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PROCESSING DATA FOR COEXTRUDED FUEL ELEMENTS IN ETR, KER AND MTR LOOPS

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PROCESSING DATA FOR COEXTRUDED FUEL ELEMENTS IN
ETR, KER AND MTR LOOPS

By
R. K. ROBINSON

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HW-71124

PROCESSING DATA FOR COEXTRUDED FUEL ELEMENTS IN
ETR, KER AND MTR LOOPS

ABSTRACT

The following data represents processing conditions used in fabricating prototypic (except for supports) natural and enriched NPR element assemblies and K-type I&E² for the following production tests:

<u>TEST</u>	<u>NUMBER</u>
ETR - 6x6 Loop	GEH-10 - Nos. 52, 53, 54 & 55
KER Loops	PT-377
MTR Loop	GEH-4 - Nos. 68, 69 and 70

The purpose in documenting the data is to provide a permanent record of processing conditions and dimensions which may be referred to for post irradiation analysis and possible future process work. Post irradiation results will be issued by the Fuels Development Operation, Hanford Laboratories Operation, and the test loop operating conditions will be issued by Process and Reactor Development Operation, Irradiation Processing Department, as outlined in the Production Test Procedure.

RK Robinson:grb
11/8/61

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PROCESSING DATA FOR COEXTRUDED FUEL ELEMENTS IN
ETR, KER AND MTR LOOPS

I. PRIOR HISTORY AND IDENTIFICATION

A. Uranium Billets

Uranium billets 31174, 31240, 31247, 31258, 33236, 33239, 33250, 33253, 35007, and 35008 were used to make up the fuel elements for these "N-Reactor" tests. These billets were all triple beta heat treated and alpha extruded. Their fabrication and charge make-up was as follows:

URANIUM BILLETS - PRIOR HISTORY

<u>BILLET</u> <u>NUMBER</u>	<u>TUBE</u> <u>NO.</u>	<u>TYPE</u>	<u>U-235</u>	<u>CAST</u>	<u>CHARGE MAKE-UP</u>
31174	139	NOT	0.949	Hollow	100% derby
31240	192	NIT	0.946	"	50% derby, 35% solid, 15% briquette
31247	215	KI&E ²	"	Solid	" " "
31258	219	NIT	"	"	" " "
33236	189	"	Normal	Hollow	" " "
33239	190	"	"	"	" " "
33250	204	"	"	Solid	100% derby
33253	204	"	"	"	"
35007	211	KI&E ²	0.946	Hollow	50% derby, 35% solid, 15% briquette
35008	209	NIT	0.947	"	" " "

B. Zircaloy Components

The zircaloy components used for these tests was wrought seamless zircaloy-2 tubing. The identification of the cladding components with the uranium core and extruded tube number is:

<u>TUBE NUMBER</u>	<u>URANIUM CORE</u>	<u>OUTER CLAD</u>	<u>INNER CLAD</u>
139	31174	8YA085	1216-714
189	33236	1391-3R	1216-715
190	33239	1391-1R	9YH007*
192	31240	1373-1F	1216-1137
204	33250 and 33253	1373-1R	1216-1137
209	35008	1380-2F	1216-1137
211	35007	1391-1F	1216-714
215	31247	1380-2F	9YH007*
219	31258	1373-1F	1216-1137

* No record of this number in Procurement files.

C. Copper Sheaths

The copper canning material for all these tubes was commercially pure copper, DHP or DLP type, meeting ASTM general minimum requirements.

II. CHEMICAL ANALYSIS AND CORROSION DATA

A. Uranium Billets - See Table No. 1

B. Zircaloy-2 Cladding Components - See Table No. 2

C. Copper Sheaths

Meeting ASTM Specification No. B-75-60 with minimum copper purity of 99.90%.

III. ASSEMBLY AND EXTRUSION DATA

A. Billet Assembly and Preparation

Tube Number	<u>Billet Evacuation</u>		<u>Billet Preheat Temperature</u>		<u>Time (Hours)</u>	<u>Billet Length (Inches)</u>	<u>Lubricant</u>
	<u>Time (Hours)</u>	<u>Seal Off Pressure ($\times 10^{-5}$ mm Hg)</u>	<u>(°F)</u>	<u>(°C)</u>			
139	2	2	1170	632	4.25	19.75	AD*
189	1.5	4	1150	621	4.0	19.75	AD
190	1.25	5	1150	621	4.25	19.75	AD
192	1	3	1155	624	6	18.75	AD
204	1	3	1150	621	5.5	18.75	AD
209	1	2	1160	627	4.5	19.75	AD
211	1	2	1170	632	5.0	18.75	AD
215	1	2	1170	632	5.5	18.75	AD
219**	1	2	1150	621	4.5	19.75	AD

* AD = Aqua Dag

** Billet was heated in the can to normal extrusion temperature, cooled, decanned and canned again.

B. Coextrusion Data - See Table No. 3

IV. TUBE EVALUATION

See Table No. 4 - Parts I and II

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TABLE NO. 1

CHEMICAL ANALYSIS AND CORROSION DATA
URANIUM BILLETS

Tube Number	Uranium Billet Number	Top Density (grs/cc)	Chemical Analysis (in PPM)			Spectrographic Analysis (in PPM)											
			H ₂	C	N	B	Be	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Si	Zr	
139	31174	18.95	--	457	13	<.2	--	<.2	6	--	65	<4	4	<10	17	--	
189	33236	18.96	--	292	30	<.2	--	<.2	13	--	54	<4	5	38	15	--	
190	33239	18.97	--	284	27	<.2	--	<.2	8	--	64	<4	6	29	22	--	
192	31240	18.97	1.3	289	11	<.2	<1	<.2	5	--	114	<4	10	25	92	5	
204	33250 & 33253	18.96	--	246	21	<.2	--	<.2	8	--	67	<4	6	25	14	--	
209	35008	18.95	1.0	399	12	<.2	<1	<.2	<5	--	105	<4	8	55	51	2	
211	35007	18.95	0.7	336	20	<.2	<1	<.2	<5	--	93	<4	9	19	52	3	
215	31247	18.89	1.1	378	13	<.2	<1	<.2	8	17	94	5	7	23	83	<5	
219	31258	18.93	1.4	467	6	<.2	<1	<.2	10	--	122	<4	14	49	47	<5	

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TABLE NO. 2
ZIRCALOY-2 CLADDING COMPONENTS

ALLOYING CONSTITUENTS

Tube Number	Heat Number	Wt. Gain (Mg/dm ²)	Alloys (in Per Cent)			
			Fe	Cr	Ni	Sn
139-Inner	1216-714	20.5	.126	.090	.053	1.53
Outer	8YA085	18	.126	.097	.052	1.37
189-Inner	1216-715	21	.125	.074	.047	1.31
Outer	1391-3R	25	.125	.095	.060	1.47
190-Inner	9YH007	(No record of this heat number in Procurement Files)				
Outer	1391-1R	23	.125	.095	.060	1.47
192-Inner	1216-1137	20	.12	.10	.06	1.43
Outer	1373-1F	19	.129	.098	.053	1.50
204-Inner	1216-1137	20	.12	.10	.06	1.43
Outer	1373-1R	20	.129	.098	.053	1.50
209-Inner	1216-1137	20	.12	.10	.06	1.43
Outer	1380-2F	19	.133	.097	.054	1.45
211-Inner	1216-714	20	.126	.090	.053	1.53
Outer	1391-1F	22	.125	.095	.060	1.47
215-Inner	9YH007	(No record of this heat number in Procurement Files)				
Outer	1380-2F	19	.133	.097	.054	1.45
219-Inner	1216-1137	20	.12	.10	.06	1.43
Outer	1373-1F	19	.129	.098	.053	1.50

IMPURITIES (IN PPM)

Tube No.	C	Cu	H	N	W	Al	B	Cd	Co	Hf	Pb	Mg	Mn	Mo	O	Si	Ti	U	V
139-Inner	145	30	9	23	<40	42	<.2	<.3	< 5	48	17	<10	<10	10	1062	40	<20	2.1	<20
Outer	90	24	6	40	<10	<30	<.2	<.2	<10	<100	<20	<20	<20	<10	----	44	<20	---	<20
189-Inner	177	23	12	28	40	44	.3	<.3	--	54	10	<10	15	10	1035	90	<20	2.1	<20
Outer	305	<20	7	70	<25	38	<.3	<.3	<10	73	5	<10	12	<10	935	<40	<20	2.5	<5
192-Inner	80	<25	7	70	25	44	<.2	<.3	< 5	74	5	<10	12	<10	935	<40	<20	2.4	5
Outer	160	<20	12	28	20	43	<.3	<.3	<10	<125	<20	<10	<25	<10	1105	54	<20	1.2	<10
209-Outer	215	<20	10	28	<20	35	<.3	<.3	<10	<125	<20	<10	<25	<10	1025	155	<20	.3	<10

Note: Tube 190-outer and Tube 211-outer are same as Tube 189-outer
 Tube 204-inner & outer, Tube 209-inner, and Tube 219-inner & outer are same as Tube 192
 Tube 211-inner is same as Tube 139-inner
 Tube 215-outer is same as Tube 209-outer

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TABLE NO 3

COEXTRUSION DATA

TUBE NUMBER	EXTRUSION		RAM SPEED (IPM)	MANDREL*			TYPE	DIE**		CUTOFF BLOCKS*** TEMPERATURE	
	DATE	UPSET (TONS)		O.D.	TEMPERATURE (°F)	(°C)		NO.	I.D.	(°F)	(°C)
139	2/14/61	1850	17.5	1.755	850	454	Free Step	1	2.445	850	454
189	4/3/61	1360	15	0.426	900	482	Free Step	2	1.290	900	482
190	4/3/61	1800	15	0.426	900	482	Face Step	2	1.290	900	482
192	4/4/61	1450	15	0.425	900	482	Free Step	1	1.290	900	482
204	4/17/61	1400	14	0.425	900	482	Traveling	1	1.290	900	482
209	4/26/61	1390	15.5	0.425	600	316	Free Step	1	1.290	600	316
219	5/25/61	1410	15.5	0.425	800	427	Traveling	1	1.290	800	427
211	5/10/61	1130	20.5	0.418	800	427	Free Step	1	1.500	800	427
215	5/11/61	1160	21.5	0.418	800	427	Traveling	5	1.500	800	427

* Mandrel lubricant for these extrusions was oil dag.

** 90° radius dies heated to 800°F (427°C)

*** The cut-off blocks were graphite and 2.5 inches long

SIGNIFICANT EXTRUSION VARIABLES

<u>TUBE NUMBER</u>	<u>COMMENTS</u>
189	Billet in can outside of furnace approximately two minutes just prior to extrusion.
190	Three minute delay on loader in "out" position.
192	Tube bowed up off table during extrusion. It was straightened by rolling.
204	Three minute delay on loader in "out" position - then rotated 85° clockwise.
209	Mandrel following block and cutoff block at 600°F (316°C) due to furnace failure. Extrusion delayed 55 seconds.

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TABLE NO. 4 - PART I
TUBE EVALUATION

TUBE NUMBER	DISTANCE FROM FRONT OF TUBE (INCHES)	OUTER CLAD THICKNESS		INNER CLAD THICKNESS	
		RANGE (MILS)	AVERAGE (MILS)	RANGE (MILS)	AVERAGE (MILS)
139	36	27-31	29	20-25	23
	175	21-27	24	27-32	30
	300	22-26	25	31-37	33
189	48	47-52	49	27-31	29
	246	43-49	45	23-32	28
	440	41-47	44	25-34	30
190	48	45-54	50	29-32	31
	246	43-47	45	24-32	37
	440	41-47	44	27-36	31
192	72	44-49	46	28-31	29
	272	44-49	46	28-32	30
	428	43-50	46	28-33	30
204	48	43-48	46	28-34	31
	237	44-49	39	29-32	31
	414	42-47	44	26-36	32
209	48	46-52	49	27-30	28
	254	44-48	46	28-32	29
	433	42-51	46	26-33	29
211	Front	28-36	33	28-31	29
	Middle	28-32	30	29-31	30
	Rear	29-32	31	29-34	31
215	Front	30-34	31	27-32	30
	Middle	27-31	30	27-33	30
	Rear	29-32	31	27-33	30
219	48	35-39	37	19-25	22
	213	32-36	34	22-26	24
	438	31-38	35	22-28	25

TABLE NO. 4 - PART II

TUBE NUMBER	DISTANCE FROM FRONT OF TUBE (INCHES)	INTERFACE CLEANLINESS		URANIUM GRAIN SIZE (mm)					
		OD	ID	0°-OD	0°-Center	0°-ID	180°-OD	180°-Center	180°-ID
139	36	5	4	.055	.065	.075	.055	.065	.090
	175	5	4	.055	.055	.090	.075	.045	.075
	300	5	5	.055	.055	.065	.055	.055	.065
189	48	5	5	.250	.110	.500	.250	.075	.500
	246	6	5	.300	.055	.500	.250	.055	.500
	440	4	6	.210	.045	.250	.110	.045	.500
190	48	3	5	.150	.045	.500	.150	.035	.500
	246	7	5	.250	.045	.500	.250	.035	.500
	440	3	5	.075	.030	.250	.075	.035	.300
192	72	6	3	.090	.035	.250	.090	.035	.210
	272	6	5	.075	.026	.180	.090	.026	.150
	428	4	4	.250	.110	.500	.250	.075	.500
204	48	3	4	.055	.045	.090	.055	.045	.090
	237	3	6	.075	.045	.090	.075	.045	.090
	414	5	6	.055	.045	.090	.055	.045	.090
209	48	5	5	.075	.030	.090	.090	.030	.075
	254	6	6	.090	.035	.180	.090	.035	.180
	433	5	7	.090	.035	.075	.075	.030	.130
211	Front	1	3	.090	.045	.500	.250	.045	.360
	Middle	5	5	.075	.045	.300	.110	.045	.500
	Rear	4	5	.055	.035	.110	.045	.035	.090
215	Front	2	3	.090	.035	.250	.065	.030	.300
	Middle	6	5	.065	.035	.300	.075	.030	.360
	Rear	3	5	.045	.030	.250	.065	.035	.210
219	48	3	3	.130	.045	.500	.250	.065	.500
	213	5	5	.130	.045	.300	.180	.045	.360
	438	5	5	.180	.045	.250	.130	.045	.210

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V. PROCESSING

A. Chemical Milling

<u>Tube Number</u>	<u>PIECE NUMBER</u>	<u>ETCH DEPTH RANGE (MILS)</u>	
		<u>NUMBERED END</u>	<u>UN-NUMBERED END</u>
139	--	285-305	290-310
189	49	281-295	293-323
	143	285-297	284-298
	305	285-295	283-293
190	119	279-304	289-309
	190	282-306	288-307
	376	284-300	285-307
192	90	285-306	288-308
	160	289-317	292-315
	248	292-317	294-318
204	143	293-310	287-309
	190	285-305	289-315
	261	314-329	360-390
209	113	290-300	286-299
	195	292-304	291-315
	328	289-305	286-299
211	20	373-410	365-397
	27	377-412	363-397
215	28	357-395	356-392
	32	357-395	354-397
219	90	290-297	287-302
	181	290-295	287-290
	329	285-298	288-300

B. Brazing

The following standard conditions were in effect for the brazing of these fuel elements:

- 1) Pickle Time - One (1) minute
- 2) Bright Etch Time - Two (2) minutes
- 3) Melting Time - Approximately forty to fifty (40-50) seconds
- 4) Delay - Five (5) seconds
- 5) Final Heating - Twenty (20) seconds
- 6) Initial Pressure - 2.5×10^{-4} mm Hg
- 7) Argon Pressure - Four (4) psi
- 8) Average Maximum Temperature - 1050°C (1922°F)

C. Heat Treatment

The following standard conditions were in effect for the heat treating of the fuel elements covered in this document: (Exceptions noted in Table No. 5).

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1. Heating Bath - Nu-Sol
 - a) Temperature - 730°C (1346°F)
 - b) Time - Five (5) minutes
2. Delay - Eighteen (18) seconds
3. Quench - Nitrate Salts
 - a) Temperature - 300°C (572 °F)
 - b) Time - Five (5) minutes
4. Delay - Eighteen (18) seconds
5. Quench - Air
 - a) Temperature - Room
 - b) Time - To room temperature

The dimensions and warp before and after heat treating are as shown on Table No. 5.

D. Vapor Blast

Prior to welding, the fuel elements are vapor blasted under the following process conditions:

1. Feed:
Double pass (external and internal) at four (4) inches per minute.
2. Air Pressure:
90-100 psi
3. Slurry:
65% water, 35% 220 mesh aluminum oxide.

E. Welding

The fuel elements were welded using the TIG welding process under the following conditions:

1. Welding Current - 80-100 amps
2. Argon Flow - 25-30 cfh
3. Spindle Speed - 8-16 rpm
4. Purge Time - 10-20 seconds

F. Nondestructive Testing

The fuel elements in this document were tested by nondestructive methods for:

1. Quality of bond between outer clad and uranium core.
2. Quality of bond between inner clad and uranium core

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TABLE NO. 5

DIMENSIONS AND WARP - BEFORE & AFTER HEAT TREATING

TUBE NUMBER	PIECE NUMBER	OD (INCHES)		ID INCHES)		WALL THICKNESS		LENGTH(INCHES)		WARP(MILS/DEGREE)*	
		BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
139 (1)	60	2.403	2.407	1.750	1.760	0.327	0.323	23.210	23.292	6.5/90	11/90
	131	2.403	2.407	1.750	1.760	0.327	0.323	23.219	23.300	7.5/280	8/240
189	213	-----	-----	-----	-----	-----	-----	11.005	11.020	6/245	9/230
190	213	-----	-----	-----	-----	-----	-----	11.005	11.020	6/205	11/320
192	125	1.253	1.251	0.435	0.436	0.407	0.407	-----	-----	18/345	24/50**
	320	1.255	1.255	0.432	0.435	0.410	0.407	-----	-----	15/315	12/200
204	166	1.248	-----	0.436	-----	0.405	0.399	23.085	-----	13/5	12/355
	238	1.249	-----	0.437	-----	0.401	0.398	23.099	-----	5.2/25	5/350
209 (2)	264	1.252	1.247	0.435	0.435	0.410	0.403	23.165	-----	15/345	3/200
219	181	1.252	1.246	0.433	0.436	0.410	0.403	-----	-----	19/145	27/130
	329	1.253	1.248	0.433	0.436	0.410	0.402	-----	-----	25/265	22/265

* 0° is twelve o'clock die position

** Double reverse bend and re-beta heat treated

- (1) Four minute heat treat, 16 second delay, four minute nitrate quench, water quench to room temperature.
- (2) Ten minute chloride heat treat, quenches standard.

NOTE:

1. Tubes 211 and 215 were given an eight minute heat treat and nitrate quench with a 25 second delay in between. Then quenched in water to room temperature.

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3. Quality of end closure bond
4. Thickness of outer clad
5. Thickness of inner clad

All of the fuel elements were acceptable. The analog chart recordings for these fuel elements are filed by FPD-Coextruded Product Engineering.

G. Autoclaving

The fuel elements were given a standard autoclave cycle of:

Medium - Super heated steam
 Temperature - $400 \pm 20^{\circ}\text{C}$ ($752 \pm 68^{\circ}\text{F}$)
 Pressure - 1500 ± 100 psig
 Time - 72 hours, maximum

VI. PRE-IRRADIATION MEASUREMENTS

<u>TUBE NUMBER</u>	<u>PIECE NUMBER</u>	<u>OD(INCHES) RANGE</u>	<u>ID(INCHES) RANGE</u>	<u>LENGTH(INCHES)</u>	<u>WARP (MILS/DEGREE)*</u>
139	84	2.403-2.422	1.758-1.765	23.121	11/90
	131	2.403-2.420	1.759-1.765	23.145	8/240
189	213	1.252-1.269	0.425-0.439	11.00	9/230
190	213	1.252-1.269	0.420-0.440	11.00	11/320
192	125	1.247-1.260	0.439	17.226	24/50
	160	1.247-1.260	0.438	17.250	6/325
	362	--	--	--	4/310
204	166	1.246-1.247	0.440-0.441	23.068	12/355
	238	1.247-1.248	0.431-0.439	23.082	5/350
	332	1.745-1.248	0.438-0.440	23.003	5/345
	355	1.245-1.248	0.439-0.441	23.028	15/290
209	90	1.241-1.256	0.443-0.446	22.980	55/95
	172	1.243-1.255	0.440-0.446	23.036	43/225
	213	1.245-1.258	0.440-0.443	23.040	37/230
	264	1.245-1.256	0.441-0.443	23.045	3/200
	305	1.245-1.257	0.440-0.442	23.020	24/120
	387	1.245-1.259	0.442-0.444	23.047	23/265
	113	1.241-1.255	0.441-0.443	17.516	19/150
	195	1.241-1.254	0.440-0.444	17.541	9/310
	328	1.242-1.254	0.441-0.444	17.565	10/355
211	24	1.443-1.465	0.437-0.439	7.425	3/--
	27	1.443-1.465	0.437	7.434	1/--
215	30	1.443-1.463	0.437-0.439	7.455	2/--
219	172	1.245-1.256	0.440-0.441	23.057	23/--
	305	1.245-1.256	0.440-0.440	23.046	16/--

VII. PROCESS FLOW SHEET - NPR FUEL ELEMENTS

See Table No. 6

RKR:grb

CCEXTRUSION PROCESS FLOW SHEET

III COPPER COMPONENTS

1. Receiving Inspection
2. Cleaning
3. Cleaning Inspection
4. Cap Assembly & Welding
5. Cap Assembly Test
6. Can Assembly & Welding
7. Can Assembly Test

I URANIUM BILLETS

1. Receiving Inspection
2. Billet Pickle
3. Billet Pickle Inspection

II ZIRCALOY-2 COMPONENTS

- Billet Clads
1. Receiving Inspection
 2. Cleaning
 3. Cleaning Inspection

IV BILLET ASSEMBLY

1. Billet Component Assembly
2. Billet Welding
3. Evacuation & Leak Test
4. Evacuation Tube Cutoff

VII STEEL SUPPORT SHOES

1. Receiving Inspection
2. Cleaning
3. Cleaning Inspection

V EXTRUSION

1. Billet Lubrication
2. Billet Preheat
3. Tool Preparation
4. Extrusion
5. Extruded Tube Handling

VI FUEL TUBE PREPARATION

1. Cut to Length
2. Destructive Test Evaluation
3. Copper Removal
4. First Zircaloy Bright Etch
5. Surface, Dimension, N.D. Audit and Temporary Marking
6. End Closure Recessing
7. Pre-Braze Cleaning
8. End Closure Brazing
9. Beta Heat Treat
10. Heat Treat Inspection
11. Straightening
12. End Closure Machining
13. Abrasive Cleaning
14. End Closure Cleaning
15. End Closure Welding
16. Nondestructive Test
17. Degrease
18. Support Welding
19. Support Weld Inspection
20. Final Etch
21. Assembly & Autoclave
22. Disassembly & Autoclave Inspection
23. Steel Shoe Attachment (Outer Supports)
24. Final Inspection
25. Final Inspection & Storage

(II) END CAPS

4. Receiving Inspection
5. Cleaning
6. Cleaning Inspection

(II) BRAZE PIECES

7. Receiving Inspection
8. Cleaning
9. Cleaning Inspection

(II) SUPPORTS-ZIRCALOY

10. Receiving Inspection
11. Cleaning
12. Cleaning Inspection

TABLE NO. 6

UNCLASSIFIED

-13-

IN-71124

UNCLASSIFIED

DATE

FILMED

8/9/94

END