**DEVELOPMENT OF A HIGH RESOLUTION, HIGH SENSITIVITY
CYLINDRICAL CRYSTAL SPECTROMETER FOR LINE SHAPE DIAGNOSTICS OF
X-RAYS EMITTED FROM HOT PLASMAS**

**Progress Report
For the period 1 August 1977 - 31 July 1978
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ABSTRACT

This report outlines progress towards development of a high resolution, high throughput, curved crystal spectrometer suitable for line shape diagnostics of x-rays emitted from hot plasmas. The instrument is designed to interface with the MIT Tokamak (Alcator) with the initial aim of studying the prominent MoL lines which occur in the x-ray spectrum. However, it will have the versatility to function over an energy range of at least 1.5 keV to 7 keV allowing determination of temperature, charge state and density distributions for important impurity ions. The spectrometer employs a large, cylindrically bent crystal which focuses the dispersed x-rays along the cylinder axis where they are recorded by a position sensitive proportional counter. Thus, a wide energy range of the spectrum can be recorded simultaneously and sensitively from a short duration plasma. Computer control of data acquisition and analysis will allow real-time diagnostics.

The spectrometer has been assembled and a large PET crystal installed in it for observation of MoL lines. A five-wire anode, plastic windowed, proportional counter has been fabricated and is being tested. We are studying the use of mosaic crystals to improve the sensitivity-resolving power product of the spectrometer by over an order of magnitude. With the inclusion of this benefit, the cylindrical focusing geometry should achieve a resolution and sensitivity per resolution element which is equal to that of any currently used spectrometer design and which has the important advantage of displaying several hundred channels of the spectrum simultaneously.

1.0 INTRODUCTION

Among the most important parameters of fusion-type plasmas are the ion temperature and impurity ion charge state and density distributions. These parameters can be obtained reliably from a detailed analysis of the x-rays emitted by the plasma provided the spectrum is obtained with sufficient resolution and sensitivity.

Current¹ and planned thermonuclear fusion plasmas are characterized by electron densities of order 10^{14} cm^{-3} and central temperatures from 1 to above 5 keV. In these plasmas, light ions will be completely stripped but heavy impurity ions, such as Fe, Mo, W, Au from containers and limiters will be highly but incompletely stripped. It is anticipated^{2,3,4} that the density, charge state and distribution of such ions will be of crucial importance in affecting radiation losses, stability, and therefore feasibility of future Tokamak plasmas. Strong transitions in highly stripped ions will correspond to x-ray lines of several hundred to several thousand eV. In this region the spectrum can be dispersed by Bragg reflection from crystal planes with resolving powers of 0.5 to 2×10^4 , or better, sufficient to determine Doppler line widths. Among parameters obtainable are: ion temperature from Doppler broadened line widths; ion charge state and density distributions from relatively easily identifiable and calculable ion core transitions; electron densities from line ratios in He-triplets; and electron temperatures from accurate line ratios of H-like or Li-like $L\alpha$ vs $L\beta$ transitions.

In this report we discuss progress towards fabrication and testing of a high wavelength resolution Bragg crystal spectrometer suitable for line shape diagnostics of x-rays emitted from hot plasmas. Our instrument concept, which has been studied previously,^{5,6} but rarely applied, employs a cylindrically bent crystal to

intercept x-rays diverging from an entrance slit located on the axis of the cylinder and to focus reflected x-rays back onto that axis (Figure 1). From each portion of the crystal only x-rays satisfying the local Bragg condition, $\lambda = 2d \sin \Theta$ with d the diffraction lattice spacing, are reflected and the dispersed spectrum is recorded on a position sensitive detector. This concept is to be contrasted with the more common Johann⁷ design spectrometer in which divergent x-rays are intercepted at almost constant Bragg angle by the curved crystal and are refocused in the dispersion plane. In this case, the desired region of spectrum from a point source is scanned by changing the Bragg angle; hence the relative position of focal point, crystal and detector must be repeatedly adjusted.

Among advantages of the proposed instrument over a Johann design are:

1. Ability to record an extended segment of spectrum simultaneously;
2. A spectrum integration mode in which scanning is unnecessary;
3. A simple unambiguous spectrum readout;
4. Minimal loss of resolution for extended or off-axis sources;
5. High quality focusing perpendicular to the dispersion plane;
6. Potential of using the high integrated reflectivity of a mosaic crystal for increased sensitivity without loss of resolution (Section 2.3).

An ability to recall many channels of spectral information simultaneously is considered particularly important for reliable spectral interpretation and analysis. Much of the quantitative information in the spectra can only be obtained from precise ratios of line intensities. Capability to record simultaneously the He-like triplet or lines of H-like or Li-like series and satellite lines, will reduce

inaccuracies which could result when observing transient laboratory plasmas.

Parallel recording of all spectral features will aid in line identification and charge state analysis since the lines shift on millisecond time scales as the plasma evolves.

A cylindrically bent crystal provides excellent focusing for sources off-axis perpendicular to the dispersion plane. Thus, if the source is inertially (e.g., laser) confined fusion plasma (diameter $\sim 100\mu$), spatial information will be displayed perpendicular to the cylinder axis while the spectrum is displayed along the axis and both can be recorded with a suitable two-dimensional spatially resolving detector.

An analysis of spectrometer parameters and expected performance was presented in a previous progress report.⁸ The following sections outline progress and any changes in concept which have occurred in the last term.

2.0 PROGRESS

2.1 Spectrometer

Figure 2 is a schematic of the instrument. Only minor changes in design were made after submission of the last progress report. Design was reworked to provide the ability to interface with a variety of diagnostic ports on both Alcator A and C Tokomaks at MIT while at the same time having versatility for laboratory testing and use at other facilities. Another change involved aligning the detector normal to the incident x-rays, rather than along the focusing axis of the cylindrically bent crystal with the consequence of oblique incidence on the detector. We encountered considerable difficulty in arriving at a position sensitive proportional counter design which would achieve both necessary sensitivity and resolution given the constraint of oblique entry through the window and oblique absorption in the gas. If the detector is aligned to be normal to the incident rays, then the spectral lines will be slightly out of focus over part of the detector. However, analytic ray tracing shows the blurring to be less than 0.4 mm in the worst case. In this mode, any part of the spectrum can be brought into focus (line thickness < 0.1 mm) by scanning the detector towards or away from the crystal.

It was decided to isolate the spectrometer vacuum from the high vacuum of Alcator by providing the instrument with a thin Beryllium window, about 2.5 mm x 25 mm just in front of the entrance slit. Slits (typical 0.2 mm x 20 mm) are mounted in a slit holder and can be interchanged by removing the holder without interfering with the Alcator vacuum. The Be window and entrance slit are at the end of a tube, part of the spectrometer vacuum container, which is re-entrant into the diagnostic port of Alcator so that the slit is about 20 cm from the plasma center.

Restricted diagnostic access to the Alcator plasma limited the spectrometer field aperture to $\Delta\theta \times \alpha \approx 0.085 \times 0.085$ radians. This translates into an equivalent range of Bragg angles, $\Delta\theta$, on the crystal, and corresponds to an energy range of $\Delta E/E = \Delta\theta \cot \theta_0$ where θ_0 is the Bragg angle between an axial ray and the crystal ($\theta_0 = 34^\circ$ and $\Delta E \approx 300$ eV for MoL and PET crystal). The closest slit to crystal distance is also limited by the restricted access to approximately $L = 107$ cm. Therefore, to make full use of the Alcator diagnostic aperture, a crystal of length $C \approx L \Delta\theta / \sin \theta_0$ (≈ 16 cm for MoL and PET) is needed. A PET crystal of length 16.8 cm and height 9.6 cm, curved to a radius of 60 cm was chosen for observing the MoL lines. This crystal can reflect the total range of available Bragg angles onto the detector where they can be simultaneously recorded without the need to scan either the crystal or the detector. The range of energies (300 eV) is compatible with the expected range covered by MoL lines arising from various charge states in the plasma.

Bragg angle calculations for a number of crystals suitable for bending and for several lines of Tokamak interest (e.g., SiK α , MoL, ArK α , XeL, CrK α , FeK α) showed that for each line a suitable crystal could be found with θ_0 in the range 27° to 40° . Thus, in the interest of future versatility, we elected to design our spectrometer around a Bragg angle of 33° , but with sufficient flexibility to accommodate angles from 25° to 41° . Use of a larger Bragg angle (above 50°) has the advantage of allowing a larger input aperture (hence, more throughput), but the range of energies subtended by the crystal is reduced. Since access to these larger Bragg angles may also be needed, the crystal chamber (Figure 2) has two ports to accommodate central Bragg angles of 33° and 50° .

The crystal is bonded with a space rated bonding agent to an aluminum block with a machined cylindrical surface of appropriate radius of curvature. The carriage allows adjustment of the Bragg angle, crystal vertical position, horizontal position, and tilt. A remotely translatable mount is provided for the detector allowing it to be moved towards or away from the crystal. The detector chamber itself is mounted so that it can rotate up to $\pm 16^\circ$ in the horizontal plane about the crystal vertical rotation axis. Vacuum coupling is by a convoluted bellows of 10" I.D., which diameter is needed to accommodate the limiting Bragg reflected rays from the crystal to the detector.

All spectrometer parts have been fabricated out of high vacuum compatible materials. Only one part, the large vacuum bellows to connect the crystal chamber to the detector chamber has been delayed by manufacturing difficulties. Aside from this, assembly is complete and is shown in Figure 3. A turbopump will provide fast non-bake cycling to required base pressure. The spectrometer is mounted on a stand convenient for laboratory testing, but an additional platform must be provided to co-align with the Alcator viewing axis which is 2.5 m from the floor.

2.2 Position Sensitive Detector

A detector area of approximately 30 cm x 2 cm with a position resolution of about 0.2 mm along the length is optimum for high resolution readout of the dispersed spectrum. After evaluating CCD arrays, linear silicon diode arrays and proportional counters in this context, a position sensitive proportional counter was settled on.

From spectra of x-rays recorded on Alcator with a Si(Li) detector, it was

inferred that count rates up to 100 kHz might be recorded in MoL lines with the cylindrical crystal spectrometer. Such count rates might be beyond the capability of the originally planned 20 cm x 1 cm Be windowed, high resistance anode, proportional counter. An investigation was made of high resolution multiwire counters and readouts. It was during this process, that it was decided to orient the detector normal to the incident x-rays rather than along the cylinder axis of the bent crystal. This practice causes a slight defocusing (line width ≈ 0.4 mm) over portions of the counter, but it eliminates the loss of position resolution and sensitivity associated with oblique incidence on the counter. A detector area of 27 cm x 3 cm allows recording of all x-rays passing through a 2 cm high entrance slit into the 0.085 x 0.085 radius field aperture without necessity to scan the detector.

To fit these needs a five-wire plastic windowed, flow proportional counter was designed and fabricated. The five wires provide the versatility to operate the detector as single wire counter, as multi-anode counter with two dimensional sensitivity, or as three effectively separate counters in parallel (in which case two of the wires are used as partitioning ground planes). The counter has a replaceable plastic window supported by a 80% transmission tungsten mesh oriented so the mesh grid is at 45° to the spectrallines and hence effects all spectrallines equally. The counter is pictured in Figure 3.

Initial testing of the counter using commercial preamps and charge division position sensing electronics resulted in a resolution of ~ 1 mm. The limitation being noise in the preamps. New lower noise preamps have been assembled after the design of Kopp and Williams.⁹ Using these preamps and the timing mode of Borkowski and Kopp,¹⁰ we expect to achieve a position sensing resolution of < 0.4 mm.

2.3 Mosaic Crystal Concept

Recently, we have realized that there exists a potential to greatly improve the sensitivity-resolving power product for the spectrometer. With the focusing geometry of the cylindrical crystal, it is possible to exploit the increased reflection window of a mosaic crystal without a corresponding loss of wavelength resolution at the detector. We plan to test this feature using mosaic crystals of graphite and possibly lithium hydride or tungsten.

The probability $R(\theta, \lambda)$ of reflecting an x-ray of wavelength λ incident at angle θ on a crystal is sharply peaked about the Bragg angle $\theta_\lambda = \sin^{-1}(\lambda/2d)$. For a perfect crystal the full width at half maximum of this function is the single crystal diffraction width W_c . If the crystal is a mosaic of single crystal domains of appropriate microscopic size, each x-ray will have an opportunity to pass through many domains with slightly different orientation before being absorbed or reflected. In this case, the "reflection window" or "half width" of the probability $R(\theta, \lambda)$ for given λ is the mosaic spread, W_m , and can be 10 or 100 times W_c .

Figure 4 is a representation of this concept in the context of the cylindrical crystal geometry. A ray reflected at the Bragg angle $\theta = \theta_\lambda$ from a mosaic oriented parallel to the crystal surface will return to the crystal axis at a distance

$$x = 2 \rho \cot \theta \quad (1)$$

However, a ray of the same wavelength can also reflect from a mosaic at angle δ to the crystal surface, and will be returned to the axis at distance

$$x = \rho \cot(\theta + \delta) + \rho \cot(\theta - \delta)$$

$$\approx 2\rho \cot\theta (1 + \delta^2/\sin^2\theta) \quad (2)$$

which differs from the $\delta = 0$ position by

$$\Delta x = 2\rho \cot\theta \cdot \delta^2/\sin^2\theta \quad (3)$$

In a direction independent of the sign of δ . The resolution element on the detector determined by the single crystal diffraction width, W_c , is, by differentiation of Equation 1:

$$\delta x = 2\rho W_c / \sin^2\theta \quad (4)$$

Using the average value of Δx as a measure of the resolution loss due to a mosaic crystal, we find that the mosaic effect, Δx , is equal to the single crystal limited resolution, δx , when

$$W_m = \sqrt{W_c \tan\theta} = W_c \sqrt{S} = \tan\theta / \sqrt{S} \quad (5)$$

where $S = E/\delta E = \tan\theta/W_c$ is the single crystal resolving power. This means that $W_m \gg W_c$ before significant resolution loss results from the mosaic spread and in fact for $S \sim 10^4$, $W_m \sim 0.5$.

Efficiency of the spectrometer, on the other hand, is determined by the integrated reflectivity

$$R_c = \int_0^\pi R(\theta, \lambda) d\theta \quad (6)$$

which can be much greater for a mosaic crystal than a single crystal, roughly by the factor W_m / W_c .

Certain crystals can be prepared with domain structure accomodating narrow diffraction width and high integrated reflectivity. Two examples are graphite (suitable for MoL), and lithium hydride (suitable for FeK lines) which have theoretical single crystal resolving powers of ≈ 5000 (2-5 keV) and ≈ 0.5 to 1×10^5 (> 3.5 keV) respectively.¹¹ Tolerable mosaic spreads are thus 0.86° for graphite at 2.5 keV and 0.4° for lithium hydride at 6.5 keV, which values are typical of commercially available samples. Integrated reflectivities for ideal mosaic crystals are 18×10^{-4} for graphite and 35×10^{-4} for LiH, and thus a factor of 10 or more higher than typical single crystals which might be chosen to reflect these energies.

We expect that with inclusion of the benefits discussed here the cylindrical focusing spectrometer geometry will achieve a resolution and sensitivity per resolution element equal to any current spectrometer design with the important advantage of displaying several hundred channels of spectrum simultaneously.

2.4 Molybdenum Spectra from Alcator

A flat crystal monochromator has been installed on the Alcator tokamak in order to study the L line of molybdenum introduced into the plasma by interaction with the limiter.¹² The spectrometer was employed with a graphite crystal and proportional counter detector, and the flux was monitored as a function of time during a shot. Temperatures in Alcator are typically ≤ 1 keV such that most of the molybdenum in the center of the machine is in a charge state between Mo^{24+} and Mo^{32+} . The actual amount of stripping of the molybdenum (and hence the shift

in energy of the line) depends not only on the electron temperature but on plasmas density and shot duration (confinement time). Figure 5 shows spectra taken under two completely different discharge conditions. The shift of the line as the current and density are raised indicates more highly stripped Mo (the $M^{O+}L$ line comes at 2.29 keV). A measured line width in the high density case of 55 eV, compared with an instrument resolution of 20 eV, indicate presence of structure; there appears to be more structure in the low density case. Thus contribution from many charge states is apparent, probably due to the chordal integration of flux across the temperature profile. The measured widths are a substantial improvement over that achieved with previously used solid state detectors which produced instrument broadened lines of 400 eV. Spectra obtained with a high resolution crystal which can resolve the emissions from various charge states will provide information on ion charge states and hence density and temperature. Absolute fluxes of Molybdenum radiation are of order 10^{11} photons/sec-cm² ster and the central Mo density is estimated to be $\sim 10^9$ cm⁻³.

3.0 EXPECTED PERFORMANCE

Table 1 lists parameters and expected performance of the spectrometer, as constructed, for observing line radiation from the Alcator A plasma. The total resolution element at the detector combines the crystal diffraction width and slit width broadening in quadrature and adds the slit height broadening ($d_t \approx \sqrt{2} w + \Delta x_H$). The optimum detector pixel size which allows proper sampling of the line is $d_p \approx d_t/2$. Energy resolution is calculated from d_t and therefore includes effects of geometrical broadening. Plasma flux per cm^3 , I , is converted to a line count per detector pixel:

$$N = I b w H \frac{\alpha R_c}{4\pi} \epsilon \tau \frac{d_p}{d_t}$$

where the symbols are as defined in Table 1. A conservative value for I has been used compared with observed fluxes from Alcator (Section 2.4).

For observing MoL lines, the performance of a mosaic graphite crystal is compared with the PET crystal to be used. For graphite we have assumed a resolving power approaching the theoretical value¹¹ of $S = 5000$ and used a typical value for the integrated reflectivity of $R_c = 1 \times 10^{-3}$. Thus, graphite is expected to achieve a similar resolution to PET but allow a factor of twenty improvement in sensitivity. The simultaneously observable energy range is reduced to 200 eV because of larger Bragg angle.

We have suggested LiF for observing the FeK line because of its high integrated reflectivity, $R_c = 6 \times 10^{-4}$. Achievable resolution is better than 1 eV which is sufficient to deconvolute FeK Doppler line profiles. A LiH crystal may achieve

higher integrated reflectivity and resolving power.¹¹ However, to gain the benefits of high crystal resolving power a detector resolution of less than 0.2 mm, preferably 0.1 mm, is needed. For a detector (PSPC) wire length of 30 cm, this requires a spatial resolution of 1/3000 which is probably beyond the capability of our present counter.

Note, from the table, that the spectrometer simultaneously displays 200 to 500 energy resolved channels covering an energy range of 200 to 500 eV.

TABLE 1

SPECTROMETER PERFORMANCE

Radiation			MoL	MoL	FeK α
Energy	E	eV	2500	2500	6550
Crystal Type			PET	Graphite	LiF
Plane Spacing	2d	cm	8.742	6.708	4.027
Crystal Resolving Power	S	$\times 10^4$	0.4	0.4	1
Integrated Reflectivity	R _c	10^{-3} rad	0.14	1	0.6
Slit to Crystal Distance	L	cm	107	107	107
Field Aperture	α	rad	0.085	0.085	0.085
Slit Height	H	cm	2	2	2
Bragg Angle	θ_0	deg	34.0	47.4	27.9
Crystal Curvature Radius	ρ	cm	60	79	50
Crystal Length	C	cm	16.2	12.4	10
Crystal Limited Energy Range	ΔE_c	eV	320	200	450
Crystal Matched Slit Width	w	mm	0.36	0.58	0.11
Slit Height Broadening	Δx_H	mm	0.11	0.14	0.11
Resolution Element at Detector	d _t	mm	0.6	0.8	0.2
Optimum Detector Pixel Size	d _p	mm	0.3	0.4	0.1
Relative Energy Resolution	dE/E	$\times 10^{-4}$	4	4	1.8
Absolute Energy Resolution	dE	eV	1	1	1
Number of Simultaneous Channels	$\Delta E_c/dE$		320	200	450 _{sp}
Detector Efficiency	ϵ		0.7	0.7	0.9
Plasma Flux	I	cm ⁻³ s ⁻¹	10 ¹⁰	10 ¹⁰	10 ¹⁰
Plasma Thickness	b	cm	5	5	5
Plasma Duration	τ	s ⁻¹	0.1	0.1	0.1
Expected Line Count Per Pixel	N	photons	70	1400	200

4.0 STATEMENT OF WORK

4.1 Current Phase

During the current term (1 August 1977 to 15 April 1978) the following tasks have been completed:

1. A 16.8 cm x 9.6 cm PET crystal, bonded to a cylindrical surface is inhouse.
2. A position sensitive proportional counter (PSPC) has been designed, fabricated, and partially tested.
3. Signal processing electronics for the above counter has been identified and is being fabricated.
4. The spectrometer vacuum system, mechanisms, and support structure were designed and fabricated.
5. The spectrometer and vacuum hardware were assembled.
6. A highly collimated x-ray source/test bench suitable for measuring the resolution of the PSPC was built and tested.
7. A contract was let for a portable, self-contained, Mo anode, micro-focus x-ray tube and power supply.
8. MoL spectra showing presence of various charge states were obtained from Alcator A with a flat crystal spectrometer.
9. A paper on the spectrometer design has been drafted.¹³
10. A paper entitled, "High Resolution X-ray Spectrometer for Line Profile Analysis" was presented at the APS High Temperature Plasma Diagnostics Conference.

11. Theory, focusing properties, and expected performance of the spectrometer have been analyzed and compared with other designs. An expected increase in performance associated with mosaic crystals has been analyzed.

4.2 Remainder of Current Phase

Before the end of the current term (31 July 1978) we will have completed the following objectives in compliance with contract requirements:

1. Complete testing of the position sensitive proportional counter.
2. Test and calibrate the spectrometer.
3. Begin interface of the spectrometer with Alcator A or C.

4.3 Renewal Phase

During a renewal term our major goal will be to apply the developed spectrometer to obtaining high quality spectra of MoL radiation from Alcator. Mo is an impurity ion arising from the Mo limiter and the charge states and distribution of this ion may be of crucial importance in effecting radiation loss and stability of the plasma. The measurements will also provide a diagnostic on ion and electron density and temperature.

Thus, during the renewal term (1 August 1977 to 31 July 1978) we will have the following objectives:

1. Complete interface of the spectrometer with Alcator C.
2. Interface the spectrometer with a computer controlled data acquisition and analysis system.
3. Test the spectrometer on Alcator as an x-ray diagnostic tool.

4. Analyze and report diagnostic results and physics obtained.
5. Extend the spectroscopy to higher resolution and/or to other regions of the spectrum.
6. Begin testing of mosaic crystals for high sensitivity and resolution.

The Principal Investigator has devoted 15% of his time and the CoInvestigator 100% of his time during the current term. These levels will continue for the remainder of this term and for a future term.

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FIGURE CAPTIONS

Fig. 1 Cylindrical crystal focusing concept.

Fig. 2 Schematic of spectrometer design.

1. Crystal	17. Adaptor
2. Crystal Chamber	18. X-ray Source
3. Detector	19. Vacuum Gate Valve
4. Detector Chamber	20. Alcator Adaptor
5. Bellows	21. Mechanical Feed Through
6. Rotary Mechanical Feed Through	22. Slit Movement Linkage
7. Isolation Bellows	23. Slit Plate
8. Vacuum Pump Adaptor	24. Detector Movement
9. Turbo-pump	25. Crystal Movement
10. Vent and TC Gauge	26. Detector Chamber Carriage
11. Vacuum Valve	27. Electrical Feed Through
12. Vent and TC Gauge	28. Stand
13. Trap	29. Bellows Support
14. Mechanical Vacuum Pump	30. Alcator Source
15. X-ray Source Adaptor Tube	31. Alcator Interface
16. Slit Plate	

Fig. 3 Spectrometer and test bench assemblies.

- a) Spectrometer assembly with turbopumped crystal chamber and large detector chamber with position sensitive proportional counter (PSPC) in place. A large bellows to connect the two chambers is removed.
- b) Crystal chamber with various horizontal ports for entrance of x-rays and with six way adjustable crystal holder exposed (crystal not in).
- c) Detector chamber with plastic windowed PSPC and translation mechanism exposed.
- d) Turbo pumped x-ray test bench providing highly collimated x-ray beams.

Fig. 4 X-ray diffraction by a mosaic crystal. The single crystal diffraction width W_c is illustrated for only one crystal block. Rays diffracted by other crystal blocks at angles $\pm \delta$ ($\gg W_c$) from the untilted block are returned to almost the same position on the axis (section 2.3). Angles are greatly exaggerated.

Fig. 5 Molybdenum L lines from Alcator A obtained with a scanning flat crystal spectrometer with resolution of 20 eV. High resolution would resolve lines from the several charge states contributing to the broad peaks measured.

Figure 1

Figure 2

Figure 3a

Figure 3b

Figure 3c

Figure 3d

Figure 4

Figure 5

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INSTRUCTIONS

Who uses this Form: ERDA contract administrators will designate the ERDA contractors who are to use this Form. Generally speaking, it will be used by educational institutions and other "not for profit" institutions. ERDA National Laboratories and other major contractors will generally use the longer Form ERDA-426.

When to use this Form: ERDA contractors are required under their contracts to transmit specified types of documents to the ERDA. Some, but not all, of these are transmitted by ERDA contract administrators to ERDA's Technical Information Center (TIC) and may be incorporated into ERDA's technical information documentation system. Types of documents which will be transmitted to TIC are identified in instructions which the contractor receives from his contract administrator. Each such document is to be accompanied by one copy of this transmittal Form recommending to TIC appropriate announcement and distribution of the document. Documents which the contractor may be required to submit to the ERDA under his contract but which are not of the type to be transmitted to TIC, e.g., contract proposals, should not be accompanied by a copy of this transmittal Form.

Where to send this Form: Send the document and the attached Form ERDA-427 to the ERDA contract administrator for transmittal to TIC unless the ERDA contract administrator specifies otherwise.

Item instructions:

- Item 1. The first element in the number shall be an ERDA-approved code. This may be a code which is unique to the contractor, e.g., MIT, or it may be the code of the ERDA operations office, i.e., COO, ORO, IDO, SRO, SAN, ALO, RLO, NVO. The contract administrator will specify the code which is to be used.

The code shall be followed by a sequential number, or by a contract number plus a sequential number, as follows: (a) Contractors with unique codes may complete the report number by adding a sequential number to the code, e.g., MIT-101, MIT-102, etc.; or they may add the identifying portion of the contract number and a sequential number, e.g., ABC-2105-1, ABC-2105-2, etc.; (b) Contractors using the

operations office code shall complete the report number by adding the identifying portion of the contract number and a sequential number, e.g., COO-2200-1, COO-2200-2, etc. Subcontractor reports shall be identified with the code used by the prime contractor.

- Item 2. Give title exactly as on the document itself.
- Item 3. If box c is checked, indicate type of item being sent, e.g., thesis, translation, etc.
- Item 4. The "normal announcement and distribution procedures" for unclassified documents may include abstracting in "Nuclear Science Abstracts" (NSA); and distribution to appropriate TID-4500 ("Standard Distribution of Unclassified Scientific and Technical Reports") addressees, to libraries which through purchase of microfiche maintain collections of ERDA reports, and to the National Technical Information Service (NTIS) for sale to the public. Check 4b if there is need for limiting announcement and distribution procedures described above.
- Item 5. If 4b is checked, give reason for recommending announcement or distribution restrictions, e.g., "preliminary information," "prepared primarily for internal use," etc.
- Item 6. Enter name of person to whom inquiries concerning the recommendations on this Form may be addressed.
- Item 7. ERDA contract administrator may use this space to show concurrence or nonconcurrence with the recommendation in item 4 and to make other recommendations.
- Item 8. ERDA contract administrators may use this space or representative should check a, b, or c, and forward this Form and the document to:

USERDA-TIC
P.O. Box 62
Oak Ridge, TN 37830