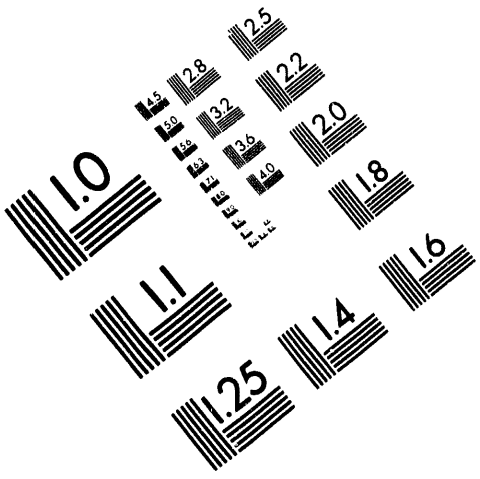

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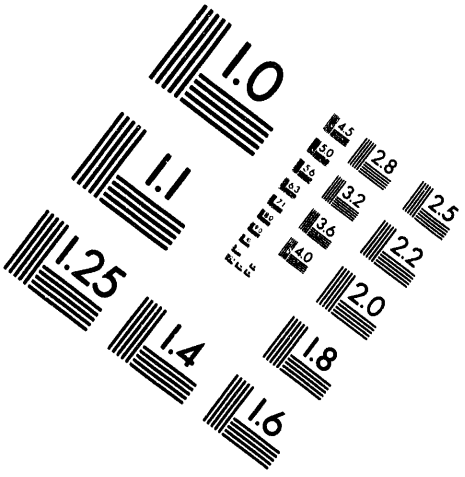

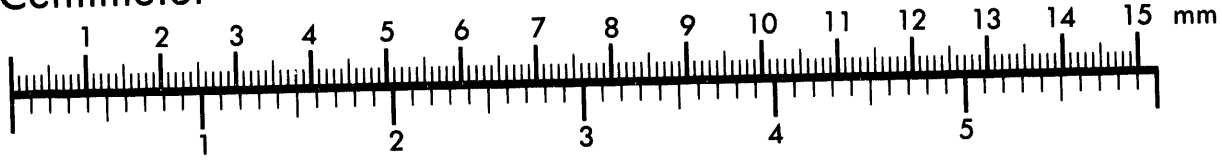

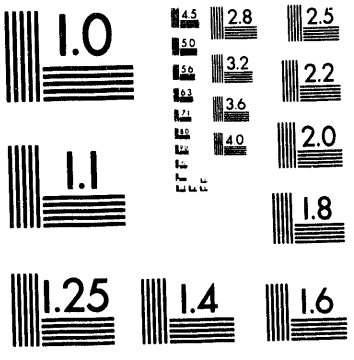

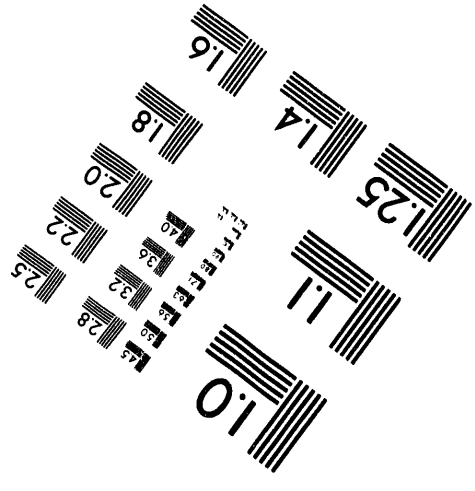

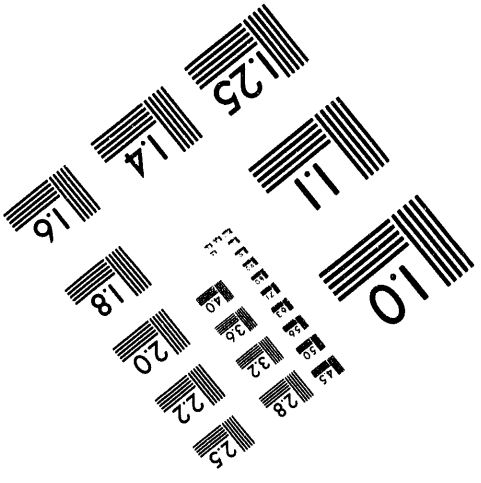

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DESIGN OF PRODUCTION TEST IP-468-A-FP
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M. A. CLINTON
and
W. H. HODGSON

January 28, 1962

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SYNOPSIS

The alpha phase extrusion of dingot bars to rods for core blank heat treatment at MCW offers a three-fold incentive, including: 1) establishment of an independent alternate source of uranium cores, 2) a slight cost improvement of MCW extrusion over FMPC rolling of dingot and 3) potential improvement in core quality and performance. The purpose of this test is two-fold: 1) evaluate gross dimensional stability and 2) evaluate the gross irradiation performance of alpha phase extruded dingot uranium fuel cores. The ultimate objective of this test program is to establish an independent alternate uranium fuel core feed source.

The irradiation test program will be conducted at B-Reactor and will consist of the following three phases:

Phase I - Ten measured monitor charges containing alpha-phase rod-extruded dingot uranium fuel cores will be irradiated in an old reactor: four to 400 MWD/T, four to 800 MWD/T, and two to 1000 MWD/T. The fuel geometry will be OIIIN non-bumpered.

Phase II - Concurrently with the 10 Phase I monitor columns, about 800 OIIIN elements containing alpha-phase rod-extruded dingot fuel cores will be lot charged for irradiation to normal variable goal. Following favorable post-irradiation examination results from the four Phase I monitor columns discharged at 400 MWD/T, up to 25 tons per month of OIIIN alpha extruded dingot cores will be irradiated to normal variable goal for seven months. If no unusual experience occurs, the maximum quantity may be increased to 90 tons/month under separate authorization. Performance of the lot charged material will be monitored under authorization of the Quality Certification Program.

Phase III (Not authorized by this test) - As soon as details are completed and material is fabricated at the feed sites, HAPO will receive uranium fuel cores for a test which will be statistically designed to evaluate alpha extrusion methods versus rolling. This evaluation may require up to 27 monitor tubes and will be carried out independently from Phases I and II. Details on this phase of the program will be covered in a supplement to this test.

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INTRODUCTION

Currently, all regular production HAPO fuel cores are rolled into rods at Fernald, consequently, HAPO is dependent upon one vendor for a critical raw material. This arrangement does not appear to be consistent with good business practice, and it is desirable to have an alternate fuel source tested and available. Mallinckrodt's Weldon Spring plant contains an extrusion press for gamma bar extrusion and a logical sequence of operations should permit further extrusion in the alpha phase to the desired rod size. As alpha extrusion is also purported to be a slightly cheaper fabrication process than rolling, it appears appropriate to carry out a testing program to evaluate the alpha extruded fuel core as an alternate to the rolled fuel core.

OBJECTIVE

The specific objectives of this test are to evaluate: 1) the gross dimensional stability and 2) the gross irradiation performance of alpha extruded dingot uranium fuel cores. The ultimate objective of this test program being to establish an independent alternate uranium fuel core feed source.

TEST SUMMARY

This irradiation test program will be conducted at B-Reactor and will consist of the following three phases:

Phase I - Ten (10) measured monitor charges containing alpha rod extruded dingot uranium fuel cores will be irradiated in incremental steps up to 1000 MWD/T goal exposure. Fuel geometry will be the OIIIN non-bumpered.

Phase II - Concurrently, up to 3 tons of OIIIN alpha extruded dingot uranium fuel cores will be charged for irradiation to normal variable goal. Following a three month delay, up to 25 tons of OIIIN alpha rod extruded dingot uranium cores will be fabricated each month for seven months and irradiated to a normal variable goal. If no unusual experience occurs, the maximum quantity may be increased to 90 tons per month under separate authorization. Performance of lot charged material will be monitored under the authorization of the Quality Certification Program.(1,2)

---

(1) HW-58271, "Production Test IP-216-A, "Evaluation of Performance of Normal Production I&E Fuel Elements", R. E. Hall and R. R. Bloomstrand, 1/6/59.

(2) HW-59271 A, "Supplement A - PT-IP-216-A, Evaluation of Performance of Normal Production I&E Fuel Elements", M. A. Clinton, 8/2/60.

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Phase III - As soon as details are complete and material is fabricated at feed sites, HAPO will receive uranium fuel cores for a test which has been statistically designed to evaluate alpha extrusion methods versus rolling. This evaluation may require up to 27 monitor tubes. The suggested test outline for this phase of the program is in Appendix B of this report. Final details will be covered in a supplement to this test.

BASIS AND JUSTIFICATION

The alpha-phase extrusion program was originated and developed under the direction of the Working Committee of the Fuel Element Development Committee to produce fuel cores more economically than by rolling. The incentives for testing extruded fuel cores have been discussed in references three through eight. Justification includes: 1) establishment of an independent alternate uranium source, 2) reduced feed material costs, and 3) improved uranium quality and performance.

The test program to evaluate alpha extruded fuel cores should be continued since it is desirable to have an alternate core fabrication process tested and available. There is some value to developing an alternate fabrication route and site in the event of some disaster to the Fernald rolling mill. Since Mallinckrodt's Weldon Spring plant contains an extrusion press for gamma extrusion of the 7 inch dingot bars, a logical sequence of operations should permit further extrusion (alpha-phase) of the 7 inch diameter bars to one and one-half inch diameter rods for core blanks.

---

(3) Letter, A. T. Gifford to L. L. German, "Extruded Fuel Cores", 8/13/59, (CONFIDENTIAL-UNDOCUMENTED).

(4) HW-61733, "Anticipated Reductions in Uranium Deliveries", A. B. Greninger, 8/31/59, (SECRET).

(5) HW-60962 A, "Design of Production Test IP-269-A-FP, "Evaluation of the Stability of Cores from Extruded Tubes", W. H. Hodgson and R. E. Hall, 9/24/59, (SECRET).

(6) Letter, R. L. Dickeman to A. T. Gifford, "Program for Evaluation of Alpha Extruded Fuel Cores", 8/15/61, (UNDOCUMENTED).

(7) Letter, E. A. Weakley to M. A. Clinton, "Justification for Alpha Rod Extruded Dingot", 12/1/61, (UNCLASSIFIED).

(8) Letter, J. H. Brown to J. T. Stringer, "Testing and Acceptance of (1) Alpha Extruded Dingot and (2) Oil Quenched Uranium Cores", 12/6/61, (UNCLASSIFIED)

Several studies have indicated a reduction of the direct cost per pound of uranium produced may be obtained by alpha phase extrusion of dingot at MCW compared to cost per pound currently experienced with rolled dingot cores. These cost improvements have ranged from 17 cents(9) per pound to the more recent 2 cents(10) per pound of finished cores. The latter would be a savings of $60,000 to $80,000 per year at current dingot usage rates.

Extrusion should produce sounder metal. The process is less susceptible to the production of laps, seams, folds, and other defects that are characteristic of a rolling mill. On the other hand, it must be acknowledged that extrusion defects can occur in the extrusion phase.

Previous small-scale testing of solid fuel cores(11) has indicated only a small difference in fuel performance would be expected and the production risk associated with the test program outlined in this report appears correspondingly small. At the same time, it must also be stated that the quantities of test material, both in the measured charges and in the lot charging of 25 tons per month will permit determination of only the gross differences between rolled and extruded material, should they exist.

TEST DETAILS

A. Fuel Elements

1. Cores

Cores for Phases I and II of this program will be OIIIN geometry obtained from alpha-phase extruded dingot rods. Fabrication of the cores will be as follows:

a) Gamma phase extrusion of dingot to 7 inch diameter bars.
b) Alpha phase extrusion of dingot bar to 1-1/2 inch diameter rods.
c) Machine rods into core blanks, drill I.D.
d) Heat treat in chloride salt bath at 1346°F for 12 minutes, transfer time to quench - 43 seconds, water (brine) quench at 130°F.
e) Drill cores.
f) Outgas drilled core blanks at 950°F to reduce hydrogen content to less than 1 ppm total hydrogen content for cores from dingots initially containing less than 5 ppm (WZ lots).(12)

---

(9) GEH-25500, "The Dingot Process - A Status Report as of May 10, 1961", Mallinckrodt Chemical Works.

(10) HW-72669, "Review of Economic Incentives for MCW Alpha Extrusion of HGE-I&E Fuel Cores", D. R. Stenquist, 2/19/62.

(11) HW-48918 D, "Final Report on Evaluation of Alpha Extruded Solid Uranium Fuel Elements, Production Test IP-58-A-87-FP", W. H. Hodgson and R. E. Olson, November 15, 1958, (SECRET)

(12) About 15% of the cores may be fabricated from low hydrogen non-outgassed dingot metal (BZ lots).

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g) Machine cores to final dimensions.

The dingot, rod and core position numbers will be stamped on each core for Phase I.

Phase III of this program is a statistically designed test to compare cores fabricated by alpha extrusion methods versus rolling. Details of a proposed test are in the appendix. Final details of this phase will be presented in a supplement to this test.

2. Components

Jacketing components will be OIIIN geometry X-8001 aluminum alloy supplied by Alcoa.

3. Assembly

All fuel elements will be fabricated by the "F" process.(13)

4. Quality

All fuel elements shall pass the normal process specifications in effect at the time this material is prepared. Provisional specifications on bumper rails and O.D. gages will be provided.

5. Quantity

Phase I - Approximately 370 acceptable fuel elements fabricated with alpha extruded cores are required for 10 measured charges.

Phase II - Currently, 800 OIIIN outgassed dingot fuel elements from lot WZ002A having alpha extruded cores are available for lot charging. Based on accumulated experience, up to 175 tons of additional alpha extruded cores will be charged at a 25 ton per month rate. Further charging rate increases to 90 tons per month, if desired, will require separate authorization. Quality Certification monitor charges will be required for each lot of lot charged material.

Phase III - All columns under this phase will be measured monitor columns and tentatively there are 27 columns in the proposed test design or outlined in the appendix to this report.

6. Material Handling

Extruded cores will follow normal process channels. Extruded fuel may be mixed with standard fuels in reprocess and recovered lots. Core identity will be retained on virgin and reprocess lots; however, no attempt will be made to identify recovered cores.

---

(13) HW-47029, "Process Specification, Fuel Element Manufacturing Processes", Fuels Preparation Department.

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PRE-IRRADIATION MEASUREMENT AND TESTING

All fuel cores and jacketed elements for Phase I of this test will be measured and tested as indicated below:

TEST	PURPOSE	CORE STATUS	DATA
1. UT-2	Grain Size Measure	Bare	Record Data
2. SORT	Grain Orientation Measure	Bare	Record Data
3. Surface Test & Inspection	Core Surface Quality	Bare	Record Data
4. a. Length	Core Dimensions	*Bare & Canned	Record Data
b. Outer Diameter (3)	Core Dimensions	*Bare & Canned	Record Data
c. Inner Diameter (2)	Core Dimensions	*Bare & Canned	Record Data
d. Warp - Ellipticity	Core Dimensions	*Bare & Canned	Record Data
5. Weight ODD 1-23	Corrosion	Canned	Record Data
6. Total Bond Count (Internal & External)	Braze Porosity	Canned	Record Data
7. Metallography	Grain Structure	Bare	Photomicrographs

* A sample of 50 - 60 bare cores received these measurements. A history of their locations is incorporated in the appendix of this report.

8. Identity and position of measured fuel elements will be recorded by a series and position number stamped on the base of each fuel element.

9. Column Make-Up

FPD will make up the monitor charges and will place these in specially identified shipping pallets in charging order.

IRRADIATION

A. Charging

All monitor columns will be serially numbered and will be charged in numerical order with piece number one downstream. Each column shall have the fuel identification number (series and/or lot number) recorded opposite the tube number on the front face sequence sheet. Charging of the Phase I material will be followed by a representative of

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Research and Engineering. Monitor columns charged under Phase II will receive the same handling treatment as columns charged under authorization of PT-IP-216 - Quality Certification Production Test.

Monitor columns for Phase I will be charged into locations which will provide similar irradiation conditions for all tubes. Locations will be selected by the assigned Process Engineer and Physicist with the concurrence of the test author and will be selected from those available as a result of scheduled discharge.

Phase II lot-charged material will be treated as if it were normal production. Aside from 800 pieces which are to be charged concurrently with the 10 Phase I charges, the lot charged material will not be charged until after four of the Phase I monitor charges (discharged at 1/2 goal) have been examined at the 105-C Metal Examination Facility (MEF).

B. Goal Exposure

Phase I

1) Four columns will be discharged at 400 MWD/T
2) Four " " " " " 800 MWD/T
3) Two " " " " " 1000 MWD/T

Phase II

Discharge of the lot-charged material will be determined by the goal exposure plan in use for normal production material of the same geometry and charged during the same period.

Exposure Changes

Goal exposure changes may be made by request from the test author with the concurrence of reactor processing manager.

C. Discharge

All monitor columns charged under Phase I may be discharged prior to reaching goal discharge exposures after two failures have occurred providing all columns can be specially picked up. If a failure occurrs in the lot charged material, the material will be treated as if it were normal production fuel.

D. Operating Conditions and Limits

The operating limits and conditions which are in use for normal production OIIIN fuel will apply toward this material.

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GENERAL

A. Schedule

Fuel elements for Phase I have been fabricated, tested, and measured, and are ready for reactor charging. Approximately 800 pieces of lot charged material (identified as WZ002A) are also ready for charging concurrently. Reactor loading of the above material is requested for the first outage following approval of this test. A test schedule is appended.

B. Duration

Irradiation of the Phase I material will require about five months. Phase II will extend over a period of fourteen months. The authorization for this test will terminate on December 1, 1963.

C. Post-Irradiation Examinations

All pre-measured fuel elements will:

1) be weaseled and visually inspected for surface conditions,
2) be measured for length, warp, and diameter changes (OD_1, OD_2, OD_3, ID_5, and ID_7),
3) have weight recorded (odd pieces 1 through 23),
4) be bond tested for total count if equipment is available. Selected pieces may be set aside for stripping and bare core measurements depending on either the preliminary visual examination results or a later analysis of the measured data. Also, selected elements may be sent to Radiometallurgy for destructive examinations.

TEST AUDIT

Notebook HW-72541 will be utilized to store pre-irradiation data pertinent to this test. The appendix to this report contains a list of items to be recorded in the notebook. Any incidents which occur, whether they seem important or not, must be recorded in the notebook.

HAZARDS

No unusual hazards are associated with this test.

M. A. Clinton

M. A. Clinton, Engineer
Research and Engineering
IRRADIATION PROCESSING DEPARTMENT

W. H. Hodgson

W. H. Hodgson, Engineer
Fuels Engineering
FUELS PREPARATION DEPARTMENT

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APPENDIX A

Data to be recorded in Production Test Notebook:

I. Fuel Element Core

A. Lot Numbers

1. Dingot Numbers and Chemical Analysis
2. Unusual Treatment

II. Aluminum Components

A. Lot Numbers

1. Alloy Type
2. Unusual Treatment

B. Finished Dimensions (Pre-Assembly)

C. Pre-Assembly Treatment (Cutoff, Sizing, Inspection, Nickel Plating - vendor, thickness, etc.)

III. Pre-Assembly Treatment of Cores (All Pieces for Measured Columns)

A. UT-2 Record Data

B. SORT Record Data

C. Surface Tester-Record Data

D. Measure Length, OD, ID, and Warp of Cores

IV. Assembly Process

A. Process Used

B. Brief Explanation of Each Process

C. Attendant Conditions

D. Total Bond Count (All Pieces for Measured Columns)

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V. Post-Assembly Treatment

A. Support Attachment

B. Nickel Plating

C. Autoclaving

D. Other Treatment

E. Inspection

VI. Pre-Irradiation Examination and Measurements (All Pieces for Measured (Monitor) columns)

A. Dimensions, Length, OD, ID

B. Warp

C. Weight (ODD 1-23)

VII. Irradiation

A. Coolant Temperature

1. Inlet

2. Outlet

B. Panellit and Crossheader Pressures

C. Number of Shutdowns (Controlled and Scram)

D. Other

VIII. Post-Irradiation Examination

A. Visual

B. Warp (And Other Profilometer Data), Weight

C. Bond Count - If Possible

IX. Log - Running account with dates recording the progress of the PT, unusual incidents (such as slight change in process during assembly), and other deviations whether or not they seem pertinent at the time of occurrence.

APPENDIX B

REVISED TEST DESIGN: ROLLING VS. EXTRUSION(14)

This test will be strictly an evaluation of fabrication routes. In interpreting the results, it is assumed that possible differences in the quality of fuel elements produced by the different fabrication routes are independent of whether ingot or dingot metal is used. If this assumption cannot be made, then test results must be interpreted as holding only for dingot metal.

The three fabrication routes to be evaluated are identified below:

H-E: Hollow Extruded

R-E: Rod Extruded

R-R: Rod Rolled

As proposed, the test will utilize bars A, B, and C from 9 dingots. A total of 27 finished fuel elements will be irradiated from each dingot bar, to result in 729 fuel elements. These will be charged in 27 process tubes, each containing 27 test fuel elements. The remaining positions (28-32) in the tubes can be charged with non-test fuel. "Treatment designations are given below.

Other test details and the charging patterns are given in reference (14).

TABLE I

TREATMENT DESIGNATIONS

Treatment #	Dingot	Bar	Fab. Route	Treatment #	Dingot	Bar	Fab. Route
1	1	A	H-E	16	6	A	R-R
2	1	B	R-E	17	6	B	H-E
3	1	C	R-R	18	6	C	R-E
4	2	A	R-E	19	7	A	R-E
5	2	B	R-R	20	7	B	H-E
6	2	G	H-E	21	7	C	R-R
7	3	A	R-R	22	8	A	R-R
8	3	B	H-E	23	8	B	R-E
9	3	C	R-E	24	8	C	H-E
10	4	A	R-E	25	9	A	H-E
11	4	B	R-R	26	9	B	R-R
12	4	C	H-E	27	9	C	R-E
13	5	A	H-E				
14	5	B	R-E				
15	5	C	R-R				

(14) Letter, "Revised Test Design: Rolling vs. Extrusion", J. L. Jaech, February 13, 1962. (UNCLASSIFIED)

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APPENDIX C

ACCEPTANCE TESTING SCHEDULE FOR ALPHA EXTRUDED DINGOT CY-1962

March 1	Charge 35 tubes including 10 Phase I monitor charges.	
April		
May	Discharge 4 Phase I tubes at 400 MWD/T	
June	Charge 25 tons Phase II.	(Discharge 25 tubes Phase II)
July	" " " " "	Discharge 4 tubes Phase I at 800 MWD/T.
August	" " " " "	Discharge 2 tubes Phase I at 1000 MWD/T.
September	" " " " "	
October	" " " " "	Discharge 25 tons Phase II.
November	" " " " "	" " " " "
December	" " " " "	" " " " "

(Six months at 90 tons prior to full acceptance. This will require participation of more than one old reactor and will be authorized by a supplement to this PT or PITA).

Phase III - The 27 tube statistically designed test comparing alpha extrusion methods versus rolling mill will probably not take place, at the earliest, before the last quarter of CY-1962.

APPENDIX D

CHARGES CONTAINING FUEL WITH BARE CORE MEASUREMENTS

SERIES NO.	POSITION NO.	SERIES NO.	POSITION NO.
WZ06BA	1	WZ07BA	1
	2		2
	3		3
	4		4
	5		5
	6		6
	7		7
	8		8
	9		9
	11		11
	12		12
	13		13
	14		14
	*		15
	16		*
	17		17
	18		18
	19		19
	*		20
	21		21
	*		22
	*		*
	*		24
	*		25
	*		26
	*		27
	*		28
	*		29
	30		30
	31		31
	32		32

* No bare core measurements

DATE
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6/14/94

END