KFKI-1992-37/G
REPORT

P. PELLIONISZ

DECISION-MAKING FOR ACOUSTIC EMISSION DATA SET

Hungarian Academy of Sciences
CENTRAL
RESEARCH
INSTITUTE FOR
PHYSICS
BUDAPEST

KFKI-1992-37/G
REPORT

Decision-making for acoustic emission data set

P. Pellionisz

Central Research Institute for Physics
Atomic Energy Research Institute
H-1525 Budapest 114, P.O.B. 49, HUNGARY

HU ISSN 0368 5330

P. Pellionisz: Decision-making for acoustic emission data set KFKI-1992-37/G

ABSTRACT

Acoustic emission techniques are widely applied in proof tests of pressure vessels. Correct interpretation of experimental data is of primary importance. The AE DATA EXPERT system performs this task in three procedures: source separation, source purification and source classification. In the paper, basic production rules are discussed.

Pellionisz P.: Döntéshozatal akusztikus emissziós adat-állományokban KFKI-1992-37/G

KIVONAT

Nyomástartó edények terhelési próbáinál széles körben alkalmazzák az akusztikus emissziós vizsgálatokat. A kísérleti adatok helyes értelmezése kulcsfontosságú. Az AE DATA EXPERT szakértői rendszer ezt a feladatot három lépcsőben végzi el: forrás-elkülönítés, forrás-tisztítás és forrás-osztályozás. A dolgozatban a főbb értékelési szabályok kerülnek ismertetésre.

1. INTRODUCTION

In acoustic emission (a.e.) testing [1], [2], [3], acoustic outbursts are captured and characterized by their most important parameters as Fig. 1 shows.

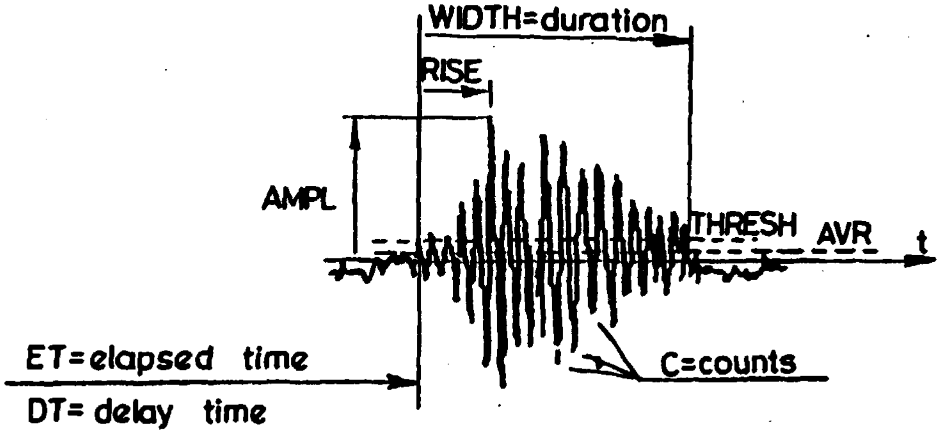

Fig. 1
Directly measured a.e. parameters

From the directly measured parameters shown above, usually further quantities are calculated, such as energy, RMS value, etc. For testing larger objects, generally, multiple sensors are used, grouped in so-called arrays - comprising 3 or 4 detectors. Knowing the sound velocity, and the DT arrival-time differences between the sensors, the origin of the sound waves, i.e. the material degradation place is calculated.

The signal waveform is determined by the character of the source, by the signal path (usually very complex), by the detector and the measuring device. Further, the originating phenomenon is statistical in character, i.e. reliable information characterizing the object under test can not be given by a single acoustic event. The analysis and the interpretation of acoustic emission data is, therefore, rather difficult and complex task [4], [5], [6], [7].

Measured and calculated acoustic emission data are recorded today in computer memory, in the form of raw data files or as processed data sets representing the measurement's history, density or cumulative functions, location maps, etc. For real-time or post-processing, many possibilities areavailable in today's a.e. data processing software packages. In the KFKI Atomic Energy Research Institute, a.e. measurements are performed by the Defectophone devices and their DEFPROC data processing software developed by the institute and applied successfully in many countries [8].

However sophisticated are the tools of the software package, they are to be handled by human experts, whose expertise must decide in the interpretation of the results, and in the safety assessment of the objects under test. For the KFKI Atomic Energy Research Institute, the most important objects regularly tested are nuclear reactor pressure vessels. Relying on the experience with four reactor vessels and more than a dozen other pressure retaining structures [9], in the institute a project has been initialized for developing a tool of artificial intelligence facilitating the interpretation task. In the framework of the project, the expert system "A.E. DATA EXPERT" is being developed, which performs automatic decision making on multiparameter a.e. data sets of pressure vessel test results.

In this paper, the source separation and the principles of one of the developed system's modules [10] are discussed. Relying on previous test results and the study of international references, the problem is analyzed, how the a.e. parameter set can be purified, i.e. noises, electromagnetic interference, signals originated by secondary acoustic sources (slipping, friction, etc.) can be eliminated.

2. ACOUSTIC EMISSION SIGNAL CHARACTERISATION

In pressure vessel tests, crack formation or crack propagation processes are to be detected during overpressurization. These processes - fortunately - are exceptional in practice, so much the more are present additional noises sources [11], which can be grouped according to Table 1 in case of typical pressure vessel tests.

Relative signal amplitudes are given in decibels, while continuous noise is designated by *.

Real acoustic emission	Secondary acoustic emission	Additional sources
Dislocation (20-30 dB) Inclusion fracture Intergranular cracking (60-80 dB) Cleavage cracking (80-100 dB)	Leakage (*) Rubbing (20-40 dB) Friction (20-60 dB)	Hydraulic noise (*) Electromagnetic interface (20 dB) External noises (?) Electronic noise (20 dB)

Table 1
Typical acoustic events detected
in pressure vessel tests
(continuous noise: * , outbursts: peak amplitude in dB)

There are many established and proven methods for reducing, eliminating and filtering unwanted noise pick-up. In the measurements we regularly use many of them; however, these are not discussed in the present paper. With improved instrumentation and shielding, by avoiding ground loops, the EMI-sensitivity and electronic noise level can be kept on fairly low value as Fig.2 shows.

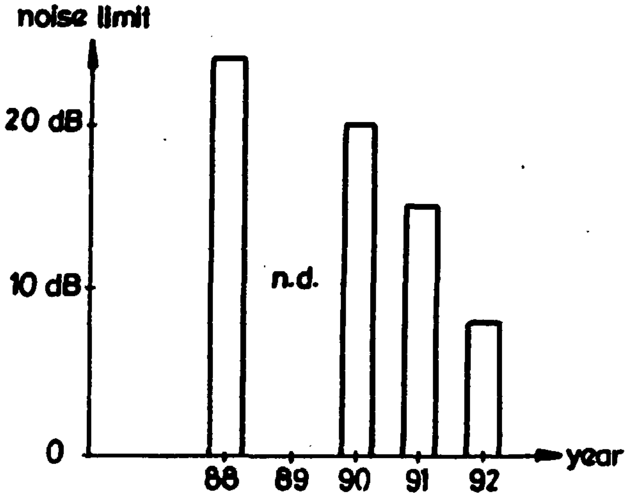

Fig.2
Electronic noise limit in the Defectophone assembly applied at Paks pressure vessel measurements

Much of the external noise can be disregarded by applying guard sensors detecting allien activity. The more perfect filtering is required, the higher is the number of the system's channel number, as Fig.3. shows for the same measuring task executed in the previous years.

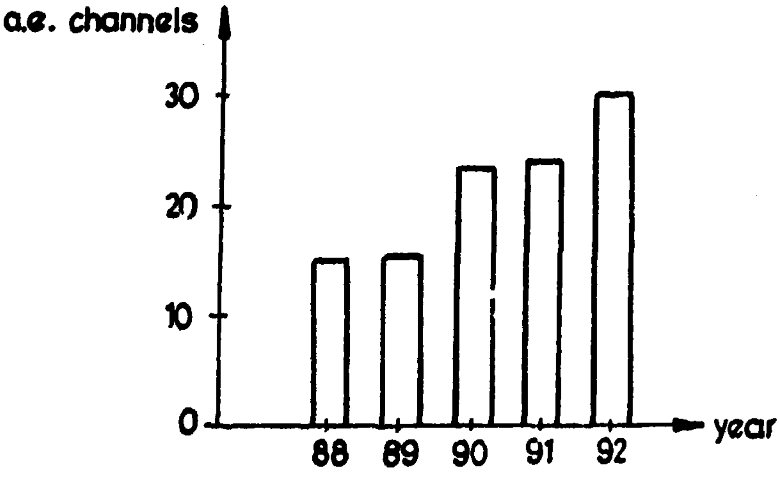

Fig.3
Channel number (including guard channels) of Defectophone assemblies applied at Paks pressure vessel measurements

The task of the guard sensors is to detect acoustic activity having its source outside the region under test and to exclude them from further processing.

The detected acoustic emission signal is the result of a number of complicated phenomena: the mechanical disturbance causing a sudden energy release, the wave propagation process in the material and the interaction of the sensor. All of them are rather difficult to be followed theoretically, even in the case of very simple objects. In the most simple case, the following approximations can be made (Table 2).

1.Source: 1.1. Single, during the captured event
1.2. Physical process: single Dirac-delta

2.Propagation: 2.1. Far-field: surface-waves only
2.2. No refraction and reflection effects

3.Sensor: 3.1. Single resonant frequency
3.2. No noise addition and reflection effects

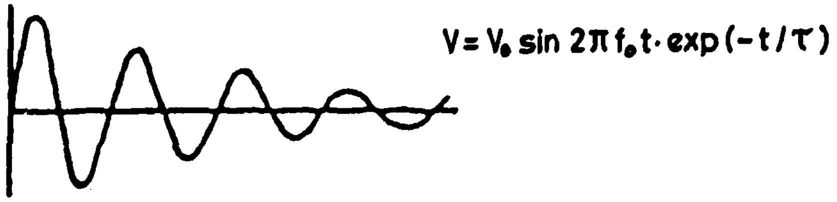

Table 2
Assumptions and signal shape of an idealized acoustic emission event

In the practice, in many cases, none of the above assumptions is valid. This is the reason that the real waveform is complicated and its interpretation is not easy (see Fig. 4). Because of the high amplitude span of the detected signals, in many cases nonlinear (e.g. logarithmic) amplifiers are used: they make the signal interpretation even more complicated.

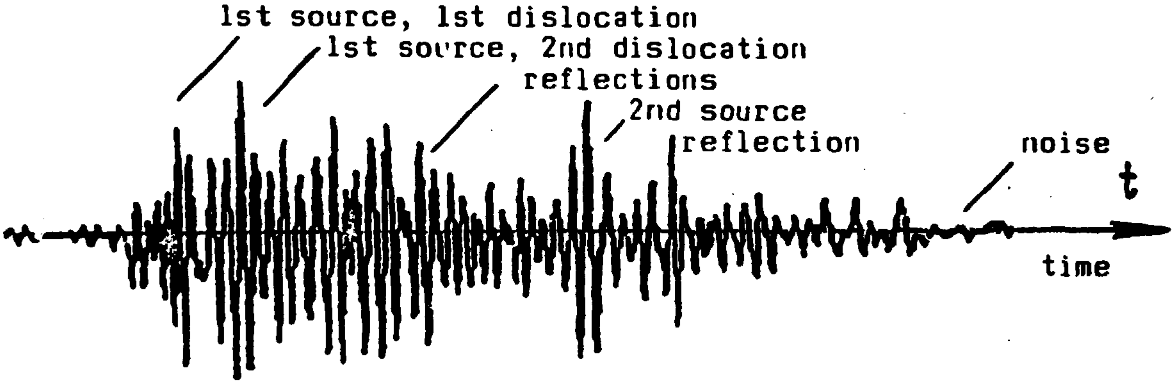

Fig.4
Real acoustic emission signal and its "decoding"

Conventional acoustic emission measuring techniques do not deliver as detailed picture on the captured signals as shown in Fig.4, partly because of technical and price limitations, partly because of the extensive data rate of the high frequency acoustic emission events (sometimes several thousand per second). The signal is generally compared to a threshold voltage. Crossing indicates the arrival of a new wavefront, and the event is represented by a corresponding Event Pulse, as shown in Fig. 5. The real signal is replaced by a data set, e.g. according to Fig. 6., where such parameters as arrival time (elapse time ET, time differences DT-s), rise time, ring-down counts, etc. represent the original signal in the DEFPROC software.

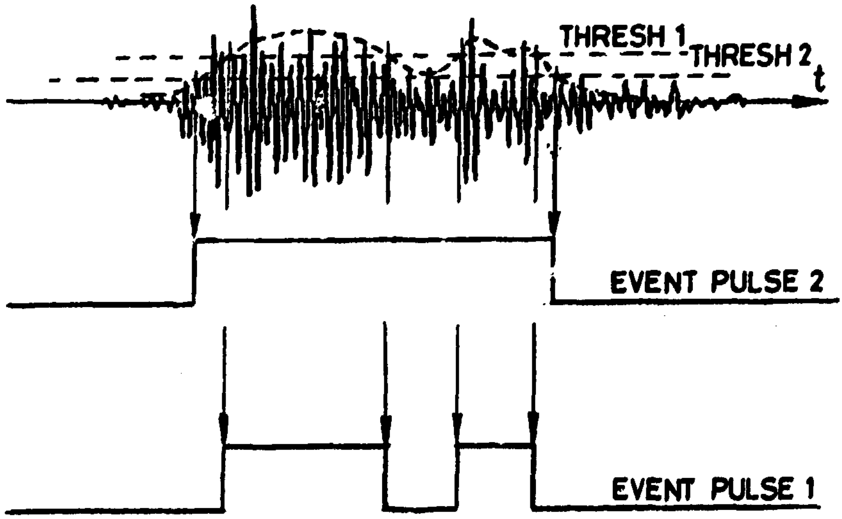

Fig.5
Comparing captured and amplified signal to threshold level

```
4,4,4,4  act. channels Threshold= 40dB DeltaET=100ms DeltaT=100 s Mem. code=  0
Dead time=  50.0ms DTmax.= 3008us ARR/INDEP Coinc=     0us Damp=  0dB/ms
 Index   El.Time G/FC Ampl  Counts  RiseTime  Ev.Width   DT1    DT2   DT3    DT4
----------[s]--------[dB]------------[us]-------[us]------[us]--[us]--[us]--[us]-
   572  13501.900  1/1   50    3652       1034     14970     0   572  2130    487
   573  13503.400  1/4   54     750        430      2910   620   572  2130      0
   578  13511.800  2/4   44    1540         48      6270   289   889    62      0
   579  13511.900  1/4   44     422        115      1540   682   572  2130      0
   581  13517.500  1/4   43     698         21      2700  1408   572  2130      0
   582  13517.500  2/4   44    1241         50      4840   293   893    66      0
   585  13527.100  1/4   51     806         94      3000   349   572  2130      0
   587  13541.100  1/4   55    1075        430      4400   616   572  2130      0
   589  13541.200  1/4   45     255         72       950   616   572  2130      0
   593  13552.900  2/4   46    3652        830     13700   452   869   570      0
   594  13552.900  1/4   43     365        114      1310   783  2855  2130      0
   597  13566.600  1/4   58    2371        443      8940   589  2816  1815      0
   598  13566.600  2/4   46    4217        691     15390   347   683    57      0
```

Fig.6
Typical data collected in acoustic emission measurements

It can be seen from Fig.5 that threshold setting is crucial for measuring the parameters correctly, or, at least, not to falsify the original signal. If the ideal signal in Table 2 is applied to a threshold level V_T , the number of the registrated ring-down counts(C) depends on V_T:

$$C = f_0 \tau \ln (Vo/V_T)$$

Three ways can be followed for facilitating the correct measurement. The most radical - and the most costly - is to change the measurement philosophy completely and rely on high-speed computing power in on-line and (almost) real-time analysis of digitalized input signals. On probability and likelihood analysis threshold setting might be adaptive and the reliability of the data set might be increased. This way is under preparation in the KFKI-AEKI by developing a system named SIGNALYZER.

The other way for increasing the reliability of the data set is based on applying a number of easily applicable criteria which decide during the measurement, whether the signal is valid, there is a single source, etc. and they reject reflections. These real-time applicable criteria are the hardware (or close-to-hardware) implementations of pattern recognition methods used to extract the "hidden" interrelations between different parameters. These "invalidity-criteria","hardware filtering", etc. are used in our acoustic emission instrumentation based on the Defectophone system [12].

However effective are these measures, post-processing on the measured data can not be avoided. This third way is based on pattern recognition methods [13], artificial intelligence, expert systems [14], etc. In the following, the considerations are presented for the post processing analysis of the measured data set, which will be applied in the "AE DATA EXPERT" system, actually under development, in the KFKI-AEKI.

3. DECISION - MAKING

When analysing acoustic emission data set, a number of problems are to be solved to assess the significance of the captured acoustic emission signals. In the following, limiting ourselves to a.e. data originated in pressure vessel tests, we overview the most important problems where decisions are to be made and introduce decision-making criteria serving as practical rules for knowledge-base of the expert system, actually under development.

3.1. SOURCE SEPARATION

In acoustic emission testing, sensors are grouped in arrays. By measuring the arrival time differences of a sound burst originated from a single source and knowing the propagation velocity, location calculations can be made and planar location maps shown, according to Fig.7.

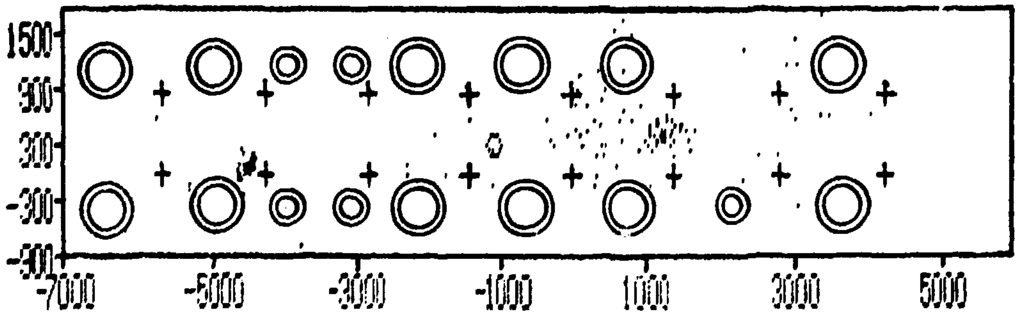

Fig.7
Planar location map of the acoustic indications during a pressure test

Location calculations are made on data of sound propagation time differences. As discussed before, the stochastical character of the signals and threshold crossing techniques do not make possible exact time measurement in all cases: a single source may result several, separately positioned indications. This is the reason that in location maps the number of indications is not equal to the real number of acoustic sources: several indications may correspond to a single source only. Its position can be identified by clustering closely located indications, taking into account location errors, geometry and the required factor of certainty (credibility).

Errors in arrival time measurements may have many sources, e.g.

- limited frequency of the sensor (e.g. a 200 kHz resonant type sensor can not yield higher rise time than 1.7 us),
- limited resolution of the measuring device,
- threshold/noise and threshold/event-amplitude problems (if threshold is too low, noise peaks may be interpreted as signal fronts, if threshold is too high, triggering is delayed by the rise time).

Some of these effects may have extreme consequences, e.g. contradictory arrival time values make impossible solving the equations. In other cases, time errors falsify the locations only.

Influence of time errors on the location accuracy highly depends on the source position related to the array borders, and the geometry of the array. In Fig.8 (a), a rectangular array of four sensors is shown, with a source S.

The acoustic source (S) is assumed to be on the symmetry axis, in a distance s from the border line. The sound wave arrives at first, simultaneously, to sensors D1 and D4, then, after a delay of DT to D2 and D3. As Fig.8.(b) shows, the longer is the distance s, the higher is the influence of the time error on the location accuracy. At a typical array size of 1.2 meter, the inaccuracy is about 30 cm in a distance of 1 m from the border, when 10 μs error is made in DT, in case of steel material (v = 3000 m/s).

When separate indications are investigated, whether they may be clustered coming from one single event, the characteristic error size (theoretical cluster diameter) at the given point is to be compared to the distance between separate indications. To calculate the function between Δs and time incertitude ΔT is rather lengthy:

$$\Delta T = \frac{1}{v}\left[\sqrt{5d^2+4d(s+\Delta s)+s(s+2\Delta s)+\Delta s^2} - \sqrt{5d^2+4ds+s^2} - \right.$$

$$\left. - \sqrt{d^2+(s+\Delta s)^2} + \sqrt{d^2+s^2}\,\right],$$

Here v is the sound propagation velocity, and geometry data are those shown in Fig.8.

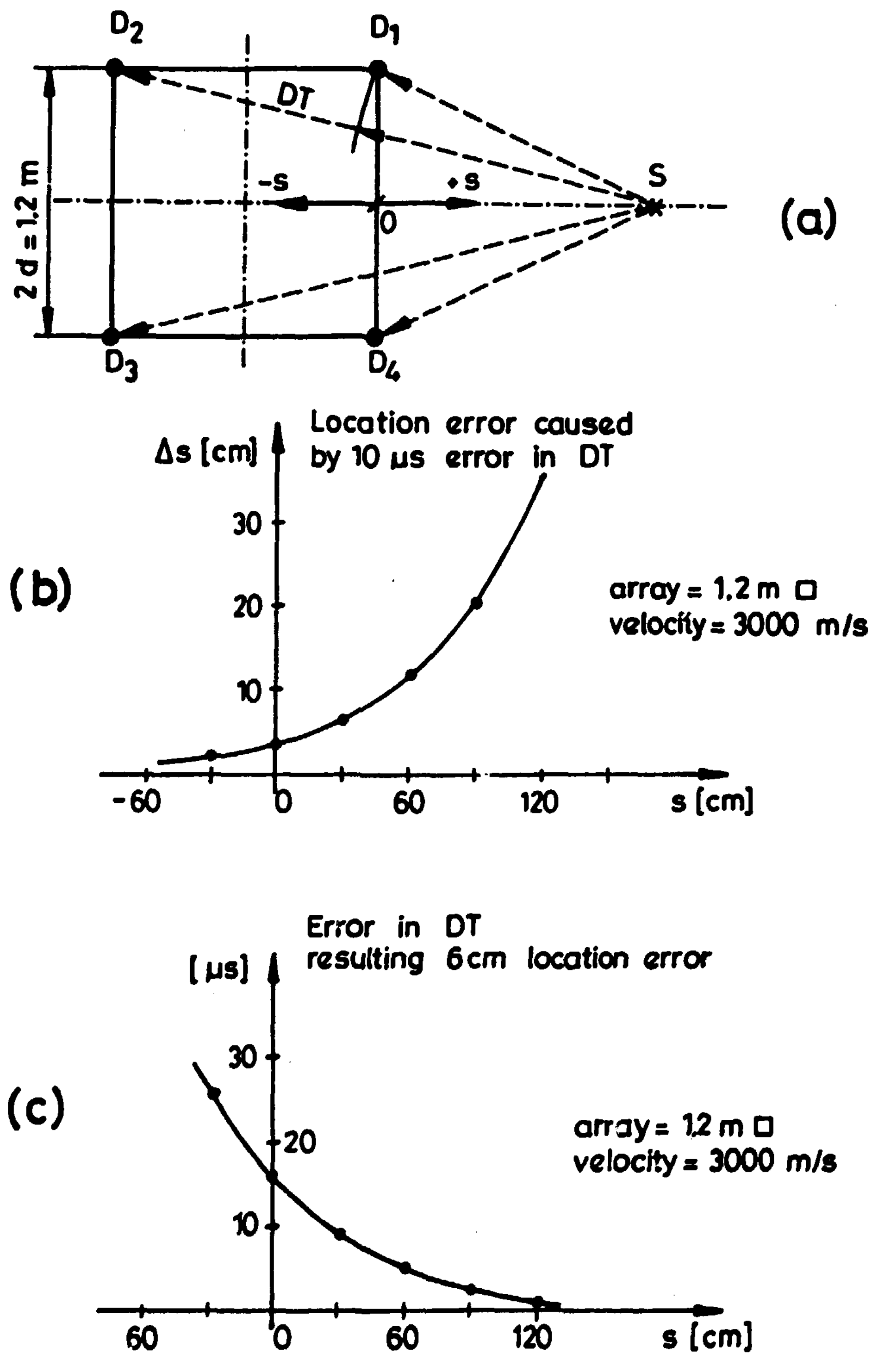

Fig.8

(a) Rectangular array with variable source position on the symmetry axis, delay time between D2-D1 and D3-D4=DT

(b) Location error caused by 10 us error in DT as a function of source position ,

(c) Error in DT resulting 6 cm location error as a function of source position

Not only time measurement inaccuracy, but geometry errors, wall thickness, approximations in the calculations, etc. are to be taken into consideration. These errors can be handled by introducing a certainty factor, which multiplies the error size.

The strategy of the expert system for separating the indications is the following. At the place of the actual indication, the product of the characteristic error size CES with the certainty factor (CF) is to be considered. In the simplest case, a rectangular array can be defined around the point, as Fig.9 shows. If areas of nearest neighbour points are overlapped, common origins may be assumed at the centers of gravity. These are regarded as new points and the process is repeated until finding the assumed source.

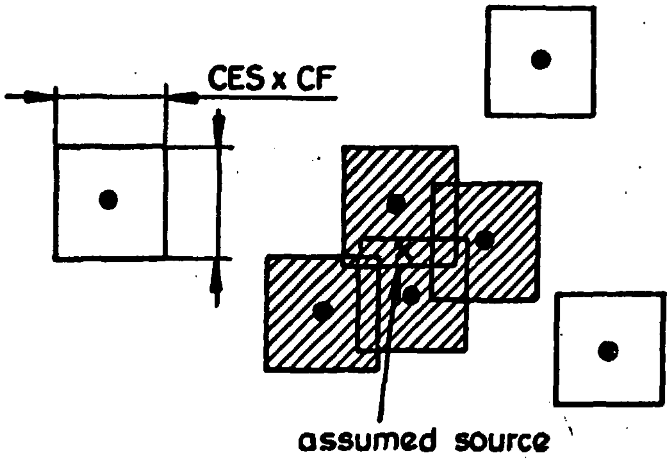

Fig.9
Clustering neighbouring indications

The calculation of the characteristic error size can be made real-time, or it can be taken from a look-up table containing CES values for different zones, speeding-up the decision making. This process can be applied to all the indications, or - using the filtering, screening capabilities of the data processing software - to some selected groups of indications (e.g. a.e. events of high amplitudes). By using linear discriminant functions or K-nearest neighbour classifiers [15] sources can be separated in the feature space.

3.2. SOURCE PURIFICATION

Sources of acoustic activity may be of different character (see Table 1). For assessing the severity of the acoustic activity, it is important to identify true primary acoustic emission sources and to disregard noises, secondary emissions, etc. Acoustic emission events are characterised by a set of data (feature vector): sorting in the feature space is called source purification. Here, the knowledge base comprises pattern recognition rules learned in acoustic emission test measurements, home and abroad [9], [16], [17], [18].

Noise contribution

Electronic noises and device imperfections are to be considered in acoustic emission signal analysis. A typical situation is when common-mode electric disturbances are captured by sensors or cables. These phenomena can be recognised by the simultaneous activity of the sensors. Fig. 10 shows the effect of filtering for DT=0. This sort of filtering can also be inserted in the expert system.

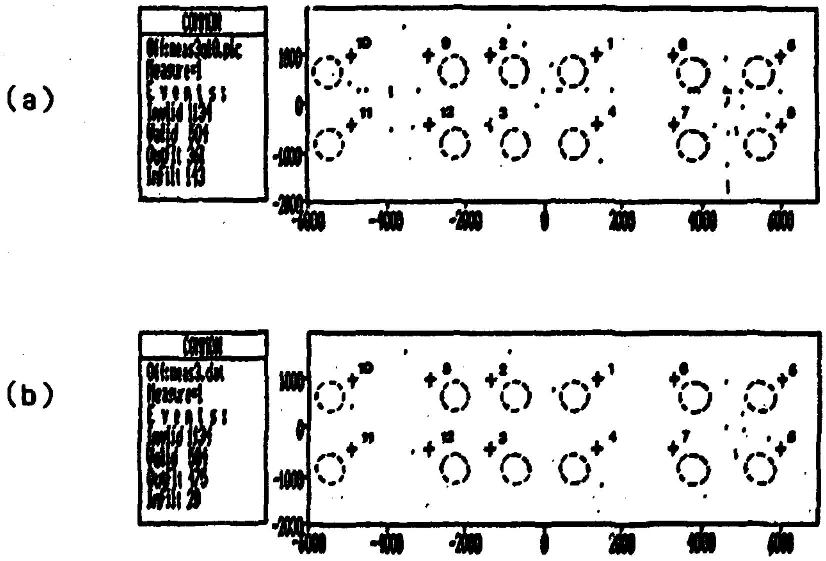

Fig.10
Acoustic indications in a pressure test (a).
The same map after filtering out simultaneous events (b).

Most electronic or device-induced noises just cross the threshold limit, thus their parameters are not higher than the possible lowest value, as Fig.11 shows.

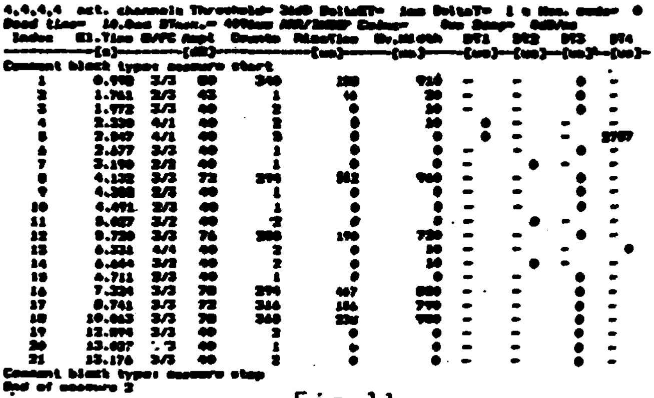

Fig.11

Electronic noises are recorded with the possible lowest values (AMPL = THRES, RISE T = 1, EVENT WIDTH = 1, etc)

Noises can be rejected if the events are filtered out which meet the above criteria. This rule is built in the expert system, again.

The third way of identifying non-acoustic emission signals is to inspect the interrelation between event duration time and the number of oscillations (counts) during this time. Acoustic emission sensors have one or more resonant frequencies, and the original physical process initiates ring-down oscillation with the characteristic frequency. Thus, there is a linear relationship between event duration and number of counts for acoustic signals as Fig.12 shows. If events are filtered but where the value of the quotient of these two parameters differs from the characteristic value in a percentage determined by the certainty factor, signals of non-acoustic origin can be eliminated.

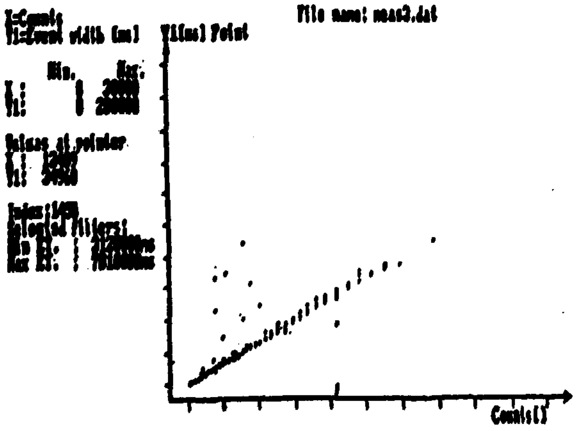

Fig.12

Interrelation between event duration and counts: for a.e. signals the dependence is a linear function

Crack identification

At pressure tests, generally two major processes may emit acoustic emission signals, namely crack formation and frictions of already existing crack surfaces. Both in laboratory and in experimental pressure vessel tests, it has been found that in rise time distribution generally two distinct maxima exist as Fig.13 shows schematically.

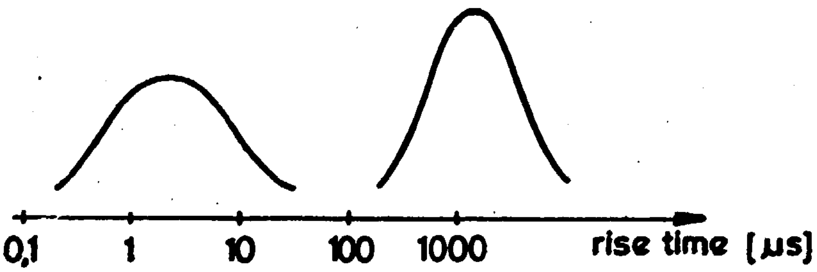

Fig.13
Two maxima of rise time distribution
from crack formation and friction

Experience shows that crack propagation emits signals of low rise time, while friction process has slower wave front. This fact has been proven both in hydrotests and at fracture mechanical investigations of CT speciments [17].

Depending on object size, wave spreading and dispersion, the position and width of the transition area is varied under different experimental conditions. At large objects it is found tipically around 100 µs, while at small CT specimens at 30 µs [17]. According to these measurements, for signal separation, the rise time is preferred to other signal parameters, because it is nearly independent from signal amplitude, contrary to e.g. signal duration which generally depends on amplitude. Rise time reflects the source life time in most of the cases. Thus, in the expert system a rule discriminating signal rise time is built-in, with using the certainty factor, reflecting the probability of the right decision.

Some other checks may help to decide between crack-origin and friction. Crack formation and crack propagation are obviously irreversible processes. Whenever up-down stress changes occur (e.g. heating and cooling or compression and decompresion) together with rising acoustic activity in both cases, reversible processes (e.g. rubbing, friction) evoke the acoustic events. Fig. 14 shows similar effects at pressurization and decompression in a pressure vessel hydrotest.

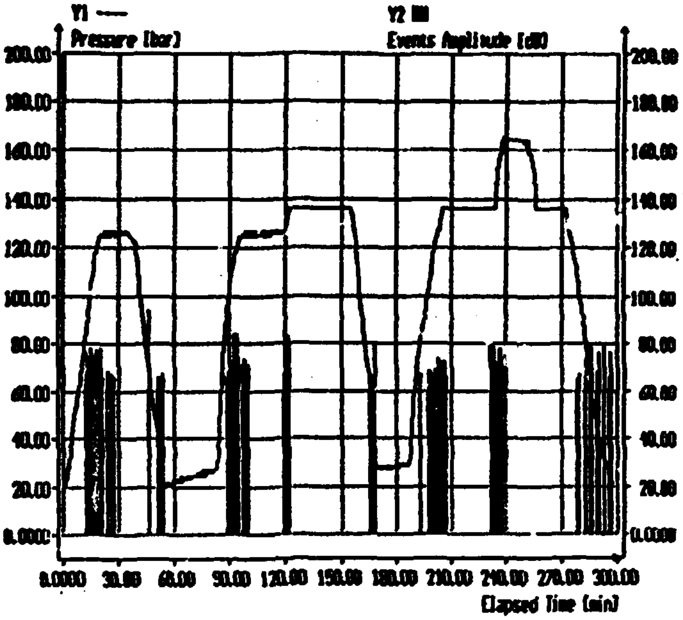

Fig.14

Secondary emission:
both pressure-rising and decreasing results
acoustic activity from the same source in
a pressure vessel hydrotest

An important knowledge-base rule of the expert system tells that repeated bidirectional acoustic activity in steel materials can not be originated by crack propagation.

On the other hand, irreversible structural changes in steel materials always show the Kaiser effect, i.e. at repeated load there is no acoustic activity, until the stress is not higher than the previous maximum. It is to be noted, however, that small load returns result the character of the Kaiser effect, even in the case of friction-originated sound processes, because of the hysteresis of the surface-slipping phenomena. The crack propagation in metals, however, is in accordance with the Kaiser effect, i.e. without Kaiser effect crack propagation can be excluded. In Fig. 15 Kaiser effect is shown.

A simple method for assessing the significance of the acoustic activity is considering the peak amplitude or energy of the acoustic events. According to Table 1, sound effects below 40 dB do not indicate crack propagation in steel materials.

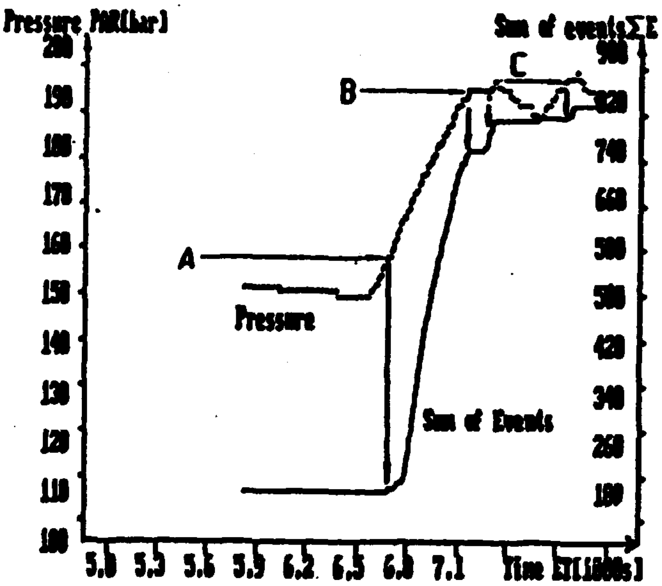

Fig.15
Kaiser-effect: A, C = previous pressure maxima, B = constant pressure

Summarizing the above considerations, localized acoustic emission sources can be effectively purified from noises and secondary acoustic emission events by using some basic production rules built into the expert system.

3.3. SOURCE CLASSIFICATION

In the field of proof tests of pressure vessels, the mostly aplied classification procedure is given by ASTM [19]. Its basic working principle that acoustic emission sources are to be classified according to their acoustic activity and intensity. The activity is measured by the number of the acoustic events or that of the acoustic emission oscillations (counts). The source is classified active if the total number of acoustic events and/or counts increases when the applied pressure remains constant or is increasing. It is critically active if the growth rate is also increasing when the applied pressure is constant or growing. Fig. 16 explains this classification.

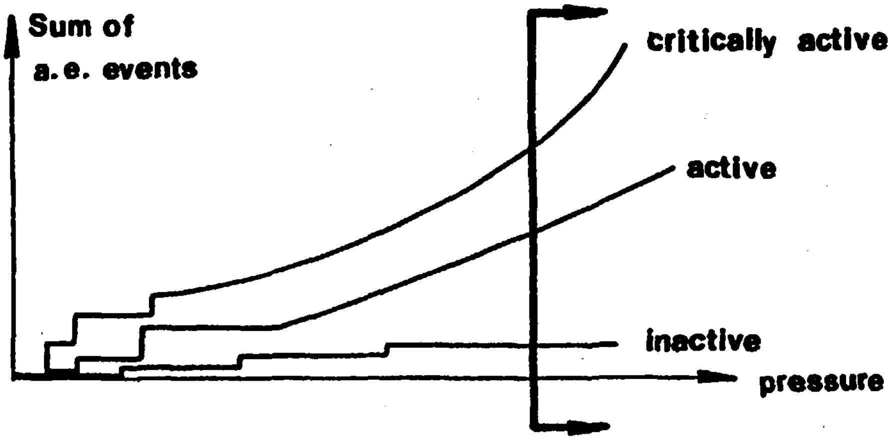

Fig.16
Classification of acoustic emission sources according to the ASTM code

For measuring the intensity, different parameters can be selected, such as peak amplitude, energy, etc. The acoustic source is classified intensive, if active and its intensity is considerably higher than that of the average of the other sources. It is critically intensive, if its intensity is significantly growing at constant or increasing load.

According to these rules, the intensity values must be calculated separately for the different sections of the proof test. The most important sections are the pressure-hold periods, where significant acoustic emission must not be found to tell the source not critically active. This decision-making is done in the AE DATA EXPERT system, after performing source separation and source purification procedures described in Sections 3.1 an 3.2.

References

[1] Nondestructive Testing Handbok, Vol.5: Acoustic Emission Testing (Eds.: Miller, R.K. and Intire, P.Mc.), American Society for Nondestructive Testing, 1987.

[2] Roget, J.: Essais non destructifs - L'emission acoustique. AFNOR-CETIM 1988, Paris.

[3] Akusztikus emissziós anyag- és szerkezetvizsgálatok. (Szerk. Pellionisz, P.). GTE, Budapest, 1992.

[4] Deuster, G., Sklarczyk, C., Waschkies, E.: Detection and location of defects in reactor pressure components by location and interpretation of acoustic emission sources. Nucl. Eng. and Design, 129 (1991) p. 185-190.

[5] Scruby, C.B., Stacey, K.A.: Acoustic emission measurements on PWR weld material with inserted defects. Journal of Acoustic Emission, 7(1988) p.81-93.

[6] Pellionisz, P. Geréb, J.: Akusztikus emissziós jelek interpretálása szilárdsági nyomáspróba értékeléséhez, KFKI Report, KFKI-1989-38.

[7] Bassim, M.N., Pedrycz, W.: Development of intelligent systems for monitoring of acoustic emission. Proc. 12 th World Conf. on Non-Destructive Testing (Eds. Boogaard, J., van Dijk, G.M.), Elsevier, Amsterdam, 1989., p. 441-446.

[8] KFKI: System Defectophone NEZ-220. Gyártmányismertető és müszaki leirás. KFKI-AEKI, Budapest 1525 Pf. 49.

[9] KFKI: Kutatási jelentések a PAV reaktortartályainak valamint egyéb nyomástartó edények akusztikus emissziós ellenőrzéseiről. KFKI-AEKI, Budapest, 1525 Pf. 49.

[10] Pellionisz, P., Szendrő, S.: Development of an expert system for acoustic emission testing: A.E. DATA EXPERT. KFKI-Report, KFKI-1991-31.

[11] Dunegan, H.L.: A.e. for when you absolutely cannot afford a failure of a critical pressure boundary. Proc. on World Meeting on Acoustic Emission, in J. of Acoustic Emission, 8 (1989) 1-2, p.71-74.

[12] Geréb J., Pellionisz P., Székely Gy.: Az akusztikus emissziós folyamat- és minőségellenőrzés uj eszköze: a bővitett Defectophone. GÉP, XL. évf. 1988, 9. (Szept.) pp. 335-338.

[13] Chan, R.W.Y., Hay,D.R., Hay,J.R., Patel, H.B.: Improving acoustic emission crack/leak detection in pressurized piping b pattern recognition techniques. Proc. on World Meeting on Acoustic Enission, in J. of Acoustic Emission, 8 (1989), 1-2, p. 512-513.

[14] Harris, R.W., Wood, B.R.A.: Facilitation of AE integrity assessment by an expert system. Proc. on World Meeting on Acoustic Emission, in J. of Acoustic Emission, 8 (1989), 1-2, p. 514-515.

[15] Tou,J.T., Gonzalez,R.C.: Pattern recognition principles. Reading, MA: Addison-Welsey Publishing (1974).

[16] Scruby,C.B., Stacey,K.A.: Acoustic emission measurements on PWR weld material with inserted defects. J. of Acoustic Emission, Vol.7 (1988), 2, p. 81-93.

[17] Deuster,G., Sklarczyk,C., Waschkies,E.: Detection and analysis of defects in reactor pressure components by location and interpretation of acoustic emission sources. Nucl. Eng. and Design 129 (1991) p. 185-190.

[18] Pellionisz,P., Geréb,J.: Akusztikus emissziós jelek interpretálása szilárdsági nyomáspróba értékeléséhez. KFKI-Report, KFKI-1989-38.

[19] Standard Practice for Acoustic Emission Monitoring of Structures during Controlled Stimulation. ASTM Standard, E-569-85, American Society for Testing Materials.

The issues of the KFKI preprint/report series are classified as follows:

A. Particle and Nuclear Physics
B. General Relativity and Gravitation
C. Cosmic Rays and Space Research
D. Fusion and Plasma Physics
E. Solid State Physics
F. Semiconductor and Bubble Memory Physics and Technology
G. Nuclear Reactor Physics and Technology
H. Laboratory, Biomedical and Nuclear Reactor Electronics
I. Mechanical, Precision Mechanical and Nuclear Engineering
J. Analytical and Physical Chemistry
K. Health Physics
L. Vibration Analysis, CAD, CAM
M. Hardware and Software Development, Computer Applications, Programming
N. Computer Design, CAMAC, Computer Controlled Measurements

The complete series or issues discussing one or more of the subjects can be ordered; institutions are kindly requested to contact the KFKI Library, individuals the authors.

Title and classification of the issues published this year:

KFKI-1992-01/E A. Czitrovszky et al.: Laser analysis of aerosol particles to calculate distribution of aerosol electric charges and size

KFKI-1992-02/A F. Glück et al.: Order-α radiative corrections for semileptonic decays of polarized baryons

KFKI-1992-03/A L. Diósi: *Coarse graining and decoherence translated into von Neumann Language*

KFKI-1992-04/E L. Diósi: On the Caldeira-Leggett Master Equation

KFKI-1992-05/B + M J. Kadlecsik: Tensor Manipulation Package for General Relativity Calculations

KFKI-1992-06/B G.S. Hall: Symmetries in General Relativity - a brief survey
C. Hoenselaers: Nonlinear Partial Differential Equations and Solitons

KFKI-1992-07/A L.L. Gabunia, T.Gémesy, L. Jenik, A.I. Kharchilava, S. Krasznovszky, V.N. Penev, Gy. Pintér, A.I. Shklovskaja, L.S. Vertogradov: Production region of identical pions at 38 GeV/c p^--nuclei interactions with high P_t particles

KFKI-1992-08/A K. Szlachányi, P. Vecsernyés: Quantum Symmetry and Braid Group Statistics in G-spin Models

KFKI-1992-09/G A. Rácz: Estimation of Quasi-Critical Reactivity

KFKI-1992-10/A + B A. Frenkel and F. Károlyházy: Progress in the K-model of Quantum mechanics

KFKI-1992-11/A	J. Révai, Y. Nogami: On the theory of atomic ionization following alpha decay
KFKI-1992-12/A	I. Lovas, L. M[illegible]r, K. Sailer, W. Greiner: Periodic structure in nuclear matter
KFKI-1992-13/A	S. Krasznovszky: Analysis of the KW Distribution Using a Generalization of the Meijer's G-function
KFKI-1992-14/M	Mária Törő: Performance Analysis of the IIASA Network
KFKI-1992-15/A	F. Glück: Measurable distributions of unpolarized neutron decay
KFKI-1992-16/J	Sz. Török, Sz. Sándor et. all: Source apportionment of individual aerosol particles at Hungarian background stations
KFKI-1992-17/G	G. Pór, L. A. Sokolov: "KAZMER" A Complex noise diagnostic system for 1000 MWe PWR WWER Type Nuclear Power Units
KFKI-1992-18/G	S. Lipcsei, S. Kiss and G. Pór: On the Eigenfrequencies of Fuel Rod Vibration in NPPs Submitted to Annals of Nuclear Energy
KFKI-1992-19/G,I	P. Pellionisz, S.K. Jha and G.L. Goswami: Acoustic Emission Experiments for PHWR Technology Development
KFKI-1992-20/K	F. Zombori, A. Andrási, I. Németh: A New Method for the Determination of Radionuclide Distribution in the Soil by In Situ Gamma-Ray Spectrometry
KFKI-1992-21/A	L. Diósi: On Digital Randomness of Quantum Coordinates
KFKI-1992-22/B	C. Hoenselaers, Z. Perjés: Remarks on the Robinson-Trautman solutions
KFKI-1992-23/G	B. Lukács and A. Rácz: Objective Judgement by Kalman Filtering in the Generalized Landsbergian Scheme
KFKI-1992-24/E	G. Konczos, B. Selmeci: Amorphous Alloys Bibliography 1987-1991: Papers from the Central Research Institute for Physics (Budapest) and Cooperating Institutions
KFKI-1992-25/G	S. Bende-Farkas, S. Kiss and A. Rácz: Logic Based Feature Detection on Incore Neutron Spectra
KFKI-1992-26/G	J. Végh, J. Huszár, J. Láz: Development of an X Window based operator's interface for a core monitoring system
KFKI-1992-27/G	Vértes P.: Code for Calculation of Spreading of Radioactivity in Reactor Containment Systems (TIBSO code)
KFKI-1992-28/B,G	B. Lukács, A. Rácz: Killing Symmetries in Neutron Transport
KFKI-1992-29/D	Z. Donkó and M. Jánossy: Modeling the cathode region of noble gas mixture discharges using Monte Carlo simulation
KFKI-1992-30/A	P. Varga: To the Problem of the Coherence Length of Neutrons

KFKI-1992-31/A	P. Lévai and J. Zimányi: Multi-heavy baryons in ultrarelativistic heavy ion collisions
KFKI-1992-32/C	B.Lukács, Sz. Bérczi, E. Lábos, I. Molnár: Mutual Dynamics of Organisation Levels in Evolution
KFKI-1992-33/G	E. Végh, J.S. Jánosy, P. Ivancsics: Extension of the Paks full-scalesSimulator to severe accidents
KFKI-1992-34/M,N	Sz. Ferenczi: Proceedings of the 1st Austrian-Hungarian Workshop on Transputer Application
KFKI-1992-35/A	L.P. Csernai, J.I. Kapusta, Gy. Kluge and E.E. Zabrodin: Phase Transition Dynamics in Ultrarelativistic Heavy Ion Collision
KFKI-1992-36/K	É. Beleznay, M. Osvay: Long term clearence of accidentally inhaled Co-60 aerosols in humans
KFKI-1992-37/G	P. Pellionisz: Decision-making for acoustic emission data set

Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Gadó János
Szakmai lektor: Horányi Sándor
Nyelvi lektor: Horányi Sándor
Példányszám: 148
Készült a PROSPERITÁS Kft. nyomdaüzemében
Budapest, 1992. december hó