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THE GDT-BASED NEUTRON SOURCE AND RELATED ISSUES (ANNOTATED BIBLIOGRAPHY)

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НОВОСИБИРСК

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PREFACE

The purpose of this report is to provide the reader with some guidance over the publications on the gas-dynamic trap neutron source - the device that should produce 14 MeV neutrons for fusion technology tests and other purposes. We have included only the papers directly related to the key physics and technology issues of such a neutron source (in particular, only those of theory papers have been covered, which contain direct references to the gas-dynamic trap). In order to provide an access to the more general information, we have included also some references to the recent surveys of mirror research. References to the alternative proposals of the plasma-type neutron sources have been also given.

The references are organized subject-wise. Within a particular section, they are ordered alphabetically (by the authors' names). Double-number system is used: the first number refers to the section, the second to the position of the paper within the section. At the end of each section, the references are given to those papers that have been described in other sections but have some relevance to the subject of the current section.

The alphabetic author index is attached at the end.

The compilers are grateful to their colleagues from the Budker Institute of Nuclear Physics for the assistance in preparing this report. The information on the missing references would be much appreciated.

1 GENERAL SURVEYS ON MIRROR RESEARCH

1.1 Hershkowitz N., Miyoshi S., Ryutov D.D. **"Mirror Devices".** Nucl. Fusion, v.30, p.1761 (1990).
The latest overview of the status of mirror research, with the chart of mirror devices that were existing at 1990.

1.2 Post R.F. **"The magnetic mirror approach to fusion".** Nucl. Fusion, v.27, p.1579 (1987).
A comprehensive survey of mirror research with a very detailed bibliography (386 references).

1.3 Ryutov D.D. **"Open-ended traps".** Sov. Phys. Uspekhi, v.31, p.301 (1988).
A survey that contains the basic principles of all the types of mirror traps, including the GDT.

2 GAS-DYNAMIC TRAP - GENERAL

2.1 Davydenko V.I., Ivanov A.A., Koz'minykh Yu.L., Kollerov Eh.P., Kotelnikov I.A., Mishagin V.V., Podyminogin A.A., Rogozin A.I., Roenko V.A., Roslyakov G.V., Ryutov D.D., Shrainer K.K. **"Experimental model of the gas-dynamic trap".** Report INP 86-104, Institute of Nuclear Physics, Novosibirsk (1986) - in Russian.
A rather complete description of the design of the GDT facility; a brief overview of the research programme for this facility.

2.2 Krivosheev M.V., Katyshev V.V. **"Parametric studies of the fusion energy producing unit on the basis of the gas-dynamic trap".** Voprosy Atomnoi Nauki i Tekhniki - Termoyadernyi Sintez (The Problems of Atomic Science and Technology - Thermonuclear Fusion), #2, p.12 (1988) - in Russian.
General analysis of the influence of various parameters on the cost of electricity produced on the GDT fusion reactor.

2.3 Kruglyakov Eh.P. **"Mirror research at Novosibirsk".** Plasma Physics and Controlled Fusion, v.29, p.1309 (1987).
Among other subjects, the GDT reactor and neutron source issues (as in Refs.[2.6], [3.3]), are presented.

2.4 Mirnov V.V., Nagornyj V.P. **"Kinetics of the high energy ions in the gas-dynamic trap".** Voprosy Atomnoi Nauki i Tekhniki - Termoyadernyi Sintez (The Problems of Atomic Science and Technology - Thermonuclear Fusion), #3, p.40 (1986) - in Russian.
The ion distribution function in the range between the injection and thermal energies has been found; contribution of these "hot" ions to the fusion yield has been evaluated; ion injection at some angle to the magnetic axis as a mean of reducing the transverse pressure of the "hot" ions has been considered.

2.5 Mirnov V.V., Ryutov D.D. **"Linear gas-dynamic system for plasma confinement".** Sov. Tech. Phys. Lett., v.5, p.279 (1979).
The first presentation of the GDT concept with its distinguishing attributes: collisional confinement with a linear dependence of the confinement time on mirror ratio; large mirror ratio; axisymmetric geometry with MHD stabilization provided by the favorable curvature of the magnetic field lines beyond the mirror throat.

2.6 Mirnov V.V., Ryutov D.D. **"Gas-dynamic trap".** Voprosy Atomnoi Nauki i Tekhniki - Termoyadernyi Sintez (The Problems of Atomic Science and Technology - Thermonuclear Fusion), #1, p.57 (1980) - in Russian.
A detailed analysis of the axial confinement; reactor calculations.

2.7 Mirnov V.V., Ryutov D.D. **"Gas-dynamic trap".** In: "Itogi Nauki i Tekhniki - Fizika Plazmy" ("Summaries in Science and Technology - Plasma Physics"), The Publishing House of the Institute of Scientific Information, Moscow, 1988, v.8, p.77 - in Russian.
The most detailed survey of all the physics issues related to the gas-dynamic trap performance: axial losses, MHD stability, cross-field transport, microstability of the sloshing ions, expander physics, reactor calculations. Brief summary of the neutron sorce concept. References up to 1987.

2.8 Post R.F., Fowler T.K., Killeen J., Mirin A.A. **"Concept for a high-power-density mirror fusion reactor".** Phys. Rev. Lett., v.31, p.280 (1973).
The paper discusses the advantages of the dense plasma linear fusion systems with a two-component plasma: warm tritium target and deuterons injected at 200 keV (for the domain of mirror ratios ~ 10).

2.9 Ryutov D.D. **"Open traps with a short mean free path plasma".** In: "Mirror-Based and Field-Reversed Approaches to Magnetic Fusion" (Proc. of the International School of Plasma Physics, Varenna, 1983) Monotypia Franchi, Citta di Castello, Italy, v.1, p.173.
This paper contains, in particular, a brief description of the GDT concept with a first qualitative discussion of the stabilizing effects caused by high power neutral beam injection.

2.10 Velikhov E.P., Kartashev K.B. **"The main results of the research on fusion and plasma physics in the USSR from August 1984 to August 1985".** Voprosy Atomnoi Nauki i Tekhniki - Termoyadernyi Sintez (The Problems of Atomic Science and Technology - Thermonuclear Fusion), #1, p.3 (1986) - in Russian.
A brief description of the GDT facility (Novosibirsk) and first information on the design of the theta-pinch type gas-dynamic trap with a cusp stabilizer (KP-2M project, Sukhumi) have been presented.

3 GDT TYPE NEUTRON SOURCE - BASIC PRINCIPLES

3.1 Kotelnikov I.A., Mirnov V.V., Nagornyj V.P., Ryutov D.D. **"New results of gas-dynamic trap research".** In: "Plasma Physics and Controlled Fusion Research", v.2, p.309, Vienna, IAEA (1985).
A brief version of the Ref.[3.3], plus discussion of some physics issues of gas-dynamic traps: reduction of the end-losses by attaching additional mirror cells at the ends of the device; possible stabilization of the flute perturbations by neutral beam injection (as in [2.9]); effect of magnetic field imperfections on the cross-field transport.

3.2 Kotelnikov I.A., Ryutov D.D.,Tsidulko Yu.A.,Katyshev V.V., Komin A.V., Krivosheev M.V. **"Mathematical model of the GDT-based neutron source".** Report INP 90-105, Institute of Nuclear Physics, Novosibirsk (1990) - in Russian.
The only more or less detailed description of the so-called 3-component version of the GDT-based neutron source (cold target plasma and fast sloshing deuterons and tritons, with the neutron production from collisions between fast deuterons and tritons), the version which is the basis of the present approach of the Novosibirsk group.

3.3 Mirnov V.V., Nagornyj V.P, Ryutov D.D. **"Gas-dynamic trap with a two-component plasma".** Report INP 84-40, Institute of Nuclear Physics, Novosibirsk (1984) - in Russian.
The first description of the GDT-based neutron source in the so-called 2-component version: a relatively dense and cold target deuterium plasma and the population of sloshing tritium ions (injection energy 240 keV).

See also [2.3], [2.7].

4 MHD STABILITY - THEORY

4.1 Berk H.L., Ryutov D.D., Stupakov G.V., Tsidulko Yu.A. **"Instability effects caused by conducting end walls in a plasma on open field lines".** In: "Plasma Physics and Controlled Nuclear Fusion Research", v.2, p.289. Vienna, IAEA (1991).
This paper contains a brief presentation of the results of Refs [4.2], [5.1], [5.2]. Besides, the interference between the temperature-gradient instability [5.1] and the centrifugal instability in the cylindrical geometry has been studied.

4.2 Berk H.L., Stupakov G.V. **"Stability of the gas-dynamic trap".** Phys. Fluids, v.B3, p.440 (1991).
It has been shown that the proper account of the sheath characteristics at the conducting end-walls may considerably reduce the predicted stabilizing contribution of the outflowing ions (for the curvature driven flute-like perturbations).

4.3 Bushkova O.A., Mirnov V.V. **"The influence of the magnetic field configuration on the MHD stability of the gas-dynamic trap".** Voprosy Atomnoi Nauki i Tekhniki - Termoyadernyi Sintez (The Problems of Atomic Science and Technology - Thermonuclear Fusion), #2, p.19 (1986) - in Russian.
The importance of a weak magnetic field region in the end-tanks for the overall stability of the GDT trap has been discovered. Evaluations of the limiting beta values are presented.

4.4 Kotelnikov I.A., Masliev I.E., Shaikhislamov I.F., Ryutov D.D., Yakovchenko S.G. **"Flute instability in an open system with injection of intense neutral beams".** Sov. Phys. Plasma Physics. v.16, p.669 (1990).

Detailed analysis of the stabilization effect first briefly mentioned in [2.9] and consisting in the radial momentum transfer from the neutral beams to the upwelling flute.

4.5 Kotelnikov I.A., Roslyakov G.V., Ryutov D.D., Stupakov G.V. **"Stabilization of flute instability in axially symmetric mirror machines".** In: "Plasma Physics and Controlled Nuclear Fusion Research", v.2, p.305, Vienna, IAEA (1987).
Among the other issues, there is presented an analysis of the stabilization method based on the matching of the sloshing ions turning points with the regions of a large favourable curvature of the magnetic field lines (as in [4.6]).

4.6 Kotelnikov I.A., Roslyakov G.V., Ryutov D.D. **"Stabilization of flute perturbations in an axisymmetric open system with instreaming ions".** Sov. J. Plasma Physics, v.13, p.227 (1985).
Detailed analysis of the stabilization technique proposed by Rosenbluth and Longmire and consisting in matching of the turning points of the sloshing ions with the regions of a large favourable curvature of the magnetic field lines.

4.7 Kotelnikov I.A., Yakovchenko S.G. **"Ponderomotive stabilization of interchange modes in mirrors during the ICRF heating".** Report INP 91-53, Institute of Nuclear Physics, Novosibirsk (1991) - in Russian.
A specific featuries of the minority ion heating scheme of Ref.[9.2] are discussed. It is shown that this force stabilizes flute modes at the plasma column periphery.

4.8 Mirnov V.V. **"Equilibrium and stability of axisymmetric open traps."** In: "Theory of Fusion Plasmas 1988", Proc. of the Joint Varenna - Lausanne International Workshop (International School of Plasma Physics, Chexbres, Switzerland, October 1988), p.41, Editrice Compositori, Bologna (1989).
The review of the problems concerned with equilibrium and stability of gas-dynamic trap is presented. In particular, the radial plasma density distribution is analyzed that results from the balance of neutral injection and end losses.

4.9 Nagornyj V.P., Ryutov D.D., Stupakov G.V. **"Flute instability of plasma in a gas-dynamic trap".** Nucl. Fusion, v.24, 1421, (1984).

The most detailed MHD stability study, with the account for non-paraxiality effects, plasma flow, trans-alfvenic transition.

4.10 Ryutov D.D. **"Axisymmetric MHD stable mirrors".** In: "Physics of Mirrors, Reversed Field Pinches and Compact Tori" (Proc. of the International School of Plasma Physics "Piero Caldirola"), v.2, p.791, Editrice Compositori, Bologna (1988).
Among the others, some stabilization techniques applicable to the gas-dynamic trap, are mentioned (favourable curvature beyond the turning points, as in [2.5], and line tying effects).

4.11 Ryutov D.D. **"Physics of open traps".** Plasma Physics and Controlled Fusion, v.28, p.191 (1986).
In particular, the MHD stability analysis (as in [4.3], [4.9]) and a brief description of the GDT facility, are given.

4.12 Stupakov G.V. **"Transit particle stabilization in mirror machines".** In: "Physics of Alternative Magnetic Confinement Schemes" (Proc. of the International School of Plasma Physics "Piero Caldirola"), p.765, Editrice Compositori, Bologna (1991).
The continuation of the study of Ref.[4.2].

4.13 Tsidulko Yu.I. **"Resistive ballooning mode in the gasdynamic trap".** Report 92-10, Institute of Nuclear Physics, Novosibirsk (1992) - in Russian.
This paper is devoted to the study of the ballooning instability caused by resistive decoupling of the unstable central part of the GDT and the stabilizing expander region - the effect that can be important at low plasma temperatures.

See also [2.7].

5 MHD STABILITY - EXPERIMENTAL

5.1 Anikeev A.V., Bagryansky P.A., Ivanov A.A., Kuzmin S.V., Salikova T.V. **"Experimental observation of non-MHD effects in the curvature driven flute instability".** Plasma Physics and Controlled Fusion, v.34, p. 1185 (1992).
A detailed experimental study of the FLR and plasma rotation effects on the flute-like perturbations in the GDT facility. A remarkable agreement with the FLR theory has been recorded.

5.2 Bagryansky P.A., Ivanov A.A., Karpushov A.N., Klesov V.V., Kotelnikov I.A., Krasnikov Yu.I., Rogozin A.I., Roslyakov G.V., Tsidulko Yu.A., Breun R.A., Molvik A.W., Casper T.A. **"Experimental MHD stability limit in the gas-dynamic trap"**. In: "Plasma Physics and Controlled Nuclear Fusion Research", v.2, p.655, Vienna, IAEA (1991).
Stability margin in the axisymmetric gas-dynamic trap has been studied. Stability integral was changed by: i) deliberatly producing a region of a large unfavourable curvature in the confinement region; ii)varying the mirror ratio and, thereby, the stabilizing contribution of the plasma flow beyond the mirror point. Qualitative agreement with theory has been found, though quantitatively the stability margin appeared to be somewhat smaller than in theory. The discrepancy has been later resolved in Ref.[5.1].

5.3 Bagryansky P.A., Ivanov A.A., Klesov V.V., Koz'minykh Yu. L., Kotelnikov I.A., Krasnikov Yu.I., Podyminogin A.A., Rogozin A.I., Roslyakov G.V., Ryutov D.D. **"First experiments on the gas-dynamic trap"**. In: "Plasma Physics and Controlled Nuclear Fusion Research", v.3, p.467. Vienna, IAEA (1987).
A brief description of the GDT device (Inst. of Nucl. Phys., Novosibirsk) and a report on the experimental study of the effect of magnetic field geometry in the end tanks on the MHD stability.

5.4 Bagryansky P.A., Ivanov A.A., Klesov V.V., Koz'minykh Yu. L., Kotelnikov I.A., Krasnikov Yu.I., Podyminogin A.A., Rogozin A.I., Roslyakov G.V., Ryutov D.D. **"The gas-dynamic trap experiment"**. In: "Physics of Mirrors, Reversed Field Pinches and Compact Tori" (Proc. of the International School of Plasma Physics "Piero Caldirola"), v.2, p.635, Editrice Compositori, Bologna (1988).
A detailed experimental study of the MHD stability of a cold plasma, with mode analysis revealing a flute structure of the perturbations. Clear demonstration of the stabilizing effect of the outflowing plasma. Photograph of the facility.

5.5 Bagryansky P.A., Ivanov A.A., Klesov V.V., Koz'minykh Yu. L., Kotelnikov I.A., Krasnikov Yu.I., Podyminogin A.A., Rogozin A.I., Roslyakov G.V.,Tsidulko Yu.A. **"Storage and decay of warm plasma in the GDT"**. Proc. XIX Int. Conf on Phenomena in Ionized Gases, Belgrade, 1989, p.832.
The MHD stability of the GDT plasma at the mirror ratios below than 25, has been reported, together with some details of the active corpuscular diagnostics used in these experiments.

5.6 Ivanov A.A., The GDT Experimental Physics Group. **"Experimental and theoretical studies of a neutron source based on gas-dynamic trap"**. In: "Physics of Alternative Magnetic Confinement Schemes" (Proc. of the International School of Plasma Physics "Piero Caldirola"), p.443, Editrice Compositori, Bologna (1991).
A brief description of the GDT neutron source, plus description of experimental results related to MHD stability, plasma potential distribution beyond the mirror points, ICR plasma heating and injection of the sloshing ions.

5.7 Ivanov A.A., Mishagin V.V., Roslyakov G.V., Tsidulko Yu.A. **"Design of the cusp stabilizer for the gasdynamic trap"**. Proc. of the National Conference on the Open-Ended Traps (Moscow, 1989), p.15. Publication of the Kurchatov Institute, Moscow (1990).
Design of the magnet system for the cusp stabilizer of the GDT facility is presented.

6 FORMATION OF THE SLOSHING ION POPULATION

6.1 Bagryansky P.A., Ivanov A.A., Klesov V.V., Koz'minykh Yu.L., Krasnikov Yu.I., Rogozin A.I., Roslyakov G.V., Tsidulko Yu.A. **"Formation of population of sloshing ions in a gas-dynamic trap"**. Proc. XIX Int. Conf on Phenomena in Ionized Gases, Belgrade, 1989, p.940.
First publication on the measurements of the angular and spatial distribution of the sloshing ions in the GDT; no anomalous effects have been detected.

6.2 Bagryansky P.A., Ivanov A.A., Klesov V.V., Koz'minykh Yu.L., Krasnikov Yu.I., Krzhizhanovskij E.R., Rogozin A.I., Roslyakov G.V., Tsidulko Yu.A. **"Experiments on neutral beam injection in a gas-dynamic trap"**. In: "Plasma Physics and Controlled Nuclear Fusion Research", v.2, p.483. Vienna, IAEA (1989).
A report on the experiments on the neutral beam injection into the GDT. Formation of the sloshing ion population with the average energy of 6 keV and angular spread of less than 5° has been documented

There haven't been revealed any indications of the anomalous losses or anomalous scattering of the sloshing ions.

6.3 Bagryansky P.A., Ivanov A.A., Karpushov A.N., Klesov V.V., Koz'minykh Yu.L., Krasnikov Yu.I. **"Plasma energy balance in the GDT with neutral beam injection"**. Proc. of the National Conference on the Open-Ended Traps (Moscow, 1989), p.18. Publication of the Kurchatov Institute, Moscow (1990).
The first study of the energy balance in the GDT in the course of the NB injection. While fast ion behavior was found to be very close to the classical, electron temperature was lower by a factor of 2 than according to the classical calculations. In the later experiments [6.2], the electron temperature was raised to the classical value by improving the vacuum conditions and removing all the material objects (like probes) from the plasma interior.

6.4 Chebotaev P.Z. **"Trapping of high-energy atoms in the case of their off-axis injection into the gas-dynamic trap"**. Report INP 86-93, Institute of Nuclear Physics, Novosibirsk (1986).
A more realistic version of the calculations of Ref.[6.6], with the account for the smooth radial distribution of plasma parameters; a brief description of the numerical codes.

6.5 Kotelnikov I.A., Schetnikov A.I. **"Adiabaticity of fast ions motion in a gas-dynamic trap"**. Report INP 87-10, Institute of Nuclear Physics, Novosibirsk (1987).
The influence of the magnetic field ripple (caused by the discreteness of the coils) and of the regions with a large curvature of the magnetic field lines on the adiabaticity of the sloshing ions is studied.

6.6 Ryutov D.D. **"Trapping of the fast atoms in a gas-dynamic trap"**. Report 85-32, Institute of Nuclear Physics, Novosibirsk (1985) - in Russian.
Analytical formulas describing spatial distribution of the fast ions trapped from the atomic beam in the case when the ion gyroradius is comparable with the plasma radius; evaluation of the electron drag effect on the subsequent modification of this distribution.

7 AXIAL CONFINEMENT

7.1 Zukakishvili G.G., Ryzhkov V.N., Salukvadze R.G., Tikhanov Eh.K., Chkuaseli Z.D., Volosevich P.P., Galiguzova I.I., Dar'in N.A., Karpov V.Ya., Levanov E.I. **"Plasma end loss confinement studies in a linear theta pinch with magnetic mirrors"**. In: "Plasma Physics and Controlled Nuclear Fusion Research", v.2, p.359. Vienna, IAEA (1989).
There has been reported of a satisfactory agreement with the gas-dynamic theory of plasma losses through the end mirrors; mirror ratio was varying between 1 and 5.

7.2 Kotelnikov I.A., Ryutov D.D. **"Effects of ambipolar potential in a two-component gasdynamic confinement system"**. Sov. J. Plasma Physics, v.11, p.655 (1985).
Analysis of the axial plasma losses from GDT in the presence of electrostatic potential peaks near the turning points of the sloshing ions.

7.3 Lam K.L., Leikind B.J., Wong A.Y., Dimonte G., Kuthi A., Olson L., Zwi H. **"Mirror ratio scaling of axial confinement of a mirror-trapped collisional plasma"**. Phys. Fluids, v. 29 (1986), p. 3433.
The linear dependence of the axial confinement time on mirror ratio has been demonstrated on the LAMEX device in the range of mirror ratios from 12 to 74.

7.4 Mirnov V.V., Tkachenko O.A. **"Electrostatic potential distribution in the gas-dynamic trap"**. Report 85-32, Institute of Nuclear Physics, Novosibirsk (1985) - in Russian.
The paper contains a theoretical analysis of the potential distribution in the mirror and expander regions of the gasdynamic trap, with the account for the presence of the Yushmanov ions.

7.5 Tsidulko Yu.A. **"Removal of the impurity ions from the mirror trap with the two-component plasma by their collisions with the hot ion component"**. Report 93-44, Budker Institute of Nuclear Physics, Novosibirsk (1985) - in Russian.
The mechanism that causes the losses of the impurity ions through the electrostatic potential barriers near the ends of the gas-dynamic trap, is discussed. The mechanism consists in the close collisions of the impurity ions with the ions of the hot component.

7.6 Zhitlukhin A.M., Safronov V.M., Sidnev V.V., Skvortsov Yu.V. **"Confinement of the $\beta \sim 1$ plasma in the open trap"**. JETP Lett., v.39, p.247 (1984).
The improvement of the axial confinement caused by the increase of the mirror ratio under the influence of a large plasma beta, has been documented. The feasibility of the $\beta \sim 1$ plasma confinent in the gas dynamic trap has been demonstrated.

See also [2.6], [2.7], [5.2]-[5.5].

8 RADIAL CONFINEMENT

8.1 Berk H.L., Ryutov D.D., Tsidulko Yu.A. **"Temperature-gradient instability caused in plasma by conducting end surfaces"**. JETP Lett., v.52, p.23 (1991).
The first paper on the instability potentially important for the GDT and caused by the interplay of two factors: non-uniformity of the electron temperature in radial direction and the presence of Debye sheaths on the conducting end-walls. Finite beta effects briefly discussed.

8.2 Berk H.L., Ryutov D.D., Tsidulko Yu.A. **"Temperature-gradient instability induced by conducting end walls"**. Phys. Fluids, v.B.3, p.1346 (1991).
Detailed analysis of the low beta case for the same instability as in [8.1], with the account for FLR effects and the finite resistivity of the end surface.

8.3 Kotelnikov I.A. **"The effect of the magnetic field errors on the transport processes in long solenoids"**. Report INP 88-74, Institute of Nuclear Physics, Novosibirsk (1988) - in Russian.
The neoclassical transport caused by non-axisymmetric magnetic field errors is studied. The tolerances to the magnetic field imperfections have been evaluated.

8.4 Ryutov D.D., Weiland J. **"Velocity shear effects in the problem of the electron temperature gradient instability induced by conducting end-walls"**. Report CTH-IEFT/PP-1992-14, Chalmers University of Technology, Gothenburg, Sweden, 1992.
The interrelation between the temperature-gradient instability as in [8.1], [8.2] and the hydrodynamic Kelvin-Helmholtz instability has been analyzed.

8.5 Schetnikov A.I. **"Magnetic field distorsions in the cusp"**. Report INP 86-46, Institute of Nuclear Physics, Novosibirsk (1992)* - in Russian.
The effects of the magnetic fields imperfections in the cusp stabilizer on the equilibrium and transport in the main cell, have been studied.

8.6 Stupakov G.V. **"Trapped particle instability in a gas-dynamic trap"**. Sov. J. Plasma Physics, v.16, p.275 (1990) - in Russian.
It is shown that the growth rate of the trapped particle instability in the gas-dynamic trap doesn't depend on the mirror ratio.

See also [2.7],[4.8].

9 RF HEATING

9.1 Garina S.M., Grishanov N.I., Elfimov A.G., Potapenko I.F. **"RF plasma heating in the gas-dynamic trap"**. Proc. of the National Conference on the Open-Ended Traps (Moscow, 1989), p.82. Publication of the Kurchatov Institute, Moscow (1990).
Numerical analysis of the fast and slow magnetosonic wave absorption is presented.

9.2 Kotelnikov I.A., Yakovchenko S.G. **"Quasistatic theory of ion-cyclotron plasma heating in open magnetic confinement system"**. Sov. J. Plasma Physics, v.17, p.177 (1991).
Heavy minority scheme of the ICRF heating is considered for the experimental situation typical for the Gas-Dynamic Trap. The theory predicts a high efficiency of this heating scheme.

See also [4.7], [5.6].

10 ENGINEERING, ECONOMICS, TIME-FRAME ISSUES

10.1 Astapkovich A.M., Gromov L.A., Komarov V.M., Krasnoperov V.G., Odintsov V.N., Roslyakova N.G., Sadakov S.N., Saksaganskii G.L.,

Safin V.M., Serebrennikov D.V., Shimov V.G.. Report #Б-0830, Efremov Institute, Leningrad (1989) - in Russian.
A brief summary of the pre-conceptual design of the GDT-based neutron source, with the feasibility analysis under the constraint of employment of only the existing technologies. Identification of the key problems: choke coil durability; durability of the neutral beam injectors.

10.2 Berk H.L., Ryutov D.D. **"Importance of a mirror based neutron source for the controlled fusion program"**. Comments on Plasma and Controlled Fusion, v.13, p.173 (1990).
The paper contains general argument in support of the timely development of the high-flux neutron source on the basis of mirror machines and brief description of two particular concepts of such sources: BPNS (as in Ref.[11.2]) and GDT (as in Ref.[3.3]).

10.3 Ivanov A.A., Ryutov D.D. **"Neutron sources for fusion reactor materials and component testing"**. Proc. of the International Fusion Materials Irradiation Facility (IFMIF) Workshop, San Siego, 1989, v.2, p.369.
A summary of the criteria for the selection of the neutron source concept.

10.4 Ivanov A.A., Ryutov D.D. **"Mirror-based neutron sources for fusion technology studies"**. Nucl. Science and Engineering, v.106, p.235 (1990).
An extended version of the report [10.3], with a summary of the competing proposals of the mirror-based neutron sources.

10.5 Ryutov D.D. **"Mirror type neutron source"**. Plasma Physics and Controlled Fusion, v.32, p.999, (1990).
A brief survey of the problems of the neutron sources with discussion of the issues of neutron spectra, irradiation geometry, cost of electricity and tritium; a summary of the data base for the 2-component version of the neutron source (as in Ref.[3.3]) and the corresponding conceptual design (as in Ref.[10.1]).

11 THE OTHER CONCEPTS OF MIRROR-BASED NEUTRON SOURCES

11.1 Coensgen F.H. **"Fusion materials irradiation facility"**. Proc. of

the International Fusion Materials Irradiation Facility (IFMIF) Workshop, San Siego, 1989, v.2, p.343.
Some information on the Livermore proposal of the neutron source (as in [11.3]), with evaluation of the capital cost.

11.2 Coensgen F.H., Casper T.A., Correll D.L., Damm C.C., Futch A.H., Molvik A.W. **"Physics data base for the beam plasma neutron source (BPNS)"**. In: "Physics of Alternative Magnetic Confinement Schemes" (Proc. of the International School of Plasma Physics "Piero Caldirola"), p.477, Editrice Compositori, Bologna (1991).
A detailed analysis of the 2XIIB experimental results supporting the concept of the beam plasma neutron source, has been presented.

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