A PROGRAM FOR THE ANALYSIS OF EXPERIMENTS WITH CONFOUNDED FACTORIAL EFFECTS

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CHAPTER I

INTRODUCTION

The use of a computer for the analysis of experiments allows for fast turn-around time by a statistician to the experimenter. The analysis of factorial experiments, though not difficult, can become quite burdensome. Computer programs are available for analysis of factorial experiments; however, none are available that accept some type of planned confounding of main effects and interactions with block effects. The need for a program of this type becomes more evident with a large number of treatments, since planned confounding must be employed in order to reduce the block size and thereby increase the precision of the estimates of factorial effects.

Computational methods commonly used for the analysis of lattice designs are not only lengthy for a large number of treatments but indeed difficult and lacking in uniformity for the varied classes of lattice designs.

The procedure for recovery of inter-block information in its most widely used form for lattice designs does not allow for an exact test of significance of equal treatment means. This stems from the procedure itself and not from the design, since the adjustment for differential block effects and recovery of inter-block information is combined into one adjustment factor. A more useful procedure would be to examine both the among all block (inter) and the within all block (intra) analyses. The combination of the two analyses can then be made, if desired.

A program was written to analyze factorial experiments where there are N factors each at P levels and some type of planned confounding was employed. P must be a prime number.

In the pages that follow the program and its use are described in Chapter II and the application of the program to lattice designs is discussed in Chapter III.

CHAPTER II

THE PROGRAM

This program is intended to analyze statistical experiments where the number of treatments, T, are in a factorial arrangement, and some type of planned confounding is employed. For purposes of uniformity, it is assumed that there are N factors each at P levels, where P is a prime number, and that there are R replications, each replication containing B blocks, each block containing K experimental units, $T = P^N = BK$.

The program uses a modified systems tape. This means that a permanent control section is maintained in the lower end of core storage that supervises the program operation and allows for optimum allocation of the remaining portion of core storage. The supervisor calls into core storage, from the systems tape, only the instructions necessary to perform a specific operation. It is not necessary for the user to create the systems tape as the program automatically builds this tape upon loading the program deck. Since the group of routines necessary to analyze any one experiment are available to the supervisor on the systems tape; it is necessary to load the program only once for the sequential analysis of any number of experiments.

The routines on the systems tape are written in records of varying length, each record containing the instructions necessary to complete a phase or part of a phase of operation as described in the following:

Record	Routine and Function
1	Common constants and areas
2	Pre-phase part 1 - Analysis of parameter card information
3	Pre-phase part 2 - Formation of effect tables
4	Format phase part 1 - Checking of format card
5	Format phase part 2 - Put input data in standard format on tape unit three
6	Phase I - Creation of the tables of sums
7	Phase II part 1 - AOV calculations: Total, Among all Blocks, Replications, and Blocks in Reps.
8	Phase II part 2 - AOV calculations: components of treatments and error
9	Phase III - Estimates of effects and generalized interactions
10	Phase IV - Estimates of the adjusted treatment means

Machine Requirements

The IBM 1410 Data Processing System on which this program is run must have at least:

40,000 positions of core storage

Two IBM 729 II, 729 IV, or 7330 Magnetic Tape Units in any combination

IBM 1403 Printer

IBM 1402 Card Read-Punch

The use of special features such as priority processing, processing overlap, and a second data channel has not been incorporated into the program; however, if additional tape units are available, a maximum of two additional units may be used at the option of the user.

Limitations of Program

The distinguishing feature of the IBM 1410 Data Processing System is the variable word length. This program takes full advantage of the feature by modifying itself to analyze many types of experiments within the P^N factorial arrangement of treatments system as well as allowing variable input formats. The principle restricting factor is the requirement of P to be a prime number.

Another limitation is that of storage capacity. This program was written for 40,000 positions of core storage; however, it can easily be modified to take advantage of larger systems by including in the object deck after the tenth card the following card:

Column	Content
1	m
2 - 6	00008
7	m
8 - 12	00007
13	m
14 - 18	yy999
19	m

(m is the symbol for a 0 - 5 - 8 punch)

Column	Content
20 - 21	xx
22 - 80	(blank)

where xx denotes the number of additional core storage positions in thousands and $yy = 39 + xx$.

There are 37 different arrangements of treatments that can be analyzed by this program each with a varying number of replications.

Given a particular arrangement of treatments with parameters P, N, B, R let:

$$E = \frac{P^N - 1}{P - 1}$$, the number of effects and generalized interactions

$$E_c = \frac{B - 1}{P - 1}$$, the number of effects and interactions confounded in each replicate

$$d_p = \begin{cases} 1 \text{ if } P \leq 7 \\ 2 \text{ if } P \geq 11 \end{cases}$$

$$d_r = \begin{cases} 1 \text{ if } R < 10 \\ 2 \text{ if } R \geq 10 \end{cases}$$

$$d_n = \begin{cases} 1 \text{ if } N < 10 \\ 2 \text{ if } N \geq 10 \end{cases}$$

and $L = 35{,}000 + xx(1000)$ with xx defined the same as above. Then the following inequalities must be satisfied in order to keep within the machine and program capacity requirements:

(1) $$10 R (B + 1) + E [40 (P + 1) + N d_p + d_r] + N d_n + (N - 1) d_p + 2 (N d_p) E_c \leq L$$

(2) $(N d_p)\ E_c \leq 74$

(3) The grand total for any one response yield must be less than or equal to a ten digit number.

(4) The total uncorrected sum of squares must be less than or equal to a twenty digit number.

For most practical purposes it is not necessary to check the above inequalities for every experiment. A quick reference chart is given in Table I denoting for each arrangement of treatments the maximum number of replicates that can be run on a system with 40,000 core storage positions, if K is less than T. If K is equal to T, then B is equal to one and the maximum number of replicates is always 99.

The final restriction pertains only to experiments where at least one of the observations is negative. For experiments of this type the maximum number of replicates that can be processed is limited to 29. However, this is hardly a serious restriction since the data can usually be coded in such a manner that it is all positive.

Control Cards

There are two control cards necessary to convey to the program essential information as to the parameters of the experiment, the format of the input, and the type and amount of output desired. The first of these cards described below is mandatory for all experiments, whereas the second card is necessary only if the input is not in the standard format (as described in the section on input) or if more than one response variable is to be analyzed. The necessary information for the first control card (parameter card) is outlined below:

TABLE I

MAXIMUM NUMBER OF REPLICATES

T	P^N	B	R_{max}	B	R_{max}	B	R_{max}
4	2^2	2	99				
8	2^3	2	99	4	99		
9	3^2	3	99				
16	2^4	2	99	4	99	8	99
25	5^2	5	99				
27	3^3	3	99	9	99		
32	2^5	2	99	4	99	8	99
49	7^2	7	99				
64	2^6	2	99	4	99	8	99
81	3^4	3	99	9	99	27	99
121	11^2	11	99				
125	5^3	5	99	25	99		
128	2^7	2	99	4	99	8	99
169	13^2	13	99				
243	3^5	3	99	9	99	27	32
256	2^8			4	35	8	19
289	17^2	17	99				
343	7^3	7	99	49	32		
361	19^2	19	99				
529	23^2	23	99				

Column	Indicates
1 - 5	Control card identification. Punch the word PARAM
6 - 7	P Punch the number of levels (02 - 23) of each factor. P must be a prime number.
8	Leave blank
9	N Punch the number of factors (2 - 8) .
10	Leave blank
11 - 13	T Punch the number of treatment combinations (004 - 529) . $T = P^N$
14 - 15	K Punch the number of experimental units per block (02 - 81) .
16 - 17	B Punch the number of blocks per replication (01 - 81). Note: The product of B and K must be T .
18 - 19	R Punch the number of replications (01 - 99) of the T treatment combinations .
20	Input media 1. Punch a C if input is from cards. 2. Punch a T if input is from tape. The input tape must be mounted on tape unit 1.

Column	Indicates
21	Format of input 1. Punch an S if input is in standard format. 2. Punch an N if input is not in standard format or if more than one response variable is indicated in columns 22 - 23 .
22 - 23	Number of response variables (01 - 16) included on input to be analyzed during this run.
24	Number of decimals (0 - 7) on input in the first response variable. This column may be left blank if there are no decimals or if more than one response variable is indicated in columns 22 - 23 .
25	Leave blank
26	Output options 1. Punch a "-" (eleven punch or minus sign) if no tape output on unit 4 is desired. 2. Punch a "4" if no components of treatments and error in the analysis of variance are desired. 3. Punch a "2" if no estimates of the effects and generalized interactions are desired. 4. Punch a "1" if no estimates of the adjusted treatment means are desired. Any combination of the above options may be suspended by the appropriate combination of of the punches -, 4, 2, and 1 in column 26.

Column	Indicates
27 - 32	Problem identification This field may be any combination of numerics, alphabetics, special characters, or blanks. It is necessary for tape input in that a comparison is made with the identification field of the file header label as described in the section on Skipping Tape Files.
33 - 39	Leave blank
40 - 80	Any comment that the user wishes, such as name of experiment or experimenter, to appear on the output.

The second control card or format card defines the form of the input data to the program whether the input medium be card or tape. This card is carefully checked for overlapping fields and invalid field lengths. It is necessary only to specify the position, length, and number of decimals for the number of response variables as specified on the parameter card in columns 22 - 23 . The information for this control card is decribed below:

Column	Indicates
1 - 6	Control card identification Punch the word FORMAT.
7 - 8	Position of replicate indicator Punch the units position in the input record of the replicate indicator.
9 - 10	Position of block indicator Punch the units position in the input record of the block within replicate indicator.

Column	Indicates
11 - 12	Position of cell indicator Punch the units position in the input record of the cell within block indicator.
13 - 14	Position of treatment combination indicator Punch the units position in the input record of the treatment combination indicator.
15 - 16	Length of treatment combination indicator Punch the length (02 - 16) of the treatment combination indicator denoted hereafter as D and is the product of the two quantities N and d_p where d_p is defined as before.
17 - 18	Position of response variable number 1 Punch the units position in the input record of the first variable.
19	Length of response variable number 1 Punch the length in characters (1 - 7) of the first response variable.
20	Number of decimal positions of the first response variable This column may be left blank if there are no decimal positions but if punched must never be greater than the length of the first response variable.
21 - 24	Information for response variable 2 similiar to columns (17 - 20)
25 - 28	Information for response variable 3 similiar to columns (17 - 20)
. . .	
77 - 80	Information for response variable

Column	Indicates
77 - 80 (cont.)	16 similiar to columns (17 - 20)

Preparation of Input Data

The primary input medium is the card reader; however, provision has been made for tape input if the additional drive is available and the experiment is so large as to make the saving in time necessary.

All input records are 80 characters in length whether they be cards or card images on magnetic tape. There are basically five fields to be defined for the input:

1. Replication number indicator -
   This field must be two characters in length and strictly numeric in nature; that is, neither position may be blank, contain zone bits, or be a special character. This number ranges from 01 to R inclusive.

2. Block number within replication indicator -
   This field must be two characters in length and strictly numeric. This number ranges from 01 to B inclusive.

3. Experimental unit number (cell) within block indicator -
   This field must be two characters in length and strictly numeric. This number ranges from 01 to K inclusive.

4. Response variable such as yield, weight, gain, etc. -
   This field can be from one to seven characters in length and must be strictly numeric except for the units position which may be signed. There may be as many as 16 of these fields.

5. Treatment combination indicator -
   This indicator is of the form $(X_1, X_2, \ldots, X_N)$ where $0 \leq X_i \leq P-1$ for $i = 1, 2, \ldots, N$ and X_i represents the level of factor i. The length of this field is D as defined under columns 15 - 16 of the second control

5. (Continued)

card.

a) 3^5 means D = 5

b) 13^2 means D = 4

This field must be strictly numeric ranging from (0, 0, ..., 0) to (P - 1, P - 1, ..., P - 1) . The following table represents the treatment combinations for a 5^3 experiment:

(000), (001), (002), (003), (004)
(010), (011), (012), (013), (014)
.
.
.
(040), (041), (042), (043), (044)
(100), (101), (102), (103), (104)
.
.
.
(140), (141), (142), (143), (144)
.
.
.
(400), (401), (402), (403), (404)
.
.
.
(440), (441), (442), (443), (444)

These fields may be positioned in the record at the convenience of the user as long as none of the fields overlap.

Standard Format

Although the format of the input is left to the discretion of the user, the program will convert the input to a standard format as follows:

Position		Content
Initial	Final	
1 -	2	Replication number indicator
3 -	4	Block within replication number indicator
5 -	6	Cell within block number indicator
7 -	13	Observation on the first variable
14 -	(13+D)	The treatment combination indicator (extending through the positions necessary).
(14+D)-	80	The observations on the remaining variables in the order specified on the format card. Each field is left-adjusted in the record adjacent to its neighbor.

The user may take advantage of the standard format if he has but one response variable. In this case it is not necessary to include the format card.

Since all input is converted to the standard format, the total number of characters must not be greater than 73 plus the length of the first response variable field.

All fields are checked for blank positions and invalid length. Since a multiple punch in a card column may be a valid character to the machine, care must be taken in the preparation of the data.

It is absolutely necessary that the input data be in sequential sort with respect to fields 1, 2, and 3. If the input is in standard format, then a normal sort must be performed starting in position 6 and proceeding through position 1.

It is also necessary that there be no missing data. Therefore, there must be exactly K observations in each block, B blocks in each replication, and R replications. Otherwise a halt will occur as noted in the section on halts and messages.

Replicate Confounding

To complete the input file, (deck for card input or group of card-images for tape input) it is necessary to specify for each replication which effects and/or generalized interactions are confounded in that replication. This is accomplished by preceeding each group of records that form a replication by a replicate confounding record of the following format:

Position	Content
1 - 2	Replication number indicator
3 - 5	000
6	? (The question mark symbol "?" denotes a "plus zero")
7, 8, . . .	C (1), C (2), . . . , C (E_c)

Each of the C (j) is strictly numeric, of length D, and of the form: $(z_1, z_2, \ldots z_N)$ where $0 < z_i \leq P - 1$ for $i = 1, 2, \ldots P-1$ and at least one of the z_i is non-zero and the first non-zero z_i is unity.

Although similar, this representation of effects and interactions should not be confused with the representation of treatment combinations.

Examples:

1. 3^3 : If AB^2 and C are confounded in the replicate, then C (1) = 120 and C (2) = 001.

2. 3^5 : If BCE and AB^2D^2E are confounded in the replicate, then C (1) = 01101 and C (2) = 12021 .

The confounded effects and/or generalized interactions may be listed in any order, although it is recommended that if the same effects and generalized interactions are confounded in consecutive replications, they be listed in the same order to realize at least a small time saving.

If the design has K equal to T, then B is equal to one and the above card would have columns one through six punched and seven through eighty blank.

Tape Label Considerations

The above description of the input file applies to both input media. However, for tape input additional records, called header labels, are necessary. There are two types of header labels, tape header labels and file header labels. The former apply to all tapes on the system while the latter apply to the input tape alone.

All header labels and the entire input data tape must be written in the move mode and in even parity.

a) Tape header labels:

These header labels though not mandatory are recommended for each tape on the system to insure the proper mounting of tapes. Certain checking operations are performed on the tapes mounted on drives one, three, four, and nine if they are in ready status at program loading time.

Tape header labels, if present, must be in either of the following formats:

1)

Positions	Contents	Description
1 - 5	1 BLNK	Header label identifier
6 - 10	xxxxx	Tape serial number
11 - 80		Unused

2)

Positions	Contents	Description
1 - 5	1 HDRb	Header label identifier
6 - 10	xxxxx	Tape serial number
11 - 15	xxxxx	File serial number
16 - 20	-xxxb	Reel sequence number
21 - 30	xxxxxxxxxx	File name
31 - 35	YYDDD	Creation date
36 - 40	-xxxb	Retention cycle
41 - 80		Unused

The letter "b" denotes a blank position and the character "-" is a minus sign.

The header labels, if present, are retained. No checking is done on the label type one; however, the type two label is checked for the possibility of being protected by the retention cycle. The creation date is of the form YYDDD where YY is the year (00 - 99) in which the file was created and DDD is the day within the year (001 - 366) on which the file was created. The three digit retention cycle is the number of days the file is to be retained after the creation date. If the current date falls within the retention cycle then the program halts and prints a message as explained in the section on operating procedures. At this point the user has the option whether to accept the reel with the discrepancy or to mount another reel in its place and repeat the checking. The other fields of the type two label are ignored and given here only to illustrate the placement of the pertinent fields. The tape header label may be followed by a tape mark.

b) File header labels:

These labels are mandatory for tape input regardless of the presence of a tape header label. A file header label preceeds each data file on the input tape and is an image of the associated file parameter card.

Since it is possible to place several files on the input tape, it is absolutely necessary that the tape be positioned properly. A comparison is made of the current parameter card and the file header label. If there is a discrepancy, the program informs the operator of the options available. These options are described in the section on operating procedures.

A tape mark may not be used to separate input files nor to separate a file header label from its associated input data. However, the last record of the input tape should always be a tape mark to signify the end of the input data tape.

Output

The output of the program is variable dependent upon the parameters of the experiment; however, the user does have some control over the amount of output.

The format for the analysis of variance is as follows:

TABLE II

ANALYSIS OF VARIANCE

Source	d.f.	S.S.	M.S.
Total	RT-1		
Among all Blocks	RB-1		
Replications	R - 1		
Blocks in Reps	R(B - 1)		
ǂ Treatments (adjusted)	(a)		
* Inter-block Error	(b)		
Within all Blocks	RB(K-1)		
ǂǂ Treatments (adjusted)	(c)		
** Intra-block Error	(d)		

Note: The appropriate values of the sum of squares and mean square for each source of variation are entered in their respective columns. The symbols in the left margin are present in each analysis of variance output.

This is the minimum breakdown of the sources of variation. Normally a further breakdown of the Treatments and Error is made into their respective components for both among blocks and within blocks and is determined by the amount and type of planned confounding that is employed. The confounding also determines the degrees of freedom (a), (b), (c), and (d) in Table II.

An effect or interaction denoted by X is confounded in a set of replicates S'_X where the number of elements in S'_X is R'_X and X is unconfounded in the remaining replicates S''_X with $R''_X = R - R'_X$

elements. With each X is associated an interaction term of X by replicates (S'_X) and another interaction term of X by replicates (S''_X). Using the above notation it is possible to write in general the components of Blocks in Reps and Within all Blocks:

TABLE III

COMPONENTS OF BLOCKS IN REPS
AND WITHIN ALL BLOCKS

Source of Variation	Degrees of Freedom
Blocks in Reps	R(B - 1)
ǂ X_1	P - 1
* X_1 by Reps (S'_{X_1})	$(P - 1)(R'_{X_1} - 1)$
ǂ X_2	P - 1
* X_2 by Reps (S'_{X_2})	$(P - 1)(R'_{X_2} - 1)$
.	
.	
.	
ǂ X_E	P - 1
* X_E by Reps (S'_{X_E})	$(P - 1)(R'_{X_E} - 1)$
Within all Blocks	RB(K - 1)
ǂǂ X_1	P - 1
** X_1 by Reps (S''_{X_1})	$(P - 1)(R''_{X_1} - 1)$
.	
.	
.	
ǂǂ X_E	P - 1
** X_E by Reps (S''_{X_E})	$(P - 1)(R''_{X_E} - 1)$

Note: The symbols in the left margin do not appear in an analysis of variance output by the program and are given here to illustrate their association with the values in Table II.

It must be noted that not all of the components in Table III will necessarily appear in a specific A. O. V. For, if an effect X is completely confounded with blocks (confounded in all replicates), then there will be no X nor X by Reps (S''_X) components from Within all Blocks. Also, if X is partially confounded in all but one replicate ($R''_X = 1$), then there will be no X by Reps (S''_X) component from Within all Blocks. Conversely, if X is not confounded in any replicate, then there will be no X nor X by Reps (S'_X) components from Blocks in Reps. If X is confounded in only one replicate ($R'_X = 1$), then there will be no X by Reps(S'_X) component from Blocks in Reps.

It is now possible to describe the components of the Treatment and Error terms and the degrees of freedom (a), (b), (c), and (d) in Table II. From Blocks in Reps, the components of Treatments (adjusted) are the terms in Table III distinguished by a record mark symbol (ǂ) and of Inter-block Error by an asterisk symbol (*) . Likewise, from Within all Blocks, Treatments (adjusted) has components distinguished by two record mark symbols (ǂ ǂ) in the left margin of Table III and Intra-block Error has components distinguished by two asterisk symbols (**) in the left margin of Table III. Therefore, degrees of freedom (a), (b), (c), and (d) are the pooled degrees of freedom of their respective components.

In a specific A. O. V. output from the program the components of the Treatment and Error terms do not appear with the identifing marks as given in Table III. It should be clear that the terms indicated by a single character in the left margin of TableII are terms made up of pooling their respective components from Among all Blocks and the terms indicated by double charcters in the left margin from Within all Blocks.

Calculation of Sums of Squares in the A. O. V.

The sums of squares for the first four entries in the A. O. V. are calculated the usual way. The Total sum of squares is corrected for its mean as are the other terms. Among all Blocks is the corrected sum of squares among the RB block totals; Replications is the corrected sum of squares among the R replicate totals; and Blocks in Reps is the pooled sum of squares among the B blocks of each replicate.

The sum of squares for each effect and interaction is somewhat more involved. Noting that the effect X_i is confounded in the set of replicates S'_{X_i} and unconfounded in the remaining replicates S''_{X_i}, the t^{th} treatment combination is denoted by $(x_{1t}, x_{2t}, \ldots, x_{Nt})$ where $t = 1, 2, \ldots, T$ with $0 \leq x_{jt} \leq P - 1$ for each $j = 1, 2, \ldots, N$. Associated with the t^{th} treatment combination in the k^{th} replicate is a response y_{tk} for $k = 1, 2, \ldots, R$. For each X_i there is a unique representation $X_i = (z_{i1}, z_{i2}, \ldots, z_{iN})$ as before restricting the first non-zero z_{ij} for each $i = 1, 2, \ldots, E$ to be unity. Now, restricting the arithmetic to modulo P the linear combination

$$\sum_{j=1}^{N} z_{ij} \; x_{jt} = q \bmod P$$

is the q^{th} level of X_i.

The total response Y_{iqk} in the k^{th} replicate of the q^{th} level of X_i is the sum of P^{N-1} terms:

$Y_{iqk} = \Sigma y_{tk}$ where the sum is over all t such that

$$\sum_{j=1}^{N} z_{ij} x_{jt} = q \mod P$$

The total response for the q^{th} level of X_i from the replicates in which X_i is confounded is

$$Y'_{iq\cdot} = \sum_{k \epsilon S'_{X_i}} Y_{iqk} \text{ and } \bar{Y}'_{i\cdot\cdot} = \sum_{q=0}^{P-1} Y'_{iq\cdot}/P$$

giving the sum of squares associated with X_i for the component in Blocks in Reps as:

$$\sum_{q=0}^{P-1} (Y'_{iq\cdot} - \bar{Y}'_{i\cdot\cdot})^2 / (P^{N-1} R'_{X_i})$$

with $P - 1$ degrees of freedom and where R'_{X_i} is the number of replicates in S'_{X_i}.

The total yield for the q^{th} level of X_i from the replicates in which X_i is unconfounded is:

$$Y''_{iq\cdot} = \sum_{k \epsilon S''_{X_i}} Y_{iqk} \text{ and } \bar{Y}''_{i\cdot\cdot} = \sum_{q=0}^{P-1} Y''_{iq\cdot} / P$$

giving the sum of squares associated with X_i for the component in Within all Blocks as:

$$\sum_{q=0}^{P-1} (Y''_{iq\cdot} - \bar{Y}''_{i\cdot\cdot})^2 / (P^{N-1} R''_{X_i})$$

with $P - 1$ degrees of freedom and where R''_{X_i} is the number of replicates in S''_{X_i}.

Similarly it is possible to obtain the sum of squares attributed to the interaction of the effect X by Reps (S'_X) from the following:

TABLE IV

INTERACTION OF EFFECT BY CONFOUNDED REPLICATES

Source	d.f.	Sum of Squares
Sub-total	$PR'_X - 1$	$\sum_{k \epsilon S'_X} \sum_{q=0}^{P-1} (Y_{iqk} - \overline{Y}'_{i..})^2$
X	$P - 1$	(As above)
Reps (S'_X)	$R'_X - 1$	$\sum_{k \epsilon S'_X} (Y_{i.k} - \overline{Y}'_{i..})^2/P^N$
X by Reps (S'_X)	$(P - 1)(R'_X - 1)$	By subtraction

The sum of squares attributed to the interaction of effect X by Reps(S''_X) can be obtained from Table IV by replacing all symbols with a single prime by the same symbols with a double prime.

Estimates of the Effects and Interactions

Following the program output of the A. O. V. is the print-out of the intra-block estimates of the effects and generalized interactions. This table lists in the left margin the numerical representation of the i^{th} effect X_i as $(z_{i1}, z_{i2}, \ldots, z_{iN})$ as defined in the previous section and also in the section on replicate confounding. Across the top margin of the table is given the level of the effects q as $0, \ldots, P-1$. The body of the table is the intra-block estimate of the q^{th} level of effect X_i:

$$(X_i)_q = (Y''_{iq.} - \overline{Y}''_{i..})/(P^{N-1}R''_{X_i})$$

Following the estimates for each effect is the value of the relative information which is given symbolically by: R''_{X_i}/R.

The output of these estimates may be suspended by punching a "4" in column 26 of the parameter card.

Intra-Block Estimates of Adjusted Treatment Means

Following the above output are the estimates of the adjusted treatment means, the overall mean, and estimates of the variance of the difference in two treatment means. This output is meaningful only for experiments termed as "lattices" and is explained in the following chapter.

This output may be suspended by punching a "1" in column 26 of the parameter card.

Operating Procedures

Assembling the Input Deck

For each experiment the input to the program must be in the following order:

1. Parameter card
2. Format card (if necessary)
3. Input data file (in sequential sort)

Starting the Program

The procedure for loading the program is as follows:

1. Insert forms in the printer and console printer and install an appropriately punched (standard) carriage tape and the H2 character set printing chain (scientific).
2. Mount scratch tapes on units nine and three (and unit four if tape output is desired). Mount the input data tape on unit one if required. Set the density switch on each tape unit to

2. (continued) the correct density.

3. Place the input decks following the program deck in the read hopper of the 1402. Press the END OF FILE key and START key on the 1402.

4. Clear Storage
   a) Set the mode switch to CE.
   b) Set the storage scan switch to LOAD +1 .
   c) Set the sense-bit switches to C-bit only.
   d) Press the START key.
   e) Type: CLEAR .
   f) Press the STOP key.

5. Standard Card Load
   a) Set the mode switch to DISPLAY.
   b) Press COMPUTER RESET then START keys.
   c) Type: 00001 .
   d) After printing of full line, press STOP.
   e) Set the mode switch to ALTER, press START.
   f) Type: L%1100257$J00247b !
   g) Set the mode switch to RUN.
   h) Press COMPUTER RESET then START keys.

6. The machine is now under control of the program and normal processing will continue.

Reader Error while Card Loading

If a halt occurs while the program deck is being loaded then it is most likely a card read error. The offending card will be stacked in the normal read pocket (0). Check this card for scrapes and bruises. Run out the cards remaining in the reader by lifting up the cards in the read hopper and pressing the read START key. Place the cards from the normal read pocket, including the offending card, in front of the unread card deck in the hopper. Then press END OF FILE and START keys on the card reader and when the reader READY light comes on, press the START key on the console.

Setting the Calendar Date

The current date must be given to the program in order that the on-line tape header labels may be checked. The date is entered by means of an inquiry request procedure. Upon loading the program, the message, SET TODAYS DATE, will be printed on the console. The operator must then press the INQUIRY REQUEST key and type the current date in the form YYDDD, where YY is the current year and DDD is the day of the year. The operator should then check the date for any errors making sure that exactly five digits were typed. If the date was typed correctly, then the RELEASE key should be pressed and the program will continue. If the date was typed incorrectly, then the CANCEL key must be pressed in order to repeat the request procedure.

Skipping Tape Files

As stated before, a file header label for each experiment on an input tape is mandatory. The program will read a record from tape unit one and check to see if it is the correct file header label. If the first five positions of this record are not PARAM, then the program will institute a search of the tape until either this condition is satisfied or the end of the tape is reached. When the above condition is satisfied, the program then compares the IDENT field of the parameter card with the IDENT field of the file header label. If this compare is equal, then normal processing will continue. If they are not equal, then the program will halt and print out error message number four. The user now has three options depending upon the validity of the detected error. The first two options are selected by an inquiry request procedure and the third by the normal RESTART procedure explained in a later section.

1. Press INQUIRY REQUEST, type the word ACCEPT, and press the RELEASE key if the label as printed out is known to be incorrect but the input file is to be accepted anyway. The program will continue as if the file header label were correct.

2. Press INQUIRY REQUEST, type the word SEARCH, and press the RELEASE key if the input data file is to be skipped. The program will then search the input tape for the next file header label. If during this search the end of tape or a tape mark is sensed, then the tape is rewound, an appropriate message is printed, and the program halts. Pressing the START key will cause the search for a file header label to be resumed. This feature allows for the analysis of the experiments on the input tape to be made in the order determined by the parameter card in the card-reader regardless of the ordering of the files on the input tape. However, to minimize the search time, the files should be in the same order on the input tape as the ordering of the parameter cards.

3. Perform the normal RESTART procedure if this is a valid error in the preparation of the input tape and the analysis of this experiment is to be suspended at this time.

Status Messages

The following messages are printed on the console printer during a program run primarily to inform the machine operator of the current status of the program or to enter required information.

1. SET TODAYS DATE

1. (Continued) After printing this message, the program enters an inquiry waiting-loop. The operator must press the INQUIRY REQUEST key, type the current date, and press the RELEASE key.

2. P TO THE N FACTORIAL
   Printed during loading of program deck.

3. xxxxxx - nn EFFECTS CONFOUNDED/REP
   Where xxxxxx is the IDENT field from the parameter card and nn is the calculated number of effects confounded in each replicate. If this number does not agree with the number of effects and generalized interactions given on each replicate confounding record, the user must stop processing, make the necessary corrections, and RESTART.

4. END OF ANALYSIS
   Printed after the last experiment has been analyzed. A halt occurs with this message.

Error Checking

Extensive checking is made of the control cards and input data. If any error is detected, a message is printed on the console printer and a halt occurs. Some of the errors may be readily corrected and allow for processing to continue. However, most errors demand that the program be restarted.

Restart Procedure

This is the normal restart procedure to be executed after most errors:

1. If possible, make correction to the current experiment input deck and place the entire deck, including the parameter and format cards, and the input data, in the reader hopper. If correction is not immediately possible, remove the remaining

1. (Continued) portion of the input deck and place the next experiment input deck in the reader hopper.
2. A parameter card must be the first card to be read.
3. Press COMPUTER RESET key.
4. Press START key.

Error Messages

1. PARAM CARD ERROR

   Reason: The first card of the input deck was not a parameter card.

   Procedure: Remove extraneous cards and RESTART, or correct parameter card and press START.

2. P NOT PRIME

   Reason: The number of levels must be a prime number from 2 to 23.

   Procedure: If key punching error, correct PARAM card and RESTART. If not, then this experiment cannot be analyzed by this program.

3. STORAGE CAPACITY OF 35000 EXCEEDED BY XXXXX

   Reason: If the parameters specified are correct, then the experiment is too large for analysis by this program.

   Procedure: If key punching error, correct PARAM card and RESTART. If not, then a possibility for analysis is to break up the problem into groups of replicates.

4. INPUT HEADER INCORRECT

   (image of file header label)

   ACCEPT/SEARCH

   Reason: IDENT field of file header label does not match IDENT field of parameter card.

4. (Continued)

Procedure: INQUIRY REQUEST procedure performed as explained in the section Skipping Tape Files.

5. INPUT TAPE END OF FILE

Reason: End of tape or tape mark is sensed. This error may occur if no file header labels were written on the input tape.

Procedure: Press START to continue the search for the next file header label. If no file header labels exist on the input tape, then input can be made via the card reader.

6. FORMAT CARD MISSING

Reason: Either FORMAT not punched in first six columns or the card is not present. The card read is stacked in the normal pocket (0) .

Procedure: The format card must be present if there is more than one response variable to analyze. Place corrected format card in the card-read hopper and press START.

7. FORMAT IS INCORRECT

Reason: One of the following five messages will accompany this print out to identify the error .

Procedure: If it can be determined that the error is in the punching of the format card, then it is only necessary to correct the card and press START as in message 6. If the error is in the parameter card or the input data, then the normal RESTART procedure must be performed.

ERROR TYPE 1

Reason: The length of the treatment combination as specified in columns 13 and 14 of the format card is incorrect .

ERROR TYPE 2

Reason: The total number of characters as determined from the field lengths specified on the format card is greater than the sum 73 plus the length of first response variable field.

ERROR TYPE 3

Reason: Either two of the fields specified on the format card overlap or the number of variables specified in columns 22 - 23 of the parameter card is greater than the number of fields defined on the format card.

ERROR TYPE 4

Reason: One of the response variable fields has been defined as more than seven characters in length.

ERROR TYPE 5

Reason: The number of decimals specified for one of the response variables is greater than the length of that response variable field.

8. CARD IS INVALIDLY PUNCHED

Reason: There may be blank positions in the active portion of the input record, or the plus-zero in position six of a replicate confounding record may have been omitted.

Procedure: If for card input a card has blank columns in the fields specified as active data, then it is necessary only to correct the offending card and press START; otherwise, RESTART.

9. NO REPCON CARD

Reason: Either a replicate confounding card is missing or incorrectly constructed.

Procedure: If input is from cards, then it is necessary only to place the correct replicate confounding card

Procedure: (Continued)

in the read-hopper with the complete data for that replicate following and press START. If tape input, then more extensive corrective action must be taken.

10. SEQUENCE ERROR

Reason: The input data is not in the proper sort as specified under the section on preparation of input, an extraneous record has been placed in the input data file, there are records missing from the input file, or the plus-zero in position six of a replicate confounding record has been omitted.

Procedure: In any case the input file should be carefully checked and resorted before an attempt is made to RESTART.

Input/Output Error Routines

The nature of the 1410 Data Processing System makes it necessary to have complete I/0 checking. The following halts and messages may occur as the result of a detected I/0 error. An associated console and/or I/0 unit light may help in diagnosing the error.

1402 Card Reader:

1. %12ER

Reason: Hole count or validity error detected by card reader. The offending card is stacked in Pocket 0.

Procedure: Runout cards, place all cards dropped in pocket 0 into the read hopper, press END OF FILE, read START, and START for retry.

2. %12NR

Reason: The card reader is not in ready status. A full stacker, card jam, or reader stop may cause this

Reason: (Continued)

error stop.

Procedure: After correcting condition, press START.

1403 Printer:

3. %20NR

Reason: The printer is not in ready status. Printer out of forms will cause this stop.

Procedure: After correcting condition, press START.

4. %20ER

Reason: Validity error detected by printer. The program will automatically retry the operation as many as ten times. If the error still persists then the above messages is printed followed by a carriage return and printing on the console of the offending line. Invalid characters are distinguished by underlining.

Procedure: Since no operator intervention is necessary, the program will not halt if this message is printed.

Magnetic Tape

The tape unit on which the error has occured is noted as "n" in the following messages. Also the select light on unit n will be lit.

5. OUTPUT TAPE n PROTECTED BY HEADER LABEL RETENTION CYCLE, ACCEPTANCE DATE - xxxxxx, PRESS INQUIRY REQUEST AND TYPE: ACCEPT/REJECT

Reason: The current date falls within the retention cycle of the tape reel on drive n.

Procedure: If it is desired to use the tape reel anyway, press the INQUIRY REQUEST key, type the word ACCEPT, and press the RELEASE key. However, if it is desired to change the tape on drive n, Procedure: (Continued)

type the word REJECT after requesting an INQUIRY, then press the RELEASE key. The program will halt allowing the operator to change tapes. After pressing the START key, the program will check the tape header label on the new tape on drive n.

NOTE: All tapes to be used during an object run must be in ready status at program load time in order to be checked for proper mounting.

6. TAPE UNIT n NT RDY

Reason: Tape unit n is not in ready status.

Procedure: Ready the specified unit and press START.

7. TAPE UNIT 1 WL RCD

Reason: A wrong length record has been detected on the input tape. The tape input data is not in the mandatory format of 80 character unblocked records.

Procedure: Either the input tape must be rebuilt or the input medium changed to the card-reader. In either case a RESTART is necessary.

8. TAPE UNIT n R PTY ER

Reason: The processing unit received a wrong parity character while reading from tape unit n. This message occurs only after the read operation has been tried ten times.

Procedure: For ten more retries, press START. If the error persists, then the tape drive read/write heads should be carefully cleaned and possibly the tape itself given "first-aid".

9. TAPE UNIT n W PTY ER

Reason: The tape adapter unit received a wrong parity character from core storage while writing on tape unit n.

Reason: (Continued)

This message is unlikely to occur unless the magnetic tape is damaged. After ten retries, 3.5 inches of tape are blanked and ten more write operations are tried. This cycle is repeated and if the error still persists by the time the message is printed and the program halted, 35 inches of tape have been blanked, and the write operation retried 100 times.

Procedure: If this message is printed, then either a machine malfunction has occured or the magnetic tape is defective. The latter condition being the more probable, the procedure described under I/0 error No. 8 is strongly recommended.

CHAPTER III

APPLICATION TO LATTICE DESIGNS

The term "lattice" is applied to quite a large class of experimental designs in which the treatments do not represent a factorial arrangement. Lattice designs are classified according to the number of treatments and to the number of restrictions imposed in the randomization. (Federer, 1955, p. 314) For example, one group consists of the prime-power, one-restrictional lattices. The number of treatments (T) is equal to P^N where P is a prime number, and the randomization is such that the placement of the treatments is restricted so that they occur in specified blocks. Since a correspondence may be established between the T generic treatments and the P^N treatment combinations of a factorial set, the program can be used to analyze the prime-power, one-restrictional lattices. Even though the treatments are not arranged in a factorial, they may be relabled according to this correspondence and for purposes of constructing the design and analyzing the experiment considered a pseudo or quasi-factorial arrangement of treatments. (Kempthorne, 1952, p. 431)

Although lattice designs of dimension greater than two exist and are, in fact, necessary for very large numbers of treatments, only the two-dimensional lattice designs will be considered in the following discussion, since they are probably the most widely used.

In constructing lattice designs for $T = P^2$ treatments in blocks of size P, one represents the P^2 treatments by the combinations of the P levels each of two factors, say A and B, so that the pseudo-name of a treatment is of the form (x_1, x_2) where $x_1 = 0, 1, \cdots, P-1$ and $x_2 = 0, 1, \ldots, P-1$. There are $P+1$ pseudo-effects and pseudo-interactions labeled A, B, AB, AB^2, ..., AB^{P-1}. The relationships between the treatments and the levels of the pseudo-effects for $T = 3^2$ are given in the following table:

TABLE V

PLAN OF NINE TREATMENTS IN FOUR REPLICATES

Level of Pseudo-Effect		Treatments
	$(A)_0$	(00), (01), (02)
I	$(A)_1$	(10), (11), (12)
	$(A)_2$	(20), (21), (22)
	$(B)_0$	(00), (10), (20)
II	$(B)_1$	(01), (11), (21)
	$(B)_2$	(02), (12), (22)
	$(AB)_0$	(00), (12), (21)
III	$(AB)_1$	(01), (10), (22)
	$(AB)_2$	(02), (11), (20)
	$(AB^2)_0$	(00), (11), (22)
IV	$(AB^2)_1$	(02), (10), (21)
	$(AB^2)_2$	(01), (12), (20)

To construct the design, various pseudo-effects are confounded with blocks in different replicates. It is of little importance which effects are confounded since the correspondence is arbitrary; however, the confounding should be spread as equally as possible among the pseudo-effects. If there are P + 1 replicates available, then one each of the P + 1 pseudo-effects should be confounded in one of the replicates. The resulting design is then termed a balanced square lattice design. For example, a balanced lattice of 3^2 treatments consists of four replicates with the composition of the three blocks of each replicate being the treatments corresponding to the three levels of the pseudo-effect confounded in that replicate. Table V represents the plan of the design prior to randomization where each row is a block and each group of three rows a replicate. There may be fewer or more than four complete replicates available to the experimenter. In the former case, say three replicates, then any of the three arrangements may be chosen unless there are some treatment comparisons that are of more interest than others. For instance, if the comparison of the treatments assigned the pseudo-names (00) and (12) is of greatest importance, then arrangement III should be chosen. In the latter case, Cochran and Cox recommend specific arrangements depending upon the number of replicates available to the experimenter. (Cochran and Cox, 1957, p. 404)

The output of the program is the intra-block analysis only, since no attempt has been made to recover inter-block information. However, a test of the hypothesis of equal treatment effects is available from the inter-block analysis of variance if at least one effect is confounded in more than one replicate. This test is made by the ratio of the mean squares: Treatments (adjusted for blocks), denoted by one record-mark (ǂ) in the left margin of the analysis of variance, to Inter-Block Error, denoted by one asterisk (*) in the left margin. If the replicates can not be considered real, then the mean squares for Replications and Inter-Block Error should be pooled for the denominator of the above Snedecors-F test.

An associated intra-block test can be made of the above hypothesis by using the corresponding mean squares denoted by two record-marks (ǂ ǂ) and two asterisks (* *) respectively. It should be noted, however, that if both of the tests are made, the tests can be combined. (Fisher, 1932, pp. 99 - 101)

Since the components of Treatments and Error in the analysis of variance output are meaningless in a lattice design, this output may be suspended as described under column 26 of the parameter card.

The intra-block estimates of the treatment effects are given along with estimates of the variance of the difference in two treatments. If the design is not balanced, then treatment differences are estimated with different precision according as to the number of times the treatment pair under consideration appear together in the same block. If the confounding is spread as equally as possible among the pseudo-effects, then there are at most two classes of treatments: those that appear together in b_1 blocks, and those appearing together in b_2 blocks. If the lattice is balanced, then $b_1 = b_2$. In this case, only one variance estimate is given. If $b_1 \neq b_2$ and the number of replicates (R) is less than $P + 1$, then $b_1 = 0$, $b_2 = 1$, and both variance estimates are given. An average variance of the possible treatment differences is also given. This average variance may be used for testing any two treatment differences. (Kempthorne, 1952, p. 460)

The treatment effect estimates output by the program represent deviations of the estimated treatment means; therefore, their sum is zero. In some cases it is desirable to have the estimated treatment means themselves. Since the program will output the overall mean, it is only necessary to add this overall mean to a treatment deviation to get the corresponding estimated treatment mean.

CHAPTER IV

SUMMARY AND EXTENSIONS

The program computes the analysis of variance for statistical experiments where the number of treatments is P^N and P is a prime number. The program will also compute the intra-block estimates of the adjusted treatment means and the estimates of the variance of the difference in two treatment means when the treatments are arranged in a one-restrictional prime-power lattice design.

The flexibility of the program allows for variable input formats as well as variable input media and variable output dependent upon the nature of the experiment and the desires of the experimenter. It will also allow as many as sixteen response variables for each experimental arrangement. A large number of diagnostic routines were built into the program to minimize the possibilities of an invalid analysis.

A logical extension of the program would allow the number of levels of each factor, P, to be the power of a prime number. The arithmetic in some of the calculations would then have to be restricted to a Galois field of P^N elements.

Another extention would be to compute the inter-block estimates of effects and adjusted treatment means as well as the intra-block estimates so that the two estimates could be combined by weighting inversely proportional to the estimated variances.

Finally, an additional routine could be included in the program that would determine the confounding scheme from the data itself instead of having this information given to the program by the user.

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Kempthorne, O. The Design and Analysis of Experiments. John Wiley and Sons, Inc., New York, 1952.

APPENDIX

INPUT SAMPLE PROBLEMS

```
**********************************************************************************
PARAM02030008020402CS012  *JHB-1        TWO-CUBED IN TWO REPS
 1000?010101111          (B,AC,ABC-CONFOUNDED IN THIS REPLICATE) ****************
 101010000675101                                                 * INPUT   FORMAT
 101020000688000                                                 *
 102010008812100                                                 *COLUMNS CONTENT
 102020000355001                                                 * 1 - 2  REP
 103010007757111                                                 * 3 - 4  BLOCK
 103020005005010                                                 * 5 - 6  CELL
 104010005791110                                                 * 7 -13  RESPONSE
 104020002209011                                                 *14 -16  TREAT.
 2000?001110111          (C,AB,ABC-CONFOUNDED IN THIS REPLICATE) ****************
 201010007735000
 201020007225110
 202010001931111
 202020008956001
 203010005775010
 203020007993100
 204010000850101
 204020006467011
PARAM03020009030302CS011  *JHB-2        THREE-SQUARED IN TWO REPS
 1000?12                 (AB2-CONFOUNDED IN THIS REPLICATE)
 10101000004502
 10102000006621
 10103000003610
 10201000003712
 10202000001001
 10203000002420
 10301000007722
 10302000002500
 10303000002011
 2000?10                 (A-CONFOUNDED IN THIS REPLICATE)
 20101000007311
 20102000002112
 20103000004010
 20201000002421
 20202000001520
 20203000001722
 20301000003502
 20302000008800
 20303000004001
```

OUTPUT SAMPLE PROBLEMS

```
**********************************************************************************
                            P TO THE N FACTORIAL CONFOUNDING
 64/044           RESPONSE- 1           TWO-CUBED IN TWO REPS                  *JHB-1
                P -  2  N -  3  T -     8  K -  2  B -  4  R -  2
                               ANALYSIS OF VARIANCE
SOURCE OF VARIATION                     DEG OF FDM   SUM OF SQUARES      MEAN SQUARE
  TOTAL                                          15   15565.8448000
  AMONG ALL BLOCKS                                7    6665.5356000
    REPLICATIONS                            1          1528.8100000
    BLOCKS IN REPS                          6          5136.7256000
      B                                 1              1308.6728000     1308.672800
      C                                 1              1384.4322000     1384.432200
      A B                               1               283.4580500      283.458050
      A C                               1               115.6720500      115.672050
      A B C                             1              1395.7696000     1395.769600
        BY REPS(1,2)                    1               648.7209000      648.720900
 +    TREATMENTS (ADJUSTED FOR BLOCKS)      5          4488.0047000     897.60094000
 *    INTER-BLOCK ERROR                     1           648.7209000     648.72090000
  WITHIN ALL BLOCKS                               8    8900.3092000    1112.53865000
      A                                 1                92.3521000       92.352100
        BY REPS(1,2)                    1              4131.9184000     4131.918400
      B                                 1               213.8312000      213.831200
      C                                 1              1081.1250000     1081.125000
      A B                               1                55.6512500       55.651250
      A C                               1              2574.0312500     2574.031250
      B C                               1               501.7600000      501.760000
        BY REPS(1,2)                    1               249.6400000      249.640000
++    TREATMENTS (ADJUSTED FOR BLOCKS)      6          4518.7508000     753.12513333
**    INTRA-BLOCK ERROR                     2          4381.5584000    2190.77920000

                                   INTRA ESTIMATES OF EFFECTS AND INTERACTIONS
EFFECTS/LEVEL          00            01
  100             2.4025000-     2.4025000
                             RELATIVE INFORMATION- 02/02
  010             5.1700000      5.1700000-
                             RELATIVE INFORMATION- 01/02
  001            11.6250000     11.6250000-
                             RELATIVE INFORMATION- 01/02
  110             2.6375000-     2.6375000
                             RELATIVE INFORMATION- 01/02
  101            17.9375000-    17.9375000
                             RELATIVE INFORMATION- 01/02
  011             5.6000000      5.6000000-
                             RELATIVE INFORMATION- 02/02
  111              .0000000       .0000000
                             RELATIVE INFORMATION- 00/02
```

```
OUTPUT (CONTINUED)
*****************************************************************************
  INTRA ESTIMATES OF ADJUSTED TREATMENT MEANS
  NUMBER    COMBINATION       MEAN
     1          000          .5825000-
     2          001          .8425000
     3          010        16.8475000-
     4          011         6.9775000
     5          100        45.3725000
     6          101        24.9525000-
     7          110        18.5575000
     8          111        29.3675000-
  OVERALL MEAN        48.8900000

                         P TO THE N FACTORIAL CONFOUNDING
 64/044            RESPONSE- 1          THREE-SQUARED IN TWO REPS              *JHB-2
                 P -  3  N -  2  T -    9  K -  3  B -  3  R -  2
                              ANALYSIS OF VARIANCE
SOURCE OF VARIATION                     DEG OF FDM   SUM OF SQUARES     MEAN SQUARE
  TOTAL                                           17        90.24500
  AMONG ALL BLOCKS                                 5        30.51166
    REPLICATIONS                             1                .09388
    BLOCKS IN REPS                           4              30.41777
      A                                   2                 20.41555       10.207777
         2
      A B                                 2                 10.00222        5.001111
+     TREATMENTS (ADJUSTED FOR BLOCKS)       4              30.41777        7.604444
  WITHIN ALL BLOCKS                               12        59.73333        4.977777
      A                                   2                 14.68222        7.341111
      B                                   2                   .02333         .011666
        BY REPS(1,2)                      2                 20.64111       10.320555
      A B                                 2                  2.30333        1.151666
        BY REPS(1,2)                      2                  3.00111        1.500555
         2
      A B                                 2                 19.08222        9.541111
++    TREATMENTS (ADJUSTED FOR BLOCKS)       8              36.09111        4.511388
**    INTRA-BLOCK ERROR                      4              23.64222        5.910555
```

```
OUTPUT (CONTINUED)
*******************************************************************************
                                  INTRA ESTIMATES OF EFFECTS AND INTERACTIONS
EFFECTS/LEVEL           00             01             02
  10                1.11111111-     .67777777-    1.78888889
                                RELATIVE INFORMATION- 01/02
  01                 .05000000-     .03333333      .01666666
                                RELATIVE INFORMATION- 02/02
  11                 .50000000      .18333333-     .31666666-
                                RELATIVE INFORMATION- 02/02
  12                2.01111111      .62222222-    1.38888888-
                                RELATIVE INFORMATION- 01/02

  INTRA ESTIMATES OF ADJUSTED TREATMENT MEANS
  NUMBER     COMBINATION       MEAN
     1          00          1.35000000
     2          01          2.64999999-
     3          02          2.03333333-
     4          10          1.53333332-
     5          11          1.05000001
     6          12          1.54999999-
     7          20           .03333335
     8          21          1.70000000
     9          22          3.63333333
  OVERALL MEAN            3.850000
AVERAGE ESTIMATE OF VARIANCE OF THE DIFFERENCE IN TWO TREATMENTS   8.86583333333
  ESTIMATE OF VARIANCE OF THE DIFFERENCE IN TWO TREATMENTS
          APPEARING TOGETHER IN  00  BLOCKS              9.85092592198
  ESTIMATE OF VARIANCE OF THE DIFFERENCE IN TWO TREATMENTS
          APPEARING TOGETHER IN  01  BLOCKS              7.88074073285
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VITA

John Hamilton Blankenship

Candidate for the Degree of

Master of Science

Thesis: A PROGRAM FOR THE ANALYSIS OF EXPERIMENTS WITH CONFOUNDED FACTORIAL EFFECTS

Major Field: Mathematics (Statistics)

Biographical:

Personal Data: Born in Houston, Texas, October 3, 1940, the son of Norvel G. and Geraldine M. Blankenship.

Education: Attended grade school and junior high school in Ponca City, Oklahoma; graduated from the Senior High School of Ponca City, in 1958; received the Bachelor of Science degree from the Oklahoma State University, with a major in mathematics, in May, 1962; completed requirements for the Master of Science degree, with a major in statistics, in May, 1964.

Professional experience: Is a member of the American Statistical Association; worked as a student assistant and graduate assistant in the Computing Center at the Oklahoma State University, from June, 1960, to May, 1962, except for the summer of 1961 when employed as an Assistant Programmer by International Business Machines Corp. in Endicott, New York in the Programming Systems Department of the General Products Division; employed in the same capacity by International Business Machines Corporation during the summers of 1962 and 1963, programming for the IBM 1440, 1401 and 1410 computers; received a National Defense Education Act Title IV Fellowship in Statistics at the Oklahoma State University in September, 1962.