LOW ENRICHMENT FUEL DEVELOPMENT AT INEL

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INTRODUCTION

EG&G Idaho, Inc. is under contract to the Department of Energy to operate the Idaho National Engineering Laboratory (INEL). The INEL is located in southeastern Idaho. This facility has been operating since 1949 and was originally called the National Reactor Testing Station. Several contractors manage projects on this facility.

Most projects at INEL are concerned with either reactor safety or irradiation testing. At Test Area North, for example, experiments are being conducted on the effects of loss of coolant. At the Test Reactor Area the ATR (Advanced Test Reactor) and ETR (Engineering Test Reactor) are used for irradiation testing and, of course, those of you working at Argonne will recognize the Experimental Breeder Reactors I and II.

FACILITY DESCRIPTION

SPERT IV, where a facility has been established for making low-enriched uranium aluminide mini-plates, is located near the Power Burst Facility as shown in Fig. 1. SPERT is an acronym for Special Power Excursion Reactor Test. A part of this former reactor facility has been converted into a fuel fabrication laboratory facility.

The floor plan for the SPERT IV facility is shown in Fig. 2. The reactor tanks are still in place, but they are due to be removed during December.

The fuel fabrication laboratory is located in the upper left hand corner of the building as shown in Fig. 2. A powder line will be installed in the corner room, that location being selected primarily because it has a warm drain. Next to the powder line is a compactor, which is in a closed-off portion of the high-bay area. Plate rolling and additional processing are done in the plate fabrication room. The flow of materials is from the powder line through the compactor, to compact assembly, plate rolling and final shearing. Fig. 3 shows the layout of the equipment. This equipment is all in place and hooked up, and is ready to operate, except for some exhaust duct work.

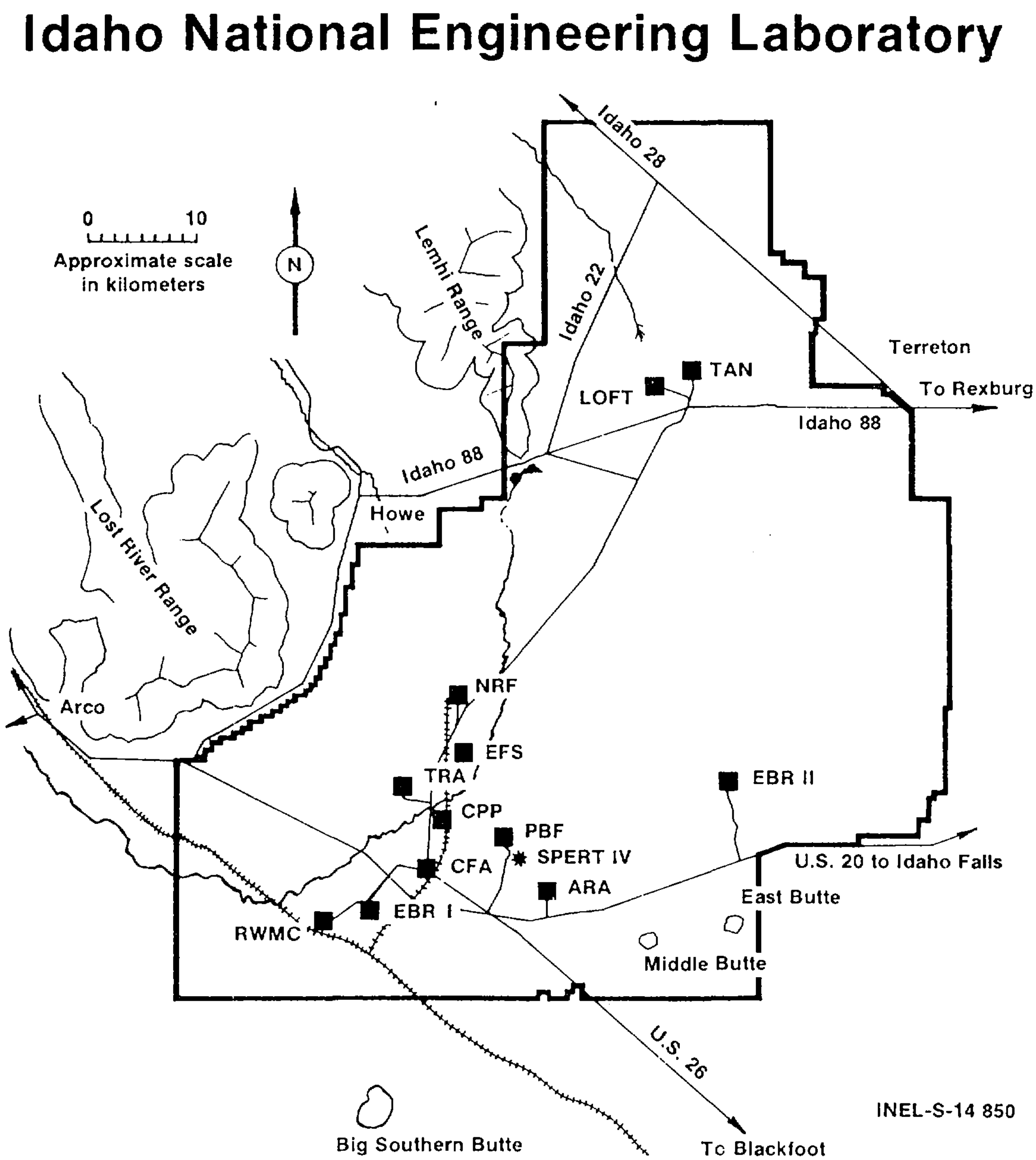

Idaho National Engineering Laboratory
0
10
Approximate scale
in kilometers
N
Idaho 28
Lemhi Range
Idaho 22
Terreton
To Rexburg
TAN
LOFT
Idaho 88
Idaho 88
Howe
Lost River Range
Arco
NRF
EFS
TRA
CPP
PBF
SPERT IV
CFA
ARA
EBR I
RWMC
EBR II
U.S. 20 to Idaho Falls
East Butte
Middle Butte
U.S. 26
INEL-S-14 850
Big Southern Butte
To Blackfoot

Fig. 1.

SPERT-IV Floor Plan

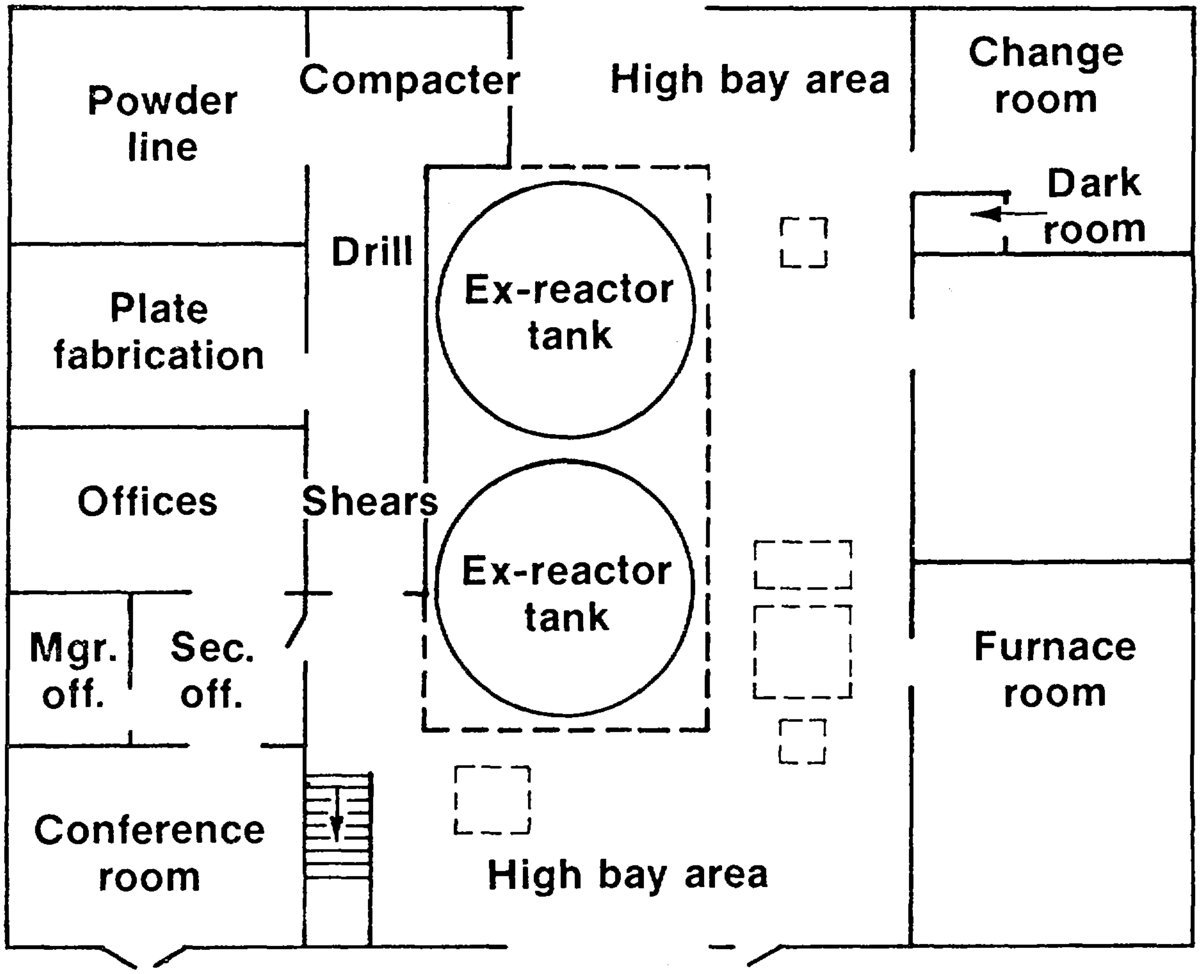
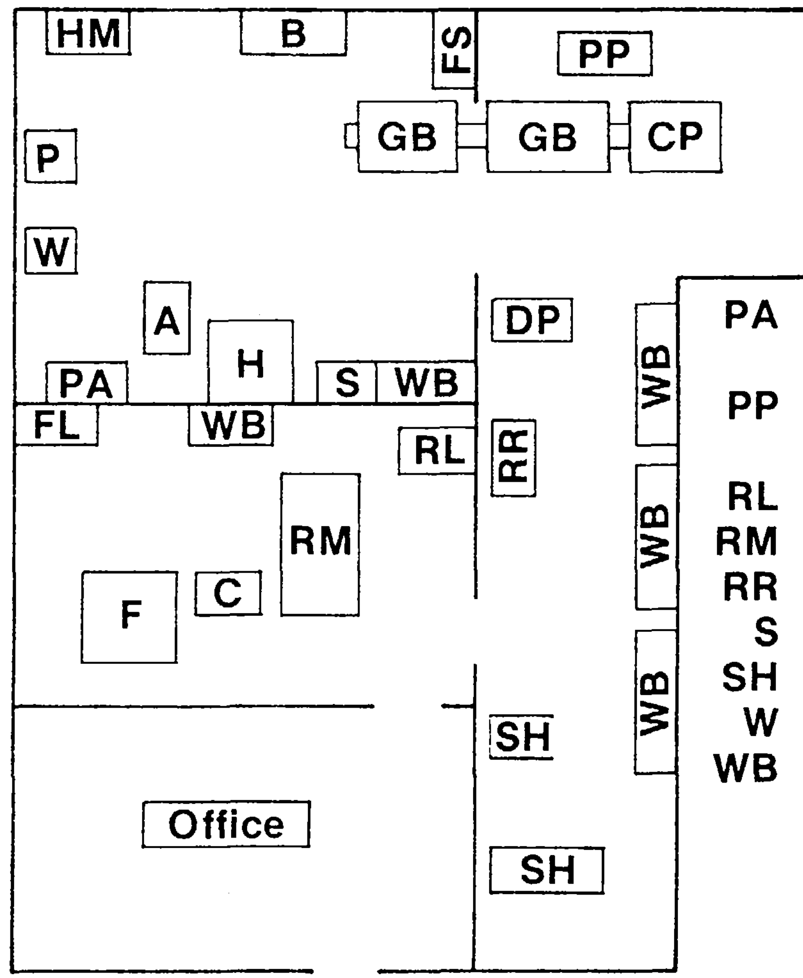


Fig. 2.

Fuel Development Laboratory

A = Arc furnace
B = Balances
C = Controls
CP = Compacting press
DP = Drill press
F = Furnace
FL = Fluoroscope
FS = Fuel storage
GB = Glove box
H = Hood
HM = Hammer mill
P = Hydraulic press



PA = Power supply for arc furnace
PP = Power supply for hydraulic press
RL = Roller leveler
RM = Rolling mill
RR = Roll rack
S = Sink
SH = Shear
W = Welder
WB = Work bench

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Fig. 3.

PROCESS DESCRIPTION

At SPERT IV a miniature fabrication faciity has been set up to duplicate the aluminide plate fuel processing line at Atomics International. In other words, a model of the supplier's processing has been created, so that whatever process changes are developed here can then be scaled up to production.

As shown in Fig. 4, the aluminum and uranium are weighed in proper portions, which are slightly less than 74 wt % uranium, the stoichiometric amount. They are then charged into an arc furnace and melted to form buttons. The button is passed through the crusher, which is enclosed so that the crushing process can be conducted in an argon atmosphere. The powder is screened and blended in a glove box train. 75% of the blend will consist of materials between 100 and 325 mesh and 25% of the material will be finer than 325 mesh. It is expected that material finer than 325 mesh will be accumulated. Some of the mini-plates will contain 100% -325 mesh fines. After blending, a sample is taken for X-ray diffraction analysis to determine how much of the material is UAl_3.

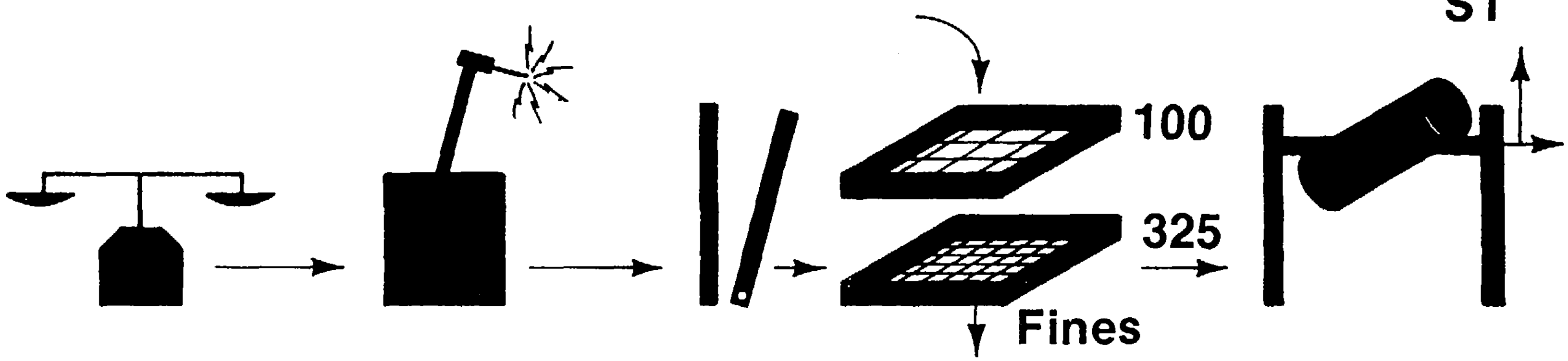
Uranium aluminide and aluminum powders are then weighed out in proper proportions to obtain the desired fuel weight loadings as shown in Fig. 5. The powders are then blended to obtain a uniform fuel distribution. Before compacting, a sample of the blended powders is taken, and analyzed for distribution of the aluminide by SEM or other methods. Verification of distribution is not part of the normal production operation, but because of the concern for getting a uniform distribution of the fuel in the highly loaded core, this step has been added on a trial basis.

After analysis the powder will be compressed into a compact, the compact will be placed in a picture frame, the covers applied, and riveted in place. As shown in Fig. 3, the glove train and the compacting press are close to each other, and between the glove box train and compacting press is a conduit or elevator which permits the transfer of the powder into the compacting die while maintaining an enclosure.

Multiple plate assemblies will be made as shown in Fig. 6. The cover plates and the picture frames will be Alclad 6061 aluminum. Better bonding is achieved between the 1100 surfaces than 6061 surfaces with this practice. Fig. 6 shows that a reduction of 8:1 in the thickness will be achieved, and that translates to an extension of about 8:1 in the longitudinal direction. How much expansion there will be in the width direction with the highly loaded fuel is not known and is one of the concerns.

As shown in Fig. 7, hot rolling is performed not as a one-step operation, but as an operation involving many repeated steps. It will be part of this investigation to determine how many passes are required, and the incremental reduction with each pass. As the UAl_x loading is increased to bring the ^{235}U content up to a useful level, it may be necessary to double or treble the number of passes because of smaller incremental reductions with each pass. The temperature used in the hot rolling process remains to be determined; 500°C may not be adequate. It may be necessary to roll at a slightly higher temperature.

Making UAl_x Powder



1. Weighing U & Al
2. Arc melting
3. Crushing
4. Screening
5. Blending

1. Weigh 7 parts U to 3 parts Al to produce UAl_3
2. Arc melt button 5 to 7 times to make homogeneous
3. Crush in argon atmosphere
4. Recyle all + 100 mesh through crusher
5. Blend 75%-100/+325 and 25%-325 mesh

S1. Sample for x-ray diffraction analysis

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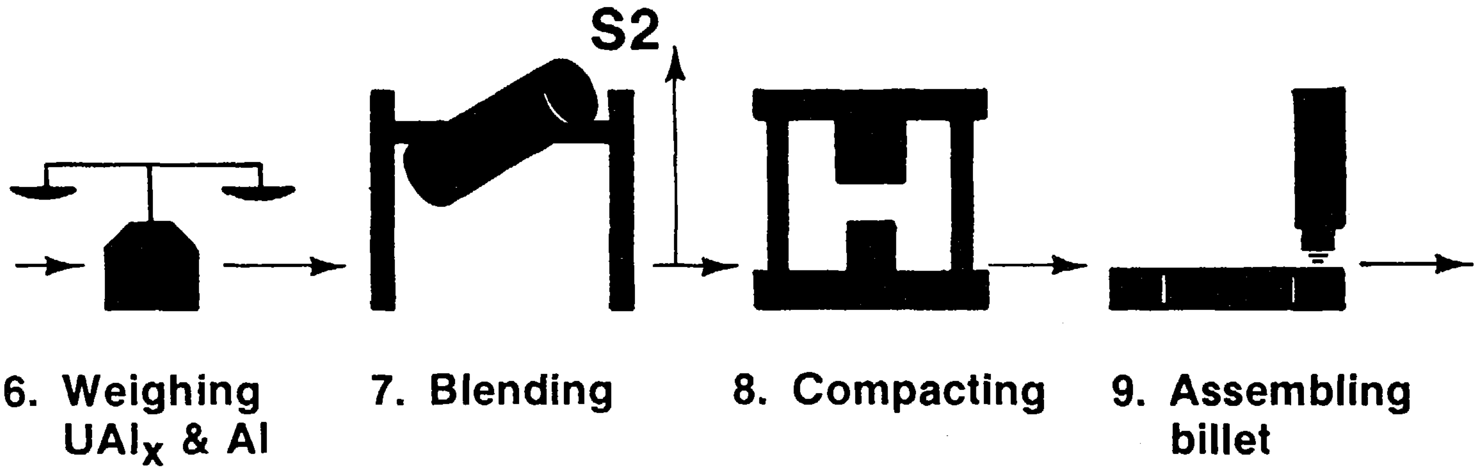
Fig. 4.

Making Compact for Fuel Core



6. Weigh proportionate amounts of UAl_x and Al

7. Blend to obtain uniform mix for core

S2. Sample for distribution analysis by SEM

8. Compress core

9. Place core in picture frame, cover, drill and install rivets

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Fig. 5.

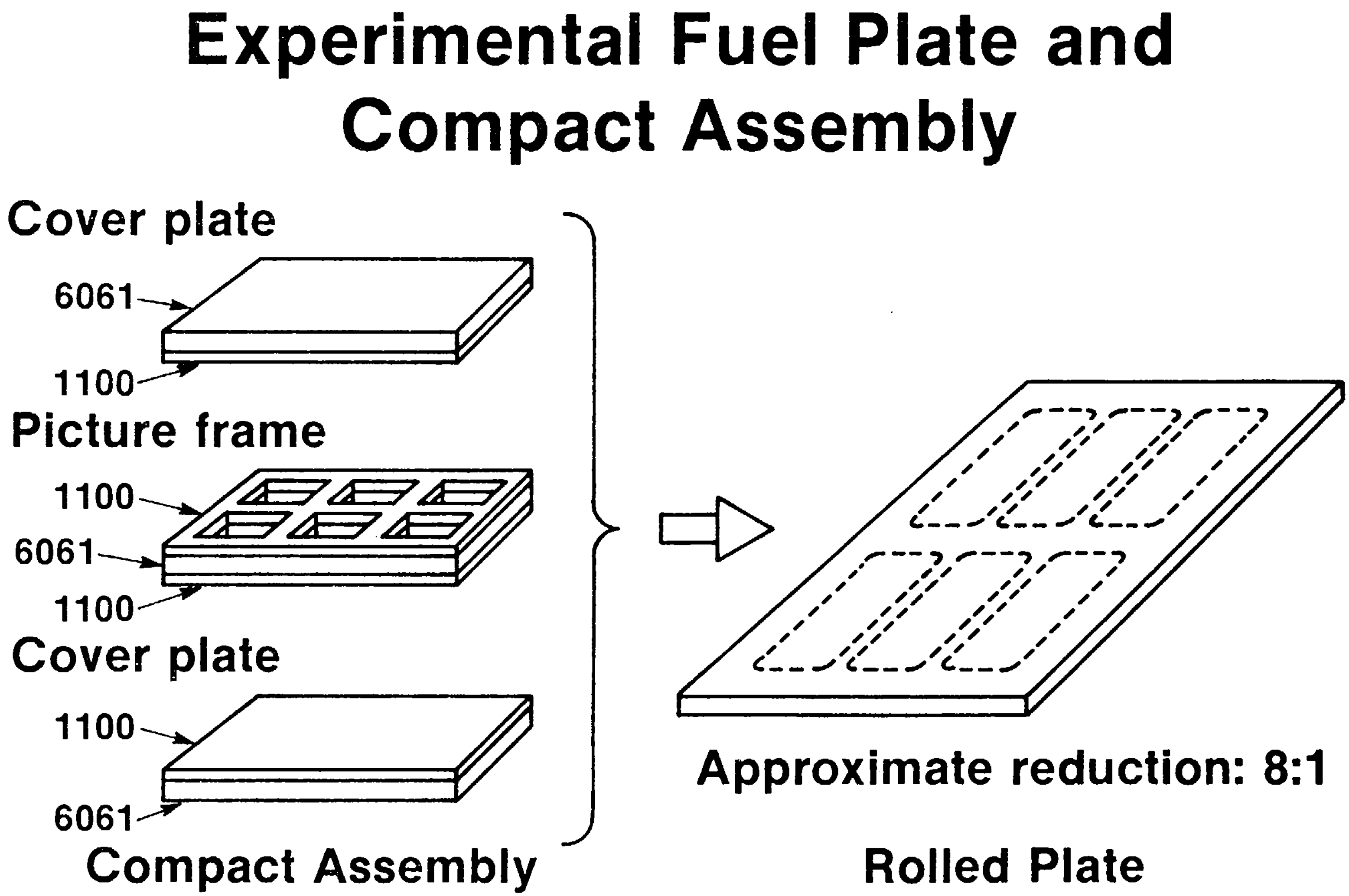
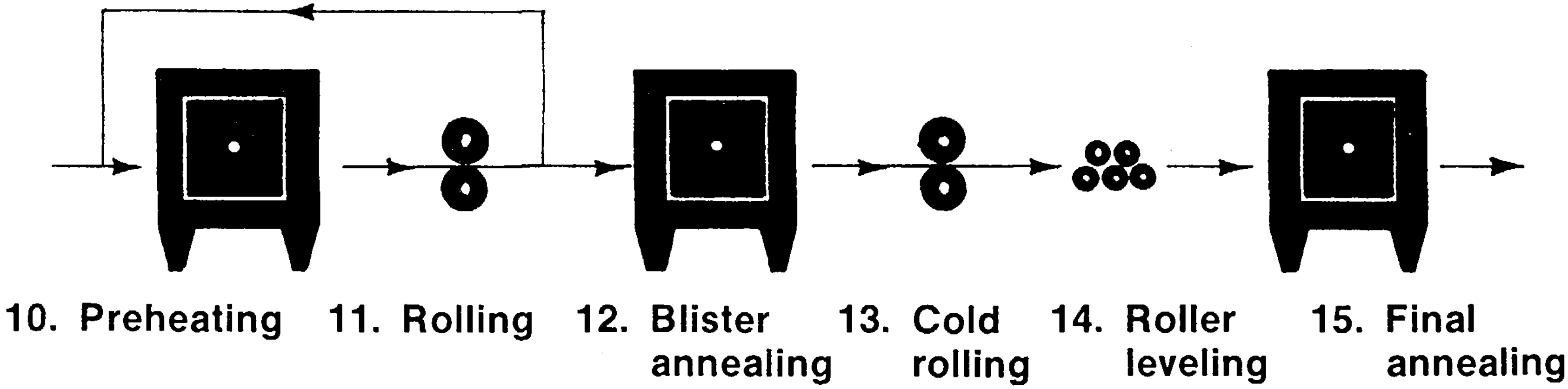

Experimental Fuel Plate and
Compact Assembly
Cover plate
6061
1100
Picture frame
1100
6061
1100
Cover plate
1100
6061
Compact Assembly
Approximate reduction: 8:1
Rolled Plate

Fig. 6.

Making and Testing Plate
Part A



10-11. Preheat and roll repeatedly for 8:1 reduction

12. Blister anneal for about 1 hour for bond integrity test

13. Roll to final dimension, preheat not required

14. Straighten in roller leveler

15. Stress reliever at about 623 K (optional)

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Fig. 7.

A one-hour blister anneal will then be conducted at 500°C. After blister annealing, the plates are cold rolled to final thickness and roller leveled. The stress relief anneal after the roller leveling is optional. This step may be included to see what effect the stress relief anneal would have on heavily loaded plates.

INSPECTION AND TESTING

After rolling, the plate will then be radiographically inspected as shown in Fig. 8 to locate the core, and at a later point in time the uniformity distribution in the core meat will be checked by radiography. After locating the cores we will then separate the mini-plates and trim them to final dimensions with shares. Ultrasonic testing is then performed to check for bond integrity and density measurements to determine the voidage. Finally, metallurgical samples will be obtained for destructive analysis.

After completing these steps there is a step that was inadvertently omitted from Fig. 8, namely, the Min-clad gauge scanning of the mini-plates for thin cladding. Min-clad scanning is basically a variation in ultrasonic inspection wherein an indication is made on a trace when the cladding in that area is below a set level. After Min-clad scanning the plates go to Oak Ridge for installation in the ORR irradiation train.

Producibility testing that will be conducted at the INEL and at Atomics International includes the following. Most of these steps are routine for production; the remainder are for control evaluations.

INEL:

1) X-ray diffraction analysis to determine comparative amount of UAl_3.

2) SEM examination to check uniformity of UAl_x distribution in core powder.

3) Radiography to determine core location and uniformity of fuel distribution, and to detect fuel flakes in the picture frame area.

4) Blister testing to determine bond integrity.

5) Density measurements to estimate voidage.

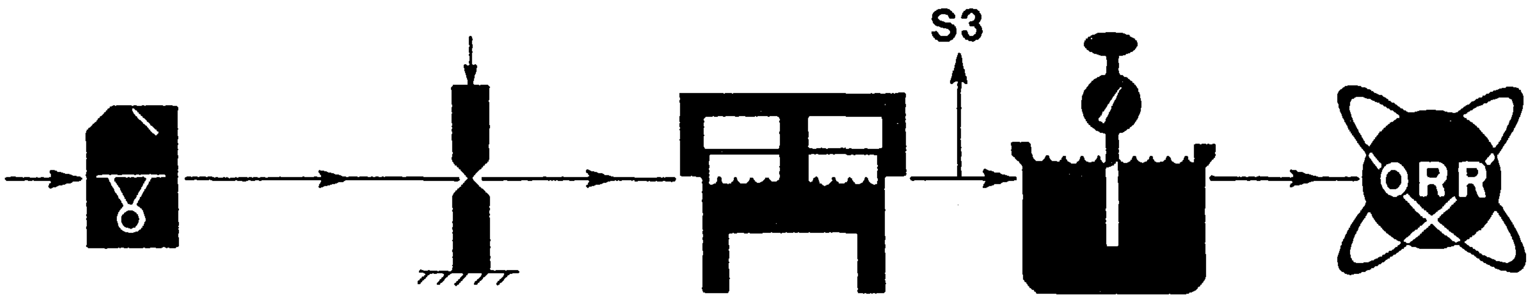
6) Ultrasonic inspection to determine bond integrity.

7) Metallurgical examination for core thickness and uniformity; also bond integrity.

ATOMICS INTERNATIONAL:

8) Min-clad gauge check for thin spots in cladding in INEL plates.

Making and Testing Plate
Part B



16. Radiography 17. Shearing 18. Ultrasonic testing 19. Density 20. Irradiation testing

16. Locate core and check density uniformity (radiography)
17. Separate individual plates and cut to final dimension
18. Ultrasonically test all plates for bond integrity
19. Estimate voidage in core
20. Subject plate samples and experimental element to reactor environment (ORR) for performance evaluation

Fig. 8.

After irradiation testing and performance evaluation in the ORR, the plates will come back to the INEL for a postirradiation examination, which will include, but may not be limited to:

1) A density measurement to determine the extent of swelling (increased voidage).

2) A gamma scan to determine possible effects of flux peaking due to nonuniform distribution of the uranium.

3) Blister testing to determine the threshold temperature at which the fission product gases will begin to collect.

4) Milling the plates down in increments to determine the extent of uranium penetration into the cladding, particularly in thin areas.

5) Metallographic examination to determine penetration of fuel into the cladding.

The miniature plate producibility studies will be performed at the INEL, the irradiation testing at Oak Ridge and the postirradiation examination at the INEL. The University of Michigan element design has been tentatively selected as typical for reduction to practice. An element similar to the Michigan element will be produced at AI and irradiation tested. The postirradiation examination steps for the element have not yet been completely defined; there are some tests in the postirradiation examination of the mini-plates that may not be included in the postirradiation examination of the element. The main concern here is the extent of swelling in the element plates. In that regard, some effort will be made to monitor swelling during irradiation.

DISCUSSION

FERADAY (Atomic Energy of Canada): What are the typical dimensions of the final plates that you produce, particularly the fuel meat thickness?

NEWTON: The fuel meat thickness will vary. The overall thickness of the plate will be 60 mils. This is an experimental plate that we are developing at INEL, and to keep the cladding thickness respectable we are going to try and keep the cladding thickness minimum to 10 mils. The length will be that of the mini-plate - not the assembly, but just an individual plate out of the assembly which would be approximately 4 1/2 in. long. The width would be about 1 3/4 in. and the overall plate thickness will be 60 mils, that is what we have tentatively selected. We are still working on finalizing the design for the irradiation specimen (mini-plate) dimensions.

SCHLAPPER (U. of Missouri): You mentioned doing gamma spectrum analysis for burnup profiles and you didn't discuss doing any chemical determinations. It was our experience with the destructive analysis of our element that in order to convince some of the regulatory bodies of the actual power peaking numbers that a chemical analysis was really required. Do you plan to institute a chemical burnup?

NEWTON: Yes, I would do whatever is necessary to get a valid indication on the gamma analysis.

LEONARD (IRM): In the irradiations in the ORR reactor, what total nvt do you plan for your test specimens and do you plan to test for destruction of the assemblies?

STAHL (ANL): The average burnup expected would be 30 atom percent of the enriched material; however, this is for normal operation. For the mini-plate irradiation we would go to at least 50 atom percent burnup of the ^{235}U in order to go beyond those conditions that would be expected in the plate fuels themselves.

SCHLAPPER: Again, the burnup limits that have been set for us have been on peak fission density or fission/cm^3. Can you put that wt % burnup into a fission/cm^3 number?

STAHL: I seem to recall that it would be about 8×10^{20} fission/cm^3. I can confirm that later on.[a]

SCHLAPPER: We currently operate our fuel to 1.8×10^{21} fission/cm^3. The ATR is now going to 2.2×10^{21} fissions/cm^3, so I would suggest in the development program the burnup be extended somewhat.

[a] The burnup range will be $1.5\text{-}2.0 \times 10^{21}$ fissions/cm^3.