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Argonne National Laboratory

A COST ESTIMATE FOR REMOTE REFABRICATION OF METALLIC FUELS

by

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Metallurgy Division

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ABSTRACT

This report describes procedures used to estimate the cost of refabrication of two typical cases of metal fast-reactor fuels. The estimate is extrapolated from the EBR-II process of close-cycle fuel reprocessing followed by fuel refabrication. A computer program was used to produce refabrication costs against variations in plant throughput and fuel and/or blanket diameter and length. It was found that refabrication costs are particularly sensitive to equipment use factor and fuel- or blanket-pin diameter. The greatest contribution to refabrication cost results from the cost of jacket material. The study is of value as a contributing factor necessary to optimize the cost of reactor system operation.

INTRODUCTION

Recently, fast breeder reactors have received considerable attention,[1-5] reflecting a national interest[6] in such systems. A significant contribution of ANL is Experimental Breeder Reactor-II (EBR-II).

EBR-II and its close-coupled Fuel Cycle Facility afford an opportunity to establish a unique fuel-cycle technology. However, the development of such a technology is desirable only insofar as motivation exists. One of the prime movers of development is economic advantage. This study of the cost of refabrication of metal fuels for fast breeder reactors is intended as a contribution to the economics of reactor systems.

OBJECTIVES

The principal objective of this work is to provide a method by which one may estimate the cost of fabrication of metallic fuels manufactured by well-developed, remote-handling methods. The secondary objectives are manifold, and among them are the: (1) determination of the contribution of the several process variables to the cost of fuel refabrication, (2) resolution of the effect of some fuel-element design variables upon refabrication cost, and (3) provision of costing data for specific design studies.[7]

FABRICATION PROCESS

The process upon which this estimation procedure is based is short-cycle fuel reprocessing of the pyrochemical variety, followed by fuel refabrication.[8,9] The fuel cycle is assumed to be at equilibrium state, and the fuel is in a conventional jacketed-rod form. Two fuel subassembly designs are considered One design is the segregated case in which the fuel and blanket are separately jacketed and assembled An example of the segregated case is the EBR-II Core I design as shown in Fig. 1.

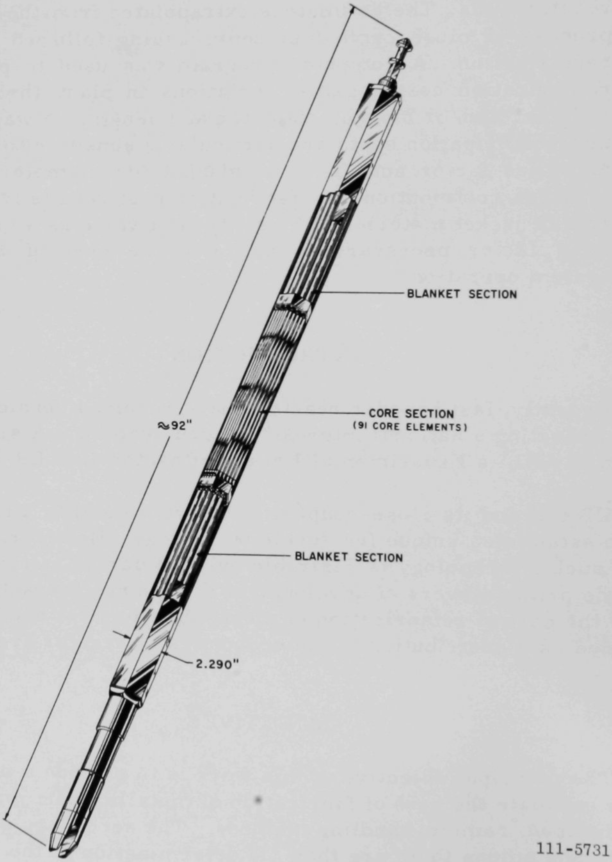

Fig. 1. EBR-II Core Subassembly

The second design is the integrated case where the fuel and blanket occupy the same jacket. The proposed core element of a 1000-MWe fast reactor[7] shown in Fig. 2 is an example of the integrated case.

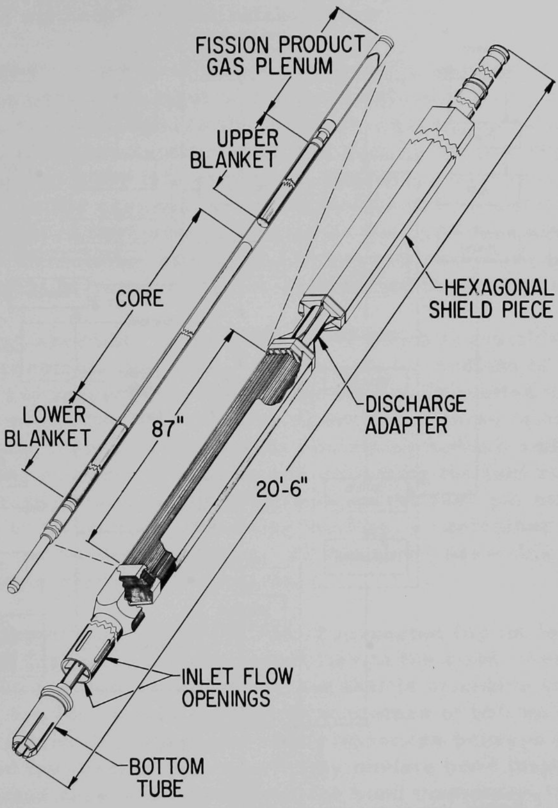

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Fig. 2. 1000-MWe Metal-fuel Reactor Subassembly

The point of departure for the generation of cost-estimation data was the EBR-II refabrication process for which many values are becoming known. Among the knowns for the system are the capacity and capital cost of each unit of in-cell process equipment, the cost of cell space, and the cost of installation of process equipment and auxiliaries. The experience gained in the fabrication of about one and one-half loadings for EBR-II[10-12] and the recent operations of the fuel-cycle facility upon irradiated fuels contributed another series of facts for the bases of this study. Fabrication experience provided knowledge of acceptance factors from each processing step, man-hour requirements for each operation in the process, processing rates for each operation, and inspection requirements.

A flow diagram of the metal-fuel refabrication process is shown as Fig. 3. The process flow and unit operation are generally the same for the manufacture of segregated or integrated subassemblies All the

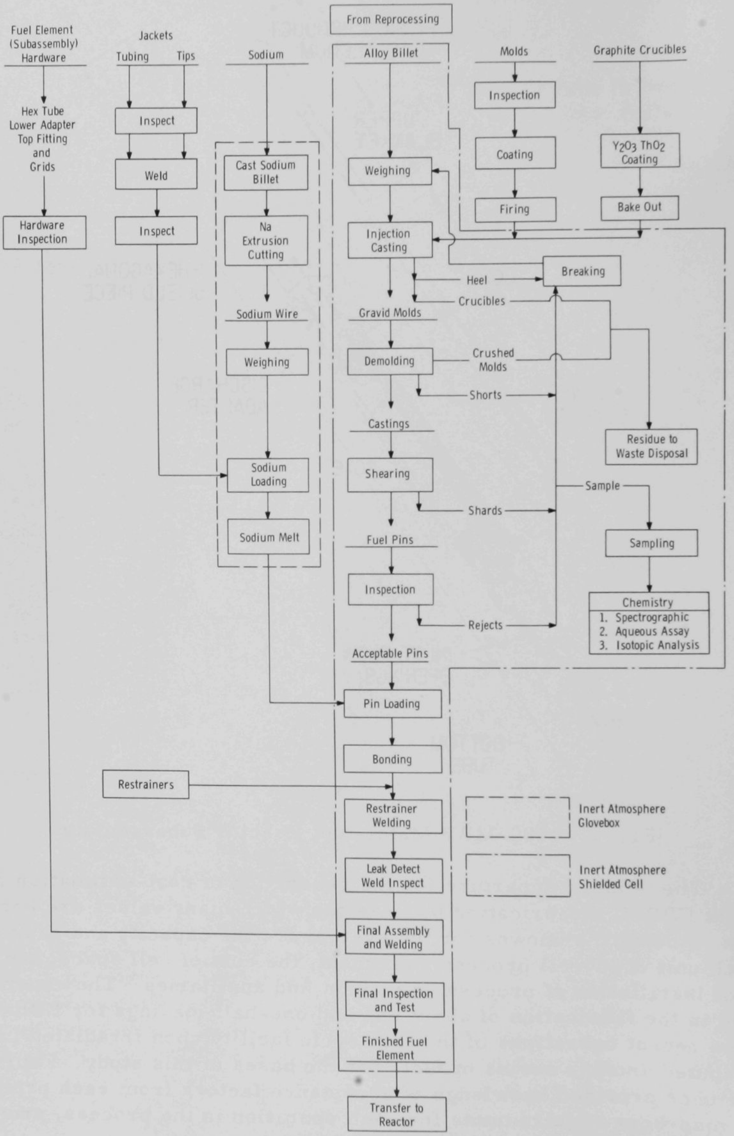


Fig. 3. Flow Diagram of Metal-fuel Refabrication Process

out-of-cell operations such as tubing cutting, inspection, and welding, and subassembly hardware inspection are standard and assume no undeveloped equipment or machinery. In-cell operations are based upon developed remote-control methods[13] of fuel refabrication.

Feed for the refabrication operation is the product of pyrochemical refining and consists of an ingot of reprocessed fuel alloy. The ingot is weighed before being charged to the injection-casting operation.[14,15] The casting method produces semifinished fuel pins by the use of gas pressure to force molten fuel alloy into evacuated, precision-bore molds. The molds are stripped from the castings, and the castings are cropped to proper length. Inspection of the finished fuel pin is the final operation before fuel-rod assembly. Demolding, sizing, and inspection have been more highly refined than would be required for an established production capability.[16]

Fuel-rod assembly is the process by which acceptable fuel pins are converted to acceptable fuel rods.[17] In this phase, sodium is loaded into preassembled and inspected jackets. The sodium is melted and settled into the fuel tubes, which are then introduced into the remote facility. Acceptable fuel pins are placed in the jackets containing sodium and are then bonded. Bonding consists of heating and impacting the fuel rod until a continuous annulus of sodium is achieved between the fuel-pin exterior and the inside surface of the jacket. Following bonding, a restrainer is inserted into the jacket and welded into place. At this time, assembly is complete and the fuel rod is ready for inspection.

A completed fuel or blanket rod is inspected for its leak-tight integrity and may be inspected for discontinuities in the bond. Leak testing is accomplished by a pressure-decay method that is sensitive to leakage of approximately 5×10^{-6} standard cubic centimeters of helium per second.[18] The tendency toward providing generous clearances between fuel pin and jacket to extend fuel burnup potential[19] may obviate bond inspection. However, if it is found necessary to inspect for bond continuity, the technology to do so exists.[17]

The final refabrication operation is subassembly construction, in which acceptable fuel and/or blanket rods are assembled into core or blanket elements.[20] In this operation, preassembled top sections of fuel-element shroud hardware are placed on an assembly machine jig Fuel rods are loaded onto a grid, which is attached to a preassembled bottom section, until a hexagonal, close-packed, fuel array is achieved. The two sections are then brought together until the fuel array is enclosed by the shroud. The two sections are then welded together, and the assembly is complete. After inspection and testing, the fuel or blanket subassembly is ready for insertion into the reactor.

MATHEMATICAL REPRESENTATION

Refabrication costs are estimated through the medium of a computer program. The programming information of the refabrication process is characterized by more than 100 different equations containing more than 200 variables. The appendixes of this report contain the computer program for the segregated case and a glossary identifying the variables. Fixed-value input data consist of such items as the capital cost of equipment of the EBR-II type, amortization life of equipment, machine production capacities, process-acceptance factors, density and cost of jacket alloys, and void space in the fuel-jacket system. Independent variables imposed upon the computer program are length and diameter of fuel and/or blanket, and fuel throughput rate. Many dependent variables such as number of fuel rods throughput, jacket thickness, length and diameter of jackets and subassembly hardware, and process multipliers are arbitrarily related to the independent variables by the use of algebraic expressions.

Three types of multipliers are used to compensate for the effects of changing fuel-pin dimensions, numbers of processing units required, and chronological time on the capital cost of processing equipment: (1) a volume and time multiplier, which is an estimate of the change in capital equipment cost with chronological time and numbers of processing units required; (2) a cost multiplier, which is an estimate of the change in capital equipment cost with changes in length and diameter of fuel pins; and (3) a rate multiplier, which is an estimate of the change of processing rate with changes in length and diameter of the fuel pin. The capital cost of equipment for each operation is modified by at least one of the multipliers.

Rate multipliers, denoted by a prefix AMR, influence the numbers of mold coating, jacket eddy-current, diameter gauging, and end-fitting welding units required by the process. The magnitude of the influence has been determined by the estimates of personnel experienced in each operation. Volume and time multipliers have been applied to all mechanical operations. These multipliers, identified by a prefix AMT, are determined by the equation $AMTxx = 1.15\ ANxxx^{0.8}$, where ANxxx is the number of processing units required to perform a certain operation at a fixed throughput, pin diameter, and pin length. The value 1.15 is an arbitrary multiplier, used to estimate escalation of the cost of processing units over that of the EBR-II case. Since EBR-II equipment costs are based on 1960 prices and the reference case for a 1000-MWe reactor feasibility study[5] was based upon a 1975 economy, a straight-line escalation of 1% per year was assumed. All estimated costs in this report are given for the year 1975 based upon this escalation technique. The exponent 0.8 is an estimating factor, based upon proven engineering practice,[21] which relates cost of process units to plant throughput. The value 0.8 is used instead of 0.6 as a conservative measure. Finally, cost multipliers, identified by the prefix AMC, are determined on the basis of physical changes required on EBR-II size equipment necessary to accommodate a product of different size than the EBR-II pin. The values of cost multipliers are equipment-size oriented and were based upon estimates of required design changes.

Daily charges for five major cost areas are generated by the computation. Daily charges for process equipment are determined by dividing the estimated life of capital equipment (5 years for in-cell equipment, and 15 years for out-of-cell equipment) into the cost of each unit of equipment, and totaling the quotients. Product material costs are totals of the costs of such materials used each day. Direct-labor charges are based upon the numbers of man-hours expended each day in all process operations, multiplied by an average wage of $3.50 per man-hour. An escalation of 15% is applied to wages in order to anticipate 1975 charges. Indirect labor is assumed at 30% of the direct labor required, and this labor is valued at $5.10 per man-hour. Area cost, which is an estimate of the cost of housing the refabrication process, is an extrapolation of the EBR-II case. Area costs are calculated by totaling the in-cell area required for the various processes, multiplying by the adjusted cost of the EBR-II fuel cycle facility per square foot of cell space, and dividing by 10,950 (the number of days in 30 years). Figure 4 is a flow chart of the computer program that was used in the segregated case. The FORTRAN program reads the set of input variables that describe the cost of refabrication. After the data are read, control passes to a nest of six do-loops. The index of the outermost do-loop is used to set the fuel length, of which four are considered. The index of the next do-loop is used to set one of three blanket lengths. Concurrently, the maximum number of blanket rods in the assembly is set. Other do-loop indices set the diameter of the fuel and the corresponding diameters of the blanket. The index of the do-loop that precedes the innermost do-loop is used to set five different throughput values. Finally, the index of the innermost do-loop is used by a "computed go to" statement to select the appropriate equations that describe the fuel, or blanket, or both. The cost per day for refabrication and the cost per kilogram of fuel and/or blanket is generated for 1080 different reactor-fuel subassembly configurations. As by-products of these calculations, each of the 1080 determinations generate such information as numbers of process machines required, numbers of operators required, and numbers and weight of fuel and blanket pins produced.

Five areas of cost are totaled for each fuel/blanket configuration. They are the daily charges for capital equipment, materials, direct labor, building, and indirect personnel. The cost figures are printed along with corresponding Hollerith headings to aid in the interpretation of results. A total of 540 pages are required to present the 1080 determinations. As further help to the reader, 24 pages of summary and "index" are presented where trends in cost and vital physical data for each determination may be found as well as the numbers of the pages displaying more detailed information.

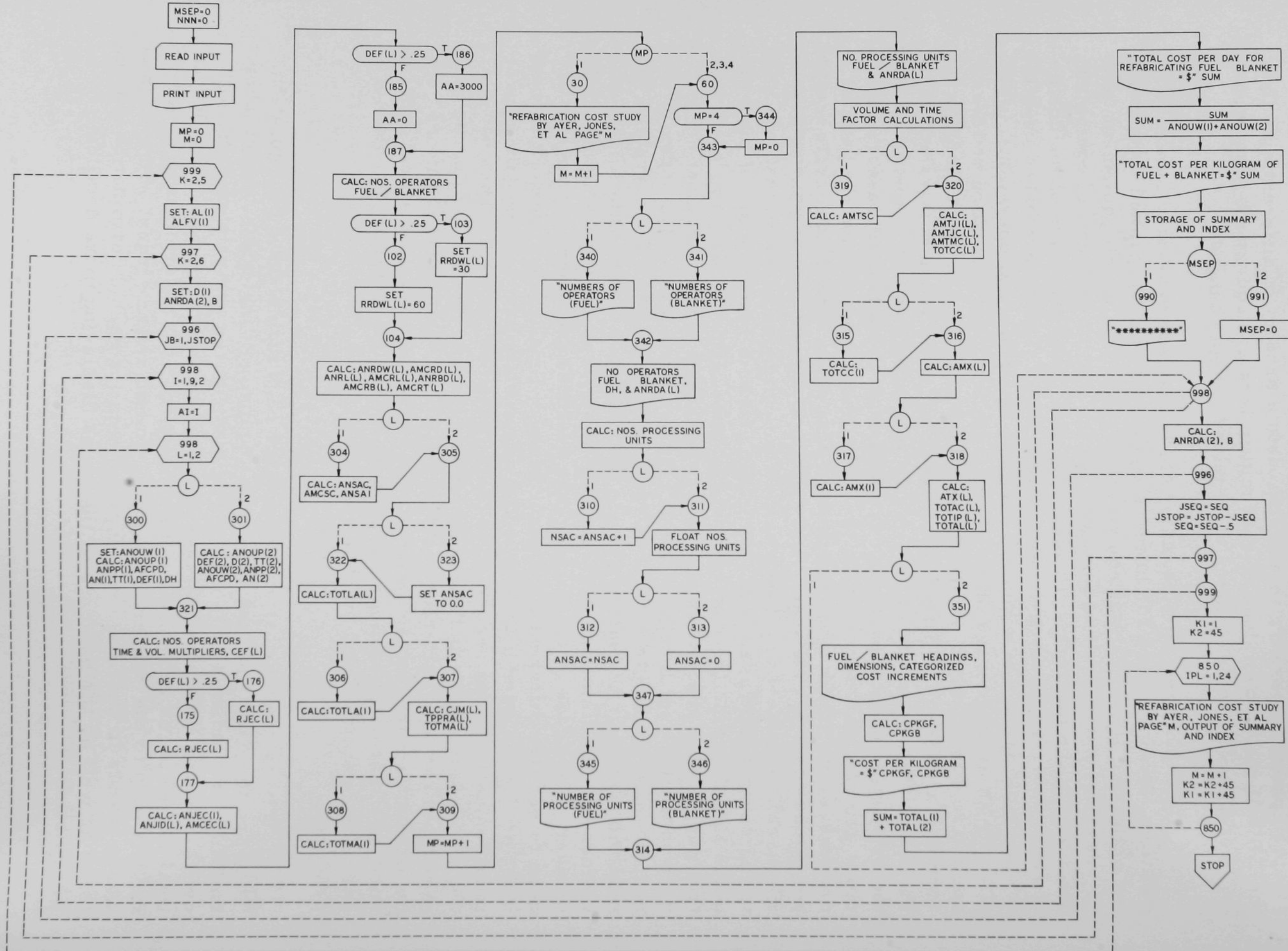
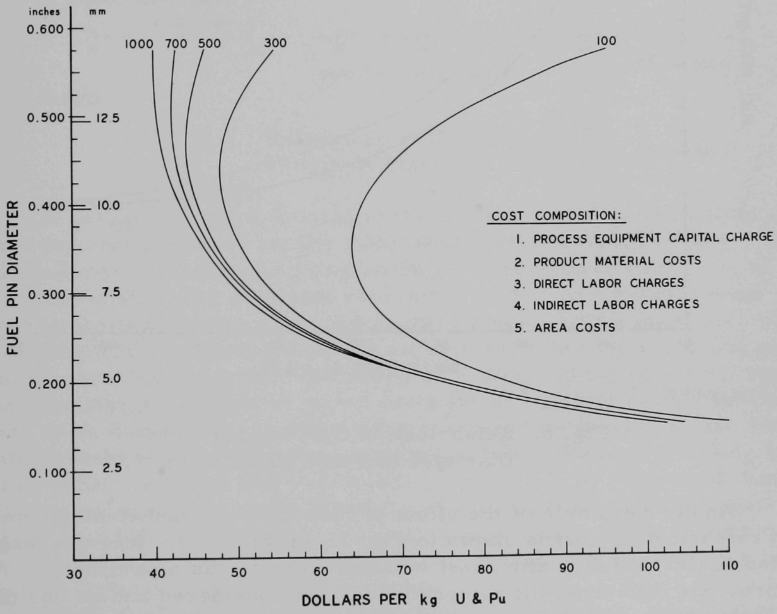


Fig. 4. Flow Chart of Computer Program

RESULTS

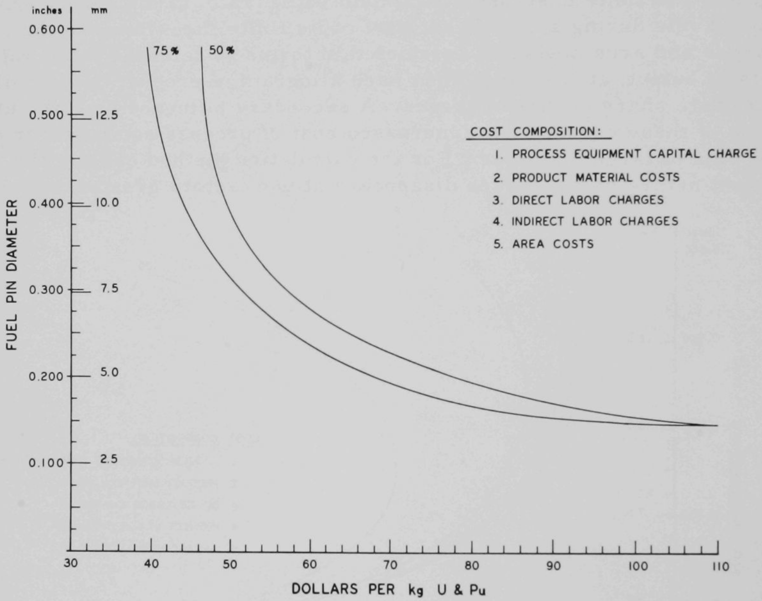
The results of the cost estimates for remote refabrication are shown in the next five figures. All curves are based upon assemblies containing 331 rods in a hexagonal close-packed array. Figure 5 shows the relationship between refabrication cost and fuel-pin diameter for various plant throughputs. The plot is based upon an integrated fuel element with a 90-cm (35.5-in.)-long fuel pin and two 36-cm (14.2-in.)-long blanket pins jacketed in refractory alloy. The re-entrant curves shown in Fig. 5 reveal the influence of a low use factor for processing units. The use factor is a function of the rate of fuel- and blanket-pin manufacture. Since a particular processing unit has a definite cost and a maximum output rate, at low throughput the unit may sit idle during a significant part of its finite life. Because the capital charges and area costs are calculated in terms of calendar days, rather than units of output, at low throughput each kilogram of product bears a disproportionate share of these charges. A secondary influence upon the unusual shape of these curves is the increased cost of process equipment to handle fuel pins of large diameter. For the calculation method chosen, the re-entrant nature of the curves disappears at use factors greater than about 75%.



106-8258

Fig. 5. Refabrication Cost versus Pin Diameter at Fixed Plant Throughput

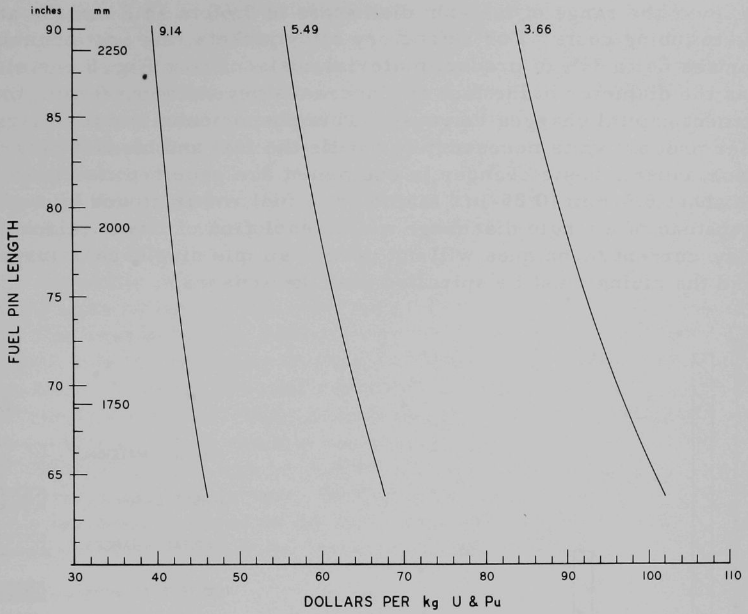
The familiar curve of refabrication cost versus fuel-pin diameter results when one normalizes the throughput rate to arrive at comparable use factors for all fuel-pin diameters. Such a curve is shown in Fig. 6 for the same fuel-rod configuration as used in Fig. 5. The increased cost of refabrication with decreasing pin diameter is attributed primarily to geometric factors. Since the volume, and thereby the weight, of enclosed fuel and/or blanket increases geometrically with the diameter and the cost of product materials and labor is affected to a lesser degree by diameter changes, the result is a geometric increase of refabrication cost with decreasing rod diameter.



106-8257

Fig. 6. Refabrication Cost versus Pin Diameter at Fixed Use Factor

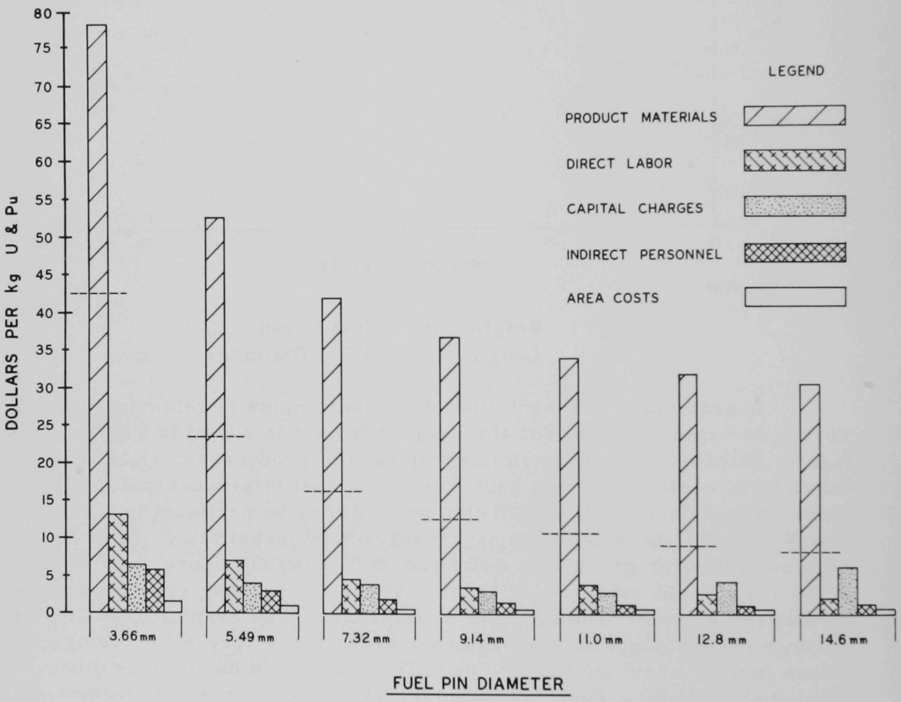
Another example of the effect of fuel- and/or blanket-pin geometry upon refabrication cost is shown in Fig. 7. In this curve, fuel-pin length is plotted against refabrication cost with pin diameter as a parameter. As in the previous instances, the integrated case is considered and an equipment use factor of about 75% is assumed. In this example the linear relationship between pin length and enclosed volume, or weight, and the weak geometric influence of product materials and labor costs result in a nearly linear effect of pin length upon refabrication costs.



106-8259

Fig. 7. Refabrication Cost versus Pin Length at Fixed Pin Diameter

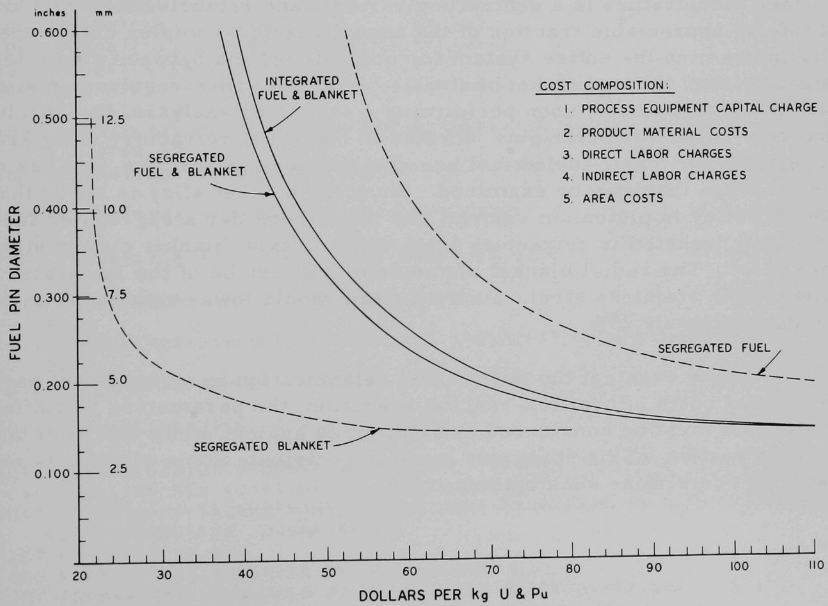
A graphical representation of the increments of refabrication cost versus fuel-pin diameter for the integrated case is shown in Fig. 8. This figure indicates the overwhelming influence of product materials upon refabrication costs. The dominant role in the cost of product materials is played by the jacket tubing. At this point it may be pertinent to mention that V-20w/oTi is considered as the refractory jacket alloy. In lieu of reliable costs for production quantities of V-20w/oTi tubing or rod stock, some reasonable estimate of jacket costs for an existing productive capacity had to be made. Tubing costs were generated by assuming that, in an advanced technology, productive capacity for refractory-alloy tubing exists. It was further assumed that V-20w/oTi tubing would be no more difficult to form than seamless Type 304 stainless-steel tubing on which present-day, reliable cost figures do exist. The cost of fabrication of the refractory alloy jacket tubing, then, is assumed to be the cost of a similar size of seamless stainless-steel tubing purchased in random mill lengths in lots greater than 20,000 ft. The cost of the refractory alloy is taken as the weight of alloy required, multiplied by a cost per pound of alloy. Finally, the total jacket cost is generated by adding fabrication costs, alloy costs, and cutting and inspection costs. In the case of stainless-steel jacketing, represented in Fig. 8 by the dashed line, 33 to 46% of product materials costs, over the range of fuel-pin diameters of 3.66 to 14.6 mm, is attributable to tubing costs. For refractory alloy jackets, the cost of tubing comprises 64 to 85% of product material costs. From Fig. 8 one also finds that as the diameter of the fuel pin increases beyond about 9 mm, process-equipment capital charges increase. This phenomenon is due to larger and heavier process units necessary to handle the fuel and blanket pins. In addition, certain basic changes in equipment are required; for example, above about 6.5-mm (0.25-in.) diameter, a fuel rod is closed by a girth weld instead of a single discharge weld; resolution of flaws in jacket tubing by eddy-current techniques will not permit simple single-pass inspection; instead the tubing must be spiralled past the sensors.



106-8256

Fig. 8. Cost of Increments of Refabrication versus Pin Diameter at 78 ± 4% Use Factor

The integrated core-element design is certainly appealing from the standpoint of design simplicity and fabrication ease. It does require a minimum number of pieces of hardware and fewer units to assemble into a core unit. There are, however, several compromises that must necessarily be made to achieve this degree of simplicity. One compromise impressed by this design is the restriction of the role of the axial blanket. The blanket-pin diameter must be nearly the same as that of the fuel. In addition, disassembly of the core element for any reason carries the axial blanket along. An obvious solution to this situation is the segregated case where fuel and blanket occupy separate and distinct jackets. Figure 9 is a series of curves showing the cost of refabrication of segregated fuel and blanket elements. In this instance, it is assumed that a core assembly contains 331 fuel pins, 90 cm long, jacketed in refractory alloy, and the axial blanket section contains 271 pins, 36 cm long, jacketed in stainless steel. In each case the assembly is hexagonal close-packed. In spite of the increased number of units of output, the refabrication cost is slightly less for this design. The reason for the reduced cost of refabrication of segregated assemblies lies in the choice of stainless steel as a jacket material for the axial blanket. Although the cost reduction is small, an additional benefit may accrue from the fuel-management aspect if it is found that blanket pins may be recharged to the reactor for extended exposure. In this case the blanket-fabrication rate can be controlled somewhat independently of the fuel-refabrication requirement. In Fig. 9, the cost of bundle hardware and assembly has been charged to the fuel, resulting in a much higher cost for the segregated fuel than for the integrated fuel and blanket.



106-8255

Fig. 9. Comparative Cost of Refabrication of Integrated and Segregated Metal-fuel Elements

CONCLUSIONS

The information presented by the computer program does not include reprocessing costs, waste disposal, scrap recovery, use charges, cost of money considerations, or other refinements. It is intended to provide basic data that may be modified by corporate fiscal policies, such as that indicated by Collins,[22] to arrive at fuel costs of a refined nature.

The study of factors affecting the cost of refabrication of metal fuels for fast reactors has revealed several important facets in the economics of the fuel cycle. In particular, an average equipment-use factor greater than 75% is necessary to realize the potential of fuel-cycle processes. The cost of refabrication is heavily influenced by the cost of jacket materials, and a penalty is exacted if refractory jackets are necessary to the reactor system. Fuel-pin diameter has a marked effect upon refabrication cost to the extent that an increase in fuel-pin diameter from 3.6 mm (0.144 in.) to 5.4 mm (0.215 in.) can result in a 25% reduction in cost.

In general, since a large fraction of the cost of fuel refabrication is associated with the cost of jacket material, one should examine closely the conditions that impress high-cost materials upon the system. If the fuel-surface temperature is a controlling variable and refabrication costs constitute an appreciable fraction of the annual reactor-complex costs, one should examine the entire system for possible optima between steam temperature, fuel burnup, jacket-material costs, fuel-alloy requirements, and fuel-pin diameter. If, upon performing a searching analysis, one concludes that only small-diameter pins jacketed in high-cost refractory alloy are acceptable for metal-fueled fast breeder reactor applications, one has a compromise that may be examined. Since the blanket alloy is lower than the fuel alloy in plutonium content, one might consider a segregated fuel assembly jacketed in refractory alloy with the axial blanket clad in stainless steel. The radial blanket elements might then be of the integrated type clad in stainless steel. Such a system would lower refabrication costs by approximately 25%.

In any event, if the cost of fuel refabrication is a significant part of the annual costs of breeder-reactor operation, the parameters that affect such costs must be considered and optimized against other variables in the reactor system. This study was made to contribute some of the data necessary to determine such optima.

APPENDIX A

Computer Program for Segregated Case

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SEQUENCE,2099
JOB,99999,108059,6
AYER J       05388METI66X41491-20106360
/PRINT OUTPUT TWO(2) TIMES.+...........
FORTRAN,L,X.
      PROGRAM  DJONES
C     SEGREGATED CASE
C
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     1TT(2),DEF(2),TS(2),ANRDA(2),AMCCS(2),AMCMO(2),RBO(2),AMCBO(2),
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 1003 FORMAT(5X,15HKG OUTPUT       2F12.5)
 1004 FORMAT(5X15HPINS PER DAY   2F12.5)
 1005 FORMAT(5X,15HDIAMETER       2F12.5)
 1006 FORMAT(5X,15HLENGTH(INCHES) 2F12.5  )
 1030 FORMAT(57X4HFUEL11X7HBLANKET)
 1020 FORMAT(14X57HTOTAL COST PER DAY FOR REFABRICATING FUEL AND BLANKET
     1 = $F14.2)
 1021 FORMAT(14X57HTOTAL COST PER KILOGRAM OF FUEL + BLANKET
     2 = $F14.2)
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     8.2)
 1008 FORMAT(10X,37HMATERIAL COST PER DAY=                  $F14.2,4H   $F14
     7.2)
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     5.2)
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     4.2)
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     2.2)
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 2     ,AMTPL,AMCST,RTT,AMTT,CCIDG,ALIDG,CCCO,ALCO,CCBO,ALBO
 3    ,FACMO,RBAKE,RMOI,RMOC,RCRI,RPP,CCPP,ALPP,CCOPC,ALOPC
 4                   ,FPPRA,FOPCA,ROPC,RXRA,FXRAA,AMCEF,CCCUT
 5    ,ALCUT,CCJEC,ALJEC,FTR,RJWL,CCJWL,ALJWL,RJLT,CCJLT,ALJLT
 6,FRBEA,TB,AMTJT,RJCT,CCNEC,ALNEC,CCNWT,ALNWT,AMTNA,CCNGB,ALNGB
 7,RNEC,RNWT,RNLD,RHOA(1),CEFA(1),VF(1),FRARB,RFCL,RECL,RRWL,FLTA
 8     ,CCRDW,ALRDW,RRL,CCRL,ALRL,FRDBA,RRDBD,CCRBD,ALRBD
 9,CCSAC,ALSAC,ANRDA(1),RHOA(2),CEFA(2),VF(2)
  PRINT 257,
 1    AMTAH,AMSAC,RSAI ,FRAR,RDIS,CCDIS,ALDIS,RDEC,RNAR,ALDEC,CCMPR,
 1          ALMPR,CCDEC,TS(1),CMO,    ACST,APP,RJID,ALXRA,ASAC,
 2  ADIS,ADEC,ARDWL,ARDLT,ARDBD,AMPR,AWGH,ATEBR,AMEBR,ACOST,
 3ALBDG,CCXRA,TS(2)
  MP=0
  M=1
  DO 999 K=2,5
  AK=K
  AL(1)=7.1*AK+7.1
  ALFV(1)=AL(1)*(1.+VF(1))
  DO 999 KB=1,3
  AKB=KB
  AL(2)=7.1*AKB+7.1
  ALFV(2)=AL(2)*(1.+VF(2))
  SEQ=2.6
  JSTOP=7
  DO 997 J=2,6
  AJ=J
  D(1)=.072*AJ
  ANRDA(2)= ANRDA(1)
  B=5.
  DO 996 JB=1,JSTOP
  DO 998 I=1,9,2
  AI=I
  DO 998 L=1,2
  GO TO(300,301),L
300 ANOUW(1)=50.*AI
  ANOUP(1)=77.7*ANOUW(1)/(D(1)**2*AL(1)*RHO(1))
  ANPP(1)=ANOUP(1)/(FPPRA*FRARB*FRBEA*FSACA)
  AFCPD=ANOUW(1)/57.5
  AN(1)=ANPP(1)/AFCPD
  TT(1)=.071*D(1)+.142*TB+.005
  DEF(1)=D(1)+2.*(TT(1)+TB)
  DH=(DEF(1)+2.*TS(1))*ANRDA(1)**.525
  GO TO 321
301 ANOUP(2)=2.*ANOUP(1)*ANRDA(2)/ANRDA(1)
  DEF(2)=  (ANRDA(2)**(-.525))*DH-2.*TS(2)
```

```
      D(2)=(DEF(2)-2.284*TB-0.01)/1.142
      TT(2)=.071*D(2)+.142*TB+.005
      ANOUW(2)=ANOUP(2)*D(2)**2*AL(2)*RHO(2)/77.7
      ANPP(2)=ANOUP(2)/(FPPRA*FRARB*FRBEA*FSACA)
      AFCPD=ANOUW(2)/57.5
      AN(2)=ANPP(2)/AFCPD
  321 ANCST(L)=ANPP(L)/(FCDPP*H*AN(L)*RCST)
  303 DP(L)=((D(L)+.10)*129.)/(D(L)*RHO(L)*AL(L)**0.5)
      AMCCS(L)=1.+.005*(AL(L)-14.2)+.1*(DP(L)-6.0)
      AMCMO(L)=(2.85*D(L)+.059*(AL(L)+4.)+.355)/CMO
      RBO(L)=(3320.*RBAKE)/((D(L)+.10)**2*(AL(L)+4.))
      ANBO(L)=ANPP(L)/(FCDPP*H*RBO(L)*FACMO)
      AMCBO(L)=((D(L)**2*AL(L))/.295)**2
      AMRMI(L)=14.2/AL(L)
      ANMOI(L)=(.1*ANPP(L))/(H*FCDPP*FACMO*RMOI*AMRMI(L))
      AMRMC(L)=2.2/(D(L)*AL(L))
      ANMOC(L)=ANPP(L)/(H*FACMO*FCDPP*RMOC*AMRMC(L))
      ANCRI(L)=ANPP(L)/(H*FCDPP*AN(L)*RCRI)
      ANOPP(L)=ANPP(L)/(H*RPP)
      AMCPP(L)=1.6*D(L)+.014*AL(L)+.6
      TPPRA(L)=FPPRA*ANPP(L)/H
      ANOPC(L)=.2*TPPRA(L)/(ROPC*FOPCA)
      ANXRA(L)=.2*TPPRA(L)/(RXRA*FOPCA*FXRAA)
      CEF(L)=.0567*RHOA(L)*CEFA(L)*DEF(L)**3+2.44*DEF(L)
      IF(DEF(L)-.25)175,175,176
  176 RJEC(L)=2120./(ALFV(L)*120.*DEF(L)+1.91)
      GO TO 177
  175 RJEC(L)=555./ALFV(L)
  177 ANJEC(L)=.1*TPPRA(L)/(RJEC(L)*FTR)
      ANJID(L)=TPPRA(L)/(RJID    *FTR)*1.2
      AMCEC(L)=1.+(D(L)-.144)*.2+(ALFV(L)-14.2)*.11
      IF(DEF(L)-.25)185,185,186
  186 AA=3000.
      GO TO 187
  185 AA=0.
  187 ANJWL(L)=TPPRA(L)/(RJWL*FTR)
      ANJLT(L)=TPPRA(L)/(RJLT*FTR)
      AMCJL(L)=  1.+(D(L)-.144)*.8+(AL(L)-14.2)*.003
      ANJCT(L)=TPPRA(L)/(RJCT*FTR)
      ANNEC(L)=TPPRA(L)/RNEC
      ANNWT(L)=TPPRA(L)/RNWT
      ANNLD(L)=TPPRA(L)/RNLD
      ANFCL(L)=TPPRA(L)/RFCL
      ANECL(L)=TPPRA(L)/RECL
      ANRWL(L)=TPPRA(L)/RRWL
      IF(DEF(L)-.25)102,102,103
  103 RRDWL(L)=30.0
      GO TO 104
  102 RRDWL(L)=60.0
  104 ANRDW(L)=TPPRA(L)/(FLTA*RRDWL(L))
      AMCRD(L)=1.+(AL(L)-14.2)*.1
      ANRL(L)=TPPRA(L)/(FLTA*RRL)
      AMCRL(L)=1.+(D(L) -.144)*.8+(ALFV(L)-14.2)*.003
      ANRBD(L)=FRARB*TPPRA(L)/(FRDBA*RRDBD)
      AMCRB(L)=1.+(D(L)-.144)*.2+(ALFV(L)-14.2)*.1
      AMCRT(L)=AMCRB(L)
      GO TO(304,305),L
  304 ANSAC=FRARB*TPPRA(1)*FRBEA/(ANRDA(1)*FSACA*5400./(ANRDA(1)*60.+136
     100.))
      AMCSC=.77*DH+.0075*(ALFV(1)+2.*ALFV(2))+.8
      ANSAI=TPPRA(1)*FRARB*FRBEA/(ANRDA(1)*RSAI*FSACA)
  305 GO TO(322,323),L
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323 ANSAC=0.
322 TOTLA(L)= (ANBO(L)+ANMOI(L)+ANCST(L)+ANOPP(L)+ANMOC(L)+ANCRI(L)+
   1ANOPC(L)+ANXRA(L)+ANJEC(L)/5.+ANJID(L)+ANJWL(L)+ANJLT(L)/5.+ANJCT
   2(L)+ANNEC(L)+ANNWT(L)+ANNLD(L)+ANFCL(L)+ANECL(L)+ANRWL(L)+ANRDW(L)
   3+ANRL(L)/5.+ANRBD(L)/2.)*RTT*AMTT*H
    GO TO(306,307),L
306 TOTLA(1)=TOTLA(1)+(ANSAC*AMSAC+ANSAI)*RTT*AMTT*H
307 CJM(L)=(11.34*DEF(L)*TT(L)*RHOA(L)*CEFA(L)/100.+((3700.*TT(L)+50.4
   1)*DEF(L)+20.)/1200.)*ALFV(L)
    TPPRA(L)=TPPRA(L)*H
    TOTMA(L)=(CCR*AMTCR*ANPP(L))/(AN(L)*FCDPP)+(CMO*ANPP(L)*AMCMO(L)*
   1AMTMO)/(FCDPP*FACMO)+(CPAL*AMTPL*ANPP(L))/(AN(L)*FCDPP)+2.*TPPRA(L
   2)*CEF(L)*AMCEF/(FOPCA*FXRAA)*(CJM(L)*TPPRA(L)*AMTJT)/FTR+AMTNA*
   3 TPPRA(L)*1.583*(D(L)+TB)*TB*ALFV(L)/100.
    GO TO(308,309),L
308 TOTMA(1)=TOTMA(1)+(TPPRA(L)*FRARB*FRBEA/ANRDA(1))*(125.*DH+1.25*
   1(ALFV(1)+ALFV(2))+107.)*AMTAH
309 MP=MP+1
    GO TO (30,60,60,60),MP
 30 PRINT 1014,M
    M=M+1
 60 IF(MP-4)343,344,343
344 MP=0
343 GO TO(340,341),L
340 PRINT 1000
    GO TO 342
341 PRINT 1100
342 PRINT 193,ANBO(L),ANCST(L),ANOPP(L),ANMOC(L),ANRDW(L),ANRL(L),
   1ANRBD(L),ANSAC    ,ANOPC(L),ANXRA(L),ANJEC(L),ANJWL(L),ANJLT(L),
   2ANJID(L),ANJCT(L),ANNWT(L),ANNEC(L),ANRDA(L),DH
    NBO=ANBO(L)+1.
    NCST=ANCST(L)+1.
    NOPP=ANOPP(L)+1.
    NMOC=ANMOC(L)+1.
    NRDW=ANRDW(L)+1.
    NRL=ANRL(L)+1.
    NRBD=ANRBD(L)+1.
    NOPC=ANOPC(L)+1.
    NXRA=ANXRA(L)+1.
    NJEC=ANJEC(L)+1.
    NJWL=ANJWL(L)+1.
    NJLT    =ANJLT(L)+1.
    NJID    =ANJID(L)+1.
    NJCT    =ANJCT(L)+1.
    NNWT=ANNWT(L)+1.
    NNEC=ANNEC(L)+1.
    GO TO(310,311),L
310 NSAC    =ANSAC    +1.
311 ANBO(L)=NBO
    ANCST(L)=NCST
    ANOPP(L)=NOPP
    ANMOC(L)=NMOC
    ANRDW(L)=NRDW
    ANRL(L) =NRL
    ANRBD(L)=NRBD
    ANOPC(L)=NOPC
    ANXRA(L)=NXRA
    ANJEC(L)=NJEC
    ANJWL(L)=NJWL
    ANJLT(L)=NJLT
    ANJID(L)=NJID
    ANJCT(L)=NJCT
```

```
      ANNWT(L)=NNWT
      ANNEC(L)=NNEC
      GO TO (312,313),L
  312 ANSAC    =NSAC
      GO TO 347
  313 ANSAC    =0.
  347 GO TO (345,346),L
  345 PRINT 1001
      GO TO 314
  346 PRINT 1101
  314 PRINT 193,ANBO(L),ANCST(L),ANOPP(L),ANMOC(L),ANRDW(L),ANRL(L),
     1ANRBD(L),ANSAC    ,ANOPC(L),ANXRA(L),ANJEC(L),ANJWL(L),ANJLT(L),
     2ANJID(L),ANJCT(L),ANNWT(L),ANNEC(L),ANRDA(L)
      AMTCS(L)=(ANCST(L)**.8*1.15)/ANCST(L)
      AMTBO(L)=(ANBO(L)**.8*1.15)/ANBO(L)
      AMTPP(L)=(ANOPP(L)**.8*1.15)/ANOPP(L)
      AMTMC(L)=(ANMOC(L)**.8*1.15)/ANMOC(L)
      AMTOP(L)    =(ANOPC(L)**.8*1.15)/ANOPC(L)
      AMTXR(L)=(ANXRA(L)**.8*1.15)/ANXRA(L)
      AMTEC(L)=(ANJEC(L)**.8*1.15)/ANJEC(L)
      AMTJW(L)=(ANJWL(L)**.8*1.15)/ANJWL(L)
      AMTJL(L)=(ANJLT(L)**.8*1.15)/ANJLT(L)
      AMTRD(L)=(ANRDW(L)**.8*1.15)/ANRDW(L)
      AMTRL(L)=(ANRL(L)**.8*1.15)/ANRL(L)
      AMTRB(L)=(ANRBD(L)**.8*1.15)/ANRBD(L)
      AMTNC(L)=(ANNEC(L)**.8*1.15)/ANNEC(L)
      AMTNW(L)=(ANNWT(L)**.8*1.15)/ANNWT(L)
      GO TO (319,320),L
  319 AMTSC=(ANSAC**.8*1.15)/ANSAC
  320 AMTJI(L)=(ANJID(L)**.8*1.15)/ANJID(L)
      AMTJC(L)=(ANJCT(L)**.8*1.15)/ANJCT(L)
      AMTMC(L)=(ANMOC(L)**.8*1.15)/ANMOC(L)
      TOTCC(L)=ANCST(L)*CCCST*AMCCS(L)*AMTCS(L)/ALCST+CCIDG/ALIDG+CCCO*
     11.15/ALCO+ANBO(L)*CCBO*AMCBO(L)*AMTBO(L)/ALBO+ANOPP(L)*CCPP*AMTPP
     2(L)*AMCPP(L)/ALPP+ANOPC(L)*CCOPC*AMTOP(L)/ALOPC+ANXRA(L)*CCXRA*
     3AMTXR(L)/ALXRA+ANJID(L)*CCIDG*AMTJI(L)/ALIDG+ANJCT(L)*CCCUT*AMTJC(
     4L)/ALCUT+ ANNEC(L)*CCNEC*AMTNC(L)/ALNEC+ANNWT(L)*CCNWT*AMTNW(L)/AL
     5NWT        +CCNGB*1.15/ALNGB+ANRDW(L)*(CCRDW+AA)*AMCRD*AMTRD(L)/ALRB
     6D+CCMPR*1.15/ALMPR+ANJEC(L)*CCJEC*AMTEC(L)*AMCEC/ALJEC+ANJLT(L)*
     7CCJLT*AMTJL(L)*AMCJL/ALJLT
      GO TO (315,316),L
  315 TOTCC(1)=TOTCC(1)+ANSAC*CCSAC*AMCSC*AMTSC/ALSAC
  316 AMX(L)=ANCST(L)*ACST+ANOPP(L)*APP+ANRDW(L)*ARDWL+ANRL(L)*ARDLT
     1+ANRBD(L)*ARDBD+AMPR+AWGH
      GO TO (317,318),L
  317 AMX(1)=AMX(1)+ANSAC*ASAC
  318 ATX(L)=AMX(L)*(ATEBR/AMEBR)**0.6
      TOTAC(L)=ATX(L)*ACOST/ALBDG
      TOTIP(L)=TOTLA(L)*5.10*0.30/3.50
      TOTAL(L)=TOTCC(L)+TOTMA(L)+TOTAC(L)+TOTIP(L)+TOTLA(L)
      GO TO (998,351),L
  351 PRINT 1002
      PRINT 1005,D(1),D(2)
      PRINT 1006,AL(1),AL(2)
      PRINT 1004,ANOUP(1),ANOUP(2)
      PRINT 1003,ANOUW(1),ANOUW(2)
      PRINT 1030
      PRINT 1007,TOTCC(1),TOTCC(2)
      PRINT 1008,TOTMA(1),TOTMA(2)
      PRINT 1009,TOTLA(1),TOTLA(2)
      PRINT 1010,TOTAC(1),TOTAC(2)
      PRINT 1011,TOTIP(1),TOTIP(2)
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      PRINT 1012,TOTAL(1),TOTAL(2)
      CPKGF=TOTAL(1)/ANOUW(1)
      CPKGB=TOTAL(2)/ANOUW(2)
      PRINT 1013,CPKGF,CPKGB
      SUM=TOTAL(1)+TOTAL(2)
      PRINT 1020 ,SUM
      SUM=SUM/(ANOUW(1)+ANOUW(2))
      PRINT 1021 ,SUM
      NNN=NNN+1
      NPG(NNN)=M-1
      PLOT1(NNN)=ANOUW(1)+ANOUW(2)
      PLOT2(NNN)=D(1)
      PLOT3(NNN)=D(2)
      PLOT4(NNN)=SUM
      PLOT5(NNN)=AL(1)
      PLOT6(NNN)=AL(2)
      MSEP=MSEP+1
      GO TO (990,991),MSEP
  990 PRINT 3000
      GO TO 998
  991 MSEP=0
  998 CONTINUE
      ANRDA(2)=(ANRDA(2)-(30.+6.*8))
      B=B-1.
  996 CONTINUE
      JSEQ=SEQ
      JSTOP=JSTOP-JSEQ
      SEQ=SEQ-.5
  997 CONTINUE
  999 CONTINUE
      K1=1
      K2=45
      DO 850 IPL=1,24
      PRINT 1014,M
      PRINT1017
      PRINT 1016,(PLOT1(IPLOT),PLOT2(IPLOT),PLOT3(IPLOT),PLOT4(IPLOT),
     1PLOT5(IPLOT),PLOT6(IPLOT) ,NPG(IPLOT), IPLOT=K1,K2)
      M=M+1
      K2=K2+45
  850 K1=K1+45
      STOP
      END
        SCOPE
LOAD,69
RUN,7,36000,3
    31000.00          1825.00        17.            18.8
     .980                0.99            16.0             0.148
      23.00              0.70             0.50             9.70
       1.00              1.00             3.50             1.30
     4000.00          5475.0          7500.0           5475.0
      3250.00          5475.              .95              .20
       90.0              50.0             2.0              40.0
      37500.0            1825.0         7600.0           5475.0
        .96               .95             90.              90.
        .95               .70           17000.           5475.
      16000.          5475.               .90              12.
     30000.           5475.              30.0           3200.
  5475.              .98             .0145           .95
       20.            20000.            5475.             3000.
      1825.            1.              45000.             5475.
      88.              88.              88.          5.72
     38.0             1.24                  .965           20.
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```
      20.              20.                 .93                  28000.
     1825.            10.0              3200.                 1825.
        .98            50.0               10000.                1825.
   85000.             1825.              331.           7.90
    0.0            1.10
    1.0            1.0               .10                 .02
    0.167         60000.               1825.           30.
   180.            1825.             20000.             1825.
   50000.             .06            1.85              18.
 42.                90.0            5475.             35.
 96.           36.                   5.           1.
  3.            9.                  7.             3000.0
   259.        2600.                10950.            24000.
          .060
[         END OF FILE
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APPENDIX B

Glossary Identifying Variables

AA	JACKET CLOSURE WELDER COST ADJUSTMENT WHEN DEF .GE. 0.25 IN. $3000
ACOST	REFABRICATIONS SHARE OF BUILDING COSTS - $2600 PER SQ. FT.
ACST	HOT CELL AREA OCCUPIED PER CASTING UNIT - 18 SQ. FT.
ADEC	HOT CELL AREA OCCUPIED PER DECANNING UNIT - 36 SQ. FT.
ADIS	HOT CELL AREA OCCUPIED PER DISASSEMBLY UNIT - 96 SQ. FT.
AFCPD	NUMBER OF CASTS PER DAY
AI	FLOATING POINT VALUE OF I
AJ	FLOATING POINT VALUE OF J
AK	FLOATING POINT VALUE OF K
AKB	FLOATING POINT VALUE OF KB
AL(L)	LENGTH OF A FUEL OR BLANKET PIN - 14.2 TO 42.6 INCHES
ALBDG	AMORTIZATION LIFE OF REFABRICATION FACILITY - 10,950 DAYS
ALBO	REPLACEMENT LIFE OF BAKE-OUT OVENS-5475 DAYS
ALCO	REPLACEMENT LIFE OF MOLD COATING EQUIPMENT-5475 DAYS
ALCST	REPLACEMENT LIFE OF CASTING EQUIPMENT-1825 DAYS
ALCUT	REPLACEMENT LIFE OF JACKET CUTTING EQUIPMENT-5475 DAYS
ALDEC	REPLACEMENT LIFE OF DECANNING EQUIPMENT-1825 DAYS
ALDIS	REPLACEMENT LIFE OF DISMANTLING EQUIPMENT-1825 DAYS
ALFV(L)	LENGTH OF CORE OR BLANKET ROD IN INCHES
ALIDG	REPLACEMENT LIFE OF MOLD AND TUBING GUAGES-5475 DAYS
ALJEC	REPLACEMENT LIFE OF EDDY CURRENT INSPECTION EQUIPMENT-5475 DAYS
ALJLT	REPLACEMENT LIFE OF JACKET TUBING LEAK TESTER-5475 DAYS
ALJWL	REPLACEMENT LIFE OF WELDER FOR JACKET LOWER END FITTING-5475 DAYS
ALMPR	REPLACEMENT LIFE OF MELT PREPARATION EQUIPMENT-1825 DAYS
ALNEC	REPLACEMENT LIFE OF SODIUM EXTRUDER AND CUTTER-5475 DAYS
ALNGB	REPLACEMENT LIFE OF SODIUM HANDLING GLOVE BOX-5475 DAYS
ALNWT	REPLACEMENT LIFE OF SODIUM WEIGHING EQUIPMENT-5475 DAYS
ALOPC	REPLACEMENT LIFE OF OPTICAL COMPARATORS-5475 DAYS
ALPP	REPLACEMENT LIFE OF PIN PROCESSING EQUIPMENT-1825 DAYS
ALRBD	REPLACEMENT LIFE OF ROD BONDING EQUIPMENT-1825 DAYS
ALRDW	REPLACEMENT LIFE OF FUEL ROD CLOSURE WELDER-1825 DAYS
ALRL	REPLACEMENT LIFE OF FUEL ROD LEAK DETECTORS-1825 DAYS
ALSAC	REPLACEMENT LIFE OF SUBASSEMBLY CONSTRUCTION EQUIPMENT-1825 DAYS
ALXRA	REPLACEMENT LIFE OF X-RAY EQUIPMENT-5475 DAYS
AMCBO(L)	PIN SIZE COST MULTIPLIER FOR BAKE-OUT OVENS
AMCCS(L)	PIN SIZE COST MULTIPLIER FOR CASTING EQUIPMENT
AMCEC(L)	PIN SIZE COST MULTIPLIER FOR JACKET EDDY CURRENT EQUIPMENT
AMCEF	PIN SIZE COST MULTIPLIER FOR END FITTINGS - .70
AMCJL(L)	PIN SIZE COST MULTIPLIER FOR JACKET LEAK TESTING
AMCMO(L)	PIN SIZE COST MULTIPLIER FOR MOLDS
AMCPP(L)	PIN SIZE COST MULTIPLIER FOR PIN PROCESSING UNITS
AMCRB(L)	PIN SIZE COST MULTIPLIER FOR ROD BONDERS
AMCRD(L)	PIN SIZE COST MULTIPLIER FOR ROD CLOSURE WELDERS
AMCRL(L)	PIN SIZE COST MULTIPLIER FOR ROD LEAK TESTERS
AMCRT(L)	PIN SIZE COST MULTIPLIER FOR BOND TESTERS
AMCSC	PIN SIZE COST MULTIPLIER FOR SUBASSEMBLY CONSTRUCTION EQUIPMENT
AMCST	CASTING FURNACES PER MAN-1.00
AMEBR	HOT-CELL AREA OCCUPIED BY EBR-II REFABRICATION EQUIPMENT-259 SQ. FT.
AMPR	HOT-CELL AREA OCCUPIED BY MELT PREPARATION EQUIPMENT - 9 SQ. FT.
AMRMC(L)	PIN SIZE RATE MULTIPLIER FOR MOLD COATING
AMRMI(L)	PIN SIZE RATE MULTIPLIER FOR MOLD INSPECTION
AMSAC	SUBASSEMBLY CONSTRUCTION MACHINES PER MAN-1.00
AMTAH	VOLUME AND TIME FACTOR FOR SUBASSEMBLY HARDWARE COSTS-1.00
AMTBO(L)	VOLUME AND TIME FACTOR FOR BAKE-OUT OVEN COSTS
AMTCR	VOLUME AND TIME FACTOR FOR CRUCIBLE COSTS - .70
AMTCS(L)	VOLUME AND TIME FACTOR FOR CASTING FURNACE COSTS
AMTEC(L)	VOLUME AND TIME FACTOR FOR JACKET EDDY CURRENT INSPECTION EQUIPMENT
AMTJC(L)	VOLUME AND TIME FACTOR FOR TUBING CUTTING EQUIPMENT

AMTJI(L)	VOLUME AND TIME FACTOR FOR TUBING GUAGING EQUIPMENT
AMTJL(L)	VOLUME AND TIME FACTOR FOR TUBING LEAK TEST EQUIPMENT
AMTJT	VOLUME AND TIME FACTOR FOR JACKET TUBING-0.95
AMTJW(L)	VOLUME AND TIME FACTOR FOR WELDER FOR JACKET LOWER END FITTING.
AMTMC(L)	VOLUME AND TIME FACTOR FOR MOLD COATING EQUIPMENT
AMTMO	VOLUME AND TIME FACTOR FOR MOLDS-0.50
AMTNA	VOLUME AND TIME FACTOR FOR SODIUM COST-1.00
AMTNC(L)	VOLUME AND TIME FACTOR FOR SODIUM EXTRUSION
AMTNW(L)	VOLUME AND TIME FACTOR FOR SODIUM WEIGHING
AMTOP(L)	VOLUME AND TIME FACTOR FOR OPTICAL COMPARISON EQUIPMENT
AMTPL	VOLUME AND TIME FACTOR FOR PALLETS-1.00
AMTPP(L)	VOLUME AND TIME FACTOR FOR PIN PROCESS UNITS
AMTRB(L)	VOLUME AND TIME FACTOR FOR ROD BONDING EQUIPMENT COSTS
AMTRD(L)	VOLUME AND TIME FACTOR FOR ROD WELDER COSTS
AMTRL(L)	VOLUME AND TIME FACTOR FOR ROD LEAK TESTERS.
AMTSC	VOLUME AND TIME FACTOR FOR SUBASSEMBLY CONSTRUCTION EQUIPMENT COS
AMTT	WAGE ESCALATION FACTOR FOR TECHNICIANS-1.30
AMTXR(L)	VOLUME AND TIME FACTOR FOR X-RAY INSPECTION EQUIPMENT COSTS
AMX(L)	TOTAL HOT-CELL FLOOR AREA OCCUPIED BY REFABRICATION MACHINERY
AN(L)	NUMBER OF PINS PER CAST
ANBO(L)	NUMBER OF BAKE-OUT OVENS REQUIRED BY PROCESS
ANCRI(L)	NUMBER OF CRUCIBLE INSPECTORS EMPLOYED IN PROCESS
ANCST(L)	NUMBER OF PERSONS EMPLOYED IN THE CASTING OF PINS
ANECL(L)	NUMBER OF PERSONS EMPLOYED IN LOADING END FITTINGS INTO JACKETS
ANFCL(L)	NUMBER OF PERSONS EMPLOYED IN LOADING PINS INTO JACKETS
ANJCT(L)	NUMBER OF PERSONS EMPLOYED IN JACKET TUBING CUTTING
ANJEC(L)	NUMBER OF PERSONS EMPLOYED IN EDDY CURRENT INSPECTION OF TUBIN
ANJID(L)	NUMBER OF PERSONS EMPLOYED IN TUBING GUAGING
ANJLT(L)	NUMBER OF PERSONS EMPLOYED IN JACKET LEAK TESTING
ANJWL(L)	NUMBER OF PERSONS EMPLOYED IN LOWER ROD END FITTING WELDING
ANMOC(L)	NUMBER OF PERSONS EMPLOYED AS MOLD COATERS
ANMOI(L)	NUMBER OF PERSONS EMPLOYED AS MOLD INSPECTORS
ANNEC(L)	NUMBER OF PERSONS EMPLOYED AT SODIUM EXTRUDING AND CUTTING.
ANNLD(L)	NUMBER OF PERSONS EMPLOYED AT SODIUM LOADING OF JACKETS.
ANNWT(L)	NUMBER OF PERSONS EMPLOYED AT SODIUM WEIGHING
ANOPC(L)	NUMBER OF PERSONS EMPLOYED AT OPTICAL COMPARATOR INSPECTION.
ANOPP(L)	NUMBER OF PERSONS EMPLOYED AT PIN PROCESSING
ANOUP(L)	PLANT OUTPUT IN RODS PER DAY
ANOUW(L)	PLANT OUTPUT - 50 TO 550 KG. PER DAY
ANPP(L)	NUMBER OF PINS TO PIN PROCESSING PER DAY
ANRBD(L)	NUMBER OF PERSONS EMPLOYED AT ROD BONDING
ANRDA(L)	NUMBER OF RODS PER ASSEMBLY - 331 FOR FUEL, VARIABLE FOR BLANKET
ANRDW(L)	NUMBER OF PERSONS EMPLOYED AT ROD WELDING
ANRL(L)	NUMBER OF PERSONS EMPLOYED AT ROD LEAK DETECTION
ANRWL(L)	NUMBER OF PERSONS EMPLOYED AT WELDER LOADING
ANSAC	NUMBER OF PERSONS EMPLOYED IN SUBASSEMBLY CONSTRUCTION
ANSAI	NUMBER OF PERSONS EMPLOYED AT SUBASSEMBLY HARDWARE INSPECTION
ANXRA(L)	NUMBER OF PERSONS EMPLOYED AT X-RAY INSPECTIONS
APP	HOT-CELL AREA OCCUPIED PER PIN PROCESSOR - 42.0 SQ. FT.
ARDBD	HOT-CELL AREA OCCUPIED PER ROD BONDING UNIT - 3.0 SQ. FT.
ARDLT	HOT-CELL AREA OCCUPIED PER ROD LEAK TESTER - 1.0 SQ. FT.
ARDWL	HOT-CELL AREA OCCUPIED PER ROD WELDER -5.0 SQ. FT.
ASAC	HOT-CELL AREA OCCUPIED PER SUBASSEMBLY CONSTRUCTION UNIT -35 SQ. FT.
ATEBR	TOTAL HOT-CELL AREA FOR EBR-II FCF -3000 SQ. FT.
ATX(L)	TOTAL HOT-CELL AREA FOR REFABRICATION PROCESS
AWGH	HOT-CELL AREA OCCUPIED PER WEIGHING UNIT - 7.0 SQ. FT.
B	VARIABLE USED TO CALCULATE ANRDA(2)
CCBO	CAPITAL COST OF BAKE-OUT OVEN -$3250
CCCO	CAPITAL COST OF COATING FACILITIES-$7500
CCCST	CAPITAL COST OF CASTING UNIT-$31,000
CCCUT	CAPITAL COST OF TUBING CUTTING UNIT-$17,000
CCDEC	CAPITAL COST OF A DECANNING MACHINE-$50,000

CCDIS	CAPITAL COST OF A DISASSEMBLY MACHINE-$60,000
CCIDG	CAPITAL COST OF A UNIT OF DIAMETER GUAGING EQUIPMENT-$4,000
CCJEC	CAPITAL COST OF AN EDDY CURRENT INSPECTION UNIT-$16,000
CCJLT	CAPITAL COST OF A JACKET LEAK TESTER-$3200
CCJWL	CAPITAL COST OF A LOWER END PLUG WELDING UNIT-$30,000
CCMPR	CAPITAL COST OF A MELT PREPARATION STATION-$20,000
CCNEC	CAPITAL COST OF A SODIUM EXTRUDING AND CUTTING UNIT - $20,000
CCNGB	CAPITAL COST OF A SODIUM HANDLING GLOVEBOX-$45,000
CCNWT	CAPITAL COST OF SODIUM WEIGHING EQUIPMENT-$3000
CCOPC	CAPITAL COST OF AN OPTICAL COMPARATOR-$7600
CCPP	CAPITAL COST OF A PIN PROCESSING UNIT-$37,500
CCR	COST OF ONE CRUCIBLE-$23
CCRBD	CAPITAL COST OF A ROD BONDING UNIT-$10,000
CCRDW	CAPITAL COST OF A ROD WELDER-$28,000
CCRL	CAPITAL COST OF A ROD LEAK TESTING UNIT-$3200
CCSAC	CAPITAL COST OF A SUBASSEMBLY CONSTRUCTION UNIT-$85,000
CCXRA	CAPITAL COST OF AN X-RAY UNIT-$24,000
CEF(L)	COST OF A ROD END FITTING
CEFA(L)	COST OF AN END FITTING ALLOY BILLET - 0., 38., 89. $/LB ALLOY
CJM(L)	COST OF ONE LENGTH OF JACKET TUBING
CMO	COST OF AN EBR-II VYCOR MOLD-$1.85
CPAL	COST OF A CASTING PALLET-$9.70
CPKGB	COST PER KG. OF BLANKET
CPKGF	COST PER KG. OF FUEL
D(L)	DIAMETER OF FUEL OR BLANKET PIN - 0.144 TO 0.504 INCHES
DEF(L)	DIAMETER OF FUEL OR BLANKET ROD IN INCHES
DH	DISTANCE ACROSS FLATS OF FUEL CLUSTER SHROUD IN INCHES
DP(L)	DIAMETER OF PALLET IN INCHES
FACMO	FRACTION OF MOLDS ACCEPTED UPON INSPECTION-0.95
FCDPP	FRACTION OF PINS FROM CASTING TO PIN PROCESSING -0.99
FLTA	FRACTION OF RODS ACCEPTABLY WELDED - 0.93
FOPCA	FRACTION OF END FITTINGS WHICH PASS DIMENSIONAL INSPECTION-0.95
FPPRA	FRACTION OF PINS TO PROCESSING ACCEPTABLE TO ASSEMBLY -0.96
FRAR	FRACTION OF RODS REJECTED AT SUBASSEMBLY CONSTRUCTION - 0.02
FRARB	FRACTION OF RODS FROM ASSEMBLY TO BONDING - 0.965
FRBEA	FRACTION OF RODS WHICH PASS FROM BONDING TO SUBASSEMBLY CONSTRUCTION - 0.98
FRDBA	FRACTION OF RODS ACCEPTED DURING BONDING -0.98
FSACA	FRACTION OF SUBASSEMBLIES ACCEPTABLE FROM ASSEMBLY -0.98
FTR	FRACTION OF TUBING PASSING EDDY CURRENT INSPECTION-0.90
FXRAA	FRACTION OF FITTINGS WHICH PASS X-RAY INSPECTION-0.95
H	WORKING HOURS PER DAY-16
I	DO-LOOP INDEX USED TO SET FUEL THROUGHPUT
IPL	DO-LOOP INDEX USED TO COUNT PAGES
IPLOT	PRINT INDEX
J	DO-LOOP INDEX USED TO SET FUEL DIAMETER
JB	DO-LOOP INDEX USED TO SET BLANKET DIAMETER
JSTOP	MAXIMUM VALUE OF JB
K	DO-LOOP INDEX USED TO SET FUEL LENGTH
K1	LOWER LIMIT OF IPLOT
K2	UPPER LIMIT OF IPLOT
KB	DO-LOOP INDEX USED TO SET BLANKET LENGTH
L	VARIABLE USED TO CHOOSE FUEL,(L=1),OR BLANKET,(L=2),VALUES AND/OR STATEMENTS
M	THE CURRENT PAGE OF OUTPUT
MP	VARIABLE USED TO FIX OUTPUT PER PAGE
MSEP	VARIABLE USED TO INSERT ASTERISKS BETWEEN PRINTED CASES
NBO	NUMBER OF BAKE-OUT OVENS REQUIRED BY PROCESS
NCST	NUMBER OF CASTING FURNACES REQUIRED BY PROCESS
NJCT	NUMBER OF JACKET TUBING CUTTING LATHES REQUIRED BY PROCESS
NJEC	NUMBER OF EDDY CURRENT INSPECTION MACHINES REQUIRED BY PROCESS
NJID	NUMBER OF JACKET ID GUAGES REQUIRED BY PROCESS

NJLT	NUMBER OF JACKET LEAK TESTERS REQUIRED BY PROCESS
NJWL	NUMBER OF MACHINES FOR LOWER END FITTING WELDING REQUIRED BY PROCESS
NMOC	NUMBER OF MOLD COATING DEVICES REQUIRED BY PROCESS
NNEC	NUMBER OF SODIUM EXTRUDERS REQUIRED BY PROCESS
NNWT	NUMBER OF BALANCES FOR SODIUM WEIGHING REQUIRED BY PROCESS
NNN	NUMBER REFERENCING FUEL-BLANKET CONFIGURATIONS
NOPC	NUMBER OF OPTICAL COMPARATORS REQUIRED BY PROCESS
NOPP	NUMBER OF PIN PROCESSORS REQUIRED BY PROCESS
NPG(NNN)	NUMBER OF PAGE AT WHICH CASE NNN IS LOCATED
NRBD	NUMBER OF ROD BONDERS REQUIRED BY PROCESS
NRDW	NUMBER OF ROD WELDERS REQUIRED BY PROCESS
NRL	NUMBER OF ROD LEAK DETECTORS REQUIRED BY PROCESS
NSAC	NUMBER OF SUBASSEMBLY CONSTRUCTION COMPLEXES REQUIRED BY PROCESS
NXRA	NUMBER OF X-RAY UNITS REQUIRED BY PROCESS
PLOT1(NNN)	SUM OF FUEL-BLANKET THROUGHPUT FOR THE NNN CONFIGURATION
PLOT2(NNN)	FUEL DIAMETER FOR THE NNN CONFIGURATION
PLOT3(NNN)	BLANKET DIAMETER FOR THE NNN CONFIGURATION
PLOT4(NNN)	COST PER KG FUEL-BLANKET FOR THE NNN CONFIGURATION
PLOT5(NNN)	FUEL LENGTH FOR THE NNN CONFIGURATION
PLOT6(NNN)	BLANKET LENGTH FOR THE NNN CONFIGURATION
RBAKE	NUMBER OF BAKE-OUT CYCLES -0.20 PER HOUR
RBO(L)	CAPACITY OF BAKE-OUT OVENS IN MOLDS PER HOUR
RCRI	CRUCIBLE COATING AND INSPECTION RATE - 2.0 UNITS PER MAN-HOUR
RCST	NUMBER OF CASTING CYCLES -0.148 PER HOUR
RDEC	RATE OF SPENT ROD DECANNING - 30.0 RODS PER MACHINE-HOUR
RDIS	RATE OF DIASSEMBLY - 0.167 ELEMENTS PER MACHINE-HOUR
RECL	RATE OF INSERTION OF END FITTINGS INTO JACKETS - 20.0 UNITS PER MAN HOUR
RFCL	RATE OF INSERTION OF PINS INTO JACKETS -20.0 UNITS PER MAN-HOUR
RHO(L)	DENSITY OF FUEL OR BLANKET - 17.0- 18.8 GRAMS PER CC.
RHOA(L)	DENSITY OF END FITTING AND JACKET ALLOY - 5.72 AND 7.90 GRAMS PER CC.
RJCT	JACKET TUBING CUTTING RATE - 20.0 UNITS PER MAN-HOUR
RJEC(L)	JACKET EDDY CURRENT INSPECTION RATE IN UNITS PER MAN-HOUR
RJID	JACKET TUBING GUAGING RATE - 90.0 UNITS PER MAN-HOUR
RJLT	JACKET TUBING LEAK TESTING RATE - 30.0 UNITS PER MACHINE-HOUR
RJWL	LOWER END FITTING WELDING RATE - 12. UNITS PER MAN-HOUR
RMOC	MOLD COATING RATE - 50. UNITS PER MAN-HOUR
RMOI	MOLD INSPECTION RATE - 90. UNITS PER MAN-HOUR
RNAR	RATE OF SODIUM REMOVAL - 180. RODS PER HOUR
RNEC	SODIUM EXTRUSION AND CUTTING RATE - 88. UNITS PER HOUR
RNLD	SODIUM LOADING RATE - 88. UNITS PER MAN-HOUR
RNWT	SODIUM WEIGHING RATE - 88 UNITS PER MAN-HOUR
ROPC	OPTICAL COMPARISON RATE - 90 UNITS PER MAN-HOUR
RPP	PIN PROCESSING RATE - 40 UNITS PER MACHINE-HOUR
RRDBD	BONDING RATE - 50 RODS PER MACHINE-HOUR
RRDWL	RATE AT WHICH RODS ARE WELDED -30 OR 60 RODS PER MAN-HOUR
RRL	RATE AT WHICH RODS ARE LEAK TESTED - 10 RODS PER MAN-HOUR
RRWL	RATE OF WELDER LOADING - 20 RODS PER MAN-HOUR
RSAI	RATE OF SUBASSEMBLY HARDWARE INSPECTION - 0.100 UNITS PER MAN-HOUR
RTT	PAY RATE OF TECHNICIANS - 3.50 DOLLARS PER HOUR
RXRA	X-RAY RATE - 90 UNITS PER HOUR
SEQ	VARIABLE USED TO CALCULATE NUMBER OF BLANKET RODS
SUM	COST FOR REFABRICATION OF FUEL AND BLANKET IN $/KG AND $/DAY
TB	BOND THICKNESS - 0.0145 INCHES
TOTAC(L)	TOTAL AREA COSTS IN DOLLARS PER DAY
TOTAL(L)	TOTAL COST OF REFABRICATION IN DOLLARS
TOTCC(L)	TOTAL CAPITAL CHARGES IN DOLLARS PER DAY
TOTIP(L)	COST OF INDIRECT LABOR IN DOLLARS PER DAY
TOTLA(L)	COST OF DIRECT LABOR IN DOLLARS PER DAY
TOTMA(L)	TOTAL MATERIAL COST IN DOLLARS PER DAY
TPPRA(L)	FPPRA*ANPP(L)/H=PINS OUTPUT PER HOUR
TS(L)	SPACE BETWEEN RODS IN HEXAGONAL ARRAY - 0.060 INCHES
TT(L)	THICKNESS OF JACKET TUBING IN INCHES
VF(L)	RATIO OF ROD VOID LENGTH TO PIN LENGTH - 1.24 AND 1.10

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