

108104

JPRS 82914

22 February 1983

19981105 021

# USSR Report

ENGINEERING AND EQUIPMENT

No. 93

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<b>REPORT DOCUMENTATION PAGE</b>	<b>1. REPORT NO.</b> JPRS 82914	<b>2.</b>	<b>3. Recipient's Accession No.</b>
<b>4. Title and Subtitle</b> USSR REPORT: ENGINEERING AND EQUIPMENT, No. 93		<b>5. Report Date</b> 22 February 1983	
<b>7. Author(s)</b>		<b>6.</b>	
<b>9. Performing Organization Name and Address</b> Joint Publications Research Service 1000 North Glebe Road Arlington, Virginia 22201		<b>8. Performing Organization Rept. No.</b>	
<b>12. Sponsoring Organization Name and Address</b>  As above		<b>10. Project/Task/Work Unit No.</b>	
		<b>11. Contract(C) or Grant(G) No.</b> (C) (G)	
		<b>13. Type of Report &amp; Period Covered</b>	
<b>15. Supplementary Notes</b>		<b>14.</b>	
<b>16. Abstract (Limit: 200 words)</b>  The report contains articles, abstracts and news items on aeronautical, marine, mechanical, automotive, civil and industrial engineering, related research and development, and engineering materials and equipment.			
<b>17. Document Analysis a. Descriptors</b>  USSR Aeronautics Industrial Engineering Marine Engineering Stress Analysis Turbines Metrology  <b>b. Identifiers/Open-Ended Terms</b>  <b>c. COSATI Field/Group</b> 1A, 13H, 13J, 14B			
<b>18. Availability Statement:</b> Unlimited Availability Sold by NTIS Springfield, Virginia 22161		<b>19. Security Class (This Report)</b> UNCLASSIFIED	<b>21. No. of Pages</b> 89
		<b>20. Security Class (This Page)</b> UNCLASSIFIED	<b>22. Price</b>

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No. 93

CONTENTS

MARINE AND SHIPBUILDING

- Diesel Plants for Underwater Vessels  
(P. A. Gordeyev; SUDOSTROYENIYE, Oct 82)..... 1
- Steam Generator Operating on Thermally Softened  
Sea Water  
(L. I. Sen'; SUDOSTROYENIYE, Sep 82)..... 1

NUCLEAR ENERGY

- Indicator of Energy Distribution in Field of  
REMK-1000 Water-Graphite Channel Reactor  
(G. N. Aleksakov, S. A. Gavriilyuk,  
A. V. Kudryavtsev, G. P. Terekhov;  
ATOMNAYA ENERGIYA, Oct 82)..... 3
- Stability of Nuclear Reactor With Natural Circulation  
of Liquid Fuel  
(V. L. Blinkin, Ye. I. Yemel'yanov; ATOMNAYA  
ENERGIYA, Oct 82)..... 4
- Use of Nuclear Fuel for Covering Seasonal Peak  
Electric Load on Power System  
(V. M. Boldyrev, M. V. Sigal, S. A. Skvortsov;  
ATOMNAYA ENERGIYA, Oct 82)..... 4
- Ways of Reorganizing Fuel Cycle in VVER-400  
Water-Moderated Water-Cooled Reactor for Better Economy  
(V. D. Simonov, V. I. Pavlov, S. F. Popilyuk;  
ATOMNAYA ENERGIYA, Oct 82)..... 5
- Some Results of Parametric Analysis of Technical and  
Economic Indicators of Power Plant with 'TROL'  
Ambipolar Hybrid Fusion Reactor  
(N. N. Vasil'yev, I. N. Golovin, M. G. Kuznetsov;  
ATOMNAYA ENERGIYA, Oct 82)..... 6

Gas Distribution in Reactor with Pelletized Fuel Elements (A. S. Pushnov, I. I. Gel'perin, A. M. Kagan; ATOMNAYA ENERGIYA, Nov 82).....	6
Synthesis of System of Local Automatic Regulators for Power Reactors (I. Ya. Yemel'yanov, L. N. Podlazov, A. N. Aleksakov, Ye. V. Nikolayev, V. M. Panin, V. D. Rogova; ATOMNAYA ENERGIYA, Nov 82).....	7
Vibration-Shock Motion of Regulating Rods in Systems of Nuclear Reactor Control and Protection (A. I. Menyaylov; MASHINOVEDENIYE, Nov-Dec 82).....	8
Microprocessor-Based System with Distributed Structure for Nuclear Electric Facility Radiation Monitoring (A. A. Denisov, V. S. Zhernov, I. S. Krasheninnikov, V. V. Matveyev, N. V. Ryzhov, V. M. Skatkin; ATOMNAYA ENERGIYA, Sep 82).....	8
Monitoring Radionuclide Propagation Through Process Channels of Nuclear Electric Facility (V. L. Antonov, A. A. Gruzdeva, V. S. Zhernov, S. K. Kozlov, O. B. Lapshev, V. V. Matveyev, V. V. Pushkin, M. K. Romanichev, A. Ye. Shermakov, Ye. P. Vargin, L. P. Drozdova; ATOMNAYA ENERGIYA, Sep 82)...	9
Axial and Radial Distribution of Flux Density and Hardness of Neutron Spectrum in Fuel Assemblies of VVER-365 and VVER-440 Reactors (B. A. Bibichev, V. P. Mayorov, V. D. Sidorenko, P. I. Fedotov; ATOMNAYA ENERGIYA, Sep 82).....	9
Promising Water Chemistries for Nuclear Electric Plants with VVER and RBMK Reactors (A. P. Mamet, V. A. Mamet, V. I. Pashevich, P. N. Nazarenko; ELEKTRICHESKIYE STANTSII, Jul 82).....	10
Accumulation of $^{233}\text{U}$ With Predetermined $^{232}\text{U}$ Content Upon Exposure of Thorium in VVER Power Reactor (A. A. Polyakov, V. P. Rukhlo, Yu. Ye. Titarenko, S. F. Komin; ATOMNAYA ENERGIYA, Aug 82).....	11
NON-NUCLEAR ENERGY	
Heat Pipe for Paraboloidocylindrical Solar Power Plant (I. I. Kokhova, V. Ya. Sasin, A. A. Borodkin, S. F. Ergashev; GELIOTEKHNIKA, Jul-Aug 82).....	12
Heat Storage Systems for Solar Electric Power Plants (R. B. Akhmedov, M. Ye. Voronkov, V. A. Pozharnov, V. M. Chakovskiy; GELIOTEKHNIKA, Jul-Aug 82).....	13

Production and Some Properties of Photovoltaic Cells Based on Layers of Polycrystalline Silicon (M. S. Saidov, Z. N. Alad'ina, R. Aliyev, V. P. Chirba; GELIOTEKHNIKA, Jul-Aug 82).....	14
Solar Cells Based on Polycrystalline CdTe (S. A. Azimov, Sh. A. Mirsagatov, S. A. Muzafarova; GELIOTEKHNIKA, Jul-Aug 82).....	15
Photovoltaic Cells Based on InP/CdS Heterostructure (E. S. Baleka, E. V. Gilan, L. V. Gorchak, A. D. Kitoroaga, A. G. Cheban; GELIOTEKHNIKA, Jul-Aug 82)...	16
Photovoltaic Solar Cells Based on 'Degenerate Semi- conductor - Semiconductor' P-N Heterojunctions (S. Yu. Pavelets; GELIOTEKHNIKA, Jul-Aug 82).....	16
Equations of Motion for Heliostats in Tower-Type Solar Electric Power Plant (M. N. Kachanovskiy, V. M. Dubilovich; GELIOTEKHNIKA, Sep-Oct 82).....	17
Heat Storing Devices for Solar Electric Power Plants (V. I. Gudkov, K. N. Chakalev; GELIOTEKHNIKA, Sep-Oct 82).....	18
Tests of Power Module of Paraboloido-Cylindrical Solar Heating Plant (B. V. Arnizhevskiy, I. I. Kokhova, S. N. Aliyev, V. A. Samoylov, S. F. Ergashev; GELIOTEKHNIKA, Sep-Oct 82)..	18
Particulars of Designing and Making Controlled Reactor with Three-Dimensional Magnetic Circuit (M. L. Pil'ch, U. Sh. Galimbayev; ENERGETIK, Jul 82).....	19
Facility for Heating Power Transformers and Reactors (N. M. Nikitin, V. I. Sidorov, V. G. Sorokin, V. Ye. Gunner; ENERGETIK, Jul 82).....	20
Method of Synchronizing Wind Turbine Electric Generator With Powerful Energy System (V. V. Sidorov; ELEKTRICHESKIYE STANTSII, Jul 82).....	20

#### INDUSTRIAL TECHNOLOGY

Frequency Analysis of Regular Vibratory Systems in Mechanisms with Programmed Translatory Motion of Common Driven Member (I. I. Vul'fson; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE; Nov 82).....	22
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	----

Technology of Producing Linear-Displacement Gas Bearings (A. A. Rodin, V. V. Arkhipov, N. K. Balatsenko, D. D. Serebrov; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Jun 82).....	22
New Models of Industrial Robots in Action (L. I. Andreyeva; VESTNIK MASHINOSTROYENIYE, Jul 82).....	23
Pneumatic Measuring Systems for Industrial Robots (V. G. Gradetskiy; VESTNIK MASHINOSTROYENIYA, Jul 82).....	24
New Light-Beam Devices for Automatic Control of Machines (S. T. Tsukkerman; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE Oct 82).....	24
Dynamic Loading of Manipulation and Tilter Mechanisms in Blooming Mill 1000 (G. M. Chitorelidze, D. A. Sharashenidze; SOOBSHCHENIYA AKADEMII NAUK GRUZINSKOY SSR, May 82).....	25
Mechanism Simulating Motion of Eye Axes (P. M. Dimentberg, Yu. L. Sarkisyan; MASHINOVEDENIYE, Nov-Dec 82).....	26
Parametric Optimization of Nonlinear Vibration Isolation Systems with Aid of Multidimensional Fourier Transformation (A. V. Sinev; MASHINOVEDENIYE, Nov-Dec 82).....	26
Dependence of Complex Resonance Modes in Highly Nonlinear Vibration Systems on Amplitude of External Perturbation (B. I. Kryukov, G. I. Seredovich; MASHINOVEDENIYE, Nov-Dec 82).....	27
Theory of Optimal Control of Hydraulic Damper Based on Model of Compressible Fluid (A. S. Rivkin; MASHINOVEDENIYE, Nov-Dec 82).....	27
Calculating Unsteady Temperature Field of Rubber Bearing With Longitudinal Lubricating Grooves (A. A. Abayev, Yu. R. Osipov, A. N. Shvetsov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE, Oct 82).....	28
Influence of Friction Forces in Engagement on Transverse Oscillations of Gears (Ye. I. Podzharov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE, Oct 82).....	29
Determining Parameters of Two-Cylinder Lever Manipulator (V. V. Vatolin, V. V. Terekhov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE, Oct 82).....	29

Outlook for Automating Plasma Sputtering by Using  
Industrial Robots and Microcomputers  
(A. N. Kosolapov, M. A. Aliyev; IZVESTIYA  
VYSSHIKH UCHEBNYKH ZAVEDENIYE: MASHINOSTROYENIYE,  
Aug 82)..... 30

Influence of Piston and Slide-Valve Seals on Vacuum  
Pump Operation  
(V. S. Yedemskiy; IZVESTIYA VYSSHIKH UCHEBNYKH  
ZAVEDENIY: MASHINOSTROYENIYE, Sep 82)..... 30

#### TURBINE AND ENGINE DESIGN

Experience With Improvement of Centrifugal Compressor  
(B. G. Shkol'nikov; S. M. Metallikov, I. A. Gurvich,  
Yu. V. Byvshev; ENERGO MASHINOSTROYENIYE, Oct 82)..... 32

Increased Vibration Resistance of Model K-300-240 LMZ  
(Leningrad Metal Works) Turbines  
(O. A. Lupolo, V. F. Bystrov; ENERGETIK, Oct 82)..... 33

Rotary Liquid-Sleeve Vacuum-Type Compressor With Load  
Reliever Bushing  
(V. D. Dubenets, A. I. Chernykh, V. I. Kucherenko;  
IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY:  
MASHINOSTROYENIYE, Nov 82)..... 33

Centrifugal Supercharger with Arcuate Intermediate Blades  
(Yu. I. Petrov, V. A. Kostomarov; SUDOSTROYENIYE, Nov 82)... 34

Resultant Characteristics of Velocity Stages in Supersonic  
Turbines Under Variable Operating Conditions  
(A. M. Topunov, B. A. Tikhomirov, A. G. Genov;  
SUDOSTROYENIYE, Oct 82)..... 34

Tuning Out Natural Vibration Frequencies of Compressor  
Blades for Gas Turbine Engines by Method of  
Successive Optimization  
(A. B. Roytman, V. P. Afanas'yev, T. F. Mikhaylova,  
S. P. Omel'chenko; PROBLEMY PROCHNOSTI, Jul 82)..... 35

Stressed State of Elements of Turbomachine Blades  
With Holes for Banding  
(V. P. Sukhinin, I. B. Vol'kovich, E. V. Lukina,  
V. A. Malyar; PROBLEMY PROCHNOSTI, Jul 82)..... 36

Theoretical Substantiation of Characteristics of  
Intermediate Superheat in Turbine Sets in AES  
(V. A. Khrustalev, V. A. Ostapenko, B. A. Arkad'yev,  
V. I. Fomenko; TEPLOENERGETIKA, Nov 82)..... 36

Performance of Evaporator in K-500-65/3000 Turbine Set in Chernobyl'sk AES (Ye. K. Golubev, Ye. Ye. Glazov, T. G. Plokhii, V. K. Bronnikov, B. F. Vakulenko, V. S. Mikhaylov; TEPLOENERGETIKA, Nov 82).....	37
Dynamic Calculation of Rotary-Piston Compressors (B. G. Nekhoroshev; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE, Sep 82).....	38
Pneumatic Fuel Injector for Gas-Turbine Engines (A. I. Melenchuk; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE, Sep 82).....	38
NAVIGATION AND GUIDANCE SYSTEMS	
Nonlinear Systems Representing Superposition of Gyrostats (A. B. Glukhovskiy; DOKLADY AKADEMII NAUK SSSR, Oct 82).....	39
Electronic Method of Stabilizing Directivity of Hydroacoustic Antennas During Rocking (S. P. Petrov; SUDOSTROYENIYE, Nov 82).....	39
Navigation Systems With Hydroacoustic Beacons (G. E. Smirnov, N. A. Tolstyakova; SUDOSTROYENIYE, Oct 82)..	40
Procedures for Determining Transfer Functions of Nonlinear Systems on Basis of Newton-Kantorovich Method (V. R. Snurnitsin, R. T. Sulaymanov; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE, Oct 82).....	41
Structural-Parametric Synthesis of Nonlinear Control System According to Prescribed Motion (S. Ye. Dushin, D. Kh. Imayev, S. S. Moiseyev; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE, Oct 82).....	41
Accuracy of Synthesis of Approximately Optimum Control for Nonlinear Object (Ye. Ye. Aleksandrov, M. V. Trigub; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE, Oct 82).....	42
Selection of Optimum Correction Characteristic for Vertical Gyro From Computer Printouts (M. A. Sergeyev; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE, Jun 82).....	42
Method of Determining Natural Frequencies of Gyromotor From Parameters of Its Vibration (A. Yu. Belyayev, V. Ye. Petrenko, Yu. V. Radysh; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE, Jun 82).....	43

Use of Bi-Oscillatory Scheme in Float-Type Cyroscopic Devices (V. M. Pankratov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE, Jun 82).....	44
Selecting Weight Factors in Problems of Optimum Damping of Elastic Wing Oscillations (T. K. Sirazetdinov, I. Kh. Khalitov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, Apr-Jun 82).....	44
Applying Phase Biplane Method to Stability Study of Spacecraft With Rotary Control System (Yu. N. Pavlov, L. V. Severova; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, Apr-Jun 82).....	45
Dynamics of Nonlinear Gyro Systems With Polyharmonic and Random Base Oscillations (N. V. Butenin, A. M. Lestev; IZVESTIYA VYSSHIKH ZAVEDENIY: PRIBOROSTROYENIYE, Aug 82).....	45
Influence of Rotor Radius on Accuracy of Electrostatic Gyroscope in Cardan Suspension (Yu. G. Martynenko, A. V. Koretskiy; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE, Aug 82).....	46

HIGH-ENERGY DEVICES, OPTICS AND PHOTOGRAPHY

Technology of Concentrator Assembly From Mirror-Glass Elements (G. Ya. Umarov, D. N. Alabutdinov, A. Abduzizov, A. Abdullayev, A. K. Alimov; GELIOTEKHNIKA, Jul-Aug 82).....	47
Magnetically Controlled Vacuum-Tube Displacement-To-Pulse Converter (N. M. Bondar'; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE, Oct 82).....	48
Optical Image Synthesizer With Magnetolectric Light Modulator (L. V. Gavrilov, A. G. Korobov, G. P. Pominov, Yu. V. Fedorov, V. V. Khvalovskiy; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE, Jun 82).....	48
Automatic Focusing in Single-Mirror Two-Dimensional Laser-Mirror Scanners (A. L. Il'in, B. S. Rozov, P. I. Savostin; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE, Jun 82).....	49

Investigation of Parabolic Glass-Ceramic Astronomical Mirror Working Surface Quality (D. T. Puryayev, V. A. Gorshkov, O. N. Fomin, V. G. Lysenko; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Aug 82).....	50
Method for Automatic Compensation of Geometric Distortions in Astronomical Television Equipment (V. A. Kachmin, Yu. A. Seliverstrov; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Aug 82).....	50
Optical Goniometric Systems of Multiplier Type (P. A. Mikheyev; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Aug 82).....	51
Mechanism of Ion Acceleration in Laser Plasma (A. Sh. Abdullayev, A. A. Asrorov, A. A. Frolov; (DOKLADY AKADEMII NAUK TADZHIKSKOY SSR, Apr 82).....	52
Formation of Fine-Structure Image by Corner Reflectors Operating on Total Internal Reflection Principle (G. V. Denisyuk, V. I. Korneyev; OPTIKO- MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	52
Evaluating Parameters of Shadow Instruments With Photoelectric Information Conversion (A. S. Avramenko, T. M. Bezdudnyaya, E. Yu. Durovich, E. I. Krasovskiy; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	53
Mathematical Modeling of Geometric Shape of Polyhedral Fiber-Optics Components (N. I. Isayev, I. A. Shirkova; OPTIKO- MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	54
Optical Schemes of Laser Scanning Devices (L. A. Markova, V. P. Mikheyev, B. S. Rozov, P. I. Savostin; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	54
Studying Gain of Electron Flux in Microchannel Plate (Ye. P. Semenov; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	55
Automated Goniometer Based on Ring Laser (A. I. Vanyurikhin, I. I. Zaytsev; OPTIKO- MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	55

FLUID MECHANICS

Mathematical Modeling of Gas Dynamic Processes at Gate Valve in Reciprocating Compressor  
(G. A. Baryshnikov, V. P. Levshin; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE, Nov 82)..... 56

Penetration of Thin Cylinder With Thin Nose Cone Into Ponderable Fluid  
(S. G. Avagyan; IZVESTIYA AKADEMII NAUK ARMYANSKOY SSR: MEKHANIKA, Jul-Aug 82)..... 57

Diffraction of Acoustic Wave by Plate Moving Near Plane  
(Ye. A. Krasil'shchikova; DOKLADY AKADEMII NAUK SSSR, Aug 82)..... 57

Investigation of Aerodynamic Characteristics of Diamond-Shaped Wing Vibrating Translationally in Supersonic Flow  
(A. N. Varnavskiy; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA, Apr-Jun 82)..... 58

Investigation of Wing Vortex Schemes  
(V. I. Men'shikov, M. M. Ovcharov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA, Apr-Jun 82)..... 59

Interaction of System of Jets Incident on Flat Obstacle  
(V. V. Startsev, N. I. Syromyatnikov, A. M. Poletayev; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA, Apr-Jun 82)..... 59

MECHANICS OF SOLIDS

Resonance Vibrations of Rotors at High Speeds  
(V. B. Bal'mont; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE, Nov 82)..... 60

Stressed and Strained State of Triple-Layer Beam Under Longitudinal Impulse Load  
(V. N. Kobelev, V. U. Kotel'nikov, A. A. Zholudev, V. V. Deryushev; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE, Nov 82)..... 60

Effect on Initial Loss of Shape on Natural Vibration Frequencies of Reinforced Conical Shells  
(S. Yu. Fialko; PRIKLADNAYA MEKHANIKA, Nov 82)..... 61

Stability of Flexible Shallow Shells of Rectangular Planform Under Thermal Shock (V. A. Krys'ko, P. B. Fedorov; PRIKLADNAYA MEKHANIKA, Nov 82).....	62
Numerical Analysis of Wave Processes in Composite Shell-Beam Structures (V. I. Patsyuk, G. A. Ryabkova, P. F. Sabodash; (PRIKLADNAYA MEKHANIKA, Nov 82).....	62
Stresses State of Laminate-Wound Cylindrical Shell With Friction (L. A. Il'in, N. A. Lobkova; PRIKLADNAYA MEKHANIKA, Nov 82).....	63
Effective Coefficients of Non-Coulomb Dry Friction Under Vibration (G. Ya. PANOVKO, I. N. Tskhakaya; SOOBSHCHENIYA AKADEMII NAUK GRUZINSKOY SSR, May 82).....	63
Factor Favorable to Occurrence of Vibrations With Traveling Strain Waves in Cyclically Symmetric Systems (N. P. Aleshin; PROBLEMY PROCHNOSTI, Jul 82).....	64
Experimental Determination of Stresses in Layers of Multilayer Reeled Shell (M. I. Burak; PROBLEMY PROCHNOSTI, Jun 82).....	65
Design of Reeled Multilayer Cylinder for Equal Strengths of Turns (A. F. Bezverbnyy; PROBLEMY PROCHNOSTI, Jun 82).....	65
Design of Thin-Walled Pressure Vessels for Resistance to Fracture (V. P. Shirshov; PROBLEMY PROCHNOSTI, Jun 82).....	66
Effect of Different Tensile and Compressive Resistances of Nonlinearly Elastic Material to Stress and Strain in Cylindrical Shell (A. F. Makeyev, I. G. Ovchinnikov; PROBLEMY PROCHNOSTI, Jun 82).....	66
Stability of Multilayer Cylindrical Shells Made Up of Orthotropic Layers (K. A. Abdulkhakov, S. B. Cherevatskiy; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, Apr-Jun 82).....	67
Calculation of Spherical Shell With Inversely Symmetric Loading (I. S. Akhmed'yanov; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, Apr-Jun 82).....	68

Some Particulars of Loss of Stability of Ribbed Cylindrical Shells (S. N. Kan, Yu. I. Kaplan, V. I. Ostrovitskiy; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, Apr-Jun 82).....	68
Solution of Thermoelastic Problem for Arbitrarily Shaped Shell of Revolution (V. V. Kuz'min; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, Apr-Jun 82).....	69
Bending of Plates and Shells With Variable Stiffness (V. A. Krys'ko, V. V. Bochkarev; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE, Sep 82).....	69
Deriving Canonical Equations for Multilayered Shells of Revolution Made of Materials With Nonlinear Elasticity (B. G. Popov; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE, Sep 82).....	70
Carrying Capacity of Spherical Sandwich Shells Under Dynamic Loading (V. U. Kotel'nikov, V. N. Kobelev; IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE, Sep 82).....	70
Principles of Method of Calculating Permissible Imbalances From Modes of Vibrations of Flexible Rotors (V. N. Barke, I. E. Krantsberg; VESTNIK MASHINOSTROYENIYE, Aug 82).....	71
Controlled Speedup of Unbalanced Rotor Through Critical Velocity (A. P. Zobnin, L. M. Malinin, D. B. Tanayev; VESTNIK MASHINOSTROYENIYE, Sep 82).....	72

#### TESTING AND MATERIALS

New Stainless Steels for Atomic Power Equipment (I. R. Kryanin, A. V. Ryabchenkov, V. I. Gerasimov, I. L. Kharina; ENERGOMASHINOSTROYENIYE, Oct 82).....	73
Pneumatic Instrument for Measuring Radii of Lenses (V. P. Zakharov, V. M. Kravchuk, A. V. Perov, V. I. Shevelev; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', Jun 82).....	74

New Microalloy Steels for Large Propeller Shafts (V. S. Pestov, B. A. Osminin, G. N. Filimonov; SUDOSTROYENIYE, Oct 82).....	74
Use of Magnetic Systems for Increasing Efficiency of Electron-Beam Bombardment of Cylindrical Objects (L. L. Akrachkova, N. K. Kuksanov, R. A. Salimov, Yu. N. Timko, E. E. Finkel'; ATOMNAYA ENERGIYA, Nov 82).....	75
Effect of Ultrasonic Treatment on Flexural Stains in Plates Made of D16 and V95 Aluminum Alloys (G. Ya. Bazelyuk, A. M. Lyubchik, S. Ya. Matsiyevskaya, G. A. Petrunin, L. V. Tikhonov; PROBLEMY PROCHNOSTI, Jun 82).....	75
Experimental Facility for Studying Kinematic Accuracy of Devices for Motion Conversion in High Vacuum (S. G. Borisov, S. N. Istomin, M. I. Nekrasov; VESTNIK MASHINOSTROYENIYA, Sep 82).....	76
Antistatic and Abrasion-Resistant Coating for Polymer Optical Components With Complex Surface Profile (G. A. Aleksandrov, N. Z. Khaliullina, V. V. Polezhayev, N. P. Anokhina; OPTIKO- MEKHANICHESKAYA PROMYSHLENNOST', Sep 82).....	77

MARINE AND SHIPBUILDING

UDC 621.436(204.1):629.127.4

DIESEL PLANTS FOR UNDERWATER VESSELS

Leningrad SUDOSTROYENIYE in Russian No 10, Oct 82 pp 19-23

GORDEYEV, P. A.

[Abstract] Diesel plants such as HIRUP-30 and HIRUP-30E developed for underwater vessels by the Hitati Shipbuilding and Engineering Co Japan over the 1971-78 period incorporate several features covered by 46 patents (including US, UK, FRG and Italian ones). These pertain to recirculation of combustion products, controlled oxygen feed, removal of carbon dioxide through absorption (use of sea water as absorber being particularly promising) or through liquefaction, solar heating of the electrolyzer for hydrogen generation for a hydrogen engine. The main performance characteristics of these diesel plants, in terms of energy output per unit of fuel and fuel cost per unit energy output, compare favorably with those of other types of power plants for underwater application. Figures 5, table 1, references 10 Western.  
[89-2415]

UDC 629.12.03-8:621.181.647

STEAM GENERATOR OPERATING ON THERMALLY SOFTENED SEA WATER

Leningrad SUDOSTROYENIYE in Russian No 9, Sep 82 pp 19-21

SEN', L. I.

[Abstract] An analysis is made of characteristics of a steam-raising unit that operates on sea water as determined by the ratio of working and heating steam pressures, thermal capacities of the steam generator circuits, and also the specific water content of the deaerator-reactor, the relative water productivity of the facility, flowrates of working fluids, multiplicity of evaporation of feed water in the salt-water circuit of the steam generator, and the overall multiplicity of evaporation of sea water in the facility. The mixer receives sea water and some of the purged solution from the salt-water circuit of the steam generator, as well as heating steam from the high-pressure circuit. The heated water goes to the deaerator-reactor for thermal softening

and outgassing. The softened feed water then goes to the salt-water circuit of the steam generator where steam is evaporated from it. The concentrate is continuously scavenged from the steam generator, and part of it is wasted. Experimental operation shows that the unit works reliably on concentrated sea water with high magnesium hardness. Figures 4, references 4 Russian.  
[41-6610]

NUCLEAR ENERGY

UDC 681.518:53.083.94

INDICATOR OF ENERGY DISTRIBUTION IN FIELD OF REMK-1000 WATER-GRAPHITE CHANNEL REACTOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No. 4, Oct 82 (manuscript received 2 Jun 81) pp 263-265

ALEKSAKOV, G. N., GAVRILYUK, S. A., KUDRYAVTSEV, A. V. and TEREKHOV, G. P.

[Abstract] An energy distribution indicator has been developed for monitoring the field in a RBMK-1000 MW water-graphite channel reactor on a television screen. This "Poleskop-5" instrument reconstructs the continuously distributed energy field in the reactor core from readings of discretely distributed sensors. The latter are placed equidistantly at nodal points of a 13x12 grid at the reactor core, the kinescope screen being correspondingly divided into 13 horizontal and 12 vertical stripes. The brightness of each of the 13x12 rectangles is modulated by signals coming from the corresponding sensor. The instrument contains a commutator, a video channel with shaper (full signal, deflection signal, reference stripes), amplifier, and control, a synchronizing channel with generator (kipp oscillator) and amplifier, two stripe decoders (vertical, horizontal), and a frequency divider for control signals. The modulation characteristics of the channels are determined with equal controllable voltages applied to all inputs. They are identical, within 3%, for all sensors. The measurement error does not exceed 0.5%, based on the threshold of brightness contrast. The instrument has been installed for pilot operation in the Kursk AES. The authors thank Yu. N. Filimontsev, O. F. Safronov and V. A. Shchigolev, all representing the Kursk AES, for support and assistance in building and testing the "Poleskop-5" instrument. Figures 2.  
[44-2415]

## STABILITY OF NUCLEAR REACTOR WITH NATURAL CIRCULATION OF LIQUID FUEL

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 4, Oct 82 (manuscript received 4 May 82) pp 261-263

BLINKIN, V. L. and YEMEL'YANOV, Ye. I.

[Abstract] A thermal reactor is considered in which liquid nuclear fuel, also serving as coolant, circulates through the core in channels surrounded by moderator (graphite). For analysis of the reactor dynamics, its physical model is described as a multipoint system with lumped parameters in each core segment. Thermal feedback is characterized by two temperature coefficients of reactivity, one with respect to fuel temperature and one with respect to moderator temperature. The corresponding system of first-order differential equations, two equations of neutro kinetics, three equations of heat transfer, and one equation of mass transfer, are solved by the method of D-partitions in the plane of two parameters (temperature coefficients of reactivity) for the purpose of stability analysis "in the small". Calculations, by way of linearization and Laplace transformation, yield the curve which separates the stability regions from those of aperiodic instability and oscillatory instability in that plane, a negative power coefficient of reactivity being the necessary condition for stability. Typical numerical results are shown for two reactors, VTZhSR (high-temperature molten-salt reactor, USSR) and MSBR-1000 (molten-salt breeder reactor, US), indicating their operating points relative to natural-circulation and forced-circulation lines. Figures 2, references 5: 4 Russian, 1 Western.

[44-2415]

UDC 621.31:621.311.2:621.039

## USE OF NUCLEAR FUEL FOR COVERING SEASONAL PEAK ELECTRIC LOAD ON POWER SYSTEM

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 4, Oct 82 (manuscript received 3 Dec 81) pp 218-222

BOLDYREV, V. M., SIGAL, M. V. and SKVORTSOV, S. A.

[Abstract] Three alternatives of covering seasonal peak electric load in regional power systems are analyzed comparatively. In one scheme nuclear fuel is used for both generating heat and driving bleeder turbines to cover the peak load, in two other schemes fossil fuel is used for driving condensation turbines to cover the peak load and nuclear fuel is used for either generating heat or that and driving condensation turbines to cover the normal load. The relative merits of ATETs' with condensation turbines and ATETs' with bleeder turbines are taken into consideration, the latter being less versatile but preferable ecologically. An operational cost analysis is made base on a VK-500 MW water-channel reactor and a VVER-1000 MW water-moderated water-cooled power

reactor, with reference to a typical seasonal demand curve for the central region in the European part of the USSR. The results indicate that an ATETs with bleeder turbines can be cost effective and also save extra fossil fuel. Figures 2, references 5: 4 Russian, 1 Western.  
[44-2415]

UDC 621.039.003:621.039.516

WAYS OF REORGANIZING FUEL CYCLE IN VVER-440 WATER-MODERATED WATER-COOLED REACTOR FOR BETTER ECONOMY

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 4, Oct 82 (manuscript received 11 Jan 82) pp 213-218

SIMONOV, V. D., PAVLOV, V. I. and POPILYUK, S. F.

[Abstract] The fuel cycle in VVER-440 MW water-moderated water-cooled reactors, now based on addition of fresh fuel once a year for average 7000 effective hours of operation, is analyzed in search of ways to improve the overall fuel economy. Most promising are two ways to achieve this without changes in reactor design or degradation of physical reactor characteristics. One way would be to raise the level of fuel enrichment ( $U^{235}$ ) from the present 2.4% in 84 element and 3.6% in 31-26 elements, without otherwise modifying the conventional base cycle. This can be done without technical difficulties. The other way, technically more problematic, would be to depart from some conventional but not always mandatory requirements as to frequency of reactor recharges and permissible fuel depletion level. More economical is found to be a tradeoff with enrichment of makeup fuel to an average 3.20-3.21% level, adjusted to match both reactor core geometry and reactor recharge frequency on basis of triennial operating periods, and partial departure from present constraints. The relative advantage of these methods are weighed in relation to the coefficient of installed power utilization, which is now usually below 0.8 but could be as low as 0.5-0.6 and then make simple fuel enrichment more advantageous. The authors thank V. A. Sidorenko for interest in this study and A. N. Novikov for helpful discussion of problems. Tables 2, references 12 Russian.  
[44-2415]

## SOME RESULTS OF PARAMETRIC ANALYSIS OF TECHNICAL AND ECONOMIC INDICATORS OF POWER PLANT WITH 'TROL' AMBIPOLAR HYBRID FUSION REACTOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 4, Oct 82 (manuscript received 4 May 82) pp 211-213

VASIL'YEV, N. N., GOLOVIN, I. N. and KUZNETSOV, M. G.

[Abstract] Technical and economic performance characteristics of a TROL ambipolar hybrid reactor with open plasma traps and with plutonium-producing uranium blanket have been analyzed parametrically, with cost of 1 g Pu production minus worth of also generated electric energy as characteristic but not necessarily absolute criterion function. Calculations were based on the plasma-physical model of such a reactor, taking into account nonuniformity of plasma density distribution in locking traps and three critical cost items (cost of blanket per meter of length, cost of superconducting magnet system per kA·m, cost of injection system per kilowatt of beam power at given current level) as well as physical and technological design constraints. The evaluation problem was formulated as one of minimizing the criterion function, with any one parameter stipulated as deterministic quantity and with several values successively assigned to the anomaly coefficient, then solved by the alternating direction method with use of penalty functions. The results are compared with those for a TMHR tandem mirror hybrid reactor with thorium blanket. They indicate that TROL reactors are uneconomical even with classical plasma traps and will remain so, unless plasma confinement can be improved significantly by such means as "thermal barriers" used in TMX-U, TARA, MFTF-B reactors (United States) and GAMMA-10 reactors (Japan). Figures 2, tables 1, references 8: 3 Russian, 5 Western.  
[44-2415]

UDC 66.023:661.566:533.608

## GAS DISTRIBUTION IN REACTOR WITH PELLETIZED FUEL ELEMENTS

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 5, Nov 82 (manuscript received 10 Oct 80, final edition received 22 Feb 82) pp 320-321

PUSHNOV, A. S., GEL'PERIN, I. I. and KAGAN, A. M.

[Abstract] A uniform gas distribution in reactors with fuel pellets can be achieved by artificially increasing the hydraulic drag at the walls or by varying the cross sections of gas dispenser and collector along the path. An experimental study was made to determine the optimum slope angle of baffles forming the dispenser and collector channels. Tests were performed under isothermal conditions, with the gas flowing along a Z-path. The slope angle was varied from 0 to 6°, and the layer of 3-5 mm pellets in the cassette was 95 mm high. Velocity profiles were measured along the cassette, also pressure

drop and temperature. The data, evaluated and compared with results of other similar studies, indicate that the least nonuniform gas distribution is achieved with a baffle slope angle of  $4^\circ$ . The nonuniformity factor also decreases with increasing loss of pressure head or Euler number. The results can be used for estimating the nonuniformity of the temperature field in the reactor. They can also be used for developing design methods. Figures 5, references 8: 5 Russian, 3 Western.  
[91-2415]

UDC 621.039.515

#### SYNTHESIS OF SYSTEM OF LOCAL AUTOMATIC REGULATORS FOR POWER REACTORS

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 5, Nov 82 (manuscript received 30 Dec 81) pp 301-305

YEMEL'YANOV, I. Ya., PODLAZOV, L. N., ALEKSAKOV, A. N., NIKOLAYEV, Ye. V., PANIN, V. M. and ROGOVA, V. D.

[Abstract] A system of local automatic regulators is required for reliable operation of large power reactors, specifically water-graphite channel reactors with inherent space-dynamic instability of the energy distribution over the reactor core. An engineering method of synthesizing such a system is described which aims not only at minimizing the necessary number of components but also to ensure, without dynamic errors, zero amplitude deviations of specific low-order harmonics in that energy distribution and to ensure, with the aid of compensating rods, automatic programmed power dumping with subsequent stabilization at the new power level. The synthesis proceeds in two stages. First comes analysis of the steady-state performance, on the basis of a linearized model of the reactor space dynamics. There follow calculations of the transient-state performance, on the basis of response to a unit-step perturbation, and optimization of the transducer array in the given configuration of rods. The calculations include also energy field dynamics in the reactor with local automatic regulation devices installed. Figures 5, references 6 Russian.  
[91-2415]

## VIBRATION-SHOCK MOTION OF REGULATING RODS IN SYSTEMS OF NUCLEAR REACTOR CONTROL AND PROTECTION

Moscow MASHINOVEDENIYE in Russian No 6, Nov-Dec 82 (manuscript received 28 Aug 81, after completion 16 Mar 82) pp 20-25

MENYAYLOV, A. I., Moscow

[Abstract] Parametric vibrations and shock motion of regulating rods driven by stepper motors in nuclear reactor control and protection systems are analyzed for existence of stability regions. On the basis of design and experimental data, the model of such a rod is an inverted double pendulum with elastic springs hinged between symmetric limiters, kinematically excited at the lower bearing. The equation of motion for the corresponding mechanical system with unilateral couplings is solved upon removal of the infinite discontinuities by a special change of variables. Resonance frequencies are found in the shock region as well as in the shockless region. The stability test is based on the Routh-Hurwitz criterion in the frequency domain and in the phase plane. Figures 4, references 11: 10 Russian, 1 Western.  
[92-2415]

UDC 621.317.794+621.039.564

## MICROPROCESSOR-BASED SYSTEM WITH DISTRIBUTED STRUCTURE FOR NUCLEAR ELECTRIC FACILITY RADIATION MONITORING

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 3, Sep 82 pp 131-138

DENISOV, A. A., ZHERNOV, V. S., KRASHENINNIKOV, I. S., MATVEYEV, V. V., RYZHOV, N. V. and SKATKIN, V. M.

[Abstract] An examination is made of questions of developing radiation monitoring systems for nuclear electric facilities with emphasis on the problem of real-time radiation monitoring, and it is shown that this problem can be solved by using microprocessors and microcomputers, and by distributing functions with respect to the levels of a subsystem. The structure of the proposed system is based on singling out the most independent parts of the problem to be solved, and on introducing hierarchically ordered levels of job handling. Microprocessor base modules are proposed for handling data from detector units. Data gathering stations are distributed over the territory of the nuclear facility and its environs, and are interconnected by a data transmission channel through which the information goes to a computer-equipped central monitoring room. The paper describes algorithms for data processing and transmission, and also display formats. Figures 6, references 6: 4 Russian, 2 Western.  
[35-6610]

MONITORING RADIONUCLIDE PROPAGATION THROUGH PROCESS CHANNELS OF NUCLEAR  
ELECTRIC FACILITY

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 3, Sep 82 pp 138-143

ANTONOV, V. L., GRUZDEVA, A. A., ZHERNOV, V. S., KOZLOV, S. K., LAPSHEV, O. B.,  
MATVEYEV, V. V., PUSHKIN, V. V., ROMANICHEV, M. K., SHERMAKOV, A. Ye.,  
VARGIN, Ye. P. and DROZDOVA, L. P.

[Abstract] In nuclear electric facilities with VVER reactors, the most likely path for radioactive contamination of the environment is through leaks in the steam-raising units. If there is a break in a pipe of the primary circuit, the leakage of coolant into the secondary circuit may go as high as  $10^5$  kg/hr. The radionuclides in the coolant accumulate in the secondary circuit, and reach equilibrium conditions within 7-9 hours. Gaseous and volatile radionuclides enter the steam lines of the secondary circuit, accumulate in the turbine condensers, and thence enter the atmosphere through the ejectors. The authors describe devices for detecting radioactive emission and propose a scheme for rational placement of such detectors in the primary and secondary circuits. A mathematical model is proposed for propagation of radionuclides through the secondary circuit when there has been a break in one of the steam-raising units. Suggestions are made for improving systems to monitor propagation of radionuclides through the process channels of a nuclear electric facility. Figures 6, references 4: 2 Russian, 1 Czech, 1 Polish.  
[35-6610]

AXIAL AND RADIAL DISTRIBUTION OF FLUX DENSITY AND HARDNESS OF NEUTRON SPECTRUM  
IN FUEL ASSEMBLIES OF VVER-365 and VVER-440 REACTORS

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 3, Sep 82 (manuscript received  
17 Aug 81) pp 143-147

BIBICHEV, B. A., MAYOROV, V. P., SIDORENKO, V. D. and FEDOTOV, P. I.

[Abstract] Flux density and neutron spectrum in the cores of VVER-365 and VVER-440 reactors can be measured only by means of special tubes provided in the centers of the fuel assemblies. Activation detectors in these channels can give the axial distribution of flux density and neutron spectrum. The radial distribution of these quantities is obtained by determining the concentration of certain fission products in the fuel after extracting the fuel assemblies from the reactor. The authors show that the distribution of flux density of thermal neutrons and the hardness of the neutron spectrum over the height and cross section of fuel assemblies of these reactors can be determined by a gamma spectrometric method without breaking fuel elements if fission products are selected that accumulate differently depending on the fluence of

thermal neutrons and the hardness of the neutron spectrum. The isotopes selected are  $^{137}\text{Cs}$ , which has a concentration only weakly dependent on hardness, and proportional in a first approximation to the product of thermal neutron flux and time of irradiation, and  $^{134}\text{Cs}$ , which accumulates in proportion to the product of hardness multiplied by the square of the product of thermal neutron flux and exposure time. It is shown that the proposed technique can be used for checking and correcting various computational programs. Figures 3, references 11: 6 Russian, 5 Western.  
[35-6610]

UDC [621.311.25:621.039].621.182.1.004

#### PROMISING WATER CHEMISTRIES FOR NUCLEAR ELECTRIC PLANTS WITH VVER AND RBMK REACTORS

Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 82 pp 12-14

MAMET, A. P., doctor of technical sciences; MAMET, V. A., candidate of technical sciences; PASHEVICH, V. I., candidate of technical sciences; NAZARENKO, P. N., engineer, Energiya Scientific Production Association, VNIIAM [expansion not given]

[Abstract] Currently operating nuclear electric facilities use the following water chemistries: for the first loop of VVER reactors--mixed ammonia-potassium with variable boric acid concentration; for the second loop of VVER reactors--ammonia-hydrazine with  $\text{pH} = 9.1 \pm 0.1$ ; for nuclear plants with RBMK reactors--uncorrected neutral. Most nuclear facilities with VVER reactors that are now in operation do not provide treatment of the turbine condensate. Newly constructed large electric plants with VVER-1000 reactors have a facility for cleaning all condensate. Even though expensive austenitic steels are extensively used in the reactor water systems, considerable amounts of metal oxides accumulate in the reactor loops of nuclear facilities, become radioactive in the neutron field, are dispersed through the circulating system and aggravate the radiation environment of the facility, especially for repair work. On the basis of experimental work and analysis of non-Soviet experience with a variety of water chemistries, the following recommendations are made on water treatment in nuclear electric plants. Electric plants using RBMK reactors should use water with neutral oxidative chemistry dosed with 100-200  $\mu\text{g}/\text{kg}$  of gaseous oxygen or hydrogen peroxide. The first loop of VVER reactors should use hydrazine water chemistry with substitution of hydrazine dosing for ammonia dosing under power while maintaining the established norm for hydrogen. The second loop in VVER facilities where copper-containing alloys are present should use reductive water chemistry with hydrazine dosing in the low-pressure channel and adjustment of dosing in accordance with the redox potential of the medium. When copper alloys are eliminated, both reductive and oxidative-neutral water chemistries may be equally effective in the second loop of VVER reactors; however, the reductive version is still preferable from the standpoint of simplicity of implementation and control. References 14: 11 Russian, 3 Western.  
[34-6610]

ACCUMULATION OF  $^{233}\text{U}$  WITH PREDETERMINED  $^{232}\text{U}$  CONTENT UPON EXPOSURE OF THORIUM IN VVER POWER REACTOR

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 2, Aug 82 (manuscript received 14 Jul 81) pp 106-107

POLYAKOV, A. A., RUKHLO, V. P., TITARENKO, Yu. Ye. and KOMIN, S. F.

[Abstract] Model experiments are done to determine the influence that different concentrations of  $\text{ZrO}_2$  in  $\text{ThO}_2$  rods have on reducing the  $N^{232}\text{U}/N^{233}\text{U}$  concentration ratio as  $^{233}\text{U}$  accumulates with irradiation of thorium in a VVER power reactor. The simulation was on a subcritical uranium-water stand using an IRT reactor as the neutron source. The power reactor core simulated in the center of the  $\text{UO}_2\text{-H}_2\text{O}$  array by the  $\text{ThO}_2 + \text{UO}_2$  rods had enrichment of 6.5% with respect to  $^{235}\text{U}$ . Accumulation of  $^{233}\text{U}$  was simulated by introducing various contents of  $^{235}\text{U}$  in the thorium rods. Measurements were made by an activation method on rods with 20 and 40 mass percent  $\text{ZrO}_2$  and  $^{235}\text{U}$  concentration of 0, 1, 5 and 10 kg of  $^{235}\text{U}$  per metric ton of  $^{232}\text{Th}$ . The  $^{232}\text{Th}(n, 2n)$  reaction was simulated by the reaction  $^{27}\text{Al}(n, \alpha)$  that has a similar effective threshold. Measurement results were extrapolated to a VVER fuel assembly of 126 rods. It was found that slight accumulation of fissile isotopes in a thorium fuel assembly leads to an abrupt increase in  $^{232}\text{U}$  production. Addition of zirconium oxide effectively reduces the accumulation of  $^{232}\text{U}$ . Figures 2, references 4: 3 Russian, 1 Western.  
[25-6610]

## HEAT PIPE FOR PARABOLOIDOCYLINDRICAL SOLAR POWER PLANT

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 10 Nov 81) pp 21-26

KOKHOVA, I. I., SASIN, V. Ya., BORODKIN, A. A. and ERGASHEV, S. F., State Scientific Research Institute of Power Engineering imeni G. M. Krzhizhanovskiy

[Abstract] A heat pipe has been developed for the special purpose of heating the hot junctions of a thermoelectric generator in a paraboloidocylindrical solar power plant. Its design is based on hydrodynamic and thermodynamic laws of mass and heat transfer along the liquid-vapor channel, assuming negligible pressure and temperature drops across the vapor phase and the phase transition front. It consists essentially of a sheath and a wick, the latter a wire mesh, both made of stainless steel (12Kh18N10T and 12Kh18N9T respectively). The effective thermal conductivity of the wick is  $\lambda_e = 1 + \frac{1}{8000b + 1.35} \text{ W/m} \cdot \text{ } ^\circ\text{C}$  (b- half-width of mesh hole). Distilled water has been chosen as the working substance, because of its nontoxicity and high latent heat of evaporation. The pipe, purged of noncondensing hydrogen evolving from stainless steel and primed with water, then purged of excess heat carrier through vaporization and subsequently vacuumized, was tested experimentally for performance evaluation. First a water calorimeter and then a commercial thermoelectric generator (100 W rated electric power output with hot junctions at 300°C and thermal power input of 2400 W) were used for extraction of heat from the condensation zone. The wick was removed from the condensation zone for operation with the thermoelectric generator. The temperature profiles in the pipe and the current-voltage characteristics of the generator were measured at various power levels under steady-state conditions, with the pipe horizontal and with the pipe inclined (10°, 20°). The results indicate a stable isothermal operation of the heat pipe up to 350°, meeting the generator performance requirements as expected. Figures 3, references 11: 9 Russian, 2 Western.

[89-2415]

## HEAT STORAGE SYSTEMS FOR SOLAR ELECTRIC POWER PLANTS

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 14 Jun 81) pp 16-20

AKHMEDOV, R. B., VORONKOV, M. Ye., POZHARNOV, V. A. and CHAKOVSKIY, V. M., State Scientific Research Institute of Power Engineering imeni G. M. Krzhizhanovskiy

[Abstract] Several heat storage systems for solar electric power plants have been developed, a few of them new, namely a dual-purpose steam-water type and a phase-transition type. The steam-water type, for use in solar electric as well as thermal electric power plants, consists of a tank with volume compensator, a steam generator, as expander, a heat exchanger for either preheating the line water or cooling the condensate, an economizer, also a feedwater pump, a line pump, and a condensate pump. Its performance is described by curves depicting the dependence of specific electric energy output (MW.h/t<sub>H<sub>2</sub>O</sub>) on steam pressure at the turbine entrance at various levels of water pressure. The maximum output corresponds to a steam pressure of 0.3-0.4 MPa at the maximum possible water pressure and reaches 0.04 MW.h/ton at a water pressure of 6 MPa. In the phase-transition type saturated or wet steam passes from the solar boiler through the heat exchanger, where it condenses and heat is transferred to a fusible storing substance (eutectic NaCl-ZnCl<sub>2</sub> mixture), and the latter melts while the condensate returns to the boiler. Its performance is described by curves depicting the thermal power density at the heat exchanger surface as function of time, and its design involves matching the diameter of the heat exchanger tube with the temperature head (typically 13.5°C during charge and 30.0°C during discharge) for maximum heat transfer. Thermochemical systems are also considered for storage of high-temperature heat (> 400°C). Promising reaction cycles are oxide (CaO, MgO) + water (or CO<sub>2</sub>) = hydroxide (or carbonate) + heat; SO<sub>3</sub>(1100 K)  $\xrightarrow{-\text{heat}}$  SO<sub>2</sub> +  $\frac{1}{2}$ O<sub>2</sub> (1100 K)  $\xrightarrow{+\text{heat}}$  SO<sub>2</sub> +  $\frac{1}{2}$ O<sub>2</sub> (300 K)  $\xrightarrow{+\text{heat}}$  SO<sub>3</sub>(300 K)  $\xrightarrow{-\text{heat}}$  SO<sub>3</sub>(1100 K); CH<sub>4</sub> + H<sub>2</sub>O(1300 K)  $\xrightarrow{-\text{heat}}$  CO + 3H<sub>2</sub>(1300 K)  $\xrightarrow{+\text{heat}}$  CO + 3H<sub>2</sub>(300 K)  $\xrightarrow{+\text{heat}}$  CH<sub>4</sub> + H<sub>2</sub>O(300 K)  $\xrightarrow{-\text{heat}}$  CH<sub>4</sub> + H<sub>2</sub>O (1300 K). Another method of heat storing is by means of hydrogen produced in a cycle of alternately endothermic and exothermic reactions, each at a specific temperature, but this requires careful purification of the reaction products. Figures 3, tables 1, references 8: 5 Russian, 3 Western. [89-2415]

## PRODUCTION AND SOME PROPERTIES OF PHOTOVOLTAIC CELLS BASED ON LAYERS OF POLYCRYSTALLINE SILICON

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 2 Jul 81) pp 12-15

SAIDOV, M. S., ALAD'INA, Z. N., ALIYEV, R. and CHIRBA, V. P., Institute of Electronics imeni U. A. Arifov, UzSSR Academy of Sciences

[Abstract] A study was made of photovoltaic cells based on fine-grain layers of n-type silicon and produced by reduction of  $\text{SiCl}_4$  in a hydrogen stream. The silicon films were deposited on As-Si substrates on graphite plates, at a rate of about 4 mm/min at about 1250°C. The surface of these films was polished and selectively etched in  $\text{HF}:\text{HNO}_3:\text{CH}_3\text{COOH} = 2:5:12$  solution with chromic acid added, a p-n junction in the material with an electrical resistivity of 12 ohm.cm was formed by injection of boron ions with 25-75 keV energy in a concentration of about  $2 \cdot 10^{20} \text{ cm}^{-3}$ . Radiation defects were cured by annealing in hydrogen for 30 min at temperatures from 200 to 100°C. The performance characteristics of such a photovoltaic cell were measured first over a temperature range from -150 to +150°C at constant illuminance. A decrease of the device temperature resulted in a higher sensitivity in the short-wave range, the sensitivity peak shifting from  $\lambda = 0.80 \mu\text{m}$  at +150°C to  $\lambda = 0.72 \mu\text{m}$  at -150°C. The performance characteristics were found to depend on the operating temperature, the short-circuit current increasing linearly with rising temperature at a rate of about 0.01 mA/°C, the open-circuit voltage decreasing at a rate of 1.6 mV/°C from -150 to +25°C and at a rate of 3 mV/°C from +25 to +150°C, the flatness of the current-voltage curve decreasing from 0.8 to 0.66 with the temperature rising from -150 to -50°C and not changing further with higher temperature, and the efficiency remaining approximately constant up to -50°C and then dropping to zero above +100°C. As the irradiation power was increased, the efficiency reached 4.5%, the short-circuit current increased almost linearly at a rate of 57  $\mu\text{A}/\text{mW}$  up to 0.7  $\text{W}/\text{cm}^2$  and then at a rate of 250  $\mu\text{A}/\text{mW}$  further, and the open-circuit voltage increased to 0.42 V at a rate of 180  $\mu\text{V}/\text{mW}$  up to 1000  $\text{mW}/\text{cm}^2$  and then reaching a plateau. The performance characteristics were also found to be affected by variation of the annealing temperature (900°C being the optimum for silicon single crystals) and on the thickness of the silicon layer. The thinnest layer of given grade of material yielded a photovoltaic cell with the highest efficiency and open-circuit voltage and the lowest short-circuit current. Figures 4, references 6: 1 Russian, 5 Western.

[89-2415]

## SOLAR CELLS BASED ON POLYCRYSTALLINE CdTe

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 10 Nov 81) pp 7-11

AZIMOV, S. A., MIRSAGATOV, Sh. A. and MUZAFAROVA, S. A., Physico-Technical Institute imeni S. V. Starodubtsev, UzSSR Academy of Sciences

[Abstract] The advantages of semiconductor-dielectric(oxide)-semiconductor structures with thick dielectric interlayer over metal-dielectric(oxide)-semiconductor structures are technological. The dielectric layer must pass minority carriers while presenting an additional barrier to majority carriers, to ensure a low dark saturation current and correspondingly high open-circuit voltage. In an experimental feasibility study polycrystalline p-CdTe films were deposited on a substrates at 350°C, mechanically and chemically polished, then rinsed and covered with SnO<sub>2</sub> films. The latter were deposited by two methods, pyrolysis and pulverization, each process producing a thin (30-50 Å) interlayer of CdO with traces of TeO<sub>2</sub>. Pyrolysis (from SnCl<sub>2</sub>.2H<sub>2</sub>O and SnCl<sub>4</sub>.5H<sub>2</sub>O with 8% SbCl<sub>3</sub>) under a pressure of 3-5 atm for 6 min yielded solar cells with open-circuit voltage of 0.35-4 V, short-circuit current of 8-9 mA/cm<sup>2</sup>, 0.30 flatness of the current-voltage curve, and 2-2.5% efficiency at an irradiation power of 55 mW/cm<sup>2</sup> from an incandescent lamp. Pulverization yielded solar cells with open-circuit voltage of 0.52 V, short-circuit current of 12 A/cm<sup>2</sup>, 0.39-0.42 flatness of the current-voltage curve, and 4-4.5% efficiency at an irradiation power of 55 mW/cm<sup>2</sup> from an incandescent lamp. Here the short-wave edge of photosensitivity lies at the 250 nm wavelength. Experience has shown that annealing such solar cells in an atmosphere of inert gas further improves their performance characteristics. Optimization of the technology of deposition of SnO<sub>2</sub> filters as thick as 1000 Å by the pulverization process should make it feasible to attain an open-circuit voltage of 0.75-0.78 V, corresponding to the contact potential difference at room temperature. Using instead of SnO<sub>2</sub> another semiconductor material with electron affinity equal to or smaller than that of CdTe, such as heavily doped indium-tellurium oxide, can result in a nearly ideal isotypic n-n heterojunction with n-CdTe. This material is also suitable for a p-n heterojunction with CdTe. Figures 3, references 6: 1 Russian, 5 Western. [89-2415]

## PHOTOVOLTAIC CELLS BASED ON InP/CdS HETEROSTRUCTURE

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 10 Apr 81) pp 5-7

BALEKA, E. S., GILAN, E. V., GORCHAK, L. V., KITOROAGA, A. D. and CHEBAN, A. G., Moldavian branch, Order of Labor Red Banner All-Union Scientific Research Institute of Current Sources, Kishinev

[Abstract] Characteristics of solar cells based on p-InP/n-CdS heterostructures with large useful surfaces of 1-2 cm<sup>2</sup> were studied experimentally, for the purpose of establishing whether such structures with theoretical efficiency of 17.2% would be suitable for solar power plant installations on earth. Specimens of such a structure were produced by deposition of n-CdS layers (5-10 μm thick, electron concentration  $n = 2 \cdot 10^{18} - 2 \cdot 10^{19} \text{ cm}^{-3}$ , electron mobility  $\mu_e = 60-130 \text{ cm}^2 \cdot \text{V}^{-1} \cdot \text{s}^{-1}$ , electrical resistivity  $\rho = 10^{-3} - 10^{-2} \text{ ohm} \cdot \text{cm}$ ) on a substrate of p-InP single crystal with (111) orientation (hole concentration  $p = (2-5) \cdot 10^{17} \text{ cm}^{-3}$ , hole mobility  $\mu_h = 70-90 \text{ cm}^2 \cdot \text{V}^{-1} \cdot \text{s}^{-1}$ , electrical resistivity  $\rho = 0.1-0.4 \text{ ohm} \cdot \text{cm}$  at room temperature) in a closed container in a hydrogen atmosphere with a 90°C temperature difference between CdS source and substrate. Measurements of the load characteristic yielded a conversion efficiency of 10%. With irradiation on the n-CdS side from an incandescent tungsten lamp with a power density of 55mW/cm<sup>2</sup> yielded an open-circuit voltage of 0.64-0.67 V and a short-circuit current of 12-15 mA/cm<sup>2</sup>, with a 0.62-0.64 flatness of the current-voltage curve. The short-circuit current is linearly dependent on the illuminance, while the open-circuit voltage is proportional to the logarithm of illuminance with a high sensitivity of 10<sup>3</sup> V/lm at low illuminance levels. The photosensitivity of such a photovoltaic cell remains high over a wide range of wavelengths, from 0.513 to 0.925 μm. Figures 1, references 6 Western.  
[89-2415]

UDC 621.383:621.472

## PHOTOVOLTAIC SOLAR CELLS BASED ON 'DEGENERATE SEMICONDUCTOR - SEMICONDUCTOR' P-N HETEROJUNCTIONS

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 14 Apr 81) pp 3-5

PAVELETS, S. Yu., Institute of Semiconductors, UkSSR Academy of Sciences

[Abstract] New methods of producing p-n junctions are sought for more economical conversion of solar energy to electrical. Use of a degenerate semiconductor on one side should contribute to a higher efficiency of a surface-barrier cell, strong degeneracy of the non-photosensitive component of such a

heterojunction making it possible to shift the Fermi level into the v-band or the c-band so as to increase the contact potential difference and making it feasible to produce a sufficiently thin and thus transparent film of this component without reducing the series electrical resistance component below permissible minimum. These advantages have been demonstrated on  $\text{Cu}_{2-x}\text{S}/\text{CdTe}$  and  $\text{Cu}_{2-x}\text{S}/\text{GaAs}$  heterojunctions with  $x=0.2$ , using polycrystalline CdTe and GaAs single crystals respectively with irradiation on the  $\text{Cu}_{1.8}\text{S}$  side. An analysis of data on photocurrent measurement and calculation reveals that under a solar radiation flux density of  $0.6 \text{ W/cm}^2$  the efficiency of a  $\text{Cu}_{1.8}\text{S}/\text{CdTe}$  converter can reach 7.7% (open-circuit voltage 0.6 V, short-circuit current  $12.5 \text{ mA/cm}^2$ ) and the efficiency of a  $\text{Cu}_{1.8}\text{S}/\text{GaAs}$  converter can reach 14.5% (open-circuit voltage 0.82 V, short-circuit current  $14.5 \text{ mA/cm}^2$ ). Decreasing the series electrical resistance component and use of transparent coatings should further raise the converter efficiency. Typically, the Fermi level reaches the upper limit of the v-band when the hole concentration in  $\text{Cu}_{1.8}\text{S}$  is  $p = (5-6) \cdot 10^{19} \text{ cm}^{-3}$ . Figure 1, references 10: 9 Russian, 1 Western. [89-2415]

UDC 621.472:621.363

#### EQUATIONS OF MOTION FOR HELIOSTATS IN TOWER-TYPE SOLAR ELECTRIC POWER PLANT

Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 82 (manuscript received 3 Apr 81) pp 31-35

KACHANOVSKIY, M. N. and DUBILOVICH, V. M., Belorussian branch, State Scientific Research Institute of Power Engineering imeni G. M. Krzhizhanovskiy

[Abstract] Development of an automatic control system for the array of heliostate in the 5 MW experimental tower-type solar electric power plant must be compatible with the dynamic characteristics of these devices, which are analyzed here on the basis of their equations of motion. Trigonometric equalities describe the position of heliostats tracking the sun in geographical coordinates (latitude) and solar coordinates. The angular velocities are calculated by differentiating these trigonometric relations with respect to time, with the aid of the l'Hospital rule, whereupon also the rates of change of velocities are determined. The critical positions are at the "antishade" points, where the zenith angle reaches its  $90^\circ$  maximum and the zenith velocity becomes indeterminate, while the angle which the horizontal projection of the normal to the heliostat plane forms with the meridian is also indeterminate. Starting at these points the azimuthal control of heliostats must be effected by tracking the mirror direction of that normal. Figures 3, references 3 Russian. [99-2415]

## HEAT STORING DEVICES FOR SOLAR ELECTRIC POWER PLANTS

Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 82 (manuscript received 8 Jan 82) pp 27-31

GUDKOV, V. I. and CHAKALEV, K. N., State Scientific Research Institute of Power Engineering imeni G. M. Krzhizhanovskiy

[Abstract] Several types of heat storing devices are evaluated comparatively, from the standpoint of their use in solar electric power plants. They are: steam-water tanks of steel, prestressed cast iron, prestressed reinforced concrete--all utilizing the large thermal capacity of this substance, storage of thermochemical heat of reversible decomposition-recombination reactions such as  $2SO_3 = 2S + 3O_2$ ; storage of heat of phase transition (of eutectic salts). Their installation cost per kW el. increases linearly with increasing length of duty cycle, that of steel steam-water tanks at the highest rate and that of tanks with melting salts at the lowest rate. The installation cost per kW el. of additional boiler capacity for operation with fossil fuel is much higher for short duty cycles (less than 4 h) but becomes much lower for long duty cycles (more than 12 h), breaking even with that of the various solar-plant heat storing devices within the intermediate range of operating hours. Various technical and environmental factors must be considered in the selection of heat storing device, namely performance characteristics, temperature and pressure limits, size, and properties of the working substance (e.g., toxicity). Underground storage of heat has also been found feasible and promising. Figures 3, references 10: 2 Russian, 8 Western.  
[99-2415]

## TESTS OF POWER MODULE OF PARABOLOID-CYLINDRICAL SOLAR HEATING PLANT

Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 82 (manuscript received 16 Dec 81) pp 19-23

ARNIZHEVSKIY, B. V., KOKHOVA, I. I., ALIYEV, S. N., SAMOYLOV, V. A. and ERGASHEV, S. F., State Scientific Research Institute of Power Engineering imeni G. M. Krzhizhanovskiy

[Abstract] The performance of the power module of a paraboloid-cylindrical solar heating plant with a heat pipe as thermoreceiver was tested at operating temperatures up to 300°C. The reflector has the dimensions  $L \times B = 5000 \times 2000$  mm, a focal length of 850 mm and an aperture angle of 120°. The concentrator surface is an electrically polished 1 mm thick aluminum sheet coated with a 10-12  $\mu$ m thick film of protective oxide, the specular aluminum having an integral reflection coefficient of 0.79-0.80 for solar radiation. The heat pipe is a 5000 mm long tube of stainless steel with an outside diameter of

50 mm and a wall thickness of 3 mm, a triple-layer criss-cross woven 0.04-0.071-0.14 mm mesh of stainless steel wire serving as wick. The tube is placed inside a sheath of molybdenum glass 90 mm in diameter, for minimization of heat losses, the coolant is water. Tests were performed in 1981 in Makhachkala. Measured were: incoming solar energy, ambient temperature, wind velocity, surface temperature along the heat pipe in evaporation zone and in condensation zone, vapor pressure in heat pipe, coolant flow rate and temperature rise, and current-voltage characteristic of ring-type thermoelectric generator also serving as calorimeter. Particularly important were measurements made during heating by a nonuniformly concentrated solar radiation flux. The surface of the heat pipe was found to be nearly isothermal in both zones even under those conditions, indicating a normal and stable operation, with maximum temperature drop of 10-15°C in evaporation zone and 7-10°C in condensation zone. With a solar radiation flux density of 850 W/m<sup>2</sup>, the heat losses reached 400 W/m<sup>2</sup>, the heat pipe delivered 2070 W at an overall efficiency of 25%. The optical efficiency was 52.3%. Figures 4, references 3: 2 Russian 1 Western.  
[99-2415]

#### PARTICULARS OF DESIGNING AND MAKING CONTROLLED REACTOR WITH THREE-DIMENSIONAL MAGNETIC CIRCUIT

Moscow ENERGETIK in Russian No 7, Jul 82 pp 12-13

PIL'CH, M. L. and GALIMBAYEV, U. Sh., engineers, Sredazremenergo

[Abstract] Alma-Ata Power Engineering Institute has developed a controlled reactor with three-dimensional magnetic circuit for continuous control of reactive power in a 35 kV power transmission line. The inductive reactance of the device is smoothly controlled by DC magnetization of the magnetic circuit. An industrial model of the reactor, the RMN-2500/35, was shown at the Exhibition of Achievements of the National Economy of the USSR in 1980. The reactor has a power of 2500 kVA and voltage of 35 kV, and is an oil-filled device with natural oil cooling using seven radiators on a circular base with total thermal power of 90 kW. Protective devices are the same as those used on transformers: expander, gas relay and exhaust pipe. Mass of the reactor is 25 metric tons, height 4.9 m, diameter with radiators 4.4 m. The active part of the installation is a magnetic circuit made up to six rods carrying the coils of the working winding, while toroidal yokes carry the field windings. The three-phase working winding is star-connected, resulting in total elimination of the third harmonic, reducing the fifth harmonic to 0.27%, and the seventh to 0.21%. The field winding carries current of 50 A at a power of 12 kW. Figures 2.  
[37-6610]

FACILITY FOR HEATING POWER TRANSFORMERS AND REACTORS

Moscow ENERGETIK in Russian No 7, Jul 82 pp 15-16

NIKITIN, N. M., SIDOROV, V. I., deceased, SOROKIN, V. G. and GUNNER, V. Ye., engineers, Tselinenergo

[Abstract] The KVTM-280/0.5 facility used for heating power transformers and reactors in insulation tests suffers the disadvantages of large mass (3.7 metric tons) and rough stepwise adjustment of voltage and current. The disadvantages of the VU-650 transformer and similar devices with continuously controlled voltage and light weight (650 kg) is that there are no facilities for holding the heating current constant throughout the test period as the winding resistance changes, and the lack of reliable protection from sudden surges of current. Tselinenergo Industrial Power Association has developed a transformer and reactor heating facility with stabilized rectified current that overcomes all these disadvantages. Maximum rectified current is 200 A, rectified voltage is adjustable from 0 to 450 V, overall dimensions are 600x500x400 mm, mass is 30 kg. The method of regulation with respect to deviation of output current is used to stabilize the current under load. The device contains a three-phase asymmetric controlled bridge power rectifier, three shaping channels for producing controlling pulses, and a comparator based on an opamp. The input is connected to a current sensor in the heating circuit. The noninverting comparator input is connected to a controlled source of direct current that sets the heating current. The total voltage drop across resistors in the current sensor, which is proportional to the current flowing through the load, is sent to the inverting input of the opamp, where it is compared with a reference voltage. The opamp is connected so that the heating current is maintained constant. Figures 2, reference 1.

[37-6610]

UDC 621.313.12:621.548:621.316.729

METHOD OF SYNCHRONIZING WIND TURBINE ELECTRIC GENERATOR WITH POWERFUL ENERGY SYSTEM

Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 82 pp 51-52

SIDOROV, V. V., engineer, All-Union Scientific Research Institute of Planning of Hydroprojects imeni S. Ya. Zhuk

[Abstract] Because of variable wind speed, until recently the only practical way to synchronize wind turbines with other facilities in an electric energy system has been self-synchronization. However, this method involves considerable electrical and mechanical problems, especially under gusty conditions. In addition, conventional self-synchronization involves certain preparatory steps that considerably complicate auxiliary equipment in wind turbine facilities. The author suggests a new method of self-synchronization in which the synchronous frequency of rotation of the generator is stabilized

directly from the AC line. The generator is disconnected from the braked wind turbine, and the generator is then run up to the frequency of rotation corresponding to sync by connecting the generator to the line in the no-load synchronous motor state with overexcitation, after which the wind turbine is started and connected to the generator when the turbine speed is equal to that of the generator. Sync time is 1-5 s. As the wind drops, there is an increase in slip between the driving and driven halves of the hydraulic clutch between the wind turbine and the generator, and when the difference reaches a certain value the turbine is disconnected from the generator. This system ensures acceptable fluctuations of voltage and current on the generator terminals. Figures 3, references 3 Russian.

[34-6610]

UDC 531.8:534.01

FREQUENCY ANALYSIS OF REGULAR VIBRATORY SYSTEMS IN MECHANISMS WITH PROGRAMMED TRANSLATORY MOTION OF COMMON DRIVEN MEMBER

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 11, Nov 82 (manuscript received 12 May 81) pp 35-39

VUL'FSON, I. I., doctor of technical sciences, professor

[Abstract] Multiloop mechanisms for producing programmed translatory motion of a follower with a set of drivers operating in parallel are used printing and textile machines as well as in rolling mills. Here the dynamic behavior of such a mechanism is analyzed on the basis of a model where the main (distributor) shaft constitutes a torsional subsystem with distributed parameters and the cams with rollers constitute subsystems with lumped parameters, all parameters in the system usually being slowly varying quantities. The transient vibration modes and the natural frequency spectrum of this model are determined from the corresponding transfer matrix of kinematic functions and from recurrence relations in the form of nonhomogeneous difference equations. The general results of this analysis are applied to a specific mechanism consisting of a belt-driven distributor shaft which carries three equally spaced identical cam disks, each driving a roller. Calculations have been programmed in FORTRAN-4 for a YeS-1022 Unified System computer. Figures 3, table 1, references 3 Russian.  
[94-2415]

UDC 62-83+62-85.002.2

TECHNOLOGY OF PRODUCING LINEAR-DISPLACEMENT GAS BEARINGS

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 6, Jun 82 (manuscript received 11 Feb 81) pp 36-37

RODIN, A. A., ARKHIPOV, V. V., BALATSENKO, N. K. and SEREBROV, D. D.

[Abstract] A technological process has been developed by the authors for production of linear-displacement gas bearings with cylindrical surfaces for various instruments such as Fourier spectrometers and vibrometers. Dimensional precision of sleeve and float is attained in two stages: preliminary treatment

and finishing treatment. Preliminary treatment involves grinding with a diamond cutter at a speed of 85 m/min. Finishing is done in three steps: rough lapping at a speed of 27 m/min and first fine lapping at a speed of 18 m/min with cast-iron (SCh 18-36) tool and diamond paste (ASM 14/10 and ASM 5/3 respectively) in kerosene, then second fine lapping at a speed of 18 m/min with presswood tool and diamond paste (ASM 2/1) in 10:1 water (distilled)+emulsifier(OP-7) solution. All fixtures and operations have been designed to produce diameters within narrow tolerances ( $+0.001$  mm for floats,  $+0.0005$  mm for cylinders) with noncircularity not exceeding 0.001 mm and surface roughness not exceeding  $0.08 \mu\text{m}$ , allowing for linear thermal expansion of the SAS-1 bearing alloy, which will ensure a radial clearance of  $0.010+0.002$  mm for the gaseous lubricant layer. Figures 3, tables 2, references 4 Russian.  
[31-2415]

#### NEW MODELS OF INDUSTRIAL ROBOTS IN ACTION

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 7, Jul 82 pp 73-75

ANDREYEVA, L. I., engineer

[Abstract] New models of industrial robots are being continuously shown in the "Mashinostroyeniye" (Machine Design) pavillion at the Exhibition of Achievements in USSR National Economy. The series of robots exhibited by the Special Design Office at the Leningrad Polytechnic Institute's Department of Engineering Cybernetics is built according to a universal physical model of an automatic manipulator, according to principles of robot-robot and robot-operator interactions, and according to algorithms of control at various levels. Their structure is modular, allowing for replacement and addition of features and programs. They are models MP-5P and MP-8 with positional control for metal cutting operations, models MP-9S and MP-11 with pneumatic drive for loading-unloading operations. Other models, built basically for operations of either of these two basic types, include automatic manipulators P-505 and KMI0Ts4201 with direct digital control developed by the Scientific Research Institute of Tractor and Agricultural Machine Manufacturing Technology, an automatic manipulator with programmable control developed by the Experimental Scientific Research Institute of Metal Cutting Machine Tools and built at the "Stankokonstruktsiya" plant, industrial robot RD-25 developed by the Rostov-na-Donu Institute of Agricultural Machinery Construction, industrial robot "BRIG-10-ZAZ" developed and built at the "Kommunar" automobile manufacturing plant, automatic manipulator 11-TPR-0 developed by the Central Scientific Research Institute "Elektronika", and automatic manipulator KSh-160MI developed by the "Kompleks" Scientific-Industrial Association. In addition, there also exhibited several new automatic production sets and lines with existing automatic manipulator and machine tool components, developed by the "Orgstankinprom" (State Planning, Technological and Experimental Institute for Organization of Tool and Machine Tool Industry) Scientific-Industrial Association and by the Planning and Design Technological Institute "Kuzrobot" (Forging Robot).  
[30-2415]

## PNEUMATIC MEASURING SYSTEMS FOR INDUSTRIAL ROBOTS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 7, Jul 82 pp 10-14

GRADETSKIY, V. G., candidate of technical sciences

[Abstract] Outstanding features of pneumatic measuring systems for industrial robots are high reliability and long life. These systems are designed to analyze external and internal information by means of sensors and transducers, basically of either pneumomechanical or pneumoacoustic type using turbulent jets, jets with elastic distension, or vacuum. Their performance is most conveniently analyzed on the basis of hydrodynamic relations, taking into account inertia and viscosity as well as compressibility of the working substance. Their performance parameters (flow rate, pressure, drag) and dynamic characteristics are calculated according to circuit theory and using equivalent four-pole networks, with available data on measuring capabilities attainable in the present state of the art: linear displacement 0-4 mm with 0.5-3% error, 200 Pa/ $\mu$ m optimum sensitivity and 0.001 s response time; presence of object from distance 0-20 mm (0.5-1 m for pneumoacoustic detector), with 2-8% error, 200 Pa/ $\mu$ m optimum sensitivity and 0.002 s response time; force 0.1-10 N or 1-100 N, with 5% error and 0.2 s response time; temperature 10-800°C, with 5-10% error, 10°C sensitivity and 20-30 s response time; pressure 0-10 MPa, with 2-5% error, 0.1 MPa sensitivity and 0.2-1 s response time. Pneumatic systems have several characteristics which render them suitable for detecting the presence of objects and determining their distance as well as small displacement, for operation under severe environmental conditions such as high temperature, radiation, electromagnetic interference, explosive media, and for operation in sensitized robot grippers. Such devices, typically a transducer using turbulent jets for detecting the presence of a blank part to be machined, are built at the Experimental Scientific Research Institute of Forging and Pressing Machinery. Figures 4, table 1, references 9: 6 Russian, 3 Western.

[30-2415]

UDC 535.317.2

## NEW LIGHT-BEAM DEVICES FOR AUTOMATIC CONTROL OF MACHINES

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 10, Oct 82 (manuscript received 22 Jul 80) pp 71-74

TSUKKERMAN, S. T., Leningrad Institute of Precision Mechanics and Optics

[Abstract] Two laser devices for automatic control of machines in land reclamation, road construction, mining, and other projects have been recently developed and tested. They are the already series produced UKL-1 and the

pilot produced PUL-N. The UKL-1 has a control beam up to  $1.2^\circ$  wide in the horizontal plane and 0.1-0.2 m wide in the vertical plane. The beam is invisible in daylight and thus requires an "optical surveyor rod" for marking its vertical position. The laser is energized by pulse trains rather than by continuous sparse modulation, which reduces the power drain to 12-15 W and increases the interference immunity of the system but requires a supply voltage as high as 10 kV. The receiver includes three FD24-K photodiodes with the distance between the outer two adjustable from 30 to 60 mm so that the sensitivity can be averaged for a given range of distances such as, e.g., 20-150 m. The PUL-N consists of a light-weight projector (0.3 kg) mounted on a T-30 rotatable telescopic sight, drawing 1.5 W of power at a voltage of 6 V. The projector beam has a maximum divergence of  $2^\circ$  and a circular cross section, designed for wide range of vertical and horizontal control. The receiver includes a two-lens objective with an FD-9K photodiode in its focus, a pre-amplifier with automatic gain control and an output amplifier feeding a relay in the control panel for machines with an up to 3 A current rating. This device has been used experimentally with a drainage rig in "Lemmelioratsiya" outfits. Its technical characteristics and performance are somewhat better than those of the UKL-1. Figures 2, table 1, references 4 Russian. [84-2415]

#### DYNAMIC LOADING OF MANIPULATION AND TILTER MECHANISMS IN BLOOMING MILL 1000

Tbilisi SOOBSHCHENIYA AKADEMII NAUK GRUZINSKOY SSR in Russian Vol 106, No 2, May 82 (manuscript received 22 May 81) pp 341-344

CHITORELIDZE, G. M. and SHARASHENIDZE, D. A., Institute of Metallurgy imeni Semi-centennial of USSR, GSSR Academy of Sciences

[Abstract] The dynamic performance of manipulator and tilter in the blooming mill 1000 recently installed, after reconstruction, in the Rustavi Metallurgical Plant is analyzed on the basis of the solution to the characteristic equation which describes transient processes in the kinematic linkwork of the system. The first and second critical frequencies have been calculated by a numerical method for six modes of tilter motion (idel stroke with  $i_{k,max}$  and with  $i_{k,min}$ ; tilting of one ingot and of two ingots, tilting with damping in rod and with damping on motor shaft) and for six modes of manipulator motion (free travel of left-hand rulers and free travel of right-hand rulers, rotation or translation in each case, straightening of one ingot and of two ingots). The results indicate a need for dampers, in the form of shock absorbers on tilter links and for stiffening or manipulator links. Figures 2, tables 2, references 6 Russian. [93-2415]

## MECHANISM SIMULATING MOTION OF EYE AXES

Moscow MASHINOVEDENIYE in Russian No 6, Nov-Dec 82 (manuscript received 21 Jul 81, after completion 26 Apr 82) pp 37-38

DIMENTBERG, P. M., Moscow, and SARKISYAN, Yu. L., Yerevan

[Abstract] An elementary mechanism is constructed for simulating the approximately synchronous macromovements of the axes of a person's two eyes tracking a point which moves in space, such movements also including "jumps" with large amplitudes. Each eye is a body rotated by three pairs of muscles about any axis approximately passing through one stationary point at the center of that body. Accordingly, the motion of both eyes is spherical with three degrees of freedom. Such a motion is simulated by a four-link mechanism which consists of a variable-length connecting rod and a "stationary" bar rotating in a hinge about its own axis, and two rockers of equal length. Each length of the connecting rod corresponds to an infinite number of fixation points located on the toroidal surface which the centroid of the connecting rod generates during rotation of the latter about the "stationary" bar as axis. The mechanism can be incorporated in a three-movement manipulator. Figures 2, reference 1 Russian.

[92-2415]

## PARAMETRIC OPTIMIZATION OF NONLINEAR VIBRATION ISOLATION SYSTEMS WITH AID OF MULTIDIMENSIONAL FOURIER TRANSFORMATION

Moscow MASHINOVEDENIYE in Russian No 6, Nov-Dec 82 (manuscript received 7 Jul 81) pp 31-36

SINEV, A. V., Moscow

[Abstract] The apparatus of multidimensional Fourier transformation is applied to optimization of vibration isolation systems subject to steady and transient deterministic perturbations as well as to steady random ones. The response of a nonlinear system to a steady random input action is analyzed, assuming that this action has a normal probability density distribution with zero mathematical expectation and that the kernels in the Volterra series are not of higher than third order. The general results are applied to the specific case of a kinematic vibration isolation with a stationary random process acting on the base and with the nonfunctional constraint  $y_{st} \leq y_0$  on the static displacement under load. This constraint becomes an equality when the acceleration dispersion is to be minimized, another special case being "white noise" when the spectral (frequency) density of acceleration is uniform. The first derivatives of the acceleration dispersion with respect to

the two optimum vibration isolation parameters yield two equations for the latter. When one of them is zero, then the other also becomes zero and the nonlinear system degenerates into a linear one with the dimensionless acceleration dispersion equal to unity. Otherwise either "stiff" or "soft" nonlinearity is possible, depending on whether one of the optimum parameters is nonnegative or nonpositive respectively. Figure 1, references 5 Russian. [92-2415]

UDC 531.014.5

DEPENDENCE OF COMPLEX RESONANCE MODES IN HIGHLY NONLINEAR VIBRATION SYSTEMS ON AMPLITUDE OF EXTERNAL PERTURBATION

Moscow MASHINOVEDENIYE in Russian No 6, Nov-Dec 82 (manuscript received 3 Apr 81) pp 26-30

KRYUKOV, B. I. and SEREDOVICH, G. I., Moscow

[Abstract] A study is made of the amplitude-frequency characteristics of highly nonlinear vibration systems, of particular interest being the changes in resonance mode produced by changes in the amplitude of the external force and by changes in the magnitude of the constant displacement. As illustrative case is considered a system describable by the Duffing equation  $\ddot{x} + \epsilon \dot{x} + kx + \theta x^3 = F \cos t$ . The evolution of the fundamental mode, second harmonic and third harmonic is examined within the range of second and third ultraharmonic resonance. The study reveals heretofore unknown anomalies of complex resonances, not found in vibrations of only slightly nonlinear systems. These must be taken into account in synthesis and design of heavy processing equipment which utilizes complex resonances. Figures 3, references 9: 6 Russian 3 Western (1 in translation). [92-2415]

UDC 621-567.2

THEORY OF OPTIMAL CONTROL OF HYDRAULIC DAMPER BASED ON MODEL OF COMPRESSIBLE FLUID

Moscow MASHINOVEDENIYE in Russian No 6, Nov-Dec 82 (manuscript received 20 Jul 79, after completion 16 Apr 81) pp 16-19

RIVKIN, A. S., Leningrad

[Abstract] The problem of optimally controlling a hydraulic damper is solved on the basis of the model of a compressible fluid. This model has certain features in common with that of an incompressible fluid, but has also its peculiar features associated with compressibility of the working substance.

The system of equations describing the dynamics of piston and stopper is converted from one with time to one with piston displacement as independent variable. The optimum program for varying the orifice area is found in the class of piecewise-continuous bounded functions, upon minimization of the integral criterion functional. The resulting Hamiltonian contains two coupled variables which satisfy two equations for its first derivatives with respect fluid pressure and to piston velocity squared. These variables require no boundary conditions, inasmuch as the state vector of the original system is completely known at both ends of the trajectory. The optimal control process can now be analyzed as a whole, with the aid of the maximum principle. It is demonstrated that, under physically feasible conditions, there is one and only one transition point to a fully closed orifice--optimally either at the beginning or at the end of the stopping action. The problem of optimal control has been reduced to a finite-dimensional problem of determining the optimum coordinates of switching points and can be solved by such methods as that of steepest descent. Figures 2, references 3 Russian.  
[92-2415]

UDC 536.21:517.9(075)

#### CALCULATING UNSTEADY TEMPERATURE FIELD OF RUBBER BEARING WITH LONGITUDINAL LUBRICATING GROOVES

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 10, Oct 82 (manuscript received 14 Jul 81) pp 15-18

ABAYEV, A. A., candidate of technical sciences, OSIPOV, Yu. R., candidate of technical sciences, and SHVETSOV, A. N., graduate student

[Abstract] Rubber bearings of two major types are currently used in Soviet machine building: with longitudinal and with helical lubrication grooves. This paper is devoted to an analytical study of the unsteady temperature field of bearings with longitudinal grooves. A segment of the bearing is modeled by a rectangular parallelepiped with given cross sectional dimensions. Boundary conditions are assigned for the surface facing the shaft, in contact with the bushing and exposed to the coolant. Due to the low thermal conductivity of rubber and intense heat transfer by the coolant, it is assumed that heat flux in the plane perpendicular to the line of the bushing-bearing interface decreases through the thickness of the segment and becomes negligible on the surface where the bearing is in contact with the bushing. Heat exchange between segment and coolant conforms to Newton's law with constant heat transfer coefficient and coolant temperature. The temperature of the segment in the longitudinal direction is taken as invariant, and it is assumed that there are no changes of thermophysical properties of the segment material. Formulas are derived for calculating the temperature field of a rubber bearing segment over a wide range of working conditions. Figures 2, references 5 Russian.  
[29-6610]

INFLUENCE OF FRICTION FORCES IN ENGAGEMENT ON TRANSVERSE OSCILLATIONS OF GEARS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 10, Oct 82 (manuscript received 8 Dec 81) pp 27-30

PODZHAROV, Ye. I., candidate of technical sciences, docent

[Abstract] Studies were done on the step-up gearing in the headstock of a screw-cutting lathe. It was found that in certain speed ranges corresponding to resonances of transverse oscillations of the shaft-gear system on the tooth frequency, intense vibrations arise in the gearing in the direction of friction forces between teeth. These vibrations are much stronger than those in the direction of the normal forces parallel to the line of engagement, although the level of these vibrations also increases in the same period ranges. Variable friction forces have a more noticeable effect on oscillations in more exact gearing. In the zone where friction forces influence vibrations, a monotonically increasing segment with elevated level of oscillations can be observed in the sonic and ultrasonic frequency bands on the spectra of gear vibrations. Figures 3, references 2: 1 Russian, 1 Western.  
[29-6610]

DETERMINING PARAMETERS OF TWO-CYLINDER LEVER MANIPULATOR

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 10, Oct 82 (manuscript received 15 Jul 81) pp 47-52

VATOLIN, V. V., candidate of technical sciences, docent, and TEREKHOV, V. V., engineer

[Abstract] Studies are done on the operation of a lever manipulator with two-cylinder pneumatic drive operated from an energy source of limited power. Consideration is taken of hydraulic pressure losses as air flows from the tank into the pneumatic cylinders. The calculation also takes account of motion parameters and the state of the gas in the drive system. Formulas are given for the effect that the drive has on motion parameters based on the Clapeyron ideal gas law. The results can be used for qualitative evaluation of manipulator parameters on the design stage. Figures 3, references 3 Russian.  
[29-6610]

## OUTLOOK FOR AUTOMATING PLASMA SPUTTERING BY USING INDUSTRIAL ROBOTS AND MICROCOMPUTERS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 8, Aug 82 (manuscript received 29 May 81) pp 154-155

KOSOLAPOV, A. N., engineer, and ALIYEV, M. A., engineer

[Abstract] It is suggested that industrial robots might be combined with microcomputers to automate the process of plasma sputtering to produce heat-resistant and anticorrosion coatings by performing the following functions: metered supply of electric energy, working gases, material to be sputtered and coolants; manipulation of workpiece in the sputtering zone; transport of the workpiece into and out of the sputtering zone; monitoring and control of the process of energizing and de-energizing the facility; stabilization of technological parameters, or programmed regulation; monitoring of technological parameters and signal indication when they go beyond set limits; logic and computer operations. Two stages are distinguished in realization of such a program: using industrial robots to automate major operations of surface preparation and application of the coating; tying in microcomputers with the robots and technological equipment. Moscow Higher Technical Academy imeni Bauman has developed a technological module implementing the first stage designed around the "universal-5" industrial robot. This unit consists of a process section and a control section accommodated in different rooms. Video equipment is used for monitoring.  
[27-6610]

## INFLUENCE OF PISTON AND SLIDE-VALVE SEALS ON VACUUM PUMP OPERATION

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 82 (manuscript received 15 Jul 81) pp 72-75

YEDEMSKIY, V. S., candidate of technical sciences

[Abstract] Internal leaks through piston and valve seals have a considerable effect on the characteristics of piston vacuum pumps with slide valve distribution. To determine the volumetric characteristics of such pumps with slide valve of piston type and to get the right overlaps when designing the gas distribution units, it is necessary to know the proper clearances of the piston and slide-valve seals. A peculiarity of operation of piston and valve seals in vacuum pumps with bypass channels located on the cylinder wall, and cylinder ports on the valve sleeve is that during the working cycle they seal the working cavities with a variable number of piston rings. The author did experiments to determine the clearances of piston and valve seals as a function

of the number of piston rings and the pressure in front of the seal. Analysis of the influence of leaks through piston seals showed that the overlap at the end of suction can be considerably reduced. The results were utilized in developing the 3VMP-3, VNP-6 and 2DVNP-6 vacuum pumps at Melitopol'kholdmash Production Association. The new design has reduced specific power by 22-28%. Figures 3, references 2 Russian.  
[28-6610]

## TURBINE AND ENGINE DESIGN

UDC 621.515.004.69

### EXPERIENCE WITH IMPROVEMENT OF CENTRIFUGAL COMPRESSOR

Moscow ENERGOMASHINOSTROYENIYE in Russian No 10, Oct 82 pp 23-26

SHKOL'NIKOV, B. G., engineer, METALLIKOV, S. M., candidate of technical sciences, GURVICH, I. A., engineer, and BYVSHEV, Yu. V., engineer

[Abstract] Further improvement of centrifugal compressors for driving gas turbine engines or supercharging diesel engines is required in terms of higher efficiency, wider stability margin, and better manufacturability. In an attempt to achieve these objectives, there was built a set consisting of a cast reaction-type closed impeller with 21 blades designed for high specific circumferential velocity ( $u_2 \approx 500$  m/s) and a radial vane-type double-row diffuser designed with an airfoil profile. This set was subsequently tested in an experimental compressor with nominal compression ratio of 3.92 and nominal specific speed of 28,000 rpm, maximum air rate not exceeding 4.3 kg/s. The necessary margin of mechanical strength for high-speed operation was ensured by using for the impeller a special high-strength cast alloy, reducing the thickness of the cover disk to the permissible minimum (1.8-2.2 mm) without making the shroud unstable, so as to reduce the stresses in the blades, and increasing the thickness of the blades and the hub. The measured performance characteristics, efficiency as function of air rate and of impeller speed, also air flow pattern at entrance to an exit from the impeller as well as at entrance to and exit from the diffuser, indicate that the goals are met in terms of efficiency (0.838 under nominal operating conditions, 0.92 at a compression ratio of 4.38 or at partial load) within the 80-100% speed range and stability margin (21.7% under nominal operating conditions). Figures 5, tables 2, references 8: 7 Russian, 1 Western.  
[83-2415]

INCREASED VIBRATION RESISTANCE OF MODEL K-300-240 LMZ (LENINGRAD METAL WORKS) TURBINES

Moscow ENERGETIK in Russian No 10, Oct 82 pp 14-15

LUPOLO, O. A., engineer, and BYSTROV, V. F., engineer, Kostroma GRES

[Abstract] No low-frequency vibrations of steam turbines in the Kostroma GRES have been recorded since 1976. A quantitative analysis of engineering data on the flowthrough stage design and dynamic stability of eight K-300-240 LMZ (Leningrad Metal Works) turbines on RVD-RSD bearings indicates that downward centering radial forces acting on the runner at various angles and loading the bearings when the runner axis moves above the stator bore axis during precession or otherwise act also as aero-dynamic spring forces which damp self-excited vibrations. An evaluation of dynamic stability relative to the critical vibration level reveals that the centering forces in the flowthrough stage can be optimized, technologically, so as to increase the dynamic stability without affecting the economy of turbine operation. Economy as well as dynamic stability of K-300-240 turbines can be improved without fundamental design changes. Figure 1, tables 2, references 2 Russian. [38-2415]

UDC 621.516

ROTARY LIQUID-SLEEVE VACUUM-TYPE COMPRESSOR WITH LOAD RELIEVER BUSHING

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 11, Nov 82 (manuscript received 22 Dec 81) pp 84-86

DUBENETS, V. D., doctor of technical sciences, professor; CHERNYKH, A. I., postgraduate student, candidate of technical sciences, docent, and KUCHERENKO, V. I., engineer

[Abstract] A performance analysis of a rotary liquid-sleeve vacuum-type compressor indicates that use of a load reliever bushing will increase its speed while reducing the specific power input. The basic structural feature of such a compressor is a solid bushing with forced air feed through the clearance between it and the housing. Slots are cut in the latter to accommodate microfilters made of acrylic plastic. Such a compressor was tested in the exhauster mode of operation with water as working substance. Effective input power  $N_e$ , kW and true delivery rate  $V_e$ ,  $M^3/s$  were measured over a range of suction pressure from 20 to 80 kPa, with air feed pressure of 108-120 kPa and circumferential velocity of the compressor wheel ranging from 12.7 to 16.5 m/s. Installation of a solid bushing was found to reduce the specific power  $N_e/V_e$  by 10-20% at the top speed, this advantage being appreciable at suction pressures below 46 kPa and vanishing at suction pressure above 60 kPa on account of air leakage which also reduces the true delivery rate (only by 5% at low suction pressure and by as much as 30% at high suction pressure). Elimination of air leakage must be the next step in improvement of this type of compressor. Figures 2, references 2 Russian. [94-2415]

## CENTRIFUGAL SUPERCHARGER WITH ARCUATE INTERMEDIATE BLADES

Leningrad SUDOSTROYENIYE in Russian No 11, Nov 82 pp 24-26

PETROV, Yu. I. and KOSTOMAROV, V. A.

[Abstract] In order to reduce the detrimental effect of secondary currents in the interblade spaces of a centrifugal supercharger on its performance without appreciably decreasing its efficiency, an arcuate shorter blade-fin was installed between each two neighboring main blades along the center line of the channel. The curvature of these intermediate blades was the same as that of the main ones, but their width was varied from 10 to 40% at the exit edge. The aerodynamic characteristics of three superchargers (TeNK-1-64-14-50-1 and TsKN-1-64-14-55-1, blower TsU 40/17) were measured before and after installation of intermediate blades. Addition of intermediate blades was found to increase the compression ratio by up to 15% with almost no change in efficiency at the optimum point, but with the maximum efficiency either increasing or decreasing by 3-5% depending on the ratio of impeller width to interblade distance on the median circle (not to exceed 0.86). Also the noise spectrum was found to have changed, with the intensity decreasing by 3-6 dB in the 25-126 Hz band and increasing by 1-3 dB in the 160-2000 Hz band. Figures 5, table 1, references 2 Russian.  
[96-2415]

UDC 621.125.018.001.5

## RESULTANT CHARACTERISTICS OF VELOCITY STAGES IN SUPERSONIC TURBINES UNDER VARIABLE OPERATING CONDITIONS

Leningrad SUDOSTROYENIYE in Russian No 10, Oct 82 pp 16-19

TOPUNOV, A. M., TIKHOMIROV, B. A. and GENOV, A. G.

[Abstract] An experimental study of velocity stages in a turbine at supersonic flow was made in a special test stand with a turbine-type air brake. The prototype booster steam turbine for this test consisted of a double-row velocity stage with partial admission and an array of drill nozzles, the expanding supersonic part of the latter designed for minimum wave and friction losses with a 22° exit angle. The runner wheel was shrouded, had blades with sharp edges at the working end and an air-tight jacket around the hub, there were no seals. The turbine was tested under various conditions, the nozzle expansion ratio ranging from 4.38 to 3.21 and the admission factor ranging from 0.015 to 0.06 depending on the number of active nozzles. The tests included conditions of energy injection, corresponding to the negative branch of the speed characteristic. The latter as well as the efficiency and the reactivity were measured. The results indicate how these performance parameters vary with the expansion ratio, the steam density, and the adiabatic

exponent. The characteristics, all smooth and continuous, differ from those of subsonic stages by having a wide range in the countersteam mode where there is no dependence on the pressure dip and on the expansion ratio. The results, generalized relative to optimum performance mode and referred to temperature drop, verify that modeling a supersonic turbine stage on the basis of invariable steam (or air) velocity and relative density at the nozzle exit is kinematically most accurate. Figures 5, references 3 Russian.  
[89-2415]

UDC 624:072.33-621.438

TUNING OUT NATURAL VIBRATION FREQUENCIES OF COMPRESSOR BLADES FOR GAS TURBINE ENGINES BY METHOD OF SUCCESSIVE OPTIMIZATION

Kiev PROBLEMY PROCHNOSTI in Russian No 7, Jul 82 (manuscript received 16 Jun 81)  
pp 86-89

ROYTMAN, A. B., AFANAS'YEV, V. P., MIKHAYLOVA, T. F. and OMEL'CHENKO, S. P., Zaporozh'ye and Dnepropetrovsk

[Abstract] The method of successive optimization is applied to the design of compressor blades for gas turbine engines. To ensure that the frequencies of their transverse natural vibrations do not fall within dangerous resonance bands. The blade fin thickness profile is selected as control function, smoothly varying through a maximum, with invariable blade volume, fin length, and chord length. The quality functional involves all frequency intervals between first and second resonance, the integral of the second variation of blade thickness with a regularization factor, and the blade volume with a Lagrange multiplier. As mathematical model of natural vibrations serves the differential equation of motion in the plane of minimum stiffness the geometrical relations are defined approximately with aid of tables, and the optimality condition with appropriate boundary conditions is obtained by equating the first variation of the quality functional to zero. The algorithm of design optimization consists of two parts. First blade deflections at natural frequencies are calculated through solution of the corresponding boundary-value problem by successive approximations, then a new distribution of the control (thickness) function is calculated until the deviation from optimum becomes equal to or smaller than the permissible one, within additional constraints imposed by strength requirements, technological feasibility, and gas dynamic characteristics. The procedure is demonstrated on a typical compressor blade made of a material with  $E/\rho = 0.26 \cdot 10^{14} \text{ mm}^2/\text{s}^2$  ( $E$ - modulus of elasticity,  $\rho$ - density) with natural frequencies in the second flexural mode allowed within the 3300-3450 Hz range. Figures 2, table 1, references 5 Russian.  
[43-2415]

## STRESSED STATE OF ELEMENTS OF TURBOMACHINE BLADES WITH HOLES FOR BANDING

Kiev PROBLEMY PROCHNOSTI in Russian No 7, Jul 82 (manuscript received 6 Aug 81)  
pp 84-86

SUKHININ, V. P., VOL'KOVICH, I. B., LUKINA, E. V. and MALYAR, V. A., Khar'kov  
Institute of Railroad Transportation Engineers

[Abstract] Blades for high-power steam turbines are usually long and twisted, their vibration resistance being increased by means of bands threading through holes. A study was made to determine the state of stress in the banding zone of such a blade under flexural load. Measurements by the photoelasticity method with "freezing" of strains were made on model plates of optically sensitive ED-20M epoxy simulating a blade on the basis of dynamic similarity. Data were processed on a Mir-1 computer and compared with the Kirchhoff model as well as with theoretical calculations by A. S. Kosmodamianskiy. The results reveal the distribution of stresses and, particularly important, the peaks of stress concentration across a blade along holes (ratio of blade thickness to hole diameter  $h/d=1.42$ ) inclined at various angles (0, 35, 45, 90°) to the blade surfaces and without or with rounding at the edges (1.5, 3.0, 4.5 mm rounding radius). The stress concentration is maximum at points in the plane of symmetry of the blade passing through the hole axis. The nonuniformity of stress distribution decreases as the angle between hole axis and blade surface increases and, at the same time, the hole becomes shorter. The stress distribution tends to become smoother with rounding of the hole edges, but no significant improvement is achieved by making the rounding radius much larger than 0.15 times the blade thickness. Figures 3, references 3 Russian.

[43-2415]

## THEORETICAL SUBSTANTIATION OF CHARACTERISTICS OF INTERMEDIATE SUPERHEAT IN TURBINE SETS IN AES

Moscow TEPLOENERGETIKA in Russian No 11, Nov 82 pp 30-31

KHRUSTALEV, V. A., candidate of technical sciences; OSTAPENKO, V. A., candidate of technical sciences; ARKAD'YEV, B. A., engineer; and FOMENKO, V. I., engineer, Saratov Polytechnic Institute; Industrial Association for Atomic Technology at Khar'kov Turbine Generator Plant; Novovoronezh AES

[Abstract] Theoretical relations are derived for the turbine economy in AES and its dependence on parameters of the intermediate superheat. The variable part of total plant cost, which includes the operating cost of the intermediate stage, is established as function of superheat temperature and separator pressure. The cost equation is optimized on the basis of 3-4

segments of the load curve and assuming a heat transfer coefficient proportional to pressure. Equating the first derivatives of normalized variable cost with respect to variable parameters to zero yields the optimum rate of superheated steam and the optimum temperature head. Calculations continue now for the high-pressure cylinder and the low-pressure cylinder, taking into account the unit cost of fuel ( $UO_2$ ), the fuel depletion rate, the fuel combustion characteristics, and the unit cost of heating surface as well as the relevant thermodynamic steam-turbine performance parameters. Figures 3, references 4 Russian.

[90-2415]

UDC 621.311.25:621.039

#### PERFORMANCE OF EVAPORATOR IN K-500-65/3000 TURBINE SET IN CHERNOBYL'SK AES

Moscow TEPLOENERGETIKA in Russian No 11, Nov 82 pp 32-35

GOLUBEV, Ye. K., candidate of technical sciences; GLAZOV, Ye. Ye., engineer; PLOKHIY, T. G., engineer; BRONNIKOV, V. K., engineer; VAKULENKO, B. F., engineer and MIKHAYLOV, V. S., engineer; All-Union Scientific Research Institute of Atomic Machinery; Chernobyl'sk AES; Industrial Association "Krasnyy Kotel'shchik"

[Abstract] In the Chernobyl'sk (also Leningrad and Kursk) AES, operating with RBMK-1000 MW water-graphite channel reactors, the K-500-65/3000 turbine sets include evaporators which serve as sources of "pure" low-radioactivity steam. These evaporators, developed at the All-Union Scientific Research Institute of Atomic Machinery and built by the Industrial Association "Krasnyy Kotel'shchik" for the Khar'kov Turbine Generator Plant, are of the vertical type and have a welded construction: a set of two vertical cylindrical housings with covers on top and bottom. The lower part of each, into which feed water is poured, contains a tubular heater (made of Okhl8N10T steel, diameter 32 mm, wall thickness 2 mm) and has taps for removal of noncondensing gases from the seam compartment. The upper part contains two steam scrubber stages: two horizontal perforated sheets, one above the other. The two cylindrical housings are joined through an equalizer tube (diameter 100 mm). The performance of this evaporator set and its technical capabilities were tested under various operating conditions for over a year. In these tests were measured the rates of secondary steam and pure condensate, the constant scavenging rate, the pressures of heating steam and secondary steam, the temperatures of feed water and pure condensate, the levels of condensate in housing and in heating compartment as well as in scrubbers, and the turbine generator load. The measurements were made with operational and special-purpose instruments. The  $Na^+$ -content in feed water was monitored with a VPF-VTI flame photometer accurately within  $2.5 \mu\text{g}/\text{kg}$ , the  $SiO_2^{-3}$ - content was monitored with a molybdenum solution accurately within  $10 \mu\text{g}/\text{kg}$ , the  $Cl^-$ -content was monitored by the nephelometric method accurately within  $20 \mu\text{g}/\text{kg}$ , and the  $\beta$ -activity was monitored with an SBT-10  $\beta$ -counter up to  $10^{-10}$  Ci/l accurately within  $\pm 20\%$ . The normal steam rate from evaporator to user is approximately 40 t/h

under a pressure of 0.65 MPa, with a reserve of at least 15 t/h. The results of the tests indicate that 38 t/h is sufficient, the rate increasing to 42 t/h during startup. The heat transfer coefficient was found to be 3600-3890 W/(m<sup>2</sup> °C), 23-28% higher than calculated. Long operation without scavenging does not lower the quality of steam, but scavenging at a constant rate of 1 t/h is recommended for more reliable operation. Figures 4, references 4 Russian.  
[90-2415]

UDC 621.514

#### DYNAMIC CALCULATION OF ROTARY-PISTON COMPRESSORS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 82 (manuscript received 3 Jul 81) pp 80-85

NEKHOROSHEV, B. G., senior instructor

[Abstract] A dynamic scheme is developed for calculating forces, torques and loads in a Wankel-type compressor with two-corner piston and housing cross section in the form of an epitrochoid. It is shown that such compressors should use only two-bearing shafts to avoid static ambiguity in finding the resultant loads on the main journals and bearings from two or more coaxially arranged stages or sections. The proposed method has been programmed in FORTRAN-4. Figures 3, references 3 Russian.  
[28-6610]

UDC 621.438.038(088.8)

#### PNEUMATIC FUEL INJECTOR FOR GAS-TURBINE ENGINES

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 82 (manuscript received 26 May 81) pp 102-105

MELENCHUK, A. I., candidate of technical sciences

[Abstract] The paper gives the results of an experimental investigation and recommendations on designing low-head air-spray injectors that operate on the cycle air of a gas-turbine engine with air takeoff from the compressor diffuser. A pneumatic fuel injector of this type is described that has been developed at the Central Scientific Research Motor Vehicle and Engine Institute. The results of experimental studies show that an injector incorporating the proposed recommendations produces fuel jets with droplets 75-120 μm in diameter in the range of engine operating parameters. Figures 3, references 3 Russian.  
[28-6610]

NAVIGATION AND GUIDANCE SYSTEMS

UDC 531.38:532.51:517.91

NONLINEAR SYSTEMS REPRESENTING SUPERPOSITION OF GYROSTATS

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 266, No 4, Oct 82  
(manuscript received 28 Dec 81) pp 816-820

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Moscow

[Abstract] A three-modal mechanical system is considered consisting of two gyrostats, its rotor spinning about one principal axis of inertia at constant angular velocity relative to the housing. The motion of such a system is describable by the Euler equations and the n-dimensional extension of the Volterra equations can be applied to it. On this basis is given a mechanical interpretation of an E. N. Lorenz model which, with a constant moment of external forces and without friction at the rotor shaft, can be reduced to a magnetohydrodynamic model of the earth. The forced motion of an n-dimensional gyrostat is also described on this basis and represented as that of superposed two Lorenz models with terms in the equations depending on the constraints. Two such superpositions are considered and analyzed, in one case with isotropic viscous friction there existing an asymptotically stable equilibrium position and with anisotropic viscous friction there existing five equilibrium positions either asymptotically stable or unstable depending on the system parameters. References 13: 5 Russian, 8 Western (1 in translation).  
[95-2415]

UDC (681.883.67.001.24:534.874):649.12.073.243

ELECTRONIC METHOD OF STABILIZING DIRECTIVITY OF HYDROACOUSTIC ANTENNAS DURING ROCKING

Leningrad SUDOSTROYENIYE in Russian No 11, Nov 82 pp 33-34

PETROV, S. P.

[Abstract] It is desirable to stabilize the axis of the directional characteristic when a discrete antenna array such as a hydroacoustic one used on ships rocks together with the carrier. The directional characteristic of

such an antenna is designed to compensate the differences in time between signal arrivals at the antenna elements differently positioned in space relative to the wavefront of the incoming signal. When the antenna and its elements are also rocking, the directional characteristic must also at every instant of time take into account the distance  $\rho_i$  of each element from some fixed plane parallel to the incoming wavefront (assumed to be plane) so that the output signals can be delayed correspondingly (delay time  $\tau_i = \rho_i/c$ ,  $c$  - velocity of sound) before they are all added. Here the general relations are established in a Cartesian system of coordinates which moves with the carrier, the rocking motion being represented as a superposition of linear and angular oscillations about the metacenter. Electronic instruments can be used for measuring those oscillations and the velocity of sound, calculating the displacement matrices and then the distances as well as the time delays. Advantages of an electronic system over a mechanical one are much easier compensation of angular and linear antenna displacements, immediate response to changes in the velocity of sound, and smaller equipment for stabilization. Figures 2, references 4: 3 Russian, 1 Western (in translation). [96-2415]

UDC 681.883.074

#### NAVIGATION SYSTEMS WITH HYDROACOUSTIC BEACONS

Leningrad SUDOSTROYENIYE in Russian No 10, Oct 82 pp 33-36

SMIRNOV, G. E. and TOLSTYAKOVA, N. A.

[Abstract] Navigation systems with hydroacoustic beacons locate ships relative to buoys installed on the seabed or on underwater structures and feed data on ship movement into the dynamic ship stabilizing system. Here three types of such systems are compared, their structures described and their operation outlined. The OASIS (Offshore Acoustic/Satellite Integrated System) has a long base and also locates a ship in geographical coordinates. There are systems with short base and recently developed systems with ultrashort base. The electronic equipment includes cathode-ray tubes and digital coordinate indicators. Hydroacoustic beacons are autonomous devices emitting signals either according to a program or in response to received coded interrogation signals. Figures 4, tables 2, references 15: 1 Russian, 14 Western. [89-2415]

PROCEDURES FOR DETERMINING TRANSFER FUNCTIONS OF NONLINEAR SYSTEMS ON BASIS OF NEWTON-KANTOROVICH METHOD

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 10, Oct 82 (manuscript received 30 Jul 81) pp 36-40

SNURNITSIN, V. R. and SULAYMANOV, R. T., Novosibirsk Institute of Electrical Engineering

[Abstract] A variant of the Newton-Kantorovich method is proposed for determining the transfer functions of nonlinear systems. The procedure is an iterative one and involves solution of nonlinear operator equations in form of Volterra functional polynomials. The relation between input signal  $x(t)$  and response  $y(t)$  is assumed to be describable by a nonlinear nonhomogeneous equation  $Ly(t) + Df[y(t)] = x(t)$  with zero initial conditions ( $L, D$  - linear differential operators,  $f(y) = \sum_{i=1}^M a_i y^i$  - polynomial of  $M$ -th degree) and a linear

approximation  $y_0(t) = \int_{-\infty}^{\infty} k(\tau) x(t - \tau) d\tau$  to be feasible. Owing to the fast convergence of the Newton-Kantorovich method, it is often possible to obtain a very accurate solution after only one iteration. The method is demonstrated on a system describable by the equation  $\frac{dy}{dt} + y + uy^3 = x$  and on the algebraic equation  $y + 3y^3 = x$  representing the majorant with respect to norm for some operator equation. The results are compared with those obtained by the substitution method and the method of simple iteration. Figure 1, references 3 Russian.

[84-2415]

STRUCTURAL-PARAMETRIC SYNTHESIS OF NONLINEAR CONTROL SYSTEM ACCORDING TO PRESCRIBED MOTION

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 10, Oct 82 (manuscript received 8 Jan 82) pp 32-36

DUSHIN, S. Ye., IMAYEV, D. Kh. and MOISEYEV, S. S., Leningrad Institute of Electrical Engineering imeni V. I. Ul'yanov (Lenin)

[Abstract] Synthesis of prescribed transient motion for nonlinear systems by the method of generalized linearization is considered, in frequency and time domains with application of the Laplace transformation. The problem is to determine the structure and the parameters of the operator of the linear correction component which will ensure prescribed motion at the input to the nonlinear component, assuming the transfer function of the linear component to be a fractional-rational one and assuming that both input motion and output motion have Laplace transforms. The sufficient condition for the output motion and thus also the transfer function of the nonlinear component to be

fractional-rational is that the statistical characteristics on nonlinearity be polynomials. On this basis, for illustration, are calculated logarithmic and normalized logarithmic phase-frequency characteristics of simple inertial components. Analysis of the results reveals that the nonlinear component acquires integrating properties when motion increases and differential properties when motion decreases. Figures 2, references 5 Russian. [84-2415]

UDC 62-551.4

#### ACCURACY OF SYNTHESIS OF APPROXIMATELY OPTIMUM CONTROL FOR NONLINEAR OBJECT

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 10, Oct 82 (manuscript received 8 Feb 82) pp 27-31

ALEKSANDROV, Ye. Ye. and TRIGUB, M. V., Khar'kov Polytechnic Institute imeni V. I. Lenin

[Abstract] A method of synthesizing an approximately optimum control has been proposed earlier for an object describable by the system of nonlinear differential equations  $\dot{x}(t) = \varphi(x, t) + u(x, t)$  ( $t \in [0, T]$ , where  $x \{x_1, x_2, \dots, x_n\}$  is the state vector and  $u \{u_1, u_2, \dots, u_m\}$  is the control vector whose components satisfy the constraint  $|u_s(x, t)| \leq u_s^{*m}$  ( $s = 1, 2, \dots, m$ ) on the  $[0, T]$  interval. Among the vector-functions  $u(x, t)$  satisfying this constraint is sought one which minimizes a certain functional of given positive-definite functions. The problem is solved by stipulating a number  $\varepsilon > 0$  defining the accuracy of the control and the number of terms in the power series expansion, performing the approximation, solving the Bellman functional equation and integrating the original vector differential equation, and determining the first approximation of the -optimum control. The procedure is repeated with additional terms in the power series expansion till the condition  $\Delta \leq \varepsilon$  has been attained. The method is demonstrated on the example of an object moving according to the equation  $\dot{x}(t) = ax(t) + bx^2(t) + cx^3(t) + du(x, t)$ . The results indicate that synthesis of approximately optimum control is feasible with any prescribed degree of accuracy. Figures 2, references 6 Russian. [84-2415]

UDC 531.383

#### SELECTION OF OPTIMUM CORRECTION CHARACTERISTIC FOR VERTICAL GYRO FROM COMPUTER PRINTOUTS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 6, Jun 82 (manuscript received 19 May 80) pp 69-73

SERGEYEV, M. A., Leningrad Institute of Precision Mechanics and Optics

[Abstract] A system of automatic design from computer printouts has been developed for astronavigation instruments including vertical gyros and laser

compasses. The software consists of more than thirteen programs. A typical application is correction of a vertical gyro. The optimum constant correction characteristic, corresponding to minimum mean-square error, is to be selected for given angular momentum and dry-friction torque. The algorithm of selection is based on the differential equation of motion for the sensing element and its solution by the method of statistical linearization. Graphs are plotted from computer printouts which indicate the insensitivity zone as well as zones of proportional and mixed correction characteristics. Figures 2, references 6 Russian.  
[32-2415]

UDC 534.014.531.383

METHOD OF DETERMINING NATURAL FREQUENCIES OF GYROMOTOR FROM PARAMETERS OF ITS VIBRATION

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 6, Jun 82 (manuscript received 30 Jun 81) pp 65-69

BELYAYEV, A. Yu., PETRENKO, V. Ye. and RADYSH, Yu. V., Kiev Polytechnic Institute

[Abstract] A convenient method of determining the axial fit of a gyromotor rotor mounted in two ball bearings is to measure its natural frequency, this method being based on the relation between both according to Hertz's law. For this purpose, the gyromotor is usually mounted in a vibration test stand and excited into monoharmonic vibrations with the frequency raised until maximum amplitude has been reached. This method is inaccurate on account of errors introduced by additional masses, finite stiffness, and noise from spinning rotor. Another method utilizes vibrations of the gyromotor caused by manufacturing and assembly errors. The gyromotor is suspended on a steel string and, with the rotor spinning, is excited not by external forces but by internal unbalance forces. The frequencies of the developing internal forces depend on the rotor speed, while the natural frequencies of the gyromotor are almost independent of the rotation. As the rotor speed is varied, therefore, the excitation frequencies will shift relative to the constant natural frequencies. Resonance occurs, and is recorded, when an excitation frequency coincides with a natural frequency. This functional method of measurement requires a spectrum analyzer with output band filter and a vibration transducer with sensitivity axis in a plane normal to the string, also a reference-frequency audio oscillator and an oscillograph. Both methods have been evaluated comparatively on a statistical basis, with a gyromotor weighing 1200 g and a rotor mounted in S1006096Yeu bearings. The motor was energized from a 500 Hz a.c. source and the nominal rotor speed was 26,400 rpm. The results of statistical analysis indicate that both systematic and random errors of the functional method are smaller. Figures 2, references 6: 5 Russian, 1 Western (in translation).  
[32-2415]

## USE OF BI-OSCILLATORY SCHEME IN FLOAT-TYPE GYROSCOPIC DEVICES

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 6, Jun 82 (manuscript received 30 Jun 81) pp 60-64

PANKRATOV, V. M., Saratov Polytechnic Institute

[Abstract] The capabilities of float-type gyroscopic devices can be extended, including programmable control of output characteristics, by insertion of an intermediate ring into the gap between housing and float. The ring, coaxial with the gyromotor carrying float and completely immersed in the working fluid which fills the housing, is free to spin about its axis. There are three pairs of mechanical or electric springs in the system: between float and housing, between ring and housing, between float and ring, each exerting a moment proportional to the respective angle of relative rotation. On the intermediate ring is also mounted a detent fixing its stationary position. Expressions for kinetic energy, potential energy, and dissipation function in the float-ring system are derived, disregarding friction in the gimbal bearings but including viscous drag during Couette flow of the fluid between float and ring. The performance of this device is described by Lagrange equations of the second kind. Depending on the way the actions of the three spring pairs are combined, there are possible eight schemes and two modes of operation. With the ring fixed relative to the housing and the spring action between them eliminated, the device operates in the basic mode. With the ring free, the device operates in the bi-oscillatory mode and elimination of any one, or two, or all springs reduces the device to a special case. The device can thus be a plain integrating gyro, a tachometer gyro, an accelerometer, or a combination of two. Figure 1, table 1, references 3 Russian.

[32-2415]

## SELECTING WEIGHT FACTORS IN PROBLEMS OF OPTIMUM DAMPING OF ELASTIC WING OSCILLATIONS

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 27 May 81) pp 35-40

SIRAZETDINOV, T. K. and KHALITOV, I. Kh.

[Abstract] Using a previously derived system of equations for controllable bending and twisting oscillations of a wing, the authors derive a formula that defines the optimum control structure. This formula contains a symmetric matrix function that must be determined to find the actual control, which depends in turn on the choice of weighting coefficients in the system of equations defining the matrix function. A solution is found for the problem of selecting

these weight factors by satisfying predetermined inequalities (secondary criteria) defining constraints on flutter, deflection of control element, phase coordinates and their derivatives, and regulation time. A practical approach to construction of an optimum controller is proposed, and applied to a specific wing in which twisting and bending vibrations are controlled by small deflections of an aileron. Figures 3, references 6 Russian.  
[36-6610]

UDC 629.7.017.2

APPLYING PHASE BIPLANE METHOD TO STABILITY STUDY OF SPACECRAFT WITH ROTARY CONTROL SYSTEM

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 15 Dec 79) pp 99-103

PAVLOV, Yu. N. and SEVEROVA, L. V.

[Abstract] An examination is made of the stability of a spacecraft with extensible elastic components and a rotary control system in the fixed orientation mode. The analysis is based on the phase biplane method proposed by V. Yu. Rutkovskiy and V. M. Sukhanov [see "Stability of Relay Control Systems for Orienting a Deformable Spacecraft", Proceedings of Sixth IFAC Symposium on Control in Space, Moscow, Nauka, 1973, Vol 11, pp 37-43]. It is shown that generalization of the solution that applies to gas-jet control units with zero moment in the neutral zone can give convenient analytical expressions applicable to rotary systems for the boundaries of stability regions, using a piecewise-linear approximation of the controlling moment with consideration of the effect of elasticity, delay, moments of friction and other factors. Figures 2, references 3 Russian.  
[36-6610]

UDC 531.383

DYNAMICS OF NONLINEAR GYRO SYSTEMS WITH POLYHARMONIC AND RANDOM BASE OSCILLATIONS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 8, Aug 82 (manuscript received 23 Dec 81) pp 59-64

BUTENIN, N. V. and LESTEV, A. M., Leningrad Institute of Aviation Instrument Making

[Abstract] An analysis is made of dynamics and accuracy of a system made up of a set of solids and  $r$  gyroscopes. The position of the system of solids relative to the base is given by  $s$  generalized coordinates  $q_1, \dots, q_s$ . The

motion of the base is assigned by coordinates  $q_{s+j}(t)$ ,  $j = 1, \dots, m$ . The coordinates of the angles of turn of the gyro rotors relative to the casings are assumed to be cyclic, and the base is subject to oscillations such that parameters  $q_{s+j}(t)$  are small. Motion of the system is considered in the vicinity of some steady-state motion  $q_j(t) = q_j(\theta)(t)$ ,  $j = 1, \dots, s$ . Expressions are derived that describe the motion of gyro devices used in systems for stabilizing and controlling moving objects. The authors analyze the dynamics and determine the errors of gyro devices with deterministic vibrations of the base, assuming that each of the parameters that determine vibrations of the base is a polyharmonic function of time. An example is given of calculations of the errors of a one-axis gyrostabilizer with polyharmonic oscillations of the base. An examination is made of the accuracy of gyro systems in the case where parameters that determine motion of the base are normal random processes with zero mathematical expectations and known correlation matrix. The methods and approaches that are described enable error analysis of specific gyro devices under conditions of deterministic and random oscillations of the base. References 5 Russian.  
[33-6610]

UDC 531.383:621.319

INFLUENCE OF ROTOR RADIUS ON ACCURACY OF ELECTROSTATIC GYROSCOPE IN CARDAN SUSPENSION

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 8, Aug 82 (manuscript received 22 Sep 81) pp 64-68

MARTYNENKO, Yu. G. and KORETSKIY, A. V., Moscow Power Engineering Institute

[Abstract] A formula is derived for the optimum radius of a rotor that minimizes angular drift rate due to first and second harmonics in rotor shape. The analysis is based on the rotor of an electrostatic gyro suspended in a spherical evacuated cavity situated inside a ceramic housing. A system of metal electrodes on the housing sets up a controlled electric field that stabilizes the noncontact rotor suspension. The authors consider an electrostatic gyro design in which the housing is installed in an additional Cardan suspension with a special servosystem that ensures angular motion of the housing such that the relative location of the rotor and housing remains nearly unchanged during operation of the device. The error of this servosystem is disregarded in the analysis. The surface of the rotor has an axis of symmetry and is nearly spherical. The procedure described for derivation of the minimum drift formula can be used in selecting parameters for an electrostatic gyro with any electrode configuration. Figures 2, references 5 Russian.  
[33-6610]

## TECHNOLOGY OF CONCENTRATOR ASSEMBLY FROM MIRROR-GLASS ELEMENTS

Tashkent GELIOTEKHNIKA in Russian No 4, Jul-Aug 82 (manuscript received 10 Nov 81) pp 26-28

UMAROV, G. Ya., ALABUTDINOV, D. N., ABDUZIZOV, A., ABDULLAYEV, A. and ALIMOV, A. K., Physico-Technical Institute imeni S. V. Starodubtsev, UzSSR Academy of Sciences and Samarkand State Pedagogical Institute imeni G. Gulyam

[Abstract] For reducing the cost of solar radiation concentrators, an experimental study was made to compare the performance of unpolished panes of window glass with that of polished ones. Measurements of the focal spot produced by parabolically bent panes with a mirror surface have revealed that unpolished and polished panes cut transversely produce focal spots of almost the same shape and size. Measured was also the angular deviation of normals to the mirror surface at points along individual panes from the mean normal to the parabolically bent pane. Both wedge strips (180 cm long, 3.3-10 cm wide) and rectangular strips (180 cm long, 10 cm wide), all approximately 3 mm thick, were broken up into 180 segments each. The angular deviation of normals was found to be 10' over 95% of the glass surface, much smaller than the divergence of solar rays ( $2 = 32'$ ) and 4-5 times smaller than with panes cut longitudinally. On the basis of these findings, a technology has been developed for assembling a paraboloidal concentrator with a diameter of 5 m and a focal length of 2.5 m. The reflector chassis is a stellate structure consisting of 12 curvilinear girder-spokes fastened to a cylindrical hub at the center and welded to concentric circular beams along the dome surface. The position of each joint is checked with a high-precision level and either raised or lowered, if necessary, into the plane it has been designed for. Glass is cut into wedge panes and coated with aluminum on one side, the mirror surface. All panes, 157 of them, are interchangeable. With a pane fastened to the chassis at 10 points, the chord approximates a parabola with a maximum deviation smaller than 0.5 mm (with a pane fastened at only 6 points, the maximum deviation is 1.5-2 mm). The thermal power of this concentrator is 8.5 kW at a radiation flux density of  $800 \text{ W/m}^2$ , the temperature in the focus reaching 1400 K. Figures 3, references 2 Russian.

[89-2415]

## MAGNETICALLY CONTROLLED VACUUM-TUBE DISPLACEMENT-TO-PULSE CONVERTER

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 10, Oct 82 (manuscript received 8 Feb 82) pp 15-18

BONDAR', N. M., Moscow Institute of Aviation imeni Sergo Ordzhonikidze

[Abstract] Feasibility of generating a pulse signal in a vacuum-tube device with a cathode between two anodes as it moves through a uniform magnetic field in the air gap of a permanent magnet is demonstrated by analysis of electron ballistics in a moving magnetic field and kinetics of the difference between the two anode currents. Theory is supported by two sets of experimental data depicting the current difference as function of displacement in the form of pulses with height depending on the anode voltage and width depending on the magnet width. In one experiment a magnet moved relative to the vacuum-tube device and voltage was supplied to both anodes through adjustable resistors. In another experiment a permanent pendulum fastened to a disk rotated with the latter driven by an adjustable-speed motor. The results indicate that such a device can be used as a pulse-type magnetically controlled displacement (linear or angular) transducer as well as velocity transducer in discrete-data systems. Figures 3, references 3 Russian.

[84-2415]

## OPTICAL IMAGE SYNTHESIZER WITH MAGNETOELECTRIC LIGHT MODULATOR

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 6, Jun 82 (manuscript received 10 Oct 80) pp 82-86

GAVRILOV, L. V., KOROBV, A. G., POMINOV, G. P., FEDOROV, Yu. V. and KHVALOVSKIY, V. V., Leningrad Institute of Precision Mechanics and Optics and Leningrad Institute of Electrical Engineering or Communications imeni Professor M. A. Bonch-Bruyevich

[Abstract] Optical image synthesizers with magnetoelectric light modulators feature high stability of operation, nondependence of deflection angles on spectrum of incident light, low intensity losses, high accuracy of modulation, and simplicity as well as compactness of construction. Such recording devices are particularly suitable for facsimile transmission. The light can be modulated either by varying the exposure of the photographic film with dimensions of the scanning element held constant, which is preferable for positive image reception, or by varying the dimensions of the scanning element with exposure of the photographic film held constant. The device consists of a lamp with the luminous object, a condenser lens, a field diaphragm, an aperture stop, another condenser lens, and the light modulator mirror, the

latter reflecting the image through another aperture stop and a recording objective lens onto a light-sensitive film. The amplitude of mirror rotation is small so that the dimensions of the mirror image, the scanning element, remain almost constant. Oscillation of the mirror causes the height of the illuminated part of the second aperture stop to vary and the luminous flux passing through the objective to be modulated proportionally. Performance of the device and design of its components are analyzed on the basis of geometrical relations in the optical system. The results reveal that the mirror dimensions are prescribed by dimensions of the scanning element and magnification of the recording objective, while the mirror deflection angle is prescribed by the necessary depth of field as well as by magnification of the recording objective and tolerances on the dimensions of the scanning element. A linear exposure characteristic requires rectangular aperture stops. Figures 2, references 4 Russian.  
[32-2415]

UDC 621.375.826

#### AUTOMATIC FOCUSING IN SINGLE-MIRROR TWO-DIMENSIONAL LASER-MIRROR SCANNERS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 25, No 6, Jun 82 (manuscript received 21 Apr 81) pp 74-78

IL'IN, A. L., ROZOV, B. S. and SAVOSTIN, P. I., Moscow Institute of Engineering Physics

[Abstract] Automatic focusing of the laser spot in a single-mirror scanner by means of a movable short-focus lens before the focusing objective is considered for high-precision input and output of graphical data. The linear displacement of this lens in the path of the laser beam is made to depend on the mirror deflection angle. The method is based on the theory of mirror scanners, according to which the locus of images of the light spot is generally the outer turn of a Pascal's limaçon and in this special case (mirror oscillation axis passes through reflecting mirror surface) a circle. The equation of this curve yields the law of lens displacement. A digital automatic control system has been developed for implementation of this law using two binary position signals. The hardware includes a clock oscillator, two squaring modules, a full adder, a comparator, a step motor, a pulse generator and a reversible pulse distributor for four amplifier channels. The necessary operations are performed by binary counters with flip-flop, AND gates, and decoders. The system is designed to maintain a spot diameter of 50  $\mu\text{m}$  or vary it according to the given law over the 50-200  $\mu\text{m}$  range within a 200x300  $\text{mm}^2$  frame. All electronic components are built with series 155 integrated microcircuits. Figures 2, references 7 Russian.  
[32-2415]

INVESTIGATION OF PARABOLIC GLASS-CERAMIC ASTRONOMICAL MIRROR WORKING SURFACE QUALITY

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 8, Aug 82  
(manuscript received 8 Jan 81) pp 7-9

PURYAYEV, D. T., GORSHKOV, V. A., FOMIN, O. N. and LYSENKO, V. G.

[Abstract] A method is described for checking the figure of a 100-inch glass-ceramic parabolic mirror in the horizontal position as during grinding. In this arrangement, the equipment and instruments used for quality control were accommodated in a special room built over the grinding shop, since the center of curvature of the mirror was about one meter over the roof of the shop. The optical bench included a laser, unequal-arm interferometer and compensator placed horizontally, and an optically flat mirror for coupling light between the center of curvature at the vertex and the interferometer. Placement of the laser on a common base with the interferometer simplified alignment. The proposed arrangement also reduces the probability of axisymmetric wavefront errors due to temperature gradient, since the latter is chiefly vertical. The system utilizes an IKAP-2 interferometer with universal compensator in the working branch. In addition to the diagram of the general checking facility, the paper gives a detailed diagram of the interferometer, the interference pattern of the mirror, and a map of its figure. Figures 3, table 1, references 4: 3 Russian, 1 Western.  
[26-6610]

UDC 621.391.8:621.397.6.522

METHOD FOR AUTOMATIC COMPENSATION OF GEOMETRIC DISTORTIONS IN ASTRONOMICAL TELEVISION EQUIPMENT

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 8, Aug 82  
(manuscript received 30 Jul 81) pp 9-11

KACHMIN, V. A. and SELIVERSTROV, Yu. A.

[Abstract] Geometric distortions of the raster in astronomical television equipment may reach 20% due to optoelectronic distortion and nonlinear scanning distortions. A calibrated test-grid projector is included in the equipment to compensate for these distortions. In view of the difficulties of real-time computer input, the television signal is first converted to isolate coordinate information, represented in digital form, and then fed to the computer. The coding unit used for data conversion imposes a constraint of no more than 10 x 10 reference points in the test grid of the calibration unit. In this paper, a method and algorithm are proposed for automatic compensation of geometric distortions with consideration of the specific requirements due to peculiarities of astronomical television equipment. Automatic compensation

is divided into two stages: 1. calibration of geometric distortions; 2. estimating the corrected coordinates that assign raster points. A mathematical model of the geometric distortions is proposed and used to evaluate the accuracy of a compensation algorithm that is based on approximation by splines. Tests of the algorithm on this model with respect to a set of points modeled by a Monte Carlo method with splines of various orders show that spline functions  $S_n(g)$  of degree  $4 \leq n \leq 7$  are optimum. Figures 2, references 8 Russian.  
[26-6610]

UDC 531.749.535.8

#### OPTICAL GONIOMETRIC SYSTEMS OF MULTIPLIER TYPE

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 8, Aug 82  
(manuscript received 12 Jun 81) pp 13-15

MIKHEYEV, P. A.

[Abstract] The author discusses optical goniometric systems in which information on the angle of mismatch between the objects of observation can be obtained in the form  $\theta' = n\theta\Gamma$  where  $\Gamma$  is the angular magnification of the optical system, and  $n = +1, +2, \dots$ . Such systems are called multiplier optical goniometric systems. A system for checking synchronism of rotation of remote bodies by using diffraction gratings in an autocollimation arrangement is considered, and it is shown that a pair of diffraction gratings multiplies the mismatch angle. Expressions are derived that characterize image formation in systems with diffraction gratings. An experimental system is described in which nonlinearity is eliminated by using one of the reflective diffraction gratings simultaneously as a dispersing component and a mirror. The angular magnification of the autocollimation tube was  $= 20\times$ , and the flat diffraction gratings had 600 lines/mm with maximum concentration in the first order of the visible region of the spectrum. The system produced up to eight images of the control mark of the autocollimator, corresponding to 16-fold multiplication of mismatch angles. Angular sensitivity was  $0.2''$  for a control range of  $10'$ . Figures 3, references 5 Russian.  
[26-6610]

## MECHANISM OF ION ACCELERATION IN LASER PLASMA

Dushanbe DOKLADY AKADEMII NAUK TADZHIKSKOY SSR in Russian Vol 25, No 4, Apr 82  
(manuscript received 7 Dec 81) pp 215-217

ABDULLAYEV, A. Sh., ASROROV, A. A. and FROLOV, A. A., Physicotechnical Institute imeni S. U. Umarov, TaSSR Academy of Sciences; Tajik Polytechnical Institute

[Abstract] The most extensively studied methods of generating fast ions are resonant acceleration and acceleration by the force of thermal pressure of plasma. In this paper the authors study a new model of ion acceleration in a cool collisional plasma upon normal incidence of both linearly polarized and circularly polarized electromagnetic radiation. The proposed mechanism involves acceleration of a self-consistent electric field that drives the ions into the accelerated mode through direct action on the plasma electrons. The process of ion acceleration is described by equations of collisional hydrodynamics in a high-frequency field and Maxwell's equations. An estimate of the maximum energy of the accelerated ions is derived from formulas that describe the dynamics of ion motion and the force of radiative pressure. For an ordinary laser plasma with emission flux density of  $10^{15}$  W/cm<sup>2</sup>, wavelength in vacuum of 1.06  $\mu$ m and ion charge number of about 10, this estimate gives an energy of 100 keV or more. References 5: 2 Russian, 3 Western.  
[34-6610]

## FORMATION OF FINE-STRUCTURE IMAGE BY CORNER REFLECTORS OPERATING ON TOTAL INTERNAL REFLECTION PRINCIPLE

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 25 Sep 81) pp 1-3

DENISYUK, G. V. and KORNEYEV, V. I.

[Abstract] The paper is devoted to an analytical and experimental investigation of the mechanism of formation of a fine-structure image by corner reflectors that operate on the basis of the total internal reflection phenomenon. It is shown that a light wave reflected by an ideal reflector of this type breaks up into six elementary light waves that are not cophased. In this case, the energy distribution in the diffraction image of a "point" comprises six nuclei symmetrically located on the joints of reflector sectors relative to a seventh central nucleus. All nuclei have approximately identical intensity, and the pattern on an individual sector is diffraction-limited. The reflector material has almost no effect on this energy distribution. Experiments showed that the reflected wave is not cophased regardless of the

orientation of the electric vector of the incident wave relative to the reflector. It is concluded that the accepted concept of the ideal corner reflector operating on the total internal reflection principle as well as the physical model of a plane mirror can be applied only in the theory of geometric optics, but not in wave optics. Figures 3, references 12: 9 Russian, 3 Western.  
[85-6610]

UDC 535.311

EVALUATING PARAMETERS OF SHADOW INSTRUMENTS WITH PHOTOELECTRIC INFORMATION CONVERSION

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 16 Dec 81) pp 4-5

AVRAMENKO, A. S., BEZDUDNYAYA, T. M., DUROVICH, E. Yu. and KRASOVSKIY, E. I.

[Abstract] Ultrasonic waves propagating in water set up alternating regions of compressions and rarefactions that are readily observable by shadow methods. This phenomenon can be used for simulating density inhomogeneities by setting up an ultrasonic field in the scanning region of a shadow instrument, which can be done while the device is directly immersed in the working fluid. The authors discuss the feasibility of using such a technique to produce inhomogeneity reference standards suitable for measuring sensitivity, and also for evaluating the dynamic range and amplitude-frequency response of an instrument directly in situ. It is analytically shown that such a standard can be made with application of amplitude-modulated voltage to the emitter plate, the carrier frequency being the resonant frequency. In this case, a linear change in percentage modulation, or a linear change in level of the amplitude-modulated voltage while holding the percentage modulation constant will produce a linear change in the gradient of the index of refraction, and hence in the light beam incident on the photocell. An experimental simulator based on this principle is described with barium titanate emitter plate and electric control module. Tests show that the device can be used to evaluate sensitivity, dynamic range and frequency characteristics of shadow instruments. Figures 2, references 10 Russian.  
[85-6610]

## MATHEMATICAL MODELING OF GEOMETRIC SHAPE OF POLYHEDRAL FIBER-OPTICS COMPONENTS

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 11 Jul 80) pp 8-10

ISAYEV, N. I. and SHIRKOVA, I. A.

[Abstract] The dimensions and shape of optical fibers as well as their relative location determine the principal characteristics of fiber-optics devices: light transmission, resolution, frequency-contrast response, inter-component nonuniformity of optical parameters and defectiveness. Since the major shape-producing factors during manufacture of light guides act periodically, the surface profiles of these components can be described by trigonometric polynomials. The authors consider the problem of mathematical modeling of the cross sectional outline of fiber-optics components, using a polar coordinate system for analytical representation. A method of harmonic analysis is given and applied to an actual batch of multistrand light guides of hexagonal shape. The results show that the proposed technique of expanding the total error of cross sectional shape in a Fourier series enables determination of the spectrum of shape deviations for a cross section of any configuration. Figures 4, references 2 Russian.  
[85-6610]

## OPTICAL SCHEMES OF LASER SCANNING DEVICES

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 2 Jun 81) pp 13-15

MARKOVA, L. A., MIKHEYEV, V. P., ROZOV, B. S. and SAVOSTIN, P. I.

[Abstract] The resolution, precision and speed of devices for processing graphic information can be considerably improved by using lasers for recording and readout. A critical component of such optical devices is the unit for shaping the laser scanning beam. The authors consider the capabilities of light beam scanners from the standpoint of maximizing resolution in three widely used arrangements: scanning by mutual shifting of the information medium and the focusing unit, in converging beams, and in parallel beams that pass through a collimating system in front of the focusing objective lens. The first arrangement forms a spot of minimum size, but requires precision displacement of the medium, thus limiting both the size of the medium and the speed of operation. The second arrangement should be preferred for large formats, and the third has the advantage of high operating speed when used with intermediate formats of the images being scanned. Figures 3, references 8: 6 Russian, 2 Western.  
[85-6610]

STUDYING GAIN OF ELECTRON FLUX IN MICROCHANNEL PLATE

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 26 Mar 81) pp 18-20

SEMENOV, Ye. P.

[Abstract] One of the main problems of image converters with microchannel plates is loss of information due to the statistical nature of secondary electron emission and signal reduction at the input of the plate. The author calculates the gain of electron flux in a microchannel plate as a function of electrostatic field strength in the channel, the coefficient of secondary electron emission of the semiconductor layer, and the coefficient of secondary emission of electrons with the first collision to select the optimum electrostatic field strength in the channel and the optimum coefficients of secondary electron emission that minimize noise. Figures 3, references 15: 10 Russian, 5 Western.  
[85-6610]

AUTOMATED GONIOMETER BASED ON RING LASER

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 27 Nov 81) pp 28-31

VANYURIKHIN, A. I. and ZAYTSEV, I. I.

[Abstract] The paper describes an automated goniometer based on a ring laser. The computational algorithm and errors of angle measurement are given. In comparison with the best goniometers with visual aiming and readout, the proposed laser unit cuts the measurement error in half, reduces measurement time by a factor of 50, and gives results as a computer printout. Requirements for operator skill are not demanding, but routine maintenance and repair requires highly skilled personnel. Figures 2, references 2 Western.  
[85-6610]

## MATHEMATICAL MODELING OF GAS DYNAMIC PROCESSES AT GATE VALVE IN RECIPROCATING COMPRESSOR

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 11, Nov 82 (manuscript received 22 Feb 82) pp 86-90

BARYSHNIKOV, G. A., docent, and LEVSHIN, V. P., engineer

[Abstract] Gas dynamic processes at a gate valve in a reciprocating compressor are analyzed assuming that, after interaction with the gate, the gas stream enters an unbounded space. During the gas transfer, moreover, the pressure drops from intake header to cylinder and from cylinder to exhaust header are assumed to be small. The space around the valve is subdivided into four characteristic region, assuming a relatively small gate lift. In region I the gas stream is one-dimensional with constant parameters and stagnation pressure equal to cylinder pressure, in region II the gas stream becomes two-dimensional, in region III there takes place viscous interaction between discharging jet and surrounding gas, in region IV the gas parameters are again constant. Equations describing the processes in regions I and II are those of potential nonviscous laminar flow, with Rayleigh-Jansen series for the subsonic mode and with correction for compressibility satisfying the Poisson equation. Region III is conformally mapped into the plane of a complex potential, by the method of Chaplygin singular points, and described here by the Prandtl equations. The boundary conditions are stipulated appropriately. Approximate solutions yield the pressure losses due to dissipation processes. Figures 3, references 4 Russian.

[94-2415]

## PENETRATION OF THIN CYLINDER WITH THIN NOSE CONE INTO PONDERABLE FLUID

Yerevan IZVESTIYA AKADEMII NAUK ARMYANSKOY SSR: MEKHANIKA in Russian Vol 35, No 4, Jul-Aug 82 (manuscript received 10 Apr 81) pp 14-20

AVAGYAN, S. G., Institute of Mechanics, ArSSR Academy of Sciences

[Abstract] The problem of a thin nose cone followed by a thin cylinder penetrating a ponderable fluid vertically downward is solved on the basis of the equation for the velocity potential field with the boundary condition of force (acceleration) balance at the free surface of the fluid. The distributions of normal pressure and drag force on the cone surface are calculated for the last stage with the entire nose cone and already part of the cylinder immersed. The solution for the initial stage of first only the nose cone penetrating corresponds to that for an infinite cone. In the case of a finite thin cone freely falling into an incompressible fluid oscillatory motion is found to occur as long as the penetration depth remains shorter than the cone height and the condition is established when the cone will always come to standstill at some depth. This depth is also determined. Figures 2, references 5: 4 Russian, 1 Western (in translation). [97-2415]

UDC 533.601+534.2.532

## DIFFRACTION OF ACOUSTIC WAVE BY PLATE MOVING NEAR PLANE

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 265, No 6, Aug 82 (manuscript received 19 May 82) pp 1345-1349

KRASIL'SHCHIKOVA, Ye. A., Moscow State University imeni M. V. Lomonosov

[Abstract] A solution is obtained to the problem of an acoustic wave traveling at velocity  $c$  along a stationary plane in a plane-parallel stream of ideal gas and striking a plate which moves at constant velocity  $u$  obliquely away from that plane. The front of the acoustic wave is inclined to the given plane and the plate moves with a zero angle of attack, in its own plane. The law of motion is stipulated as  $x = F(t)$ , where  $F$  is an arbitrary continuous function with first derivative  $F'(t) = u$ , and the velocity potential satisfies the equation  $\phi_{xx} + \phi_{zz} - \frac{1}{c^2} \phi_{tt} = 0$  in a stationary rectangular system of coordinates  $Oxz$  with the origin at some distance from the given plane. At the rear edge of the plate, where the acoustic wave strikes, the Zhukovskiy-Chaplygin condition must be satisfied at all times. The corresponding boundary-value problem is solved with the aid of two-dimensional Volterra integral equations for the potential function  $\phi(x, z, t)$  in each characteristic region of space and by resolving the latter in characteristic coordinates with subsequent inversion according to the rule generally applicable to Abel integral equations. The acoustic field around the wave diffracting plate is plotted on this basis, results being shown here specifically for a plate moving at subsonic velocity.

The results can be extended to motion of a wing of infinite span, a problem considered by this author in an earlier study (DOKLADY AKADEMII NAUK SSSR Vol 256, No 3, 1981). Figures 2, references 7 Russian.  
[45-2415]

UDC 533.6.011

INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF DIAMOND-SHAPED WING VIBRATING TRANSLATIONALLY IN SUPERSONIC FLOW

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 4 Jul 79) pp 51-52

VARNAVSKIY, A. N.

[Abstract] This paper gives the results of a study of the effect that translatory oscillations of a diamond-shaped wing in a supersonic flow have on aerodynamic characteristics obtained by the method of gas-hydraulic analogy. Oscillations are considered over the range of dimensionless vibration frequencies  $p^*$  from 0 to 1.0 and relative amplitudes  $\bar{y}=0.008, 0.02, 0.04$  at zero angle of attack. Vertex angle of the wing was  $10^\circ$ , and length of the chord was 250 mm. Analysis of the measurement results demonstrates the influence of translatory oscillations on instability of compression shocks, pressure distribution and aerodynamic characteristics. Analysis of relations for pitching moment and lift as functions of the phase of oscillations shows that these relations are periodic, but not strictly sine-wave, and that there is a delay in settling of amplitude values of these oscillations. An increase in dimensionless vibration frequency increases the amplitude values of  $C_{y_a}$  and  $m_z$  due to an increase in the pressure difference between the upper and lower wing surfaces. It is concluded that instability of bow waves has an influence on aerodynamic characteristics and coefficients of rotational derivatives in translatory vibrations of a wing in a supersonic flow that must be taken into consideration in theoretical calculations. Figures 2, references 5.

[36-6610]

## INVESTIGATION OF WING VORTEX SCHEMES

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 13 Nov 79) pp 78-79

MEN'SHIKOV, V. I. and OVCHAROV, M. M.

[Abstract] The problem of studying undetached flow of ideal incompressible fluid around a finite-aspect wing reduces to solution of a singular integral equation. A widely used approach is approximation solution with replacement of the integral by sums, which is equivalent to substituting discrete broken vortices for the vortex surface that replaces the wing. Calculations have shown that use of a small number of discrete vortices in this scheme leads to intensity and values of the coefficients  $c_y$  and  $m_z$  that differ appreciably from the exact values. In this paper, a vortex arrangement is found such that these coefficients of the wing will be close to exact even for a small number of vortices. The lifting vortices are arranged just as on an infinite-aspect plate, and the free vortices--as on a zero-aspect plate. It is shown that in such an arrangement where the vortices parallel to the chord of the wing are situated uniformly with respect to angular coordinate along the span the values of coefficients  $c_y$  and  $m_z$  are sufficiently exact for practical purposes even with only two free vortices. Figures 4, references 2 Russian. [36-6610]

UDC 532.522

## INTERACTION OF SYSTEM OF JETS INCIDENT ON FLAT OBSTACLE

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 3 Mar 80) pp 86-88

STARTSEV, V. V., SYROMYATNIKOV, N. I. and POLETAYEV, A. M.

[Abstract] An approach is suggested for describing flow in the region of interaction near a flat barrier upon incidence of jets that produce intense eddy flows. The proposed technique is based on a two-dimensional model of a straight vortex filament. Such an approach is valid where it can be assumed that intense eddy flow is due to a vortex pair. Formulas are given for the circulation and velocity field that determine the gas flow directed away from the plate. Experiments with interaction of two axisymmetric jets show satisfactory agreement with the proposed model. Figures 2, references 4: 2 Russian, 2 Western. [36-6610]

UDC 621.752

RESONANCE VIBRATIONS OF ROTORS AT HIGH SPEEDS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 11, Nov 82 (manuscript received 23 Mar 82) pp 39-43

BAL'MONT, V. B., senior lecturer

[Abstract] The behavior of a rotor at high speed is analyzed according to the linear theory of V. F. Zhuravlev (IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA TVERDOGO TELA No 5, 1971) for rotors in nonideal bearings with defective balls and races. The corresponding system of nonhomogeneous linear equations of motion for a rotor in two ball bearings, describing vibrations of such a rotor, are solved for the simple case of two identical bearings. The solution represents a buildup of the amplitude of angular vibrations during acceleration to high speed and subsequent continuation of resonance at speeds above critical. This phenomenon is attributed to coincidence of frequencies of perturbations due to unbalance with nutation frequencies, occurring most likely when the moment of inertia with respect to the shaft axis is smaller than the moment of inertia with respect to the rotor diameter through the center between bearings. Figures 3, references 1 Russian.  
[94-2415]

UDC 624.072.05

STRESSED AND STRAINED STATE OF TRIPLE-LAYER BEAM UNDER LONGITUDINAL IMPULSE LOAD

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 11, Nov 82 (manuscript received 10 Nov 80) pp 20-24

KOBELEV, V. N., doctor of technical sciences, professor, KOTEL'NIKOV, V. U., candidate of technical sciences, ZHOLUDEV, A. A., engineer, and DERYUSHEV, V. V., engineer

[Abstract] An experiment was performed in order to determine the dynamic behavior, under longitudinal impact, of a triple-layer beam consisting of two

sheaths with a filler between them. Such a beam, 90 cm long, consisting of two 1.5 mm thick sheaths of AMg-3M aluminum alloy and a 17 mm thick filler of polyurethane foam was fixed at one end and struck at the free other end with a steel ball moving at a finite velocity prior to impact. Three balls were used in the experiment, with masses of 0.044730, 0.08395, 0.112065 kg and moving at velocities of 3, 5, 7 m/s respectively. Only one of the sheaths was struck, the other one thus being loaded indirectly through the filler. Measurements were made with strain gauges, transducer signal amplifiers, oscillographs, and on recording paper tape. The results reveal a redistribution of shearing stresses which can lead to delamination. They also indicate that direct extrapolation of static test results for dynamic stress and strain analysis based on linearity in the impact zone is inadequate. A correction factor of 4-5 will take into account the dependence of contact time as well as of energy and momentum transfer on mass and velocity of the striking body within the given range of both. Figures 3, table 1, references 2 Russian. [94-2415]

UDC 539.3

EFFECT ON INITIAL LOSS OF SHAPE ON NATURAL VIBRATION FREQUENCIES OF REINFORCED CONICAL SHELLS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 11, Nov 82  
(manuscript received 13 May 82) pp 118-122

FIALKO, S. Yu., Institute of Mechanics, UkSSR Academy of Sciences

[Abstract] A closed circular frustum shell with a regular array of discrete reinforcing stringers and hoops is considered, all reinforcement members being aligned with the lines of corresponding principal curvatures of the median shell surface. The shell is initially out of shape before a static axial compression load is applied to it. Small linear vibrations of the shell about its static equilibrium position are analyzed, assuming that all reinforcement members are one-dimensional elements subject to flexure in one plane only. Determination of the natural vibration modes and frequencies involves calculating the state of stress and strain by converting the fundamental system of equations to a system of finite-difference equations of the corresponding eigenvalue problem in the perturbation vector with the stiffness matrix, the geometrical stiffness matrix, and the inertia matrix as coefficients. The solution reveals the effect of initial shape loss on the natural frequencies and their dependence on the load parameter. Application of this method and numerical results of calculations are demonstrated on a conical shell with reinforcing stringers only and with an initial loss of shape in the form of longitudinal and circumferential waves with amplitudes equal to the shell thickness. Both critical load and natural frequencies are lowered by initial shape imperfection, by an amount which depends on the mode of imperfection and on the load parameter. Figures 3, references 8:

7 Russian, 1 Western.

[98-2415]

## STABILITY OF FLEXIBLE SHALLOW SHELLS OF RECTANGULAR PLANFORM UNDER THERMAL SHOCK

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 11, Nov 82  
(manuscript received 21 Mar 80) pp 111-114

KRYS'KO, V. A. and FEDOROV, P. B., Saratov Polytechnic Institute

[Abstract] Flexible shallow shells of rectangular planform are considered under thermal shock, with temperature dependence of the Young modulus  $E$  and the linear thermal expansion coefficient  $\alpha_t$  taken into account. A uniformly distributed thermal flux impinges on the inside of such a shell, while its outside surface and lateral surfaces remain thermally insulated. The corresponding problem of heat conduction is solved analytically, with the transient temperature field expressed in the form of an infinite series. The differential equations of the corresponding mechanical problem are solved by the method of finite differences. The dynamic stability of the shell is analyzed and the critical thermal flux density is determined with  $E$  and  $\alpha_t$  simultaneously temperature dependent and with either only  $E$  or only  $\alpha_t$  temperature dependent, also with both assumed to be constant. Disregarding the temperature dependence of  $\alpha_t$  is found to result in the largest error, overestimation of the critical thermal flux density and underestimation of the deflections at loss of stability. The results are compared with those for spherical and cylindrical shells. Figures 3, references 6 Russian.  
[98-2415]

UDC 539.3:534.1

## NUMERICAL ANALYSIS OF WAVE PROCESSES IN COMPOSITE SHELL-BEAM STRUCTURES

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 11, Nov 82  
(manuscript received 30 Nov 81) pp 57-64

PATSYUK, V. I., RYBAKOVA, G. A. and SABODASH, P. F., Odessa Technological Institute of the Food Industry

[Abstract] The dynamic behavior of an elastic composite shell-beam structure consisting of coaxial outer cylindrical shell with stepwise changing wall thickness and inner solid waveguide beam with correspondingly stepwise changing cross section is described by the Timoshenko system of hyperbolic equations for shells and wave equations for thin elastic beams. Lumped inertial masses are rigidly coupled to the beam at both ends and at the shoulders where its cross section changes. A pulse load is applied in the axial direction at time zero. The transient response of such a structure, including evolution of radial displacement profiles and of vibrations, is calculated according to a difference scheme constructed for this model with zero initial conditions and static equilibrium as well as kinematic boundary

conditions. Numerical results have been obtained for a structure made entirely of duralumin and consisting of two segments, a 0.53 m long one (shell radius 0.455 m, wall thickness 0.003 m, beam cross section  $0.71 \cdot 10^{-4} \text{ m}^2$ ) and a 0.8 m long one (shell radius also 0.455 m, wall thickness 0.0045 m, beam cross section  $1.75 \cdot 10^{-4} \text{ m}^2$ ), carrying three masses: 104 kg at the thin end, 100 kg at the shoulder, 1000 kg at the thick end. Figures 3, references 8: 7 Russian, 1 Western.  
[98-2415]

UDC 539.319

#### STRESSES STATE OF LAMINATE-WOUND CYLINDRICAL SHELL WITH FRICTION

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 18, No 11, Nov 82  
(manuscript received 29 Jul 81) pp 49-56

IL'IN, L. A. and LOBKOVA, N. A., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] An infinitely long laminate-wound cylindrical shell is considered under internal pressure. Its state of stress and strain is determined in sectors of actual and potential slippage, with the friction coefficient regarded as a continuously variable parameter. Calculations are shown for a shell of  $n=5$  turns with some overlap of the innermost and the outermost ones. Five critical values of the friction coefficient  $f$  are stipulated and six modes of slippage distinguished on this basis: 1)  $f > f_1$ ; 2)  $f_1 \geq f \geq f_2$ ; 3)  $f_2 \geq f \geq f_{3(n-3)}$ , 4)  $f_{3(n-3)} \geq f \geq f_4$ , 5)  $f_4 \geq f \geq f_5=0$ ; 6)  $f_5 \geq f > 0$ . The resolving function does not depend on the friction coefficient in ranges 1,5,6 and slippage is then described by simple analytic expressions. In the intermediate ranges 2,3,4 the corresponding equations of slippage are transcendental, differentiable with respect to the friction coefficient, and the resulting differential equations can be integrated numerically by the Runge--Kutta method. Numerical results are shown for an overlap of end turns  $\varphi_{1-5} = \alpha = 5/23$  rad. Figures 2, references 2 Russian.  
[98-2415]

#### EFFECTIVE COEFFICIENTS OF NON-COULOMB DRY FRICTION UNDER VIBRATION

Tbilisi SOOBSHCHENIYA AKADEMII NAUK GRUZINSKOY SSR in Russian Vol 106, No 2, May 82 (manuscript received 5 Feb 82) pp 345-348

PANOVKO, G. Ya. and TSKHAKAYA, I. N., Institute of Machine Sciences imeni A. A. Blagonravov, USSR Academy of Sciences

[Abstract] Interaction of a solid body and a vibrating plate is considered along with the attendant apparent conversion of non-Coulomb dry friction to nonlinear viscous friction. A body of mass  $m$  moving on the rough surface of

a horizontal plate is assumed to be subject to a constant horizontal pull force, a constant normal pressure force, and a friction force depending on the velocity as a polynomial function of velocity and velocity cubed. The plate is assumed to perform harmonic longitudinal vibrations. The solution to the corresponding equation of motion for the body is sought as the sum of two dimensionless velocity components: slow average velocity and  $2\pi$ -periodic fast alternating velocity. Assuming a constant average velocity, the pull force (dimensionless) is calculated as a function of that velocity for various values of the vibration parameter  $n = A\omega/v_0$  ( $A$  - vibration amplitude,  $\omega$  - vibration frequency,  $v_0$  - sliding velocity at which coefficient of sliding friction is minimum). The results reveal that, unlike in the case of Coulomb dry friction, there is an optimum vibration mode here which corresponds to the minimum effective friction coefficient. Figures 3, references 4 Russian. [93-2415]

UDC 534.1

FACTOR FAVORABLE TO OCCURRENCE OF VIBRATIONS WITH TRAVELING STRAIN WAVES IN CYCLICALLY SYMMETRIC SYSTEMS

Kiev PROBLEMY PROCHNOSTI in Russian No 7, Jul 82 (manuscript received 16 Apr 80) pp 92-94

ALESHIN, N. P., Zaporozh'ye

[Abstract] Available laboratory and field data are analyzed, to explain why traveling strain waves and attendant vibrations occur in some cyclically symmetric systems such as arrays of banded turbine blades rotating at certain speeds but not necessarily in stationary turbine disks excited by air jets from rotating nozzles. Internal compression forces acting as hoops on turbine disks and on the hubs of a blade belt, produced by thermal stresses and excessive mechanical stresses due to nonuniform heating and improper assembly respectively, are found to be a factor not only favorable to but often governing the occurrence of vibrations with traveling strain waves. These can be avoided by elimination of any constant continuous compression forces which are likely to sustain deformation of the belting. Figures 2, references 7 Russian. [43-2415]

## EXPERIMENTAL DETERMINATION OF STRESSES IN LAYERS OF MULTILAYER REELED SHELL

Kiev PROBLEMY PROCHNOSTI in Russian No 6, Jun 82 (manuscript received 2 Feb 81) pp 67-71

BURAK, M. I., Belorussian branch, Central Scientific Research and Planning Institute of Metal Structures

[Abstract] Reeled multilayer structures are finding broad applications in chemical and power equipment, mainly because of higher resistance to brittle fracture at low temperatures. An important step in the design of such structures is evaluation of experimental data, especially on ductility under static load and fatigue under cyclic load. Here data are presented on static tests performed on two cylindrical steel vessels (gas tanks) with a wall consisting of six 3 mm thick layers and with flat covers at both ends. Circumferential and meridional stresses were measured with strain gauges in a hole through the wall, first under nominal pressure of 9.6 MPa, then with the shells stepwise overloaded: one to 14.6 MPa and one to 16 MPa. The results are compared with calculations according to standard formulas for steel. Into consideration are taken residual stresses due to reeling and strains due to the hole. The results reveal that, while axial strains of the layers remain equal, the stress is highest in the innermost layer under nominal load. As the load increases, the outermost layer also becomes more highly stressed but the difference between stresses in both extreme layers and the intermediate four layers decreases. Stresses in a less tightly reeled shell equalize less readily and only under heavier loads. At fracture, under a pressure of 18 MPa, all layers in the shells were found to be stressed equally. Figures 2, tables 3, references 13: 11 Russian, 2 Western (1 in translation).

[42-2415]

## DESIGN OF REELED MULTILAYER CYLINDER FOR EQUAL STRENGTHS OF TURNS

Kiev PROBLEMY PROCHNOSTI in Russian No 6, Jun 82 (manuscript received 8 May 81) pp 64-67

BEZVERBNYY, A. F., Institute of Strength Problems, UkSSR Academy of Sciences, Kiev

[Abstract] Design calculations are shown for a reeled multilayer cylinder with turns of equal strengths under internal pressure. It is assumed, theoretically, that metal layers are wound around a monolithic inner tube so as to ensure equal equivalent stresses in all turns. The procedure involves determining the increments of radial and tangential stresses in any pair of adjacent turns, according to Lamé relations and theory of closed thin

shells, then treating the entire cylinder as a thick-walled one. With the inside radius given, the optimum tube thickness and outside cylinder radius are determined on this basis. The results reveal that the optimum tube thickness is one equal or close to the tube thickness, such a tube thus being equivalent to another layer. The design method is applied to a cylinder with inside radius of 100 cm for internal pressure of 50 MPa, made of material with 150 MPa strength. Such a cylinder consisting of wound layers only is found to be about 6% lighter than one with a 13.7 cm thick inner tube and about 25% lighter than one consisting of two tubes shrunk one on the other with an interference fit. Figure 1, references 2 Russian.  
[42-2415]

UDC 62-98:620.165

#### DESIGN OF THIN-WALLED PRESSURE VESSELS FOR RESISTANCE TO FRACTURE

Kiev PROBLEMY PROCHNOSTI in Russian No 6, Jun 82 (manuscript received 6 Aug 81) pp 60-63

SHIRSHOV, V. P., Tula

[Abstract] Design calculations are shown for thin-walled pressure vessels made of isotropic homogeneous and monotonically hardening material. The breaking pressure is determined as function of three standard mechanical characteristics: tensile strength, conventional yield strength and percent elongation. Design formulas are derived from the relations  $\sigma_{true} = A(\epsilon_{true} - \sigma_{true})^\alpha$  and  $E_{true} = \frac{3E}{2(1+\mu)}$  E- Young's modulus,  $\mu$ - Poisson's ratio,  $\sigma$  - stress,  $\epsilon$  - strain), with constants A and  $\alpha$  determined from the state of stress and strain during necking. These formulas are applied, for illustration, to a cylindrical shell and a spherical shell subject to fracture under an either still increasing or already decreasing load. Figure 1, references 2 Russian.  
[42-2415]

UDC 539.3

#### EFFECT OF DIFFERENT TENSILE AND COMPRESSIVE RESISTANCES OF NONLINEARLY ELASTIC MATERIAL TO STRESS AND STRAIN IN CYLINDRICAL SHELL

Kiev PROBLEMY PROCHNOSTI in Russian No 6, Jun 82 (manuscript received 1 Jul 81) pp 55-60

MAKEYEV, A. F. and OVCHINNIKOV, I. G., Saratov Polytechnic Institute

[Abstract] The behavior of a cylindrical shell made of nonlinearly elastic material with different tensile and compressive resistances under stress and

strain is analyzed, on the basis of the hypothesis of nondeformable normals and with linear geometrical relations between displacements and strains added to integral relations for forces and moments. Since the parameters of physical relations are indeterminate, dependent on the state of stress, the corresponding boundary-value problem is solved by reducing it to a problem of successive load applications. The resolvent equation, in an orthogonal system of coordinates, can be solved either by the Lyapunov-Duboshin method, which yields accurate results only for very short shells, or by the Godunov method of discrete orthogonalization. In the latter method the nonlinear problem is reduced to a sequence of linear ones and those are solved by a stable procedure with any desired accuracy. Typical results obtained on a BESM-6 high-speed computer are shown for a short shell with one end fixed and one end hinged. They indicate that disregarding a 30% difference between tensile and compressive resistances produces a 20% error in stress, assuming zero Poisson ratios can produce a 25% error in deflection and a 28% error in stress. The physical model proposed here is applicable to many low-carbon and medium-carbon steels, high-carbon tool steels, structural alloy steels, cast iron, aluminum, aluminum alloys, magnesium alloys, titanium bronze, and Textolite. Figures 4, tables 1, references 16: 15 Russian, 1 Western.  
[42-2415]

UDC 539.3:629.7

#### STABILITY OF MULTILAYER CYLINDRICAL SHELLS MADE UP OF ORTHOTROPIC LAYERS

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 8 Apr 81) pp 45-47

ABDULKHAKOV, K. A. and CHEREVATSKIY, S. B.

[Abstract] A system of differential equations in displacements is derived for stability of thin circular cylindrical shells. The analysis is based on relations using the hypothesis of flat cross sections and the assumption that normal stresses are independent of interlayer shifts. The solution of the system is sought in double trigonometric series in a form that satisfies boundary conditions in the case of hinged support at the edges. An expression is given that can be minimized with respect to parameters of wave formation to give critical values of external pressure and axial force of compression with a given ratio of  $T_1^0/T_2^0$ . Comparison of calculations with experimental data obtained on fiberglass plastic specimens shows satisfactory agreement with little difference between critical loads found with consideration of transverse shear and on the basis of the classical theory. Table 1, references 6 Russian.  
[36-6610]

## CALCULATION OF SPHERICAL SHELL WITH INVERSELY SYMMETRIC LOADING

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 29 Apr 80) pp 47-50

AKHMED'YANOV, I. S.

[Abstract] In a previous paper, the author gave relations necessary for studying the stressed and strained state of a spherical shell under the action of a load that is symmetric relative to some meridional plane [see Akhmed'yanov, I. S., "Calculation of Spherical Shell Under Symmetric Loading", IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA, No 4, 1980, pp 7-12]. Here, analogous relations are derived for calculating a spherical shell with inversely symmetric loading, where the components of a load that is inversely symmetric relative to the plane of the meridian are represented as trigonometric series. Expressions are given for the forces and moments that arise in the spherical shell, and for the displacements of the middle surface and the angles of turn of the normal to the middle surface. Figure 1, reference 1 Russian.

[36-6610]

UDC 539.3:629.735.33.024

## SOME PARTICULARS OF LOSS OF STABILITY OF RIBBED CYLINDRICAL SHELLS

Kazan IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 7 Jul 80) pp 56-59

KAN, S. N., KAPLAN, Yu. I. and OSTROVITSKIY, V. I.

[Abstract] A simple method is proposed for selecting approximating functions in the energy approach to solving problems of shell stability. The approximating expressions are a linear combination of functions corresponding to simpler limiting cases of reinforcements. If the components of these expressions satisfy kinematic and static boundary conditions along with the differential equation of the problem, the solution may be nearly exact. The error of the solution will not be significant even if the differential equation is not satisfied, as long as the boundary conditions are met. The proposed approach is illustrated by analysis of a longitudinally compressed freely supported shell discretely reinforced by elastic stringers, and results are compared with known solutions. Figures 2, references 8 Russian.

[36-6610]

## SOLUTION OF THERMOELASTIC PROBLEM FOR ARBITRARILY SHAPED SHELL OF REVOLUTION

Kazan IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 82 (manuscript received 27 Nov 80) pp 62-65

KUZ'MIN, V. V.

[Abstract] An analysis is made of a thin elastic shell of revolution under the action of a steady-state temperature field. It is assumed that the stiffness characteristics and coefficient of linear temperature expansion of the shell material may vary along the generatrix. The effective temperature is axially symmetric and linearly dependent on shell thickness. An expression is derived for the potential energy of the heated shell, and a variational principle is then used to minimize a discrete analog of this energy functional obtained by replacing integration with summation by elements of a net superimposed on the meridian of the shell with simultaneous replacement of the derivatives in this functional with finite-difference operators. An example is given of the use of the proposed algorithm for analyzing the stressed and strained state of a shell in the form of a frustum of a cone. The computer program takes a small volume of storage. Figures 3, references 3 Russian. [36-6610]

UDC 539.37

## BENDING OF PLATES AND SHELLS WITH VARIABLE STIFFNESS

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 82 (manuscript received 16 Oct 81) pp 41-45

KRYS'KO, V. A., doctor of technical sciences, and BOCHKAREV, V. V., assistant instructor

[Abstract] A Vlasov-Kantorovich method of variational iterations is used in higher approximations to reduce the two-dimensional problem of bending of plates and shells of variable stiffness to one-dimensional form. It is demonstrated that in the first approximation this method gives considerable errors in determination of the stressed and strained state of such solids. The model example is an elastic square plate with hinged support around the edge, assuming a uniformly distributed load. Results are compared with solution by the Bubnov method in higher approximations. A finite-difference method is used to solve the ordinary differential equations derived from the initial partial differential equations. The results show that higher approximations must be considered when using the method of variational iterations to solve problems of bending of plates and shells of variable thickness, especially in optimization problems where the thickness varies in a complicated way. Figures 3, references 7 Russian. [28-6610]

## DERIVING CANONICAL EQUATIONS FOR MULTILAYERED SHELLS OF REVOLUTION MADE OF MATERIALS WITH NONLINEAR ELASTICITY

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 82 (manuscript received 22 Feb 82) pp 45-49

POPOV, B. G., candidate of technical sciences

[Abstract] Analytical derivation of canonical systems of equations is difficult for multilayered shells when deformations of transverse shear and stretching must be accounted for in individual layers. A variational-matrix method developed for this stage of solution has been previously applied with success to some linear problems. In this paper, a modification of this method is applied to physically nonlinear systems of multilayered shells of revolution. Displacements and angles of turn are selected in a normal annual cross section for characteristic surfaces. These parameters completely define the distribution of tangential and normal displacements with respect to thickness of the multilayer stack for predetermined kinematic models of the layers. Strain distribution through the layers is described by using known relations between displacements and strains from elasticity theory. Strain of individual layers in the general case is described by various kinematic hypotheses. The proposed method of deriving systems of resolving first-order differential equations and constructing iteration processes of solution of physically nonlinear axisymmetric problems of statics can be used to automate preparatory stages for computer solution of the problems. References 6 Russian. [28-6610]

UDC 624.074

## CARRYING CAPACITY OF SPHERICAL SANDWICH SHELLS UNDER DYNAMIC LOADING

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 9, Sep 82 (manuscript received 16 Jul 80) pp 49-54

KOTEL'NIKOV, V. U., candidate of technical sciences, and KOBELEV, V. N., doctor of technical sciences, professor

[Abstract] The paper gives the results of an experimental study of spherical sandwich shells that can be used to reconstruct the physical pattern of strain and to evaluate the carrying capacity of such shells under the action of external axisymmetric pulse loading with nonuniform distribution along the generatrix. The experimental specimens were sandwich hemispheres with outside layers of variable thickness. The outer layers were formed from AMTs-M aluminum alloy by spinning. The inner layer was epoxy foamed in the space between the metal layers. The thickness of the outer shells varied from 0.1 cm at the pole to 0.06 cm at the equator. Loading was by underwater explosion of foil with calibrated weight. The inner cavity under the hemisphere was

filled with air at atmospheric pressure during testing. Strain gages were cemented in a predetermined pattern to the specimens. Plots were made of the time dependence of the deformed state of the shells as a function of the nature and magnitude of applied pressure. The critical load level was determined. A method of calculation is given that agrees with the experimental data. Figures 3, references 4 Russian.  
[28-6610]

UDC 62-251-755.001.24

PRINCIPLES OF METHOD OF CALCULATING PERMISSIBLE IMBALANCES FROM MODES OF VIBRATIONS OF FLEXIBLE ROTORS

Moscow VESTNIK MASHINOSTROYENIYE in Russian No 8, Aug 82 pp 18-21

BARKE, V. N., candidate of technical sciences, and KRANTSBERG, L. E., engineer

[Abstract] In balancing a flexible rotor, the purpose is to attain a permissible specific imbalance  $[e_b]$  in each of the bearing planes by sequentially balancing the rotor with respect to  $n$  modes of oscillations, including static and moment imbalances. With respect to each of the  $n$  modes, the value of the specific imbalance is to be  $e_i \leq [e_i] = q_i [e]$  so as to satisfy the condition  $\sum_{i=1}^n \vec{e}_{bi} \leq |\vec{e}_b|$ , where  $\vec{e}_{bi}$  is the vector of specific imbalance with respect to

the  $i$ -th mode in the bearing plane,  $q_i$  is the coefficient of the fractional influence of the  $i$ -th mode of imbalance on its resultant ( $i=1, 2, 3, \dots, n$ ;  $n = S + 2$ ;  $S$  is the number of flexural modes being balanced). The authors propose a method of determining coefficients  $q_i$  with sequential balancing of  $n$  modes (including  $S$  flexural modes) for a rotor on balancing machines. In the proposed procedures, the coefficient is represented as  $q_i = a \beta_i$ , where  $a$  is the coefficient of the number of modes of oscillations accounted for and  $\beta_i$  is a normalizing factor that relates the  $i$ -th mode on the rotor to its occurrence in the bearing plane. The described technique can be used to set up a unified system for normalizing imbalances of rotors of all types, and for developing quantitative criteria to account for the number of modes of oscillations of a rotor in imbalance. Figures 1, tables 2, references 3 Russian.

[40-6610]

## CONTROLLED SPEEDUP OF UNBALANCED ROTOR THROUGH CRITICAL VELOCITY

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 9, Sep 82 pp 26-30

ZOBNIN, A. P., candidate of technical sciences, MALININ, L. M., engineer and TANAYEV, D. B., engineer

[Abstract] An analysis is made of speedup of a rotor system through the critical velocity based on a model of a massless flexible shaft with a single disk in the middle (Laval rotor) driven by external torque. A solution is found for the problem of optimum control of the drive torque in the near-critical region yielding a law of torque variation that ensures attainment of transcritical speed in a given time and minimizes a certain criterion functional that may take the form of time of attainment of a given velocity, energy expended in the acceleration process, average resonant amplitudes, maximum drive torque during acceleration or other factors of this kind. Pontryagin's maximum principle shows that optimum control in this case will be on-off, so that the problem reduces to determining times of energizing and de-energizing the motor. It is shown that the drive torque needed for overcoming the critical velocity can be appreciably reduced by using a control system with vibrotorque feedback. A control system of this kind is described with switching frequency that is low compared with the frequency of rotation, and with relatively low sensitivity to small changes in vibrotorque. Figures 6, references 7 Russian.  
[39-6610]

UDC 669.14.018.8:621.039.5

## NEW STAINLESS STEELS FOR ATOMIC POWER EQUIPMENT

Moscow ENERGO MASHINOSTROYENIYE in Russian No 10, Oct 82 pp 27-31

KRYANIN, I. R., doctor of technical sciences, RYABCHENKOV, A. V., doctor of chemical sciences, GERASIMOV, V. I., engineer and KHARINA, I. L., engineer

[Abstract] Corrosion of equipment in AES with water-moderated water-cooled power reactors or water-graphite channel reactors affects mainly the structural materials in the first loop, namely Kh18N10T austenitic chromium-nickel steel and Kh2M pearlitic chromium steel with austenitic beading. Stress corrosion is the dominant mode, causing 41.6% of all corrosive defects (according to statistical data collected in Japan), followed by pitting (19.4%), intergranular corrosion (17.6%), general corrosion and others. While pearlitic steels have high resistance to intergranular and stress corrosion, austenitic steels have high resistance to pitting and uniform corrosion. For certain operating conditions, especially with stationary or stagnant cold or hot water at high oxygenation rate, there are needed structural materials with about equally high resistance to all these corrosion modes and thus with the necessary chemical and mechanical properties inhibiting brittleness. Seven new grades of stainless steel have been developed at the Central Scientific Research Institute of Machine Manufacturing Technology: OkhN45B (EP350), OKhN35B-VI (EP756-VI), OKhN45MVB (DI-65) for tubular equipment (steam generators, heat exchangers, heating pipes, separators), 03Kh16N9M2, 015Kh18M2B-VI (EP882-VI), 08Kh14MF, 06Kh12N3DL for frames and housings. They have been tested for mechanical characteristics at 20° and 350°C, aging characteristics in 3000 h tests, effect of tempering temperature and time on their corrosion resistance, and oxidation in hard water. Prototype GTsN195 pumps and GZZ D<sub>u</sub> 850 gate valves have already been built with 06Kh12N3DL steel at "Izhorskiy" plant imeni A. A. Zhdanov and "Chekhovskiy" plant respectively, installed in the Novovoronezh AES or to be installed in the Yuzhno-Ukrainskaya AES and in the Kalinin AES. Figures 5, tables 3, references 8: 6 Russian, 2 Western. [83-2415]

## PNEUMATIC INSTRUMENT FOR MEASURING RADII OF LENSES

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 6, Jun 82  
(manuscript received 11 Sep 81) pp 38-40

ZAKHAROV, V. P., KRAVCHUK, V. M., PEROV, A. V. and SHEVELEV, V. I.

[Abstract] A high-precision pneumatic spherometer has been developed, built and tested for measuring the radii of ground lenses and glued lens stacks. Its operation is based on relative measurements by a differential scheme with 1-4 measuring nozzles. The instrument includes also three compensating nozzles and a pneumoelectric contact-type transducer. Connections are made through chlorinated tubing. Lenses are placed in a multicavity fixture, a spherical cap on a stem, under the nozzle set resting on a conical spacer-base. The instrument can read radii from  $\pm 20$  mm to  $\infty$  of lenses with a diameter not smaller than 10 mm. Accuracy and stability of readings by this instrument have been evaluated statistically, on the basis of the Student's t-test. Its performance is superior to that of a plain laid-on spherometer ring evaluated in a concurrent series of tests. Figures 3, table 1, references 1 Western (in translation).

[31-2415]

UDC 669.15:629.12.037.4

## NEW MICROALLOY STEELS FOR LARGE PROPELLER SHAFTS

Leningrad SUDOSTROYENIYE in Russian No 10, Oct 82 pp 37-39

PESTOV, V. S., OSMININ, B. A. and FILIMONOV, G. N.

[Abstract] Three new grades of special-purpose low-carbon alloy steel have been developed for hollow propeller shafts: Volga-1, Volga-2, Volga-3. They feature a low sulfur and phosphorus content, less than 0.04% total and less than 0.025% each, ensuring a favorable macrostructure with excellent plastic characteristics and high resistance to eccentric liquation. The carbon content within the 0.20-0.27% range is sufficiently low to ensure an adequate degree of chemical homogeneity in large forgings and castings. The manganese content within the 0.60-0.90% range compensates, in terms of strength, for the reduced carbon content. The silicon content within the 0.20-0.50% range maintains the yield point at required level. Tables 3.

[89-2415]

## USE OF MAGNETIC SYSTEMS FOR INCREASING EFFICIENCY OF ELECTRON-BEAM BOMBARDMENT OF CYLINDRICAL OBJECTS

Moscow ATOMNAYA ENERGIYA in Russian Vol 53, No 5, Nov 82 (manuscript received 21 Dec 81) pp 317-319

AKRACHKOVA, L. L., KUKSANOV, N. K., SALIMOV, R. A., TIMKO, Yu. N. and FINKEL', E. E.

[Abstract] Electron accelerators such as beam tubes are now extensively used in industry for modifying polymer (polyethylene) insulation on cables and wires. This irradiation technology is characterized by high technical and economic indicators, but an analysis of the manufacturing process reveals that its performance can be still improved and its application broadened by appropriate shaping of the irradiation zone. Long cables, wires, or thermo-setting tubes constitute part of the conveyor mechanism and the system must be configured accordingly. Typical conveyor schemes are 1) rotating and intermediate rollers; 2) rocking drums; 3) rocking drums and intermediate rollers, with either unilateral or bilateral electron-beam bombardment from stationary sources. The beam current utilization factor and the electron energy utilization factor, two main technological performance indicators, are evaluated for such schemes with the cable geometry taken into account. Results are reported on the performance of an ELV-2 electron accelerator with a magnet system for beam shaping. Two C-form magnets produce a nonuniform magnetic field which focuses a 1.5 MeV electron beam on a cylindrical object up to 11 mm in diameter. A circular irradiation field ensures high product quality, almost regardless of the active conductor cross section in a cable. Tests were performed on cables with outside diameters of 25-30 mm and 2.5-10 mm thick insulation. Figures 5, table 1, references 3 Russian.

[91-2415]

## EFFECT OF ULTRASONIC TREATMENT ON FLEXURAL STRAINS IN PLATES MADE OF D16 AND V95 ALUMINUM ALLOYS

Kiev PROBLEMY PROCHNOSTI in Russian No 6, Jun 82 (manuscript received 26 Mar 80) pp 117-121

BAZELYUK, G. Ya., LYUBCHIK, A. M., MATSIYEVSKAYA, S. Ya., PETRUNIN, G. A. and TIKHONOV, L. V., Institute of Metal Physics, UkSSR Academy of Sciences, Kiev

[Abstract] An experimental study was made to determine the effect of ultrasonic treatment on relaxation of internal stresses in metal plates during forming processes. As specimens were used  $2 \times 4 \times 35$  mm<sup>3</sup> rectangular plates made of D16 and V95 aluminum alloys. These materials age characteristically with coherent and semi-coherent precipitation of excess phases, which inhibits glissile dislocations. Ultrasonic treatment was effected unilaterally with

one or bilaterally with two PMS 15A-18 magnetostrictive transducers through waveguides. The plates were loaded statically without and with acoustic load, satisfactory acoustic contact in the latter case being ensured between plunger and curving plate surface. Residual stresses and strains as well as microhardness were measured after load removal. Microstructural examination was performed by the "reverse" X-radiography method on a URS-55 stand with a Cu-K $\alpha$  radiation source inside a KROS chamber and with the (333) interference line serving as indicator of crystal lattice distortion. In addition, foil slices cut from the plates were, after grinding, polishing, and etching, examined under a Tesla-5133A electron microscope with 100 kV accelerating voltage. The results indicate that ultrasonic treatment increases residual strains in D16 and V95 plates under light flexural load, producing a high density of helicoidal dislocations and dislocation loops. Such a treatment can, therefore, be recommended as aid in forming (bending) thin small objects made of aluminum alloys. Figures 4, table 1, references 4: 3 Russian, 1 Western.

[42-2415]

UDC 621.833-182.634:62-982

EXPERIMENTAL FACILITY FOR STUDYING KINEMATIC ACCURACY OF DEVICES FOR MOTION  
CONVERSION IN HIGH VACUUM

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 9, Sep 82 pp 25-26

BORISOV, S. G., engineer, ISTOMIN, S. N., candidate of technical sciences,  
and NEKRASOV, M. I., candidate of technical sciences

[Abstract] An experimental facility is described for checking kinematic accuracy of harmonic drives used for transmitting motion to high vacuum with various wave generator designs. The housing of the strain wave gearing is combined with the vacuum chamber. The input and output shafts of the drive are elements of contact inputs that are sealed by sections in the drive housing and a flange. A guard vacuum is set up between the sealing sections. The input shaft is driven by a P-11 DC electric motor with stable frequency of rotation through a speed reducer and change gears. The vacuum system consists of a 2NVR-5D roughing pump with nitrogen trap, and an NORD-100 magnetic-discharge pump. A VIT-3 vacuum meter is used for checking the vacuum. Stationary connections to the speed reducer are sealed with annealed copper gaskets, and moving connections are sealed with special F4K15M5 poly-fluoroethylene rings and vacuum rubber. A vacuum of about  $10^{-5}$  Pa can be maintained. The output data in drive testing is in the form of kinematograms enabling precise location of a kinematic error. The facility is sensitive enough for the finest measurements. Figures 2, references 4 Russian.

[39-6610]

## ANTISTATIC AND ABRASION-RESISTANT COATING FOR POLYMER OPTICAL COMPONENTS WITH COMPLEX SURFACE PROFILE

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 9, Sep 82  
(manuscript received 30 Jul 81) pp 38-39

ALEKSANDROV, G. A., KHALIULLINA, N. Z., POLEZHAYEV, V. V. and ANOKHINA, N. P.

[Abstract] A method is proposed for coating plastic optical components of complex shape with films of silicon oxides by vacuum sputtering. Experiments showed that the optimum thickness for optical, antistatic and abrasion-resistant properties is  $(0.75 \pm 0.05) \mu\text{m}$ . The surface resistivity of the films with this optical thickness is  $10^{11} - 10^{12}$  ohms, decreasing to  $10^{10} - 10^{11}$  ohms with an increase to a thickness of  $1.0 - 1.3 \mu\text{m}$ . Transmission is 92-94% in the spectral region of  $0.4 - 0.7 \mu\text{m}$ . Under visual inspection against a black background in reflected light at an angle of  $15 - 20^\circ$ , the resultant coatings show a slightly greenish cast, and are colorless in transmitted light. The films withstand careful cleaning with a soft cloth or cotton soaked in alcohol and are not damaged by three temperature cycles from  $-50$  to  $+50^\circ\text{C}$  (for an hour at each temperature) or by relative humidity of  $(95 \pm 3)\%$  for 48 hours at  $20 - 23^\circ\text{C}$ . Fresnel lenses and rasters made of polymethyl methacrylate retained their optical properties when coated with SiO films, and had a much cleaner field of view thanks to the antistatic properties of the films. Figure 1, references 5: 2 Russian, 3 Western.  
[85-6610]

CSO: 1861

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