HEDL-TME 72-95

**Length Changes in Prototypic
Cladding Irradiated in EBR-II to
 1×10^{22} N/CM², $E > 0.1$ MeV**

Hanford Engineering Development Laboratory

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LENGTH CHANGES IN FTR PROTOTYPIC CLADDING IRRADIATED

IN EBR-II TO 1×10^{22} N/CM², E > 0.1 MeV

(PIN B-65)

(RM-24)

By

J. L. Straalsund, G. L. Guthrie, T. J. Larson

July 1972

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SUMMARY

Swelling in prototypic FTR cladding and duct specimens is being determined from a series of three irradiations designed to cover a range of temperatures ~ 800 - 1500°F and peak fluences of approximately 1×10^{22} , 6×10^{22} and 1×10^{23} n/cm². The length change measurements for the low fluence irradiation have been completed and are summarized in this report. No swelling, only shrinkage, was found in the 20% cold worked Type 316 stainless steel cladding specimens. This shrinkage is of the same magnitude and has the same temperature dependency as unirradiated, control samples. Annealed specimens did swell slightly. Details of the experiment and analysis are given.

INTRODUCTION

At the present, swelling data comes from a wide variety of different experiments involving different heats of material with different processing and irradiation histories. For a particular set of estimated irradiation conditions the scatter within this data is usually about $\pm 60\%$ of the mean

value. For instance, if the present correlation for swelling in solution treated Type 304 stainless steel predicts 2% swelling for a given set of irradiation conditions, the experimental data for those conditions is expected to range from about 1 to 3% swelling. Much of this variation is thought to be due to the uncertainty in irradiation conditions as well as differences in the metallurgical conditions of the samples. A program at HEDL has therefore been instituted to measure accurately the length changes of a large number of the prototypic FTR cladding samples irradiated in Pins B-65, B-66, and B-67. The large number of essentially identical samples for each irradiation condition affords the opportunity to obtain statistically meaningful data on the reproducibility of the swelling phenomenon in a group of specimens with tightly controlled specifications. These data will be used for the following:

- To determine the reproducibility of the swelling phenomenon; i.e., to ascertain the variation in swelling or length change to be expected among fifty cladding samples irradiated under essentially identical conditions when all samples come from the same, closely controlled lot of tubing.
- To generate sufficient data to obtain statistically meaningful trends of swelling with cold work level.
- To obtain sufficient data to establish variations in swelling due to lot-to-lot variations in cladding remaining within the same FTR specification level.
- To clearly establish the dependence of swelling on the irradiation temperature and fluence for FTR prototypic material as outlined in WDTRS 1.12.

At the present time, original lengths for all the cladding samples encapsulated in Pins B-65, B-66, and B-67 have been measured. B-65 has been discharged from EBR-II and postirradiation cladding length measurements have

been completed. Although the results from Pin B-65 represent only low fluence (1×10^{22} n/cm²) results, trends are evident within the data. The following sections summarize the results and report on the preirradiation characterization and the postirradiation measurements.

EXPERIMENTAL

Irradiations

The major source of irradiated prototypic cladding samples for mechanical properties testing at HEDL are three large irradiation pins, B-65, B-66, and B-67. These pins are approximately 2 inches in diameter and are composed of subcapsules as shown in Figure 1. Each subcapsule contains 55 samples of prototypic size (0.230 diameter by 15 mil wall thickness) Type 316 stainless steel cladding samples. Figure 2 is a schematic layout of the cladding sample distribution in irradiation Pin B-65. Some of the capsules contain almost all 20% cold worked N lot tube samples whereas some of the other capsules contain groups of cladding samples with other levels of cold work or from other heats. The target irradiation conditions for Pin B-65 are given at the top of Figure 2. Pins B-66 and B-67 are similar except for higher peak exposures of 6×10^{22} and 1×10^{23} n/cm² ($E > 0.1$ MeV), respectively.

Preirradiation Measurements

Preirradiation length measurements were made on a system composed of a "Federal" machinshop type electronic gauge and a stand and positioning system to align the cladding specimen to the gauge head. A picture of the apparatus is shown in Figure 3 and a schematic arrangement is shown in Figure 4. As may be visualized from Figure 4 the clad length measurements are performed by measuring the distance between two knife edges positioned on the cladding. The cladding sample is held coincident with the axis of the gauge by the

V-block. Four measurements at 90 degree intervals were made on each cladding sample. The position of the first measurement (0°) was always made coincident with the center identification letter stamped on the clad. This was done so that the 0° position could be repeated during postirradiation measurements. All of the cladding samples for Pins B-65, B-66, and B-67 (approximately 1500 samples) were characterized in this manner. The measurements on the cladding were made relative to a standard sample which had previously been measured in the HEDL Standards Laboratory.

The measurements were conducted over a period of about three months. During this time one particular sample was measured at random intervals approximately 100 times in order to determine the overall reproducibility of the measurement apparatus. The measurement-frequency histogram for this series of measurements is shown in Figure 5. The standard deviation associated with the measuring apparatus when used out of cell is 8×10^{-5} inches. This amounts to about 0.003% $\Delta L/L$ for the ~ 2.5 inch long samples used in this study.

Postirradiation Measurements

The postirradiation measurements of the clad lengths were performed in the HCA hot cell at the Aerojet Nuclear Corporation Test Area North Facility in Idaho Falls. The same measurement system which was used to measure the preirradiation lengths was used to measure the postirradiation lengths. A photograph of this apparatus as installed in the cell is shown in Figure 6. Due to heating from the high intensity lamp required for visibility through the thick cell window, in-cell temperatures generally ranged from 90°F to 100°F . On any given day, however, the temperature fluctuations were slight. Furthermore, the standards which were used to calibrate the measuring

apparatus were made from 20% cold worked N lot cladding and therefore have the same coefficient of thermal expansion as the irradiation samples. Thus, it was not necessary to correct for differences in measurement temperatures when calculating irradiation induced length change. The standards were used to reset the calibration of the measurement apparatus after every ten measurements, approximately every hour.

A data handling computer program, DATAPR, was written to calculate the fractional length change of the individual tube specimens. The program is listed in Appendix I. The length measurements were entered on data cards with pre- and postirradiation data for a given sample on consecutive cards. The actual data listings are in Appendix II. Each data card has a sample identification number, four length measurements, and a code symbol indicating pre- or postirradiation data. The data reduction program takes the cards in consecutive pre- postirradiation pairs of given samples and calculates the average fractional swelling or shrinkage for each sample by averaging over the four azimuthal data pairs for each sample. A "huge error" criterion was used to discard any one azimuthal position length change if it differed moderately from the other three. The "huge error" decision is based on the comparison of the individual error to the RMS error. The fraction of error allowed relative to the RMS error was set to discard about 5% of the data.

The program was set up so that groups of samples with identical metallurgical⁽¹⁾ and/or irradiation conditions could be analyzed. The average fractional length change for each group was calculated using only that data which passed another "huge error" criterion. In this instance, data was sorted on "fractional swelling" and the extreme values were tested for remoteness from the main group, using a procedure given by Dixon and Massey.⁽²⁾

The rejection criterion was set to discard 1% of normal data. In addition, the data were required to pass a 3.3μ test (μ is the mean error).

Results

In general, the postirradiation measurements showed greater variability than the preirradiation out-of-cell measurements. This appeared to be particularly true for the four successive measurements at different angles on a given sample. Careful examination of the postirradiation samples revealed that much of this variability was attributable to small particulates remaining from the postirradiation cleaning operation or to slight dents or nicks probably introduced during de-encapsulation. Nevertheless, when appreciable numbers of samples with the same material and irradiation conditions were compared, the measurement statistics appeared to be quite good. Figure 7 shows frequency histograms for overall irradiation induced length changes of two typical groups of samples. The standard deviation on the overall change was typically on the order of 0.01-0.02% $\Delta L/L$. This, of course, includes the uncertainty associated with the original measurements (σ approximately = 0.003%). Although there were several instances in which one of the four azimuthal measurements for an individual sample was rejected, only two of the overall length change measurements for individual cladding samples fell outside the "huge error" criterion for groups of samples.

A summary of all of the dimensional change measurements for Pin B-65 is provided by Table I. The 95% confidence interval on the mean⁽³⁾ is indicated for each series of measurements. The number in parenthesis below each reading is the number of samples measured. The irradiation temperatures indicated are the range of calculated irradiation temperatures for each

subcapsule⁽⁴⁾. The range of temperatures indicates the difference in temperature from the outside row of specimens to the center specimen for each capsule.

Because of the relatively low neutron exposure very little swelling (volume increase) was found in the materials. Small amounts of swelling were found in the 0% cold worked N lot samples but no systematic trend with irradiation temperature was obvious. At the low fluences associated with this pin, possible changes due to swelling were of the same order of magnitude as the length changes due to thermal densification,⁽⁵⁾ and could therefore be masked. The thermal densification phenomenon depends both on temperature and dislocation density which in turn depends upon the irradiation conditions. Thus, for very low neutron exposures the dimensional changes of annealed materials may be expected to behave in a very complex fashion. Furthermore, significant numbers of annealed samples were available only in subcapsules A and B so the dimensional changes for the annealed materials are not as well known as for the cold worked materials.

No swelling was found in any of the 20% cold worked samples measured. These samples were found to shrink in amounts similar to that observed during thermal aging of unirradiated cold worked tubing specimens.⁽²⁾ In Figure 8 the tube shrinkage is of the 20% cold worked samples plotted as a function of irradiation temperature. In constructing the figure, the data were grouped by subcapsule and the mean of the temperature range indicated in Table I was used. The data have been plotted in terms of fractional change in density by assuming isotropic shrinkage ($\Delta\rho/\rho = 3\Delta L/L$). Data on the change in density of unirradiated thermally aged 20% cold worked N-lot cladding were obtained as a function of aging temperature and time, Table II. These data are plotted on the figure for reference. Inspection of Figure 8 suggests

that the shrinkage of the irradiated samples is slightly greater than the unirradiated samples aged for comparable times. However, an alternative explanation could be a low estimate of irradiation temperature. Part of this difference may be due to uncertainties ($\pm 100^\circ\text{F}$ max) in irradiation temperature. Shifting some of the points for irradiated samples 100°F to the right would tend to bring the two curves into coincidence. Another factor which may explain differences between the curves is the fact that the densification phenomenon may not be isotropic. A comparison of the length change measurements and density change measurements of the thermal control samples, shown in Figure 8, suggests that this may be the case.

Considering the above uncertainties, it appears that for all practical purposes, the densification occurring during irradiation to low fluences is essentially the same as the densification obtained during thermal aging of nonirradiated samples.

Although the dependence of thermal densification on temperature is relatively weak, the measurements appear to be sufficiently accurate to detect small differences in densification among samples within the same capsule due to temperature gradients in that capsule. This is illustrated in Figure 9. In this figure the tube samples were divided into three groups within a given capsule; those samples near the periphery of the capsule, those near the very center of the capsule, and those at intermediate locations. Due to the gamma heating in the reactor, the temperature of the center samples may have been as much as 130°F hotter than the outside samples for capsules located next to the midplane in EBR-II. Thus for capsule D, where the range is estimated to be 120°F , a slight increase in densification was found upon proceeding from the outside specimens to the inside specimens. Capsule G was located further away from the EBR-II midplane and therefore

had a lower value of gamma heating and a lower thermal gradient (-30°F). In this case, the densification phenomenon was essentially the same throughout the subcapsule.

Figure 10 shows the amount of densification observed in four different lots of 20% cold worked cladding. For these particular irradiations, no difference in behavior was noted.

Figure 11 shows the length changes as a function of cold work level for a target irradiation temperature of about 850°F . Again, within the sensitivity of the measurements very little difference was noted. This result is different than expected. It is possible that at this particular irradiation temperature the swelling to be expected in the solution treated material was small in comparison to the densification phenomenon. Furthermore, at the relatively low irradiation temperature, the irradiation induced dislocation density in the solution treated material may have been similar in magnitude to the dislocation density in the 20% cold worked material. Since the densification phenomenon appears to be associated with cold work or dislocation density, similar thermal densification could be attained in the solution treated and cold worked materials for low irradiation temperatures and fluences.

Figure 12 shows the variation in swelling with cold work found at a higher target irradiation temperature, 1005°F . In this case a small amount of swelling was found in the 0% cold worked samples. It is interesting to notice that the length changes measured for the mill annealed material fell between values obtained for the 0 and 5% cold worked samples. This is probably because of the 2-3% straightening strains associated with mill-annealed material. A possible corollary to this is the wide degree of data scatter in the mill-annealed material, due presumably to an ill-defined amount of cold work.

SUMMARY AND CONCLUSIONS

1. Length change measurements have been completed on approximately 250 samples or prototypic Type 316 stainless steel cladding. Although most of the samples contained 20% cold work, cold work levels including 0, 5, 10, 15% as well as the mill-annealed conditions were included.
2. The standard deviations associated with the overall length change measurements of samples within a group is typically on the order of $1/100\% \Delta L/L$. It appears that this level of reliability will also be obtained in the higher fluence irradiations.
3. No swelling was found in the 20% cold worked samples (for the relatively low fluence range covered). Irradiation temperatures varied from approximately 800 to 1500°F with fluences up to $1 \times 10^{22} \text{ n/cm}^2$ ($E > 0.1 \text{ MeV}$).
4. The 20% cold worked cladding samples were found to shrink or densify. The densification was found to have approximately the same magnitude and temperature dependence as found during thermal aging of unirradiated control samples. Thus, for the cold worked samples, the densification phenomenon does not appear to be appreciably affected by the neutron flux. Irradiation may, however, significantly increase the amount of densification in annealed materials by increasing the effective dislocation density.

REFERENCES

1. Material produced in a single heat by a single manufacturer and given one single heat treatment or one level of cold work by a particular process is all designated by a common letter, as for instance "L lot". The details of the chemistry, thermal-mechanical treatment and the identification of the manufacturer of any particular lot can be obtained from the HEDL Cladding Information Center.
2. W. J. Dixon and F. J. Massey, Introduction to Statistical Analysis, Third Edition, P. 500 (McGraw-Hill 1969).
3. R. Lowell Wine, Statistics for Scientists and Engineers, Prentice-Hall, 1964, P. 197.

4. Irradiation Temperatures in Pin B-65, WHAN Report in progress.
5. J. L. Straalsund and M. M. Paxton, Nuclear Technology, Vol. 13, January 1972.

TABLE I. SUMMARY OF DIMENSIONAL CHANGE MEASUREMENTS ON PIN B-65

CAPSULE NUMBER	IRRADIATION TEMPERATURE RANGE (°F)	FLUENCE n/cm ² E > 0.1 MeV x 10 ²²	SHRINKAGE - 1 UNIT = -0.01% $\Delta l/l$				OTHER	
			20% CW N LOT	10% CW M LOT	5% CW L LOT	0% CW N LOT		
BB	950- 960	0.225	2.4 ± 0.24 (7)*	-2.1 (1)	-0.4 (1)	8 (1)		
A	1000-1010	0.365	4.4 ± 0.6 (12)	4.1 ± 0.6 (10)	3.0 ± 0.9 (11)	-1.0 ± 1 (12)	MILL ANNEALED N-LOT 2.9 ± 2.8 (5)	
B	1015-1045	0.6	4.0 ± 0.6 (6)	3.8 ± 4.8 (2)	3.3 (1)	-2.2 (1)		
C	985-1040	0.85	4.6 ± 0.6 (7)	4.2 (1)	2.4 (1)	2.8 (1)		
D	1410-1530	0.98	7.0 ± 0.8 (14) ^a 6.8 ± 0.7 (14) ^b 5.7 ± 0.6 (17) ^c	3.7 (1)	3.4 (1)	3.3 (1)		
E	1320-1450	0.97	5.2 ± 0.5 (6)	4.2 (1)	8.9 (1)	5.7 (1)		
F	940-1005	0.79	3.3 ± 0.7 (7)	1.5 (1)	4.9 (1)	-0.2 (1)		
G	835- 865	0.6	2.1 ± 0.6 (11) 2.5 ± 0.6 (11) 2.2 ± 0.9 (3)	2.2 ± 0.7 (7)	3.4 ± 1.5 (7)	2.4 ± 1.6 (6) 2.8 (1)	0 LOT 0% 0 LOT 20%	3.1 ± 6.4 (3) 3.1 ± 0.7 (6)
H	990-1005	0.365	3.6 ± 0.5 (14)			FTL ^d 20% CW Se 20% R ^f 20%	4.5 ± 0.5 (10) 4.1 ± 0.5 (20) 3.5 ± 0.6 (10)	

NOTES: * NUMBERS IN PARENTHESIS INDICATE NUMBER OF SAMPLES
± FIGURES 95% CONFIDENCE INTERVAL ON MEAN

a) SAMPLES 1-14, LOCATED IN CENTER POSITION OF CAPSULE (HOTTEST)
b) SAMPLES 15-28 LOCATED ~ HALFWAY BETWEEN CENTER AND PERIPHERY
c) SAMPLES 29-51 LOCATED ALONG PERIPHERY OF CAPSULE AND THEREFORE COLDEST.

d) FTL LOT OF TUBING
e) S LOT OF TUBING
f) R LOT OF TUBING

TABLE II
DENSITY CHANGES IN 20% C.W. N-LOT CLADDING
SAMPLES AFTER VARIOUS AGING TREATMENTS

<u>Condition</u>	<u>Density (Ave of 2 Meas) (g/cm³)</u>	<u>Spread in Measurements (%)</u>	<u>Change in Density (Relative to As Received) (%)</u>
As Received (20% CW)	7.97718	.002	.000
As Received + 1000 hrs at 800°F	7.98275	.003	.070
As Received + 1000 hrs at 1000°F	7.98426	.006	.089
As Received + 1000 hrs at 1100°F	7.98478	.001	.095
As Received + 1000 hrs at 1200°F	7.98619	.002	.113
As Received + 6000 hrs at 800°F	7.98288	.003	.072
As Received + 6000 hrs at 1000°F	7.98545	.012	.104
As Received + 6000 hrs at 1100°F	7.98609	.000	.112
As Received + 6000 hrs at 1200°F	7.98801	.004	.136

FIGURE 1. LAYOUT OF M-1A CAPSULES

FIGURE 2. SPECIMEN LAYOUT - COLD WORK CLADDING SUBASSEMBLY

FIGURE 3. MEASUREMENT APPARATUS

FIGURE 4. SCHEMATIC DIAGRAM OF MEASURING APPARATUS

FIGURE 5. FREQUENCY DIAGRAM FOR OUT OF CELL MEASUREMENTS

FIGURE 6. IN CELL MEASURING APPARATUS

FIGURE 7. TYPICAL FREQUENCY DIAGRAMS FOR LENGTH CHANGE MEASUREMENTS - IRRADIATED, 20% COLD WORKED N LOT SAMPLES FROM CAPSULES G AND D OF PIN B-65.

FIGURE 8. THERMAL SHRINKAGE OF IRRADIATED AND UNIRRADIATED 20% COLD-WORKED TYPE 316 STAINLESS STEEL.

FIGURE 9. VARIATION OF TUBE SHRINKAGE WITH POSITION OF SPECIMENS IN CAPSULE DUE TO GAMMA HEATING, THE "INSIDE" SPECIMENS IN CAPSULE D ARE ESTIMATED TO BE ABOUT 150°F COOLER THAN SPECIMENS ALONG THE OUTSIDE EDGE. CONSEQUENTLY, MORE SHRINKAGE OCCURS NEAR THE CENTER. γ HEATING IS MUCH LOWER IN CAPSULE G SO THE EFFECT IS NOT EVIDENT.

FIGURE 10. LOT TO LOT VARIATION IN TUBE SHRINKAGE
 TYPE 316 STAINLESS STEEL -1000°F $-0.4 \times 10^{22} \text{ n/cm}^2$ ($E > 0.1 \text{ MeV}$)

FIGURE 11. EFFECT OF COLD WORK ON TUBE LENGTH CHANGES (TYPE 316 STAINLESS STEEL)
 $850^{\circ}\text{F} - 0.6 \times 10^{22} \text{ n/cm}^2 \text{ E} > 0.1 \text{ MeV}$

FIGURE 12. EFFECT OF COLD WORK ON TUBE LENGTH CHANGES IN TYPE 316 STAINLESS STEEL
 $1005^{\circ}\text{F} - 0.4 \times 10^{22} \text{ n/cm}^2$ ($E > 0.1 \text{ MeV}$)

APPENDIX 1

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C  FR5  DATAPR,DATAPR
C  THIS PROGRAM DOES AN ELEMENTARY STATISTICAL TREATMENT OF TUBE
C  LENGTH CHANGES.  THE TUBES WERE GIVEN FOUR AZIMUTHAL LENGTH MEAS-
C  UREMENTS BEFORE AND AFTER IRRADIATION.  THE PROGRAM CALCULATES
C  THE FRACTIONAL LENGTH SHRINKAGE AND DISCARDS BAD DATA WHILE RE-
C  PORTING THE THROWOUTS AND OTHER PERTINENT COMMENTS.  TO USE IT,
C  LOAD THE PROGRAM DECK, FOLLOWED BY THE XOT CARD.  THEN PUT IN A
C  CARD THAT IS COMPLETELY BLANK.  FOLLOW THIS WITH A CARD THAT
C  HAS A P IN COLUMN 50 AND THE REST BLANK.  THEN PUT IN A CARD WITH
C  AN S IN COLUMN 50 AND THE REST BLANK.  THEN PUT IN THE DIXON-
C  MASSEY TABLE AND FOLLOW THIS WITH THE DATA CARDS
C  IN PAIRS WITH THE PRE-IRRADIATION CARD FIRST, AND THE POSTIRRAD-
C  IATION CARD SECOND, IN MATCHED PAIRS.  PUT PAIRS FROM SAMPLES
C  WITH SIMILAR HISTORY AND SIMILAR METALLURGY ADJACENT WITHOUT
C  SPACERS, BUT SEPARATE UNSIMILAR GROUPS, USING A SEPARATOR CARD
C  WHICH IS BLANK EXCEPT FOR AN S IN COLUMN 50.  ALSO PLACE A SEPAR-
C  ATEUR CARD AT THE END OF THE FINAL GROUP, I.E. AT THE END OF THE
C  DATA.  THEN PUT FOUR BLANK CARDS AND A FIN CARD.  THE PROGRAM
C  CAN TAKE A PAIR IN THE WRONG ORDER, UNMATCHED PAIRS, OR DATA
C  SHIFTED BY ONE COLUMN WITHOUT PRODUCING AN ERROR IN THE OUTPUT.
C  TO CHANGE THE TIGHTNESS OF THE THROWOUT CRITERION FOR REJECTING
C  ONE OR MORE OF THE READINGS ON A SINGLE SAMPLE, ADJUST THE FACTOR
C  IN THE LINE WHICH STARTS QUOTE TSTOUT=FACTOR*SQRT ETC.  A FACTOR
C  OF .866 OR GREATER RESULTS IN NO THROWOUT AT ALL.  .84 THROWS OUT
C  ABOUT ONE IN 20..
C  FORMAT FOR DATA CARDS IS BLANK IN COL 1, 5 CHARACTER ALPHANUMERIC
C  SAMPLE CODE IN COLS 2-6, BLANKS IN 7-8, 21-22, 28-29, 35-36, WITH
C  SAMPLE LENGTH MEASUREMENTS IN COLS 10-13, 17-20, 24-27, 31-34,
C  WITH THE SAMPLE LENGTH GIVEN AS EXCESS OVER 2.443360 INCHES AND
C  REPORTED AS AN INTEGER AFTER MULTIPLYING BY TEN TO THE FIFTH.
C  THE SIGNS OF THE EXCESSES APPEAR IN COLS 9, 16, 23, AND 30.  COLS
C  37-40 CONTAIN A CODE INDICATING THE DATA SET.  COL 50 IS A BLANK
C  FOR A CARD WHICH IS PRE-IRRADIATION DATA AND A 'P' FOR A CARD
C  WHICH CONTAINS POST IRRADIATION DATA.  A LENGTH READING REFERRING
C  TO A PARTICULAR AZIMUTHAL POSITION OF THE SAMPLE SHOULD APPEAR IN
C  THE SAME POSITION ON BOTH THE PRE AND THE POST CARD.
C  THE DIXON-MASSEY TABLE IS FOUR CARDS, EACH CONTAINING 14 NUMBERS
C  IN FIXED POINT FORM WITH THREE DIGITS PER NUMBER.  IT IS USED

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C      IN THE ANALYSIS OF GROUPS OF SIMILAR SAMPLES AND IS EXPLAINED
C      FURTHER AT THE APPROPRIATE POINT IN THE PROGRAM.
      DIMENSION IDE(100),R(100),ERR(100),DICKS(2,100),IP(100)
C      NEXT COMMAND READS IN THE PREIRRADIATION TEST CODE IN 50 AND ALSO
C      READS IN THE TEST BLANKS WHICH SHOULD BE IN THE BLANK SPACES.
      READ (5,52) JTST1,JTST2,JTST3,JTST4,JTST5,JTST6,IPREE
52  FORMAT (6X,4(A2,5X),A1,5X,A5,A5)
C      DITTO THE POST TEST CODE IN 50
      READ (5,55) IPOST
C      ISTOP CARD HAS AN S IN COLUMN 50 AND IS A TYPICAL SEPARATOR CARD
C      FOR SEPARATING UNSIMILAR GROUPS. PAIRS GROUPED TOGETHER BETWEEN
C      SEPARATOR CARDS ARE GIVEN AN ELEMENTARY STATISTICAL ANALYSIS.
      READ (5,55) ISTOP
55  FORMAT (45X,A5)
56  FORMAT (1X,14F5.3)
C      NEXT 8 CARDS SET UP THE DIXON-MASSEY TABLE.
      DO 23 I=1,2
      READ (5,36) (DICKS(I,IRE),IRE=3,16)
      READ (5,36) (DICKS(I,IRE),IRE=17,30)
23  CONTINUE
      DO 35 M=31,100
      RLM=M
      DICKS(1,M)=.376*SQRT(30.0/RLM)
35  DICKS(2,M)=.457*SQRT(30.0/RLM)
C      M IS THE NUMBER OF SIMILAR PAIRS IN A GROUP HAVING SIMILAR
C      HISTORY AND METALLURGY. SET EQUAL TO ZERO PRIOR TO COUNTING THEM.
      M=0
C      SET ITIT=1 FOR 1 IN 20 THROWOUT WITHIN A SET OF SAMPLES BETWEEN
C      SEPARATOR CARDS. SET=2 FOR 1 IN 100 THROWOUT.
C      THROWOUT BASED ON DIXON-MASSEY FIRST EDITION PAGE 319. FOR
C      EITHER VALUE OF ITIT A 3.3RMS ERROR WILL ALSO CAUSE THROWOUT.
      ITIT=2
      WRITE (6,19)
19  FORMAT (1H,40HSAFPLF, LENGTH, AND FRACTIONAL SHRINKAGE)
C      NEXT 9 CARDS READ A PAIR OF DATA CARDS AND TEST BLANK SPACES
C      FOR BLANKS.
32  READ (5,51) IDEN11,JTBT1,N11,JTBT2,N21,JTBT3,N31,JTBT4,N41,JTBT5,
1  IDEN21,JTBT6,IDEN31
51  FORMAT (1X,A5,4(A2,I5),A1,I5,A5,A5)
      IF (IDEN31.EQ.ISTOP) GO TO 25
      IF (JTBT1.NE.JTST1.OR.JTBT2.NE.JTST2.OR.JTBT3.NE.JTST3.OR.JTBT4.N
1E.JTST4.OR.JTBT5.NE.JTST5.OR.JTBT6.NE.JTST6) GO TO 44
33  READ (5,51) IDEN12,JTAT1,N12,JTAT2,N22,JTAT3,N32,JTAT4,N42,JTAT5,
1  IDEN22,JTAT6,IDEN32
      IF (IDEN32.EQ.ISTOP) GO TO 25
      IF (JTAT1.NE.JTST1.OR.JTAT2.NE.JTST2.OR.JTAT3.NE.JTST3.OR.JTAT4.N
1E.JTST4.OR.JTAT5.NE.JTST5.OR.JTAT6.NE.JTST6) GO TO 46
      JIRDF1=IDEN32-IDEN31
C      IF BOTH PRE OR BOTH POST, GO TO 75 IF HAPPENS AGAIN IMMEDIATELY
C      PROGRAM QUILTS.
      IF (JIRDF1.EQ.0) GO TO 75

```

```

C      NOW CHECK TO SEE THAT THE PAIR ARE BOTH FOR THE SAME SAMPLE
      JIRDF2=IDEN11-IDEN12
      IF (JIROF2.NE.0) GO TO 90
C      TAKE DIFFERENCES ON THE FOUR DATA READINGS , GET 4 DIFFERENCES
C      IN INTEGERS.  CHANGE TO DECIMAL NUMBERS TO CALCULATE.
      RIDIF1=N11-N12
      RIDIF2=N21-N22
      RIDIF3=N31-N32
      RIDIF4=N41-N42
      SUMDF=RIDIF1+RIDIF2+RIDIF3+RIDIF4
      AVDIF=SUMDF/4.0
      RDIF1=RIDIF1-AVDIF
      RDIF2=RIDIF2-AVDIF
      RDIF3=RIDIF3-AVDIF
      RDIF4=RIDIF4-AVDIF
      ADIF1=ABS(RDIF1)
      ADIF2=ABS(RDIF2)
      ADIF3=ABS(RDIF3)
      ADIF4=ABS(RDIF4)
      RN11=N11
      RN21=N21
      RN31=N31
      RN41=N41
      RN12=N12
      RN22=N22
      RN32=N32
      RN42=N42
C      TAKE THE SUM OF SQUARES AND CALCULATE HUGE ERROR CRITERION FOR THE
C      INDIVIDUAL READINGS ON ONE PAIR OF CARDS.
      TSTOUT=.84*SQRT(RDIF1**2+RDIF2**2+RDIF3**2+RDIF4**2)
C      REAV IS PLACE WHERE DIFFERENCE IN READINGS ACCUMULATES
      REAV=0.0
C      REFIK IS FOUR TIMES EXCESS LENGTH ON PRE READING
      REFIK=0.0
C      SET NUMBER OF GOOD DATA POINTS EQ 0 PRIOR TO COUNTING THEM
      RN=0.0
C      IDENTIFY GOOD DATA, COUNT THEM ADD THEM TO GET AVERAGE CHANGE
C      WHEN DIVIDED BY THE NUMBER OF DATA POINTS USED
      IF(ADIF1.LT.TSTOUT) GO TO 78
      WRITE (6,10)
10  FORMAT (1H ,38HFIRST DATA POINT THROWN OUT, NEXT ITEM)
82  IF (ADIF2.LT.TSTOUT) GO TO 79
      WRITE (6,11)
11  FORMAT (1H ,39HSECOND DATA POINT THROWN OUT, NEXT ITEM)
83  IF(ADIF3.LT.TSTOUT) GO TO 80
      WRITE (6,12)
12  FORMAT (1H ,38HTHIRD DATA POINT THROWN OUT, NEXT ITEM)
84  IF (ADIF4.LT.TSTOUT) GO TO 81
      WRITE (6,13)
13  FORMAT (1H ,39HFOURTH DATA POINT THROWN OUT, NEXT ITEM)
85  AVDIF=REAV/RN

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--
AVLN=REFIR/RN
ALN=2.443360+AVLN*1.0*10.0**(-5)
PRCNCH=(AVDIF*1.0*10.0**(-5.0))/ALN
JIRDF5=IDEN32-IPRFE
JIRDF6=IDEN32-IPOST
IF (JIRDF5.NE.0.AND.JIRDF6.NE.0) GO TO 92
JIRDF3=IDEN31-IPRFE
JIRDF4=IDEN31-IPOST
IF (JIRDF4.NE.0.AND.JIRDF3.NE.0) GO TO 92
IF (JIRDF5.EQ.0) GO TO 95
94 WRITE(6,91) IDEN11,ALN,PRCNCH
   M=M+1
   R(M)=PRCNCH
   IDE(M)=IDEN12
91 FORMAT (1H ,A5,4X,1PF14.8,5X,1PE14.8)
   GO TO 32
92 WRITE (6,93) IDEN11,IDEN12
93 FORMAT (1H ,30HCOL 50 WRONG ONE OR BOTH CARDS,2X,A5,2X,A5)
   GO TO 94
75 READ (5,51) IDEN11,JTRT1,N11,JTRT2,N21,JTRT3,N31,JTBT4,N41,JTBT5,
1IDEN21,JBT16,IDEN31
   IF (IDEN31.EQ.ISTOP) GO TO 25
   READ(5,51) IDEN12,JTA11,N12,JTAT2,N22,JTAT3,N32,JTAT4,N42,JTAT5,
1IDEN22,JTA16,IDEN32
   IF (IDEN32.EQ.ISTOP) GO TO 25
   JIRDF1=IDEN32-IDEN31
   IF (IDEN31.EQ.IPRFE.AND.IDEN32.EQ.IPRE) GO TO 77
   WRITE (6,29)
29 FORMAT (1H ,28HHAVE JUST IGNORED FOUR CARDS)
   GO TO 32
77 CALL EXIT
78 RN=RN+1.0
   REAV=REAV+RIDIF1
   REFIR=REFIR+RN11
   GO TO 82
79 RN=RN+1.0
   REAV=REAV+RIDIF2
   REFIR=REFIR+RN21
   GO TO 83
80 RN=RN+1.0
   REAV=REAV+RIDIF3
   REFIR=REFIR+RN31
   GO TO 84
81 RN=RN+1.0
   REAV=REAV+RIDIF4
   REFIR=REFIR+RN41
   GO TO 85
44 WRITE (6,45)
45 FORMAT(1H ,42HCARD PUNCHED IN BLANK AREA.  SKIPPED CARD.)
   GO TO 32
46 WRITE (6,45)

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```

      GO TO 33
90 IDEN11=IDEN12
      N11=N12
      N21=N22
      N31=N32
      N41=N42
      IDEN21=IDEN22
      IDEN31=IDEN32
      WRITE (6,28)
28 FORMAT(1H ,36HJUST IGNORED ONF CARD TO GET IN STEP)
      GO TO 33
95 ALN=ALN-AVDIF*10.0**(-5)
      PRNCH=-PRNCH
      WRITE (6,37)
37 FORMAT (1H ,27HCARDS REVERSED ON NEXT ITFM)
      GO TO 94
25 RM=M
C      ILOHAD AND IHIBAD ARE THE SEQUENCE NUMBERS OF THE BAD DATA. SET
C      TO NONSENSE NUMBERS TO START WITH .
      ILOHAD=-1
      IHIBAD=-1
C      DO A BUBBLE-UP SORT ON THE DATA PRIOR TO DIXON-MASSEY TREATMENT.
C      THIS OCCURS BETWEEN HERE AND STATEMENT 15.
      DO 14 IR = 1,M
14 IP(IR)=IR
      M1=M-1
      DO 15 K=1,M1
      MK=M-K
      DO 15 IR=1,MK
      IPIR=IP(IR)
      UP=R(IPIR)
      IPIR1=IP(IR+1)
      UPPER=R(IPIR1)
      IF (UP.GT.UPPER) GO TO 16
      GO TO 15
16 ITRANS=IP(IR)
      IP(IR)=IP(IR+1)
      IP(IR+1)=ITRANS
15 CONTINUE
      IF (M.GE.0.AND.M.(T.3)) GO TO 34
      IF (M.GE.3.AND.M.(E.7)) GO TO 17
      IF (M.GE.8.AND.M.(E.10)) GO TO 18
      IF (M.GE.11.AND.M.(E.13)) GO TO 20
      IF (M.GE.14.AND.M.(E.100)) GO TO 22
17 IP2=IP(2)
      IP1=IP(1)
      IPM=IP(M)
      IPM1=IP(M-1)
      RLO=(R(IP2)-R(IP1))/(R(IPM)-R(IP1))
      RHI=(R(IPM)-R(IPM1))/(R(IPM)-R(IP1))
      GO TO 31

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```

18 IP2=IP(2)
   IP1=IP(1)
   IPM1=IP(M-1)
   IPM=IP(M)
   RLO=(R(IP2)-R(IP1))/(R(IPM1)-R(IP1))
   RHI=(R(IPM)-R(IPM1))/(R(IPM)-R(IP2))
   GO TO 31
20 IP3=IP(3)
   IP1=IP(1)
   IPM1=IP(M-1)
   IPM2=IP(M-2)
   IPM=IP(M)
   IP2=IP(2)
   RLO=(R(IP3)-R(IP1))/(R(IPM1)-R(IP1))
   RHI=(R(IPM2)-R(IPM))/(R(IP2)-R(IPM))
   GO TO 31
22 IP3=IP(3)
   IP1=IP(1)
   IPM2=IP(M-2)
   IPM=IP(M)
   RLO=(R(IP3)-R(IP1))/(R(IPM2)-R(IP1))
   RHI=(R(IPM2)-R(IPM))/(R(IP3)-R(IPM))
31 IF (RLO.GT.DICKS(ITIT,M)) ILOBAD=IP(1)
   IF (RHI.GT.DICKS(ITIT,M)) IHIBAD=IP(M)
34 RTOTE=0.0
   DO 40 IJ=1,M
   RTOTE=RTOTE+R(IJ)
40 CONTINUE
   AVECHN=RTOTE/RM
   ERRSQT=0.0
   DO 41 IJ=1,M
   ERR(IJ)=AVECHN-R(IJ)
41 ERRSQT=ERRSQT+ERR(IJ)*ERR(IJ)
   AVESQT=ERRSQT/RM
   RMSERR=SQRT(AVESQT)
   HUGERR=3.3*RMSERR
   AVE1=0.0
   RL=0.0
   DO 42 IJ=1,M
   Y73=ERR(IJ)
   ABERR=ABS(Y73)
   IF (IJ.EQ.IHIBAD.OR.IJ.EQ.ILOBAD) GO TO 21
   IF (ABERR.GT.HUGERR) GO TO 21
   RL=RL+1.0
   AVE1=AVE1+R(IJ)
   GO TO 42
21 WRITE (6,70) IJ,IDE(IJ)
42 WRITE (6,67) ERR(IJ),IJ,IDE(IJ)
   AVE1=AVE1/RL
   WRITE (6,71) AVE1
   WRITE (6,72) RMSERR

```

```

M=0
GO TO 32
72 FORMAT (1H ,40HRMS ERROR, USING DATA FROM ALL SAMPLES =,1PE14.8, //
1//)
67 FORMAT (1H ,24HDEVIATION FROM AVERAGE =,1PE14.8,19H, SEQUENCE NUMB
1ER =,15,33H, SAMPLE IDENTIFICATION NUMBER = ,A5)
71 FORMAT(1H ,43HAVERAGE FRACTIONAL SHRINKAGE FOR THIS SET =,1PE14.8)
70 FORMAT (1H ,26HHUGE ERROR ON ITEM NUMBER ,15,25H, INPUT DATA CARD
1NUMBER ,A5)
END
THIS IS THE END OF THE PROGRAM DECK. REMOVE THIS CARD WHEN RUNNING.
XQT DATAPR

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P
S
C NEXT 4 CARDS ARE DIXON-MASSEY TABLE. DON'T RUN THIS CARD. REMOVE IT.
.941 .765 .642 .560 .507 .554 .512 .477 .576 .546 .521 .546 .525 .507 DM1
.490 .475 .462 .450 .440 .430 .421 .413 .406 .399 .393 .387 .381 .376 DM2
.988 .889 .780 .698 .637 .683 .635 .597 .679 .642 .615 .641 .616 .595 DM3
.577 .561 .547 .535 .524 .514 .505 .497 .489 .486 .475 .469 .463 .457 DM4

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APPENDIX 2

32

A-01	0876	0931	0802	0808	0002	
A-01	0757	0794	0717	0701	0002	P
A-02	0510	0458	0502	0479	0003	
A-02	0399	0360	0396	0386	0003	P
A-03	0474	0483	0515	0503	0004	
A-03	0378	0369	0401	0402	0004	P
A-04	0721	0721	0699	0677	0005	
A-04	0566	0578	0572	0549	0005	P
A-05	0483	0490	0466	0478	0006	
A-05	0385	0417	0367	0389	0006	P
A-06	0063	0013	0065	0070	0007	
A-06	-0012	-0031	-0034	-0020	0007	P
A-07	0492	0432	0433	0457	0008	
A-07	0343	0316	0280	0306	0008	P
A-08	0415	0423	0418	0426	0010	
A-08	0339	0309	0339	0342	0010	P
A-09	0202	0277	0333	0311	0011	
A-09	0166	0211	0229	0221	0011	P
A-10	0712	0777	0690	0669	0012	
A-10	0573	0616	0591	0555	0012	P
A-11	0533	0573	0545	0529	0013	
A-11	0418	0477	0492	0404	0013	P

A-12	0295	0281	0308	0313	0014	
A-12	0182	0182	0202	0208	0014	P
						S
A-13	0392	0430	0448	0410	0015	
A-13	0310	0347	0422	0337	0015	P
A-14	0745	0819	0809	0780	0016	
A-14	0681	0656	0653	0686	0016	P
A-15	0736	0720	0885	0770	0017	
A-15	0652	0630	0660	0713	0017	P
A-16	0736	0693	0681	0819	0018	
A-16	0621	0613	0565	0696	0018	P
A-17	0767	0720	0740	0783	0019	
A-17	0640	0589	0617	0576	0019	P
A-18	0554	0516	0496	0530	0020	
A-18	0437	0439	0385	0420	0020	P
A-19	0887	0861	0825	0874	0021	
A-19	0779	0778	0735	0745	0021	P
A-20	0737	0744	0836	0810	0022	
A-20	0648	0641	0666	0713	0022	P
A-21	0712	0609	0585	0715	0024	
A-21	0587	0559	0533	0604	0024	P
A-22	0517	0609	0513	0575	0025	
A-22	0473	0478	0476	0485	0025	P
						S
A-23	0656	0694	0725	0672	0026	
A-23	0571	0585	0651	0589	0026	P
A-24	0637	0633	0605	0627	0027	
A-24	0576	0568	0544	0576	0027	P
A-25	0758	0787	0762	0816	0028	
A-25	0720	0699	0705	0753	0028	P
A-26	0748	0648	0620	0732	0029	
A-26	0673	0630	0579	0649	0029	P
A-27	0536	0539	0473	0488	0030	
A-27	0478	0473	0435	0430	0030	P
A-29	0786	0785	0807	0831	0032	
A-29	0732	0710	0740	0760	0032	P
A-30	0780	0760	0681	0712	0033	
A-30	0631	0664	0596	0620	0033	P
A-31	0443	0481	0494	0527	0034	
A-31	0355	0401	0417	0455	0034	P
A-32	0814	0879	0916	0880	0035	
A-32	0738	0760	0861	0798	0035	P
A-33	0592	0588	0649	0663	0036	
A-33	0441	0400	0492	0478	0036	P
A-34	0640	0631	0604	0612	0037	
A-34	0540	0550	0528	0530	0037	P
						S
A-36	0340	0412	0384	0377	0039	
A-36	0297	0370	0560	0407	0039	P
A-37	0776	0828	0761	0713	0040	
A-37	0810	0854	0940	0863	0040	P

A-38	0291	0309	0313	0362	0041	
A-38	0237	0338	0360	0440	0041	P
A-39	0281	0271	0247	0388	0042	
A-39	0377	0267	0278	0330	0042	P
A-40	0455	0491	0474	0441	0043	
A-40	0510	0571	0470	0486	0043	P
A-41	0630	0709	0695	0686	0045	
A-41	0636	0729	0774	0745	0045	P
A-42	0465	0494	0512	0479	0046	
A-42	0429	0496	0444	0466	0046	P
A-43	0434	0478	0502	0449	0047	
A-43	0412	0522	0664	0515	0047	P
A-44	0678	0697	0668	0723	0048	
A-44	0707	0725	0685	0707	0048	P
A-45	0429	0388	0348	0374	0051	
A-45	0464	0433	0388	0432	0051	P
A-46	0336	0314	0332	0345	0052	
A-46	0331	0296	0293	0314	0052	P
A-47	0524	0480	0455	0513	0053	
A-47	0509	0434	0424	0494	0053	P
						S
A-48	0534	0588	0517	0540	0054	
A-48	0473	0477	0481	0488	0054	P
A-49	0336	0323	0367	0592	0055	
A-49	0338	0273	0302	0501	0055	P
A-50	0676	0673	0675	0686	0056	
A-50	0620	0628	0641	0633	0056	P
A-51	0502	0517	0485	0571	0057	
A-51	0453	0478	0453	0573	0057	P
A-52	0775	0791	0768	0839	0058	
A-52	0609	0637	0615	0652	0058	P
						S
A-53	0758	0749	0571	0582	1109	
A-53	0670	0654	0527	0523	1109	P
						S
A-55	0611	0649	0675	0623	1111	
A-55	0497	0544	0597	0513	1111	P
						S
B-07	0469	0441	0428	0445	0067	
B-07	0574	0336	0329	0345	0067	P
B-09	0357	0332	0352	0355	0069	
B-09	0268	0323	0247	0252	0069	P
B-12	0521	0527	0515	0536	0073	
B-12	0380	0425	0427	0426	0073	P
B-25	0452	0446	0418	0416	0087	
B-25	0361	0355	0331	0316	0087	P
B-26	0862	0898	0809	0823	0088	
B-26	0774	0776	0719	0721	0088	P
B-30	0570	0566	0550	0556	0092	
B-30	0526	0468	0468	0465	0092	P
						S

B-48	0817	0856	0772	0866	0111	
B-48	0688	0738	0697	0767	0111	P
B-49	0616	0636	0651	0631	0112	
B-49	0540	0500	0626	0542	0112	P
						S
B-51	0712	0623	0594	0645	0116	
B-51	0578	0553	0545	0577	0116	P
						S
B-54	0449	0411	0397	0449	0119	
B-54	0415	0631	0383	0494	0119	P
						S
C-17	0426	0407	0426	0453	0139	
C-17	0322	0336	0326	0325	0139	P
C-22	0414	0426	0445	0372	0145	
C-22	0263	0289	0316	0244	0145	P
C-01	0324	0339	0355	0359	0123	
C-01	0229	0221	0237	0253	0123	P
C-25	0335	0377	0340	0296	0148	
C-25	0167	0245	0238	0167	0148	P
C-29	0332	0320	0299	0324	0152	
C-29	0179	0235	0220	0229	0152	P
C-36	0379	0493	0450	0384	0160	
C-36	0293	0341	0352	0227	0160	P
C-43	0508	0526	0523	0493	0168	
C-43	0402	0410	0418	0395	0168	P
						S
C-53	0706	0710	0727	0697	0178	
C-53	0620	0577	0647	0588	0178	P
						S
C-54	0408	0388	0356	0387	0179	
C-54	0338	0361	0305	0307	0179	P
						S
C-55	0456	0487	0462	0450	0180	
C-55	0347	0442	0470	0318	0180	P
						S
D-01	0476	0518	0535	0497	0183	
D-01	0325	0387	0392	0338	0183	P
D-02	0587	0616	0667	0622	0184	
D-02	0406	0478	0475	0411	0184	P
D-03	0381	0350	0305	0338	0185	
D-03	0202	0214	0221	0191	0185	P
D-04	0366	0386	0404	0389	0186	
D-04	0233	0247	0257	0229	0186	P
D-05	0624	0607	0570	0571	0187	
D-05	0458	0429	0387	0377	0187	P
D-06	0740	0776	0773	0756	0188	
D-06	0533	0554	0521	0476	0188	P
D-07	0236	0285	0289	0282	0189	
D-07	0075	0149	0161	0089	0189	P
D-08	0521	0529	0545	0535	0190	
D-08	0395	0409	0395	0377	0190	P

D-09	0360	0362	0351	0317	0191	
D-09	0223	0225	0202	0158	0191	P
D-10	0578	0584	0575	0695	0192	
D-10	0394	0398	0417	0348	0192	P
D-11	0724	0735	0718	0709	0194	
D-11	0526	0572	0578	0510	0194	P
D-12	0382	0397	0386	0369	0195	
D-12	0175	0209	0180	0124	0194	P
D-13	0377	0379	0350	0348	0196	
D-13	0169	0178	0123	0114	0196	P
D-14	0673	0649	0669	0691	0197	
D-14	0537	0513	0534	0536	0197	P
						S
D-15	0401	0409	0418	0551	0198	
D-15	0234	0370	0224	0333	0198	P
D-16	0231	0232	0226	0228	0199	
D-16	0076	0115	0107	0048	0199	P
D-17	0751	0781	0761	0756	0200	
D-17	0547	0610	0630	0578	0200	P
D-18	0468	0454	0456	0441	0201	
D-18	0267	0231	0202	0284	0201	D
D-19	0506	0500	0517	0527	0202	
D-19	0357	0365	0374	0382	0202	P
D-20	0805	0801	0776	0790	0203	
D-20	0680	0672	0638	0815	0203	P
D-21	0598	0688	0606	0598	0206	
D-21	0428	0553	0470	0439	0206	P
D-22	0595	0737	0645	0605	0207	
D-22	0308	0515	0461	0342	0207	P
D-23	0552	0518	0496	0549	0208	
D-23	0378	0374	0372	0421	0208	P
D-24	0498	0518	0468	0461	0209	
D-24	0321	0359	0293	0261	0209	P
D-25	0213	0254	0270	0237	0210	
D-25	0028	0089	0106	0037	0210	P
D-26	0648	0606	0599	0670	0211	
D-26	0416	0473	0464	0473	0211	P
D-27	0674	0681	0673	0686	0212	
D-27	0578	0514	0523	0577	0212	P
D-28	0688	0717	0735	0713	0213	
D-28	0522	0568	0522	0468	0213	P
						S
D-29	0369	0500	0474	0485	0214	
D-29	0233	0374	0303	0316	0214	P
D-30	0526	0506	0498	0552	0215	
D-30	0367	0354	0363	0361	0215	P
D-32	0368	0322	0279	0343	0218	
D-32	0252	0167	0157	0177	0218	P
D-33	0464	0417	0395	0457	0219	
D-33	0351	0300	0273	0307	0219	P
D-34	0534	0529	0531	0563	0220	

D-34	0410	0400	0392	0386	0220	P
D-35	0299	0314	0290	0292	0221	
D-35	0183	0512	0163	0141	0221	P
D-36	0716	0701	0683	0708	0222	
D-36	0572	0684	0515	0523	0222	P
D-37	0817	0878	0860	0823	0223	
D-37	0673	0717	0724	0664	0223	P
D-39	0571	0552	0522	0542	0225	
D-39	0430	0392	0373	0402	0225	P
D-40	0225	0175	0118	0178	0226	
D-40	0087	0024	-0029	0039	0226	P
D-42	0600	0628	0601	0583	0229	
D-42	0490	0491	0477	0462	0229	P
D-43	0461	0500	0451	0533	0230	
D-43	0293	0374	0367	0326	0230	P
D-44	0601	0626	0642	0632	0231	
D-44	0464	0478	0520	0502	0231	P
D-45	0361	0402	0454	0411	0232	
D-45	0221	0281	0324	0275	0232	P
D-49	0812	0803	0793	0769	0236	
D-49	0620	0661	0666	0634	0236	P
D-50	0122	0112	0133	0146	0237	
D-50	-0001	0025	0063	-0002	0237	P
D-51	0810	0813	0857	0814	0239	
D-51	0655	0667	0691	0660	0239	P
						S
D-41	0456	0499	0463	0416	0228	
D-41	0150	0118	0218	0249	0228	P
						S
D-53	0776	0806	0817	0816	0241	
D-53	0650	0741	0751	0709	0241	P
						S
D-54	0534	0555	0534	0512	0242	
D-54	0417	0475	0488	0426	0242	P
						S
D-55	0410	0438	0436	0405	0243	
D-55	0350	0360	0344	0313	0243	P
						S
E-12	0479	0502	0508	0483	0258	
E-12	0356	0352	0360	0365	0258	P
E-15	0277	0315	0336	0322	0261	
E-15	0165	0189	0229	0168	0261	P
E-17	0464	0442	0432	0458	0263	
E-17	0336	0313	0303	0323	0263	P
E-22	0719	0711	0710	0712	0269	
E-22	0585	0543	0593	0573	0269	P
E-30	0752	0755	0781	0790	0279	
E-30	0628	0638	0692	0682	0279	P
E-45	0458	0543	0460	0424	0295	
E-45	0322	0445	0346	0297	0295	P
						S

E-53	0738	0743	0775	0769	0303	
E-53	0612	0622	0716	0664	0303	P
						S
E-54	0431	0522	0544	0545	0304	
E-54	0216	0283	0380	0290	0304	P
						S
E-55	0473	0466	0427	0441	0305	
E-55	0341	0177	0323	0407	0305	P
						S
F-08	0573	0524	0544	0602	0315	
F-08	0496	0434	0457	0510	0315	P
F-18	0398	0390	0425	0426	0326	
F-18	0324	0310	0345	0502	0326	P
F-21	0429	0421	0460	0682	0330	
F-21	0347	0344	0358	0444	0330	P
F-30	0787	0812	0814	0794	0339	
F-30	0713	0749	0723	0745	0339	P
F-35	0637	0665	0656	0647	0345	
F-35	0546	0586	0594	0561	0345	P
F-37	0829	0821	0757	0822	0347	
F-37	0694	0735	0685	0774	0347	P
F-40	0672	0655	0637	0636	0350	
F-40	0572	0571	0555	0605	0350	P
						S
F-53	0777	0714	0742	0746	0364	
F-53	0736	0679	0709	0668	0364	P
						S
F-54	0543	0666	0619	0634	0365	
F-54	0502	0489	0472	0516	0365	P
						S
F-55	0436	0406	0375	0397	0366	
F-55	0470	0403	0337	0424	0366	P
						S
G-01	0661	0709	0698	0593	0369	
G-01	0605	0674	0664	0559	0369	P
G-02	0733	0727	0784	0790	0370	
G-02	0694	0677	0724	0738	0370	P
G-03	0100	0106	0120	0047	0371	
G-03	0023	0050	0108	0019	0371	P
G-04	0296	0345	0333	0316	0372	
G-04	0244	0503	0266	0253	0372	P
G-05	0721	0731	0723	0728	0373	
G-05	0645	0651	0653	0679	0373	P
G-06	0676	0674	0706	0706	0374	
G-06	0611	0636	0606	0562	0374	P
G-07	0899	0933	0900	0881	0375	
G-07	0841	0884	0843	0837	0375	P
G-08	0785	0827	0753	0731	0376	
G-08	0690	0783	0723	0680	0376	P
G-09	-0058	-0083	-0163	-0117	0377	
G-09	-0099	-0097	-0147	-0168	0377	P

G-10	0146	0123	0110	0138	0378	
G-10	0189	0089	0054	0077	0378	P
G-11	0329	0400	0384	0312	0380	
G-11	0221	0333	0323	0244	0380	P
						S
G-12	0193	0238	0217	0173	0381	
G-12	0141	0186	0201	0150	0381	P
G-13	0142	0275	0194	0199	0382	
G-13	0100	0155	0150	0126	0382	P
G-14	0552	0563	0521	0538	0383	
G-14	0474	0485	0437	0427	0383	P
G-15	0272	0282	0322	0277	0384	
G-15	0223	0246	0253	0235	0384	P
G-16	0009	0047	-0023	-0026	0385	
G-16	-0014	-0021	-0000	-0083	0385	P
G-17	0326	0276	0242	0292	0386	
G-17	0190	0256	0173	0196	0386	P
G-18	0322	0313	0261	0296	0387	
G-18	0258	0239	0184	0197	0387	P
G-19	0453	0489	0453	0407	0388	
G-19	0358	0407	0380	0320	0388	P
G-20	0075	0085	0145	0097	0389	
G-20	0007	0040	0065	0000	0389	P
G-21	0210	0202	0196	0206	0391	
G-21	0168	0167	0166	0190	0391	P
G-22	-0033	-0047	-0006	0024	0392	
G-22	-0061	-0086	-0063	-0043	0392	P
						S
G-23	0751	0754	0719	0786	0393	
G-23	0690	0691	0682	0722	0393	P
G-24	0776	0842	0812	0776	0394	
G-24	0698	0759	0733	0685	0394	P
G-25	0747	0775	0727	0740	0395	
G-25	0677	0714	0724	0684	0395	P
G-26	0551	0545	0507	0526	0396	
G-26	0483	0459	0466	0484	0396	P
G-27	0363	0261	0270	0326	0397	
G-27	0338	0235	0282	0271	0397	P
G-28	0421	0493	0426	0407	0398	
G-28	0361	0445	0413	0391	0398	P
G-29	0746	0806	0738	0722	1112	
G-29	0709	0739	0682	0672	1112	P
						S
G-30	0786	0729	0734	0762	1113	
G-30	0673	0657	0652	0668	1113	P
G-31	0856	0851	0812	0748	1115	
G-31	0810	0824	0919	0736	1115	P
G-32	0938	1054	0897	0903	1116	
G-32	0852	0905	0799	0778	1116	P
G-33	0923	0932	0925	0871	1117	
G-33	0811	0826	0795	0767	1117	P

G-34	0748	0718	0727	0730	1118	
G-34	0625	0628	0655	0639	1118	P
G-35	0772	0790	0765	0771	1119	
G-35	0722	0733	0667	0688	1119	P
G-36	0733	0845	0672	0734	1120	
G-36	0695	0710	0641	0628	1120	P
						S
G-37	0834	0881	0861	0781	1121	
G-37	0688	0780	0753	0662	1121	P
G-38	0561	0586	0554	0515	1122	
G-38	0485	0545	0427	0417	1122	P
G-39	0513	0508	0460	0474	1123	
G-39	0485	0447	0447	0463	1123	P
G-40	0752	0826	0804	0741	1124	
G-40	0728	0743	0755	0731	1124	P
G-41	0347	0378	0415	0358	1125	
G-41	0314	0360	0338	0322	1125	P
G-42	0861	0872	0886	0861	1127	
G-42	0835	0833	0856	0834	1127	P
						S
G-43	0898	0972	0914	0841	1128	
G-43	0857	0902	0874	0807	1128	P
G-44	0729	0724	0714	0722	1129	
G-44	0662	0666	0654	0654	1129	P
G-45	0680	0650	0658	0677	1130	
G-45	0598	0595	0605	0633	1130	P
						S
G-46	0569	0583	0569	0568	1131	
G-46	0500	0535	0533	0503	1131	P
G-47	0628	0685	0597	0571	1132	
G-47	0487	0437	0431	0530	1132	P
G-48	0609	0617	0575	0590	1133	
G-48	0577	0591	0568	0562	1133	P
						S
G-49	0665	0713	0728	0683	1134	
G-49	0572	0618	0713	0591	1134	P
G-50	0695	0688	0612	0626	1135	
G-50	0608	0636	0580	0557	1135	P
G-51	0557	0589	0566	0539	1136	
G-51	0471	0507	0492	0440	1136	P
G-52	0697	0753	0659	0630	1137	
G-52	0625	0686	0641	0579	1137	P
G-53	0722	0717	0660	0669	1138	
G-53	0633	0627	0574	0541	1138	P
G-54	0575	0593	0563	0582	1139	
G-54	0505	0525	0501	0482	1139	P
						S
G-55	0778	0774	0693	0730	1140	
G-55	0677	0641	0675	0709	1140	P
						S
H-01	0268	0247	0266	0280	0401	

H-01	0151	0155	0094	0146	0401	P
H-02	-0157	-0158	-0129	-0140	0402	
H-02	-0227	-0217	-0188	-0214	0402	P
H-03	0619	0593	0537	0554	0403	
H-03	0479	0499	0415	0395	0403	P
H-04	0028	0010	0017	0007	0404	
H-04	-0083	-0016	-0039	-0081	0404	P
H-05	0613	0641	0618	0601	0405	
H-05	0501	0542	0527	0489	0405	P
H-06	0341	0391	0366	0323	0406	
H-06	0246	0265	0272	0227	0406	P
H-07	0235	0201	0194	0223	0407	
H-07	0144	0125	0114	0139	0407	P
H-08	0328	0316	0374	0310	0408	
H-08	0244	0251	0265	0226	0408	P
H-09	0196	0191	0178	0198	0409	
H-09	0108	0104	0099	0112	0409	P
H-10	0070	0075	0009	0014	0410	
H-10	-0005	0008	-0050	-0060	0410	P
H-11	0204	0156	0171	0274	0412	
H-11	0160	0101	0112	0185	0412	P
H-12	0346	0352	0403	0373	0413	
H-12	0260	0257	0310	0283	0413	P
H-13	0065	0064	0107	0135	0414	
H-13	-0023	-0009	-0007	0025	0414	P
H-14	0450	0456	0439	0523	0415	
H-14	0379	0363	0367	0442	0415	P
						S
H-15	-0096	-0098	-0084	-0085	0416	
H-15	-0159	-0158	-0149	-0151	0416	P
H-16	0637	0676	0624	0625	0417	
H-16	0528	0530	0523	0531	0417	P
H-17	0546	0603	0617	0559	0418	
H-17	0436	0479	0502	0443	0418	P
H-18	0605	0581	0602	0642	0419	
H-18	0496	0460	0490	0521	0419	P
H-19	0517	0536	0527	0508	0420	
H-19	0410	0426	0428	0383	0420	P
H-20	0408	0401	0366	0355	0421	
H-20	0279	0297	0263	0215	0421	P
H-21	0477	0508	0517	0500	0423	
H-21	0388	0394	0410	0393	0423	P
H-22	0567	0586	0577	0571	0424	
H-22	0461	0480	0462	0459	0424	P
H-23	0389	0384	0331	0353	0425	
H-23	0258	0281	0263	0258	0425	P
H-25	0500	0496	0495	0518	0427	
H-25	0399	0402	0371	0374	0427	P
						S
H-26	0540	0508	0536	0577	0428	
H-26	0441	0380	0377	0412	0428	P

H-27	0299	0296	0307	0289	0429	
H-27	0215	0202	0229	0218	0429	P
H-28	0556	0440	0375	0601	0430	
H-28	0428	0331	0272	0381	0430	P
H-29	0672	0625	0654	0618	0431	
H-29	0510	0507	0485	0477	0431	P
H-30	0564	0532	0562	0584	0432	
H-30	0469	0448	0476	0500	0432	P
H-31	0689	0669	0701	0683	0434	
H-31	0595	0567	0561	0522	0434	P
H-32	0095	0082	0116	0149	0435	
H-32	0038	0017	0009	0023	0435	P
H-33	0337	0336	0350	0364	0436	
H-33	0251	0248	0234	0242	0436	P
H-34	0683	0800	0677	0675	0437	
H-34	0570	0681	0580	0571	0437	P
H-35	0293	0295	0307	0308	0438	
H-35	0222	0216	0237	0235	0438	P
H-36	0761	0720	0667	0741	0439	
H-36	0679	0634	0587	0664	0439	P
H-37	0474	0490	0449	0416	0440	
H-37	0388	0408	0380	0337	0440	P
H-38	0633	0642	0696	0687	0441	
H-38	0570	0555	0608	0623	0441	P
H-39	0645	0584	0599	0664	0442	
H-39	0553	0510	0495	0542	0442	P
H-40	0523	0478	0440	0483	0443	
H-40	0334	0405	0385	0370	0443	P
H-41	0502	0506	0513	0418	0445	
H-41	0330	0362	0448	0352	0445	P
H-42	0593	0634	0657	0617	0446	
H-42	0493	0533	0550	0512	0446	P
H-43	0601	0630	0556	0513	0447	
H-43	0518	0541	0444	0400	0447	P
H-44	0540	0628	0646	0633	0448	
H-44	0495	0535	0605	0539	0448	P
H-45	0526	0613	0583	0520	0449	
H-45	0471	0526	0516	0456	0449	P
						S
H-46	0658	0761	0646	0632	0450	
H-46	0573	0629	0594	0553	0450	P
H-47	0663	0629	0658	0697	0451	
H-47	0581	0569	0579	0618	0451	P
H-48	0347	0368	0580	0413	0452	
H-48	0267	0285	0352	0303	0452	P
H-49	0705	0730	0689	0626	0453	
H-49	0618	0629	0544	0545	0453	P
H-50	0723	0711	0613	0650	0454	
H-50	0622	0614	0514	0501	0454	P
H-51	0562	0545	0609	0619	0455	
H-51	0492	0452	0513	0533	0455	P

H-52	0297	0346	0379	0337	0456	
H-52	0238	0262	0316	0256	0456	P
H-53	0391	0523	0484	0399	0457	
H-53	0291	0388	0417	0331	0457	P
H-54	0387	0384	0326	0377	0458	
H-54	0341	0324	0260	0335	0458	P
H-55	0359	0370	0404	0394	0459	
H-55	0295	0302	0338	0331	0459	P
						S
BB-06	0241	0263	0250	0246	0467	
BB-06	0189	0194	0213	0178	0467	P
BB-12	0362	0484	0340	0362	0474	
BB-12	0296	0400	0312	0302	0474	P
BB-13	0372	0374	0311	0343	0475	
BB-13	0308	0305	0265	0281	0475	P
BB-17	0353	0355	0367	0321	0479	
BB-17	0275	0289	0286	0263	0479	P
BB-22	0332	0328	0323	0330	0485	
BB-22	0277	0265	0275	0275	0485	P
BB-44	0420	0441	0423	0422	0509	
BB-44	0363	0373	0363	0358	0509	P
BB-49	0215	0177	0167	0205	0514	
BB-49	0157	0131	0123	0151	0514	P
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BB-53	0157	0141	0068	0098	0518	
BB-53	0335	0230	0076	0030	0518	P
						S
BB-54	0336	0335	0355	0339	0519	
BB-54	0308	0323	0406	0366	0519	P
						S
BB-55	0202	0172	0138	0175	0520	
BB-55	-0021	0056	-0026	-0110	0520	P
						S

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 J. F. Bates
 T. K. Bierlein
 H. R. Brager
 T. T. Claudson
 R. E. Dahl
 R. L. Fish
 G. L. Guthrie (5)
 J. J. Holmes
 J. E. Irvin
 R. L. Knecht
 T. J. Larson (5)
 A. J. Lovell
 P. K. McDaniel (5)
 M. M. Paxton (3)
 L. A. Pember
 L. H. Rice
 W. F. Sheely
 J. L. Straalsund (30)
 A. L. Ward

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