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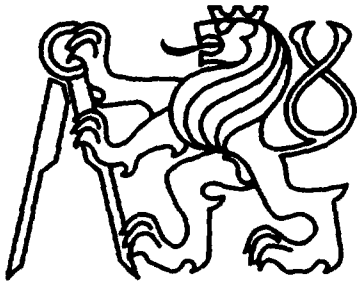

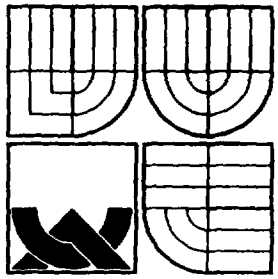

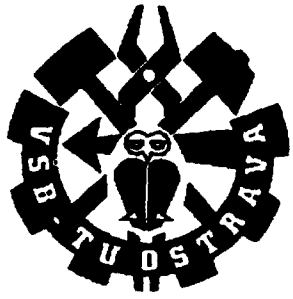

WORKSHOP 97

PRAGUE, JANUARY 20–22, 1997

PART I.

Mathematics – Physics – Chemistry – Engineering Informatics and Cybernetics – Computers

These are the Proceedings of the Sixth Annual university-wide seminar WORKSHOP 97 which will take place at the Czech Technical University in Prague from 20–22 January, 1997.

The aim of the seminar is to present and discuss the latest results obtained by researchers especially at the Czech Technical University in Prague, Technical University in Brno, VŠB – Technical University Ostrava and at collaborating institutions.

The organizing committee has selected a total of 598 contributions divided into 22 different areas of interest.

Part I has contributions in the areas of:

- mathematics
- physics
- chemistry
- engineering informatics and cybernetics
- computers

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CONTENTS

1. MATHEMATICS

MODELLING OF FLOWS OF VISCOUS FLUID IN POROUS MEDIA AND FICTITIOUS DOMAIN METHOD 17
S. Kračmar

ALMOST PERIODIC FREE VIBRATIONS OF A CIRCULAR PLATE 19
L. Herrmann

STABILITY OF SOLUTIONS TO THE NAVIER-STOKES EQUATIONS WITH MIXED BOUNDARY CONDITIONS 21
J. Neustupa

THE STEADY NAVIER-STOKES EQUATIONS WITH THE MIXED BOUNDARY CONDITIONS 23
P. Kučera

STRUCTURE OF SOLUTIONS FOR ONE DIFFERENTIAL EQUATION WITH DELAY 25
J. Diblík

SINGULAR IMPLICIT SYSTEM OF INTEGRO-DIFFERENTIAL EQUATIONS DEPENDING ON A PARAMETER 27
Z. Šmarda

SOLUTION OF THE KIESSL MODEL AND ITS APPROXIMATION 29
J. Dalík, J. Daněček, S. Šťastník, J. Vala

COMPOSITE SCHEMES FOR CONSERVATION LAWS 31
R. Liska, B. Wendroff

ON TOPOLOGICAL ENTROPY OF INTERVAL MAPS 33
J. Bobok

PARAMETER ACCURACY IN KINEMATIC PROCESSING OF SHORT GPS DATA SPANS 35
L. Mervart

BASIS STABILITY OF AN INTERVAL LINEAR PROGRAMMING PROBLEM 37
J. Koníčková

TECHNICAL INITIAL PROBLEMS AND THEIR NUMERICAL SOLUTIONS 39
K. Mikulášek

CARDINAL CHARACTERISTICS OF ORDERED SETS, DISTINGUISHING SUBSETS ON LATTICES, AND n-ARY ORDERED SETS 41
J. Karásek, V. Novák, J. Šlapal, J. Zapletal

COMPUTER ALGEBRA SYSTEMS (CAS) IN EDUCATION 43
A. Němeček

AN ANALYSIS OF METHODS FOR SOLVING THE INVERSE PROBLEMS OF MOISTURE TRANSPORT IN POROUS MATERIALS 45
R. Černý, P. Semerák

STATISTICAL PROCESS CONTROL WITH MATLAB 47
D. Jarušková

COMPUTER ALGEBRAIC SYSTEMS IN TEACHING MATHEMATICS AT TECHNICAL UNIVERSITY 49
Č. Zlatník, V. Beneš

2. PHYSICS

WHY HAS MAXWELL'S DEMON SURVIVED FOR 130 YEARS? 53
J. Jelen

RIGOROUS MODELS OF INTEGRABLE AND CHAOTIC QUANTUM SYSTEMS 55
Č. Burdík, G. Chadzitaskos, J. Dittrich, P. Exner, M. Havlíček, L. Hlavatý, E. Pelantová, P. Šeba, P. Šťovíček, M. Tater, J. Tolar, M. Znojil

ANALYTIC SOLUTION OF THE VLASOV EQUATION IN THE FIELD OF STRONG ELECTRO-MAGNETIC WAVE (CASE OF AN OBLIQUE INCIDENCE) 57
M. Kálal

TEACHING MODERN PHYSICS USING COMPUTERS: A COMPLEX APPROACH 59
L. Drška

EXPERIMENTAL INVESTIGATION OF CONVECTION HEAT LOSSES IN BOX-TYPE SOLAR COOKER 61
M. Ramadan, S. Aboul-Enein, A. Ibrahim, Z. Chobola

NON-DESTRUCTIVE TESTING OF SOLAR CELLS 63
Z. Chobola, V. Juránková, A. Ibrahim

NON-DESTRUCTIVE TESTING OF CONTACTS ON GaAs SUBSTRATES 65
Z. Chobola

NOISE AND DLTS IN LED'S 67
Z. Chobola, V. Juránková

NOISE AS A DIAGNOSTIC TOOL FOR THE RELIABILITY IMPROVEMENT OF MICROELECTRONICS COMPONENTS 69
J. Šikula, B. Koktavý, P. Hruška, P. Koktavý, P. Vašina

TRANSPORT AND FLUCTUATION PHENOMENA IN METAL-INSULATOR-METAL (M-I-M) STRUCTURES 71
J. Šikula, P. Schauer, B. Koktavý

RELIABILITY PREDICTION OF RELANEX ELECTRICAL INSULATION FOR LARGE ROTATING MACHINES 73
S. Vymlátil

AN IMPROVED TYPE OF ULTRASONIC TRANSDUCER FOR IDENTIFYING AND PINPOINTING POWER EQUIPMENT DEFECTS BY ULTRASOUND 75
K. Malinský

INDICATION OF PARTIAL DISCHARGES IN INSULATORS USING THE ACOUSTIC EMISSION METHOD 77
M. Kořenská, L. Pazdera, Z. Weber

SUPERCONDUCTING MAGNETIC BEARING FOR HIGH-SPEED ENGINES 79
J. Vlček, J. Novák, V. Papež, J. Kuba, I. Galaš, P. Schustr, M. Vinš, L. Trubač

STRUCTURE PROPERTIES OF Y-Ca-Ba-Cu-O SYSTEM BY NEUTRON DIFFRACTION 81
S. Vratislav, M. Dlouhá, Z. Jirák

LUMINESCENCE SPECTROSCOPY OF COPPER-DOPED PLZT CERAMICS 83
Z. Bryknar, Z. Potůček, H.-J. Schulz

MOLECULAR TIME-RESOLVED FLUORESCENCE SPECTROSCOPY 85
V. Fidler, P. Kapusta, M. Vrbová, M. Hof, K. Yoshihara

USE OF AE TO STUDY OF THE EFFECT OF CONGELATION ON THE STRENGTH OF TIMBER 87
M. Kořenská, L. Pazdera, Z. Weber

ON THE EFFECT OF TIMBER HUMIDITY ON THE AE GENERATION IN LOW TEMPERATURE STRESSING MODE 89
M. Kořenská, L. Pazdera, Z. Weber

ACTIVE CONTROL OF SOUND IN WAVE-GUIDE 91
O. Jiříček, P. Koníček

NARROW BAND IMPLEMENTATION OF ANC IN DUCT 93
P. Koníček, O. Jiříček

WAVE UNCERTAINTIES IN REVERBERANT MEASUREMENTS 95
Z. Kyncl

STRONG ASSYMETRY X-RAY SOURCE IN CARBON FIBRE MAGNETIC PINCH 97
P. Kubeš, J. Kravárik, M. Paduch, K. Tomaszewski, P. Gogolewski

PRESENT STATE OF THE Z-PINCH EQUILIBRIUM CALCULATIONS 99
M. Žáček, J. Koller, P. Kulhánek

HYDRODYNAMICS SIMULATIONS OF SHORT-PULSE LASER–TARGET INTERACTIONS 101
J. Limpouch, L. Drška

METHOD OF ULTRA HIGH-SPEED PHENOMENA REGISTRATION IN PLASMA 103
J. Píchal

MONITORING OF REMANENT RADIATION FIELDS AT HIGH-ENERGY MEDICAL LINEAR ACCELERATORS 105
J. Sabol, L. Frencl, E. Khalifa

PHOTON RADIATION AND RADON LEVELS AT THE MICROTRON LABORATORY 107
J. Sabol, M. Vognar

CURRENT RESEARCH ACTIVITIES IN NUCLEAR PHYSICS GROUP OF DEPARTMENT OF PHYSICS FNSPE CTU PRAGUE 109
S. Pospíšil, J. Jakůbek, Z. Janout, J. Koníček, J. Kubašta, V. Linhart, I. Štekl

THE FITTINGS OF THE NEUTRON DETECTOR AT PSI (PAUL SCHERRER INSTITUT), SWITZERLAND 111
M. Laub, J. Zicha, J. Bernard

VAPOUR-LIQUID EQUILIBRIA OF ALTERNATIVE REFRIGERANTS 113
R. Budinský, V. Vacek, M. Lísal

ESTIMATION OF THEORETICAL STRENGTH ON THE BASIS OF LMTO METHOD 115
P. Šandera, J. Pokluda, L. G. Wang, M. Šob

ION BEAM THIN FILM DEPOSITION, SURFACE AND THIN FILM ANALYSIS .. 117
T. Šikola, J. Spousta, J. Zlámal, S. Průša, F. Lopour, R. Kalousek, M. Tříska, P. Tichopádek, T. Krejzlík, A. Nebojsa, B. Lencová

DEVELOPMENT OF SFM TECHNIQUE - ANALYSIS OF THE TIP-SURFACE INTERACTION 119
R. Kalousek, T. Šikola, F. Lopour, L. Tůma

THERMOPHYSICAL PROPERTIES OF NONMETALLIC SOLIDS 121
L. Vozár, T. Šrámková, S. Horváth, I. Štubňa

EVALUATION OF ATTEMPT-TO-ESCAPE FREQUENCY FROM TIME RELAXATION OF CONDUCTIVITY IN AMORPHOUS SILICON 123
V. Čech, F. Schauer

IMPLEMENTATION OF METHOD LISA: APPLICATION TO WAVE PROPAGATION IN 2D SYSTEMS 125
P. P. Delsanto, L. Drška, R. Liska, M. Šiňor

USING INTEGRATED COMPUTING SYSTEMS AND COURSEWARE PACKAGES IN PHYSICS TEACHING 127
L. Drška, R. Liska, M. Šiňor

RELAXATION PHENOMENA IN RELANEX CONTAINING VARIOUS IMPREGNANTS 129
H. Navarová, F. Matějka, Z. Chobola

A STUDY OF TRANSPORT CHARACTERISTIC TEMPERATURE DEPENDENCE FOR RELANEX 131
V. Juránková, H. Navarová, Z. Chobola

NON-DESTRUCTIVE TESTING OF RELANEX INSULATING FOILS 133
H. Navarová, V. Juránková, Z. Chobola

RANDOM CURRENT IMPULSES IN HIGH-TENSION BUSHINGS 135
Z. Chobola, V. Juránková

ACOUSTIC EMISSION AS A NON-DESTRUCTIVE TOOL OF STUDY OF CRACK GROWTH IN STRESSED MATERIALS 137
L. Pazdera

ACOUSTIC EMISSION FROM THERMAL LOADED ISOLATING BUILDING MATERIALS 139
M. Kořenská, L. Pazdera, Z. Weber

THE ONSAGER–CASIMIR RECIPROCAL RELATIONS IN EXTENDED IRREVERSIBLE THERMODYNAMICS (Application to electric conduction) 141
M. Kheilová, M. Štrunc

3. CHEMISTRY

AB INITIO CALCULATIONS OF MOLECULAR PROPERTIES WITH THE INCLUSION OF ELECTRON CORRELATION 145
Š. Sklenák, Ľ. Lapčík, Jr.

STRUCTURE OPTIMIZATION OF AMPHOLYTIC pI STANDARDS 147
Z. Friedl, K. Šlais

THEORETICAL STUDY OF HYALURONIC ACID MONOMER UNIT 149
J. Vala, P. Pelikán, M. Straka

ISOCHORES OF XENON BETWEEN 295 AND 360 K FOR VOLUMES 65 TO 115 CCM/MOL 151
Č. Šimáně, M. Vognar, D. Chvátil

THE STUDY OF PYROLYSIS PRODUCTS OF SORBENTS BASED ON SOUTH MORAVIAN LIGNITES 153
P. Voznica, Z. Šimek

DEGRADATION OF ORGANIC COMPLEXANTS USING PHOTO-OXIDATION PROCESSES 155
E. Danačíková, J. John, F. Šebesta, E. W. Hooper

THE STUDY OF PHOTOCATALYTIC DECOMPOSITION OF SURFACTANTS IN WATER SOLUTION 157
M. Veselý, P. Voznica, Z. Šimek, J. Toužín

ELECTRON BEAM DECHLORINATION OF PCBs IN ALKALINE 2-PROPANOL SOLUTION 159
V. Múčka, R. Silber, M. Kropáček, M. Pospíšil, V. Kliský

THE METHODOLOGY IMPROVEMENTS OF EVALUATION OF BATCH REACTOR SORPTION EXPERIMENTS (URANYL SOLUTIONS - SOIL) 161
D. Vopálka, M. Kynclová, K. Štamberg

INPUT-OUTPUT ANALYSIS AND ADAPTIVE PREDICTIVE CONTROL OF TUBULAR CHEMICAL REACTOR 163
P. Dostál, M. Fikar, R. Prokop, Z. Prokopová

MONITORING OF HIGH PRESSURE RF PLASMA REACTOR CONDITIONS 165
O. Salyk, P. Beneš, P. Pivoňka

OPTIMIZATION OF CONTROLLED FERMENTATION PROCESS WITH INJECTATION OF SELECTIONED MICROORGANIZMS 167
M. Drdák, E. Hybenová, M. Veselá

DECARBONIZATION OF ELECTROLYTES FROM ALKALINE ACCUMULATORS 169
M. Pekař, M. Cenek

CHARACTERIZATION OF SURFACE OF MICROPARTICULATE MATERIALS 171
Z. Šimek, R. Vespalec, P. Voznica

STUDY OF BIOLOGICAL EFFICIENCY OF AGROFELTILIZER SYSTEM ON SOUTH-MORAVIAN LIGNITE BASES 173
Z. Cihlářová, L. Lapčík, M. Smatanová

MODELING THE EMISSION OF PHEROMONES - I. EVAPORATION FROM AN OPEN CAPILLARY TUBE 175
J. Hrnčiřík, B. Koutek

4. ENGINEERING INFORMATICS & CYBERNETICS

AUTOMATIC TEMPLATE GENERATION FOR IMAGE RECOGNITION 179
V. Líbal, P. Zahradník, M. Vlček

IMPLEMENTATION OF OPTIMAL LOOSLESS COMPRESSION OF BINARY IMAGES 181
J. Müller, V. Hlaváč

SOFTWARE FOR P1394 DIGITAL CAMERA 183
V. Smutný, J. Klaus

BEAUTY — THE LANGUAGE FOR PARALLEL PROGRAMMING 185
P. Přikryl

SOME EXTENSIONS OF THE OBJECT-ORIENTED DATABASE MODEL 187
T. Hruška

EXTENDED QUERY LANGUAGE FOR MEASURED DATA 189
M. Beneš

MATHEMATICAL METHODS OF PROJECT MANAGEMENT 191
J. Klapka, P. Ošmera

PRODUCTION SYSTEM PROJECT OPTIMIZATION 193
J. Dvořák, J. Klapka

MODELS FOR RESOURCE- -CONSTRAINED SCHEDULING 195
M. Šeda, J. Klapka

KNOWLEDGE-BASED SUPPORT FOR STRUCTURAL DESIGN 197
F. Wald, J. Pertold, M. Pultar, M. Holický, M. Říhová

ADVANCED SOFTWARE FOR RUR - REALLY USEFUL ROBOTS 199
P. Nahodil, M. Gruncl, J. Kurzveil, V. Maixner

AGGREGATION METHOD IN NONLINEAR CONTROL 201
A. Víteček

SIMPLE DIGITAL AND ANALOG CONTROLLER TUNING 203
M. Vítečková

THEORY OF OPTIMAL CONTROL EXTENDED FOR SYSTEMS WITH REDUNDANT COORDINATES 205
M. Valášek, P. Bastl

DISTRIBUTED INDUSTRIAL AUTOMATION SYSTEM 207
V. Vašek, A. Navrátil, P. Kopečný

THE ELECTRO-HYDRAULIC LOAD-SENSING SYSTEM 209
P. Noskievič

ALGORITHM PROCEDURE OF THERMAL PRODUCTION HOT-WATER SYSTEMS OF CENTRALISED SUPPLYING OF HEAT 211
M. Kubalčík, J. Balátě

ROBUST CONTROL OF SISO CONTINUOUS-TIME SYSTEMS 213
R. Prokop, Z. Prokopová, P. Dostál

NEW APPROACHES TO MACHINE TOOLS CONTROL BASED ON PMAC MOTION CONTROLLER 215
F. Vacek

CONTROL SYSTEM BASED ON ALPHA DATA AD66 BOARD 217
T. Pácha

STRUCTURE OF HIERARCHICAL FUZZY LOGIC CONTROLLER 219
T. Kučera

TOOLS FOR VISUALIZATION AND PROCESS CONTROL IN HETEROGENEOUS FIELDBUS SYSTEMS 221
F. Zezulka, M. Hrdlička, M. Hrdlička, R. Poláček

APPROXIMATE IDENTIFICATION OF CONTINUOUS SYSTEM 223
M. Hofreiter

ESTIMATION OF DIFFERENTIAL PARAMETERS ON TRIANGULATED SURFACE 225
P. Krsek, T. Pajdla, V. Hlaváč

NONLINEAR SIGNAL FILTERING BASED ON T–S MODEL 227
P. Horáček, J. Hofreiter

ANISOCHRONIC STATE OBSERVER DESIGN FOR HEREDITARY PROCESS FAULT DETECTION 229
P. Zítek, R. Petrová, D. Garagič

PARALLEL PROCESSING OF IMAGE DATA IN REMOTE SENSING 231
M. Jeřábek

COMMUNICATION ASPECTS OF PARALLEL COMPUTING 233
Z. Hanzálek

BACKWARD ERROR RECOVERY IN PETRI NETS 235
R. Szturc, J. Vosyka

INFORMATION SYSTEM BASED ON EXCHANGE 237
M. Vichta

SIMULATION OF INTERDISCIPLINARY SYSTEMS VIA INTERNET 239
H. Mann, L. Waldmann

RECONFIGURATION IN A HETEROGENEOUS MULTIAGENT SYSTEM 241
T. Hazdra

KNOWLEDGE BASED SYSTEM FOR HYPERMEDIA APPLICATIONS 243
T. Vlček, L. Lhotská, Z. Kouba, L. Přeučil

GATE OFF COMPLEXITY – ARTIFICIAL INTELLIGENCE OR ARTIFICIAL LIFE 245
J. Bíla, I. Jelínek

TOOLBOX FOR POLYNOMIAL AND RATIONAL MATRICES 247
P. Hušek, J. Štecha

COMPUTER BASED ANALYZER OF THE PLASTIC MATERIALS 249
T. Sysala, V. Vašek, Z. Navrátil

PROCESSING OF ACOUSTIC EMISSION DATA 251
D. Kolář, P. Mazal

INTERACTIVE TECHNOLOGIES IN THE REAL ESTATE CADASTRE OF THE CZECH REPUBLIC 253
P. Soukup, R. Zimová

RESEARCH AND EDUCATIONAL LABORATORY AT KART 255
P. Neumann, V. Vašek

ASSIGNED POLES AND LQ-OPTIMAL TRACKING 257
V. Soukup

A BADLY CALIBRATED CAMERA IN EGO-MOTION ANALYSIS, AN ERROR PROPAGATION 259
T. Svoboda, P. Sturm

RECOVERY OF CAMERA POSITION AND ORIENTATION FOR IMAGE SYNTHESIS FROM THREE FRAMES 261
M. Urban, T. Pajdla, T. Werner, V. Hlaváč

PROGRAM AID OF SIMULATION OF DYNAMIC SYSTEMS 263
R. Farana

DISTRIBUTED MEASUREMENT AND CONTROL SYSTEMS WITH SMART SENSORS 265
L. Smutný

FUZZY CONTROL OF THE ELECTRICAL FURNACE 267
P. Jura

AN ESTIMATION OF THE SYSTEM PARAMETERS USING ALTERNATIVE MODELS 269
P. Dopita, J. Štecha

BACKGROUND KNOWLEDGE IN MACHINE LEARNING METHODS 271
J. Klema, J. Kubalík, Š. Lauryn

ACTIVE SUSPENSION CONTROLLER DESIGN 273
A. Stříbrský, K. Hyniová, M. Hlinovský

5. COMPUTERS

NEW APPROACHES TO SEQUENTIAL STRONG LR(1) PARSING 277
B. Melichar, P. Šaloun

CLASSIFICATION OF PATTERN MATCHING PROBLEMS 279
B. Melichar

SPACE COMPLEXITY OF APPROXIMATE STRING MATCHING BY FINITE AUTOMATA 281
J. Holub

EMBEDDING OF K-ARY COMPLETE TREES INTO 2-DIMENSIONAL MESHES 283
J. Trdlička, P. Tvrdík

SCALABILITY OF DE BRUIJN NETWORKS 285
P. Tvrdík

PARALLEL MERGE SORT ON SHARED MEMORY MULTICOMPUTER 287
V. Havran, P. Šimek, M. Šoch, P. Tvrdík

RECONFIGURABLE CO-PROCESSOR 289
M. Novotný

EYE – THE NAVIGATION AND TRAINING SYSTEM FOR BLIND 291
R. Berka, M. Novotný, V. Píč, P. Slavík

THE GROWTH DIRECTION IN VIRTUAL PLANTS SIMULATION 293
B. Beneš

CONTROL OF LOSSY COMPRESSION OF THREE-DIMENSIONAL DATA 295
P. Diblík, P. Slavík

EXPERIMENTAL MULTIMEDIA AND HYPERMEDIA SYSTEM EMHS 2.0 297
P. Hollay, I. Jelínek

TERRAIN EROSION MODEL BASED ON REWRITING MATRICIES 299
I. Marák, B. Beneš, P. Slavík

SHIFT-ADD NEURON ON STANDARD CELLS 301
M. Skrbek

PARALLEL IMPLEMENTATION OF THE GMDH NEURAL NETWORK 303
P. Náplava, M. Šnorek

GENERALIZED FINGERPRINT 305
M. Šnorek

BINARY NEURAL NETWORKS 307
T. Macek

STUDENT SUCCESS PREDICTION BY MEANS OF NEURAL NETS 309
T. Macek

PERFORMANCE COMPARISON OF RPC COMMUNICATION PROTOCOLS 311
J. Kubr, J. Janeček

ROUTING IN ATM NETWORKS USING PNNI 1.0 313
M. Červený, A. Dryák

GLOBAL MODEL OF FPGA LAYOUT ENVIRONMENT 315
Z. Muzikář, M. Servít

STRATEGIES FOR IN-SERVICE TEACHERS EDUCATION IN TELEMATICS 317
B. Mannová, K. Vosátka

ONE-PASS FORMAL TRANSLATION DIRECTED BY LR PARSING 319
J. Janoušek

PARALLEL RAY-TRACER ON SHARED MEMORY MULTIPROCESSOR MACHINES CONNECTED VIA INTERNET 321
V. Havran

RASTER IMAGE OUTPUT FOR BLIND USERS 323
L. Mikšíček

GLOBAL VISIBILITY 325
M. Trefný, J. Bittner

PARTICLE-SYSTEM BASED SUPPORT FOR BEHAVIORAL ANIMATION 327
M. Brachtl

IMPROVEMENT OF TRAINING OF THE NEOCOGNITRON NEURAL NETWORK 329
M. Steuer, L. Rothkrantz, M. Šnorek

MODIFICATION OF RM CELL IN ABR SERVICE 331
J. Filip

ON THE PERFORMANCE AND TUNING OF THE UNIX OPERATING SYSTEM 333
V. Bahyl, P. Dufek, J. Zajíc, P. Zemánek

STANDARD TYPES OF FORMS WHICH ARE NOT SUPPORTED BY FORMS GENERATOR OF ORACLE CASE DICTIONARY 335
M. Valenta

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ANALYTIC SOLUTION OF THE VLASOV EQUATION IN THE FIELD OF STRONG ELECTRO-MAGNETIC WAVE (CASE OF AN OBLIQUE INCIDENCE)

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Key words: Vlasov equation, electron distribution function

In order to achieve a controlled thermonuclear reaction large-amplitude high-frequency monochromatic electro-magnetic waves are launched into plasmas both in laser-pellet experiments and rf-heating in tokamaks. Spatial modulation of amplitudes of these waves is crucial in changing the plasma equilibrium. In many problems of interest, the collisionless regime is appropriate and so the Vlasov equation can be used to determine the electron distribution function.

One particular method of solving the Vlasov equation under such conditions was proposed and successfully applied to the simplest case of the plasma wave [1]. That was followed by the case of the electro-magnetic wave with electric and magnetic vectors of this wave *perpendicular* to the plasma density gradient [2].

In this paper one even more general analytic solution of the Vlasov equation is presented. This time for the case of the electro-magnetic wave under an *oblique incidence* to the plasma gradient (with magnetic vector perpendicular to the plasma density gradient). As in both previous cases we assume the phase velocity being appreciably higher than the electron thermal velocity (the case of non-resonant diffusion). The ambipolar potential is taken into account and the form of the electron distribution function at the boundary need not be Maxwellian.

The Vlasov equation relevant to our case can be written in the form

$$\frac{\partial f}{\partial t} + v_x \nabla f + \frac{e}{m_e} \nabla \varphi \frac{\partial f}{\partial v_x} - \frac{e}{m_e} \mathsf{A} f = 0 \tag{1}$$

with the following boundary conditions:

$$\mathsf{A}(0,t) = 0; \quad \varphi(0) = 0; \quad f(0, v_x, v_y, t) = f_0^{(0)}(v_x, v_y). \tag{2}$$

Here e and m_e are the electron charge and mass; $\varphi(x)$ is the ambipolar potential; $\mathsf{A}(x,t)$ is the differential operator in velocity space defined as follows:

$$\mathsf{A} = \mathsf{A}(x,t) = E_x(x,t)\frac{\partial}{\partial v_x} + E_y(x,t)\frac{\partial}{\partial v_y} + B_z(x,t)\left(v_y \frac{\partial}{\partial v_x} - v_x \frac{\partial}{\partial v_y}\right), \tag{3}$$

where $E_x(x,t)$, $E_y(x,t)$ and $B_z(x,t)$ are the electric and magnetic field components of the high-frequency monochromatic electro-magnetic wave with the angular frequency ω; ∇ denotes $\frac{\partial}{\partial x}$.

Using the same algorithm as described in Ref. 1 we arrive to the following system of recurrent relations:

$$v_x \nabla f_0^{(2n)} = \frac{e}{m_e}\left[-\nabla\varphi \frac{\partial f_0^{(2n-2)}}{\partial v_x} + \mathsf{A}(x) f_1^{(2n-1)*} + \mathsf{A}^*(x) f_1^{(2n-1)}\right], \tag{4}$$

$$f_n^{(n)} = \frac{ie}{nm_e\omega}\left(1 - \frac{iv_x\nabla}{n\omega}\right)\mathsf{A}(x) f_{n-1}^{(n-1)}, \tag{5}$$

$$f_m^{(n)} = \frac{ie}{mm_e\omega}\left(1 - \frac{iv_x\nabla}{m\omega}\right)\left[-\nabla\varphi \frac{\partial f_m^{(n-2)}}{\partial v_x} + \mathsf{A}(x) f_{m-1}^{(n-1)} + \mathsf{A}^*(x) f_{m+1}^{(n-1)}\right], \tag{6}$$

where $n \geq 1$, $m = n - 2k \geq 1$, $k \geq 1$.

Since $f_0^{(2n-1)} = 0$, $n \geq 1$, what we need to determine is a general formula for the term $f_0^{(2n)}$. This was found to fit the form

$$f_0^{(2n)} = \sum_{l=0}^{n}\sum_{k=0}^{l} \frac{1}{(k!)^2}\left(\frac{\psi}{2}\right)^k \frac{\partial^{2k}}{\partial w_{\mathsf{E}}^{2k}} \frac{(-\psi\mathsf{M})^{(l-k)}}{(l-k)!} \frac{(\phi\mathsf{M})^{(n-l)}}{(n-l)!} f_0^{(0)}. \tag{7}$$

All new quantities introduces in this formula are the same as in Ref. 2 with the exception of E which denotes a unit vector in the direction of the electric field.

Eventually the function f_0 can be found in the form

$$f_0 = \mathsf{L} f_0^{(0)}, \tag{8}$$

where L is the differential operator in velocity space which can be expressed formally as

$$\mathsf{L} = J_0\left(i\sqrt{2\psi}\frac{\partial}{\partial w_{\mathsf{E}}}\right) e^{(\phi-\psi)\mathsf{M}} \tag{9}$$

and J_0 is a zero-order Bessel function. Slow time dependence of the function f_0 may be incorporated using the slow time dependence of the ponderomotive and ambipolar potentials respectively.

The form of the differential operator L found in this paper is a generalization of our particular results published in Refs. 1 and 2.

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STRUCTURE PROPERTIES OF Y-Ca-Ba-Cu-O SYSTEM BY NEUTRON DIFFRACTION

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Key words: neutron diffraction, crystal structures, superconductors

Among possible cationic substitution in the $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ superconductor, the partial replacement of Y^{2+} by Ca^{2+} has been found to be especially interesting. The heterovalent substitution changes the carrier concentration and may influence the charge transfer from the Cu-O chains to the conducting CuO_2 layers. Early studies have shown that such replacement was limited to about 25 % of yttrium and the critical temperature for the superconductivity in the orthorombic samples ($y \sim 7$) was lowered from 93 K for the calcium free compound to about 78 K for 20 % of calcium [1, 2]. For the latter compound, the superconductivity was detected also for highly reduced tetragonal samples ($y = 6.0 - 6.2$). This suprising behavior was reported firstly for nearly 100% dense ceramics cooled from 950°C by switching of the furnace. The occurrence of superconductivity was ascribed to a surface oxidation of otherwise oxygen-deficient crystal grains. However, the superconductivity at temperatures as high as 44 K was subsequently observed on assumedly homogenious samples with 20 % of Ca, prepared under reducing conditions and quickly quenched [3]. In order to investigate complexly the hole doping and the interlayer charge transfer also in the calcium substituted systems, we have undertaken simiultaneous structural (X-ray and neutron diffraction), transport (electrical resistivity, thermoelectric power, Hall effect) and magnetic (AC susceptibility) studies on the $Y_{0.8}Ca_{0.2}Ba_2C_3O_y$ ceramics within the whole accesible range of y.

One of the important findings og the neutron diffraction performed on the $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ system is the linear increase of the c lattice parameter with decreasing oxygen convent y. Similar behavior was reported for $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ by Jorgensen et al. [4] and Cava et al. [5]. The comparison of our results with [4, 5] suggested that in the whole region of the oxygen content the c parameter is shortened due to the Ca substitution roughly to about 0.0035 nm. They refer, however, to the helium temperature so that the comparison is not strightforward. The structure of the $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ type consists of a sequence of atomic layers which play different roles in the carrier doping and charge transfer. Two copper cations per formula unit occupy sites Cu2 in the CuO_2 planes, considered as the main conducting part of the superconductor, and one copper cation occupies the Cu1 site in the CuO_δ plane of variable oxygen content ($\delta = 7 - y$). In the orthorhombic region (y=7-6.4 for $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$) the oxygen atoms in the CuO_δ plane are located preferentially in sites [0 1/2 0] and form characteristic Cu-O chains along the b-direction. The occupation of alternative sites [1/2 0 0]. is generally very small [4]. For lower y values the structure

is macroscopically tetragonal because the oxygen atoms are distributed equally over the [0 1/2 0] and [1/2 0 0] sites or, for y=6 are eventually absent.

The $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ samples with a large range of oxygen content $y = 6.89 - 6.03$ have been prepared under reducing or oxidizing conditions and were equilibrated at 460°C. Their complex study has shown that the superconductivity occurs for $y \geq 6.4$. The investigation of the structure, electric transport and diamagnetism in $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ evidenced the important role of the oxygen ordering in the CuO_δ planes for the superconductivity. In contrary to the two superconducting plateaux found for $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ with $Tc = 90$ and 60 K, three-plateau behavior was observed and was identified with crystallographically different phases in the present system. First two plateaux correspond to phases with Tc of 80 K ($6.89 > y > 6.75$) and 50 K ($6.75 > y > 6.50$) and are associated with the Ortho I and II structures, characterized with infinite Cu-O chains. The third plateau corresponds to macroscopically tetragonal phase with $Tc = 25$ K ($6.50 > y > 6.40$) and is possibly associated with formation of the Cu-O-Cu dimers [6]. Moreover, each phase exhibits a distinct value of the room-temperature thermopower coefficient which is preserved over the respective regions. All the superconducting phases in $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_y$ exhibit sharp magnetic trnsitions with nearly complete diamagnetism at low temperatures and a metallic-like electric conductivity in the normal state. The situation is dramatically changed at the transition to the nonsuperconducting region below $y = 6.4$ where a sudden localization of carriers is observed.

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STRONG ASSYMETRY X-RAY SOURCE IN CARBON FIBRE MAGNETIC PINCH

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Key words: X-ray emission, magnetic pinches, plasma diagnostics

In this paper the results of complex visualisation and X-ray diagnostics of the carbon fiber load located between the copper electrodes of the small $500J$ energy pinch devices are presented. The population inversion driven by Z-pinch was demonstrated in [1]. A great step in evolution of magnetic pinch lasing was made by capillary discharge [2]. In [3] the amplified spontaneous emission of the CVI 18.22 nm for electron density $10^{25}\,m^{-3}$ and temperature 10 eV was observed.

The carbon fiber with the diameter 6 μm was placed between top of copper electrodes. The strong asymmetry soft-X-ray source radiated along the axial direction is hundert times more intensive than along the radial direction. The emitted plasma was studied by schlieren photography and Wollaston prism interferometry, by fast silikon p-i-n diode, by Quadro camera with 1 ns exposure and 10 ns delay between snaps, by method of grazing impact reflection and by thin Al foil absorption of the radiation for wavelength determination.

The soft-X-ray pulse is emitted during interval (100–400) ns after breakdown at the current of (3–12) kA. FWHM of this pulse is (10–30) ns. The energy detected by the p-i-n diode having the sensitive plate of 1 mm^2 in distavce 25 cm is 10^{-8} J.

The pulse emission was completely absorbed by the 200 μm plate of Si glass and/or by 1.5 μm Al foil. The insertion of 0.75 μm Al foil decreases the intensity of the pulse till 5 percentage and this value correspondes to the absorption of (17–20) nm wavelength window of AL L series. The upper boundary of this interval was limited by using of the grazing impact reflection method up to 20 nm.

From schlieren pictures the mean diameter (100–200) μm of the plasma column is without great variations during the time (100–500) ns after breakdown. The boundary of the column is sharply bordered and the inside electron density before, during and after the soft-X-ray pulse was estimated as $(10^{24} - 10^{25})\,m^{-3}$.

In the schlieren pictures exposed before the X-pulse emission the helical tube with few threads have been seing with the pitch and diameter 100 μm. At the time of the increase of the X-pulse intensity the visible radiation of the plasma increases and radiate diameter increases to (400-700) μm with typical radial $3\cdot10^4$ m/s and axial velocity $(1--1.7)\cdot10^5$ m/s. During the X-pulse emission at Quadro camera diagnostics the structure like helical ribbon of the discharge channel was observed with 2–3 threads, (400–700) μm diameter and length (2–3) mm (Fig.). The decrease of X-pulse intensity is in correlation with the decrease of the intensity of the visible radiation and after emission the stable narrow channel - diameter (100–200) μm - is formed again.

The stable form of plasma channel can be probably explained via magnetic pressure confinement and via current filaments with high conductivity.

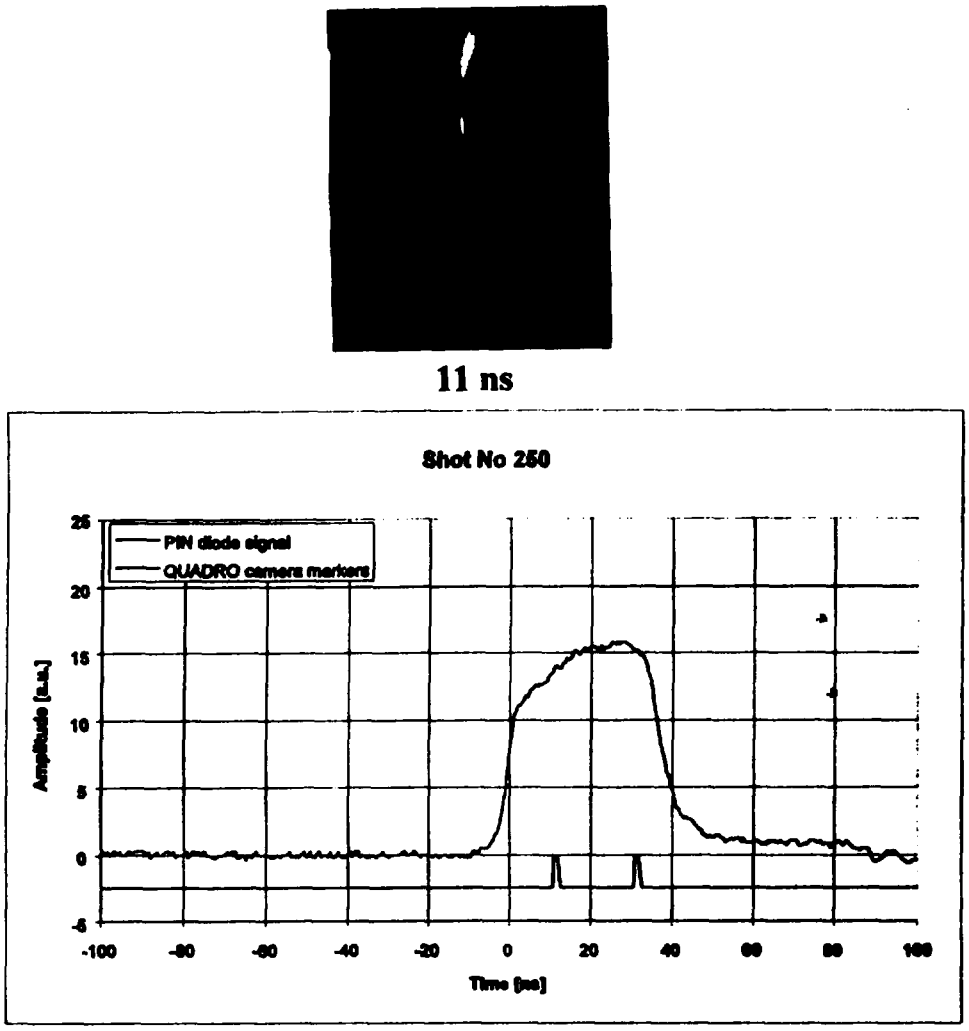

Fig. 1: Shot No. 250. Quadro camera record in spectral window 596 nm. Helical ribbon form of the plasma column 11 ns after increase of the laser pulse intensity.

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PRESENT STATE OF THE Z-PINCH EQUILIBRIUM CALCULATIONS

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Key words: plasma equilibrium, *z* pinch, plasma radiation

First equilibrium calculations of the *z* pinch equilibrium were made by Bennett in 1934 [1]. Bennett had found the equilibrium pressure dependence on the *z* pinch radius for uniform current density distribution and constant temperature. The wellknown Bennett equilibrium relation between total current and plasma concentration is suitable for first order estimations of the z pinch behaviour.

Pease and Braginski solved in 1957 the energy equilibrium between Joule heating and radiation cooling of the pinch [2,3]. A very interesting phenomenon arised from the calculations: If the total current overflows approximatelly 1 MA, the uncontrolled electromagnetic collapse of the pinch can occure.

There were many other attempts to solve the equilibrium problem. In classical *z* pinch, the concentration, current density, magnetic field, temperature and pressure must be determined. Our first attempts assumed the power dependence of the current density on the radius of the *z* pinch and the basic set of the equilibrium equations: The Lorentz force balanced by the pressure gradient, Ampere law and the equation of state. The calculations had been done both for the classical *z* pinch and for the pinch with azimuthal current and axial magnetic field [4]. The only problem was the undetermined and predefined current density.

If the Ohm law and energy balance equation with radiation cooling are introduced in the model, a selfconsistent set of equations arises for the classical pinch without axial current [5]:

- force equilibrium
- energy equilibrium
- Ampere law
- Ohm law
- equation of the state

The solutions are similar to the Bennett ones, but there are some differences, espetially on the border of the pinch. We have also proved the polytropic behaviour of the *z* pinch. The model was tested for recombination radiation, brehmstrallung and synchrotron radiation.

Unsolved are some problems connected with similar radiation model for the pinch with azimuthal current component and axial magnetic component. The Ohm law seems to have to be modified, the polytropic behaviour cannot be proved (the pinch is probably nonpolytropic) and the number of the functions to be determined overcomes the number of the equations.

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HYDRODYNAMICS SIMULATIONS OF SHORT-PULSE LASER–TARGET INTERACTIONS

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Key words: ultrashort laser pulses, resonance absorption, fast particles, ionic populations, spectral lines, radiation transport

Plasmas produced and heated by intense subpicosecond laser pulses are at present being studied very actively, both experimentally and theoretically. In the previous paper [1] we have presented the basic features of our 1D Lagrangian hydrocode, which has been tailored for description of interactions of subpicosecond laser pulses with solid targets. It includes a detailed description of implemented model of resonance absorption of p-polarized laser radiation and of the model of atomic ionization and excitation kinetics. This paper is devoted to further extensions of our hydrodynamics code in areas, that are important for comparison of the simulation results with experiments.

Two new parts of the code are described here. Firstly, a model of ion acceleration by double-layer mechanism is included. The calculated ion spectra may be compared to spectra recorded by time-of-flight ion spectroscopy. Secondly, a detailed description of the plasma line emission and of the transport of radiation in optical thick spectral lines is coupled to the excitation kinetics in a post-processor to the hydrocode. The results of simulations include brightness, position and shape of spectral lines, that may be detected in high-resolution X-ray spectroscopy [2].

High energy ions and electrons are important part of the physics of short-pulse laser-target interactions. A substantial part of energy of p-polarized laser wave is absorbed by resonance absorption. Laser energy is transformed to an electron plasma wave propagating to the underdense plasma which is in its turn absorbed due to Landau damping by a group of electrons, that are accelerated to suprathermal energies. Fast electrons are then reflected from the plasma-vacuum boundary and a part of their energy is transferred to ions. Fast electrons then penetrate deep into the target, leading to a precursor of the thermal wave and enhance x-ray emission from the target [3].

When reflected from the plasma-vacuum boundary, fast electrons drive the expansion of ions to vacuum by an electrostatic force in a double layer. The calculated distribution of electrons accelerated by resonance absorption is used to obtain fast ion spectrum via modified Gurevich-Mescherkin model [4]. It assumes quasineutrality and the time of fast electron roundtrip in corona small compared to the laser pulse duration. Fast electron distribution in corona is then symmetric in the longitudinal velocity and electron concentration is controlled by the electrostatic potential. As the ion charge varies only slightly in corona of aluminium targets during the main part of laser pulse, we keep Z constant in the model of fast ion spectra to avoid the necessity of using a more complex model for mixtures. The resulting spatial profile of ion density transforms to ion spectra in a simple way.

In our previous simulations, electron states and energies were analyzed in the framework of the SCAAM model. The program RACHEL [5] allows us to find the positions and the approximate shapes of x-ray lines and calculate the relevant opacities for dense plasmas of intermediate and high-Z elements, where the approximation of LTE and the density functional theory are valid. However, the interpretation of spectra of laboratory plasmas often requires models that do not use the LTE approach.

In the new radiation code, projected as a postprocessor to hydrocodes with approximate description of ionization and radiative processes, the spectra of K-shell line emission are calculated together with a self-consistent description of the excitation kinetics. The coupling between ionic populations and radiative transfer in plasma is the major problem to solve in the code.

Various potential approaches have been analyzed. In the implemented model for the simulation of nonequilibrium line transfer, the coupling is carried out by an iterative procedure, where the populations are obtained by linearization while the line transfer is computed within the core saturation approximation and with complete frequency redistribution [6]. The core saturation concept is used, both for the acceleration of convergence and for the description of variation of radiative intensity within each hydrodynamic cell. Voigt line profile is assumed, taking into account natural, pressure and Doppler broadening, macroscopic Doppler shift is taken into account on a Lagrangian hydrodynamic grid.

The code has been tested on the problem of two-level atom in a homogeneous optically thick atmosphere. As the first results, atomic populations and spectra of He-like aluminum ions are presented for conditions of short-pulse laser-target interaction. An extensive atomic database necessary for detailed simulations of line emission is under construction. It considers some recommendation given in [6], but also data from several new sources are available.

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METHOD OF ULTRA HIGH-SPEED PHENOMENA REGISTRATION IN PLASMA

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Key words: plasma, ultra high-speed phenomena, method of registration, photographic image

There are ultra high-speed changes in the structure and electric and physical properties in non-stationary electrical discharges in high-heated dissociated gases. The complex physical model of discharges of this type is not known up to now and, in many cases the use of semi-empirical descriptions based on the experimental results is necessary.

For experimental purposes either obtrusive or non-obtrusive diagnostic methods can be used. As a rule, the high-heated gas regions, in which we usually take measurements are small. With the use of an obtrusive method their structure would be affected and required appropriate physical properties would be changed. For this reason, non-obtrusive methods, must be applied. Optical diagnostic methods are probably the most important non-obtrusive diagnostic methods.

An the important prerequisite for ultra high-speed phenomena mechanism study is the stationarity, or as the case may, be quasi-stationarity of the phenomena during measurement. This requirement means, that the measurement has to be taken in a time interval much shorter than the frequency of the structure change or, at least, in a time interval comparable with it, while no change in the phenomenon instant characteristics is taking place.

Applying optical diagnostics methods, a photograph or a hologram is often taken for registration. When photographic registration or a hologram is used for the study of ultra high-speed effects, the requirement of phenomenon stationarity can lead to fundamental problems. This is due to the fact, that the duration of a measurement also determines the maximum possible exposure time of the photographic layer.

In the case of extremely short exposure times the photographic image is created in another way, as a consequence of the Schwarzschild effect. For the photo-chemical effect of light falling on the photographic emulsion the reciprocity law is no longer valid. The blackening of a photographic emulsion is then not simply proportional to the exposure, i.e. to the product of the illumination and exposure time. Simultaneously, the characteristic curve of density becomes shallower.

These effects become apparent in practice, especially through the contrast reduction in the image, which also reduces its informative value. When evaluating the images it is advisable to make a correction with respect to these effects, if it was not possible to avoid them during chemical processing.

Further relevant misrepresentation or reduction of the informative value of the photograph or hologram can be caused by complex chemical reactions in the course of processing. These changes in the photosensitive layer properties are primarily related to the mechanism

of latent image creation. Improvement of the studied phenomena recording latent image can be achieved only-partially by way of processing, and especially by way of developing.

Both practical tests and the literature confirm, that fine-grain and compensating developers are most suitable ones for chemical processing of materials exposured within ultra short exposure times.

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MONITORING OF REMANENT RADIATION FIELDS AT HIGH-ENERGY MEDICAL LINEAR ACCELERATORS

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Key words: activity, dose equivalent, induced activity, linear accelerator

Induced activity results from photoneutron reactions of high-energy X rays and neutron capture reactions with nuclei of the air nuclei as well as machine parts such as the target holder, the collimator, flattening filter, and other structures which intercept the primary beam. Most of the induced radionuclides are pure β^+ emitters: it is therefore impossible to separate them by gamma spectrometry. These radionuclides with half-lives ranging from a few minutes to several hours are contribute to the exposure of both the patients and the staff operating a medical linear accelerator[1]. Following previous experiments[2], further measurements of dose equivalent rate were carried out in the treatment room and at the operator desk at a 21 MV medical linear accelerator Saturne 2 Plus installed in the Radiotherapy and Oncology Clinic (ROC), Praha - Vinohrady as well as at a 18 MV Saturne 43 accelerator used at the Institute of Radiation Oncology (IRO), Praha - Bulovka. The dose equivalent rate monitor responded to all photons of different origin, i.e., leakage photons, scattered photons and especially photons emitted by radionuclides induced in the structure of the accelerator and in its surrounding. While leakage and scattered radiation are present only during accelerator operation (prompt radiation), photons emitted by induced radionuclides (remanent photons) contribute to the exposure also after the machine stops generating the primary beam. The measurements were carried out by the semicontinuous dose equivalent rate monitor Gamma Tracer[3], which can record the results in one-, ten-, or 60-minute intervals. The monitor uses two energy-compensated GM tubes and sophisticated electronics for processing, evaluation, storage and transfer of data to a computer via an infrared radiation modem. Because the number of radionuclides produced in the air and in the accelerator components is large and accelerator operation is often variable, the build-up and decay of gross gamma activity is a complex function of time, which is reflected by the dose equivalent rate presented as a function of elapsed time.

The photon radiation levels in the treatment room and at the control console (ROC) are shown in Fig. 1. The dose equivalent rate in the accelerator room at various time intervals before and after its operation are given in Fig. 2 (IRO). The contribution due to the formed radionuclides may be significant particularly during the time immediately following the machine stoppage. It can be seen that there is no effect of induced radioactivity on the dose equivalent rate outside the treatment room.

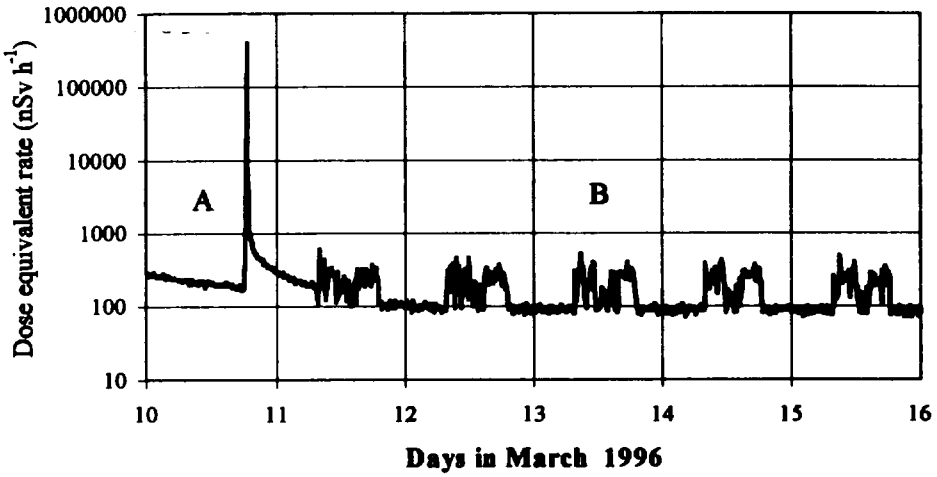

Fig. 1: Photon dose equivalent rate: A - treatment room, B - control desk.

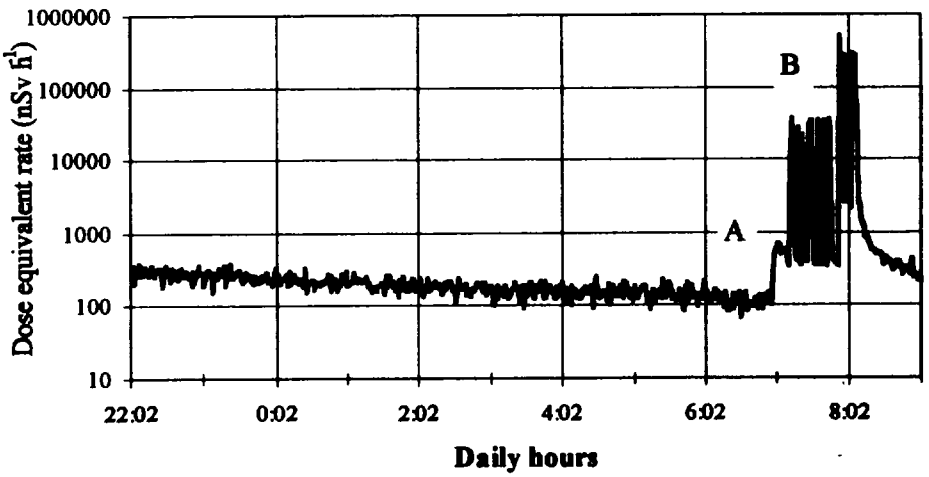

Fig. 2: Time profile of the dose equivalent rate in the treatment (A - 17 hours after the last accelerator operation, B - during a normal operation).

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PHOTON RADIATION AND RADON LEVELS AT THE MICROTRON LABORATORY

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Key words: gamma radiation, microtron, radon concentration, radiation monitoring

The Microtron Laboratory of the Faculty of Nuclear and Physical Engineering is situated inside in Vítkov Hill in a tunnel enclosure inside the hill of about 20 to 30 m below ground level. The location was used previously as a shelter operated by the Civil Defence authorities. In this laboratory, the microtron is the most important radiation source; a 14 MeV neutron generator (Philips PW 5320) and a PuBe neutron source having an emission rate of $5.6 \cdot 10^6\ s^{-1}$ are also employed. The Microtron MT 25 is a circular, chamberless microtron with a vacuum tight magnetic yoke[1]. The Microtron MT 25 can generate electrons with energies ranging from 5 to 24 MeV.

While in previous years the microtron was mainly utilised for gamma activation analyses of ore samples in order to identify the content of gold, at present the principal activities of the Microtron Laboratory are related to the use of the microtron for (a) dosimetric metrology of high energy electron and photon beams, and (b) research and development aimed at the production of ^{123}I from ^{124}Xe using photonuclear reaction (γ, n). Both aspects of this programme are essentially connected with the usage of radiation and radionuclides in medicine. This paper summarises and interprets the results of area monitoring in order to assess the radiation protection characteristics in the laboratory. Dose equivalent rates of external photons were measured using a semicontinuous gamma monitor Gamma Tracer based on two energy compensated GM counters (Genitron Instruments, Frankfurt/M)[2]. The time profiles of the dose equivalent rates are shown in Fig. 1 and Fig. 2. The laboratory background gamma level is normally about 70 nSv h^{-1}, which, due to the considerable soil and rock shielding of the hill against cosmic rays, is notably lower than a typical dose rate inside an average building, which is usually about 110-120 nSv h^{-1}.

Because of the underground position of the Laboratory, the presence of radon is always of main concern. The radon measurements (Alpha Guard monitor simultaneously recording radon concentration, ambient temperature, relative humidity and atmospheric pressure)[2] have shown far higher concentrations than expected. The situation is illustrated in Fig. 3 and Fig. 4, from which one can conclude that radon related exposures represent the most significant contribution to the occupational doses of the microtron operating staff. Taking into account the mean radon concentration of 400 Bq m^{-3}, the equilibrium factor of 0.5, 1500 annual working hours spent in this Laboratory, and the conversion factor[3] of $7.95 \cdot 10^{-6}$ mSv Bq^{-1} m^3 h^{-1}, the resulting occupational effective dose may reach 2.4 mSv y^{-1}, which is more than 20 times higher than the annual effective dose from photon radiation received by the Laboratory personnel during the same working hours.

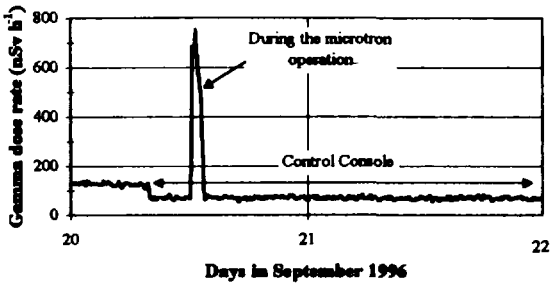

Fig. 1: Dose equivalent rate

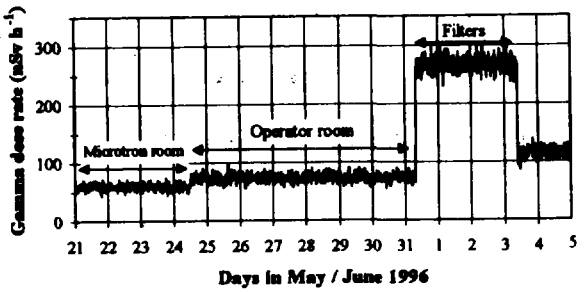

Fig. 2: Dose equivalent rate

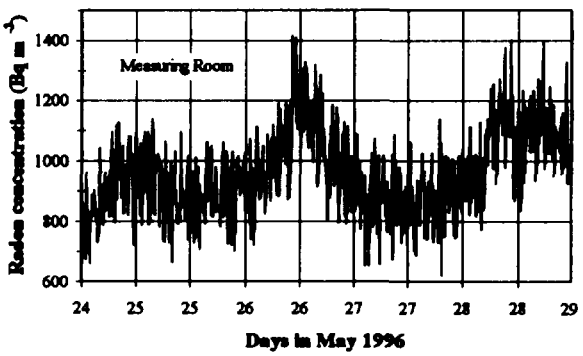

Fig. 3: Radon concentration

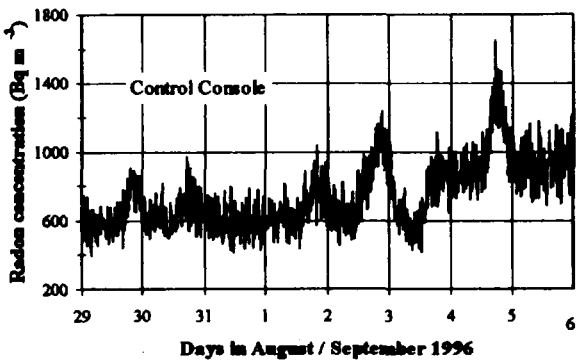

Fig. 4: Radon concentration

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This research has been conducted at the Department of Dosimetry and Application of Ionizing Radiation as part of the research project "Radiation Monitoring" and has not been supported.

CZ9727087

CURRENT RESEARCH ACTIVITIES IN NUCLEAR PHYSICS GROUP OF DEPARTMENT OF PHYSICS FNSPE CTU PRAGUE

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Key words: ATLAS experiment at LHC, pp interactions, radiation detectors, GaAs, silicon, pixel detectors, neutrons, radiative capture, double beta decay, radon daughters products,

Research activities in Nuclear Physics Group of the Department of Physics FNSPE CTU Prague have been oriented on fundamental research in nuclear and particle physics and applied nuclear physics. All activities can be summarized as follows:

1. Experiment ATLAS on LHC. The work is oriented on construction of the ATLAS Inner Detector and neutron shielding for ATLAS Forward Region [1]. This is a broad international collaboration, particularly with CERN and University of Montreal. The project has been supported by the Czech Committee for Collaboration with CERN under a Grant "GaAs Wheels in Inner Detector for the ATLAS at CERN". It has also been supported by the Grant Agency (GA) of the CTU Prague under a Grant 10048288/1995 "Detection Structures for Inner Detector of ATLAS Experiment at CERN". The experimental test of the neutron shielding on PS accelerator was recently done.

2. Polarization of nucleons in N-N elastic scattering. The experiments were performed on the accelerator SATURNE II at LNS Saclay in collaboration with LNS, JINR Dubna, University of Geneva, ANL, UCLA and Freiburg University. The polarized proton beam and the PPT were used. The complete set of spin-dependent observables in n-p and p-p elastic scattering between 0.3 and 2.7 GeV were measured [2].

3. Double beta decay. Investigation of double beta decay consists of two experiments: TGV (measurement of ^{48}Ca) and NEMO (measurement of ^{100}Mo, which is at present in phase III - preparation). The experiments are conducted in Modane underground laboratory in close cooperation of LAL Orsay, CSNSM Orsay, JINR Dubna, FMP of the Charles University, Prague and FNSPE CTU Prague [3]. This work has been supported by the GA of the Czech Republic (CR) under Grant 202/94/0022 "Double Beta Decay of ^{100}Mo".

4. Experimental study of rare elements nuclei by radiative capture of resonance neutrons. This is done in collaboration with JINR Dubna (^{158}Gd(n_{res}, γ) [4]. The project is supported by the Czech Committee for Collaboration with JINR Dubna under a Grant "Study of Atomic Nuclei Properties using Neutrons".

5. Research and development of semiconductor detectors:

– GaAs detectors are a new type of detectors expected to have higher radiation hardness compared to silicon detectors. GaAs single pad detectors have been tested as part of CERN

RD8 collaboration (CERN, Glasgow, Sheffield, Freiburg, Udine, Charles University and Physics Institute of AS CR) [5]. This work has been supported by the GA of the CR under Grant 202/94/0901 "Development of the Radiation Detectors based on III-V Semiconductor Materials" and by the Czech Committee for Collaboration with CERN under a Grant "The GaAs - RD8 Collaboration at CERN".

– Development of silicon pixel detectors and their application for neutron imaging [6]. This work has been done under the CERN RD19 Collaboration and has been supported by the GA of the CR under Grant 202/95/1623 "The Data Processing for the DELPHI and ATLAS experiments" and by the GA of the AS of the CR A1010624 "Silicon Coordinate Detectors for Fundamental Research in Particle Physics".

6. Coincidence activation analysis based on two HPGe detectors. The system has been built based on NIM spectroscopic modules in connection with the data acquisition system in VME standard [7]. This work has been supported by the GA of the CR under a Grant 203/95/0260 "Coincidence Instrumental Activation Analysis" and by the GA of the CTU Prague under a Grant 10048287/1995 "Flexible System for the Fast Experimental Data Acquisition".

7. Applied alpha spectroscopy devoted to the measurements of Rn and thoron daughter products in air samples [8]. The project was supported by the GA of the CR under a Grant 202/93/0392 "New Methods for Measurements of Rn and its Progeny in the Air".

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CZ9727088

THE FITTINGS OF THE NEUTRON DETECTOR AT PSI (PAUL SCHERRER INSTITUT), SWITZERLAND

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Key words: neutron detector, support construction, $PbWO_4$ crystals

In December 1995 I joined an international cooperation on the project TOF WALL, PSI experiment R-95-08, that has been lead by prof. M. Finger (MFF UK, SUJV Dubna, CERN, PSI) and prof. H. Schmitt (TU Freiburg, CERN, PSI). The cooperation has concerned a neutron detector fitted up at PSI (Villigen, Switzerland) for Faculty of Physics TU Freiburg, Germany. Mr. Zicha charged me with a task to design a support construction for the neutron detector and to ensure its production, transport and fittings at PSI.

The support construction has to accomplish many requirements. The detector wall is composed of fifteen "neutron bars" with total weight 1500 kilograms, so the construction has to be adequate firm and stable. The detector wall has to be located precisely towards an axis of the neutron beam. The falling down neutrons have to reach the detector wall without meeting any obstacle. The neutron bars are not allowed to be at direct contact with magnetic parts of the construction.

A basic conception of the support construction had come from Mr. Zicha, I realized his idea. The construction stands on three adjustable "legs". It allows to locate the detector wall perpendicularly towards the axis of the neutron beam and to ensure that its axis passes through the centre of the detector wall. The support construction is composed of standard steel U-profiles that create two basic triangles: a horizontal one and a vertical one. The vertical triangle holds a horizontal beam and the whole construction is reinforced with two steel tubes. The total weight of the neutron bars is carried by a steel L-profile. The detector wall is fixed to the construction with two vertical aluminium BOSCH-profiles (non-magnetic material).

Our group fitted up the support construction at PSI in the first June week 1996. According to directions of prof. Schmitt we installed the detector wall. The result of our international cooperation is the biggest particle detector at history of PSI. The detector should work at least five years. The first outcomes are expected in December 1997 and they will be presented at CERN. Thanks our successful contribution to the international science cooperation I could join CERN project CMS (The Compact Muon Solenoid), particularly project ACCOS (Automatic Crystal COntrol System). This project concerns a device for measuring of mechanical and optical parameters of $PbWO_4$ crystals. The scintilation crystals will be applied at an electromagnetic calorimeter.

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This research has been conducted at the Department of Precision Mechanics and Optics as part of the research project "Rozvoj mezioborového studia: Biomedicínské a rehabilitační inženýrství ČVUT" and has been supported by CTU grant No. 2396311.

CZ9727089

ION BEAM THIN FILM DEPOSITION, SURFACE AND THIN FILM ANALYSIS

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Key words: ions, deposition, thin films, in-situ analysis

Ion beams can efficiently be applied as the direct source of the deposited particles either in the ion energy range above 20 keV (implantation) or below 100 eV where the sputtering yields are sufficiently low. Recently, the ion beam techniques based on the ions with the energy in the range of a few tens eV have recently become very popular [1]. Contrary to the ion beam assisted deposition of thin films, their deposition from low energy ion beams enables us to use the apparatus with mass and energy selection of ions working under UHV conditions. This fact substantially improves control of the deposition parameters. The apparatus equipped with a few in-situ analytic techniques may thus become an excellent research tool for a study and monitoring of the deposition processes. In this contribution we present some basic design features of such an apparatus being now developed in our group. A schematic view of the apparatus setup is shown in figure 1. The ion beam applied both for deposition and analysis is generated in the main equipment branch.

Two different energy modes of the ion beam operation will be used: 30–300 eV (direct thin film deposition) and 300–5000 eV (sputtering deposition and analysis). To get the maximum growth rate of the films in the order of tens nanometres per hour at the beam energy of 30–300 eV we face requirements to transfer the ion beam current densities 10^0–10^1 $\mu A/cm^2$. To avoid strong repulsive forces due to ion space charge at these low energies the beam after being extracted from an ion source must be first accelerated to energies of a few keV and then as near the target as possible decelerated. The maximal ion beam current density needed at the higher energy mode (300–5000 eV) is 10^1–10^2 $\mu m/cm^2$. The beam spot diameter falls into the range 1–5 mm and 0.1–1 mm for 30–300 eV mode and 300–5000 eV mode, respectively. The beamline consists of the three differentially pumped sectors. The first sector contains the plasma ion source, the 1st Einzel lens system and Wien filter equipped with the octopole lens for correction of the filter aberrations. The second sector includes the 2nd Einzel lens system with deflection plates. The third one involves the final lens system inserted into the main UHV chamber. The latter lens system is assembled from 5 lenses optimizing deceleration of the ions below 200 eV and from the deflection plates setup. All sectors are pumped by turbopumps backed by rotary pumps.

The calculated working pressure in the main chamber does not exceed during deposition the order of 10^{-6} Pa.

The computer design of the optical systems was performed by the software Simion [2]. The space charge effect during deceleration of ions in the third lens assembly was studied by a special 3D program developed in our group.

The UHV environment and the presence of the mass selected ion beam in the apparatus offer to carry out some in-situ analytical methods. For SIMS analysis of the growing thin films a quadrupole mass analyser QMG 421-4 (fy Balzers) together with a specially designed entrance/transfer optics and small energy analyser (CMA) will be used. This configuration makes it also possible to perform LEIS spectroscopy and thus to compare its results with those obtained by time-of-flight (TOF) technique which is also being developed for this equipment. The electronics which will be used for TOF measurements is based on the time-to-amplitude convertor and multichannel analyser card ACE-8K-W3 (fy ORTEC). Optical properties of the growing films are to be studied by an ellipsometer. The ellipsometer will run on two optical wavelengths at the constant angle of incidence. The STM/AFM instrument being now developed under direct cooperation with the TESCAN Ltd. will be operated both in contact and noncontact mode [4]. The apparatus described above is intended to be used mainly for direct ion beam deposition of thin films, e.g. nitrides and diamond like carbon films (using ions generated from gaseous compounds). In-situ analysis performed by SIMS, LEIS, ellipsometry and STM/AFM will be used both for the monitoring of deposition processes and study of the growing thin films.

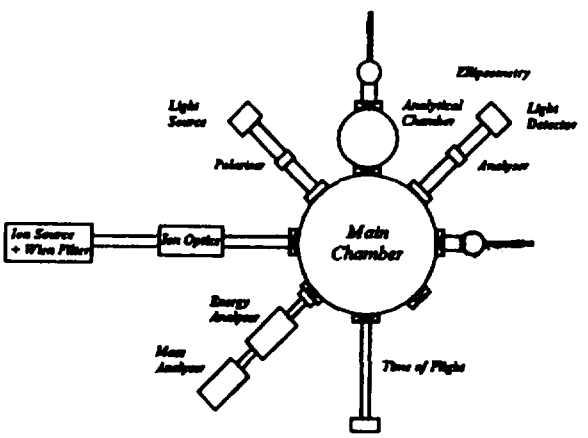

Fig. 1: Schematic view of equipment setup

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This work has been conducted at the Department of Physical Engineering and has been supported by the COPERNICUS project No. CIPA-CT94-0224 and the Czech Grant Agency project No. 202/94/0565.

CZ9727090

ELECTRON BEAM DECHLORINATION OF PCBs IN ALKALINE 2-PROPANOL SOLUTION

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Key words: radiation degradation, electron beam, chlorinated hydrocarbons, PCBs

Introduction. A degradation of polychlorinated biphenyls (PCBs) in alkaline 2-propanol solution under the influence of accelerated electrons was investigated.

Experimental procedures. A mixture of polychlorinated biphenyls produced in the Czech Republic under commercial name DELOR 103 for all experiments was used. Samples containing PCBs in alkaline (KOH) 2-propanol were deaerated by bubbling with nitrogen gas and placed into 25mL dry glass ampoules. Consequently the samples were irradiated using 4.5 MeV electrons produced by accelerator UR-4-1200 TESLA. The dose was determined using the Fricke's dosimeter (Pikaev, 1975). The concentration of Fe^{3+} ions was measured spectrofotochemically at 303 nm. The applied dose was varied from 2 to 100 kGy by means of repeated moving of samples under the exit window of the accelerator. A constant dose rate was given by the fixing setting of the value of 150 μA.

The amount of PCBs and biphenyl in irradiated solution was determined using gas chromatography with flame-ionization (FID) detector. A 5m glass packed column containing 5% N-AW SE 30 on CHROMATON N was used for analysis. The amount of PCBs congeners or biphenyl in irradiated solutions was expressed relatively as a ratio of the i-peak-area to the area of all peaks belonged to PCBs and biphenyl.

For determination of chloride produced by the irradiation of the samples the alcohol was evaporated and the rest of potassium chloride was dissolved in water. The aqueous solution was then analyzed for chloride electrochemically using ion-selective electrode CRYTUR and the reference calomel electrode. A degree of dechlorination of PCBs (%) was calculated as a ratio $m_{KCl}/\sum m_{KCl}$ where m_{KCl} is experimentally measured amount of KCl and $\sum m_{KCl}$ is theoretically presumed total amount of KCl which would create after the total dechlorination of PCBs containing on the average 3 Cl atoms in each molecule of PCB (verified by measuring of density of PCB solution).

2-propanol (or ethanol) was of chemical purity. All other chemicals used were of reagent purity.

Results. The samples containing PCBs in alkaline (KOH) 2-propanol solution were irradiated with the doses of 2, 4, 6, 8, 10, 20, 40 and 100 kGy. The decrease in the initial

concentration of PCBs was found under the influence of accelerated electrons. The biphenyl and potassium chloride as one of products of dechlorination of PCBs were detected. The decrease of amount of PCBs in irradiated solution appears to be a gradual process being a function of the absorbed dose. Amount of higher chlorinated biphenyls decreased quickly, whereas less chlorinated biphenyls were formed in the irradiated samples and then converted into the biphenyl. During the dechlorination potassium chloride was formed too. Its amount as well as amount of biphenyl rose up with increasing dose of irradiation.

The dependence of degree of dechlorination of PCBs (%) on initial amount of KOH in irradiated solution was observed. The degree of dechlorination of PCBs (%) rose up with increasing concentration of potassium hydroxide, while in the case of absence of potassium hydroxide the radiation degradation of PCBs was found to be negligible.

The influence of biphenyl on the degree of dechlorination of PCBs was studied. The samples containing PCBs in alkaline (KOH) 2-propanol solution with addition of biphenyl in concentration range from 0 to 0.1 mol.dm^{-3} was irradiated with the doses of 6 and 20 kGy. No inhibiting effect of biphenyl was found in this concentration range.

The influence of acetone on the degree of dechlorination of PCBs was also studied. The samples containing PCBs in alkaline (KOH) solution with addition of acetone in concentration range from 0 to 1 mol.dm^{-3} were irradiated with the dose of 20 kGy. The presence of the acetone in irradiated solution in concentration lower then 0.125 mol.dm^{-3} has no significant influence on the degree of dechlorination of PCBs, whereas the inhibiting effect of acetone in concentration higher then 0.125 mol.dm^{-3} was found. In the case of acetone concentration higher then 0.3 mol.dm^{-3} the radiation degradation of PCBs appears to be negligible.

The influence of oxygen and water content on the degree of dechlorination of PCBs was further investigated. The inhibiting effect of oxygen especially at the lower doses applied was observed, while no significant effect of water in concentration range from 0 to 2 vol.% was found.

Finally, the possibility of the radiation degradation of PCBs in alkaline (KOH) ethanol solution was studied. In this case, a negligible degradation of PCBs was found.

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This research has been conducted at the Department of Nuclear Chemistry as part of the research project "Radiolytic Degradation of Chlorinated Organic Compounds with a View the Polychlorinated Biphenyls" and has been supported by Grant Agency of the Czech Republic, grant No. 104/94/0063.

CZ9727091

THE METHODOLOGY IMPROVEMENTS OF EVALUATION OF BATCH REACTOR SORPTION EXPERIMENTS (URANYL SOLUTIONS – SOIL)

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Key words: soils, contaminants, batch reactor, evaluation method, modelling, uranium

Some methodological problems of the use of batch method for the study of the interaction of uranyl solutions with soils were analysed and previous approaches to the evaluation of results [1] of such experiments were extended. The aim of the performed work was also to gain the information about those chemical forms of uranium which are preferably sorbed on specified types of soil.

To accomplish the computational simulations of migration processes it is necessary to know the mathematical form of the sorption equilibrium and kinetic relations. The knowledge of this equations enables not only to include the description of the sorption phenomena into a complicated migration model but secondly also give the information about fundamental principles that should be taken into account in the study of the interaction of radionuclides and contaminants with soils . The most frequently used method of experimental study is batch arrangement in stirred reactor. The experiments performed with different liquid-to-solid ratios (V/m) enables to construct the equilibrium relationship and the kinetic experiments executed with the constant V/m enables to choose the appropriate kinetic model.

The uptake of uranium from four types of uranyl solutions (No. 1-4) on two samples of forest soil, which mainly differ in the content of clay, was studied. The standard spectrophotometric method with AZOIII was used for the determination of uranium in the liquid phase.

1. $UO_2(NO_3)_2$ (10^{-4} mol/l)
2. $UO_2(NO_3)_2$ (10^{-4} mol/l) + $NaNO_3$ (0.1 mol/l)
3. UO_2SO_4 (10^{-4} mol/l)
4. UO_2SO_4 (10^{-4} mol/l) + Na_2SO_4 (0.1 mol/l)

The experimental equilibrium and kinetic relations were evaluated by fitting with four equilibrium models (K_d, Langmuir, Freundlich, double Langmuir) [2] and with six models of kinetics [1], respectively. The fitting was performed by least square method. The best equilibrium models were used in an original fitting code for the evaluation of kinetics (KINET), by means of which the kinetic coefficients for all models and the most appropriate model were determined. The graphical form of presentation of results helps also to choose the most

relevant kinetic model. The speciation code MINTEQA2 [3] was used for the estimation of abundance of uranium forms presented in the system under experimental conditions.

The results of equilibrium experiments show that the sorption of uranium on our samples of soil is influenced in great measure by the type of the soil and by the ionic strength. Further, the very low sorption of uranium from the solution No. 4 can be explained by computational speciation studies: in contrary to other solutions, where for experimental conditions (pH≈4) the form UO_2^{2+} is dominant, in solution No. 4 preponderates the anionic form $UO_2(SO_4)_2^{2-}$, the sorption mechanism of which should be different than that of the cationic form OU_2^{2+}. Although the experimental error is significant, the analysis of all equilibrium curves clearly shows their nonlinearity, and the Langmuir or the S-shaped double Langmuir models can be regarded as the most suitable.

The rate of the sorption kinetics was greater for nitrate solutions with the soil containing less amount of clay (29%), and for the second soil containing a greater part of small particles (67%) the obtained kinetic coefficient are better comparable between nitrate and sulphate solutions. The sorption rate for the systems with the solution No. 4, where the anionic form is preferable, is slowest for both soil samples.

The computational evaluation of kinetic experiments proves that the most convenient control processes are chemical reaction and diffusion in the inert layer[1]. The simple statistical method included in the code KINET shows that for experimental data with higher experimental errors the uncertainty in determination of kinetic coefficient is significant and further that the choise of the most convenient kinetic model is not unique.

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INDEX

Abd El-Shafy, M., 1241
Aboul-Enein, S., 61
Adamec, J., 417, 1075
Adamec, L., 877
Ahmad, M., 441
Ambrož, O., 1449
Andersová, I., 1315
Anger, L., 481, 1051
Ansorge, L., 1273
Aubrecht, L., 1295, 1297
Aubrecht, V., 861, 879
Autrata, R., 1025

Bača, P., 835
Bačáková, L., 1055
Bahyl, V., 333
Bach, P., 497
Balátě, J., 211
Bálek, R., 927
Báňa, V., 931
Bareš, K., 1079
Bartes, F., 1419, 1537
Bártík, H., 979
Bartl, J., 861
Bartlová, M., 877, 879
Bartoš, O., 675
Bartůsek, J., 1525, 1541
Bastl, P., 205
Bašta, J., 1293
Běhalová, J., 1395
Bejček, L., 929, 937
Bělák, V., 647, 1445
Bém, J., 1273
Benabdallah, H., 1483
Bend, J., 1077
Benda, V., 911
Beneš, B., 293, 299
Beneš, M., 189, 449, 833
Beneš, P., 165, 935, 1227, 1259
Beneš, V., 49
Beran, V., 1515
Beran, Z., 1541
Berka, L., 567
Berka, R., 291
Berka, Z., 1229
Bernard, J., 111
Bernas, M., 941
Bičák, J., 893
Bíla, J., 245
Bílek, E., 503
Bílek, V., 617
Bilík, J., 1429, 1453
Biolek, D., 967
Biolek, Z., 967
Biolková, V., 1019
Bittnar, Z., 465, 467, 469
Bittner, J., 325
Blaha, A., 649
Blaha, J., 1085
Bobák, R., 1541
Bobok, J., 33
Böck, H., 1475
Bouda, V., 635
Bouška, P., 543
Božek, V., 535
Brachtl, M., 327
Brandštetr, J., 655
Briš, R., 1363
Brož, K., 447
Brož, P., 483
Brüstlová, J., 1021, 1029
Bryknar, Z., 83
Brzobohatý, J., 889
Březina, J., 597
Bubeník, F., 939
Budinský, R., 113
Buchal, A., 597
Buchar, J., 595
Buchta, M., 1521
Bujok, P., 1319
Bumbálek, B., 1423
Bumbálek, L., 1423
Burdík, Č., 55
Burian, A., 1083
Burian, Z., 1005
Buřič, P., 1077

Cabalka, A., 583
Cakl, J., 1455
Calábek, M., 835
Cejp, J., 569
Cenek, M., 169, 579
Cihlář, J., 1313
Cihlářová, Z., 173
Cipra, J., 863
Císlerová, M., 455
Coufal, O., 877

Čada, R., 1403, 1405
Čáp, J., 1027
Čapek, M., 1059
Čech, M., 1011
Čech, V., 123
Čechák, T., 1219, 1221, 1233
Čejková, I., 1275
Čermák, J., 1295
Čermáková, A., 1281
Čermáková, E., 1249
Černík, M., 911
Černý, F., 1057
Černý, M., 473, 625
Černý, R., 45, 423, 551, 621, 623
Červený, M., 313
Čeřovský, Z., 849
Češpíro, Z., 509
Čochnář, Z., 653
Čulík, J., 1047, 1049

Dagbert, C., 581
Dalík, J., 29, 619
Danačíková, E., 155
Daněček, J., 29, 619
Daněk, M., 431
Danihelka, P., 1315, 1317
Dedouch, K., 501, 1073
Delsanto, P. P., 125
Dembovský, V., 587
Diblík, J., 25
Diblík, P., 295
Dirner, V., 1299
Dittrich, J., 55
Divina, L., 897
Diviš, J., 1441
Dlask, P., 1515
Dlouhá, M., 81
Dlouhý, I., 575, 657
Dobis, P., 1021, 1029
Dolejš, J., 549
Doležal, J., 831, 837
Dopita, P., 269
Dostál, J., 1233
Dostál, P., 163, 213
Dostál, T., 895
Dostál, Z., 489
Dostálek, J., 1233
Doubek, P., 1277
Drápal, J., 1339
Drápala, J., 581
Draxler, K., 987
Drdácký, M., 531
Drdák, M., 167
Drchalová, J., 623
Drkal, F., 1271
Drochytka, R., 615
Drška, L., 59, 125, 127
Dryák, A., 313
Dufek, P., 333
Dunovská, T., 1271
Dunovský, J., 1409
Durčák, M., 1235, 1237
Dvořáčková, M., 1239
Dvořák, J., 193, 491, 1521
Dvořák, P., 1017
Dynybyl, V., 509, 1341

Eck, V., 1079, 1081
Eliášová, M., 529
Elich, M., 1327
Exner, P., 55

Fadrus, H., 1237, 1239
Fajkus, M., 1369
Fajnor, R., 1353
Fanta, Š., 949
Fara, J., 829
Farana, R., 263
Fejfar, L., 871
Fiala, P., 993
Fidler, V., 85
Fikar, M., 163
Filakovský, K., 861

Filip, J., 331
Filipová, J., 611
Fischer, J., 931
Fišarová, L., 869
Fišer, J., 917
Foltiny, F., 1003
Forejt, M., 595, 1407
Foret, R., 577
Fořt, I., 437
Frencl, L., 105
Friedl, Z., 147
Fuchs, Z., 543
Funda, M., 637

Gainish, V., 1463
Galaš, I., 79, 1035
Galland, J., 581
Ganev, N., 559
Garagič, D., 229
Gavlas, J., 867
Gavrilov, P., 1101
Gebauer, G., 1313
Gerndt, J., 1341
Gerža, D., 1287
Gleeson, D. J., 1017
Glogar, A., 1525, 1541
Glogar, P., 663, 1055
Gogolewski, P., 97
Gorenstein, P., 1023
Gosman, A., 1231
Gosmanová, G., 559
Grasblum, P., 857
Gregor, J., 869, 1309
Gregor, V., 589
Grmela, L., 679, 1021, 1029
Gross, B., 855, 881, 883, 885
Gruncl, M., 199
Grünwald, A., 1241, 1281
Gřegorčík, J., 1329, 1331
Gřešák, V., 1061
Gurecký, J., 825

Habán, V., 457
Habel, J., 859
Hájek, K., 955
Hajný, M., 919
Hajšman, L., 621
Haluza, M., 435
Hamal, K., 1011
Hamata, V., 817
Hanáček, P., 879
Hanák, J., 629
Hanák, V., 1465
Hánek, P., 939
Hanika, J., 1451, 1457
Hanus, S., 889, 959
Hanušová, I., 1023
Hanzálek, Z., 233
Harna, Z., 869, 999
Harok, V., 495
Hašlar, V., 1039
Havel, J., 579
Havlica, J., 665
Havlíček, F., 603
Havlíček, M., 55
Havlíček, S., 679
Havlík, V., 421, 423, 451
Havran, V., 287, 321
Hazdra, P., 1039, 1041, 1043
Hazdra, T., 241
Házová, K., 421
Hejma, J., 1277
Helán, J., 1413
Hell, J., 625
Heller, J., 1379
Hemerka, J., 1277
Heptner, T., 1511
Hermann, P., 1069
Herrmann, L., 19
Herzanová, P., 1347
Heřmanský, B., 1469
Himmel, J., 1265
Hlaváč, V., 181, 225, 261
Hlaváček, B., 641
Hlaváček, J., 433
Hlaváček, P., 649, 1061, 1063, 1431
Hlaváčková, L., 669
Hlavatý, L., 55
Hlinovský, M., 273
Hnatowicz, V., 639
Hnilica, F., 663
Hof, M., 85
Hoffmann, K., 943
Hofman, P., 1425, 1427

Hofmann, P., 1277
Hofreiter, J., 227
Hofreiter, M., 223
Hojerová, M., 1077
Holeček, S., 583, 585
Holický, M., 197, 1367, 1369
Hollay, P., 297
Holub, J., 281
Holuša, M., 963
Holý, S., 481, 517, 1051
Honč, T., 953
Hooper, E. W., 155
Horáček, M., 1413
Horáček, P., 227
Horák, P., 1523
Horáková, J., 681
Horká, H., 865
Horký, B., 613
Horníková, J., 599
Horváth, S., 121
Hošek, P., 1379, 1381
Hošková, Š., 621
Housa, J., 503
Houser, J., 1239
Houška, A., 881, 885
Hozman, J., 1067, 1069
Hrabánek, M., 1375
Hrad, J., 925
Hradílek, Z., 825
Hradilová, J., 1005
Hrdlička, M., 221
Hrnčiřík, J., 175, 1269
Hron, M., 1471
Hrouda, F., 629
Hrubá, I., 661
Hruška, P., 69
Hruška, T., 187
Hříbek, P., 1003, 1013, 1103
Hubáček, P., 1331
Hubáčková, B., 1333
Hudec, R., 1023
Hudeček, B., 571
Hušák, R., 605
Hušek, P., 247
Hybenová, E., 167
Hyniová, K., 273
Hyspecká, L., 581, 601
Hytka, Z., 853

Chadzitaskos, G., 55
Chmela, F., 1383, 1385
Chmela, P., 1007, 1009
Chobola, Z., 61, 63, 65, 67, 129, 131, 133, 135
Chod, J., 865
Chvátil, D., 151, 1083, 1463
Chyský, J., 827, 1077

Ibrahim, A., 61, 63
Inneman, A., 1023

Jakůbek, J., 109
Jakubová, I., 869, 1309
Jan, J., 1085
Janáčová, D., 1451
Jančárek, A., 1101
Jančář, J., 675
Jandera, J., 1535
Jandora, J., 433
Janeček, J., 311
Janoušek, J., 319
Janoušek, K., 421
Janout, Z., 109, 1221
Janovec, J., 605
Janžurová, I., 939
Jára, J., 843
Jarušková, D., 47
Javůrek, J., 849
Jelen, J., 53
Jelínek, I., 245, 297
Jelínek, V., 865
Jelínková, H., 1011, 1013
Jerome, M., 581
Jeřábek, M., 231
Jeynes, C., 1039
Jíchová, N., 665
Jílek, M., 459
Jindra, V., 1387
Jirák, J., 579, 1025
Jirák, Z., 81
Jirásek, V., 961
Jirava, P., 1501, 1507
Jirků, S., 419, 493
Jirouš, M., 625

Jirout, L., 1079, 1081
Jirsa, F., 833
Jiříček, O., 91, 93
Joanidis, J., 859
John, J., 155, 1221, 1227, 1259
Jonšta, Z., 601
Joska, L., 1057
Jura, P., 267
Juránková, V., 63, 67, 131, 133, 135
Jurča, L., 1541
Jurová, M., 1417, 1525, 1539, 1545
Juříček, V., 1481

Kábrt, J., 635
Kadlčák, J., 471
Kadlec, F., 1089
Kálal, M., 57
Kaloč, R., 859
Kalousek, R., 117, 119
Kalousková, M., 1359, 1361
Kalus, D., 1319
Kameníček, I., 1497
Kaminský, D., 989
Kanaval, J., 509, 1341
Kapičková, O., 865
Kapitánová, R., 1407
Kapusta, P., 85
Karásek, J., 41
Karlický, P., 1501
Karlík, M., 557
Kárník, T., 1301
Kavan, M., 1553
Kazelle, J., 579
Kblan, A., 513
Keating, J., 1017
Kemel, M., 441, 1285
Keršner, Z., 617, 1373
Keyzlarová, L., 647
Khalifa, E., 105
Kheilová, M., 141
Klapka, J., 191, 193, 195
Klaus, J., 183
Klema, J., 271
Klika, Z., 1303
Klíma, M., 1017
Kliský, V., 159
Klusáček, V., 943
Knápek, J., 833
Kocman, K., 1421
Kocmanová, A., 1417, 1419, 1537
Kocmanová, R., 651
Kocourek, P., 947
Kočárník, P., 419
Kočí, J., 859
Kodym, O., 1435
Kohout, Z., 1043
Kojecký, B., 951
Koktavý, B., 69, 71
Koktavý, P., 69
Koláčný, J., 873
Kolář, D., 251
Kolář, J., 1427, 1511
Kolářová, P., 1005
Kolářský, J., 1309
Kolat, P., 587
Koller, J., 99, 1295, 1297
Kolouch, J., 969
Kolros, A., 1473, 1479, 1483
Komárek, M., 861
Komrzý, P., 439
Konečný, M., 1545
Koníček, J., 109
Koníček, P., 91, 93
Koníčková, J., 37
Kóňová, J., 1307
Konvička, M., 1329, 1331
Konvičková, S., 1053, 1057
Kopáčik, G., 1331
Kopečný, P., 207
Kopřiva, P., 565
Koráb, V., 1517
Koruna, P., 1449
Kořenská, M., 77, 87, 89, 139
Kořený, R., 603
Kořínek, Z., 637
Kostohryz, J., 505
Košťál, P., 1437
Kotačka, L., 995
Kouba, O., 1099
Kouba, Z., 243
Koubík, L., 831
Kouřil, Z., 605
Kousal, J., 671
Koutek, B., 175

Koutný, J., 1325, 1333
Kovář, L., 1001
Kovář, P., 917
Kovářová, M., 677
Kozák, V., 1541
Kozánek, J., 505
Kozel, K., 443
Kozelský, P., 603
Kozumplík, J., 1085, 1097
Kožíšek, J., 1533
Kračmar, S., 17
Král, J., 661, 1217, 1221, 1275
Král, P., 875
Kramářová, I., 1447
Krátký, J., 609, 611
Kratochvíl, C., 845, 847
Kratochvíl, J., 433, 589, 591, 865
Kraus, I., 559, 567
Kravárik, J., 97
Krč, P., 1417
Kreibich, V., 1399
Krejča, P., 853
Krejčí, J., 595, 597, 645, 1033
Krejčí, R., 1217
Krejčiříková, H., 1315
Krejčová, J., 1407
Krejzl, J., 1091
Krejzlík, T., 117
Krekule, I., 1059
Kremer, R., 1255
Kret, J., 1429, 1453
Krištofová, D., 1301
Kropáček, M., 159
Kropík, M., 1475, 1479, 1483
Kropš, S., 1475
Krsek, P., 225
Kruis, J., 465
Krzyžánek, V., 997
Křemen, J., 817
Křenek, J., 969
Křesálek, V., 643
Křístek, V., 545, 865
Křivák, P., 835
Křížová, Z., 1527
Kuba, J., 79, 829
Kuba, V., 1541
Kubalčík, M., 211
Kubalík, J., 271
Kubašta, J., 109
Kubeček, V., 1011, 1013, 1103
Kubelík, M., 1341
Kubeš, P., 97
Kubík, J., 1541
Kubínek, R., 1067, 1069
Kubínová, L., 1059
Kubr, J., 311
Kučera, P., 23
Kučera, T., 219
Kudláček, I., 1257
Kucháriková, E., 1437
Kuklík, P., 515, 549, 1359, 1361
Kuklíková, A., 549
Kula, D., 681
Kůla, V., 419, 493
Kulhánek, P., 99
Kunc, J., 667, 669
Kunz, J., 565
Künzel, K., 841
Kunzová, D., 1051
Kursa, M., 581
Kurzveil, J., 199
Kvačková, H., 1275
Kvasnička, I., 593, 1425, 1427
Kvasnička, J., 1013
Kyncl, Z., 95
Kynclová, M., 161
Kynčl, M., 1325
Kyselka, M., 1325
Kytýr, J., 471

Lakomý, L., 1333
Lamboj, L., 513
Langmaier, F., 1063
Lapcík, L., 579
Lapčík, Jr., Ľ., 145, 651, 1065, 1261, 1269
Lapčík, L., 173
Laub, M., 111
Lauryn, Š., 271
Lauschmann, H., 495
Lehovec, F., 1489, 1495
Lelek, F., 1397
Lencová, B., 117
Leško, J., 1307

Ležák, D., 443
Lhotáková, Z., 1263
Lhotská, L., 243
Líbal, V., 179
Liedermann, K., 679, 1065
Linhart, V., 109
Lísal, M., 113
Liska, R., 31, 125, 127
Liška, M., 929, 999, 1029
Lombino, R., 1013, 1103
Lopour, F., 117, 119
Losertová, M., 601
Losinská, J., 1233
Lowitová, O., 477
Lukáš, P., 567
Lukovics, I., 1433, 1445
Luxemburk, F., 1489, 1491, 1493, 1495

Máca, J., 521
Maca, K., 653
Macek, J., 427
Macek, K., 571
Macek, L., 1241, 1281, 1337
Macek, T., 307, 309
Macura, Z., 1529, 1543
Mach, P., 909
Macháč, J., 899
Macháčková, A., 641
Maier, K., 1327
Maixner, V., 199
Makovička, D., 543
Malá, J., 1237
Malec, Z., 935
Maleček, K., 865
Malenovský, E., 875
Malinský, K., 75
Malý, J., 1235, 1239
Mann, H., 239
Mannová, B., 317
Marák, I., 299
Mareš, K., 1051
Mareš, L., 1277
Maršík, F., 1075
Martínez Nieto, J. L., 1231
Martiník, A., 659
Masljuk, M., 1463
Mašek, J., 881
Matějka, F., 129
Matějka, K., 1221, 1467, 1471, 1475, 1477, 1479, 1481, 1483
Materna, A., 561
Matoušek, J., 1261
Mazáč, J., 1319
Mazal, P., 251
Mazánek, F., 987
Mazánek, M., 913, 973, 979, 983
Medek, J., 437
Medvec, Z., 825
Medvedíková, L., 1455
Mega, J., 1265
Melecká, P., 535
Melcher, J., 537
Melichar, B., 277, 279
Mervart, L., 35, 953
Micka, K., 835
Mičín, J., 1267
Mikšíček, L., 323
Mikulášek, K., 39
Mikulášková, B., 1269
Mikuláštík, M., 1541
Mikulecký, S., 1397
Miláček, S., 487
Milion, B., 577
Mindl, P., 851
Mišurec, J., 967
Mládek, M., 1061
Modrý, S., 1375
Mohelník, L., 1339
Molnár, J., 1481
Moravec, M., 1093
Moudrý, I., 535
Mrázek, Z., 909
Mrozek, S., 1303, 1305
Múčka, V., 159
Mucha, J., 1417
Müller, J., 181
Müller, K., 1519
Muras, J., 647, 675
Muric, J., 655
Musil, J., 1075
Musílek, L., 1219, 1341
Muzikář, Z., 315
Myška, M., 633

Nahodil, P., 199
Náplava, P., 303
Náprstek, J., 525
Navara, M., 1071
Navarová, H., 129, 131, 133
Navrátil, A., 207
Navrátil, P., 1087
Navrátil, V., 667
Navrátil, Z., 249
Nebojsa, A., 117
Nedbal, I., 565
Nejedlý, Z., 1217, 1275
Němcová, M., 1347
Němcová, Š., 1015
Němec, R., 509
Němeček, A., 43
Němeček, J., 1019
Nesvadbová, R., 677
Neumann, P., 255
Neustupa, J., 21
Nezbeda, Š., 933
Noskievič, P., 209
Nováček, V., 1541
Novák, D., 1365, 1373
Novák, J., 79, 667, 839, 947
Novák, L., 827
Novák, P., 1057, 1421
Novák, R., 593
Novák, V., 41, 579
Nováková, D., 593
Novotný, A., 915, 1011, 1013
Novotný, B., 1487, 1495
Novotný, M., 289, 291, 535
Novotný, V., 1355
Nožička, J., 417
Nypl, V., 1243

Obrazová, H., 1051
Obroučka, K., 1255
Ochodek, T., 1317
Oliva, V., 561
Ondrůšek, Č., 847, 875
Ošmera, P., 191, 873, 1267
Ozga, Z., 1069

Pačesová, H., 1549
Paduch, M., 97
Pácha, T., 217
Pajdla, T., 225, 261
Palmerová, J., 1355
Pánek, J., 1103
Papež, V., 79, 671, 951
Papežová, S., 1077
Pardubský, Z., 923
Parlag, O., 1463
Pařízek, A., 1077
Páta, P., 941
Patuelli, C., 567
Pavelka, F., 1541
Pavelka, J., 843
Pavelka, K., 1253
Pavelková, D., 1525, 1541
Pavlačková, J., 1061, 1431
Pavlík, M., 883, 1341
Pavlínek, V., 449, 673
Pavlok, B., 1251
Pazdera, L., 77, 87, 89, 137, 139, 965, 977, 1289
Pechač, P., 913, 973
Pekař, M., 169, 651
Pelantová, E., 55
Peleška, K., 533
Pelikán, K., 891
Pelikán, P., 149, 651
Pernikář, J., 1537
Pertold, J., 197, 527
Pešek, L., 505
Peška, L., 855, 881, 883, 885
Petr, J., 829
Petr, O., 1027
Petráček, J., 1007, 1009
Petrová, R., 229
Petrtýl, M., 1049
Pexidr, Z., 421
Picek, T., 1273
Píč, V., 291
Píchal, J., 103
Pína, L., 1023, 1027
Píšek, M., 1551
Pištěk, M., 921
Pivoňka, P., 165
Plšková, R., 1325
Podolka, L., 541
Podrábský, T., 1423

Pochylý, F., 435, 457
Pokluda, J., 115, 573
Pokorný, M., 963
Poláček, A., 1321
Poláček, M., 1007
Poláček, R., 221
Polák, M., 475, 1543
Polášek, M., 427
Polívka, M., 913, 983
Pollert, J., 439
Polsterová, H., 679
Ponížil, P., 573
Pospíšil, J., 865, 889, 953
Pospíšil, M., 159
Pospíšil, S., 109
Potůček, Z., 83
Poupová, E., 1225
Poušek, L., 1101
Požár, J., 585
Prax, P., 1267
Preclík, V., 1351
Procházka, I., 1011
Procházka, J., 953
Procházka, P., 519, 523, 525, 1497
Prokeš, A., 1019
Prokop, R., 163, 213
Prokopová, Z., 163, 213
Prošková, K., 639
Provazník, I., 1085, 1097
Průša, S., 117
Pruška, J., 479
Prušková, M., 1547
Přádka, M., 1033
Přech, P., 1101
Přeučil, L., 243
Přeučil, M., 817
Převorovská, S., 1075
Příhoda, J., 1081
Přikryl, P., 185, 423
Pultar, M., 197
Punčochář, J., 905, 907
Půst, L., 507
Půža, T., 1081

Quadrát, O., 449

Rafaj, J., 1391, 1393, 1401
Rais, K., 1529
Rajman, J., 635
Ramadan, M., 61
Reinisch, M., 657
Richter, I., 993
Ripka, P., 1087
Rónai, P., 1353
Rossel, H., 1315
Rothkrantz, L., 329
Rott, J., 1017
Roubíček, M., 1409
Roubíček, V., 1429, 1453
Roubík, K., 1091
Rovnaníková, P., 1373
Roztočil, J., 949
Rudolf, B., 1389, 1395
Rudolf, J., 903
Rusek, S., 825
Rusev, Z., 1505
Rusín, K., 655, 1411
Růžička, P., 1071
Růžička, Z., 1433
Rybín, J., 1397
Rybka, V., 639
Ryndová, A., 1287
Rypl, D., 467
Ryšavá, H., 1263
Rytíř, V., 1541
Ryzí, Z., 993

Řeřicha, P., 469
Říčný, V., 921
Říha, J., 433
Říha, Z., 1415
Říhová, M., 197
Římal, J., 547, 865

Sabol, J., 105, 107, 1229
Sadovský, Z., 1529, 1543
Sáha, P., 449, 647, 673, 675, 1525
Salyk, O., 165, 1261
Samek, J., 987
Samsonek, J., 1247
Santarius, P., 831
Satorie, M., 985
Saxlová, M., 589, 591
Sebök, T., 1247

Seborský, S., 841
Sedláček, M., 945
Sedlák, J., 1333
Sedlaríková, M., 579
Seidl, L., 917
Semerák, P., 45
Servít, M., 315
Schauer, F., 123
Schauer, P., 71
Schmeidler, K., 1329, 1331
Schmid, P., 617
Schröfel, J., 1005
Schulz, H.-J., 83
Schustr, P., 79
Schwarzer, J., 1291
Siegl, J., 561, 565
Sichrovský, P., 1037
Silber, R., 159
Silbrník, V., 1365
Skalický, J., 845, 847, 875
Sklenák, Š., 145
Sklenář, P., 429, 1273
Sklenka, Ľ., 1467, 1473, 1477, 1479, 1483
Skoumal, V., 885
Skrbek, M., 301
Slabý, P., 1499, 1501
Slavík, P., 291, 295, 299
Smatanová, M., 173
Smutná, J., 597
Smutný, J., 965
Smutný, L., 265
Smutný, V., 183
Sochor, M., 1053
Sokanský, K., 867
Sokol, Z., 527, 531
Sommer, L., 1335
Sopko, B., 1043
Souček, P., 1381, 1385
Soukup, P., 253
Soukup, V., 257
Spěváček, V., 1233
Spousta, J., 117
Spurný, F., 1041
Staněk, Z., 1295, 1297
Starý, O., 833
Starý, V., 663, 1055
Stejskal, V., 1071
Steuer, M., 329
Straka, M., 149
Strakoš, V., 1435
Stránský, K., 577
Stříbrský, A., 273
Střílka, T., 445
Studničková, M., 1371
Stuchlík, J., 575
Stupka, P., 423
Sturm, P., 259
Subodh, K., 1539
Suchánek, M., 1245
Suske, P., 1345
Sušická, Z., 1235, 1237
Sutner, O., 543
Svačina, J., 643, 971
Svirák, P., 1529
Svoboda, J., 925
Svoboda, T., 259
Swietlicki, E., 1217
Sýkora, J., 923, 975
Sýkora, P., 1395
Sýkorová, L., 1433
Synáčková, M., 1243, 1337
Sysala, T., 249
Szabó, Z., 1085
Szendiuch, I., 1033
Szromek, P., 603
Szturc, R., 235

Šácha, L., 835
Šálek, B., 1509
Šálek, J., 1235, 1237
Šaloun, P., 277
Šanda, M., 455
Šandera, P., 115, 573, 599
Šeba, P., 55
Šebesta, F., 155, 1227, 1259
Šebesta, V., 891
Šeda, M., 195
Šefrna, V., 1389, 1395
Šejnoha, J., 523, 1359, 1361
Šenk, J., 1309
Šíba, J., 1511
Šika, Z., 485, 487
Šikola, T., 117, 119

Šiková, P., 535
Šikula, J., 69, 71, 955
Šimák, B., 925
Šimák, J., 1091
Šimáně, Č., 151, 1083, 1461
Šimek, P., 287
Šimek, Z., 153, 157, 171
Šimoník, I., 1267
Šindlar, J., 1347
Šiňor, M., 125, 127
Škrdla, I., 1415
Škrkal, J., 1311
Škvor, Z., 897
Šlais, K., 147
Šlapal, J., 41
Šmarda, V., 835
Šmarda, Z., 27
Šmejkal, V., 1439
Šmíd, R., 1095
Šnorek, M., 303, 305, 329
Šob, M., 115
Šoch, M., 287
Šonovský, P., 1255
Šotkovský, R., 1279
Šourek, B., 447
Špinka, J., 1025
Šrámková, T., 121
Šrytr, P., 1283, 1337
Štamberg, K., 161, 1223, 1311
Štastná, P., 1063
Šťastná, P., 1431
Šťastník, S., 29, 619, 627
Šťastný, B., 1283
Šťastný, J., 839
Štefka, J., 879
Štecha, J., 247, 269
Štekl, I., 109
Štěpka, Z., 947
Štěpková, D., 911
Štětina, J., 671
Ševula, M., 545
Štikarová, J., 1507
Šťovíček, P., 55
Štrunc, M., 141
Štubňa, I., 121
Šuba, O., 677
Šulc, J., 435
Šumberová, P., 1541
Šupčík, J., 659
Šustai, O., 1303, 1305
Šustek, P., 1411
Švarc, P., 563
Švejcar, J., 597
Švejkovský, K., 439
Švorčík, V., 639

Tachecí, P., 1285
Talácko, J., 1395
Tater, M., 55
Tayari, J., 1037
Tecl, J., 1223
Teplý, B., 1373
Terzijski, I., 629
Tesař, V., 425, 443, 445, 453, 461
Tichopádek, P., 117
Tichý, J., 1077
Tisoň, P., 1535
Titěra, M., 945
Tlustý, J., 831
Tocháček, M., 483
Tolar, J., 55
Toman, J., 423, 551, 621
Toman, Z., 1255
Tománek, P., 1021, 1029
Tomaszewski, K., 97
Tomek, K., 1543
Toužín, J., 157
Trčková-Skořepová, J., 481, 517, 1051
Trdlička, J., 283
Trefný, M., 325
Trlica, J., 449, 673
Trojan, S., 1077
Trtík, K., 609, 611
Trubač, L., 79
Trunčík, M., 581
Třískala, M., 117
Tuček, K., 1469, 1471
Tuhovčák, L., 1325
Tůma, J., 499
Tůma, L., 119
Tutko, M., 949
Tvrdík, P., 283, 285, 287

Uhlíř, I., 827, 1077

Urban, M., 261
Urbánek, J., 1415, 1417, 1539

Vacek, F., 215
Vacek, J., 477
Vacek, V., 113
Vacula, V., 1463
Vaculín, O., 485
Vačkář, J., 1419, 1433, 1537
Vala, J., 29, 149
Valášek, M., 205, 485, 487
Válek, M., 523
Valenta, M., 335
Van den Berg, S., 1057
Vařenka, J., 1067, 1069
Vastl, J., 833
Vašek, V., 207, 249, 255
Vašíček, J., 833
Vašina, P., 69
Vávra, Z., 861
Vavřinka, M., 901
Včelová, H., 611
Vébr, L., 1491, 1503
Večeřa, M., 641
Vejražka, F., 917
Venkrbec, J., 671
Verburg, T., 1219
Věříš, J., 987
Veselá, M., 167
Veselý, J., 505, 1227
Veselý, M., 157
Vespalec, R., 171
Videcká, Z., 1537
Vichta, M., 237
Viktorin, F., 629
Vilímek, T., 1431
Vinš, M., 79
Víteček, A., 201
Vítečková, M., 203
Vítek, J., 865
Vítek, J. L., 539, 545, 547
Vítek, K., 517, 1051
Vítek, M., 833
Vítek, P., 539
Vlach, B., 575, 657
Vlček, J., 79
Vlček, M., 179
Vlček, T., 243
Vnouček, S., 837
Vobecký, J., 1039, 1041
Vodička, J., 609, 611
Vodvářková, L., 1481
Vognar, M., 107, 151, 1083, 1461, 1463
Volf, J., 481, 1051, 1491, 1495
Voltr, J., 1217, 1275
Vondrák, V., 489, 579
Vondruška, M., 1247
Vondřich, J., 493
Vopálka, D., 161, 1223
Vorel, I., 1327
Vorlíček, M., 1369
Vorlíček, Z., 497
Vortel, V., 1443
Vosáhlo, J., 1465
Vosátka, K., 317
Vospěl, Z., 865
Vosyka, J., 235
Voves, J., 1037
Vozár, L., 121
Voznica, P., 153, 157, 171
Vráblík, M., 1541
Vraný, T., 529
Vratislav, S., 81
Vrbová, M., 85
Vtípil, J., 1053
Vyčítal, J., 429, 451
Vydra, V., 865
Vymlátil, S., 73
Vytlačil, D., 553

Wald, F., 197, 527, 531
Waldmann, L., 239
Wang, L. G., 115
Weber, Z., 77, 87, 89, 139
Weiss, V., 631
Weiss, Z., 1305
Wendroff, B., 31
Werner, T., 261
Westman, E., 477
Wichterle, D., 1079
Wilfert, O., 1019
Willmann, B., 833
Wohlmuth, F., 823
Wolterbeek, H., 1219

Yoshihara, K., 85

Zábrodský, V., 1091
Zahradník, P., 179
Zajíc, J., 333
Zakopalová, K., 577
Záliš, K., 819, 821
Zapletal, J., 41
Zatloukal, J., 591
Závěšický, P., 913
Zdeněk, J., 857
Zdražil, V., 855
Zdražilová, B., 647, 675
Zehentner, J., 899
Zeithammerová, J., 1281, 1283
Zeman, J., 1467, 1469, 1471
Zeman, T., 925
Zeman, V., 957
Zemánek, P., 333, 999
Zemánková, A., 1491, 1493
Zemánková, H., 1349
Zezulka, F., 221
Zíb, A., 1481
Zicha, J., 111, 1015
Zimola, B., 1541
Zimová, R., 253
Zítek, P., 229
Zlámal, J., 117
Zlámal, P., 981
Zlatník, Č., 49
Zlochová, M., 1457
Znojil, M., 55
Zralý, M., 1531
Zýma, J., 1341

Žabičková, I., 1343
Žáček, J., 841
Žáček, M., 99
Žák, J., 517, 1051
Žalmanová, P., 1347
Ženíšek, P., 1399
Žídek, J., 989