Y/DZ-781
Visuals

Y-12

OAK RIDGE
Y-12
PLANT

MARTIN MARIETTA

SUMMARY REVIEW OF ROVER PROGRAM IN Y-12

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Y-12 Development Division

July 17, 1991

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SEI Committee Meeting
Oak Ridge National Laboratory
July 15, 1991

Prepared by the
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Oak Ridge, Tennessee 37831
managed by
Martin Marietta Energy Systems, Inc.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

Y-12 CENTRAL FILES
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THE OAK RIDGE PLANTS HAVE BEEN INVOLVED WITH CARBON TECHNOLOGIES SINCE THE 1940's

- Graphite Fabrication
- Coatings
- Joining
- Synthetic Pitch Technology

PREVIOUS CARBON MATERIAL PROGRAMS

- NUCLEAR ROCKET FUEL ELEMENTS
- CARBON INSULATORS
  - FOAMS
  - CHOPPED FIBERS
- MOLDED GRAPHITES
  - ISOTROPIC
  - 3D WEAVE
- IMPREGNATIONS
  - LIQUID
  - CVD

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NUCLEAR ROCKET PROGRAM

- JOINTLY FUNDED BY DOE-NASA (1960 - 1972)
- Y-12 MADE FUEL ELEMENTS FOR BOTH LANL AND WESTINGHOUSE
- AERO-JET GENERAL MADE HARDWARE OTHER THAN THE FUEL ELEMENTS FOR WESTINGHOUSE
- LANL MADE HARDWARE FOR THEIR REACTORS
- REACTORS TESTED EACH YEAR FOR ABOUT 12 YEARS - 2 OR MORE TESTS/YEAR

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Y-12'S ROLE IN ROVER

- DEVELOPED RAW MATERIALS
- DEVELOPED MANUFACTURING METHODS FOR MASS PRODUCTION OF EXTRUDED FUEL ELEMENTS
- DEVELOPED MANUFACTURING METHODS FOR MASS DEPOSITION OF NIOBIUM CARBIDE INTO GAS HOLES
- DEVELOPED INSPECTION AND COMPUTERIZED DATA FOR MASS PRODUCTION (2000 OR MORE INSPECTIONS/ELEMENT)
- PRODUCED 10,000 TO 20,000 FUEL ELEMENTS PER YEAR FOR ABOUT 13 YEARS
- REACTOR PERFORMANCE EXTENDED FROM A COUPLE OF MINUTES TO 1 HOUR (MULTI CYCLE) BY IMPROVEMENTS IN MANUFACTURING PROCESSES
- FUEL ELEMENT STEPS - ABOUT 13 OPERATIONS OVERALL YIELD OF 60 TO 70% WITH EACH OPERATION GREATER THAN 95%

ROVER REACTOR

- GRAPHITE MATRIX FILLED WITH UC2 (ABOUT 300 Kg FOR 1000 ELEMENT REACTOR)
- GAS HOLES COATED WITH NbC TO PREVENT HYDROGEN CORROSION
- HYDROGEN GAS PROPELLANT
- OPERATING TEMPERATURE 2200C
- MULTI CYCLES UP TO 60 MINUTES
- SEVERAL REACTOR SIZES - 1000 ELEMENTS, 5000 ELEMENTS, 50 ELEMENTS

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COEFFICIENT OF THERMAL EXPANSION (CTE)

- Extruded fuel elements had a CTE of 4×10^{-6} in/in/°c in 1960's

- Vapor coated NbC had a CTE of 7.5×10^{-6} in/in/°c

- Program goals -

  - Reduce mismatch of CTE - Produce a extruded fuel element having a high CTE

  - Obtain graphite filler particles that could be extruded into high CTE fuel elements

  - Obtain organic binder that could be graphitized (not a glassy carbon)

- In 1970's, high CTE fuel elements were produced but program was terminated. Fuel element performance was significantly improved.

MANUFACTURING OPERATIONS

- RAW MATERIALS
- CERTIFICATION
- BLENDING/MIXING
- EXTRUSION
- BAKING
- GRAPHITIZATION
- BRAZING
- INSPECTION
- MACHINING
- INSPECTION - PHYSICAL
- INSPECTION - NDT, GAMMA, X-RAY, ETC.
- CVD
- INSPECTION - PHYSICAL AND NDT, ETC.

EXAMPLES OF PROBLEMS AND SOLUTIONS (NUCLEAR ROCKET)

- VARIABLE RAW MATERIALS - WORKED WITH MANUFACTURERS; DEVELOPED INSPECTION PROCEDURES
- MANUFACTURING PROCESS - DEVELOPED AND AUTOMATED MANY OF THE PROCESSES
- MACHINING - DEVELOPED NEW MACHINES TO PRODUCE MACHINED PARTS IN A FEW SECONDS
- INSPECTION - DEVELOPED AUTOMATED PROCEDURES; MORE THAN 2000 INSPECTION OPERATIONS PER FUEL ELEMENT
- CVD - DEVELOPED NEW PROCESSES; FUEL ELEMENT LIFE EXTENDED FROM 10 MINUTES TO 60 MINUTES
- QUALITY - ACCEPTANCE RATE INCREASED FROM 30% TO 70% BY DEVELOPMENT OF PROCESS CONTROLS

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MANUFACTURING STEPS

- PROCUREMENT OF RAW MATERIALS
  - GRAPHITE POWDER
  - BINDER
  - NIOBIUM PENTACHLORIDE
  - URANIUM OXIDE POWDER
  - PYROCARBON COATED URANIUM DICARBIDE PARTICLES

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EXTRUSION PROCESS

- GRAPHITE POWDER/URANIUM FUEL/BINDER
  - BLENDING
  - BAKING
  - CURING
  - GRAPHITIZATION
  - INSPECTION

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BRAZING

- A 1-INCH MACHINED GRAPHITE END WAS MOLY BRAZED TO ELEMENT

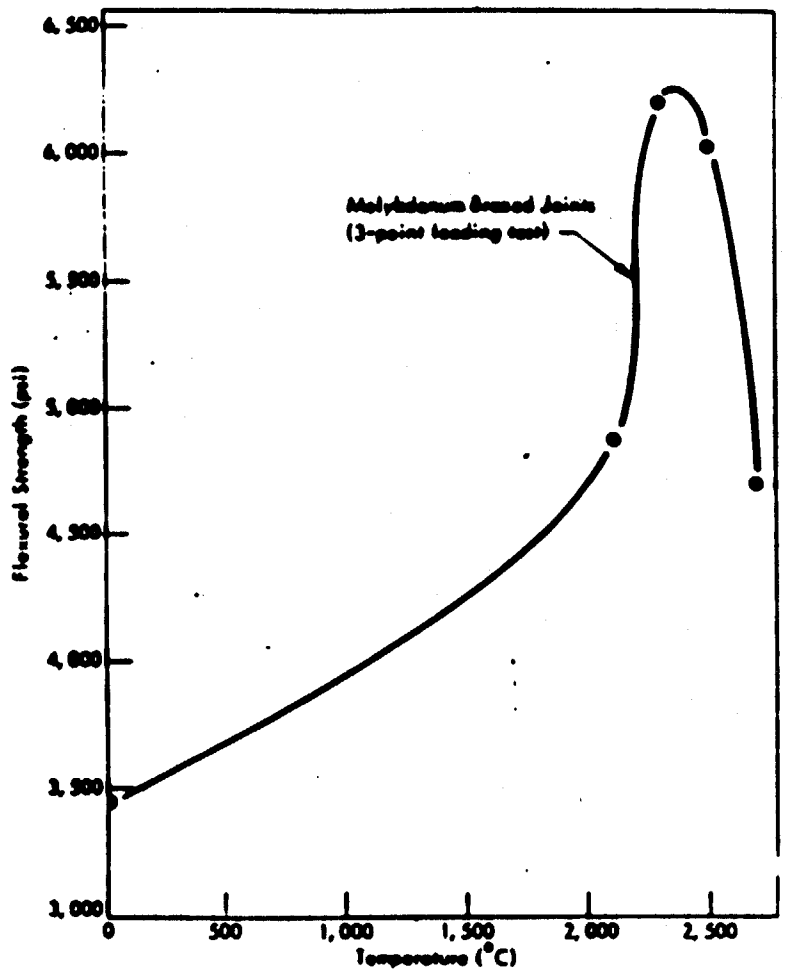

Figure 5. HIGH-TEMPERATURE FLEXURAL STRENGTHS OF Y-12-PRODUCED MOLYBDENUM BRAZED JOINTS.

MACHINING PROCESS

- GAS HOLES REAMED TO PLUS OR MINUS 0.0002 INCHES OF SPECIFIED DIAMETER (ALL HOLES MACHINED IN LESS THAN 1 MINUTE)
- OUTER SURFACES MACHINED TO PLUS OR MINUS 0.0002 INCHES (9 SECOND MACHINE TIME)
- CUT TO LENGTH (52 INCHES ± .005 INCHES)
- END OF ELEMENT (1 OR 2 INCHES) MACHINED TO A TAPER (O AT FIRST TO 0.002 INCHES AT END)
- LEACHING - ELEMENT WAS LEACHED AT 1800C IN GASEOUS HCI TO REMOVE UNCOATED UC2.
- INSPECTION - PHYSICAL MEASUREMENTS
  URANIUM FUEL MEASUREMENT
  (X-RAY AND GAMMA COUNT)

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COATING PROCESS

- NbC FILM DEPOSITED IN ELEMENT GAS HOLES (HOLES WERE TYPICALLY 0.100 INCH DIAMETER, 52 INCH LONG, 19 HOLES IN EACH ELEMENT)
- NbC FILM THICKNESS VARIED FROM 0 TO 0.002 INCHES AT END WITH VARIOUS SHAPES IN THE MIDDLE
- OUTER END OF ELEMENT ALSO NbC COATED TO VERY CLOSE SPECIFICATIONS
- NbC THICKNESS MEASURED IN ALL HOLES (BETA BACKSCATTER, 1 INCH INSPECTION INCREMENT)
- PROCESS YIELD WAS MORE THAN 90%
- ELEMENT WAS AGAIN GAMMA SCANNED (1 INCH INCREMENTS)

APPENDIX A

PROCESS FLOW SYSTEM

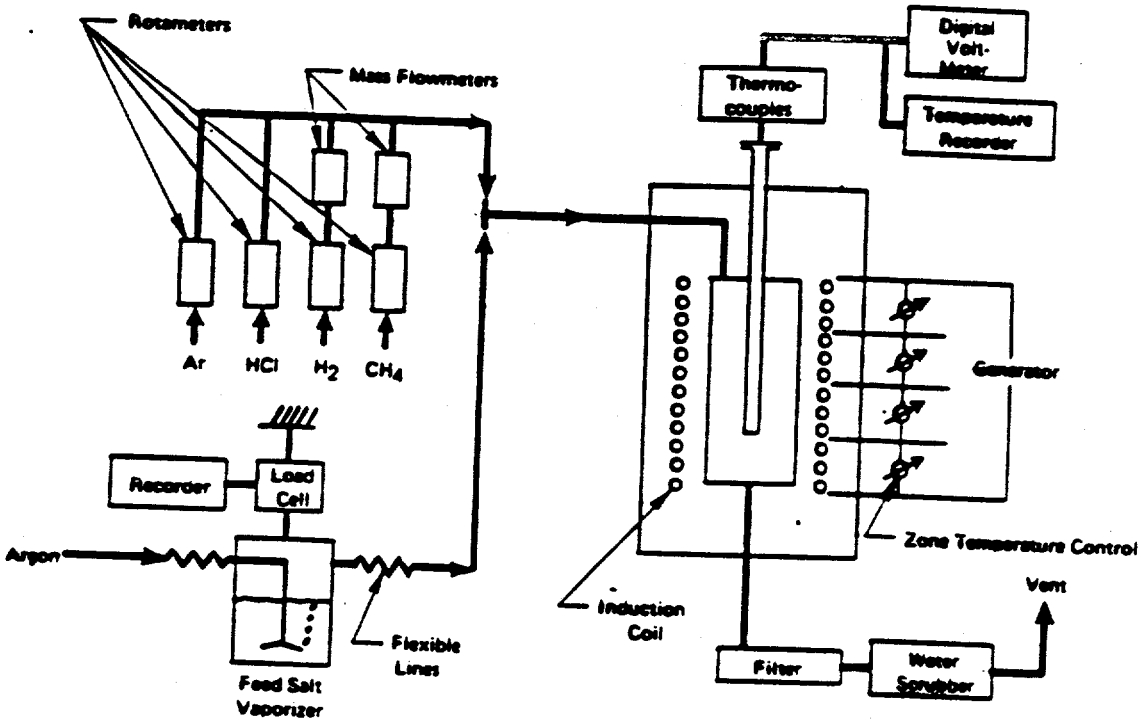


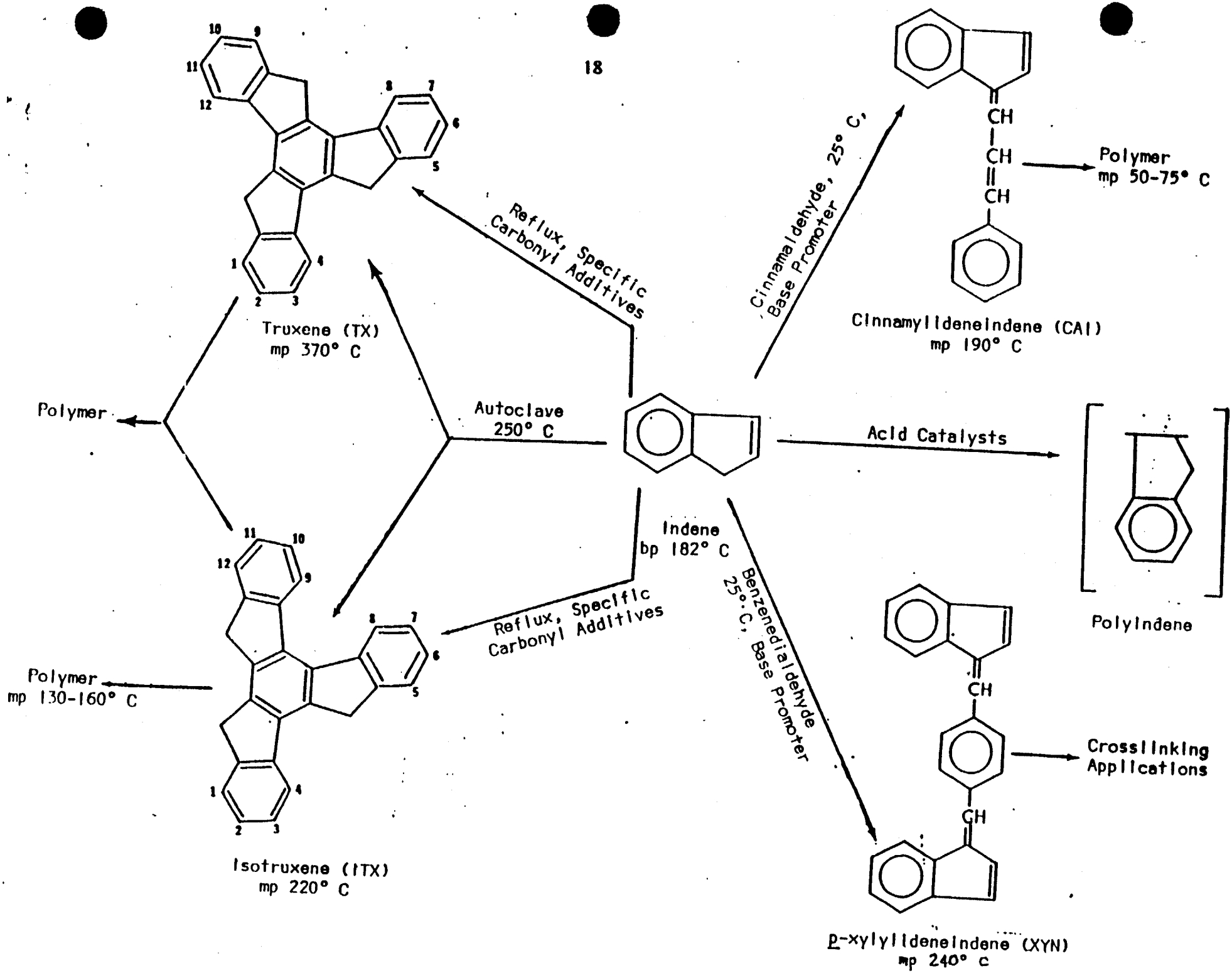
Figure A-1. PROCESS FLOW.

TYPICAL CONDITIONS FOR CARBIDES

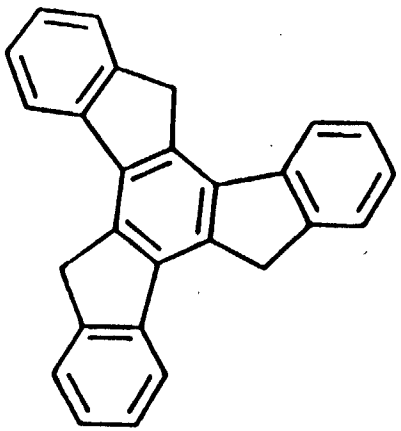
Low Temperature	Methane Coating
	Vol %
Argon	82.69
HcL	13.78
H_2	1.51
CH_4	.37
$NbCl_5$	1.65

Temperature	1055 to 1125°C
Weight gain/hr per NERVA fuel element	3.63 gms/hr
Coating thickness	0.2 to 2.4 mils

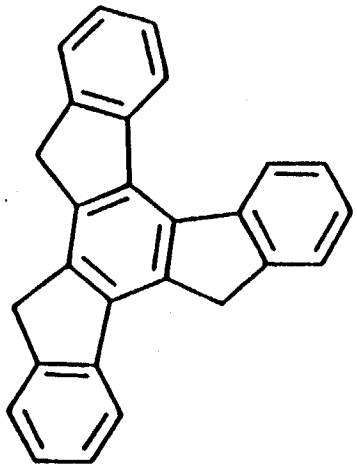
Dependent on location in the fuel element.


Truxene (TX)
mp 370° C
Reflux, Specific Carbonyl Additives
Cinnamaldehyde, 25° C, Base Promoter
CH
CH
CH
Polymer
mp 50-75° C
Cinnamylideneindene (CAI)
mp 190° C
Polymer
Autoclave
250° C
Indene
bp 182° C
Acid Catalysts
Polyindene
Polymer
mp 130-160° C
Reflux, Specific Carbonyl Additives
Benzenedialdehyde
25°.C, Base Promoter
CH
CH
Crosslinking Applications
Isotruxene (ITX)
mp 220° C
p-xylylideneindene (XYN)
mp 240° c

INDENE DERIVATIVES



TRUXENE



ISOTRUXENE

	TRUXENE	ISOTRUXENE
MOLECULAR FORMULA	$C_{27}H_{18}$	$C_{27}H_{18}$
MELTING TEMPERATURE	~370°C	223-224°C
COKE YIELD - WITH AIR CURE	80-90%	70-80%
WITHOUT AIR CURE	~ 60%	~ 50%
TYPE OF CARBON	NONGRAPHITIZABLE	GRAPHITIZABLE

Carbon Density Change

Ex. #3. Ex. #4.

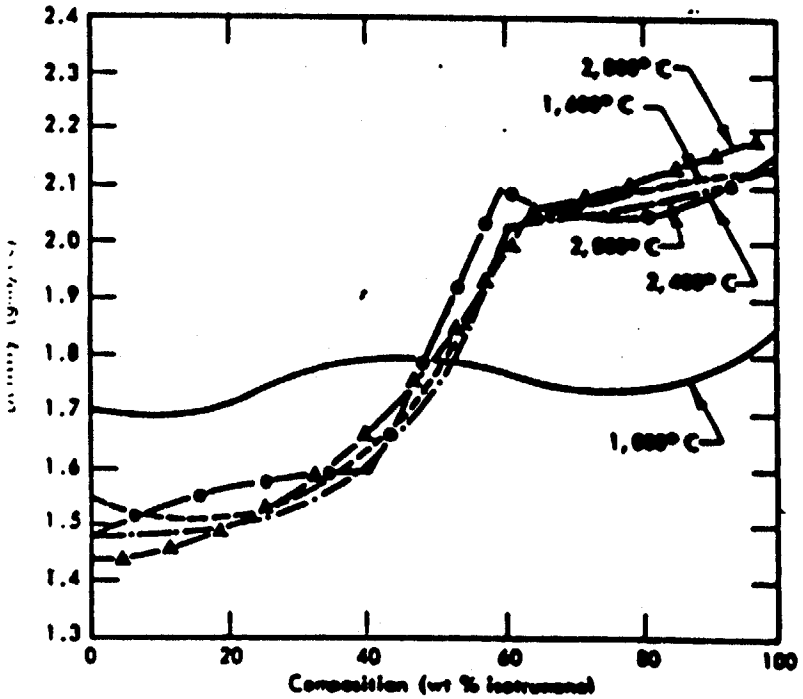


Figure 96. DENSITY ON GRAPHITIZATION OF MIXTURES OF VARCUM 8266 AND ISOTRUXENE-100 AT DIFFERENT TEMPERATURES AS A FUNCTION OF COMPOSITION.

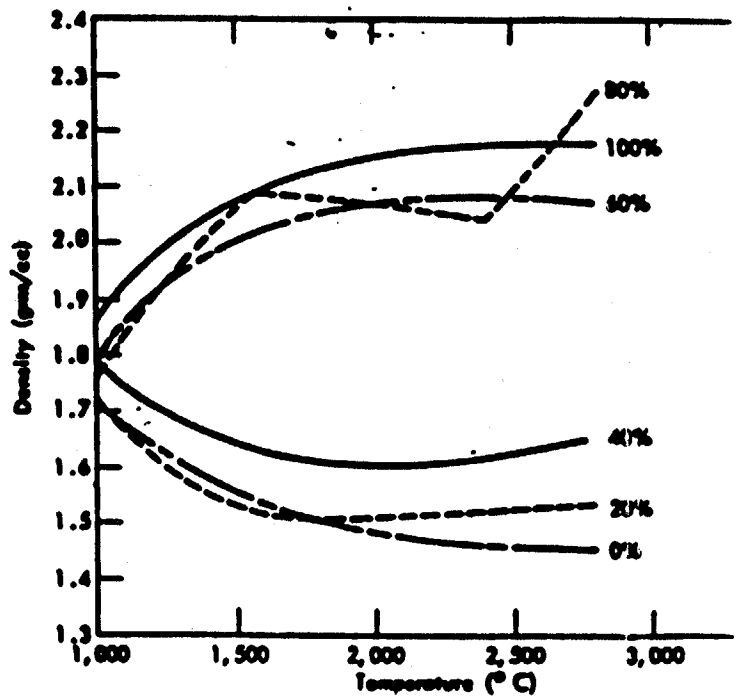
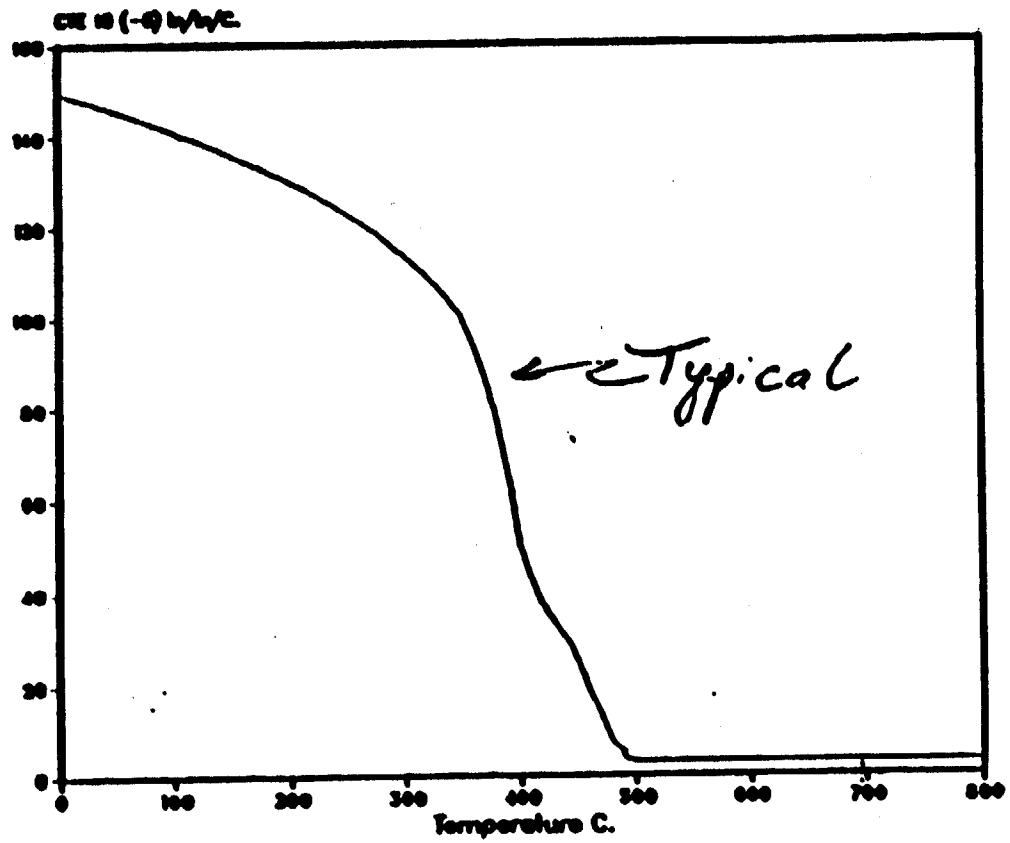


Figure 95. DENSITY ON GRAPHITIZATION OF MIXTURES OF VARCI AND ISOTRUXENE-100 AT DIFFERENT WEIGHT PERCENT ISOTRUXEN TENTS AS A FUNCTION OF TEMPERATURE.

CTE Property Change During Bake Cycle



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