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PROGRESS ON SOL-GEL SPHERE-PAC DEVELOPMENT*

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Fabrication and performance advantages of the proposed sol-gel sphere-pac fuel fabrication process are well known and have been widely discussed. Much of the available irradiation data is traceable to an Oak Ridge National Laboratory (ORNL) program of the late 1960s.(1) Renewed development efforts are currently underway at ORNL to apply the sol-gel sphere-pac process to both oxide and carbide based fast breeder reactor fuels. One goal of the program is to sufficiently advance the technology to allow the fabrication of relevant irradiation test rods.

Sol-gel development efforts presently involve a review of the many recently proposed flowsheets. Sol-gel research, performed for a number of years in several European countries, has produced new gelation processes which do not require preparation of a true "sol" and has produced refinements of traditional sol-gel methods. At ORNL the best green microspheres are presently being made using an internal chemical gelation process. With this process, droplets of an acidic solution containing heavy metal are precipitated by neutralization with ammonia. Oxide particles produced by this method have recently been sintered to greater than 99% of theoretical density.

Sphere-pac loading studies, presently being performed at ORNL, utilize three distinct sizes of microspheres of identical composition. With the current flowsheet, the two largest sized fractions are blended together before being loaded into the fuel rod. The smallest microspheres are then packed into void spaces in this bed by an infiltration process during which the cladding is vibrated at low energy. This type of loading process would have to be repeated three times to load an actual fuel rod having a lower blanket, core, and upper blanket. Alternate loading processes are being considered in order to simplify the flowsheet; such alternatives are also attractive since they do not require fissile material in the smallest microspheres. Additionally, emphasis is also being placed on improved equipment and processes for conveying, dispensing, blending, and loading microspheres.

REFERENCES

1. A. L. Lotts, Comp., *Fast Breeder Reactor Oxide Fuels Development — Final Report*, ORNL-4901 (November 1973).

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INFORMATION MEETING ON FUEL ELEMENT
DEVELOPMENT PROGRAM

MAY 4, 1978

THE PRESENT ORNL PROGRAM HAS SEVERAL OBJECTIVES

1. REVIEW RECENT EUROPEAN SOL-GEL DEVELOPMENTS

2. MANUFACTURE DENSE MICROSPHERES OF VARIOUS COMPOSITIONS

3. DEMONSTRATE THAT SPHERE-PAC LOADING IS A VIABLE FABRICATION PROCESS

4. DEVELOP TECHNOLOGY TO PERMIT FABRICATION OF IRRADIATION TEST SPECIMENS

THERE ARE MANY REASONS FOR RENEWED INTEREST IN SOL-GEL SPHERE-PAC DEVELOPMENT

A. SAFEGUARDS

- SUITABLE FOR PROLIFERATION RESISTANT FUEL CYCLES
- ADAPTABLE TO REMOTE FABRICATION OF ANY FUEL CYCLE

B. FABRICATION

- PERSONNEL EXPOSURE REDUCED DURING PRODUCTION AND MAINTENANCE
- LESS MECHANICALLY INTENSIVE

C. PERFORMANCE

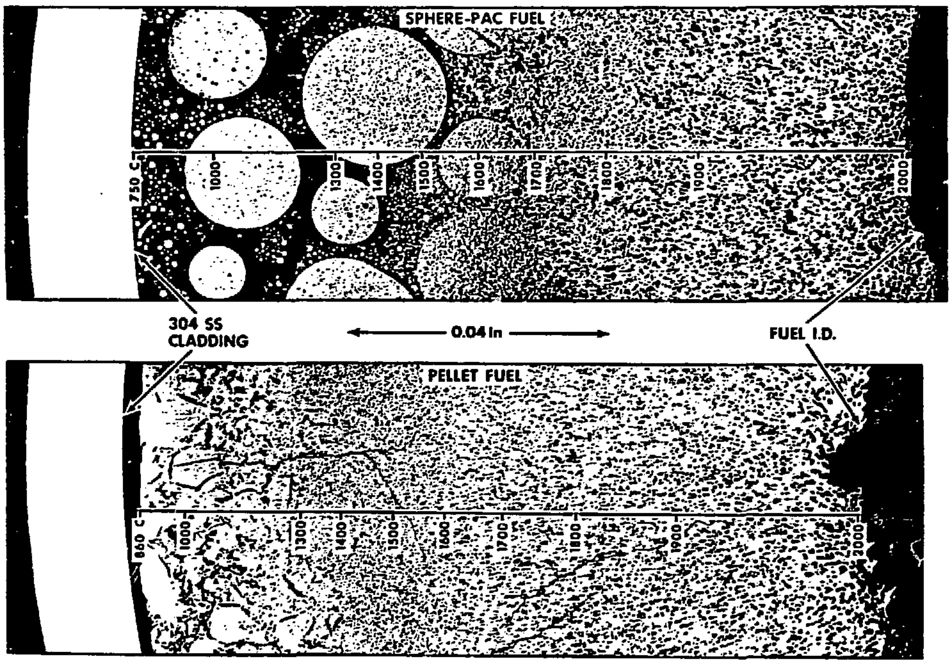
- HIGHER HEAT CONDUCTANCE ACROSS FUEL-CLAD GAP
- LESS FUEL-CLAD CHEMICAL AND MECHANICAL INTERACTIONS

IN AN EARLIER PROGRAM ORNL FABRICATED SPHERE-PAC FUEL RODS FOR IRRADIATION TESTING IN ETR, ORR, EBR-II, AND TREAT

FUEL MATERIAL	NUMBER OF SPHERE-PAC RODS
UO_2	6
$Th_{0.95}Pu_{0.05}O_2$	10
$U_{0.85}Pu_{0.15}O_2$	15
$U_{0.83}Pu_{0.17}O_2$	4
$U_{0.80}Pu_{0.20}O_2$	25
	60

RESTRUCTURING KINETICS ARE SIMILAR FOR SPHERE-PAC AND PELLET FUELS

R-53576



TEMPERATURES IN $(U_{0.8},Pu_{0.2})O_{1.99}$ FUEL DURING IRRADIATION

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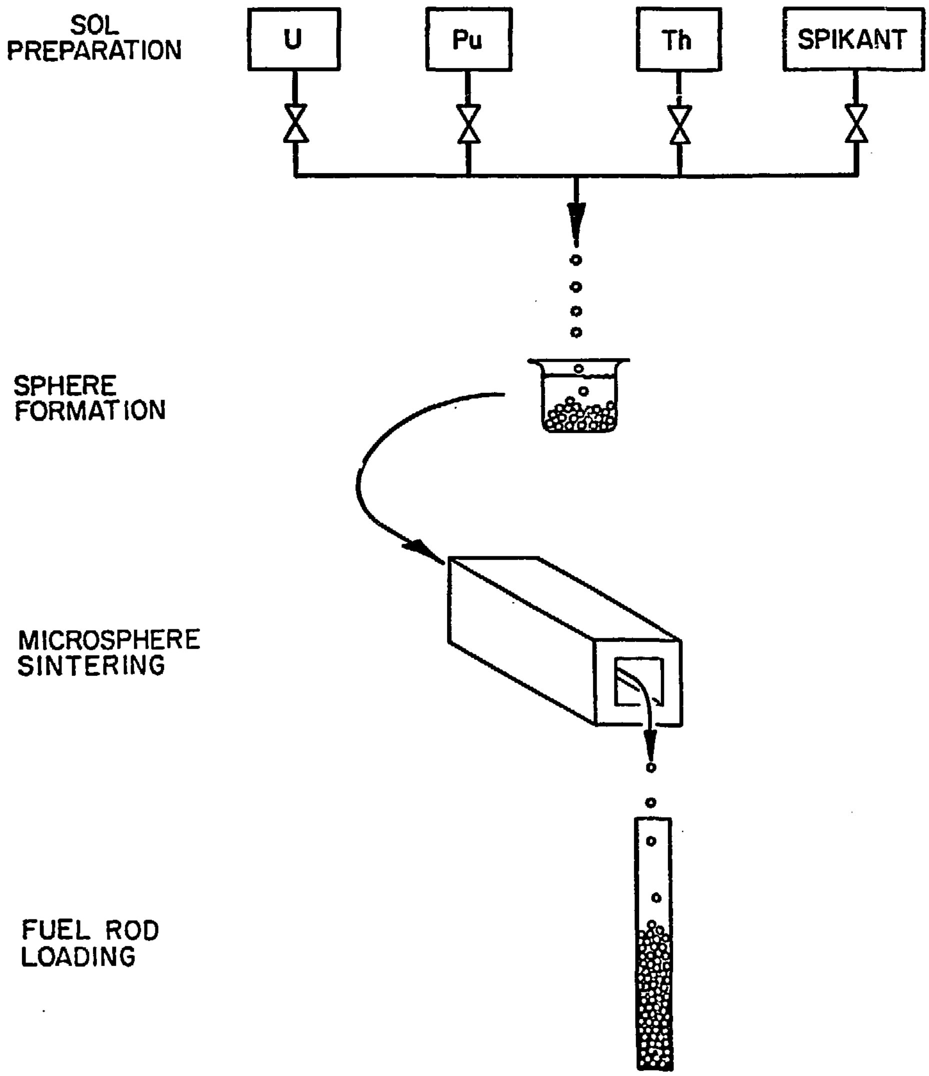
SPHERE-PAC HAS COMMON TECHNOLOGY FOR ALL FUEL CYCLES

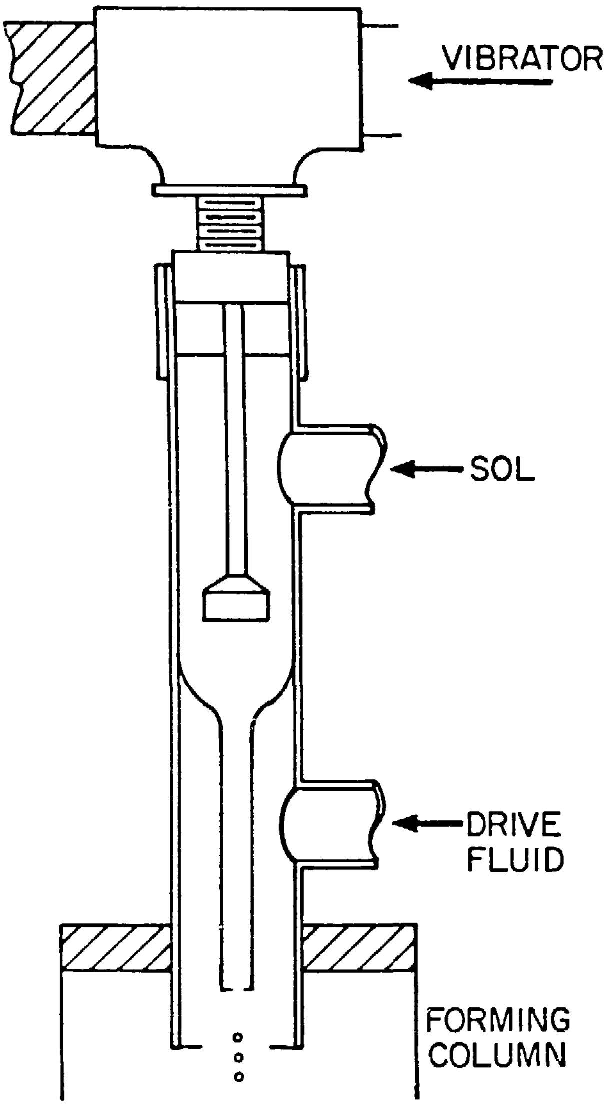


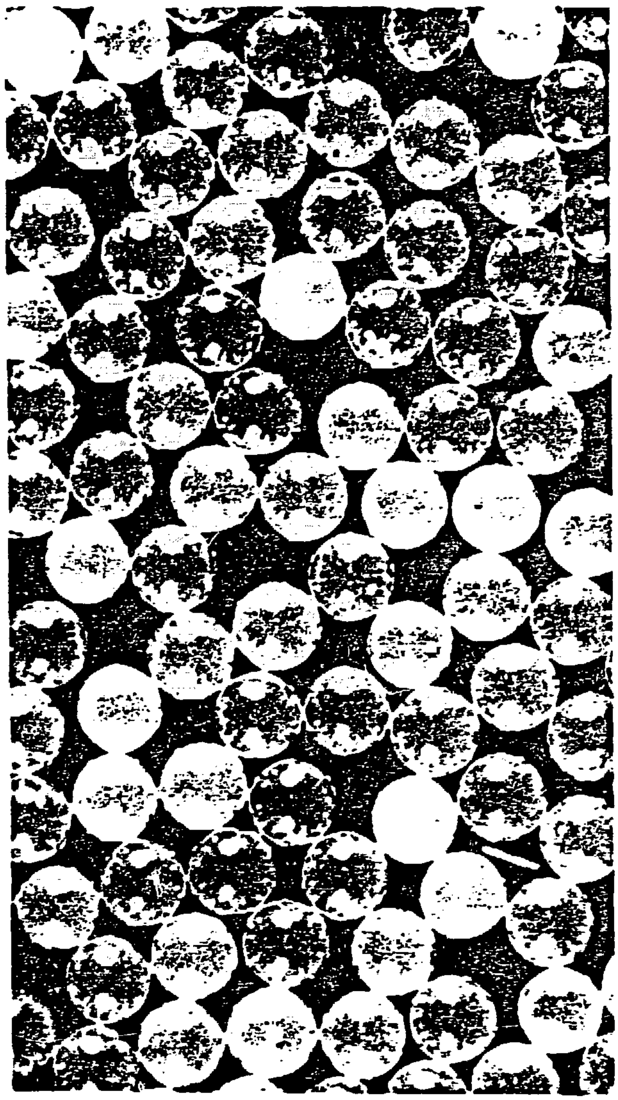
A VARIETY OF METHODS ARE BEING INVESTIGATED FOR DROPLET FORMATION

- WATER EXTRACTION (SOL-GEL)
  - USED FOR Pu, Th, Th-U, U^{+4}
  - URANIUM — AMINE SOLVENT EXTRACTION
  - THORIUM — THERMAL DENITRATION
  - IDEAL FOR FINES
- INTERNAL CHEMICAL GELATION
  - USED WITH U^{+6}, Pu
  - GOOD SUCCESS WITH ALL SIZES
- EXTERNAL CHEMICAL GELATION
  - REQUIRES GEL SUPPORT

ORNL-DWG 78-3206

IN MICROSPHERE FORMING, A TWO-FLUID NOZZLE WITH VIBRATION YIELDS MONOSIZE PARTICLES





PRODUCT

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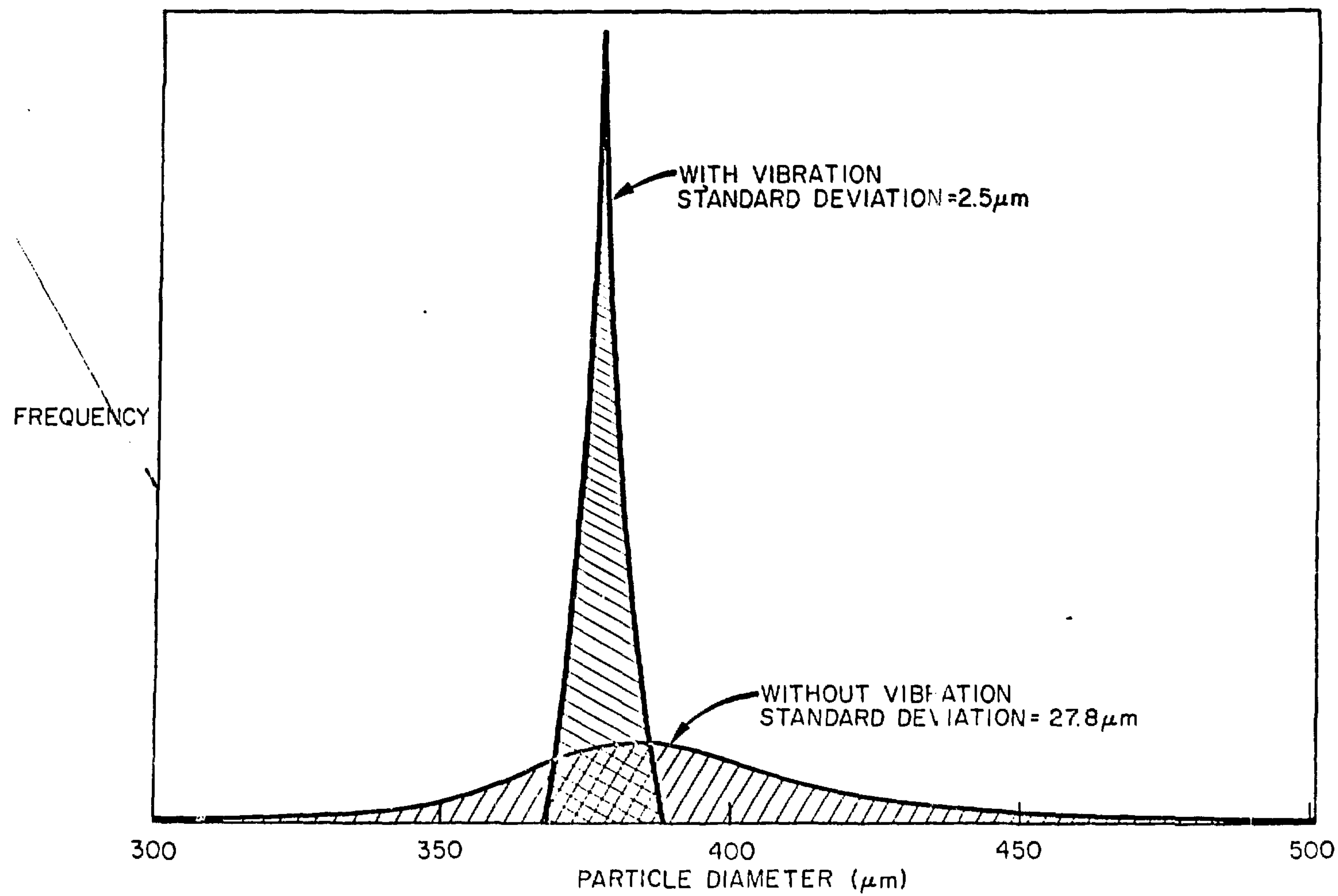
PULSED NOZZLE VIBRATION PRODUCES CLOSELY SIZED MICROSPHERE BATCH



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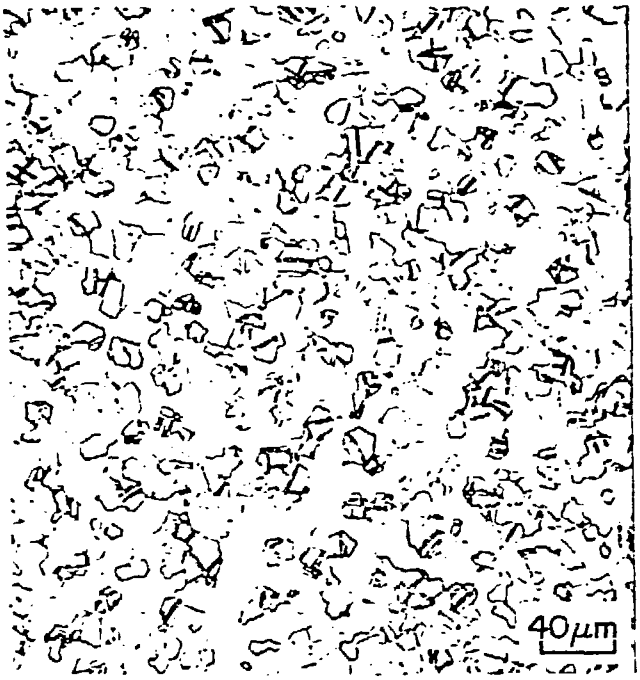
SINTERING STUDIES SHOW THAT VERY DENSE MICROSPHERES CAN BE PRODUCED BY THE SOL-GEL PROCESS



$\underline{UO_2}$

ETCHED POLISHED SECTION

DENSITY = 99.7% T.D.
SINTERING TEMP. 1450°C

$\underline{ThO_2}$

FRACTURE SURFACE

DENSITY = 99.6% T.D.
SINTERING TEMP. 1450°C

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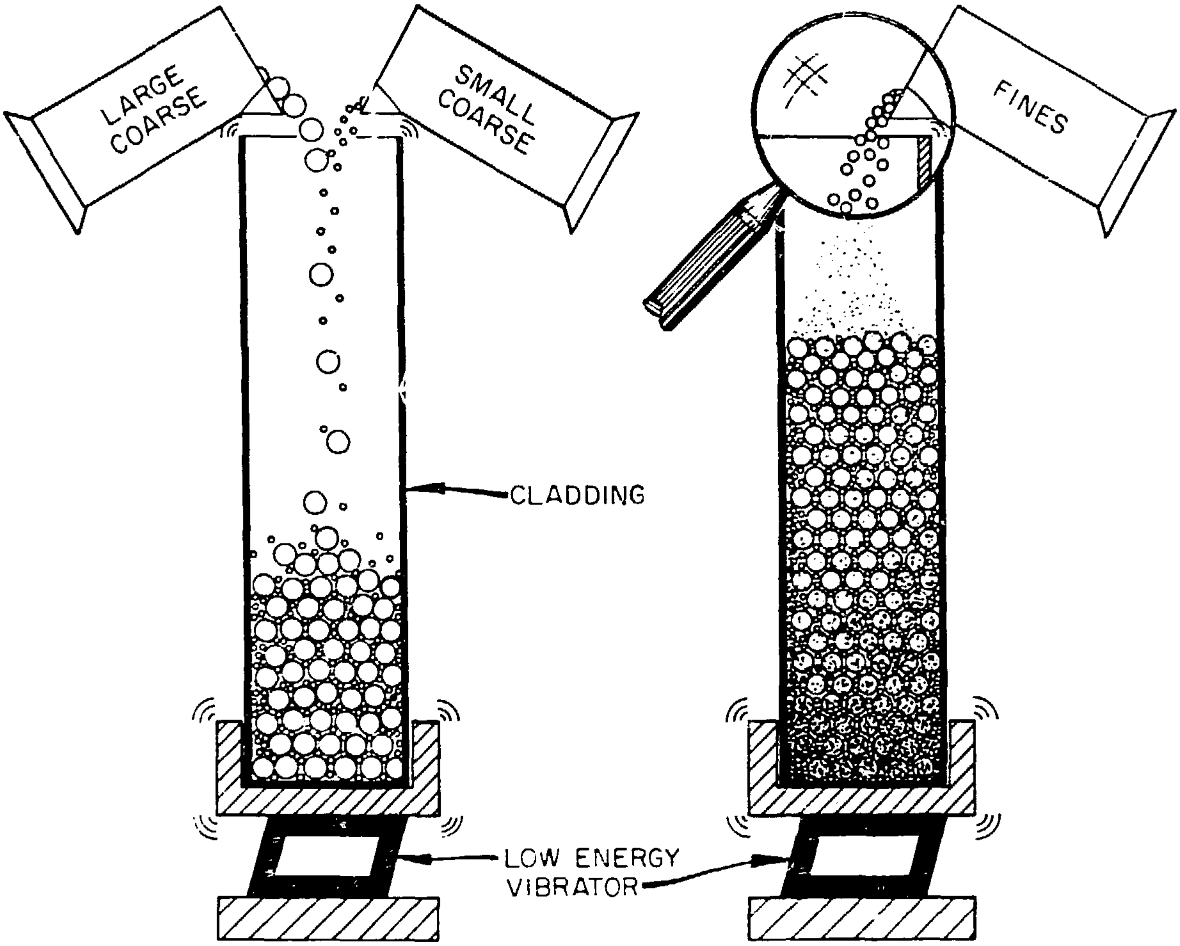
IN THE SPHERE-PAC PROCESS,
LOW ENERGY VIBRATION CAUSES FUEL MICROSPHERES
TO ASSUME A HIGH DENSITY CONFIGURATION



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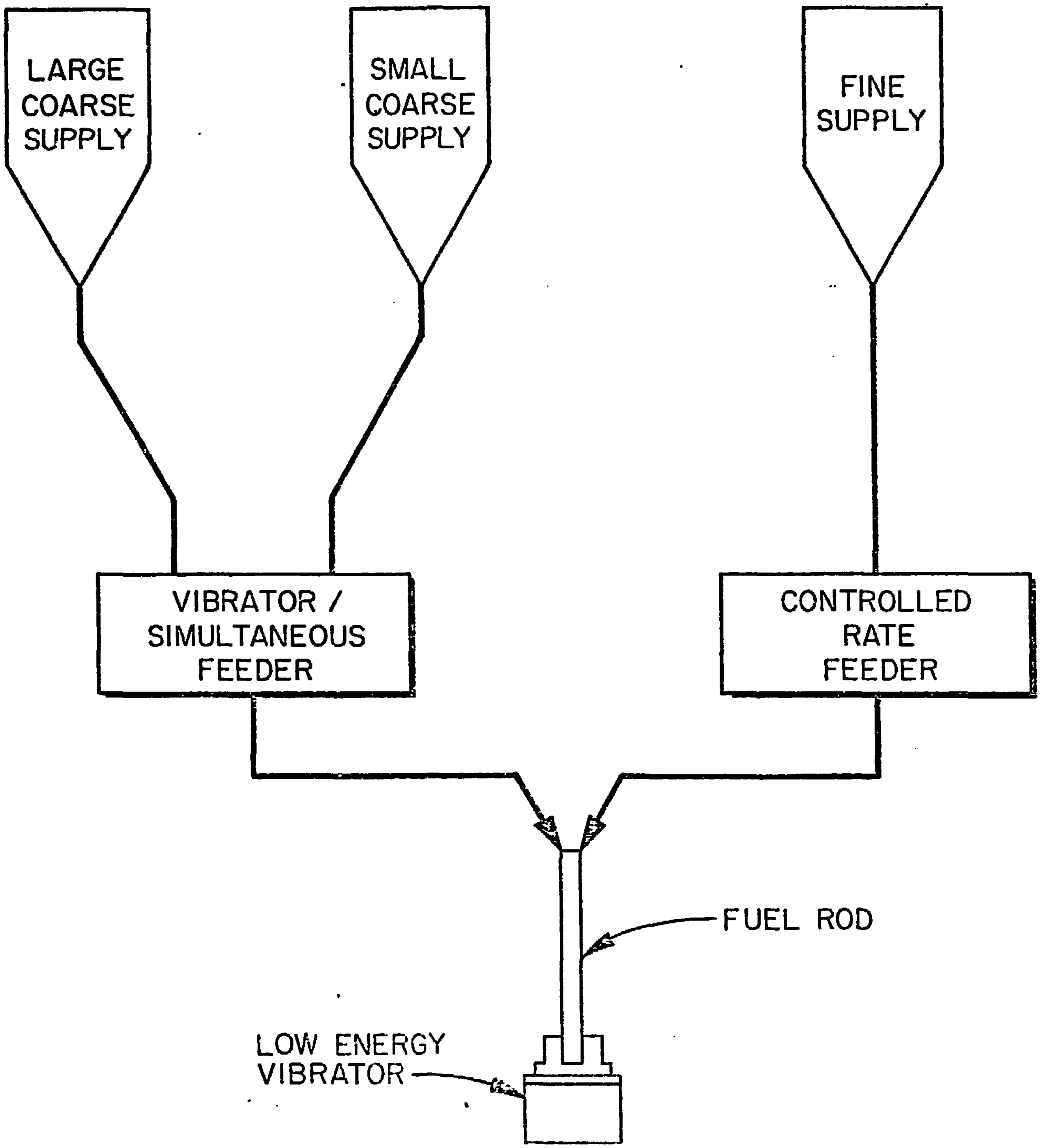
SPHERE-PAC LOADING REQUIRES A VERY SIMPLE EQUIPMENT CONFIGURATION



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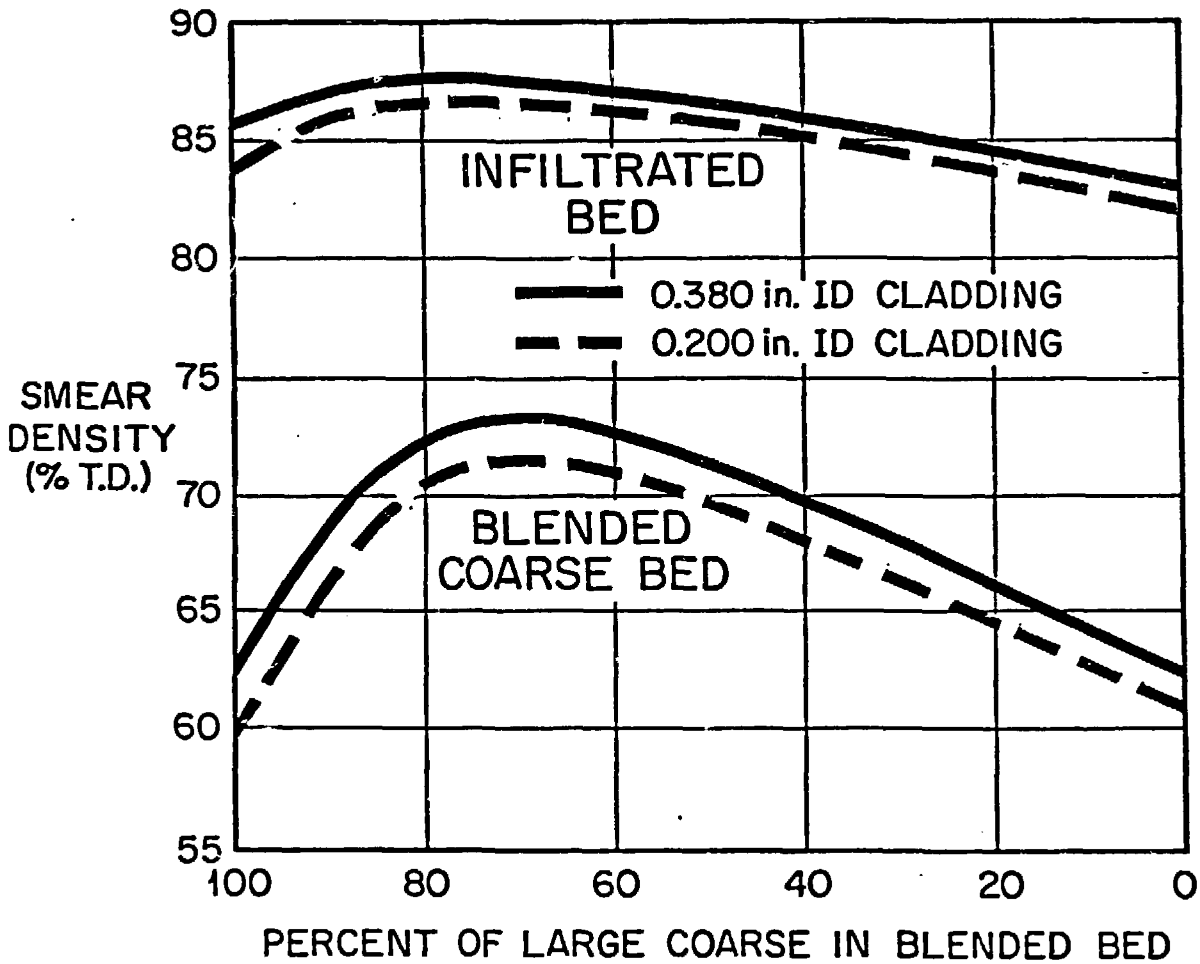
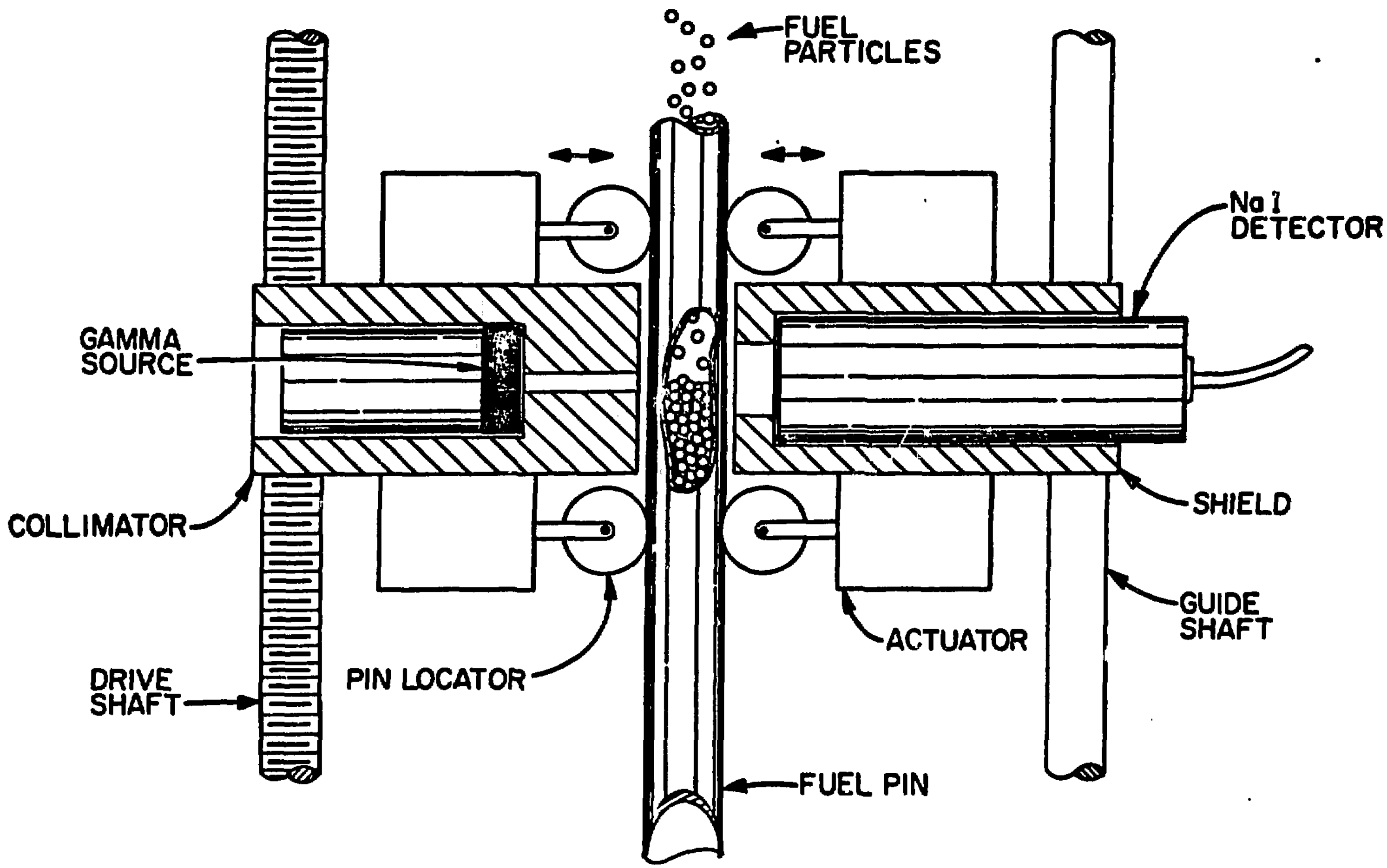
USE OF TWO SIZES OF COARSE SPHERES PRODUCES HIGHER DENSITY



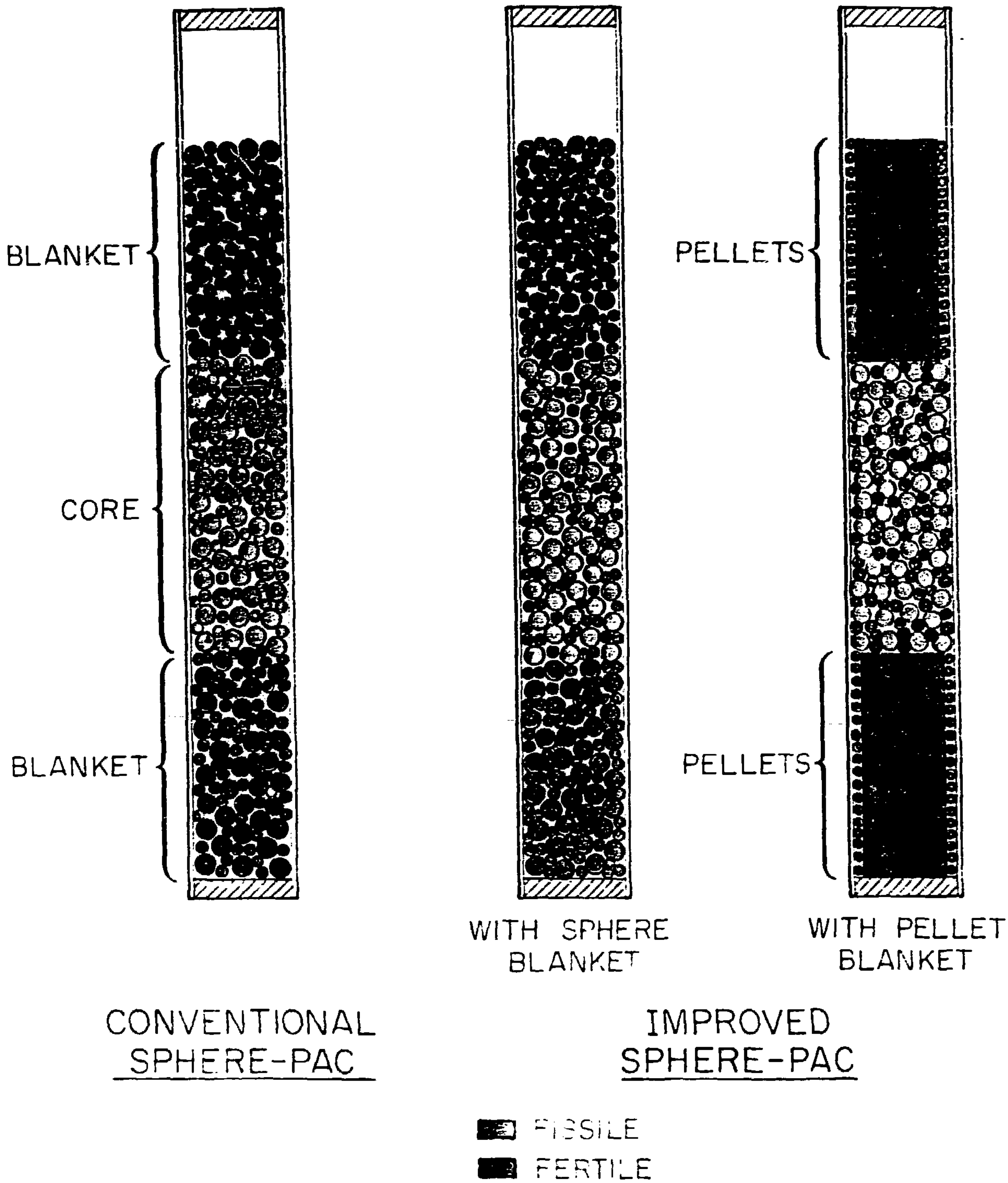
ORNL-DWG 78-3548

GAMMA DENSITOMETER PROVIDES INSPECTION DATA PLUS CONTROL FEEDBACK FOR ROD LOADING



ORNL-DWG 77-10014

BY NOT HAVING FISSILE IN THE FINE MICROSPHERES, TWO IMPROVED SPHERE-PAC PROCESSES ARE POSSIBLE



MUCH TECHNOLOGY HAS ALREADY BEEN DEVELOPED FOR FABRICATING SPHERE-PAC FUEL

- HIGH SPEED PNEUMATIC CONVEYING
- SAMPLING ON ONE PART IN 2^{10} BY GRAVITY FLOW
- PRECISE VOLUMETRIC DISPENSING
- SHAPE SEPARATION
- SCREENING
- AUTOMATED ANALYSIS OF PARTICLE SIZE DISTRIBUTION
- RAPID REMOTE ASSAY
- RAPID REMOTE HOMOGENEITY INSPECTION

NEAR TERM ORNL GOALS ARE WELL DEFINED

- IDENTIFY SOL-GEL FLOWSHEET
- LOAD LONG RODS TO FFTF REFERENCE SMEAR DENSITY
- ADVANCE LOADING PROCESS BEYOND MANUAL MODE
- PROVIDE PROCESS TO EXXON FOR FABRICATION OF UO_2 LWR IRRADIATION TEST PINS

SOL-GEL SPHERE-PAC APPEARS ATTRACTIVE FOR BREEDER REACTOR FUEL FABRICATION

- POTENTIAL FABRICATION AND PERFORMANCE ADVANTAGES
- AMENABLE TO REMOTE OPERATION
- ATTRACTIVE FOR SPIKED FUEL
- PROVIDES ADEQUATE SMEAR DENSITY