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Title: Magnetized Target Fusion Bibliography

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MTF BIBLIOGRAPHY

First Author: Alexeff
Date: 91,1,1
Author List: I. Alexeff, M. Rader
Citation: Proc. 1991 IEEE Int. Conf. on Plas. Science, Paper 5P19
Title: A simple derivation of classical and bohm diffusion based on magneto-hydro-dynamics
Abstract: (none)

First Author: Alikhanov
Date: 82,9,1
Author List: S. G. Alikhanov, V. P. Bakhtin, A. G. Es'kov, R. K. Kurtmullaev, V. N. Semenov, E. F. Strizhov, N. P. Kozlov, V. I. Khvesyuk, A. V. Yaminskij
Citation: Proc. Ninth IAEA Intl. Conf. On Plasma Physics and Controlled Nuclear Fusion Research, Baltimore, Maryland, September 1-8, 1982, Vol. 3, IAEA-CN-41/W3
Title: Three-dimensional plasma compression in a z-pinch liner system—transport and compression of a compact torus by a quasi-spherical liner
Abstract: The use of cylindrical liners driven by a longitudinal for three-dimensional plasma compression is considered. The transformation of a cylindrical to an ellipsoidal cavity is accomplished by the development of a programmed m instability. The research was carried out with the help of a numerical experiment on plasma compression by a liner longitudinal wall thickness modulation. Two variants were considered: one with a solid-state liner and a magnetic field, the other with a rotating liquid-metal liner. The calculations indicate that it is possible to ignite a D-T mixture with an energy storage system of reasonable size. Further experiments in the 'torus-liner' (three-dimensional-liner collapse, closed magnetic configuration) are described. The consistency of solutions involving an extended transport channel is shown (for applications, protection of the shock chamber against disintegration products, radiation shielding, etc.). It established that for transport through cylindrical with l approx.= 2 m the level of losses will be small. Losses at the conical transitions correlate with hydrodynamic perturbations, and this governs the method of optimizing the transitions. The compression parameters (Vsub(liner) approx.= 10{sup 5} cm.s{sup -}{sup 1}, K approx.= 10{sup 3}) correspond to those originally formulated. Calculations of a theta-pinch start-up circuit with a shaped coil-liner gap ensure preferential accumulation of energy in the central region. At the same time, diffusion of the driving field into the cavity is suppressed to a level B <or approx. 1 T (taking into account relaxation and skin losses). Neutron yield calculations (including the experimentally observed region N approx.= 10{sup 8}) were performed for the two extreme assumptions regarding losses (classical and Bohm).

First Author: Alikhanov
Date: 80,7,1
Author List: S. G. Alikhanov, V. P. Bakhtin, V. I. Vasil'ev, I. S. Glushkov, A. D. Muzychenko, V. P. Novikov, A. G. Olejnik, D. A. Toporkov
Citation: Proc. Eight Int'l. Conf., Brussels, July 1-10, 1980, IAEA-CN-38/AA-1-2, pp. 699-705
Title: Review of fast-z-pinch liner programme
Abstract: The paper reviews some studies being performed in framework of the 'Fast-Z-pinch-liner' programme. An experimental modelling of the basic processes in the given scheme has been carried out at the LN-20 device, providing an aluminium liner cumulation velocity of 3-5km.s{sup -}{sup 1}. It has been shown that a stable cumulation of the liner occurs. Moreover, a liner stoppage caused by the pressure of compressed magnetic field has been recorded. The problems of foreplasma creation in a 'gas-kinetic trap' were investigated. The achieved parameters are as follows: T=20eV, n=2x10{sup 1}{sup 8}cm{sup -}{sup 3}. The experiments on plasma compression are described. Computations on the boundary-layer dynamics for the case of gas-kinetic confinement as well as on the liner-plasma system with an axial magnetic field in the range of liner velocities of more than 100km.s{sup -}{sup 1} have been carried out.

First Author: Alikhanov
Date: 78,1,21
Author List: S.G. Alikhanov, I.S Glushkov.
Citation: Dokl. Akad. Nauk SSSR; **226**, 21 Jan. 1976, pp. 547-549
Title: Stationary cooling wave in magnetized plasma

Abstract: The interaction of a magnetized hot plasma $\omega_e\tau_e > \sim 1$ with cold plasma or a gas leads to the appearance of a cooling wave. The transition layer between hot and cold plasma is the main source of radiation losses which should be compensated by a heat flow from the hot region. A stationary state is considered, equations are written in the system in which temperature and magnetic field profiles are steady, and the plasma flux with magnetic field passes through the cooling wave. Calculations, have been carried out on a computer. The dependence of the magnetized plasma flux velocity V_r on the ratio p/H_r is shown, where p is the pressure, H_r is the magnetic field in the hot reqion. The dependence of the characteristic dimension of the cooling wave on the magnetic field is determined for the hot plasma region. A considerable fraction of the rediation losses is shown to fall to the region of $\omega_e\tau_e <$ or ~ 1.

First Author: Alikhanov
Date: 74,4,1
Author List: S.G. Alikhanov, I.K. Konkashbaev
Citation: Nuclear Fusion **14**, (1974), pp. 341-343
Title: Dynamics of an axially wall-limited theta pinch compressed by a metallic liner
Abstract: Axial plasma flow during compression of a limited theta pinch have been determined. An approximate formula for the temperature dependence on the compression ratio is compared with the results of an exact numerical calculation.

First Author: Bangerter
Date: 77,11,9
Author List: R.O. Bangerter D.J. Meeker
Citation: Presented at the 2nd Int. Topical Conf. on High Power Electron and Ion Beam Research and Technology, Ithaca, NY, Oct. 3-5, 1977, UCRL-79875, CONF-771035-15
Title: Charged particle fusion targets
Abstract: The power, voltage, energy and other requirements of electron and ion beam fusion targets are reviewed. Single shell, multiple shell and magnetically insulated target designs are discussed. Questions of stability are also considered. In particular, it is shown that ion beam targets are stabilized by an energy spread in the ion beam.

First Author: Barnes
Date: 97,4,1
Author List: D.C. Barnes
Citation: Los Alamos National Laboratory report LA-UR-96-2656 to be published in Comments on Plasma Phys. and Controlled Fusion **18**(3), (1997)
Title: Scaling relations for high-gain, magnetized target fusion systems
Abstract: Scenarios for high-gain, magnetized target fusion (MTF) systems are considered. As in inertial confinement fusion (ICF), MTF heats and confines plasma by spherical implosion of a (relatively) massive wall. In contrast to ICF, MTF implosion velocities are significantly reduced, with correspondingly reduced density and drive requirements. Thermal losses of the wall-confined plasma are inhibited by a strong magnetic field. As in ICF, high gain may result if a central hot plasma produces sufficient fusion power to heat additional fuel during the wall dwell time. Conventional burn propagation is practically impossible for MTF. High-gain can result only by refueling the hot plasma if a minimum ρr^2 is achieved (ρ hot plasma density, r compressed radius). This condition, which is related to the Lawson criterion, requires $r_a v_a > 700 m^2/s$ (r_a initial target radius, v_a implosion velocity). Then MTF gain is order 1000 and the yield will be large (~10GJ).

First Author: Basko
Date: 98,11,1
Author List: M. Basko
Citation: Association Euratom-CEA report EUR-CEA-FC-1645 (November 1998)
Title: Inertial confinement fusion with magnetized fuel in cylindrical targets
Abstract: Basic physical principles underlying the performance of cylindrical targets within the concept of magnetized target fusion (MTF) are discussed. If confirmed feasible, such targets might offer an alternative way to a thermonuclear ignition facility for a heavy ion driver. It is shown that inherent inefficiency of cylindrical implosions can be offset by introduction of initial magnetic field of $B_o \cong (1\text{-}3) \times 10^5$ G. By inhibiting thermal heat conduction, the magnetic field can lower the fuel (pr) threshold for ignition by about a factor 10. An external fuel preheat of up to 100 eV may be needed. A possible target scheme for high gain in cylindrical geometry is outlined.

First Author: Binderbauer
Date: 96,4,8
Author List: M. W. Binderbauer and N. Rostoker
Citation: J. Plasma Physics **56**(2), (1996) pp. 451-465
Title: Turbulent transport in magnetic confinement: how to avoid it
Abstract: From recent tokamak research, there is considerable experimental evidence that superthermal ions slow down and diffuse classically in the presence of turbulent fluctuations that cause anomalous transport of thermal ions. Furthermore, research on field-reversed configurations at Los Alamos is consistent with the view that kenetic effects suppress instability growth when the ratio of plasma radius to ion orbital radius is small: turbulence is enhanced and confinement degrades when this ratio increases. Motivated by these experiments, we consider a plasma consisting of large-orbit non-adiabatic ions and adiabatic electrons. For such a plasma, it is possible that the anomalous transport characteristic of tokamaks can be avoided and a compact reactor design becomes viable.

First Author: Bowers
Date: 98,4,15
Author List: R.L. Bowers, J.H. Brownell, H. Lee, K.D. McLenithan, A.J. Scannapieco, and W.R. Shanahan
Citation: Jour. Appl. Phys. **83**(8), (1998), pp. 4146-4159
Title: Design and modeling of precision solid liner experiments on Pegasus
Abstract: Pulsed power driven solid liners may be used for a variety of physics experiments involving materials at high stresses. These include shock formation and propagation, material strain-rate effects, material melt, instability growth, and ejecta from shocked surfaces. We describe the design and performance of a cylindrical solid liner that can attain velocities in the several mm/μs regime, and that can be used to drive high-stress experiments. An approximate theoretical analysis of solid liner implosions is used to establish the basic parameters (mass, materials, and initial radius) of the driver. We then present one-dimensional and two-dimensional simulations of magnetically driven, liner implosions which include resistive heating and elastic-plastic behavior. The two-dimensional models are used to study the effects of electrode glide planes on the liner's performance, to examine sources of perturbations of the liner, and to assess possible effects of instability growth during the implosion. Finally, simulations are compared with experimental data to show that the solid liner performed as predicted computationally. Experimental data indicate that the liner imploded from an initial radius of 2.4 cm to a target radius of 1.5 cm, and that it was concentric and cylindrical to better than the experiment resolution (60 μm) at the target. The results demonstrate that a precision solid liner can be produced for high-stress, pulsed power applications experiments.

First Author: Braginskii
Date: 75,1,1
Author List: S.I. Braginskii
Citation: Rev. Plas. Physics **1** (Consultants Bureau, NY, 1965), pp. 205-311
Title: Transport processes in a plasma
Abstract: (none)

First Author: Bussac
Date: 78,1,1
Author List: M.N. Bussac, H.P. Furth, M. Okabayashi, M.N. Rosenbluth, and A.M.M. Todd
Citation: Plasma Physics and Controlled Nuclear Fusion Research **3**, Proc. 7th Int. Conf., Innsbruck (1978)
Title: Low-aspect-ratiolLimit of the toroidal reactor: the spheromak
Abstract: The ideal and resistive MHD stability properties of a class of toroidal plasma configurations ("spheromaks") having internal toroidal and poloidal fields and external poloidal fields are considered. The reactor advantage of the spheromak is two-fold: (1) The maximum field strength at the external coils is about half the field at the plasma centre, rather than twice, as in a tokamak. (2) A roughly spherical blanket can be used, rather than a blanket that links the plasma topologically. - Taylor's criterion, which ensures stability against both ideal and resistive modes, has been applied to force-free spheromaks of unity aspect ratio. In the presence of a loosely fitting external conducting shell, oblate spheromaks are stable against all modes except short-wave surface kinks (which are an artifact of the idealized current density profile). The Mercier criterion gives a β-limit below 1%; however, at aspect ratio ≥1, the β-limit for representative spheromak models rises into the range 2-4%. The Mercier analysis has been confirmed by Balloon Code studies. The ideal MHD Pest Code is being applied to spheromaks of various

aspect ratios and current density profiles. Ideal-MHD stability can be obtained in the presence of a loosely fitting conducting shell.

First Author: Call
Date: 89,10,2
Author List: C.J. Call, R.W. Moir
Citation: Nucl. Science & Engineering **104**, (1990), pp. 364-373
Title: A novel fusion power concept based on molten-salt technology: PACER revisited
Abstract: Modifications to an old concept for using peaceful nuclear explosions to achieve practical fusion power are discussed. With this concept, useful energy and materials are obtained by repetitively setting off nuclear explosions in an underground cavity. This proposal, which is based on molten-salt technology, involves two modifications: (1) line the cavity with steel to make it engineerable and predictable rather than relying on an unsupported earthen cavity such as a cavity excavated in a salt dome and (2) use molten salt rather than steam. More than 70% of the energy released is then absorbed by liquid-salt evaporation, and the pressure to be contained for a given yield can be reduced by a factor of 3 or more. These modifications result in several improvements in the safety and feasibility of the contained fusion concept: (1) the tritium produced, being insoluble in the molten salt, can easily be pumped away and purified when all the vaporized salt condenses, rather than being mixed with steam; (2) the tritium inventory is substantially reduced, effectively reducing the large hazard in case of accidental venting to the atmosphere; and (3) reducing the yield used in the older studies could reduce the cost of the cavity considerably. These improvements may make the concept practical today, and a reexamination of the concept appears in order.

First Author: Chang
Date: 78,2,7
Author List: J. Chang, M.M. Widner, A.V. Farnsworth, Jr., R.J. Leeper, T.S. Prevender, L. Baker, J.H. Olsen
Citation: Proc. of the Topical Meeting on Inertial Confinement Fusion, February 7-9, 1978, San Diego, California
Title: Neutron production from advanced RDB fusion targets
Abstract: Experiments have been performed in which plastic shells, containing a CD2 fuel wire, were irradiated and imploded by a single beam from the Rehyd REB accelerator (1 MeV, 250 kA, 100 nsec). The fuel wire is pre-exploded by beam prepulse, providing preheat and magnetic fields in the fuel which permit high fuel temperatures upon implosion. Initial results indicate that greater than 106 neutrons, of energy 2.5 ± 0.2 MeV, were produced during the last 30 nsec of the voltage pulse, consistent with the expected implosion time. Additional "null" shots with portions of the target cut away and/or without prepulse did not produce such neutrons. These initial data suggest the origin of the neutrons to be thermonuclear.

First Author: Chu
Date: 73,4,25
Author List: M.S. Chu
Citation: Phys. of Fluids **16**(9), (Sept. 1973), pp. 1441- 1445
Title: Hot plasma in contact with a cold wall
Abstract: The effect of a cold wall on a hot plasma with initial uniform temperature and strong magnetic field parallel to the wall is studied. For physical values of thermal conductivity, resistivity, and electron-ion equilibration coefficients, the full set of one-fluid, two-temperature equations is solved numerically. These results are then compared with analytic self-similar solutions. The dynamic behavior of the plasma is presented. The total energy loss to the wall per unit area is evaluated and may be approximated rather well by an analytical expression derived from the fundamental equations.

First Author: Commisso
Date: 79,8,6
Author List: R.J. Commisso, R.E. Siemon, K.F. McKenna, C.A. Ekdahl, R.R. Bartsch
Citation: Phys. Rev. Lett., **43**(6), 6 Aug. 1979, pp. 442-445
Title: Energy- and particle-confinement properties of an end-plugged, linear, theta pinch
Abstract: Experiments show that axial confinement of plasma in a straight theta-pinch solenoid is improved by placing solid lithium deuteride plugs at the ends. The energy confinement is increased nearly threefold in agreement with theoretical estimates which assume classical electron thermal conduction and no convective losses. The confinement of deuterium ions is explained by classical Coulomb collisions in the ablated lithium deuteride plasma.

First Author: Commisso
Date: 77,1,24
Author List: R.J. Commisso, W.E. Quinn, K.F. McKenna, K.B. Freese, C.A. Ekdahl
Citation: Phys. Rev. Lett., **39**(3), 18 Aug. 1977, pp. 137-139
Title: Solid-end-plug experiment on a theta pinch
Abstract: Results from the first end-stopping experiment on a high-energy ($T_I \sim 1.5$ keV, $n \sim 10^{16}$ cm^{-3}) θ pinch are reported. The experiment was done with quartz end plugs. The results show that the insertion of the plugs improves plasma stability, reduces particle end loss out of the device, and improves the energy confinement.

First Author: Conn
Date: 88,10,12
Author List: R.W. Conn, F. Najmabadi, R.A. Krakowski, K.R. Schultz, D. Steiner
Citation: Proc. 12th Int'l Conf. on Plasma Physics and Controlled Nuclear Fusion Research, October 12-19, 1988, Nice, France, UCLA-PPG-1179
Title: The TITAN reversed-field-pinch fusion reactor study: compact, high-power-density reversed-field-pinch fusion reactors
Abstract: The TITAN Reversed-Field Pinch (RFP) fusion reactor study has been a multi-institutional research effort to determine the technical feasibility and key developmental issues for an RFP reactor operating at high power density. Two different detailed designs, TITAN-I and TITAN-II, have emerged both of which have a high neutron wall loading of 18 MW/m{sup 2} and a high mass power density of 800 kWe/tonne of fusion power core (FPC). Despite such compactness, the TITAN designs would meet US criteria for the near-surface disposal of radioactive waste and achieve a high Level of Safety Assurance. The FPC small size and mass permits both designs to be maintainable by a ``single-piece" FPC maintenance procedure. Both designs rely on ohmic heating to ignition and would operate at steady state. Parametric system studies have been used to find the cost-optimized designs and to determine the design window associated with each approach. Both designs retain their major features for neutron wall loadings in the range of 10 to 20 MW/m{sup 2}. The study has also illuminated key physics and engineering issues central to achieving reactors with the features of TITAN-I and TITAN-II.

First Author: Dawson
Date: 76,1,1
Author List: J.M. Dawson, B. Rosen, H. Okuda, B. Alder, M. Rotenberg, S. Fernbach
Citation: Methods in Computational Physics. Advances in Research and Applications **16**, (1976), pp. 281-325
Title: Collective transport in plasmas
Abstract: (none)

First Author: Degnan
Date: 99,3,29
Author List: J.H. Degnan, M.L. Alme, B.S. Austin, J.D. Beason, S.K. Coffey, D.G. Gale, J.D. Graham, J.J. Havranek, T.W. Hussey, G.F. Kiuttu, B.B. Kreh, F.M. Lehr, R.A. Lewis, D.E. Lileikis, D. Morgan, C.A. Outten, R.E. Peterkin, Jr., D. Platts, N.F. Roderick, E.L. Ruden, U. Shumlak, G.A. Smith, W. Sommars, and P.J. Turchi
Citation: Phys. Rev. Lett. **82**(13), March 29, 1999
Title: Compression of plasma to megabar range using imploding liner
Abstract: Axial current discharges were used to implode spherical aluminum shells with thickness tapered to match the external magnetic pressure. These implosions were used to compress hydrogen plasmas with an initial pressure >100 bar and an initial temperature >1 eV. The implosion and compressed plasma effect on a central target were observed radiographically. The target's radius vs time indicates that the plasma pressure reaches ~1 Mbar prior to liner-target contact.

First Author: Drake
Date: 96,3,4
Author List: R.P. Drake, J.H. Hammer, C.W. Hartman, L.J. Perkins, D.D. Ryutov
Citation: Fusion Tech. **30**, (1996), pp. 310-325
Title: Submegajoule liner implosion of a closed field line configuration
Abstract: Adiabatic compression of a preformed closed field line configuration by an imploding liner is considered. Three configurations are discussed: the field-reversed configuration, the spheromak, and the Z-pinch. It is shown that by employing a two-dimensional compression, one can reach a breakeven condition with an energy input into the plasma as low as 100 kJ.

Typical initial dimensions of the liner are length, 5 to 6 cm; radius, ~ 1 cm; and wall thickness, ~0.01 cm. Liner mass is in the range of a few grams. It is assumed that the initial plasma beta is of the order of unity; in this case, the final beta is much greater than 1, and the plasma is in a wall confinement regime. Typical plasma parameters for the final state (for the linear compression ratio equal to 10) are density. 10^{21} cm^{-3}; temperature, 10 keV; and magnetic field, 10^7 G. A brief discussion of various phenomena affecting the wall confinement is presented (magnetic field diffusion, radiative losses, and impurity penetration); the conclusion is drawn that the heat losses to the walls are modest and are not a factor that limits plasma enhancement Q. It is shown that at least for relatively thin liners, whose compressibility can be neglected, what limits Q is a relatively short liner dwell time near the maximum compression point. The scaling law for the Q versus the input parameters of the system is derived, which shows a relatively weak dependence of Q on the input energy. Possible ways for increasing the dwell time are discussed. Reactor potentialities of the system are briefly described. It is emphasized that the possibility of performing crucial experiments on small-to medium-scale experimental devices may considerably shorten the development path for the system under consideration. Some nonfusion applications of the system described are mentioned. Among them are burning and transmutation of long-lived fusion products, medical isotope production, a pulsed source of hard X rays, and fusion neutrons.

First Author: Eliezer
Date: 98,1,1
Author List: S. Eliezer, J.M. Martinez Val, Z. Henis
Citation: Informal report form Soreq NRC, Yavane, Israel and Institute of Nuclear Fusion, Madrid, Spain
Title: Magnetized targets induced by circular polarized laser light
Abstract: It is suggested to trigger fusion in a central filament by compressing and heating it via the kinetic energy cumulated in an outer annular shell. This shell is imploded by an electric pinch during a long discharge time. In order to properly drive the filament implosion, an axial magnetic is generated around the filament by the action of a circularly polarized laser light (CPLL). The field acts as a magnetic cushion in order to compress the central filament before it is heated. First estimate points out that large energy gain could be reached in a powerful Z-pinch device combined with sub-nanosecond laser.

First Author: Es'kov
Date: 83,1,1
Author List: A.G. Es'kov, N.P. Kozlov, R.Kh. Kurtmullaev, V.I. Semenov, V.I. Khvesyuk, A.V. Yaminskii
Citation: Sov. Tech. Phys. Ltt. **9**(1), (January 1983), pp. 16-17
Title: Energy balance in a system with quasispherical liner compression
Abstract: This letter reports the results of some experimental studies and a numerical simulation of the Tor-Liner fusion system, in which a heavy plasma shell with a closed magnetic structure is compressed in a quasispherical manner.

First Author: Es'kov
Date: 81,9,14
Author List: A.G. Es'kov, M.I. Kitsev, R.Kh. Kurtmullaev, V.M. Novikov, V.I. Semenov, E.F. Stritkov
Citation: Proc. 10th European Conference on Controlled Fusion and Plasma Physics, Vol. 1, Part 2, September 14-19, 1981, Moscow, Russia
Title: Experiments in the "tor-liner" device
Abstract: (none)

First Author: Es'kov
Date: 73,1,1
Author List: A.G. Es'kov, O.A. Zolotovsky, R.Kh. Kurtmullaev, Ya.N. Laubin, A.J. Malyutin, A.J. Markin, V.N. Semenov
Citation: Proc. 6th European Conference on Controlled Fusion and Plasma Physics, Vol. 1, 1973, Moscow, Russia
Title: Experiments on producing the plasma of high-β by longitudinal shock waves
Abstract: In the work presented here the authors investigate plasma heating and motion under the action of a piston formed of elongated poloidal magnetic lines of force. First of all possibilities of reaching large values of nT, β, T were of interest, these being among urgent problems in the programme on toroidal plasma devices. The system was simultaneously examined as an induction injector of a hot plasma for the scheme of a θ-pinch with liner. Finally, the plasma and magnetic field behaviour at the controlled lines of force reconnection is of interest for astrophysical applications.

First Author: Es'kov
Date: 73,1,1
Author List: A.G. Es'kov, R.Kh. Kurtmullaev, A.J. Malyutin, V.N. Semenov, A.L. Chernyakov
Citation: Proc. 6th European Conference on Controlled Fusion and Plasma Physics, Vol. 1, 1973, Moscow, Russia
Title: Shock heating in toroidal systems with elongated cross-section
Abstract: This work considers some possible ways of widening the range of shock plasma heating in an elongated toroidal configuration up to $nT \sim 10^{18}+10^{19} ev/cm^3$ at T~1+10 kev including amethod of controlled magnetic fluxes reconnection for the formation of a powerful shock piston.

First Author: Farnsworth
Date: 78,2,7
Author List: A.V. Farnsworth, Jr., M.M. Widner, J. Chang, R.J. Leeper, L. Baker,J.N. Olsen
Citation: Proc. of the Topical Meeting on Inertial Confinement Fusion, February 7-9, 1978, San Diego, California, SAND-77-1640C; CONF-780202-17
Title: Particle beam targets containing preheated fuel and magnetic fields
Abstract: (none)

First Author: Feinberg
Date: 76,1,1
Author List: B. Feinberg
Citation: Plasma Physics **18**, (1976), pp. 265-275
Title: An experimental study of hot plasma in contact with a cold wall
Abstract: An experimental study has been made of the interaction (heat transfer and wall surface damage) of a hot ($T \sim 5 \times 10^6$ K), dense ($n \sim 10^{16}$ cm^{-3}) deuterium plasma containing a strong magnetic field ($\beta \sim 10^4$ G) brought into sudden contact with a cold wall. The energy flux from this high $\beta(\beta \sim 1)$ plasma to the wall was measured using a thin film, fast rise-time bolometer. The measured energy flux is found to be about that predicted by classical theory. The measured plasma transverse thermal conductivity exhibits the functional dependence on temperature, magnetic field, and density that is expected from classical theory. The extent of damage to the cold wall surface was measured using a scanning electron microscope to examine various wall samples exposed to the plasma. The observed surface damage to a copper wall sample was in reasonable agreement with the predicted damage due to sputtering. The damage to the surface of a 304 austenitic stainless steel wall sample was considerably greater than predicted by sputtering.

First Author: Fowler
Date: 98,11,5
Author List: T.K. Fowler and P.F. Peterson
Citation: University of California at Berkeley report UC-BFE-052, November 5, 1998
Title: Conceptual design of a pulsed spheromak fusion power plant
Abstract: This paper extends recently published calculations showing that ohmic ignition and high fusion power gain can potentially be obtained in spheromaks operated in a pulsed mode, using only a flux conserver to confine the plasma and a liquid wall to absorb the fusion energy during the high-power burn phase. Here we deal conceptually with the main features of reactor design required to exploit this concept expeditiously in fusion reactors of exceptional simplicity, low cost and favorable environmental characteristics. Topics include a brief review of the published operating scenarios, design of the gun that creates and ignites the spheromak plasma and its power supplies, design of the flux conserver and heat transfer system, tritium breeding for the DT fuel cycle, waste management and safety, and critical steps in the development of the concept. We find that, exluding the heat exchanger and tritium facility, the usual type of cost estimate based on component weight and fabrication costs of $100/kg would give an exceptionally low value for the cost of the fusion heat source itself -- about $15 M for a reactor producting 250 - 500 Mwe -- thereby leaving a large margin for error as realistic designs emerge in the future.

First Author: Gerwin
Date: 79,1,1
Author List: R.A. Gerwin, R.C. Malone
Citation: Nucl. Fusion **19**(2), (1979), pp.155-177
Title: Adiabatic plasma heating and fusion-energy production by a compressible fast liner

Abstract: Adiabatic plasma heating by the implosion of a compressible, cylindrical, end-plugged liner is studied by means of an approximate analytical model and by a computer code that employs sophisticated equation-of-state tables for the metal liner. The model contains cylindrical convergence effects and an approximate but realistic equation-of-state. Analytic expressions are derived for the pressure profile in the liner, for the internal energy of the liner, for the maximized fusion energy output of the enclosed D-T plasma, for the corresponding optimized initial conditions, and for the resulting peak pressure, final radius and thickness, and burn time. In this idealized model that ignores losses, energy transfer efficiencies (liner to plasma) of 70% are found, and a gain of 4 (ratio of fusion energy to liner energy) can occur with an initial liner energy of 300MJm-1. Finally, losses from the plasma are briefly discussed.

First Author: Gol'berg
Date: 93,4,1
Author List: S.M. Gol'berg, A.L. Velikovich
Citation: Physics of Fluids B **5**(4) (United States), (April 1993), pp. 1164-1172
Title: Suppression of Rayleigh-Taylor instability by the snowplow mechanism
Abstract: Rayleigh-Taylor instability developing in a layer of matter accelerated by the pressure of magnetic field or of a light fluid is shown to be suppressed if the accelerated layer scoops unperturbed matter, entraining it into motion. This stabilizing mechanism is effective for plasma focus devices, multicascade systems like magneto-cumulative (MC) generators of high-pulsed magnetic fields or multiple gas-puff Z pinches, for impact acceleration of thin foils by high-velocity plasma clouds. Linear stability analysis of one-dimensional solutions of the piston problem demonstrates that perturbation of the given wavelength λ does not grow appreciably until the thickness of the accelerated layer $L(t)$ exceeds λ. Before that, if acceleration is increased rapidly enough, amplitudes of the long-wavelength perturbations remain almost constant. If acceleration is increased not too rapidly, stays constant, or is decreased, then the long-wavelength perturbations with $\lambda > 2L(t)$ are damped.

First Author: Hoffman
Date: 93,3,1
Author List: A.L. Hoffman, G.A. Wurden, R. Maqueda, J.T. Slough, R.D. Milroy, J.L. McNeil, K.F. McDonald, T.E. DeHart, D.G. Harding, E.A. Crawford, L.N. Carey
Citation: Fusion Technology **23**(2), (1993), pp. 185-207
Title: The large-s FRC experiment (LSX)
Abstract: The Large-s Experiment (LSX) was built to study the formation and equilibrium properties of field-reversed configurations (FRCs) as the scale size increases. The dynamic, field-reversed theta-pinch method of FRC creation produces axial and azimuthal deformations and makes formation difficult, especially in large devices with large s (number of internal gyroradii) where it is difficult to achieve initial plasma uniformity. However, with the proper technique, these formation distortions can be minimized and are then observed to decay with time. This suggests that the basic stability and robustness of FRCs formed, and in some cases translated, in smaller devices may also characterize larger FRCs. Elaborate formation controls were included on LSX to provide the initial uniformity and symmetry necessary to minimize formation disturbances, and stable FRCs could be formed up to the design goal of s = 8. For x {le} 4, the formation distortions decayed away completely, resulting in symmetric equilibrium FRCs with record confinement times up to 0.5 ms, agreeing with previous empirical scaling laws ({tau}{proportional_to}sR). Above s = 4, reasonably long-lived (up to 0.3 ms) configurations could still be formed, but the initial formation distortions were so large that they never completely decayed away, and the equilibrium confinement was degraded from the empirical expectations. The LSX was only operational for 1 yr, and it is not known whether s = 4 represents a fundamental limit for good confinement in simple (no ion beam stabilization) FRCs or whether it simply reflects a limit of present formation technology. Ideally, s could be increased through flux buildup from neutral beams. Since the addition of kinetic or beam ions will probably be desirable for heating, sustainment, and further stabilization of magnetohydrodynamic modes at reactor-level s values, neutral beam injection is the next logical step in FRC development. 24 refs., 21 figs., 2 tabs

First Author: Hoffman
Date: 93,1,1
Author List: A.L. Hoffman, J.T. Slough
Citation: Nuclear Fusion **33**(1), (1993), pp. 27-38
Title: Field-reversed configuration lifetime scaling based on measurements from the large s experiment
Abstract: Flux, energy and particle lifetimes have been measured in the new Large s Experiment field reversed configuration (FRC) facility. By careful control of the formation process, it was possible to form symmetric, quiescent FRCs, with s values

higher than 4, in the one year of operation of the device. A wide range of plasma conditions was achieved, with ion temperatures varying between 0.1 and 1.5 keV. The lifetimes continue to scale approximately with the r^2_s/ρ_i parameter found in earlier work, with a coefficient proportional to x_s to a power between 0.5 and 1.

First Author: Horovitz
Date: 98,6,12
Author List: Y. Horovitz, S. Eliezer, Z. Henis, Y. Paiss, E. Moshe, A. Ludmirsky, M. Werdiger, B. Arad, and A. Zigler
Citation: Physics Letters A **246,** (1998), pp. 329-334
Title: The inverse Faraday effect in plasmas produced by circularly polarized laser light in the range of intensities 10^9-10^{14} W/cm^2
Abstract: Measurements of the axial magnetic field produced during the interaction of circularly polarized laser light with plasma are reported. The experiments were performed with a circularly polarized Nd:YAG laser, with a wavelength of 2.06 μm and a pulse duration of 7 ns, in a range of irradiances from 10^9 to 10^{14} W/cm^2. Axial magnetic field from 500 G up to 2.17 MG were measured. Up to 5 x 10^{13} W/cm^2 the results are in agreement with a nonlinear model of the inverse Faraday effect dominated by the ponderomotive force.

First Author: Horovitz
Date: 97,3,3
Author List: Y. Horovitz, S. Eliezer, A. Ludmirsky, Z. Henis, E. Moshe, R. Shpitalnik, and B. Arad
Citation: Phys. Review Letters **78**(9)**,** (1997), pp. 1707-1710
Title: Measurements of inverse Faraday effect and absorption of circularly polarized laser light in plasmas
Abstract: Measurements of the inverse Faraday effect and of the absorption of circularly polarized laser light in plasmas are reported. The experiments were performed with a Nd:YAG laser system. For the laser irradiance range studied here, 9 x 10^{13}-2.5 x 10^{14} W/cm^2, the absorption of circularly polarized light was higher by 14% relative to the absorption of linear polarized light. It is suggested that the above increase in the laser absorption is related to the axial magnetic field in the plasma created by the circularly polarized laser light. Axial magnetic field of tens of kilogauss were measured at irradiances in the range of 10^{12}-10^{13} W/cm^2 using the Faraday rotation diagnostic.

First Author: Horton
Date: 97,1,1
Author List: W. Horton
Citation: Phys. Reports **283**, (1997), pp. 265-302
Title: Chaos and structures in the magnetosphere
Abstract: The nonlinear plasma transport mechanisms that control the collisionless heating in the Earth's magnetosphere and the onset of geomagnetic substorms are reviewed. In the high-pressure trapped in the reversed magnetic field loops on the nightside of the magnetosphere, the key issue of the role of the ion orbital chaos as the mechanism for the plasma sheet energization is examined. The energization rate is governed by a collisionless conductance and the solar wind driven dawn-to-dusk electric field. The low frequency response function is derived and the fluctuation dissipation theorem is given for the system. Returning to the global picture, the collisionless energization rate from the transport physics is the basis for a low-dimensional energy-momentum-conserving dynamical model of magnetospheric substorms.

First Author: Humpries, Jr.
Date: 96,12,1
Author List: S. Humphries, Jr., C.A. Ekdahl
Citation: IEEE Transactions on Plasma Science **24**(6), (December 1996), pp. 1334-1347
Title: Numerical models of pressure pulse generation by imploding metal liners
Abstract: We describe numerical calculations of pressure pulse generation using imploding liners. Liners are metal cylinders that are magnetically compressed by an intense axial current flow from a high-power pulse generator. The simulations cover the acceleration of the liner, collision with an internal diagnostic target, followed by compression and shock wave heating of the target. With the projected current waveform of the Atlas capacitor bank (in development at Los Alamos National Laboratory), initial results suggest that it may be possible to achieve pressures exceeding 3000 Gpa (30 Mbar) in a 4 mm diameter sample over an interval of 100-200 ns. The simulations were carried out with Crunch, a new one-dimensional hydrodynamics package for advanced personal computers. The program uses finite-element techniques to solve the coupled problems of hydrodynamics

and magnetic diffusion. Crunch fully supports loading and interpolating Sesame equation-of-state tables. The program exhibits excellent stability, even for collisions between material shells and shock convergence on axis.

First Author: Ichimaru
Date: 73,1,1
Author List: S. Ichimaru
Citation: W. A. Benjamin, Inc., Reading, MA (1973)
Title: Basic principles of plasma physics, a statistical approach
Abstract: (book)

First Author: IAEA
Date: 96,1,1
Author List: (none)
Citation: ITER EDA Documentation series **9**, IAEA, Vienna (1996)
Title: ITER interium design report pacage and relevant documents
Abstract: (none)

First Author: Jarboe
Date: 98,1,1
Author List: T.R. Jarboe
Citation: Fusion Technology **15**, (January 1989), pp. 7-11
Title: Formation and steady-state sustainment of a tokamak by coaxial helicity injection
Abstract: A possible method for steady-state sustainment of a tokamak through coaxial helicity injection is presented. To keep the toroidal flux constant, two insulators are used, one that injects and one that absorbs toroidal flux. The scheme is made attractive by incorporating the toroidal field of the tokamak in the source to raise its impedance.

First Author: Jarboe
Date: 94,1,1
Author List: T.R. Jarboe
Citation: Plasma Phys. Control. Fusion **36,** (1994), pp. 945-990
Title: Review of spheromak research
Abstract: Spheromak research from 1979 to the present is reviewed including over 160 references. Emphasis is on understanding and interpretation of results. In addition to summarizing results some new interpretations are presented. An introduction and brief history is followed by a discussion of generalized helicity and its time derivative. Formation and sustainment are discussed including five different methods, flux core, q -pinch, coaxial source, conical q-pinch, and kinked z-pinch. All methods use helicity injections. Steady-state methods and rules for designing spheromak experiments are covered, followed by equilibrium and stability. Methods of stabilizing the tilt and shift modes are discussed as well as their impact on the reactor designs. Current-driven and pressure-driven instabilities as well as relaxation in general are covered. Energy confinement is discussed in terms of helicity decay time and βs limits. The confinement in high and low open-flux geometries are compared and the reactor implications discussed

First Author: Jones
Date: 86,2,1
Author List: R.D. Jones, W.C. Mead
Citation: Nucl. Fusion **26** (2), (Feb. 1986) pp.127-137
Title: Physics of burn in magnetized deuterium-tritium plasmas: spherical geometry
Abstract: There is a large region of density-temperature space in which the effects of a magnetic field on heat transport and alpha-particle mobility are significant and the magnetic pressure is small compared with the pressure of a deuterium-tritium plasma. Spherical fusion burn in this regime is examined. It is found that for volume burn, magnetic fields can greatly increase the yield. In regimes where propagating burn does not occur, the burn can be enhanced by a magnetic field. In regimes where propagating deflagration would normally occur in the absence of a magnetic field, magnetic fields actually degrade the cross-field propagation. A detonation wave is harder to ignite in the presence of a magnetic field. Once a detonation wave is ignited,

no change in the propagation speed is produced by applying a magnetic field.

First Author: Kadomtsev
Date: 92,1,1
Author List: B.B. Kadomtsev
Citation: Translation editor, Professor E. W. Laing, Institute of Physics Publishing, Bristol and Philadelphia (1992)
Title: Tokamak plasma: a complex physical system
Abstract: (none)

First Author: Kirkpatrick
Date: 91,12,1
Author List: R.C. Kirkpatrick, I.R. Lindemuth
Citation: Fusion Technology **20,** (Dec. 1991)
Title: Ignition and burn in inertially confined magnetized fuel
Abstract: At the third International Conference on Emerging Nuclear Energy Systems, we presented computational results which suggested that ``breakeven" experiments in inertial confinement fusion (ICF) may be possible with existing driver technology. We recently used the ICF simulation code LASNEX to calculate the performance of an idealized magnetized fuel target. The parameter space in which magnetized fuel operates is remote from that of both ``conventional" ICF and magnetic confinement fusion devices. In particular, the plasma has a very high β and is wall confined, not magnetically confined. The role of the field is to reduce the electron thermal conductivity and to partially trap the DT alphas. The plasma is contained in a pusher which is imploded to compress and adiabatically heat the plasma from an initial condition of preheat and pre-magnetization to the conditions necessary for fusion ignition. The initial density must be quite low by ICF standards in order to insure that the electron thermal conductivity is suppressed and to minimize the generation of radiation from the plasma. Because the energy loss terms are effectively suppressed, the implosion may proceed at a relatively slow rate of about 1 to 3 cm/μs. Also, the need for low density fuel dictates a much larger target, so that magnetized fuel can use drivers with much lower power and power density. Therefore, magnetized fuel allows the use of efficient drivers that are not suitable for laser or particle beam fusion due to insufficient focus or too long pulse length. The ignition and burn of magnetized fuel involves very different dominant physical processes than does ``conventional" ICF. The fusion time scale becomes comparable to the hydrodynamic time scale, but other processes that limit the burn in unmagnetized fuel are of no consequence. The idealized low gain magnetized fuel target presented here is large and requires a very low implosion velocity. 11 refs.

First Author: Kirkpatrick
Date: 81,1,1
Author List: R.C. Kirkpatrick
Citation: Nuclear Fusion **21** (11), (1981)
Title: Ignition critical profiles for small fusion targets
Abstract: To determine the minimum conditions necessary for ignition in a small fusion target, ignition critical profiles have been calculated for a static, isobaric DT plasma filling a spherical cavity which has a specified wall temperature. The results indicate that a minimum value of the product of pressure and radius PR $\cong$ to 4 x 10^6 Mb$\bullet\mu$m is required for ignition, and that the value increases as the radiation temperature decreases. The limiting value of an effective areal density derived here is smaller than previous crude estimates of a minimum ρR based on large laser fusion simulation codes, notwithstanding the fact that the plasma temperature θ is nowhere less than the wall temperature θr. Arguments are presented which suggest that the minimum PR criterion derived here should apply crudely to the case of ignition by collapse of a single strong shock. A surprising result is suggested for this dynamic case: the initial value of PR must exceed about 2 x $10^5\bullet$Mbμm, compared with less than 1000 Mb$\bullet\mu$m for DT compressed adiabatically one-thousand-fold.

First Author: Kirkpatrick
Date: 79,1,1
Author List: R.C. Kirkpatrick
Citation: Nuclear Fusion **19**(1), (1979) pp. 69-79
Title: An overview of design space for small fusion targets

Abstract: A twelve-parameter burn code has been used to gain an overview of the design space available for laser and E-beam fusion targets. The results of a few thousand implosion calculations are presented here in terms of an initial-condition space. The initial conditions include temperature, density and pusher jump-off velocity. For marginal driving energy there is an isolated region in the initial-condition space (θ_o, ρ_o) for which ignition may be achieved.

First Author: Knoepfel (Editor)
Date: **66,7,1**
Author List: H. Knoepfel, F. Herlach (Editors)
Citation: Proc. of Conf. On Magagauss Magnetic Field Generation by Explosives and Related Experiments, EUR 2750.e, Brussels, France, July 1996
Title: Conference on Megagauss Magnetic Field Generation by Explosives and Related Experiments
Abstract: The scope of the "Conference on Magagauss Magnetic Field Generation by Explosives and Related Experiments" was held to provide, for the first time, an occasion to present and discuss experimental and theoretical results in the field of megagauss generation by explosives and, more in general, of the transformation of explosive energy into electromagnetic energy. Furthermore we wanted to include the application of these techniques to other domains of physics. It goes without saying that on top of this the personal contact among fellow scientists was a most positive experience at this meeting. This was particularly the case in this relatively new field of research, still largely hidden behind a wall of secrecy before the Conference, where only a few names of actively engaged physicists were known and even less was known about their work.

First Author: Lindemuth
Date: 97, 10, 7
Author List: I.R. Lindemuth, C.A. Ekdahl, R.C. Kirkpatrick, R.E. Reinovsky, P.T. Sheehey, R.E. Siemon, F.J. Wysocki, V.K. Chernyshev, V.N. Mokhov, A.N. Demin, S.F. Garanin, V.P.Korchagin, I.V. Morozov, V.A.Yakubov, J.L. Eddleman, J.H. Hammer, D.D. Ryutov, A. Toor, D.H. McDaniel, C. Deeney, J.H. Degnan, G.F. Kiuttu, R.E. Peterkin, Jr.
Citation: Proc. of 16th International Conference on Fusion Energy, IAEA-CN-64/DP-27, Montreal, Canada, October 7-11, 1996, Vol. 2, 723-733
Title: Magnetic-compression/magnitized-target fusion (MAGO/MTF): a marriage of inertial and magnetic confinement
Abstract: Recent advances in high-energy pulsed power capabilities, plasma formation techniques, plasma diagnostics, and multidimensional plasma computer codes make possible the evaluation of an unexplored approach to controlled thermonuclear fusion that is intermediate between magnetic confinement (MFE) and inertial confinement (ICF) in time and density scales. Existing capabilities appear adequate to explore the major physics issues in this area, perhaps up to and including fusion ignition, with relatively low operating costs and essentially no major capital investment.

First Author: Lindemuth
Date: 95,7,11
Author List: I.R. Lindemuth, C.A. Ekdahl, C.M. Fowler, R.E. Reinovsky, S.M. Younger, V.K. Chernyshev, V.N. Mokhov, A.I. Pavlovskii
Citation: 10th IEEE Int. Pulsed Power Conference, Albuquerque, New Mexico, July 11-13, 1995, LA-UR-95-2868DE96000010, CONF-950750-40
Title: The Los Alamos/Arzamas-16 collaboration of ultrahigh magnetic fields and ultrahigh energy pulsed power
Abstract: The end of the Cold War has made possible some remarkable scientific adventures--joint research projects between scientific institutions of the United States and the Russian Federation. Perhaps most unprecedented of the new partnerships is a formal collaboration which has been established between the All-Russian Scientific Research Institute of Experimental Physics and the Los Alamos National Laboratory (LANL), the two institutes which designed the first nuclear weapons for their respective countries. In early 1992, emerging governmental policy in the US and Russia began to encourage ``lab-to-lab'' interactions between the nuclear weapons design laboratories of the two countries. Each government recognized that as nuclear weapons stockpiles and design activities were being reduced, highly qualified scientists were becoming available to use their considerable skills in fundamental scientific research of interest to both nations. VNIIEF and LANL quickly recognized a common interest in the technology and applications of magnetic flux compression, the technique for converting the chemical energy released by high-explosives into intense electrical pulses and intensely concentrated magnetic energy. This document reports on current projects of the collaboration.

First Author: Lindemuth

Date: 95,9,4
Author List: I.R. Lindemuth, V.A. Yakubov, G.I. Volkov, A.N. Skobelev, N.Y. Seleznev, E.S. Pavlovskii, S.V. Pak, I.V. Morozov, O.D. Mikhailov, V.P. Korchagin, et.al.
Citation: Physical Review Letters **75** (10), 4 Sep. 1995, pp. 1953-1956
Title: Target plasma formation for magnetic compression/magnetized target fusion
Abstract: Experimental observations of plasma behavior in a novel plasma formation chamber are reported. Experimental results are in reasonable agreement with two-dimensional magnetohydrodynamic computations suggesting that the plasma could subsequently be adiabatically compressed by a magnetically driven pusher to yield 1 GJ of fusion energy. An explosively driven helical flux compression generator mated with a unique closing switch/opening switch combination delivered a 2.7 MA, 347 μs magnetization current and an additional 5 MA, 2.5 μs electrical pulse to the chamber. A hot plasma was produced and 10^{13} D-T fusion reactions were observed.

First Author: Lindemuth
Date: 91,12,1
Author List: I.R. Lindemuth, R.C. Kirkpatrick
Citation: Fusion Technology **20**, (Dec. 1991)
Title: The promise of magnetized fuel: high gain in inertial confinement fusion
Abstract: At the third International Conference on Emerging Nuclear Energy Systems, we presented computational results which suggested that ``breakeven'' experiments in inertial confinement fusion (ICF) may be possible with existing driver technology. Our computations used a simple zero-dimensional model to survey the parameter space available for magnetized fuel. The survey predicted the existence of a totally new region in parameter space where significant thermonuclear fuel burn-up can occur. The new region is quite remote from ``conventional'' parameter space and is characterized by very low fuel densities, very low implosion velocities, and, most importantly, driver requirements reduced by orders of magnitude. Whereas our initial computations considered only the yield from a hot, magnetized central fuel, we have extended our simple model to include a ``cold fuel'' layer. In the same spirit as our earlier work, our extended model is intended to provide a starting point for more comprehensive investigations. Our extended model predicts that it is possible to obtain a large cold fuel burn-up fraction, leading to very high gain, and once again, the optimum parameter space is quite remote from that of conventional high gain targets. Although conventional drivers optimized for conventional targets are probably not optimum for magnetized fuel at its extremes, there is a continuum between the conventional parameter space between the conventional parameter space and the new parameter space, suggesting a possible role for conventional drivers. However, it would appear that magnetized fuel warrants a complete rethinking of the entire driver/target configuration.

First Author: Lindemuth
Date: 83,6,1
Author List: I.R. Lindemuth, R.C. Kirkpatrick
Citation: Los Alamos National Laboratory preprint, LA-UR-82-3571, (1983)
Title: The Promise of magnetized fuel: inertial confinement fusion with existing driver technology
Abstract: A simple, zero-dimensional model describing the temporal behavior of an imploding-shell, magnetized-fuel inertial confinement fusion target is used to survey the parameter space available for magnetized fuel by computing the behavior of thousands of targets. The survey predicts the existence of a totally new region in parameter space where significant thermonuclear fuel burn-up can occur. The new region is characterized by very low fuel densities, very low implosion velocities, and most importantly, driver requirements reduced by several orders of magnitude, suggesting that 'break-even' experiments may be possible with existing inertial confinement fusion drivers. The new parameter space for magnetized D-T fuel in both spherical and cylindrical geometries and for magnetized D-3 He fuel in spherical geometries is examined.

First Author: Lindemuth
Date: 83,1,1
Author List: I.R. Lindemuth, R.C. Kirkpatrick
Citation: Nuclear Fusion **23(**3), (1983), pp. 263-284
Title: Parameter space for magnetized fuel targets in inertial confinement fusion
Abstract: A simple, zero-dimensional model describing the temporal behavior of an imploding-shell, magnetized fuel inertial confinement fusion target is formulated. The model includes effects not normally considered in inertial confinement fusion such as magnetic back-pressure on the imploding shell, magnetic reduction of thermal conductivity, magnetic diffusion, and Ohmic

heating. The model is simple enough to permit a survey of the parameter space available for magnetized fuel by computing the behavior of thousands of targets. The survey predicts the existence of a totally new region in parameter space where significant thermonuclear fuel burn-up can occur. The new region is characterized by very low fuel densities, very low implosion velocities, and, most important, driver requirements reduced by several orders of magnitude, suggesting that 'break-even' experiments may be possible with existing inertial confinement fusion drivers. The computed results are in reasonable agreement with more complete two-dimensional magnetohydrodynamic simulations.

First Author: Lindemuth
Date: 81,4,1
Author List: I.R. Lindemuth, M.M. Widner
Citation: Phys. Fluids **24**(4), (April 1981), pp. 746-753
Title: Magnetohydrodynamic behavior of thermonuclear fuel in a preconditioned electron beam imploded target
Abstract: Two-dimensional magnetohydrodynamic numerical calculations have been performed to study the fuel behavior of a preconditioned relativistic electron beam target in which, experimentally, a portion of the beam current prepulse entered the target to provide fuel preheat magnetothermoinsulation. The magnetohydrodynamic plasma model used includes radiation, thermal conduction, ionization, and resistive diffusion. The magnetohydrodynamic partial differen tial equations are solved by a computer code employing implicit finite-difference methods. The fuel is shown to develop counter-streaming vortices during the implosion phase. The computed neutron yield is in reasonable agreement with the experimental value, suggesting the origin of the neutrons to be thermonuclear. The effect of both magnetothermoinsulation and preheat is examined.

First Author: Lindemuth
Date: 78,10,1
Author List: I.R. Lindemuth, J.S. Pettibone, J.C. Stevens, R.C. Harding, D.M. Kraybill, L.J. Suter
Citation: Phys. Fluids **21**(10), (October 1978), pp. 1723-1734
Title: Unstable behavior of hot, magnetized plasma in contact with a cold wall
Abstract: The behavior of a hot, magnetized plasma brought into contact with a cold wall is studied numerically in one and two dimensions. A fully nonlinear, time-dependent magnetohydrodynamic plasma model which includes thermal conduction, resistive diffusion, radiation, and ionization is used. The model is solved numerically with an Eulerian computer code which employs implicit finite difference methods. One-dimensional calculations for cylindrical geometry examine the effect of the electrical properties of the wall on the plasma. Two-dimensional calculations for cylindrical geometry show the formation of a wall-induced instability which enhances thermal conduction losses from the plasma; the reemergence of short wavelengths, a new feature of unstable behavior, is evident in the calculations. Two-dimensional calculations for toroidal geometry show that heat losses to a cold wall lead to double-vortex convection flow of the plasma with no evidence of the formation of smaller scale convective cells.

First Author: Lindemuth
Date: 78,1,1
Author List: I.R. Lindemuth, T.R. Jarboe
Citation: Nuclear Fusion **18**(7), (1978), pp. 929-938
Title: Initial numerical studies of the behavior of z-pinch plasma under liner implosion conditions
Abstract: The principle of achieving thermonuclear temperatures by compression of a z-pinch plasma with a solid liner is demonstrated by one- and two-dimensional numerical calculations of the behaviour of the plasma under liner implosion conditions. The magnetohydrodynamic plasma model used includes radiation, thermal conduction, and resistive diffusion. The magnetohydrodynamic partial differential equations are solved by a computer code employing implicit finite-difference methods. The liner is represented by a moving, rigid wall, and the entire Eulerian finite-difference mesh linearly contracts as the liner moves inward. The effectsof end losses and unstable boundary layer formation are demonstrated. The plasma is shown to behave significantly nonadiabatically, although some plasma is nearly adiabatically compressed. For an assumed initial plasma/ magnetic-field configuration and an assumed liner velocity of 1 $cm \bullet \mu s^{-1}$, plasma of 10 cm^{-3} and 600 eV is heated to peak temperatures of nearly 20 keV when the plasma volume is reduced by a factor of 900.

First Author: Lindl
Date: 98,11,1
Author List: J. Lindl

Citation: Phys. of Plasmas **2**(11) (United States), (Nov. 1995), pp. 3933-4024
Title: Development of the indirect-drive approach to inertial confinement fusion and the target physics basis for ignition and gain
Abstract: The ignition target requirements for hohlraum energetics, radiation symmetry, hydrodynamic instabilities and mix, laser plasma interaction, pulse shaping, and ignition requirements are all consistent with experiments. The NIF laser design, at 1.8 MJ and 500 TW, has the margin to cover uncertainties in the baseline ignition targets. In addition, data from the NIF will provide a solid database for ion-beam-driven hohlraums being considered for future energy applications. In this paper we analyze the requirements for indirect drive ICF and review the theoretical and experimental basis for these requirements. Although significant parts of the discussion apply to both direct and indirect drive, the principal focus is on indirect drive.

First Author: Logan
Date: 93,1,1
Author List: B.G. Logan
Citation: Fusion Engineering and Design **22**, (1992) pp. 151-192
Title: Inertial fusion reactors using compact fusion advanced Rankine (CFARII) MHD conversion
Abstract: This study evaluates the potential performance (efficiency and cost) of inertial fusion reactors assumed capable of vaporizing blankets of various working materials to a temperature (10,000-20,000 K) suitable for economical MHD conversion in a Compact Fusion Advanced Rankine II (CFARII) power cycle. Using a conservative model, 1-D neutronics calculations of the fraction of fusion yield captured as a function of the blanket thickness of Flibe, lithium and lead-lithium blankets are used to determine the optimum blanket thicknesses for each material to minimize CoE for various assumed fusion yields, "generic" driver costs, and target gains. Lithium-hydride blankets are also evaluated using an extended neutronics model. Generally optimistic ("advanced") combinations of lower driver cost/joule and higher target gain are assumed to allow high enough fusion yields to vaporize and ionize target blankets thick enough to stop most 14 MeV neutrons, and to breed tritium. A novel magnetized, prestressed reactor chamber concept is modeled together with previously developed models for the CFARII Balance-of-Plant (BoP), consisting of a supersonic plasma jet, MHD generator, and "raindrop" condensor. High fusion yields (10 to 80 GJ) are found necessary to heat and ionize the Flibe, lithium, and lead-lithium blankets for MHD conversion, with initial solid thicknesses sufficient to capture most of the fusion yield. Much smaller fusion yields (1 to 20 GJ) are required for lithium-hydride blankets. For Flibe, lithium, and lead-lithium blankets, improvements in target gain and/or driver cost/joule, characterized by a "Bang per Buck" figure-of-merit of ≥ 20 joules yield per driver $, would be required for competitive CoE, while a figure-of-merit of ≥ 1 joule yield per driver $ would suffice for lithium-hydride blankets. Advances in targets/driver costs would benefit any IFE reactor, but the very low CFARII BoP costs (contributing only 3 mills/kWh to CoE) allows this type of reactor, given sufficient advances that non-driver costs dominate, to ultimately produce electricity at a much *lower* cost than any current nuclear plant.

First Author: Logan
Date: 92,3,6
Author List: B.G. Logan
Citation: American Nuclear Society annual meeting, 7-12 Jun 1992, Boston, MA (United States) UCRL-JC-109517; DE92011964 CONF-920606-16
Title: Low cost, high yield IFE reactors: revisiting Velikhov's vaporizing blankets
Abstract: The performance (efficiency and cost) of IFE reactors using MHD conversion is explored for target blanket shells of various materials vaporized and ionized by high fusion yields (5 to 500 GJ). A magnetized, prestressed reactor chamber concept is modeled together with previously developed models for the Compact Fusion Advanced Rankine II (CFARII) MHD Balance-of-Plant (BoP). Using conservative 1-D neutronics models, high fusion yields (20 to 80 GJ) are found necessary to heat Flibe, lithium, and lead-lithium blankets to MHD plasma temperatures, at initial solid thicknesses sufficient to capture most of the fusion yield. Advanced drivers/targets would need to be developed to achieve a ``Bang per Buck" figure-of-merit approximately > 20 to 40 joules yield per driver $ for this scheme to be competitive with these blanket materials. Alternatively, more realistic neutronics models and better materials such as lithium hydride may lower the minimum required yields substantially. The very low CFARII BoP costs (contributing only 3 mills/kWehr to CoE) allows this type of reactor, given sufficient advances that non-driver costs dominate, to ultimately produce electricity at a much lower cost than any current nuclear plant.

First Author: Lovberg
Date: 94,1,1

Author List: R.H. Lovberg, R.A. Riley, J.S. Shlachter
Citation: Dense Z-Pinches, Third Int. Conf., M. Haines and A. Knight, Eds. (Am. Inst. Physics, NY, 1994), pp. 59-68
Title: Instability heating of the HDZP
Abstract: We present a model of dense Z-pinch heating. For pinches of sufficiently small diameter and high current, direct ion heating by m = 0 instabilities becomes the principal channel for power input. This process is particularly important in the present generation of dense micro-pinches (e.g. HDZP-II) where instability growth times are much smaller than current risetimes, and a typical pinch diameter is several orders smaller than that of the chamber. Under these conditions, m = 0 formation is not disruptive; the large E_z field reconnects the instability cusps externally, after which the ingested magnetic flux decays into turbulent kinetic energy of the plasma. The continuous process is analogous to boiling of a heated fluid.

First Author: McCullen
Date: 89,2,1
Author List: J.D. McCullen, W.A. Neuman, R.L. Morse, L.M. Montierth
Citation: Phys Fluids B **1**(2), (Feb. 1989), pp. 448-467
Title: Surface plasma structures in the kinetic regime
Abstract: A numerical study is done of a plasma in contact with a solid surface that reemits some fraction of the incident plasma as neutral gas. The calculation uses a steady-state, kinetic treatment of the transport equations in one space dimension and one or two velocity dimensions to determine self-consistently the distribution functions of the interacting species and the electrostatic potential. The dominant phenomena are the ionization of the neutral gas and the acceleration of the resulting ions away from a potential maximum that is predicted to form in the ionization region. Other effects involved are a Debye sheath structure between the solid surface and the potential maximum, and collisional trapping and untrapping of electrons in the well represented by the potential maximum. Results are presented from a nondimensional model with a monatomic returning neutral species, and for diatomic molecular deuterium returning from the surface. For each set of physical parameters chosen, a one parameter family of solutions is obtained. A hypothesis is presented for the choice from this family of solutions that would be found experimentally.

First Author: McDonnell Douglas Aerospace Team
Date: 92,3,1
Author List: (none)
Citation: McDonnell Douglas Aerospace Team Final Report, Vol. II and III, DOE/ER-54101, MDC 92E0008 (March 1992)
Title: Inertial fusion energy reactor design studies
Abstract: (none)

First Author: Meier
Date: 92,3,1
Author List: W.R. Meier, M.J. Monsler, R.L. Bieri, et.al.
Citation: DOE/ER/54100-1-Vol.1; DE93019139 WJSA-92-01-Vol.1
Title: Osiris and SOMBRERO inertial confinement fusion power plant designs vol. 1, executive summary and overview, final report
Abstract: Conceptual designs and assessments have been completed for two inertial fusion energy (IFE) electric power plants. The detailed designs and results of the assessment studies are presented in this report. Osiris is a heavy-ion-beam (HIB) driven power plant and SOMBRERO is a Krypton-Fluoride (KrF) laser-driven power plant. Both plants are sized for a net electric power of 1000 Mwe.

First Author: Moir
Date: 96,12,1
Author List: R.W. Moir.
Citation: Fusion Technology **30**, (December 1996), pp. 1613-1623
Title: IFE power plant design strategy
Abstract: If the present research program is successful, heavy-ion beams can be used to ignite targets and to produce high gain for yields of about 400 MJ. HYLIFE-II is a power plant design based on surrounding such targets with thick liquid Flibe, (Li_2BeF_4) so that the chamber and other apparatus can stand up to these bursts of energy at 6 Hz for 1 Gwe without replacing components during the plant's 30-year life. With liquid protection the capacity factor will be increased and the cost of

component replacement will be decreased. The design is robust to technology risks in the sense that if the performance of targets, drivers and other components fall short of predictions, the cost of electricity rises surprisingly little. For example at 2 Gwe, if it takes twice as much energy to ignite a target as previously projected instead of only 1.5 times, the COE increases 9% from 4¢/kW · h, and if the driver cost is increased by 30%, the COE increases by 12%.

The design strategy we recommend is to use conventional engineering principles and known materials in an optimized way to obtain the lowest cost of electricity while keeping the design robust to short falls in predicted cost and performance of components. For a number of components with a high technology risk we have fall-back options. However, good target performance (Gain >50 for driver energy <7MJ) and low cost drivers (<800 M$ direct at driver energy ≥7 MJ) would be helpful to achieving good economics.

First Author: Moir
Date: 95,1,18
Author List: R.W. Moir
Citation: Lawrence Livermore National Laboratory unpublished presentation, Fusion Skunk Works, January 18, 1995.
Title: PACER Revisited: History and Future Challenges
Abstract: (none)

First Author: Moir
Date: 94,10,1
Author List: R.W. Moir
Citation: Proc. 15th IAEA Conf. on Plasma Physics and Controlled Nuclear Fusion, Seville, Spain, September 26-October 1, 1994, IAEA-CN-60/F-7, Vol. 2, pp. 673-680
Title: HYLIFE-II: An approach to a long lived first wall component for inertial fusion power plants
Abstract: The HYLIFE-II concept for inertial fusion energy is based on non-flammable, renewable liquid wall fusion target chambers formed with FLiBe (Li_2BeF_4) molten salt jets, a heavy ion driver, and single sided illumination of indirect drive targets. As a direct result of using thick, renewable liquid walls, the predicted cost of electricity is reduced by about 30% to 4.4 cents/kW· h at 1 GW(e)(3.2 cents/kW· h at 2 GW(e)). The development programme for HYLIFE-II can be shortened and reduced in cost by not requiring expensive neutron sources to develop first wall materials.

First Author: Moir
Date: 94,1,1
Author List: R.W. Moir
Citation: Fusion Technology **25**, (January 1994), pp. 5-25
Title: HYLIFE-II: A molten-salt inertial fusion energy power plant design - final report
Abstract: Enhanced safety and performance improvements have been made to the liquid-wall HYLIFE reactor, yielding the current HYLIFE-II conceptual design. Liquid lithium has been replaced with a neutronically thick array of flowing molten-salt jets (Li_2BeF_4 or Flibe), which will not burn, has a low tritium solubility and inventory, and protects the chamber walls, giving a robust design with a 30-yr lifetime. The tritium inventory is 0.5 g in the molten salt and 140 g in the metal of the tube walls, where it is less easily released. The 5-MJ driver is a recirculating induction accelerator estimated to cost $570 million (direct costs). Heavy-ion targets yield 350 MJ, six times per second, to produce 940 MW of electrical power for a cost of 6.5¢/kW· h. Both larger and smaller yields are possible with correspondingly lower and higher pulse rates. When scaled up to 1934 MW(electric), the plant design has a calculated cost of electricity of 4.5¢/kW· h. The design did not take into account potential improved plant availability and lower operations and maintenance costs compared with conventional power plant experience, resulting from the liquid wall protection. Such improvements would directly lower the electricity cost figures. For example, if the availability can be raised from the conservatively assumed 75% to 85% and the annual cost of component replacement, operations, and maintenance can be reduced from 6% to 3% of direct cost, the cost of electricity would drop to 5.0 and 3.0¢/kW· h for 1- and 2-GW(electric) cases.

First Author: Montierth
Date: 92,4,1
Author List: L.M. Montierth, R.L. Morse, W.A. Neuman
Citation: Phys. of Fluids B **4**(4) (United States), (Apr. 1992), pp. 784-795
Title: Fluid model treatment of surface plasma structures

Abstract: A fluid model is presented for the purpose of calculating numerically the structures of surface plasmas with neutrals returning from the surface, in collision-dominated parameter regimes. Limiting corrections to thermal conduction and viscous pressure are obtained through comparisons with previous Fokker--Planck transport calculations. The model includes removal by pumping, as well as by ionization, of some of the returning neutrals, and solutions are obtained for different relative strengths of pumping. Increasing velocities of plasma flow toward the surface and increasing plasma temperatures near the surface are seen with increased pumping. In the asymptotic region, far from the surface, agreement is found between these families of numerical model solutions and two classes of analytic solutions. Applications to other fundamental and applied problems are discussed.

First Author: Montierth
Date: 89,9,1
Author List: L.M. Montierth, W.A. Neuman, R.L. Morse
Citation: Phys Fluids B **1**(9), (Sep. 1989), pp. 1911-1925
Title: Collisional transport treatment of surface plasma structures
Abstract: Calculations are shown of the structure of plasmas in equilibrium with solid surfaces that reemit incident plasma ions as relatively cold neutral gas. A numerical transport model that includes a Fokker--Planck treatment of ion--ion collisions obtains the distribution function for ions in a phase space of one spatial coordinate and two velocities. This is done self-consistently with an electrostatic potential, a Maxwell--Boltzmann description of electrons, and electron impact ionization of the reemited neutrals. Solutions are obtained from a higher temperature kinetic regime where Coulomb collisions are nearly negligible to a lower temperature regime where plasma behavior is approximately fluidlike. A result of these calculations is the resolution of an ambiguity posed by previous kinetic regime calculations that omitted ion--ion collisions and obtained a family of solutions for each set of physical parameters [Phys. Rev. Lett. 49, 650 (1982); Phys. Fluids 1, 448 (1989)]. The physically correct solution for semi-infinite surface plasmas is shown to be the member of each family that maximizes the ion thermal conduction to the surface and the magnitude of a maximum in the electrostatic potential that is found in these and the previous calculations. Further results are in agreement at lower temperatures with solutions obtained from a fluid model and the identification of the correct boundary condition on normal flow velocity to be used in fluid models.

First Author: Moses
Date: 79,12,1
Author List: R.W. Moses, R.A. Krakowski, R.L. Miller
Citation: Los Alamos Scientific Laboratory informal report, LA-7686-MS (1979)
Title: A conceptual design of the fast-liner reactor (FLR) for fusion power
Abstract: The generation of fusion power from the Fast-Liner Reactor (FLR) concept envisages the implosion of a thin (3-mm) metallic cylinder (0.2-m radius by 0.2-m length) onto a preinjected plasma. This plasma would be heated to thermonuclear temperatures by adiabatic compression, pressure confinement would be provided by the liner inertia, and thermal insulation of the wall-confined plasma would be established by an embedded azimuthal magnetic field. A 2- to 3-μs burn would follow the ~10^4 m/s radial implosion and would result in a thermonuclear yield equal to 10-15 times the energy initially invested into the liner kinetic energy. For implosions occurring once every 10 s a gross thermal power of 430 MWt would be generated. The results of a comprehensive systems study of both physics and technology (economics) optima are presented. Despite unresolved problems associated with both the physics and technology of the FLR, a conceptual power plant design is presented.

First Author: Olsen
Date: 79,5,1
Author List: J.N. Olsen, M.M. Widner, J. Chang, L. Baker
Citation: J. Appl. Phys. **50**(5), (May 1979), pp. 3224-3230
Title: Fuel preconditioning studies for e-beam fusion targets
Abstract: Fuel temperature and density conditions, achieved during the preheat phase of electron-beam fusion compression experiments, must be accurately known to understand experimental results via numerical simulations. We present studies of discharge preheating in a simplified cylindrical geometry which compare measured quantities with results from the one-dimensional Lagrangian CHARTB magnetohydrodynamic code. Experimental meaurements included schlieren photography and ultraviolet through visible time- and space- resolved spectroscopy in various configurations. It is seen that an 8-kA 500-ns heating pulse in 100 Torr of D_2+10% O_2 produces 10--12 eV temperatures, 10^{18} cm^{-3} electron densities, and 7 x 10^5 cm/s expansion velocities in the heated discharge channel. These results are consistent with previous claims for neutron-producing targets, although the target geometry is different.

First Author: O'Neil
Date: 66,11,1
Author List: T. O'Neil, T.K. Fowler
Citation: Physics of Fluids **9**(11), (November 1966), pp. 2219-2223
Title: Plasma expansion in a magnetic field
Abstract: The expansion of a hot plasma in a magnetic field is treated. A background atmosphere may be present, but in examples emphasized the atmospheric pressure is low enough so that its influence is less than that of the magnetic field. The calculation begins after an initial collisional phase, during which free expansion transforms most of the energy into outward radial motion. It is demonstrated by means of a modified virial theorem that this initial outward momentum then dominates the dynamics until expansion is first halted by the field. Though allowed by the theorem, complications such as shock formation, plasma instability, and sweeping up an atmospheric mass comparable to that of the plasma have limited effect. We derive from the virial theorem a lower bound on the plasma radius as a function of time which compares well with simple models neglecting these complications.

First Author: Oparin
Date: 97,9,24
Author List: A. Oparin and J. Meyer-terVehn
Citation: Poster contribution to the 12th Int. Symp. on Heavy Ion Inertial Fusion, Heidelberg, September 24-27, 1997
Title: Cylindrical implosions driven by heavy ion beams
Abstract: Most ICF target design uses a spherical geometry for the fuel core. It is clear, spherical geometry is most favourable for implosion. But cylindrical configurations are well adapted to the irradiation geometry of heavy ion beams with ion energies 10-100 GeV. Therefore we are exploring cylindrical targets configurations, driven axially by heavy ion beams, which are either magnetized or not. The work is motivated (1) by future target experiment at GSI with deposition powers in the range of 100-1000 TW/g and (2) by potential application to inertial fusion. Compared with spherical configurations, however, one has to face the loss problem at both ends of the cylinder.

We estimate analytically energy gain of cylindrical targets, study zero-dimensional model, describing the temporal behaviour of DT-fuel imploded inside a shell, including options for cylindrical geometry and for magnetized fuel. End losses are considered for concrete problem via 2D-simulation.

First Author: Parker
Date: 93,11,1
Author List: J. Parker
Citation: Los Alamos National Laboratory ATHENA Technical Report No. 1 (November 1993).
Title: A primer on liner implosions with particular application to the Pegasus II capacitor bank
Abstract: (none)

First Author: Parks
Date: 98,10,1
Author List: P.B. Parks
Citation: GA-A22977 submitted to Nuc. Fusion October 1998.
Title: Self-similar adiabatic compression of highly-elongated field reversed configurations
Abstract: A theoretical model of an elongated field reversed configuration (FRC) adiabatically compressed to high density by an imploding liner is presented. Compression is assumed to be self-similar, equal along length and radius, and is accomplished by means of a shaped liner [D.D. Ryutov, R.P. Drake, *et al*., Fusion Technol. **30** (1996) 310]. In particular, the model here takes into account the special magnetic topology of the FRC, and the nonuniformity of the radial plasma profiles in order to quantify final to initial compression ratios of the fluid quantities.

First Author: Parks
Date: 90,4,1
Author List: P.B. Parks
Citation: J. Appl. Phys. **67**(7), (April 1990), pp. 3511-3516

Title: Current melt-wave model for transitioning solid armature
Abstract: A model is developed to describe the evolution of a solid armature to the point where metallic contact with the rails is lost. The idea is that a current/melt wave begins at the rear of the armature, where current is concentrated by velocity skin effect, and propagates forward along the rail/armature interface as molten armature material is lost. When the melt wave reaches the front of the armature, the transition to plasma brush contract occurs. A calculation with the model simulating an earlier solid armature experiment at General Atomics shows close agreement with the measured transition velocity, as inferred from the increase in muzzle voltage observed during the shot.

First Author: Perkins
Date: 98,9,14
Author List: L.J. Perkins, B.G. Logan, M.D. Rosen, M.D. Perry, T. Diaz de la Rubia, N.M. Ghoniem (UCLA), T. Ditmire, W.G. Wolfer
Citation: Lawrence Livermore National Laboratory report UCRL-JC-132334 (September 1998) prepared for submittal to Nuc. Fusion.
Title: High-intensity-laser-driven micro neutron sources for fusion materials applications at high fluence
Abstract: (none)

First Author: Perkins
Date: 98,1,1
Author List: L.J. Perkins
Citation: Nuclear Instruments and Methods in Physics Research, A415 (1998) 44-60
Title: The role of inertial fusion energy in the energy marketplace of the 21st century and beyond
Abstract: The viability of inertial fusion in the 21st century and beyond will be determined by its ultimate cost, complexity, and development path relative to other competing, long term, primary energy sources. We examine this potential marketplace in terms of projections for population growth, energy demands, competing fuel sources and environmental constraints (CO_2), and show that the two competitors for inertial fusion energy (IFE) in the medium and long term are methane gas hydrates and advanced, breeder fission; both have potential fuel reserves that will last for thousands of years. Relative to other classes of fusion concepts, we argue that the single largest advantage of the inertial route is the perception by future customers that the IFE fusion power core could achieve credible capacity factors, a result of its relative simplicity, the decoupling of the driver and reactor chamber, and the potential to employ thick liquid walls. In particular, we show that the size, cost and complexity of the IFE reactor chamber is little different to a fission reactor vessel of the same thermal power. Therefore, relative to fission, because of IFE's tangible advantages in safety, environment, waste disposal, fuel supply and proliferation, our research in advanced targets and innovative drivers can lead to a certain, reduced-size driver at which future utility executives will be indifferent to the choice of an advanced fission plant or an advanced IFE power plant; from this point on, we have a competitive commercial product. Finally, given that the major potential customer for energy in the next century is the present developing world, we put the case for future IFE "reservations" which could be viable propositions providing sufficient reliability and redundancy can be realized for each modular reactor unit.

First Author: Perkins
Date: 96,10,7
Author List: L.J. Perkins, R.P. Drake, J.L. Eddleman, J.H. Hammer, C.W. Hartman, N.N. Mattor, B. Moosman, A.A. Newton, P. Ney, H.U. Rahman, Y.S. Song, A. Van Drie, F.J. Wessel
Citation: Proc. of the 16th Int'l. Conf. on Fusion Energy, organized by the Int'l. IAEA, Montreal, Canada, October 7-11, 1996, IAEA-CN-64/GP-18, pp. 619-625
Title: High density, high magnetic field concepts for compact fusion reactors
Abstract: One rather discouraging feature of conventional approaches to fusion energy is that they do not appear to lend themselves to a a small reactor for developmental purposes. This is in contrast to the normal evolution of a new technology, which typically proceeds to a full scale commercial plant via a set of graduated steps. Accordingly, several concepts concerned with dense plasma fusion systems are being studied theoretically and experimentally. A common aspect is that they employ: (a) high to very high plasma densities ($\sim 10^{16}$ - $\sim 10^{26}$ cm^{-3}) and (b) magnetic fields. If they could be shown to be viable at high fusion Q, they could conceivably lead to compact and inexpensive commercial reactors. At least, their compactness suggests that both proof of principle experiments and development costs will be relatively inexpensive compared with the present

conventional approaches. In the paper, the following concepts are considered: (1) the staged Z pinch; (2) liner implosion of closed field line configurations; (3) magnetic "fast" ignition of inertial fusion targets; (4) continuous flow Z pinch.

First Author: Ribe
Date: 81,1,1
Author List: F.L. Ribe, A.R. Sherwood
Citation: Fusion **1**, Part B (Academic Press, 1981), E. Teller, Ed., pp. 59-78
Title: Fast-liner-compression fusion systems
Abstract: Fast-liner-compression systems are essentially inertial confinement systems which use magnetic fields to insulate the plasma and to drive the compressing liner. The plasma is in contact with the imploding metallic liner wall and has an internal magnetic field. With respect to this magnetic field, the plasma beta is much greater than unity. At its ends the plasma is in contact with material end plugs, whose ablating surfaces confine the fusion plasma in the axial direction.

First Author: Ribe
Date: 75,1,1
Author List: F.L. Ribe**Citation:** Rev. Modern Phy. **47**(1), (January 1975), pp. 7-41
Title: Fusion reactor systems
Abstract: A comprehensive review of the proposed deuterium-tritium fusion reactors: the Tokamak, theta-pinch, magnetic-mirror and laser-pellet systems. Describes the plasma physical aspects of each system, its plasma confinement and heating conversion methods, and discusses the characteristics of the corresponding conceptual power plants.

First Author: Rosenbluth
Date: 79,1,1
Author List: M.N. Rosenbluth and M.N. Bussac
Citation: Nuclear Fusion **19**(4) (1978)
Title: MHD stability of spheromak
Abstract: The "Spheromak," an optimal force-free spherical plasma configuration, is analyzed for its MHD stability properties. It is shown that flattened ellipse (oblimak) with j = kB (k independent of r) should be stable against all magnetically driven MHD and resistive tearing modes if surrounded by a conducting wall at about $r_w/r_o = 1.15$. B's of at least 2% can be stably confined, equivalent to 20% in tokamaks.

First Author: Ryutov
Date: 99,4,19
Author List: D.D. Ryutov
Citation: Lawrence Livermore National Laboratory report UCRL-JC-133716 prepared for submittal to Z-Pinches for Energy, Albuquerque, New Mexico, April 27-28, 1999
Title: A problem of stand-off energy sources for MTF
Abstract: Fusion devices based on the adiabatic (or shock) compression of the plasma by electromagnetically driven liner need specific energy sources capable of delivering a high current (10 MA) in the pulses 0.1 - 1 microsecond long. In the present experimental facilities, the plasma load is situated very close to the pulse-power energy source. In the future fusion devices, one would have to place a plasma load at a considerable distance from the energy source (to avoid strong neutron and thermo-mechanical damage to the source). Several versions of the stand-off energy sources are considered. All are based on the idea of an "assembly" - an object where the plasma load is nested and which contains all necessary circuitry that allows conversion of the energy delivered to the assembly into the magnetic energy. Such "assemblies" will be dropped (or inserted) into the reaction chamber at a desired rate and energized by a stand-off energy source. Four specific concepts have been mentioned.

First Author: Schaffer
Date: 78,1,1
Author List: M.J. Schaffer, R.F. Bourque, C.L. Hsieh, R.E. Waltz, and T. Yamagishi
Citation: General Atomic Company report 789226 (1978) pp. 1383-1388
Title: A calculation of linear magnetic liner fusion reactor performance
Abstract: The fusion reactor performance of an open field line, linear, magnetically confined plasma column compressed radially by a rotating liquid metal liner is analyzed and calculated. Models for liner dynamics and plasma confinement are

derived from the results of specialized one-dimensional computer calculations. It is shown that this plasma and liner combination is mutually self-consistent and is capable of fusion power production at reasonable net efficiencies.

First Author: Sheehey
Date: 97,1,1
Author List: P. Sheehey, I. Lindemuth
Citation: Phys. Plas. **4**(1), (1997), pp. 146-152
Title: Hall and two-temperature magnetohydrodynamic simulation of deuterium-fiber-initiated z pinches
Abstract: Two-dimensional "cold-start" resistive magnetohydrodynamic computations of formation and evolution of deuterium-fiber-initiated Z pinches have been extended to include separate ion and electron energy equations and some finite-Lamor-radius ordered terms. In the Ohm's law (magnetic field evolution) equation, Hall and diamagnetic pressure terms have been added, and corresponding terms have been added to the energy equation. None of the extended model computations show stabilizing effects for fiber-initiated Z pinches; in fact, further slight destabilization is noted. This continues the good agreement shown between previous computational results and experiment.

First Author: Sheehey
Date: 96,1,1
Author List: P. Sheehey, J. Guzik, R. Kirkpatrick, I. Lindemuth, D. Scudder, J. Shlachter, F. Wysocki
Citation: Fusion Technology **30**, (Dec. 1996), pp. 1355-1359
Title: Computational and experimental investigation of magnetized target fusion
Abstract: In Magnetized Target Fusion (MTF), a preheated and magnetized target plasma is hydrodynamically compressed to fusion conditions. Because the magnetic field suppresses losses by electron thermal conduction in the fuel during the target implosion heating process, the compression may be over a much longer time scale than in traditional inertial confinement fusion (ICF). Bigger targets and much lower initial target densities than in ICF can be used, reducing radiative energy losses. Therefore, 'liner-on-plasma' compressions, driven by relatively inexpensive electrical pulsed power, may be practical. Potential MTF target plasmas must meet minimum temperature, density, and magnetic field starting conditions, and must remain relatively free of high-Z radiation-cooling-enhancing contaminants. At Los Alamos National Laboratory, computational and experimental research is being pursued into MTF target plasmas, such as deuterium-fiber-initiated Z-pinches, and the Russian-originated 'MAGO' plasma. In addition, liner-on-plasma compressions of such target plasmas to fusion conditions are being computationally modeled, and experimental investigation of such heavy liner implosions has begun. The status of the research will be presented. 9 refs., 4 figs.

First Author: Sheffield
Date: 94,7,1
Author List: J. Sheffield
Citation: Reviews of Modern Physics **66**(3), (July 1994), pp. 1015-1103
Title: The physics of magnetic fusion reactors
Abstract: During the past two decades there have been substantial advances in magnetic fusion research. On the experimental front, progress has been led by the mainline tokamaks, which have achieved reactor-level values of temperature and plasma pressure. Comparable progress, when allowance is made for their smaller programs, has been made in complementary configurations such as the stellarator, reversed-field pinch and field-reversed configuration. In this paper, the status of understanding of the physics of toroidal plasmas is reviewed. It is shown how the physics performance, constrained by technological and economic realities, determines the form of reference toroidal reactors. A comparative study of example reactors is not made, because the level of confidence in projections of their performance varies widely, reflecting the vastly different levels of support which each has received. Success with the tokamak has led to the initiation of the International Thermonuclear Experimental Reactor project. It is designed to produce 1500 MW of fusion power from a deuterium-tritium plasma for pulses of 1000 s or longer and to demonstrate the integration of the plasma and nuclear technologies needed for a demonstration reactor.

First Author: Sheffield
Date: 86,3,1
Author List: J. Sheffield, R.A. Dory, S.M. Cohen, J.G. Delene, and L. Parsley (ORNL); D.E.T.F. Ashby (Culham); W.T. Reiersen (PPPL).

Citation: Fus. Technology **9,** (March 1986), pp. 199-222
Title: Cost assessment of a generic magnetic fusion reactor
Abstract: A generic reactor model is used to examine the economic viability of electricity generation by magnetic fusion. The simple model uses components that are representative of those used in previous reactor studies of deuterium-tritium burning tokamaks, stellarators, bumpy tori, reversed-field pinches, and tandem mirrors. Conservative costing assumptions are made. The generic reactor is not a tokamak but rather it is intended to emphasize what is common to all magnetic fusion reactors. The reactor uses a superconducting toroidal coil set to produce the dominant magnetic field. To this extent, it is not as good an approximation to systems, such as the reversed-field pinch, in which the main field is produced by a plasma current.

The main output of the study is the cost of electricity as a function of the weight and size of the fusion core--blanket, shield, structure, and coils. The model shows that a 1200-MW (electric) power plant with a fusion core weight of ~10000 tonnes should be competitive in the future with fission and fossil plants. Sensitivity studies that vary the assumptions show that this result is not sensitively dependent on any given assumption. Of particular importance is the result that this scale of fusion reactor may be realized with only moderate advances in physics and technology capabilities.

First Author: Sheffield
Date: 85,1,1
Author List: J. Sheffield
Citation: Nuc. Fusion **25**(12), (1985), pp. 1733-1743
Title: Physics requirements for an attractive magnetic fusion reactor
Abstract: The plasma parameters beta (β) and thermal diffusivity χ_E required for a self-sustained deuterium-tritium (D-T) reactor plasma may be written in terms of the geometry and technological requirements of the reactor. While there are, separately, constraints on each parameter, it is instructive to combine them in a single parameter $(\beta)/\chi_E$ to characterize the reactor region. In a separate study of a generic toroidal magnetic fusion reactor it has been found that, for a fusion reactor to be competitive with alternative sources of electricity, it must have a fusion island weight of not more than half that of the Starfire and Mars reference reactors. A simple model, based upon this result, is used to determine the region of minimum $(\beta)/\chi_E$ and the self-consistent physics and technology requirements for a reactor as a function of its plasma geometry. The requirements are compared with experimental achievements and the theoretical predictions for the parameters (β), χ_E, and $(\beta)/\chi_E$, for a variety of magnetic configurations - tokamak, stellarator, reversed-field pinch, bumpy torus, tandum mirror, and field-reversed theta pinch. It is shown that all these configurations are, "classically," capable of reaching the attractive reactor region and that good progress is being made experimentally towards that goal.

First Author: Sherwood
Date: 77,8,1
Author List: A.R. Sherwood, B.L. Freeman, R.A. Gerwin, T.R. Jarboe, R.A. Krakowski, R.C. Malone, J. Marshall, R.L. Miller, B. Suydam
Citation: Los Alamos Scientific Laboratory proposal, LA-6707-P, (1977)
Title: Fast liner proposal
Abstract: This is a proposal to study, both theoretically and experimentally, the possibility of making a fusion reactor by magnetically imploding a cylindrical metallic shell on a prepared plasma. The approach is characterized by the following features: (1) the nonrotating liner would be driven by an axial current, (2) the plasma would also carry an axial current that provides an azimuthal magnetic field for thermal insulation in both the radial and longitudinal directions, (3) solid end plugs would be utilized to prevent axial loss of particles, and (4) liner speeds would be in the 10^6 cm/s range.

Our preliminary calculations indicate (1) that the energetics are favorable (energy inputs of about 10 MJ might produce a machine in the break-even regime), (2) that radiation and heat losses could be made tolerable, (3) that alpha-particle heating could be made very effective, and (4) that Taylor instabilities in a fast liner might be harmless because of the large viscosities at high pressures.

A preliminary conceptual design of the sort of fusion reactor that might result from such an approach is discussed, as are some of the relevant reactor scaling arguments.

First Author: Siemon
Date: 97,3,5

Author List: R.E. Siemon
Citation: Los Alamos National Laboratory talk LA-UR-97-764, presented at the Innovative Confinement Concept Workshop, Marina del Rey, California, March 3-6, 1997.
Title: Magnetized target fusion - a high-density pulsed-power approach to fusion
Abstract: Magnetized Target Fusion (MTF) is a new thrust in fusion energy research that would utilize plasma parameters intermediate ($n = 10^{18}$ to 10^{20} cm^{-3}) between inertial confinement fusion ($n \sim 10^{24}$ cm^{-3}) and conventional magnetic fusion ($n \sim 10^{14} cm^{-3}$). The idea is to compress a magnetized plasma inside an electrically conducting shell imploded at hypervelocity. Pulsed power technology developed under the auspices of Defense Programs is capable of generating peak-pressure dwell-time products of relevance to fusion (ntT). Magnetic field in the compressed plasma is needed to suppress thermal conduction in the regime of interest (liner velocity of a few cm per microsecond). Plasma beta greater than unity with pressure supported by material walls is desirable. Examples of radial density and temperature profile evolution in a preheated cylindrical z pinch and theta pinch have been calculated using Braginskii transport coefficients. The results show parameters fairly close to simple adiabatic heating expectations for realistic liner compression speeds even though a significant amount of plasma accumulates in a cold low-beta sheath at the metal boundary. A bibliography of relevant papers on the physics of MTF is being assembled and is available on the web at http://wsx.lnl.gov/mtf_bib.html. As a pulsed system with explosive energy densities, MTF is akin to ICF as a future energy technology. A possible key advantage for long-term energy development is that MTF appears to require less capital investment than other approaches, and thus has the potential for a significantly lower-cost development program. The first phase of needed research will advance the science of wall-plasma interactions, which may impact our understanding of tokamak disruptions or have application to plasma processing. An exciting possibility is that after successful work on plasma preheating, MTF could provide a modest-cost approach to studying alpha physics and thermonuclear burn phenomena.

First Author: Siemon
Date: 86,6,7
Author List: R.E. Siemon, W.T. Armstrong, D.C. Barnes, R.R. Bartsch, R.E. Chrien, J.C. Cochrane, W.N. Hugrass, R.W. Kewish, Jr., P.L. Klingner, H.R. Lewis, R.K. Linford, K.F. McKenna, R.D. Milroy, D.J. Rej, J.L. Schwarzmeier, C.E. Seyler, E.G. Sherwood, R.L. Spencer, M. Tuszewski
Citation: Fusion Technology **9**(1), (January 1986), pp. 13-37
Title: Review of the Los Alamos FRX-C experiment
Abstract: The FRX-C device is a large field-reversed theta pinch experiment with linear dimensions twice those of its FRX-A and FRX-B predecessors. It is used to form field-reversed configurations (FRCs), which are high-beta, highly prolate compact toroids. The FRX-C has demonstrated an R_2 scaling for particle confinement in FRCs, indicating particles are lost by diffusive processes. Particle losses were also observed to dominate the energy balance. When weak quadrupole fields were applied to stabilize the n = 2 rotational mode, FRC lifetimes >300 μs were observed. Detailed studies of the FRC equilibrium were performed using multichord and holographic interferometry. Measurements of electron temperature by Thomson scattering showed a flat profile and substantial losses through the electron channel. The loss rate of the internal poloidal flux of the FRC was observed to be anomalous and to scale less strongly with temperature than predicted from classical resistivity.

First Author: Siemon
Date: 80,12,2
Author List: R.E. Siemon, R.R. Bartsch
Citation: Proc. 3rd Symp. Physics and Technology of Compact Toroids, Los Alamos, New Mexico, December 2-4, 1980, LA-8700-C, p. 172, Los Alamos National Laboratory (1980)
Title: Scaling laws for FRC formation and prediction of FRX-C parameters
Abstract: A semi-emperical method has been developed to extrapolate the experimental results from FRX-B, a field-reversed theta pinch which generates an FRC (Field-Reversed Configuration - a compact toroid with no toroidal field), to the larger size FRX-C. Even though there are many uncertainties about details the dynamic processes by which an FRC is formed, the scaling exercise has proven useful in identifying limitations in the original FRX-C design and the design has been modified to have a lower voltage and larger capacitance. The goal of FRX-C remains unchanged: to test the confinement scaning of an FRC in a larger device over a wider range of temperatures. Of particular interest is the testing of possible MHD stability limits as the ratio of plasma size to gyro radius increases.

First Author: Smitherman
Date: 91,12,1

Author List: D.P.Smitherman, R.C. Kirkpatrick
Citation: Fusion Technology **20,** (Dec. 1991), pp. 838-842
Title: Energetic alpha particle deposition in a magnetized plasma
Abstract: The problem of energetic alpha particle deposition in a dense, magnetized deuterium-tritium (DT) thermonuclear fuel has been studied numerically for the case of coulomb interactions in cylindrical geometry. This was done by following the particle trajectories initiated at various radii and in different directions through the plasma and its imposed field until they had either left the plasma or deposited all their energy. The resulting complex particle trajectories in the static magnetized fuel make a detailed treatment of the problem computationally intensive. Therefore, we have attempted to use detailed modeling to produce a data base for a neural nets algorithm for incorporation in an ignition critical profile code. While the accuracy of the neural net in reproducing the detailed calculational results is not high, it is approximately 6000 times faster.

First Author: Sweeney
Date: 81,1,1
Author List: M.A. Sweeney, A.V. Farnsworth, Jr.
Citation: Nuclear Fusion **21**(1), (1981), pp. 41-54
Title: High-gain, low-intensity ICF targets for a charged-particle beam fusion driver
Abstract: A class of high-gain ICF targets driven by electrons or light ions is discussed. The targets are characterized by low-beam-intensity requirement and large size. A magnetic field provides thermal insulation of pre-heated, low-density fuel. The addition of a cryogenic fuel layer increases the gain without requiring significantly increased beam power and intensity. The higher fuel adiabat and reduced fuel losses produce ignition and burn for lower implosion velocities and at lower power and intensity than conventional ablative designs. Gains of 20 to 40 are expected for intensities of approximately < 80 $TW \bullet cm^{-2}$, initial magnetic fields of approximately > 30-60 kG, an initial fuel radius of 0.2-0.4 cm, and irradiation uniformities of 6-7%. Driver requirements are approximately <45 $TW \bullet cm^{-2}$ if the initial magnetic field is approximately >300-600 kG, sufficient for alpha trapping in the compressed low-density fuel. Voltage shaping increases fuel burn-up and target rr and lowers power and intensity levels by an additional factor of about 0.6.

First Author: Tabak
Date: 94,5,1
Author List: M.Tabak, R.J. Mason, M.D. Perry, E.M. Campbell, J. Woodworth, S.C. Wilks, W.L. Kruer, M.E. Glinsky, J. Hammer
Citation: Physics of Plasmas **1**(5), (May 1994), pp. 1626-1634
Title: Ignition and high gain with ultra-powerful lasers
Abstract: Ultrahigh intensity lasers can potentially be used in conjunction with conventional fusion lasers to ignite inertial confinement fusion (ICF) capsules with a total energy of a few tens of kilojoules of laser light, and can possibly lead to high gain with as little as 100 kJ. A scheme is proposed with three phases. First, a capsule is imploded as in the conventional approach to inertial fusion to assemble a high-density fuel configuration. Second, a hole is bored through the capsule corona composed of ablated material, as the critical density is pushed close to the high-density core of the capsule by the ponderomotive force associated with high-intensity laser light. Finally, the fuel is ignited by suprathermal electrons, produced in the high-intensity laser--plasma interactions, which then propagate from critical density to this high-density core. This new scheme also drastically reduces the difficulty of the implosion, and thereby allows lower quality fabrication and less stringent beam quality and symmetry requirements from the implosion driver. The difficulty of the fusion scheme is transferred to the technological difficulty of producing the ultrahigh-intensity laser and of transporting this energy to the fuel.

First Author: Thio
Date: 99,1,1
Author List: Y.C.F. Thio, E. Panarella, R.C. Kirkpatrick, P. Parks, and G. Schmidt
Citation: University of Alabama informal report
Title: Magnetized target fusion in a spheroidal geometry with standoff drivers
Abstract: An embodiment of magnetized target fusion (MTF) with the potential that the drivers can be positioned in a standoff distance from the site of the fusion burn is proposed. The magnetized target plasma is formed out of two merging compact toroids, and is imploded by a spherical plasma liner formed out of the merging of a number (nominally 60) of high momentum density plasma jets. These plasma jets are produced by highly efficient electromagnetic accelerators. They also carry the main fusion fuel. The implosion dynamics is studied in three phases: the preliminary shock heating and compression, the acoustic

compression, and the containment of the burning target and liner. Mathematical models are developed to model these three phases of the implosion dynamics, and have been implemented in a suite of computer codes. Preliminary results produced by the models have been very encouraging, showing the great potential of the proposed MTF scheme. The scheme has a low energy threshold for economic breakeven, and has the potential of high wall-plug energy gain of more than 50 or so. Moreover, the pulsed power drivers are very modest and can be accommodated with current state of the art and existing facilities. The embodiment thus potentially provides a low-cost and fast R&D path towards demonstrating practical fusion energy and followed-on commercialization.

First Author: Thio
Date: 98,1,1
Author List: Y.C.F. Thio, B. Landrum, R.C. Kirkpatrick, B. Freeze, G. Schmidt, and H. Gerrish
Citation: University of Alabama final report for contract SUB1998-105 (1998)
Title: Advanced interplanetary propulsion using magnetized target fusion
Abstract: We present here a concept of using pulsed, non-solid-liner, magnetized target fusion[1] (MTF) for space propulsion for interplanetary flights. MTF is a new entry to fusion development. MTF is an approach to fusion that could be attained within 15 years. The propulsion system presented here thus has the potential of revolutionizing NASA's access to interplanetary travel in about 20 years.

Since MTF is a relatively new concept in fusion, a thorough study of its potential for space propulsion has never been undertaken previously. The propulsion system may have several unique features quite different from previously considered fusion propulsion system. Preliminary analyses show that specific impulse (ISP) of over 1.5×10^5 s and a thrust-to-engine-mass ratio of 0.2 kN per ton are quite achievable. A round trip to Mars can be achieved within a month and to Jupiter in less than 250 days.

One possible propulsion system would use a set of high velocity plasma guns to implode a magnetized target plasma to fusion burn conditions. A magnetic nozzle is used to react against the expanding fusion plasma producing the thrust. The neutron energy released by the fusion is converted into electricity which in turn is used to power the plasma guns via a capacitor bank. The plasma guns may double as MHD thrusters capable of augmenting the direct fusion thrust with extremely high ISP.

First Author: Tidman
Date: 82,1,1
Author List: D.A. Tidman, S.A. Goldstein
Citation: IEEE Transactions on Magnetics **18**(1), (Jan. 1982), pp. 115-120
Title: Applications of REP-ratable mass accelerators (such as MAID)
Abstract: Several applications of mass-accelerators are discussed with emphasis on impact fusion as one of the most ambitious goals for such devices. Many applications require that the accelerator be capable of being repetitively fired. 20 refs.

First Author: Toropin
Date: ?
Author List: Y.M. Toropin, O.D. Toropina, V.V. Savel'e, M.M. Romanova, V.M. Chechetkin, R.V.E. Lovelace
Citation: Submitted to the Astrophysical Journal
Title: Spherical bondi accretion onto a magnetic dipole
Abstract: Quasi-spherical supersonic (Bondi-type) accretion to a star with a dipole magnetic field is investigated using resistive magnetohydrodynamic simulations. A systematic study is made of accretion to a non-rotating star, while sample results for a rotating star are also presented. We find that an approximately spherical shock wave forms around the dipole with an essential part of the star's initial magnetic flux compressed inside the shock wave. A new stationary subsonic accretion flow is established inside the shock wave with a steady rate of accretion to the star smaller than the Bondi accretion rate M_B. Matter accumulates between the star and the shock wave with the result that the shock wave expands. Accretion to the dipole is almost spherically symmetric at radii larger than $2R_A$, where R_A is the Alfvén radius, but it is strongly anisotropic at distances comparable to the Alfvén radius and smaller. At these small distances matter flows along the magnetic field lines and accretes to the poles of the star along polar columns. The accretion flow becomes supersonic in the region of the polar columns. In a test case with an unmagnetized star, we observed spherically-symmetric stationary Bondi accretion without a shock wave. The accretion rate to the dipole M_{dip} is found to depend on $b \propto M_B/m^2$, where m is the star's magnetic moment, and h_m the magnetic

diffusivity. Specifically $M_{dip} \propto b^{0.5}$ and $M_{dip} \propto h_m^{0.38}$. The equatorial Alfvén radius is found to depend on b as $R_A \propto b^{-0.3}$ which is close to theoretical dependence $\propto b^{-2/7}$. There is a weak dependence on magnetic diffusivity, $R_A \propto h_m^{0.07}$.

Simulations of accretion to a rotating star with an aligned dipole magnetic field show that for slow rotation the accretion flow is similar to that in non-rotating case with somewhat smaller values of M_{dip}. In the case of fast rotation the structure of the subsonic accretion flow is fundamentally different and includes a region of "propeller" outflow. The methods and results described here are of general interest and can be applied to systems where matter accretes with low angular momentum.

First Author: Trainor
Date: 97,7,1
Author List: R.J. Trainor, W.M. Parsons, et.al.
Citation: Los Alamos National Laboratory report LA-UR-097-2434 presented at the 11th IEEE International Pulsed Power Conference in Baltimore, Maryland, July 1, 1997.
Title: Overview of the Atlas project
Abstract: Atlas is a high energy pulsed power facility under development at Los Alamos National Laboratory to perform high energy-density experiments in support of the Department of Energy's stockpile stewardship responsibility. Its design is optimized for materials properties and hydrodynamics experiments under extreme conditions. Atlas will be operational in late-1999 and is designed to provide 100 shots per year. The Atlas capacitor bank design consists of a 36-MF array of 240-kV Marx modules. The system is designed to deliver a peak current of 40-50 MA with a 4-5 ms risetime. The Marx modules are designed to be reconfigured to a 480-kV configuration, if needed, for opening switch development. The bank is resistively damped to limit fault currents and capacitor voltage reversal. The system is configured for very low-inductance operation (total inductance ~ 10 nH) to rapidly implode heavy liner loads. An experimental program for testing and certifying prototype components is currently underway. For many applications the Atlas liner will be a nominal 70g aluminum cylinder. Using composite inner layers and a variety of interior target designs, a wide variety of experiments in ~cm3 volumes may be performed. These include shock compression experiments up to ~3 TPa (30 Mbar), quasi-adiabatic compressions up to 6-fold compression and pressures above 10 TPa, hydrodynamic instability studies in nonlinear and turbulent regimes over multi-cm propagation lengths, experiments with dense plasmas in the so-called high-gamma regime, studies of materials response at very high strains and strain rates, and materials studies in ultrahigh magnetic fields (above 103 T).

First Author: Turchi
Date:
Author List: P.J. Turchi
Citation:
Title: A compact-toroid fusion reactor design at 0.5 megagauss, based on stablized liner implosion techniques
Abstract: Techniques had been successfully developed at the Naval Research Laboratory permitting repetitive, stable implosion of liquid liners. Plasma/magnetic field configurations suitable for compression in relatively long times (~100 μsec) were not available, however, so program activity ceased. Continued progress over the last few years on the generation and control of compact toroid plasmas indicates that such a plasma/field configuration indeed exists. It is useful, therefore, to review the characteristics of a fusion reactor design in which a rotationally-stabilized liquid metal liner is driven by axisymmetric free-pistons and adiabatically compresses a compact toroid plasma. Calculations of the reactor operation indicate that peak magnetic fields of 0.54 Mgauss should be optimum, using liners of lead-lithium alloy (0.8 Pb, 0.2 Li by atom). Reactor output power would be 500 Mw(e) with a circulating power fraction of less than 0.15. The principal problem areas appear to be generation of the initial compact toroid at reactor-level conditions (initial plasmoid energy ≈15 MJ) and control of axial motion of the liner material. Design considerations are detailed and directions for future development are suggested.

First Author: Turchi
Date: 74,1,1
Author List: P.J. Turchi
Citation: Naval Research Laboratory report, NRL Memorandum Report 2711 (January 1974)
Title: Spherical implosion of thick liners with compressibility and plasma loss
Abstract: Fusion reactors based on imploding liner flux compression can utilize the imploded liners surrounding the reacting plasma as a neutron-absorbing blanket and thermal reservoir. In this report, the final stages of liner-plasma compression are modelled in terms of the one-dimensional implosion of a thick, spherical shell. Spindle cusp plasma confinement is assumed,

with plasma loss by particle efflux through the ring and point cusps. The liner material is treated as an inviscid, incompressible fluid. Compressibility effects are included in the liner motion, however, by correcting for energy loss to liner material compression. A finite buffer region of constant magnetic flux is also included between the liner surface and the plasma. Normalized equations for the liner-plasma dynamics are solved numerically, indicating the interaction between liner compression and plasma loss, and providing operating conditions for a flying cusp fusion reactor.

First Author: Tuszewski
Date: 91,5,24
Author List: M. Tuszewski, D.P. Taggart, R.E. Chrien, D.J. Rej, R E. Siemon, B.L. Wright
Citation: Phys. Fluids B **3**(10), (October 1991), pp. 2856-2870
Title: Axial dynamics in field-reversed theta pinches. II: stability
Abstract: Detailed stability studies are made with new diagnostics in the FRX-C/LSM field-reversed theta pinch [Plasma Physics and Controlled Nuclear Fusion Research (IAEA, Vienna, 1989), Vol II, p. 517]. These studies seek the origin of a degradation of the confinement properties of field-reversed configurations (FRC's) that appears associated with strong axial dynamics during plasma formation. Several instabilities are observed, including rotational modes, interchanges, and tilt instabilities. Only the latter are strongly correlated with FRC confinement. Title instabilities are observed for FRC's with larger average number of ion gyroradii ($s \sim 3$-5) and smaller separatrix elongations ($e \sim 3$-4). Coincidently, strong axial dynamics occurs for cases with larger s and smaller e values, through increases in either reversed bias field or fill pressure. These data provide some understanding of FRC stability. In agreement with finite Larmor radius theory, there is a regime of gross stability for the very kinetic and elongated FRC's with $s/e < 0.2$-0.3. This is the regime that has been studied in most FRC experiments. However, tilt and other instabilities are observed for FRC's with $s/e \sim 1$. Additional stabilization techniques will be required for future large-size FRC's.

First Author: Tuszewski
Date: 88,11,1
Author List: M. Tuszewski
Citation: Nuclear Fusion **28**(11), (1988), pp. 2033-2092
Title: Field reversed configurations
Abstract: The review is devoted to field reversed configurations and to the related field reversed mirrors; both are compact toroids with little or no toroidal magnetic field. Experimental and theoretical results on the formation, equilibrium, stability and confinement properties of these plasmas are presented. Although they have been known for about three decades, field reversed configurations have been studied intensively only in years. This renewed interest is due to the unusual fusion reactor potential of these high beta plasmas and also to their surprising macroscopic stability. At the present time, field reversed configurations appear to be completely free of gross instabilities and show relatively good confinement. The primary research goal for the near future is to retain these favourable properties in a less kinetic regime. Other important issues include the development of techniques for slow formation and stability, and a clearer assessment of the confinement scaling laws. (author). 416 refs, 37 figs, 8 tabs.

First Author: Vekshtein
Date: 90,1,1
Author List: G.E. Vekshtein
Citation: Rev. Plas. Physics **15** (Consultants Bureau, NY, 1990), (edited by Acad. B. B. Kadomtsev), translated from Russian by D. H. McNeill)
Title: Magnetothermal processes in dense plasmas
Abstract:

First Author: Vekshtein
Date: 75,1,1
Author List: V.E. Vekshtein, P.Z. Chebotaev, D.D. Ryutov
Citation: Sov. J. Plasma Phys.**1**(3) (Engl. Transl.), (May-June 1975), pp. 220-222
Title: Diffusion of heavy impurities in a dense, wall-confined plasma
Abstract: The theoretical analysis considers a single species of impurity ions with a specified charge. The mass of these ions is

assumed to be much larger than the mass of the heavy ions. Radial profiles of the plasma velocity, density, and temperature for the case of heating by a high-power relativistic beam are given. Impurity effects are shown.

First Author: Wurden
Date: 99,1,1
Author List: G.A. Wurden, K.F. Schoenberg, R.E. Siemon, M. Tuszewski, F.J. Wysocki, R.D. Milroy
Citation: Los Alamos National Laboratory report, LA-UR-99-4763 (Jan. 1999)
Title: Magnetized target fusion: a burning plasma in an imploded metal can
Abstract: We are designing a compact (r = 5 cm, *l*=30 cm), high density (n ~10^{17} - 10^{18} cm^{-3}) field-reversed configuration (FRC) target plasma for magnetized target fusion (MTF) experiments, using theta pinch formation techniques. The resulting FRC will then be translated into an aluminum liner for subsequent compression by implosion of the aluminum "can." The stored plasma energy will be modest (~ 7.5 kJ), with average plasma beta of 1, and an initial external magnetic field strength of 5.4 T. Numerical modelling using the MOQUI FRC code shows that the required plasma can be formed using conical theta pinch coils, and our existing 0.25 MJ Colt capacitor bank, and then translated in a few microseconds into the aluminum liner, where it is trapped by mirror fields. We hope to demonstrate 10-fold cylindrical compression of the plasma with an imploding liner, which should allow significant burn in the resulting (deuterium) fusion-grade plasma.