which comprises an *ultrasonic reading head (tool)*, an *ultrasonic flaw detector* and *a portable computer*. A second implement, called *handling tool* is employed on site to install/remove the *Sealing-Bolts*. A special procedure is used to compare an instant reading (*signature)* to a *reference signature* acquired previously at delivery time by inspectors. Presently, sealed MEBs can be verified underwater at a rate of 15/hour.	Jointly used by EURATOM/IAEA teams at BNFL plant of Sellafield. Sealing-Bolts and related equipments are available on the basis of procurement contracts.
CONTACT: B.C. d'Agraives, JRC, TP 450, I-21020 Ispra (VA), ITALY - Phone +39-0332-789107, Fax +39-0332-785780						
2.7	Titus Seal	In situ readable multipurpose ultrasonic seal.	An ultrasonic seal, incorporating its own transducer, which locks a cable loop at the moment of installation. The loop has to be passed through some hole or eyelet before to be sealed by the inspector. A *delay line* and a *random marking* provide a *signature* which is read by means of *portable computer*. Can be connected by modem to the HQ.	All applications of a multipurpose seal: doors, containers, vehicles, etc.	Titus seals are small cylinders with a PNC connector on the one end and a protruding "scratched" peg on the other. At sealing, the cable is passed around the peg and pressed by an aluminium ring which is squeezed by means of special snippers. This causes the already scratched peg (acting as a delay line) to be permanently deformed and to generate random echoes when energized by the adjacent incorporated transducer. Attempt to slide the cable or to force the ring open would change or cancel the signature.	Presently used by CEA in domestic applications (refer to CEA). Tested on a large scale at JRC-Ispra Lasco laboratory. Available along with portable reading equipment from ELCA company under procurement contract.
CONTACT: B.C. d'Agraives,						

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
2.8	VACOSS-S	Seal	Monitoring of the integrity of a containment/ cask. Associating an identity with a container.	Any closure of a containment/cask which can be secured with a fibre optic cable (required minimum hole diameter is 7 mm). Any place within a facility where inspector access is possible. E.g. transport and storage casks.	B. Richter, G. Stein, R. Günzel, K.J. Gärtner, E. Yellin. "The Design and Quality Assurance of the VACOSS Series Production Model". BMBF/IAEA Joint Programme. Report No. 162, June 1988. B. Richter, G. Stein, R. Günzel, K.J. Gärtner, E. Yellin. "The Environmental Qualification of the VACOSS-S Seal: Test Programme and Results". BMBF/IAEA Joint Programme. Report No. 184, July 1989.	Implemented by IAEA and EURATOM. Commercial supplier: Aquila Technologies Group, Inc. 8401 Washington Place NE Albuquerque NM 87113 USA Phone +1-505-828-9100 Fax +1-505-828-9115
CONTACT: Bernd Richter, Forschungszentrum Jülich GmbH, Programme Group TFF, D-52425 Jülich, GERMANY - Phone +49-2461-614884, Fax +49-2461-612496, E-mail: B.Richter@fz-juelich.de						
2.9	VAK-III Ultrasonic Cap Seal System Oct 1994	On site readable fuel assembly ultrasonic seal.	An ultrasonic seal, specially designed for clamping on BWR fuel assemblies. It locks on a special *tie rod end* thus preventing an illegal disassembly of the fuel bundle. Can withstand the whole cycle from fuel fabrication to dismantling. It provides an *identity* and an *integrity* features. Can be read and/or installed at HQ or in a reactor dry or wet storage.	BWR fuel assemblies with pre-installed extended tie-rod ends. Any structure to be closed or stored in high radiation level. Not yet suitable for PWR fuel assemblies.	*VAK-III Seals* are small cylinders with a *clamping device* at the lower end and a flat upper end. The upper half embodies randomly distributed cavities and a fracture link -connected to the lower clamping mechanism - which breaks when the seal is pulled off from the *upper grid* by means of a *breaking tool.* Both *signature* and *integrity status* are ultrasonically read with *reading heads/ tools* and computerized *reading equipment*. The procedure compares the spot measurements to *references signatures*.	Extensively tested until 1986 at the German facility of Kahl, during long term experiments. Not yet implemented. Candidate for MOX BWR fresh fuel storage. Not available without prior restarting of the production means.
CONTACT: B.C. d'Agraives, JRC, TP 450, I-21020 Ispra (VA), ITALY - Phone +39-0332-789107, Fax +39-0332-785780						
2.10	Ultrasonic (ARC) Sealing System	Seal/Seal Reading and Analysis/Containment/ Database	Provides sealing of irradiated reactor fuel in underwater storage facilities.	The ARC seal is a situ-verifiable seal which contains a single identity and integrity element. When the seal is removed the identity and integrity are destroyed. ARC seals are installed on underwater containment structures filled with spent fuel in storage bays at CANDU reactor facilities. Ultrasonic "signatures" (reference readings) from the seals are recorded in situ, in digital form, on bubble cassette memories using a Seal Pattern Reader (SPAR) operated by IAEA inspectors. Seal signatures are then transferred to a database at IAEA HQ for archiving and further analysis, if required.	E. Yellin and S. Morsey (IAEA), J. Brauneisen and J. Hodgkinson (AECB), D.Aubin (Hydro Quebec), M.T. Smith (AECL/CRL). "Field Evaluation of a Sealing System for CANDU Spent Fuel". Proceedings of the 29th Annual meeting of the Institute of Nuclear Materials Management, 26-29 June 1988. A.J. Stirling, S. Kupca, R.E. Martin, R.J. West, A.E. Aikens, C.A. Cox, B.F. White, M.T. Smith and W.E. Payne (AECL/CRL). "The CANDU Irradiated Fuel Safeguards Sealing System at the Threshold of Implementation". Proceedings of the 26th Annual Meeting of the Institute of Nuclear Materials Management, 21-24 July 1985.	Authorized for safeguards inspection use by the IAEA. Seal commercially available through AECL. SPAR no longer in production.
CONTACT: R.N. Nishimura, Program manager, AECL Safeguards Program, AECL Research, Chalk River Laboratories, Chalk River, Ontario, CANADA K0J 1J0 - Phone +1-613-584-3311 ext 3665, Fax +1-613-584-1770 **J. Brauneisen,** Canadian Safeguards Support Program, Atomic Energy Control Board, 280 Slater Street, Ottawa, Ontario, CANADA K1P 5S9 - Phone +1-613-995-8062, Fax +1-613-995-5086						
2.11	Aquila Remote Reader (ARR) & E-Tag	Seal, Tag, Position Monitor	Verify position and placement of safeguards instruments. Read, store and report information stored on a "touch" memory device (E-Tag).	Surveillance. The ARR records the identifying information from the E-Tag, along with the date and time the connection was made, and can watch for a "break" in the communication of the E-Tag and record the	Steve Kadner, Kevin Ferguson (Aquila); Kaluba Chitumbo (IAEA). "The Technical Implementation of a Safeguards Location Indicating Device". INMM Report, July 1993.	Implemented by IAEA. Commercial Supplier: Aquila Technologies Group, Inc.

				event when it occurs. Utilized in the IAEA/CEC "Partnership" Initiative.		
CONTACT: S. Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
2.12	AutoCobra	Verifier-for Automatic Verification of Passive Fiber Optic Seal	Automatic Seal Verification System for monitoring the integrity of a containment/cask - associating an identity with a container.	Computer assisted automatic classification and verification of COBRA Seal images. Provides a "go/nogo" sequence for inspector. Allows computer image database of seals information.	Steve Kadner, Jesse Bozone (Aquila). "Cobra II Manufacture of a Lightweight Cobra Seal Camera/Verifier". INMM Report, July 1991. US POTAS Task E.92 (IAEA).	Currently under development.
CONTACT: S. Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
2.13	Cobra seal and verifier	Seal & Verifier	Passive fiber-optic based seal consisting of a loop of multi-fiber cable secured with a tamper proof assembly for monitoring the integrity of a containment/cask - associating an identity with a container.	Any closure of a containment/cask which can be secured with fiber-optic cable; any place within a facility where inspector access is possible. Verifier for visual comparison.	Steve Kadner, Jesse Bozone (Aquila). "Cobra II Manufacture of a Lightweight Cobra Seal Camera/Verifier". INMM Report, July 1991.	Implemented by IAEA, CEC. Commercial Supplier: Aquila Technologies Group, Inc.
CONTACT: S. Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
2.14	LoCOSS Seal	Seal	An inexpensive, active fiber-optic seal, intended for long-duration surveillance.	Any closure of a containment/cask which can be secured with fiber-optic cable. Any place within a facility where inspector access is possible .	CEC Contract No. 93 L 013/C - mn 392-93 - (Study and manufacture). BIRD Foundation Grant (December 1993)- (continued Study and manufacture).	Currently under development.
CONTACT: S. Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
2.15	AIMS Fiber Optic Seal (AFOS) 11.11.96	Active, re-usable fiber optic seal system	The AFOS seal is a part of the Authenticated Item Monitoring System (AIMS). The AIMS system includes a variety of sensors, an authenticated radio frequency (RF) communications link, a Receiver Processing Unit (RPU), and an inspector friendly PC interface. The RPU collects, authenticates and stores messages transmitted by sensors. The PC interface allows the operator to view and archive pertinent event histories. Each re-usable seal is based on the concept of continually transmitting, and subsequently receiving, specially encoded message packets over a fiber optic cable/loop, that may be up to 100 meters in length. Any missing or suddenly re-occurring fiber optic messages (due to loop opening or closings), any message that cannot be verified (due to tampering), or any indication of seal body tampering are construed as seal event anomalies and are immediately transmitted to the RPU for collection, storage, and later interrogation. The inspector is provided with a user-friendly, interactive, menu-driven PC based system that is used during seal initialization and event collection periods thereby providing an easy method of determining when and if the seals have been opened and closed, and when and if they have been tampered with. The seal event histories can also be transferred to other compatible PCs for further sorting, viewing and archiving purposes.	The AIMS system along with the AFOS fiber optic seal has potential applications in the areas of treaty verification, arms control, and international safeguards.	J. L. Schoeneman. "Authenticated Item Monitoring System (AIMS)". VST-039, 32nd Annual Meeting Proceedings of the Institute of Nuclear Materials Management, July, 1991.	The AIMS system including the AFOS seal has been fully developed and deployed at selected test sites. The estimated cost of the AFOS seal is $75; the cost of the Receiver Processing Unit is $3,000.
CONTACT: J. Lee Schoeneman, Sandia National Laboratories, Cooperative Monitoring Systems Dept., Department 5749 MS0656, P.O. Box 5800, Albuquerque NM 87185-0656, USA Phone +1-505-844-2049, Fax +1-505-844-5321						

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
2.16	Tamper-Evident Shrink Wrap Seal 12.01.94	Whole volume seal	Shrink-wrap seals were proposed as a method of securing strategic elements (valves, flanges, etc.) of a shutdown chemical weapons facility to assure that chemical weapon production could not be resumed. However, the Sandia version of the shrink-wrap seal is versatile enough for a variety of treaty (CWC, INF, START) and non-treaty verification applications.	Shrink-wrap seals are whole volume seals that can be easily implemented into treaties (CWC, INF, START) aimed, in part, at establishing a verifiable ban on the production of weapons. Shrink-wrap seals can be used to secure complex configurations, which is not possible using other existing tag/seal technologies. The seals are also compatible with and easily incorporated into other tamper-indicating technologies. A family of whole volume seals have been developed using clear shrink films of polyvinyl chloride, polyvinylidene chloride and a polyoelifin. Each shrink film contains uniquely inked patterns and a clear fluorescent coating, both of which discourages the transfer or replacement of a seal once it is applied to an object to be protected. The seals were designed to be easily applied by one person using commercially available equipment. The seal signature can be verified using a polaroid camera, a still video camera system or a video camcorder.	BDM draft Environmental Test Report. "Polyvinylidene Chloride (PVDC) and Polyvinyl Chloride (PVC) Shrink-Wrap Seal". June, 1993. BDM draft Final Test Report. "Initial Operational Test and Evaluation (IOT&E) of the Shrink-Wrap Seal Developed by Sandia National Laboratories". June, 1993.	The development of the tamper-evident shrink-wrap seal is complete and the films are available from Progressive Packaging and Design Inc., Milwaukee, WI, USA.
CONTACT: R.L. Courtney, Sandia National Laboratories, Special Verification Applications Dept., 9208/MS0567, P. O. Box 5800, Albuquerque NM 87185-0567, USA - Phone +1-505-844-7867, Fax +1-505-844-6067 **J.O. Young,** Sandia National Laboratories, On-Site Monitoring Technology Dept., 9249/MS0656, P.O. Box 5800, Albuquerque NM 87185-0656, USA - Phone +1-505-844-9335, Fax +1-505-844-0491						
2.17	CIVES Colour based Image Verifier for E-metal Seals May 97	Verification station for metal cap seals	Provides acquisition and storage of seal reference images before installation and automatic verification by detecting eventual changes in seal images after removal.	Computer assisted verification metal cap seals.	E. Bettendroffer, S. Colzani. CIVES Operator Manual. May 97.	Development completed. System used by EURATOM.
CONTACT: F. Sorel, JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789411, Fax +39-0332-789185						

3. IDENTIFIERS

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
3.1	MK4-R Ultrasonic Tags Identifier Oct 1994	On site readable ultrasonic identifier.	Not a locking function. Once mechanically fastened on a structure such as a *transport cask*, this very sturdy *seal*, provided with an *identity* and an *integrity features,* becomes a *marker* or *tag*, since it can be verified and cannot be removed without changing its *integrity status*. Can be read either in air or underwater.	In the *present version*, with a threaded rod of about 10mm length, can be applied to the wall of a cask by means of an intermediate supporting plate. Can be applied to any valuable structure destinated to moving in severe outdoor environment.	It is installed like a screw and needs only to be tightened with a minimum torque of 50 Nm. It is read at HQ like a *MK4-R Sealing-Bolt* and on the spot with a portable *reading head* and associated *ultrasonic/electronic equipment.* A procedure similar to the one used with the MK4-R Sealing-Bolts can be used for its verification.	Passed all environmental tests such as acid washing, high pressure vapor jets, shocks, etc ... at the COGEMA facility, La Hague. Not yet licensed for use on casks because of the necessity to drill hole to fix the intermadiate plate. Production ready if required, for instance for nuclear storage baskets.
CONTACT: B.C. d'Agraives, JRC, TP 450, I-21020 Ispra (VA), ITALY - Phone +39-0332-789107, Fax +39-0332-785780						
3.2	Reflective Particle Tagging (RPT) Technology Nov 1996	Technology for Uniquely Identifying Items	Reflective Particle Tags can be applied to uniquely identify individual items. The tag consists of optically reflective particles mixed in a transparent adhesive matrix which is applied to the surface of the item to be identified and then cured. A reader consisting of a number of lights are some means of recording an image is used to read the patterns formed by the reflectors in the tag. Comparing images of the tag to images taken when the tag was applied verifies the identity of the tag and therefore the item.	Reflective Particle Tags were developed and proposed for counting mobile nuclear missiles for the Strategic Arms Reduction Treaty. The technology is also being used to identify other items such as fiber optic seals.	K. M. Tolk. "Reflective Particle Technology for Identification of Critical Components". 33rd Annual Meeting Proceedings of the Institute of Nuclear Materials Management. July 1992.	Tags were developed and tested for use on items made of steel, aluminium, and composites used in U.S. missiles. Adhesives for other materials should be tested before deployment on any other materials. Prototype readers have been developed and tested, including a fieldable prototype developed by BDM International in cooperation with Sandia National Laboratories. There are no readers commercially available at this time.
CONTACT: Keith Tolk, Sandia National Laboratories, On-Site Monitoring Technology Dept., Department 5749/MS0656, P. O. Box 5800, Albuquerque NM 87185-0656, USA - Phone +1-505- 845 9014						

4. OPTICAL SURVEILLANCE

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
4.1	CARES Computer Aided Review Station 30.09.93	Optical surveillance	Review of video tapes and alarm files recorded by CAVIS-2 stations. The system can retrieve surveillance pictures associated with any alarm logged by the recording station.	See application of CAVIS-2S.	M. Mol et al. "CAVIS-2S and CARES: Systems for computer aided video recording and reviewing in multi-camera applications". Proceedings INMM, Orlando USA, July 1992. M.Mol. "CARES Computer Aided Review System for CAVIS-2 tapes". JRC technical note I.92.38, 1992.	In use by EURATOM.
CONTACT: F. Sorel, JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789411, Fax +39-0332-789185 **M. Mol,** JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789621, Fax +39-0332-789185						
4.2	AVIS Active Vision Surveillance System 30.09.93	Optical surveillance	To get more details in images of alarm scenes. The system comprises one or more wide angle cameras, a scene change detector and one camera equipped with motorized zoomand focus and pan/tilt unit. When a scene change occurs in one of the selected areas of the wide angle picture, the system points the motorized camera to that location, activates the zoom, automatically focus and records a detailed image of the alarm zone.	Areas of optical surveillance.	V. Sequeira et al. "Double camera scene change detection system with automatic zooming and focussing". Proceedings ESARDA symposium, Rome, 1993.	Laboratory prototype available.
CONTACT: J. Gonçalves, JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789416, Fax +39-0332-789185 **F. Sorel,** JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789411, Fax +39-0332-789185						
4.3	CAVIS-2S Computer Aided Video Surveillance 30.09.93	Optical surveillance and monitoring	Multiplexed recording of video signals from up to 16 cameras during extended surveillance periods, combined with simultaneous data logging from 16 analog and 32 digital input signals.	Areas of optical surveillance with TV cameras and monitoring devices (gamma & neutron detectors, proximity switches, infra-red trigger etc.).	M.Mol et al. "CAVIS-2 and CARES: Systems for computer aided video recording and reviewing in multi-camera applications". Proceedings INMM, Orlando/USA, July 1992. E.Bettendroffer et al. "CAVIS-2S: Computer Aided Video Surveillance System, Single recorder, Single Rack Version". Technical note Ispra no. I.92.116, Nov. 1992.	In use by EURATOM.
CONTACT: F. Sorel, JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789411, Fax +39-0332-789185 **M. Mol,** JRC, T.P. 270, I-21020 Ispra (VA), ITALY - Phone +39-0332-789621, Fax +39-0332-789185						
4.4	Multi-System Optical Review Station (MORE)	Video review station	Technical and safeguards reviews of video scenes recorded on different optical surveillance systems (MOS, MUX, MIVS, COSMOS, Uniplex, ...).	Evaluation of video tapes on site or at HQ.	B. Richter, G. Neumann, K.J. Gärtner, J.V. Whichello. "The Generic Review Station MORE, Design and Evaluation". BMBF/IAEA Joint Programme. Report No. 242, July 1993.	Implemented by IAEA and EURATOM Commercial supplier: Dr. Neumann elektronik GmbH Schiffgesweg 9 D-50259 Pulheim GERMANY Phone/Fax +49-2234-83917
CONTACT: B. Richter, Forschungszentrum Jülich GmbH, Programme Group TFF, D-52425 Jülich, GERMANY - Phone +49-2461-614884, Fax +49-2461-612496, E-mail B.Richter@fz-juelich.de						
4.5	Multi-Camera Optical Surveillance (MOS) System	Optical surveillance system	Recording of video scenes from up to 16 cameras. Recording modes are by time-triggering and by scene change detection (front end triggering).	Unattended optical surveillance of strategic points within in a facility.	B. Richter, G. Neumann, K.J. Gärtner, G. Laszlo, P. Otto, H. Wagner. "The Multi-camera Optical Surveillance System (MOS) - Design and Reliability".	Implemented by IAEA and EURATOM. Commercial supplier:

					BMBF/IAEA Joint Programme. Report No. 214, May 1991. B. Richter, G. Neumann, K.J. Gärtner, G. Laszlo, P. Otto, H. Wagner. "The Reliability of the Multi-camera Optical Surveillance (MOS) System". BMBF/IAEA Joint Programme. Report No. 218, June 1991.	Dr. Neumann elektronik GmbH Schiffgesweg 9 D-50259 Pulheim GERMANY Phone/Fax +49-2234-83917
CONTACT: B. Richter, Forschungszentrum Jülich GmbH, Programme Group TFF, D-52425 Jülich, GERMANY - Phone +49-2461-614884, Fax +49-2461-612496, E-mail B.Richter@fz-juelich.de						
4.6	Multiplexed Closed Circuit TV (MUX-CCTV) Surveillance System - Mark-II (MUX-16)	Optical surveillance	Provide optical surveillance using up to 16 cameras.	A MUX-CCTV system is comprised of the following subsystems: The Recording subsystem has 3 identical, fully independent channels, each of which records scenes sequentially from all cameras. The Download subsystem segregates the scenes sequentially from all cameras. The MORE Review subsystem, developed by the German Support Program, is used to review the video tapes.	International Atomic Energy Agency. "Instruction Manual for MUX-CCTV Surveillance System". International Atomic Energy Agency. "MUX-16 Instruction Manual". Draft by K.Ciang (IAEA), 28 March 1993. International Atomic Energy Agency. "Operating Manual for MUX-CCTV Mark-II Surveillance System" (draft). Chiang K. (IAEA), J.Fung (AECL), T.Kontakos (AECB). "The MUX Mark II Surveillance CCTV System for International Safeguards". Proceedings of the 31st Annual Meeting of the Institute of Nuclear Materials Management, 15-18 July 1990.	Authorized for inspection use by the IAEA. MUX-16 installed in CANDU reactors worldwide. Equipment available commercially from AECL.
CONTACT: R.A.P. Walker, 2251 Speakman Drive, Mississauga, Ontario, CANADA L5K 1B2 - Phone +1-905-823-9040 ext. 3043, Fax +1-905-855-0056 **R. Messner,** Canadian Safeguards Support Program, AECB, P.O. Box 1046, 280 Slater Street, Ottawa, CANADA K1P 5S9 - Phone +1-613-995-2546, Fax +1-613-995-5036, E-mail Messner.R@atomcon.gc.ca						
4.7	Tamper Resistant TV-Link (TRTL)	Subsystem of optical surveillance system	Authentication of video scenes transmitted from camera to recording unit via standard transmission line (coax, fibre optic cable).	Unattended optical surveillance systems in facilities. It has a standard interface to match with any video system which has a standard interface. The TRTL is an integrated part of the MOS-System and implemented into the MUX-System.	B. Richter, G. Stein, G. Neumann, K.J. Gärtner, J.V. Whichello. "Design and Evaluation of the Tamper Resistant TV-Link". BMBF/IAEA Joint Programme Report No. 183, July 1989.	Implemented by IAEA and EURATOM. Commercial supplier: Dr. Neumann elektronik GmbH Schiffgesweg 9 D-50259 Pulheim GERMANY Phone/Fax +49-2234-83917
CONTACT: B. Richter, Forschungszentrum Jülich GmbH, Programme Group TFF, D-52425 Jülich, GERMANY - Phone +49-2461-614884, Fax +49-2461-612496, E-mail B.Richter@fz-juelich.de						
4.8	Modular Integrated Video System (MIVS)	Camera	Provide surveillance in an unattended mode.	Surveillance. Microprocessor-controlled CCTV system designed to operate at 1-99 minute intervals in an unattended mode.	Jesse Bozone, Jim Coffing (Aquila). Factory support "The Development of a Strategy for the Factory Support of a Fielded Surveillance System". INMM Report, July 1993.	Implemented by IAEA, CEC EURATOM. Commercial Supplier: Aquila Technologies Group, Inc.
CONTACT: Steve Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
4.9	MIVS Advanced Review Station (MARS)	Review Station (Technical and Safeguards, MIVS)	Provide review in an unattended or computer assisted mode.	Safeguards and technical review of MIVS generated 8mm surveillance video tapes.	Steve Kadner, Marck Doppke (Aquila); Klaus Gärtner, Julian Whichello (IAEA). "Evaluation of the Aquila Prototype Generic Review Station (GRS)". INMM Report, July 1993. US POTAS Task E.83 (IAEA) - Training, acceptance tests, equipment.	Currently under development.
CONTACT: Steve Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
4.10	MARK IV Review Station for MIVS	Review Station (Technical, MIVS)	Provide technical review in an unattended or computer assisted mode.	Technical review of MIVS generated 8mm surveillance video tapes.	Steve Kadner, Marck Doppke (Aquila); Klaus Gärtner, Julian Whichello (IAEA). "Evaluation of the Aquila Prototype Generic Review Station (GRS)". INMM Report, July 1993. US POTAS Task E.83 (IAEA) - Training, acceptance tests, equipment.	Implemented by IAEA/ CEC EURATOM. Commercial supplier: Aquila Technologies Group, Inc.
CONTACT: Steve Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
4.11	Gemini Digital Surveillance System	Digital Surveillance System - Upgrade of analog based (MIVS, COSMOS) or film (Twin Minolta) surveillance systems. Compatible with state of art computer based networked technologies.	Long term unattended or digitally networked Surveillance.	Integrated surveillance applications where extended storage of digital images (≈ 100,000) are required and where digital image review techniques are possible.	Steve Kadner (Aquila). "Development of Gemini - An All-Digital Video Surveillance System". INMM Report, July 1992. Steve Kadner, Mark Bronson, Chris Martinez (Aquila). "Gemini - Test of a Digital Surveillance System". INMM Report 1993.	Currently under development.
CONTACT: Steve Kadner, Executive Vice President, Aquila Technologies Group, Inc., 8401 Washington Place NE, Albuquerque NM 87113, USA						
4.12	BUD Burn Up Device Jan 1994	Gamma and neutron monitoring coupled with an optical surveillance to count, determine and survey spent fuel movements and to control burn up declared by the operator of reprocessing plants, nuclear facilities and intermediate or long term storage.	Provide: An analog recording of data on a logger and a digital storage of gamma and neutron measurements. A video recording of events coupled with MEMOBANK (HYMATOM Ltd) or CAVIS (JCR-ISPRA). Transmission of video and nuclear data through a fibre optical network. The using of BUD software to: -Configure the data acquisition device. -Test nuclear detectors and electronics. -Record alarms and tamper resistant events (door opening, high and low power etc.) -Transfer stamped data from acquisition system to a main computer. -Store nuclear data. -Review automatically nuclear events and provide an inspection report with control of burnup.	C/S of the Head End of UP3 and UP2-800 reprocessing plants. Installed to control the shearing cell T1 (A and B workshops) and R1. Allows for C/S of dry and wet unloading storages in the reprocessing plant at la Hague, France. Gamma and neutron detectors are monitoring in unattended mode and provide nuclear signatures. Analog and digital recording are used. First, to have a backup on a data logger and second, to store and review automatically data of a period, by using of "BUD" software. 4 nuclear cameras in the two cells A and B, 2 CCD cameras in the storage ponds. Possibility to upgrade over 8 cameras.	Used by EURATOM Inspectors since August 1992. G.Daniel, P.Gourlez (CEA) and B.Smith (EURATOM). "The C/S system BUD for T1 workshop". INMM 32nd annual meeting, New Orleans (USA). G.Daniel, F.Tola, G.Sannie (CEA) and M.Swinhoe, P.Roesgen (EURATOM). "Upgrading of BUD C/S". ESARDA Symposium, Rome (ITALY). Technician training courses organised by CEA/DAMRI.	Installed for EURATOM at la Hague reprocessing plant. Accepted by EURATOM for routine inspection in August 1992. Used by EURATOM inspectors at la Hague reprocessing plant to control UP3 Head End. Hardware and software are commercially available.
CONTACT: G.Sannie, CEA/DTA/DAMRI/SAR, BP 52, 91192 Gif-sur-Yvette, FRANCE - Phone +33-1-69082003, Fax +33-1-69086030 INTERTECHNIQUE, BP 101, 91943 Zi de Courtaboeuf Les Ulis, FRANCE - Phone +33-1-69827800, Fax +33-1-69827878						
4.13	Experimental Inventory Verification System 21.01.94	Video monitor	Maintain continuity of knowledge of inventory by detecting any changes in stored nuclear material, or confirming that changes have not occurred.	Nuclear material storage.	C.A. Steverson and M.J. Angerman. "Experimental Inventory Control System: an Application of Image Processing to Nuclear Safeguards". 32nd Annual Meeting Proceedings of the Institute of Nuclear Materials Management, July 1991.	System has been installed at two U.S. Department of Energy sites to reduce the frequency of physical inventories. The system is also being evaluated by EURATOM.
CONTACT: Cheryl Rodriguez, Mail Stop E541, Los Alamos National Laboratory, Los Alamos NM 87545, USA						

4.14	Image Compression and Authentication Module (ICAM) Nov 1996	A module to provide digital authentication for video images.	The ICAM performs the digitization, compression, and authentication of video images in a small module which can be installed in a camera enclosure to protect the transmission and storage of video images. The ICAM functions with both NTSC 525 line and PAL 625 line cameras and contains a neuron chip (integrated circuit) permitting it to be interfaced with a local operating network, which is part of the Modular Integrated Monitor System (MIMS). The MIMS sends commands to the ICAM from a central controller or any sensor on the network. The ICAM is capable of working as a stand alone unit, or it can be multiplexed into a network of other ICAMs. As a stand alone unit it sends its video images directly over a high speed serial digital link to a central controller for storage. Images are captured by an ICAM and held until it receives commands for the stored image to be transmitted. The ICAM can capture images on a time interval basis or upon receipt of a trigger signal from another sensor on the network. An ICAM which collects images based on other sensor signals forms the basis of an intelligent "front end" image collection system. The burden of image review associated with present video systems is reduced by only recording the images with significant action. The cards used in the ICAM can also be used to decompress and display the compressed images on a realtime basis.	The ICAM is designed for use in unattended video surveillance systems which need to have images authenticated.	"Development of an Image Compression and Authentication Module for Video Surveillance Systems". 36th Annual Meeting of the Institute of Nuclear Materials Management, July 1995.	Field test of ICAMs in progress. Commercial modules available.
CONTACT: John Matter, Sandia National Laboratories, MS 0656, Albuquerque NM 87185-0656, USA - Phone +1-505-845-8103, Fax +1-505-844-5321 **Steve Dupree,** Sandia National Laboratories, MS 0567, Albuquerque NM 87185-0567, USA - Phone +1-505-844-9930, Fax +1-505-844-6067						
4.15	Digital Image Surveillance System	Optical surveillance system	Recording of video scenes from one up to many cameras (no limitation). Recording modes are by time-triggering and by scene change detection (front end triggering).	Unattended optical surveillance of strategic points within in a facility.	B. Richter, K.J. Gärtner, J.V. Whichello, J.J. Goerten, K. Schoop, G. Neumann. "The Design of a Digital Video Data Authentication and Encryption Device". BMBF/IAEA Joint Programme. Report No. 262, May 1995. K. Gärtner, J. Whichello, A. Owen, A. Vincent, D. Sorokowski, G. Neumann, B. Richter, K. Schoop. "The Design and Testing of a Digital Video Data Authentication and Encryption Device". BMBF/IAEA Joint Programme. Report No. 268, July 1996.	Digital camera commercially available; it consists of a low-power CCD-camera, digital camera module DCM14, IAEA/EURATOM standard camera housing. Commercial supplier: Dr. Neumann elektronik GmbH. Schiffgesweg 9 D-50259 Pulheim GERMANY Phone/Fax +49-2234-83917 Recording and review modules under development. Developer: Dr. Neumann Beratungsbüro für elektronische und physikalische Technik. Schiffgesweg 9 D-50259 Pulheim GERMANY Phone/Fax +49-2234-83917
CONTACT: B. Richter, Forschungszentrum Jülich GmbH, Programme Group TFF, D-52425 Jülich, GERMANY - Phone +49-2461-614884, Fax +49-2461-612496, E-mail B.Richter@fz-juelich.de						

5. MOVEMENT MONITORS

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
5.1	Darlington Core Discharge Monitor (CDM)	Radiation monitor	Provide count of irradiated CANDU fuel bundles as they are discharged from the reactor core by acquiring and storing radiation signatures.	For each reactor, the following components are installed: - 4 detector assemblies; 2 per reactor face, - 4 sets of analog and digital preamplifiers, - 4 GRANDs (Gamma Ray And Neutron Detectors) front-end data acquisition units. Data is transmitted from the detectors to a "Collect Computer" which is monitored and controlled by a watchdog device. Status and health information is routed by the Watchdog to both the on-site printer and via modem to the printer at the IAEA Toronto Regional Office (TRO) The data can be examined on review computers located at the facility, the TRO or at IAEA HQ to determine the number of fuel bundles discharged.	The development was jointly undertaken by the IAEA and USA and the Canadian Safeguards Support Program (CSSP). Halbig, J. (LANL), A.C. Monticone, L.Ksiezak and V.Smiltnieks (IAEA). "The Design and Installation of a Core Discharge Monitor for CANDU-Type Reactors". Proceedings of the 31st Annual Meeting of the Institute of Nuclear Materials Management, 15-18 July 1990. Halbig, J. (LANL), A.C. Monticone (IAEA). "Proof-of-Principle Measurements for an NDA-Based Core Discharge Monitor". Proceedings of the 31st Annual Meeting of the Institute of Nuclear Materials Management, 15-18 July 1990.	Installed by the IAEA at the Canadian 4-Unit Darlington Nuclear Generating Station. Modified version of the CDM equipment installed at facilities in Japan by the IAEA. System hardware components are commercially available.
CONTACT: R. Messner, Canadian Safeguards Support Program, AECB, P.O. Box 1046, 280 Slater Street, Ottawa, CANADA K1P 5S9 - Phone +1-613-995-2546, Fax +1-613-995-5086, E-mail Messner.R@atomcon.gc.ca						
5.2	VXI Irradiated Fuel Monitor - CANDU Bundle Counter (VIFM-CBC)	VXIbus based radiation monitor	Detect the quantity and direction of transfer of irradiated fuel bundles. Distinguish between fuel and non-fuel measurements using energy-discriminating detectors. Provide data both in raw and interpreted transfer tally summary format. Provide remote interrogation capability of systems operational status and data transmission.	PIN diode detectors are positioned to detect gamma radiation from CANDU irradiated fuel bundles being transferred between the reactor core and the storage bay. The core of the system is based on the generic Autonomous Data Acquisition Module (ADAM) which in the bundle counter configuration is connected to PIN diode detectors. A modular concept with an open architecture is used to enhance design flexibility. Can operate as a stand-alone unit with the capability of integration into a (safeguards) system network. Could be used to monitor the flow of any irradiated fuel assemblies. Will serve as the basis of a new generetion of radiation detection equipment.	D. Bot and R. Messner. "Development of a New Class of NDA Measurement System". 17th Annual Symposium on Safeguards and Nuclear Material Management ESARDA Proceedings, 9-11 May 1995. D. Bot. "Development of a New Spent Fuel Bundle Counter". IAEA Symposium on International Safeguards, 14-18 March 1994.	Development completed and the units are commercially available from Bot Engineering. The IAEA has purchased 26 systems with the VIFM-CBC configuration.
CONTACT: D. Bot, Bot Engineering Ltd., 7393 Twiss Road, Campbellville, Ontario, CANADA L0P 1B0 - Phone +1-905-876-4301, Fax +1-905-875-0525, E-mail David_Bot@botcorp.com **R. Messner,** Canadian Safeguards Support Program, AECB, P.O. Box 1046, 180 Slater Street, Ottawa, CANADA K1P 5S9 - Phone +1-613-995-2546, Fax +1-613-995-5086, E-mail Messner.R@atomcon.gc.ca						
5.3	CONSULHA CONtainment SUrveillance for Low and	Gamma and neutron monitoring coupled with an optical	Provide: An analog and a digital recording of gamma and neutron measurements. A video recording of events.	C/S of dry and wet unloading ponds in COGEMA reprocessing plant (France). Gamma and neutron measurements are monitored in unattended mode	Inspectors training course organised by IAEA since 1991.	Installed for IAEA and EURATOM at la Hague reprocessing plant.

	Jan 1994	count, determine and survey spent fuel movements in reprocessing plants, nuclear facilities and wet or dry storage	through a fibre optical network. The using of CONSULHA software to: -Configure the data acquisition device. -Test nuclear detectors and electronics. -Record alarms and tamper resistant events (door opening, high and low power etc.) -Transfer stamped data from acquisition system to a main computer. -Store nuclear data. -Review automatically nuclear events and provide an inspection report classifying in 4 types of movements (Input, Output, Internal movements, Undetermined movements) and in addition a report of alarms. -Trigger 3 TTL signals used to display icons to a video recording system.	to trigger TTL signals in order to display icons in video screens. Analog and digital recording are used. First, to have a paper plotting and second, to store and review automatically data of a period, using "CONSULHA" software. 4 cameras used. 2 nuclear cameras in the cell, 2 CCD cameras in the storage ponds. Possibility to upgrade over 8 cameras.	"Study of a reprocessing plant fuel unloading surveillance system". INMM 30th Annual Meeting, Florida. G.Daniel and P.Gourlez. "Upgrading of CONSULHA C/S system installed in the dry unloading workshop of the cap de la Hague reprocessing plant". ESARDA Symposium, Avignon, France. Technician training courses organised by CEA/DAMRI.	one year by IAEA and MSSP (1989, 1990). Accepted by IAEA and EURATOM for routine inspection in February 1991. Used by IAEA and EURATOM inspectors in joint team at la Hague reprocessing plant. Hardware and software are commercially available. Video and software training courses are available.
CONTACT: G.Sannie, CEA/DTA/DAMRI/SAR, BP 52, 91192 Gif-sur-Yvette, FRANCE - Phone +33-1-69082003, Fax +33-1-69086030 **DIALECTICA Ltd.**, 9 Rue du Vieil Etang, 78180 Montigny le Bretonneux, FRANCE - Phone +33-1-30450909, Fax +33-1-30450123						
5.4	VXI irradiated Fuel Monitor - Core Discharge Monitor (VIFM-CDM)	VXIbus based radiation monitor	Provide a count and event summary of irradiated CANDU fuel bundles as they are discharged from the reactor core by acquiring and storing gamma and neutron sensor data. Provide remote interrogation capability of systems operational status and data transmission.	For each reactor the following components are installed: -4 detector assemblies consisting of gamma and neutron detectors inside the reactor. -19" rack-mount cabinet outside of the reactor containing the VXI electronics (slot-0) collect computer and the ADAM (Autonomous Data Acquisition Modules) used for the acquisition and collection of count data . System is designed to facilitate retrofit into existing reactors.	D. Bot and R. Messner. "Development of a New Class of NDA Measurement System". 17th Annual Symposium on Safeguards and Nuclear Material Management ESARDA Proceedings, 9-11 May 1995.	The first system has been installed in one reactor of the Canadian Bruce-A Nuclear Generating Station in November 1996 and is undergoing a field trial. Further installations in Bruce are scheduled for 1997. The system is commercially available.
CONTACT: D. Bot, Bot Engineering Ltd., 7393 Twiss Road, Campbellville, Ontario, CANADA L0P 1B0 - Phone +1-905-876-4301, Fax +1-905-875-0525, E-mail David_Bot@botcorp.com **R. Messner,** Canadian Safeguards Support Program, AECB, P.O. Box 1046, 280 Slater Street, Ottawa, CANADA K1P 5S9 - Phone +1-613-995-2546, Fax +1-613-995-5086, E-mail Messner.R@atomcon.gc.ca						

6. ACCESS CONTROL

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
6.1	Access Control System with Authenticated Keys Oct 1994	Access control using randomly marked keys bearing *analog* signatures.	A kind of lock to control access to rooms or to the use of specific protected structures. Keys are randomly marked simple metallic bars two inches long to be slided into a slot in front of the lock. One key can be personalized to opening several selected locks. No digital coding is used. Apart their own structure keys do not bear any information.	In the *present version*, these locks are used to control access to laboratories. They can be installed on a wall near rooms or cells doors. They are suitable in case of strong magnetic environment. The incorporated *memory* of one lock can store up to 100 keys signatures.	A key is *initialized* by a first reading which stores its *texture relief* taken in a very small (unknown) area of the surface by the incorporated *sensor*. Each time the key is introduced into the lock, the signature is acquired and compared to all stored signatures in few seconds. If its reference signature is found, the lock "opens". The *relief* of the key is a unique analog signal.	Available commercially from the licensed French company SPECTEC, under a request for quotation.
CONTACT: B.C. d'Agraives, JRC, TP 450, I-21020 Ispra (VA), ITALY - Phone +39-0332-789107, Fax +39-0332-785780						

7. STATION MONITORING

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
7.1	Straight Line Electronic Tag (ET) 29.10.96	FM wireless/RF electronic tag	The ET is a micropower, modular, and programmable battery operated electronic device. The ET had its genesis from domestic and international safeguards and security work at Sandia. The main function of the ET is to periodically monitor a variety of internal and/or external sensors and transmit any events or state of health messages via radio frequency (RF) to a magazine data unit (MDU). The flexible ET design is composed of a motherboard, two daughter boards, a transmitter/antenna module, an external digital/analog interface, a fiber optic interface, a D-size lithium battery, and a housing (plastic or stainless steel). One of the daughter boards is connected to the microcontroller s eight analog to digital converter (ADC) ports and the other one, to eight of the microcontroller s bi-directional ports. This flexibility allows the user to easily replace the daughter boards with a different suite of sensors without having to re-layout the whole board. The transmitter and antenna are integrated into one module. This modularity allows the user to quickly change the operating frequency band by simply replacing this module. Additional versatility is provided by an external digital/analog interface. This interface is used to monitor two bi-level switches (on/off) and/or a sensor pack that can transmit a serial data stream or two external analog sensors. The ET also has internal security sensors (light, motion, high/low temperature thresholds, and case tamper) to detect tampering of the ET and the item being monitored. All the sensors are individually programmed by the user.	The ET is versatile enough to accommodate any suite of sensors and adapt to any application that the customer wants. It has applications in a variety of safeguards and commercial applications. In the safeguards arena, it has potential applications in the areas of arms control, treaty verification, and high value inventory control. In the commercial arena, it has applications in security systems, in the medical field to remotely monitor patients, in the farming community to control irrigation systems, etc. The only limitation is one s immagination.	G. Patrick Muyshondt. "Electronic Tag (ET) Functional Description and Interface Document". Internal Sandia Document, June 7, 1996.	A pre-production version of the ET exists and is undergoing field tests at the Pantex Plant near Amarillo, Texas.

CONTACT: G. Patrick Muyshondt, Sandia National Laboratories, Special Radars Dept., Department 2346/MS 0529, P.O. Box 5800, Albuquerque NM 87185-0529, USA - Phone +1-505-844-6744, Fax +1-505-844-0858
Steven J. Blankenau, Sandia National Laboratories, Special Radars Dept., Department 2346/MS 0529, P.O. Box 5800, Albuquerque NM 87185-0529, USA - Phone +1-505-844-4443, Fax +1-505-844-0858

8. SECURE CONTAINERS

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
8.1	Secure Suitcase	Secure volume	A Secure Suitcase design was developed to permit the storage of equipment used for treaty verification applications. The contained volume is provided by an anodized aluminium suitcase modified to permit sealing with a fiber optic loop seal. When the suitcase is closed, the fiber optic cable can be threaded through tubing that routes the cable around the suitcase volume, passing through blocks located at all four corners of the suitcase.	When the suitcase is closed and sealed, it cannot be opened without breaking the fiber optic loop. In field applications, the suitcase has been used to protect inspection equipment from tampering. If the enclosed equipment is additionally protected by another security "layer" such as a shrink wrap seal, the level of security is enhanced.		The Secure Suitcase can be procured from: Zero-Halliburton, Pacoma, CA, USA, as Part Number H62415
CONTACT: K. Ystesund, Sandia National Laboratories, MS 0567M, P.O. Box 5800, Albuquerque NM 87185-0567, USA						
8.2	Sample Vial Secure Container (SVSC)	Secure Sample Vial Container	The sample vial secure container will assure the integrity of a sample vial from the point at which the sample is taken to the receipt and treatment of the sample in an analytical laboratory. The SVSC consists of three components: a cartridge, a cover and an identification label. A device to open the SVSC is also required. To use the system the sample vial containing the sample is inserted into the cartridge. The cover is then pressed onto the cartridge. The cover is designed so that it cannot be removed without destroying the cartridge. At the point of receipt the inspector must cut open the cartridge and verify an identification label located inside the cartridge.	Within a reprocessing plant, from the time that a sample is taken to the start of sample treatment the sample is unattended by an inspector. At the present time, there is no assurance that the sample solution that is processed is the same sample the inspector witnessed being drawn. This product will provide the inspectors with a technique to assure the integrity of the sample vial from the point at which the sample is taken to the point where the sample is processed.	Mark J. Baumann. "Sample Vial Secure Container". 34th Annual Meeting Proceedings of the Institute of Nuclear Materials Management, 18-21July 1993.	A prototype system has been demonstrated and a limited number of prototype containers have been produced. When commercialized, the SVSC is expected to cost approximately $10 each.
CONTACT: Mark J. Baumann, Sandia National Laboratories, MS 0656, P.O. Box 5800, Albuquerque NM 87185-0656, USA - Phone +1-505-844-9887, Fax +1-505-844-0491						

9. SAFEGUARDS COMMUNICATION SYSTEMS

N	NAME OF DEVICE, DATE	TYPE	FUNCTION	APPLICATION	REFERENCE TO DESIGN OR USE	STATUS
9.1	Integrated Monitoring System (IMS) 12.01.94	A network system to interconnect sensors, radiation devices, etc.	The IMS is a low cost network and is made possible through the use of a low cost integrated communications processor. An applications processor has the power to handle most of the safeguards sensor and control requirements. A third microprocessor can be added if still more processing power is required. An important feature of the IMS is the capability to authenticate all the data transfers over the network. The network uses a "carrier sense multiple access (CSMA)" contention protocol to handle data. The hardware used in one of the node designs in the Integrated Monitoring System (IMS) uses dual processors and interfaces for accepting computer data through an RS-232 port. Bi-level inputs and outputs are provided to interface to a number of different sensors and control devices. The network processor handles all the tasks associated with transmitting and receiving data from the network s physical medium layer which can be anything from twisted pair wires to radio frequency signals.	The IMS can be used in facility monitoring applications to collect, store, display and review data from a number of different sensors.	"Application of Network Technology to Safeguards and Security Systems". 33rd Annual Meeting of the Institute of Nuclear Materials Management, July 1992.	Development complete. Field test of system in progress. Commercialization in progress.
CONTACT: **Charles S. Johnson,** Sandia National Laboratories, On-Site Monitoring Technology Dept., 9249/MS0656, P.O. Box 5800, Albuquerque NM 87185-0656, USA - Phone +1-505-844-7911, Fax +1-505-844-8478 **Cecil Sonnier,** Sandia National Laboratories, Special Verification Applications Dept., 9208/MS0567, P.O. Box 5800, Albuquerque NM 87185-0567, USA - Phone +1-505-844-2124, Fax +1-505-844-6067						
9.2	Remote Monitoring System (RMS)\ Integrated Monitoring System (IMS) Nov 1996	A low cost network system designed to collect information from sensors, radiation devices, etc.	The RMS and IMS are basically the same systems except that the RMS has a modem and communication software to send the data over either a telephone line or a satellite link. The systems use a local operating network (LON) developed by Echelon Corporation which permits the development of low cost sensor nodes. The nodes can process a variety of data from sample switches to video images and transmit the data over a number of different links including twisted pair cable, fiber optic cable and radio frequency links. Each node uses a special integrated circuit containing three microprocessors of which one microprocessor can be used to process application data. The other processor handles all the communication protocol. Through the selection of various sensors it is possible to install systems which will collect data and images only when there is activity in an area under safeguards surveillance. The system reduces the data and images collected thereby reducing the amount that must be stored, transmitted and reviewed.	The RMS/IMS can be used in Facility monitoring applications to collect, store, transmit and review data from sensors and video cameras.	"The International Remote Monitoring Project - Results of the Swedish Nuclear Power Facility Field Trial". 36th Annual Meeting of the Institute of Nuclear Materials Management, July 1995.	Field test of systems in progress. Systems based on commercial hardware that is widely available.
CONTACT: **John Matter,** Sandia National Laboratories, MS 0656, Albuquerque NM 87185-0656, USA - Phone +1-505-845-8103, Fax +1-505-844-5321 **Steve Dupree,** Sandia National Laboratories, MS 0567, Albuquerque NM 87185-0567, USA - Phone +1-505-844-9930, Fax +1-505-844-6067						

9.3	Multiple Precision Cryptographic Library (MPCL) 12.11.96	Public-key Data Authentication Software Library	The MPCL is a collection of software routines for developers of software with cryptographic requirements. The primary use of the MPCL is in the authentication of digital data using digital signatures. The MPCL provides an interface to functions that will allow a user program to generate and validate digital signatures and generate key parameters in compliance with the Digital Signature Standard. The MPCL includes routines for performing modular multiple-precision mathematics which can be used for other cryptographic algorithms besides the Digital Signature Algorithm (DSA). It also includes routines for performing the Secure Hash Algorithm in compliance with the Secure Hash Standard. The time to generate a signature on a 80386DX-40 using 1024-bit parameters is 0.33 seconds. The time to validate is 0.68 seconds. The MPCL was designed to offer a fast, modular, and easy to use toolkit to support the growing use of digital signatures.	Any online system with the need to replace handwritten signatures with digital signatures - email, file integrity/authenticity (e.g. medical and legal), and communications where source identification and data integrity is required. Any monitoring or surveillance system (e.g. digital cameras) where integrity of acquired data is required.	Multiple-Precision Cryptographic Library Application Program Interface Description, Version 1.6, October, 1996	The MPCL is currently copyrighted and licensable.
CONTACT: Tim Draelos, Sandia National Laboratories, Cooperative Monitoring Technologies Dept., 5736/MS 0655, P.O. Box 5800, Albuquerque NM 87185-0655, USA - Phone +1-505-845-8872, Fax +1-505-844-5632						
9.4	Autonomous Data Acquisition Module (ADAM)	VXIbus radiation monitor module	Detect, store and transmit radiation sensor data. Generic module can accommodate a large variety of radiation sensors thus permitting a wide range of operating modes. Operate as a VXIbus module or as a stand-alone radiation monitor controlled by a laptop computer. Operate on battery power for up to 3 months.	Currently part of VXI based Bundle Counter. Currently part of VXI based Core Discharge Monitor systems. Has been used in its stand-alone mode to conduct measurements outside of the reactor vault of fuel discharges from the reactor. Can be used to monitor flow of any irradiated fuel assembly or radiation source.	D. Bot and R. Messner. "Development of a New Class of NDA Measurement System". 17th Annual Symposium on Safeguards and Nuclear Material Management ESARDA Proceedings, 9-11 May 1995. D. Bot. "Development of a New Spent Fuel Bundle Counter". IAEA Symposium on International Safeguards, 14-18 March 1994.	The ADAM is part of the bundle counter and Core Discharge Monitor systems undergoing field trials. The ADAMs are commercially available from Bot Engineering Ltd.
CONTACT: D. Bot, Bot Engineering Ltd., 7393 Twiss Road, Campbellville, Ontario, CANADA L0P 1B0 - Phone +1-905-876-4301, Fax +1-905-875-0525, E-mail David_Bot@botcorp.com **R. Messner,** Canadian Safeguards Support Program, AECB, P.O. Box 1046, 280 Slater Street, Ottawa, CANADA K1P 5S9 - Phone +1-613-995-2546, Fax +1-613-995-5086, E-mail Messner.R@atomcon.gc.ca						

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