Appendix E

NUCLEAR WASTE MANAGEMENT PROCEDURE Sandia National Laboratories	**Design Document Criteria**	**Form Number: NP 19-1-4** **Page 1 of 1**

1. **Software Name:** LHS
2. **Software Version:** 3.00
3. **Document Version:** 3.00
4. **ERMS #:** 574194

Prior to sign-off of the DD, all items shall be appropriately addressed by the code sponsor so that "**Yes**" may be checked. Include this form as part of the DD.

Are the following appropriately defined and documented in the DD?

5. Major Software Components — ☒ Yes
6. Technical description of the software with respect to: theoretical basis, embodied mathematical model, major control flow, control logic, and data structures — ☒ Yes
7. Functionalities and interfaces of object components, functions, and subroutines. — ☒ Yes
8. Allowable or prescribed ranges for inputs and outputs — ☒ Yes
9. Verifiability: Is the design verifiable through testing or other means? — ☒ Yes
10. Consistency and Traceability: Is the design consistent with and traceable to the software's requirements? — ☒ Yes
11. Technical Feasibility: Is the design technically feasible? — ☒ Yes
12. Implementation: Is the design presented in sufficient detail to allow for implementation as computer software? — ☒ Yes

13.	L. Michael Feng **Code Team/Sponsor** (*print*)	*Signature on File* Signature	11/30/21 Date
14.	Dwayne Curtis Kicker **Technical Reviewer** (*print*)	*Signature on File* Signature	12/6/21 Date
15.	Shelly Nielsen **QA Reviewer** (*print*)	Shelly K. Nielsen Signature	H62022 Date
16.	Steve Wagner **Responsible Manager** (*print*)	Steve Wagner Signature	12/15/2021 Date
17.	Jennifer Long **SCM Coordinator** (*print*)	*Signature on File* Signature	1/19/22 Date

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Appendix G

NUCLEAR WASTE MANAGEMENT PROCEDURE Sandia National Laboratories	**User's Manual Criteria**	**Form Number: NP 19-1-6** **Page 1 of 1**

Does the User's Manual contain as appropriate:

1. **Software Name:** LHS
2. **Software Version:** 3.00
3. **Document Version:** 3.00
4. **ERMS #:** 574194

Prior to sign-off of the User's Manual, all items shall be appropriately addressed by the code sponsor so that "**Yes**" or "**N/A**" may be checked. Include this form as part of the User's Manual.

5.	A statement(s) of functional requirements (consistent with those in the RD)?	☒	Yes		
6.	An explanation of the mathematical model and numerical models, where applicable as based on code functionality?	☐	Yes	☒	N/A
7.	Physical and mathematical assumptions, where applicable as based on code functionality?	☐	Yes	☒	N/A
8.	The capabilities and limitations inherent in the software?	☒	Yes		
9.	Instructions that describe the user's interaction with the software?	☒	Yes		
10.	The identification of input parameters, formats, and valid ranges?	☒	Yes		
11.	Messages initiated as a result of improper input and how the user can respond?	☒	Yes		
12.	The identification and description of output specifications and formats?	☒	Yes		
13.	A description of any required training necessary to use the software?	☒	Yes		
14.	The identification of components of the code that were not tested?	☒	Yes	☐	N/A

15.	L. Michael Feng **Code Team/Sponsor** (*print*)	*Signature on File* Signature	11/30/2021 Date
16.	Dwayne Curtis Kicker **Technical Reviewer** (*print*)	*Signature on File* Signature	12/6/2021 Date
17.	Shelly Nielsen **QA Reviewer** (*print*)	Shelly R. Nielsen Signature	12-6-2022 Date
18.	Steve Wagner **Responsible Manager** (*print*)	Steve Wagner Signature	12/15/2021 Date
19.	Jennifer Long **SCM Coordinator** (*print*)	*Signature on File* Signature	1/19/22 Date

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WIPP PA

Design Document and User's Manual

for

LHS Version 3.00

Document Version 3.00

ERMS # 574194

November 2021

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1.0 INTRODUCTION AND SCOPE

This Design Document and User's Manual for LHS Version 3.00, describes the following major features of software design: software components, theoretical basis, mathematical model, control flow and logic, data structures, and functionality and the interfaces of subroutines. It also describes in detail the allowed or prescribed ranges for input data and user interface, in accordance with the *Nuclear Waste Management Procedure NP 19-1 Software Requirements* (Long, 2020). This code is used by the Sandia National Laboratories' Performance Assessment (PA) Department in support of the performance assessment calculations for the Waste Isolation Pilot Plant (WIPP). It is controlled under the software configuration management system Concurrent Versions System (CVS) on the Linux cluster.

1.1 Software Identification

Code Name:	LHS
Version:	3.00
CVS Repository:	/data/cvs/CVSLIB/WIPP_CODES/PA_CODES/LHS
Platform:	CentOS 7/Dell PowerEdge C6420
Host:	fwm.sandia.gov
Compiler:	Gfortran/GCC 8.2.0

1.2 Points of Contact

Code Sponsor:	Todd Zeitler	tzeitle@sandia.gov	(505) 284-9519

1.3 Code Overview

The LHS program samples distributions of input parameters using either normal Monte Carlo sampling or efficient Latin Hypercube Sampling. LHS permits correlations (restricted pairings) between parameters. The LHS program also can rescale sampled values to enforce conditional rules of the type "parameter 1 must be less than parameter 2". Latin hypercube sampling reduces the minimum number of sample vectors required to obtain reasonable estimates for various statistical properties of a distribution (Iman and Shortencarier, 1984). Only Latin hypercube sampling is used for WIPP PA.

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2.0 REQUIREMENTS

The requirements for LHS Version 3.00 are listed in the Requirements Document (Feng, 2021a). They are repeated here for the reader's convenience.

2.1 Functional Requirements

The functional requirements for LHS, Version 3.00 are listed below.

R.1 LHS performs Latin hypercube sampling.

R.2 Generate the distribution for each parameter to be sampled: NORMAL, LOGNORMAL, UNIFORM, LOGUNIFORM, USER DISTRIBUTIONs (Cumulative, Data, Delta), TRIANGULAR, STUDENT, LOGSTUDENT, STUDENTMSD, LOGSTUDENTGGD.

R.3 Correctly use the general input data sets used for WIPP/PA analysis: TITLE, NOBS, RANDOM SEED, OUTPUT.

R.4 Generate a correlation matrix as requested.

R.5 Impose a conditional relationship between pairs of variables indicated by EDIT. After the sampled values are calculated, the restricted variable will be modified so that its values are less than or equal to the controlling variable.

R.6 Can generate random numbers using an intrinsic Fortran function, a built in portable random number function, or use random numbers externally supplied.

Addition to above functional requirements, below additional functionality will be tested also.

A.1 LHS can detect invalid input in WIPP/PA data sets.

2.2 External Interface Requirements

The external interface requirements are listed below:

R.7 LHS can read the text transfer file from PRELHS (or a file in the same format).

R.8 LHS generates a text output data file. This file contains descriptions of each parameter, the values of the sampled parameters of which the Latin hypercube sample consists, and the rank correlation matrix.

R.9 LHS generates a text output diagnostics file.

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R.10 LHS writes the sampled parameter values and the rank correlations matrix to a database.

R.11 LHS can generate a file listing the stream of uniform random number used in the sampling process.

R.12 LHS can read in a file listing the stream of uniform random numbers to be used in the sampling process.

2.3 Other Requirements

There are no other requirements for LHS.

2.4 Functionality Not Tested

The following features are not tested nor to be used as part of the WIPP compliance calculations:

- Monte Carlo sampling: RANDOM SAMPLE,
- Distribution types not used for WIPP/PA analysis: BETA, UNIFORM*, LOGUNIFORM*, USER DISTRIBUTION (Cumulative Histogram), EXPONENTIAL, RAYLEIGH, RAYLEXP,
- Random pairing of samples: RANDOM PAIRING,
- Multiple repetitions of distribution generation: NREPS.

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3.0 MAJOR SOFTWARE COMPONENTS

Code LHS is written in FORTRAN 90/77. It contains one main program and 78 routines (60 subroutines, 17 functions and one entry point). The main program and routines are defined in seven source code files. In addition to the LHS exclusive routines, LHS makes use of the WIPP PA libraries CAMCON_LIB, CAMSUPES_LIB and DB_LIB to standardize common user interface and I/O functions (WIPP PA, 1995a, 1995b). These libraries are linked to the LHS executable during the build process as documented in the LHS Implementation Document (Feng, 2021b).

3.1 LHS Routines

The following is a list of all the LHS routines, including the main program of LHS, with a brief description (Table 3.1). For details of these routines and the main program, please refer to the source code files.

Table 3.1 LHS Routines Description

Number	Routine/Function entity	Location and Description
1	LHS	Defined in source file A1main_LHS.f: The main program of LHS. It is the starting point of LHS execution. It calls different routines to print out QA information, parse command line arguments, open the input and output files, connect to the result database, complete LHS execution. All the distribution types are calculated here with different subroutines.
2	ADDNEWVAR	Defined in source file readecho.f: Processes the distribution parameter statements. It increases NV (checks against maximum), sets the distribution type IDIST(NV), and isolates the variable label.
3	BANNER	Defined in source file readecho.f: Echoes user input concerning the sample setting. It is called at the start of each repetition of the sample and is used to delimit repetitions in the printout. Write transfer file header.
4	BETA	Defined in source file A1main_lhs.f: BETA is used to generate a beta distribution on the interval (A,B) and with parameters P and Q.
5	BETAFN	Defined in source file A1main_lhs.f: BETAFN is used in generating a beta distribution.
6	BETAHKH	Defined in source file A1main_lhs.f: Evaluate beta(k/2,1/2), where k is the input argument.
7	BETAIC	Defined in source file A1main_lhs.f: BETAIC computes an n member sequence of beta distributions.

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8	BETALN	Defined in source file A1main_lhs.f: BETALN computes the natural log of the complete beta function.
9	CHKDIM	Defined in source file readecho.f: Checks to see if program dimensions have been exceeded. Value must be >0 and <NMAX.
10	CHLSKY	Defined in source file A1main_lhs.f: Computes the Cholesky factorization of a correlation matrix stored in lower triangular symmetric form.
11	CMCRD	Defined in source file readecho.f: Processes the correlation matrix parameter card.
12	CORCAL	Defined in source file A1main_lhs.f: Computes a correlation matrix from the sample.
13	COROUT	Defined in source file A1main_lhs.f: Outputs the raw and rank correlation matrices of the sample if requested.
14	CUMSTT	Defined in source file A1main_lhs.f: Calculates Cumulative Student's *t*-distribution.
15	DATOUT	Defined in source file A1main_lhs.f: DATOUT outputs the sample and its ranks if requested.
16	DEFNEWVAR	Defined in source file readecho.f: Assigns the distribution parameters.
17	DMFSD	Defined in source file A1main_lhs.f: DMFSD is used in inverting a correlation matrix.
18	DSINV	Defined in source file A1main_lhs.f: DSINV is used in inverting a correlation matrix.
19	ENDCHK	Defined in source file A1main_lhs.f: This function is used to make sure that when X is supposed to be sampled from [a,b], that X is within the interval. If X is not, it is due to the rounding error using single precision. In this case, we define X to be one of the endpoints.
20	ERRCHK	Defined in source file A1main_lhs.f: ERRCHK is an error checking routine used in generating a beta distribution. The routines ERRCHK, ERXSET, and ERRGET together provide a uniform method with several options for the processing of diagnostics and warning messages which originate in the mathematical program library routines.
21	ERRGET	Defined in source file A1main_lhs.f: ERRGET is an error checking routine used in generating a beta distribution. It is a companion routine to subroutine ERRCHK.
22	ERRPRT	Defined in source file A1main_lhs.f:

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		Utility routine to simply print the character message.
23	ERSTGT	Defined in source file A1main_lhs.f: ERSTGT is an error checking routine used in generating a beta distribution. This routine is a slave to ERRGET and ERRSET.
24	ERXSET	Defined in source file A1main_lhs.f: ERXSET is an error checking routine used in generating a beta distribution. It is a companion routine to subroutine ERRCHK.
25	EXPONT	Defined in source file A1main_lhs.f: EXPONT generates an exponential distribution.
26	FINDIT	Defined in source file A1main_lhs.f: FINDIT is used in the positive definite check of the correlation matrix.
27	FINVER	Defined in source file A1main_lhs.f: FINVER is used in generating the beta distribution. It inverts F(X)=Y or finds a root of F(X)-Y=0.
28	FINVNOR	Defined in source file A1main_lhs.f: FINVNOR is used in generating the normal and lognormal distributions.
29	GAMALN	Defined in source file A1main_lhs.f: An entry point of subroutine BETALN.
30	GETTOKEN	Defined in source file readecho.f: Isolates the next blank-delimited token in a line.
31	HISTO	Defined in source file A1main_lhs.f: HISTO generates histograms of the variables.
32	HPSRT	Defined in source file A1main_lhs.f: HPSRT is used in the ranking of the sampled data.
33	HSTOUT	Defined in source file A1main_lhs.f: HSTOUT is used to generate histograms of the variables.
34	HYPGEO	Defined in source file A1main_lhs.f: HYPGEO is used in generating a beta distribution. It sums the series for f(a,b,c,x) when sum=1. Or f(a,b,c,x)-1. when sum=0. where f(a,b,c,x) is the Gauss Hypergeometric Function.
35	I1MACH	Defined in source file A1main_lhs.f: I1MACH sets integer machine dependent constants.
36	IMTQL2	Defined in source file A1main_lhs.f: This subroutine finds the eigenvalues and eigenvectors of a symmetric tridiagonal matrix by the implicit QL method.
37	INVCST	Defined in source file A1main_lhs.f: Calculate inverse cumulative student t-distribution.
38	J4SAVE	Defined in source file A1main_lhs.f:

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		J4SAVE saves and recalls several global variables needed by the library error handling routines.
39	LHSEDIT	Defined in source file lhs_edit.f: Edit a LHS output file by restricting the value in column col2 to never exceed the value in col1
40	LOC1	Defined in source file lhs_param_mod.f90: Evaluates ((i*i-i)+j)/2.0 for correlation.
41	LOC2	Defined in source file lhs_param_mod.f90: Evaluates (j-1)*n+i
42	MATINV	Defined in source file A1main_lhs.f: MATINV is used to invert a lower triangular matrix.
43	MIX	Defined in source file A1main_lhs.f: Mix the generated data or random integers.
44	NORMAL	Defined in source file A1main_lhs.f: NORMAL generates normal and lognormal distributions.
45	OUTDAT	Defined in source file A1main_lhs.f: OUTDAT outputs the sample and its ranks.
46	PMTRX	Defined in source file A1main_lhs.f: PMTRX prints out a correlation matrix.
47	POSDEF	Defined in source file A1main_lhs.f: POSDEF is used in the positive definite check of the correlation matrix.
48	PYTHAG	Defined in source file A1main_lhs.f: PYTHAG is used in the positive definite check of the correlation matrix. It finds SQRT(A**2+B**2) without overflow or destructive underflow.
49	R1MACH	Defined in source file A1main_lhs.f: R1MACH is used to set floating point machine dependent constants.
50	RAN3	Defined in source file rngen_mod.f90: Returns a uniform random deviate between 0.0 and 1.0. Based on method in W. H. Press et al., Numerical recipes in Fortran (1992), pp. 273-4.
51	RAN_GEN_CONTROL	Defined in source file rngen_mod.f90: Reads the random number generation control file.
52	RAN_INIT	Defined in source file rngen_mod.f90: Initializes options for control of random number generation. It must always be called before RAN3.
53	RANKER	Defined in source file A1main_lhs.f: RANKER is used to find the ranks of a vector of data.
54	RAN_WRAPPER	Defined in source file rngen_mod.f90: Random number generation wrapper.
55	RAYLEIG	Defined in source file A1main_lhs.f:

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		RAYLEIG generates the Rayleigh distribution.
56	RAYLEXP	Defined in source file A1main_lhs.f: RAYLEXP generates the Rayleigh-exponential distribution.
57	RDPAR	Defined in source file readecho.f: Processes the parameter statements, defines variables in common /param/ and stores distribution information on units 7 and 8 and in argument arrays. Writes parameter definitions to the debug file.
58	RESCALE_EDIT	Defined in source file lhs_edit.f: Adjusts varval2 so that it never exceeds varval1.
59	RIERFC1	Defined in source file A1main_lhs.f: Function RIERFC1 is used in generating the normal and lognormal distributions.
60	SCANPAR	Defined in source file readecho.f: Processes the parameter statements for sizing. SCANPAR counts the number of variables (but does not process them) and processes most non-variable inputs.
61	SETDEF	Defined in source file readecho.f: Sets the default values of the parameters.
62	SIFT	Defined in source file A1main_lhs.f: SIFT sorts a vector of data in increasing order.
63	SSPEV	Defined in source file A1main_lhs.f: Computes the eigenvalues and, optionally, the eigenvectors of a real symmetric matrix stored in packed form.
64	STUDENT	Defined in source file A1main_lhs.f: STUDENT generates the Student t-distribution.
65	TQLRAT	Defined in source file A1main_lhs.f: Computes eigenvalues of symmetric tridiagonal matrix a rational variant of the QL method.
66	TRBAK3	Defined in source file A1main_lhs.f: Forms eigenvectors of real symmetric matrix from the eigenvectors of symmetric tridiagonal matrix formed TRED3.
67	TRED3	Defined in source file A1main_lhs.f: Reduces real symmetric matrix stored in packed form to symmetric tridiagonal matrix using orthogonal transformations.
68	TRIANG	Defined in source file A1main_lhs.f: TRIANG generates the triangular distribution.
69	UNIFRM	Defined in source file A1main_lhs.f: UNIFRM generates the uniform, loguniform, uniform*, or the loguniform* distributions.
70	USRDST	Defined in source file A1main_lhs.f: Generates the User Distributions.

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71	VIF	Defined in source file A1main_lhs.f: VIF computes the variance inflation factor of a correlation matrix.
72	WRTDBCOR	Defined in source file wrtdb.f: RTDBCOR writes the rank correlations to the Database. Rank correlations must be in CORR on input/output.
73	WRTDBDAT	Defined in source file wrtdb.f: WRTDBDAT writes the variable values to the Database.
74	WRTTRNCOR	Defined in source file wrttrn.f: WRTTRNCOR writes the rank correlation matrix to the transfer file. X must be sampled values on input, unknown on output. CORR is rank correlation matrix on output.
75	WRTTRNDAT	Defined in source file wrttrn.f: WRTTRNDAT writes the sampled values to the transfer file. X must be sampled values on input/output.
76	XERPRT	Defined in source file A1main_lhs.f: Prints the error message.
77	XERRWV	Defined in source file A1main_lhs.f: Processes error message allowing 2 integer and two real values to be included in the message.
78	XERSAV	Defined in source file A1main_lhs.f: Records that an error occurred.
79	XGETUA	Defined in source file A1main_lhs.f: Returns unit number(s) to which error messages are being sent.

3.2 CAMCON_LIB Routines

The CAMCON_LIB library is a collection of routines whose purpose is to standardize the user interface to all programs and to simplify coding by providing commonly used functions, such as handling command line arguments, displaying standardized output and parsing free-field input, providing a code banner with credits (authors), software ID, revision date, and current date and time.

LHS uses the following routines defined in the CAMCON_LIB library (Table 3.2).

Table 3.2 CAMCON_LIB Routines Called by LHS

Number	Routine/Function entity	Location and Description
1	FILDFNAM	FILDFNAM defines a file whose name will be read by FILRDNAMS. Each time FILDFNAM is called, a file description is added to a table used by FILRDNAMS.

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2	FILRDNAMS	FILRDNAMS requests the names of all files previously defined by FILDFNAM. The file names are read from the command line. Any file names not found on the command line may be requested from the user. If the file is an input file, it must exist.
3	FILWRNAMS	FILWRNAMS writes the file names defined by FILDFNAM and read by FILRDNAMS to the terminal or an output file.
4	QAABORT	QAABORT prints a fatal error message to the terminal and to the diagnostics file (if defined). It then aborts the program.
5	QABANNER	QABANNER prints the program banner to the terminal or an output file. The banner includes the program name in large letters, the program description, the version information, the author, the sponsor, the current run information, and information about the executable. A short version of the banner may also be printed by starting LINE1 with "<NO>". The short banner includes the program name and version, information about the executable, and the current run information. Routine QASETUP must be called to set up the CAMCON_LIB common before QABANNER is called.
6	QAFETCH	QAFETCH returns the program QA information. Routine QASETUP must be called to set up the CAMCON_LIB common before QAFETCH is called.
7	QASETUP	QASETUP should be called at the start of any program. It performs initialization details common to all programs. Specifically, it • Initializes the CPU time • Fetches information from the executable • Sets the current run date and time • Sets the execution machine and operating system • Starts a new page on the terminal
8	STRUPCASE	STRUPCASE converts the passed string to upper-case letters.

3.3 CAMSUPES_LIB Routines

The CAMSUPES_LIB library is a collection of machine-dependent functions and allocate memory for arrays at run time for FORTRAN77.

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LHS does not call routines defined in the CAMSUPES_LIB library directly. But the CAMCON_LIB routines called by LHS need the following routines defined in the CAMSUPES_LIB library (Table 3.3).

Table 3.3 CAMSUPES_LIB Routines required to build LHS

Number	Routine/Function entity	Location and Description
1	EXABORT	EXABORT aborts the program (with EXIT code 1).
2	EXCPUS	EXCPUS returns an accumulated CPU time. The base time is undefined; only relative times are valid.
3	EXDATE	EXDATE returns the current date in a character string.
4	EXEXEINFO	EXEXEINFO returns information about the current or supplied executable. Most of the information is attached to the executable by an official build, so executables not linked in this way will not have this information.
5	EXFILDAT	EXFILDAT returns the last update date and time for a file.
6	EXFILFLD	EXFILFLD parses an input file name into its component fields.
7	EXPARM	EXPARM defines various operating environment parameters. A character ID is supplied for both the processor hardware type and the operating system. The job processing mode, batch or interactive, is identified; for this purpose an interactive job is defined as one where the standard input device is attended by the user who can respond to unforeseen events. The number of character storage units and the number of numeric storage units in the smallest block of storage which contains an integral number of each are defined here. This routine further defines whether the record length of a direct access unformatted file is counted in character or numeric storage units.
8	EXREAD	EXREAD prompts, reads, and echos from the standard input device. For an interactive job, this would prompt for input from the terminal and read (with echo) from the keyboard. For a batch job, this would read from the main input file and echo to the log file with the prompt string as a prefix. This routine should assume the burden of assuring that the standard input and output devices are properly opened.
9	EXTIME	EXTIME returns the current time in a character string. The format is: HH:MM:SS, where HH is the hour, MM is the minute, SS is the second.

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3.4 DB_LIB Routines

The DB_LIB library, whose previous name is SDBREAD_LIB, is a collection of routines that retrieve information from the Performance Assessment Parameter Database, store information into or retrieve from the PA_Results database.

LHS uses the following routines defined in the DB_LIB library (Table 3.4).

Table 3.4 DB_LIB Routines Called by LHS

Num	Routine entity	Functions
1	RDBCLOSE	RDBCLOSE disconnects the Results database connected with RDBOPEN.
2	RDBDELETELHS	RDBDELETELHS deletes LHS data from the Results database.
3	RDBLOADLHS	RDBLOADLHS loads LHS sampled values into the Results database from a file. Each line of the file must contain: "mat", "prop", ivar, ivec, value
4	RDBLOADLHSCORR	RDBLOADLHSCORR loads an LHS correlation matrix into the Results database from a file. Each line of the file must contain: "mat1", "prop1", ivar1, "mat2", "prop2", ivar2, corrval
5	RDBOPEN	RDBOPEN sets the analysis information and connects to the Results database. Database access information is set to defaults, but may be overridden by environment variables.
6	RDBPREPLHS	RDBPREPLHS writes the LHS vector values for a material-property to a file that will later be loaded into the Results database with RDBLOADLHS.
7	RDBPREPLHSCORR	RDBPREPLHSCORR writes the LHS correlation values for a material-property to a file that will later be loaded into the Results database with RDBLOADLHSCORR. The correlation is to all variables less that the current variable. That is, it is one row of a symmetric array.

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4.0 MODELS AND METHODS

Description of the Model

LHS neither models physical phenomena nor solves differential equations that model physical process. Its principal role in WIPP PA is to sample, using Latin hypercube sampling methods, distributions that represent reasonable values of WIPP input-parameter data. LHS treats each parameter independently, but permits user-specified correlations (restricted pairings) between parameters.

The situation generally addressed by LHS is the following. We are given a variable of interest, Y, that is a dependent function of several other variables, including a discrete set of physical parameters $X_1, X_2,...,X_k$. However, due to unresolvable uncertainties, the physical parameters are not specifiable as single, unique numbers. Rather, they are characterized by ranges or distributions of values together with probabilities of occurrence associated with the values included in the distributions. A question of central concern is how does Y vary when the Xs vary?

The conventional approach to addressing this question is to use Monte Carlo sampling. By sampling repeatedly from the given joint probability density function of the Xs and evaluating Y for each sample, the distribution of Y, its mean, percentiles, etc., can be estimated. However, to receive a reasonable estimate, a large number of samples must be taken, and a large number of evaluations of Y must be performed. If Y is computationally expensive to evaluate, this can be infeasible. Additionally, Monte Carlo sampling is inefficient in the sense that most of its samples will be taken from the higher probability of occurrence portions of the distributions. Thus, extreme values, which usually reside toward the outer wings of the distributions tend to be ignored for all but very large samples. To remedy this shortcoming, an alternative constrained sampling system was introduced. The particular system selected is known as Latin hypercube sampling.

Latin hypercube sampling was developed by McKay, Conover, and Beckman (1979). Much of the following discussion of the methodology of LHS is from Iman and Shortencarier (1984) and Wyss and Jorgensen (1998). For a more detailed description of LHS, see Iman et al. (1981a, 1981b) for sensitivity analysis techniques. A tutorial on LHS may be found in Iman and Conover (1982b). A comparison of Latin hypercube sampling with other sampling techniques can be found in Iman and Helton (1985).

4.1 Sampling

The first step in Latin hypercube sampling is to divide the range of X_1 into n non-overlapping intervals on the basis of equal probability. Then, one value from each interval is randomly selected

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with respect to the probability density in the interval. Thus, for X_1, n values are obtained. n values for X_2, …, X_K are obtained in a similar manner. The n values of X_1 are randomly paired with the values of X_2. These n pairs are randomly paired with the n values of X_3. This process is repeated with the remaining X_s until n K-tuplets are formed. It is useful to think of the Latin hypercube sample as a matrix with n rows and K columns. The i^{th} row of this matrix consists of one set of values of X_s that Y evaluates.

To further clarify how Latin hypercube sampling chooses the values of the X_s, we examine an example from Iman and Shortencarier (1984). Consider the case where Y has two input variables, X_1 and X_2, and it is necessary to generate a Latin hypercube sample of size n=5. We assume that X_1 has a normal distribution with mean μ and variance σ^2 and that X_2 has a uniform distribution.

In many applications, it is desirable to sample values from a truncated normal distribution. For this example, Iman and Shortencarier restrict sampling of X_1 the interval bounded below by the 0.001 quantile and bounded above by the 0.999 quantile. Namely, if $P(X_1 \le A) = .001$ and $P(X_1 \ge B) = .001$, only values from [A,B] are sampled, and values outside of [A,B] are excluded. A is defined as the .001 quantile, and B is the .999 quantile. For this example, we will sample from this truncated distribution. (LHS Version 3.00 samples values between the 0.01 and 0.99 quantiles for normal, lognormal, student, and logstudent distributions.) For these quantiles, the mean of the truncated normal distribution is $\mu = (A+B)/2$ and $\sigma^2 = \{(B-A)/6.18\}^2$ (Iman and Shortencarier, 1984). For more discussion on computing the mean and variance of a truncated normal distribution, see Kortum (2002).

To begin the Latin hypercube sampling process, the ranges of X_1 and X_2 need to be divided into n=5 intervals of equal probability. The parameters μ and σ determine the endpoints of these intervals. The intervals for n=5 are illustrated in terms of the probability density function (PDF) for X_1 in Figure 4.1. Figure 4.2 displays the intervals using the cumulative distribution function (CDF) for X_1. Note that in Figure 4.2, the endpoints of the intervals (in terms of probabilities) are 0, .2006, .4002, .5998, .7794, and .999 (as opposed to 0, .2, .4, .6, .8, and 1) because the normal distribution is truncated between the .001 and .999 quantiles for this example.

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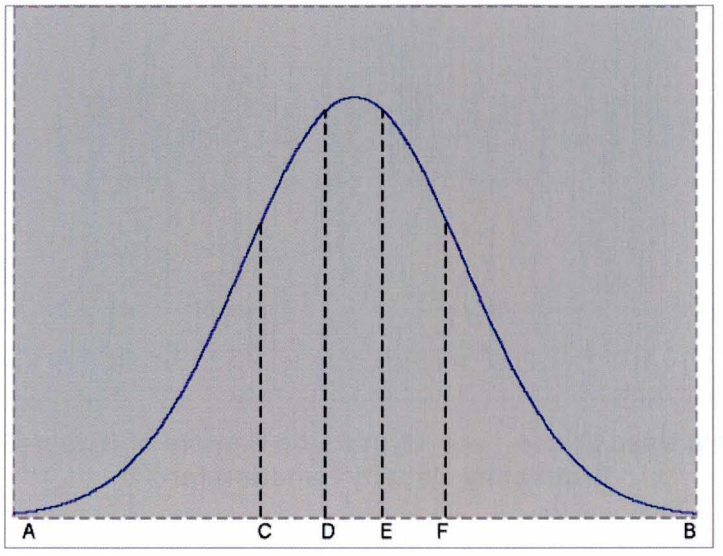


Figure 4.1 Intervals Used With a Latin Hypercube Sample of Size n=5 in Terms of the Probability Density Function for X_1

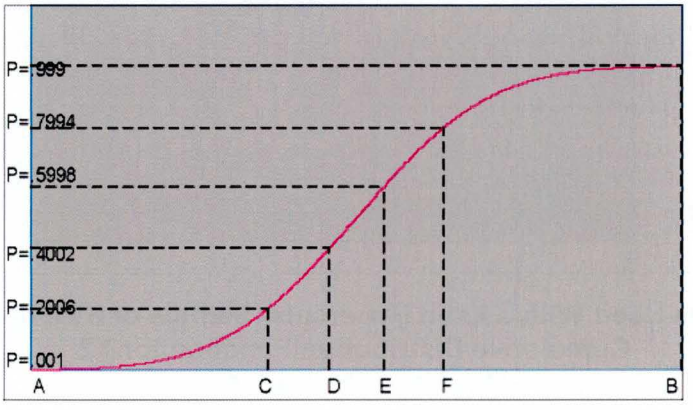


Figure 4.2 Intervals Used With a Latin Hypercube Sample of Size n=5 in Terms of the Cumulative Distribution Function for X1

Since X_2 is assumed to have a uniform distribution, the intervals for n=5 are shown in Figure 4.3 and Figure 4.4.

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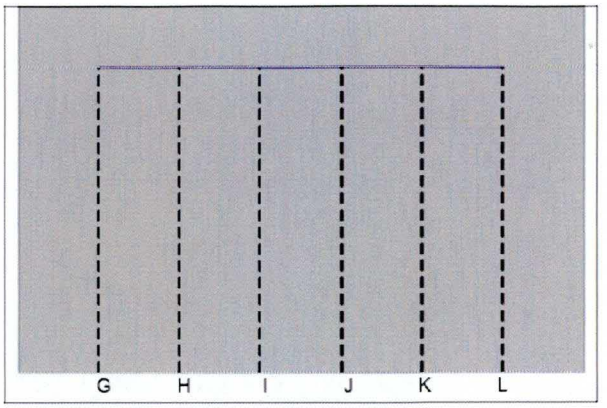


Figure 4.3 Intervals Used With a Latin Hypercube Sample of Size n=5 in Terms of the Probability Density Function for X2

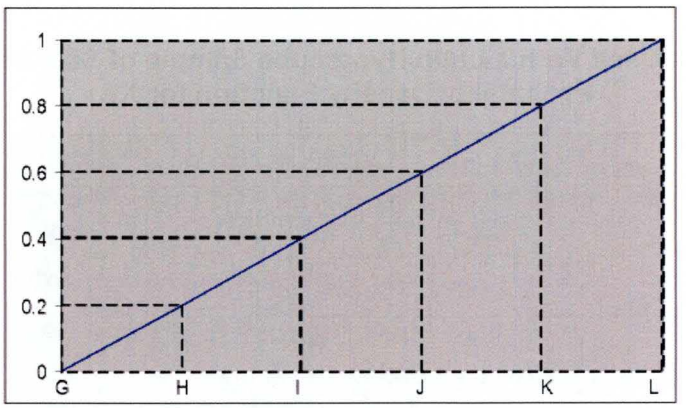


Figure 4.4 Intervals Used With a Latin Hypercube Sample of Size n=5 in Terms of the Cumulative Distribution Function for X2

To sample values of X1 within the intervals, the algorithm actually uses the CDF, not the PDF. First, n=5 numbers are chosen at random from the uniform distribution on (0,1). Denote these numbers by U_m, m=1, 2, 3, 4, 5. The U_m are then scaled and translated to get the corresponding cumulative probabilities in the appropriate intervals. That is,

$$P_m = .001 + (.999 - .001)\left(\frac{U_m}{5} + \frac{m-1}{5}\right), m = 1,2,3,4,5$$

Exactly one P_m falls into each of the intervals (.001,.2006), (.2006,.4002), (.4002,.5998), (.5998,.7994), and (.7994,.999). Note that the above formula can be generalized if the distribution is truncated at different quantiles or if the distribution is not truncated at all.

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Using the inverse normal distribution function, P_m is converted to the corresponding standard normal distribution value and then scaled for the appropriate non-standard normal distribution. These are the values used for the Latin hypercube sample. Sampling of values of X_2 is done in a similar manner.

The process of sampling is illustrated in Table 4.1 for a normal distribution with mean $\mu=5$ and variance $\sigma^2=2.618$.

Table 4.1 A Possible Selection of Values for a Latin Hypercube Sample of Size 5 from a Normal Distribution That Has a Mean of 5 and Variance of 2.618 and Is Truncated Between the .001 and .999 Quantiles

Interval Number m	*Uniform (0,1) Random No. U_m*	*Scaled Probabilities Within the Interval P_m*	*Corresponding Standard Normal Value (Z-score) from the Inverse Distribution*	*Corresponding $N(5,2.618^{1/2})$ Observation Within the Intervals*
1	0.080	0.016	-2.144	1.529
2	0.610	0.322	-0.462	4.252
3	0.525	0.505	0.013	5.021
4	0.935	0.787	0.796	6.288
5	0.620	0.924	1.433	7.319

The intervals for this distribution are illustrated in terms of the PDF and CDF in Figure 4.5 and Figure 4.6. Note that the precise endpoints for the intervals are given in these figures. Figure 4.7 shows where the sampled values fall within the intervals for this distribution.

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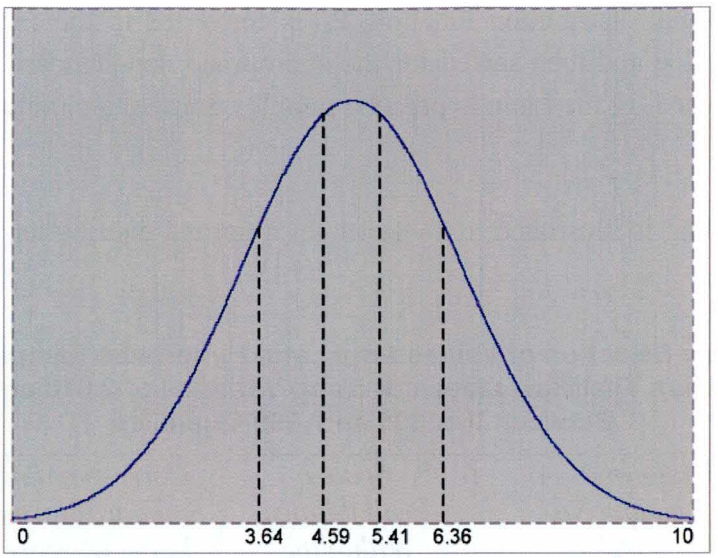


Figure 4.5 Intervals Used With a Latin Hypercube Sample of Size n=5 in Terms of the Probability Density Function for X_1 when $\mu=5$ and $\sigma^2=2.618$

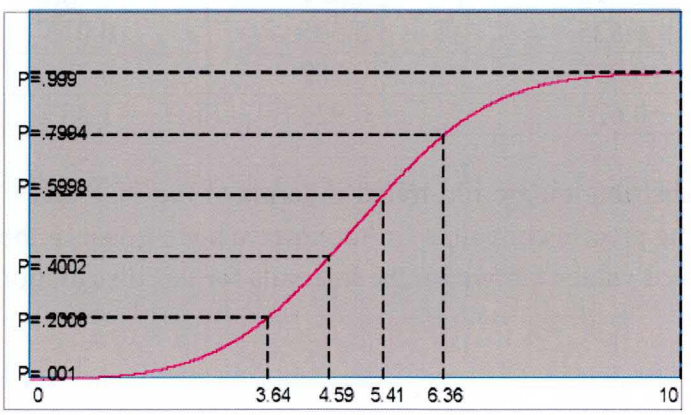


Figure 4.6 Intervals Used With a Latin Hypercube Sample of Size n=5 in Terms of the Cumulative Distribution Function for X_1 when $\mu=5$ and $\sigma^2=2.618$

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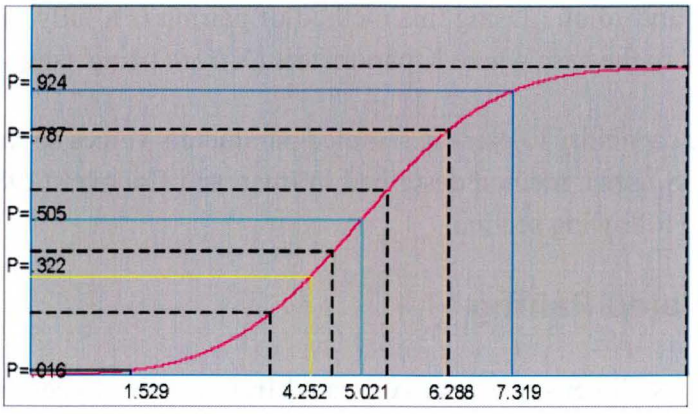


Figure 4.7 Intervals and Sampled Values Used With a Latin Hypercube Sample of Size n=5 in Terms of the Probability Density Function for X_1 when $\mu=5$ and $\sigma^2=2.618$

4.2 Pairing the Sampled Values

The last step in creating the Latin hypercube sample is to pair the X values. For our specific example, that means pairing the X_1 and X_2 values. Originally, in McKay et al. (1979), pairing was done by associating a random permutation of the first *n* integers with each sampled variable. For the current example (when $n=5$), consider the two permutations of (1,2,3,4,5) as follows:

Permutation Set Number 1: (3,1,4,2,5)
Permutation Set Number 2: (2,4,1,3,5)

By using the respective position within the permutation sets as interval numbers for X_1 and X_2, the pairings that are formed are shown in Table 4.2.

Table 4.2 Random Pairing of the Sampled Values for X_1 and X_2

Number of Y Evaluation	*Interval Number to be Used for X_1*	*Interval Number to be Used for X_2*
1	3	2
2	1	4
3	4	1
4	2	3
5	5	5

Thus, the first time that Y is evaluated, Y is evaluated using the third sampled value for X_1 and the second sampled value for X_2. For the second evaluation, the first and fourth values of X_1 and X_2,

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respectively, are used, and so on. Using this method of pairing is a fully random process, and it can also be generalized to the case where K parameters (X_s) are being sampled.

However, LHS has the capability to pair the sampled parameters values so that they are correlated according to rank. LHS uses a method described in Iman and Conover (1982a). This method is described briefly in the following section.

4.3 Rank Correlated Pairing

Let R denotes the *n* by K dimensional matrix created from a Latin hypercube sample where the rows were created by the random pairing method described in the previous section. The i^{th} row of this matrix consists of the i^{th} input vector to be evaluated by the evaluating function Y. C* denotes the user defined correlation matrix which, by definition, must be symmetric and positive definite. The objective of this pairing method is for the Spearman rank correlation matrix, M, of the matrix R to be "close" to C*, while preserving certain important properties of R such as the stratified sampling structure that Latin hypercube sampling employs.

Since C* is symmetric and positive definite, there exists a lower triangular matrix P such that $C^*=PP^T$, where P^T denotes the transpose matrix of P. Multiplication of R by P^T results in a matrix $R^*=R\ P^T$ whose rank correlation matrix, M, is close to C. Thus, the i^{th} row of R* will be the i^{th} input vector for Y, and R* will be the rank correlated Latin hypercube sample.

LHS employs this method to create a rank correlated Latin hypercube sample. For a more detailed discussion of this method, see Iman and Conover (1982a).

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5.0 CONTROL FLOW AND LOGIC

The general control flow and logic for LHS follows. The names of the major subroutines that currently perform the functions described are provided in brackets([ ]).

LHS control flow and logic:

- Read the input file name from the command line. [FILDFNAM]
- Read the parameter statements, define variables in common /PARAM/, and store parameter information. [RDPAR]
- Echo a description of the Latin hypercube sample as input by the user and a description of the distributions used with the input variables. [BANNER], [WRTPAR]
- Echo, check, and process the correlation matrix, if one is specified. [PMTRX], [POSDEF]
- Generate the distribution for the current parameter. There are several different subroutines that generate the distributions, and the ones called depend upon the user defined specifications. Each subroutine also has its own set of subroutines that are called to check for errors.
- Pair the sample observations. [MIX]
- Output the samples, corresponding ranks, histograms, and row and rank correlations for the current samples. [DATOUT], [HSTOUT], [COROUT]

5.1 Data Structures

LHS requires the user to specify the names of (i) certain already-existent input files and of (ii) the output files the code will create as a result of being exercised. The following sections discusses the file specification requirements of LHS.

5.1.1 LHS's Input Text Transfer File

LHS's input file is, verbatim, the ASCII text output file from PRELHS. LHS does have the possibility of running with a user-generated input file, but **that option will not be used for regulatory calculations and, therefore, it will not be discussed herein.** LHS's input file serves a dual purpose. It serves (i) as a control file that directs LHS's function by specifying the code-execution keywords in a format suitable for direct usage by LHS, and (ii) as a data file that provides the parameter-distribution data on which LHS will operate. The user specifies the name of this input file with command line argument (-input).

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The LHS input file is designed to be used without modification. Therefore, for the purposes of regulatory calculations, it will not be edited or otherwise modified in any way after it has been created by PRELHS.

An example of an LHS input control file is the PRELHS output transfer file lhs2_qa0242_t3.inp. It is described in Section 5.2 , below, and listed in full in Appendix A.

The LHS input transfer file is described in Section 5.2.1 below.

5.1.2 LHS's Random Number Control File

Recognizing that different systems and compliers have different implementation of the Fortran intrinsic random generation function, a system-independent random generation function was introduced to LHS Version 3.00. So the random number generation inside LHS Version 3.00 can come from one of three sources, an input stream of random numbers, the FORTRAN intrinsic RAN function, or the portable LHS RAN3 function. The selection of random number generation is done with the random number control file. The user specifies the name of this file with command line argument (-random).

The random number control file is described in Section 5.2.3 below.

5.1.3 Database for LHS Data

LHS Version 3.00 writes its results to a database for post-processing. The official database is PA_Results; test database PA_Results_test and users' database PA_Results_xxx have an identical structure and can be provided for informal runs. The PA_Results database should be used in all regulatory calculations. Only the "production user", defined as user "run_mast" in group "cvsuser", can write to the PA_Results database. The user must provide the database with the analysis name (e.g., PABC09), the analysis revision (optional, default 0), and the replicate number. The sampled values for each vector are stored for each parameter. Parameters are identified by variable number, material and property. The rank correlation between each pair of parameters is also stored in the database.

5.1.4 LHS's Output Data File

In addition to the database output, LHS's results are written to an ASCII output data file. The user specifies the name of the output data file with command line argument (-output).

The LHS output data file contains descriptions of each parameter, the values of the sampled parameters of which the Latin hypercube sample consists, and the rank correlation matrix. This

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file may serve as an unofficial transfer file to POSTLHS and other utility codes, **but this use is not allowed in regulatory calculations**.

An example of LHS's output text file is given in lhs2_300_t3.dat. This file is described in Section 5.3 below, and listed in full in Appendix B.

5.1.5 LHS's Output Debug File

The output debug or diagnostics file contains the actual numerical values LHS produces for each sampled parameter, on an outcome-by-outcome basis. The information in this file is the same as that available in the output ASCII text file, but with~~out~~ the inclusion of descriptive text or plots. The user specifies the name of the output debug/diagnostics file with command line argument (-debug).

An example of a LHS debug/diagnostics file is lhs2_300_t3.dbg. It is reproduced in full in Appendix C of this document.

The LHS output debug file is described in Section 5.4 below.

5.1.6 LHS's Random Number Stream File

LHS's random number stream file can be an output file of LHS execution. An existing LHS random number stream file can also serve as an input file of LHS execution, depending on the specification of LHS's random number generation control file.

The name of LHS's random number stream file is specified in LHS's random number generation control file.

The LHS random number stream file is described in Section 5.2.4 below.

5.2 Description of the Input Files

PRELHS creates an ASCII output transfer file (see the User's Manual for PRELHS Version 2.45, Feng, 2021c) that ordinarily serves as LHS's input control file. That file is described in detail in the paragraphs that follow. A sample listing of the LHS input file is given in Appendix A of this manual. It contains all of the information necessary for LHS to exercise and thereby create a sample. The input file has as its first and last record a title line created by PRELHS from information found in the WIPP PA database identifying the database's title and version number.

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Also included is the date and time stamp signifying when PRELHS created the LHS input file. This title record is carried through to the completion of the LHS run and appears on the ASCII text output file. After the initial title record, a second title record gives a descriptive title that identifies the LHS input file. It serves no other purpose.

Following the two title records, the LHS input file lists code execution keywords. In the case of the sample file in Appendix A, keywords NOBS and RANDOM SEED appear and specify that a sample of 75 outcomes will be created by LHS, along with specifying the value of the starting random seed as 933090934. Next comes the information necessary to calculate each of the distributions to be included in the sample. For the sample file in Appendix A, ten data distribution types are included. They are NORMAL, LOGNORMAL, UNIFORM, LOGUNIFORM, CUMULATIVE USER DISTRIBUTION, DATA USER DISTRIBUTION, DELTA USER DISTRIBUTION, STUDENT, LOGSTUDENT and TRIANGULAR. These 10 distributions, plus STUDENTMSD and LOGSTUDENTGGD, which are not included in this sample, correspond to the data distribution types that will be utilized for the regulatory calculation.

After specification of the data distribution input, the LHS input file in Appendix A lists further input. The CORRELATION MATRIX keyword is listed, followed by the various correlation pairs and the desired correlation values. Next, the OUTPUT keyword is listed, followed by its attendant keywords: CORR, HIST, and DATA. These keywords are used to instruct LHS as to which of three types of output are to be prepared and written to the database and one of the LHS output files. The last record in the PRELHS output transfer file is a repeat of the title record found at the beginning of the file.

The LHS input file is designed to be used without modification. Therefore, for the purposes of regulatory calculations, it will not be edited or otherwise modified in any way after it has been created by PRELHS.

5.2.1 Description of LHS keywords

The following is a description of LHS's input file entries. Each paragraph gives the entry name and a brief description of its function. Please note that some input keywords applicable to the LHS code are not used in regulatory calculations.

5.2.1.1 LHS keyword commands used in regulatory calculations

The following commands are used by LHS to set up the run or control its execution.

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TITLE

The TITLE record specifies the title for the LHS run. The record after TITLE may contain up to 100 alphanumeric characters. An example of usage of this keyword follows:

```
TITLE CMS TEST INPUT FILE FOR THE LHS CODE
```

NOBS

The NOBS record is used, with its associated parameter value, *no._obs*, to specify the number of vectors to be created for a sample (sample size [n_v]). An example of usage of this keyword follows:

```
NOBS    75
```

RANDOM SEED

THE RANDOM SEED record, along with its associated parameter value, *number*, is used to specify the starting point for the random number generator. An example of usage of this keyword follows:

```
RANDOM SEED     933090934
```

CORRELATION MATRIX

The CORRELATION MATRIX record, along with its associated parameter values, establishes the desired rank correlation among variables. If this parameter is omitted, all pairwise correlations will be assumed to be 0. The CORRELATION MATRIX record is followed by one or more lines containing the number of pairs to be rank correlated, *no._rank_corr*, followed by that many ordered triplets *no._rank_corr* specifying the number IDs of the two variables being correlated and their rank correlation. An example of usage of this keyword follows:

```
CORRELATION MATRIX
    4
    1       3      0.999
    2       5      0.950
    4       6      0.800
    5       2      0.950
```

EDIT

The EDIT record specifies a relationship *code* (must be "1"), the controlling variable number *cvar*, the restricted variable number *rvar*, and the output variable number *ovar* (if different from *rvar*).

After the sampled values are calculated, the values of the restricted variable are rescaled by assuming that the distribution of the restricted value is a uniform distribution with an upper bound that is the minimum of the upper bound assigned to the parameter in the Parameter Database and the sampled value of the controlling variable. If the restricted value exceeds the value

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of the controlling variable, the conditioned value of the restricted variable is computed using:

$$v_i' = \frac{v_i - U_{V,lower}}{U_{V,upper} - U_{V,lower}} \times \left(Min(x_i, U_{V,upper}) - U_{V,lower} \right) + U_{V,lower}$$

where v_i' is the conditioned value of the restricted variable, v_i is the sampled value of the restricted variable, x_i is the sampled value of the controlling variable, and $U_{V,lower}$ and $U_{V,upper}$ are the bounds of the uniform distribution assigned to the restricted variable. This method preserves the probability associated with the value of the restricted variable but will affect the rank-order correlations with the other variables.

The edited values are output as the sampled distribution values of the restricted variable. They are also used to calculate the rank sampled distribution outcomes and the raw and rank correlations for the sampled distributions.

For example, the following command would enforce the conditional relationship "*rvar* must be less than *cvar*" (*rvar* is modified), where *cvar*=41, *rvar*=42, and the final 42 (*ovar*) is optional:

```
EDIT   1   41   42   42
```

OUTPUT

The OUTPUT record, along with its associated parameter keywords CORR, HIST, and DATA, controls the amount and type of output generated. The parameter keywords are defined as follows:

CORR signifies that both the raw and rank correlation matrices of the sample will be printed out in tabular form.

HIST signifies that histograms and associated statistical information will be printed for each variable in the sample.

DATA signifies that the individual values of each sampled variable will be printed, followed by the ranks of each variable. For the regulatory calculation, this output control keyword must be specified in conjunction with the OUTPUT keyword.

Examples of usage of the OUTPUT keyword follow:

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```
OUTPUT CORR HIST DATA
OUTPUT CORR DATA
OUTPUT HIST DATA
```

5.2.1.2 LHS keyword commands *NOT* used in regulatory calculations

The following LHS execution commands may be included in the input file, as described previously. **However, these particular commands are not to be used for regulatory calculations.**

NREPS	The NREPS record specifies the number of repetitions of the sample (each with a sample size of *no._obs*. If not specified, NREPS defaults to 1).
RANDOM PAIRING	When present, the RANDOM PAIRING record specifies that sample values are to be paired randomly; otherwise, sample values are restrictively paired subject to any conditions under the CORRELATION MATRIX parameter. If both RANDOM PAIRING and CORRELATION MATRIX records appear, the former is ignored with a message to that effect printed after the correlation matrix.
RANDOM SAMPLE	When present, the RANDOM SAMPLE record specifies that a random sample is to be generated; otherwise, a Latin hypercube sample is generated.

5.2.2 Description of LHS Distribution Types

A description of the input for the different distribution types capable of being sampled by LHS is included here. Since all of the distribution information will be present on the LHS input file generated by PRELHS, the treatment of the distribution parameters is brief. The first 12 distribution types listed cover the types used for the certification calculation. The remaining seven entries will pertain to distribution types that can be processed by LHS but will not be used for the final certification calculation.

5.2.2.1 LHS Distribution Types Used in the Regulatory Calculation

NORMAL	The NORMAL record specifies a truncated normal distribution. An example of the distribution format follows:
	
	`NORMAL material_name parameter_name`
	`minimum maximum`

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LOGNORMAL

The LOGNORMAL record specifies a truncated LOGNORMAL distribution. An example of the distribution format follows:

```
LOGNORMAL        material_name     parameter_name
      minimum   maximum
```

UNIFORM

The UNIFORM record specifies a uniform distribution. An example of the distribution format follows:

```
UNIFORM          material_name     parameter_name
      minimum   maximum
```

LOGUNIFORM

The LOGUNIFORM record specifies a loguniform distribution. An example of the distribution format follows:

```
LOGUNIFORM       material_name     parameter_name
      minimum   maximum
```

USER DISTRIBUTION (CUMULATIVE)

The USER DISTRIBUTION (CUMULATIVE) record specifies a cumulative user supplied distribution. An example of the distribution format follows:

```
USER   DISTRIBUTION          (CUMULATIVE)   material_name
parameter_name
   nval          SPECIFIED          CONTINUOUS
   value1        probability1
   value2        probability2
      ...              ...
   valuenval     0.
```

USER DISTRIBUTION (DATA)

The USER DISTRIBUTION (DATA) record specifies a data user supplied distribution. An example of the distribution format follows:

```
USER   DISTRIBUTION        (DATA)            material_name
parameter_name
     nval          EQUAL              CONTINUOUS
     value1   value2  ...  valuenval
```

USER DISTRIBUTION (DELTA)

The USER DISTRIBUTION (DELTA) record specifies a delta user-supplied distribution. An example of the distribution format follows:

```
USER  DISTRIBUTION     (DELTA)          material_name
parameter_name
         nval          SPECIFIED        DISCRETE
         value1        probability1
         value2        probability2
         ...                ...
         valuenval     probabilitynval
```

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STUDENT — The STUDENT record specifies a truncated student-t distribution. An example of the distribution format follows:

```
STUDENT          material_name     parameter_name
      nval
      value1   value2  ...  valuenval
```

LOGSTUDENT — The LOGSTUDENT record specifies a truncated logstudent-t distribution. An example of the distribution format follows:

```
LOGSTUDENT       material_name     parameter_name
     nval
     value1   value2  ...  valuenval
```

TRIANGULAR — The TRIANGULAR record specifies a triangular distribution. An example of the distribution format follows:

```
TRIANGULAR       material_name     parameter_name
      minimum  apex  maximum
```

STUDENTMSD — The STUDENTMSD record specifies a truncated student-t distribution. An example of the distribution format follows:

```
STUDENTMSD          material_name     parameter_name
      ndegrees_freedom   mean   standard_error
```

LOGSTUDENTGGD — The LOGSTUDENTGGD record specifies a truncated logstudent-t distribution. An example of the distribution format follows:

```
LOGSTUDENTGGD       material_name     parameter_name
    ndegrees_freedom                          geometric_mean
geometric_standard_error
```

5.2.2.2 LHS Distribution Types *NOT* Used in the Regulatory Calculation

BETA — The BETA record specifies a beta distribution. An example of the distribution format follows:

```
BETA     material_name     parameter_name
    minimum  maximum  shape_p  shape_q
```

EXPONENTIAL — The EXPONENTIAL record specifies an exponential distribution. An example of the distribution format follows:

```
EXPONENTIAL      material_name     parameter_name
     minimum  maximum  lambda
```

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RAYLEIGH — The RAYLEIGH record specifies a Rayleigh distribution. An example of the distribution format follows:

```
RAYLEIGH          material_name     parameter_name
      minimum  maximum  lambda
```

RAYLEXP — The RAYLEXP record specifies a Rayleigh-exponential distribution. An example of the distribution format follows:

```
RAYLEXP           material_name     parameter_name
     minimum  crossover  maximum  lambda
```

UNIFORM* — The UNIFORM* record requests a uniform distribution with specific sampling frequencies on subintervals. An example of the distribution format follows:

```
UNIFORM*          material_name     parameter_name
     m  freq1 ... freqm  c1 ... cm+1
```

LOGUNIFORM* — The LOGUNIFORM* record requests a loguniform distribution with specific sampling frequency on subintervals. An example of the distribution format follows:

```
LOGUNIFORM*       material_name     parameter_name
      m  freq1 ... freqm  c1 ... cm+1
```

USER DISTRIBUTION (CUMHISTOGRAM) — The USER DISTRIBUTION (CUMHISTOGRAM) record specifies a cumhistogram user-supplied distribution. An example of the distribution format follows:

```
USER  DISTRIBUTION          (CUMHISTOGRAM)  material_name
parameter_name
      nval          SPECIFIED         DISCRETE
      value1        probability1
      value2        probability2
      ...                 ...
      valuenval     probabilitynval
```

5.2.3 Random Number Control File

The random number control file is a three-line ASCII file to control how random number generation is done within LHS (Figure 5.1). The first line of the file selects the random number generation source, with an integer entry of 1 for a input file stream, 2 for the intrinsic FORTRAN RAN function, and 3 for the LHS portable RAN3 function. If the random numbers are generated with the intrinsic RAN or portable RAN3 function, a stream of random numbers can be written out. If this stream is desired the second line of the control file should contain an integer entry of 1, otherwise the entry should be 0 (this entry should always be 0 if a input source stream file is

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used). The third line of the control file is the filename of the stream file, which is an input file to LHS if the random number generated was a source file (option 1 of first line) and is an output file otherwise.

Figure 5.1 Sample of 3-line random number control file

```
3                       # Source 1=FILE 2=RAN 3=RAN3
1                       # Store generated numbers? 0=NO 1=YES
ran_stream.txt          # Filename for storing
```

For LHS Version 3.00:

1) The random number control file is required to run LHS
2) The command line argument *-random* is optional
3) When the command line argument -random is not provided, the default random number control file is ran_cntrl.txt in the directory from where you launch LHS.
4) RAN3 is modified from Numerical Recipes, which is independent with the system and complier.

5.2.4 Random Number Stream File

LHS's random number stream file is a simple text file that contains a series of random numbers and a tag indicates the different generators. LHS Version 3.00 generates random numbers and writes these random numbers to the random number stream file. Or, when the random number stream file exists, LHS can read random numbers from the random number stream file. Below are five rows of one random number stream file:

```
0.34221098 p_rn
0.03193971 p_rn
0.51031246 p_rn
0.03187237 p_rn
0.70839708 p_rn
```

Tag p_rn means portable RAN3 function. Tag c_rn means FORTRAN intrinsic RAN function.

5.3 Description of LHS Output Data File

The format of the LHS output data file is described briefly below. Appendix B is a sample of LHS's output data file, lhs2_300_t3.dat. The sample file contains raw data for each of the 10 distributions, for each of the 75 outcome vectors.

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The header contains 7 records, as follows. The "!" character is used in the file as a comment.

1. Integer "1" representing the file type (do not change)
2. Title (full-line string) from the TITLE card
3. The analysis name (string), revision number (integer), and replicate (integer).
4. The run date and time (strings)
5. Integer random seed
6. Integer number of variables (N_V)
7. Integer number of observations (N)

Example of the header (with line number in file lhs2_300_t3.dat):

```
1    1    !file version
2 TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4    02/13/96 13:26:27
3 LHS245_T3       0       2    !Analysis name, revision, replicate
4 11/17/2021 08:05:42
5    933090934    !Random seed
6           10    !Number of variables
7           75    !Number of observations
```

The header is followed by the parameter descriptions, with one line for each of the N_V variables. Each line contains the variable number, the number of lines that follow (*nlins*), material, property, distribution type, and four distribution-specific floating-point values. The distribution-specific values are usually the values input for that distribution type. For example, minimum and maximum for a uniform distribution (the two final values are 0.0 for undefined). For the user supplied distributions, the first value is the number of points, the second value is 2 if probabilities are specified or 1 if not, and the third value is -1 for continuous or 1 for discrete. The following *nlins* lines list the values and probabilities, if appropriate. For the Student-type distributions, the distribution-specific values are the number of degrees of freedom, the mean, the standard error, and the standard deviation, if available. For LogStudent and LogStudentGGD, these are the logarithmic mean, etc. The following *nlins* lines list the input data points, for Student and LogStudent.

Example of parameter descriptions (with line number in file lhs2_300_t3.dat):

```
  8      1      0  GLOBAL    DISPPERC  NORMAL              5.00000000E-02  2.00000000E-01
0.00000000E+00  0.00000000E+00
```

and

```
 55      7     14  BOREHOLE  DIAMMOD   DELTA                          14.              2.
1.  0.00000000E+00
 56    5.08000000E-02  7.14300000E-02
 57    1.01600000E-01  7.14300000E-02
 58    1.52400000E-01  7.14300000E-02
```

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```
 59   1.93680000E-01  7.14300000E-02
 60   2.19080000E-01  7.14300000E-02
 61   2.28600000E-01  7.14300000E-02
 62   2.50830000E-01  7.14300000E-02
 63   2.79400000E-01  7.14300000E-02
 64   3.04800000E-01  7.14300000E-02
 65   3.49250000E-01  7.14300000E-02
 66   3.81000000E-01  7.14300000E-02
 67   4.44500000E-01  7.14300000E-02
 68   5.58800000E-01  7.14300000E-02
 69   6.09600000E-01  7.14400000E-02
```

The sampled data section is next. It lists the raw sampled values for each of the distributions over all the vector outcomes. For each vector it lists the vector number and N_V, then, starts from a new line, the sampled values for all variables for the vector. The sampled data are listed in the same order in which they were given in the LHS input file. There are about five sampled values per line, so there are multiple lines per vector.

Example of sampled data (with line number in file lhs2_300_t3.dat):

```
109      1    10
110          9.500259254406300E-02      1.833462417566156E+01      8.149024458160401E+00
3.500045610758840E-16  6.382973371028900E+00
111          2.026792339086531E-01      2.286000000000000E-01      2.595930688173129E-07
1.400753306213971E-02  9.200959445714469E-05
112      2    10
113          1.577137857840651E-01      2.054968669694798E+00      1.609475160865784E+00
1.301527353397215E-16  7.983987920045851E+00
114          2.179183440744863E-01      4.445000000000000E-01      8.276741951418272E-08
1.340362694975296E-02  1.103685645777620E-04
```

In the above example, the first outcome vector lists the value 9.500259254406300E-02 as the value associated with distribution 1. The value of the last (or 10th) sampled distribution for outcome vector 1 is 9.200959445714469E-05. This first distribution is a NORMAL distribution with lower and upper bounds of 5.000E-02 and 0.2000. The tenth distribution is a LOGSTUDENT distribution with lower and upper bounds of 9.550E-07 and 9.525E-03.

The rank correlation table appears next in the file. It starts with two comment lines, then one line for each variable. Each line lists the variable number, then its rank correlations with all preceding variables. For example, the line for variable 17 would list 16 correlations. This section ends with a comment line.

Example of rank correlation table (with line number in file lhs2_300_t3.dat):

```
334 !RANK correlation matrix
335 !       1       2       3       4       5       6       7       8       9      10
336     1  1.0000
337     2  0.0249  1.0000
338     3 -0.9991 -0.0231  1.0000
```

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```
339     4 -0.0478  0.0054  0.0468  1.0000
340     5 -0.0124 -0.9477  0.0108 -0.0232  1.0000
341     6 -0.0009 -0.0100  0.0053 -0.8032  0.0337  1.0000
342     7  0.0576  0.1072 -0.0578  0.0183 -0.1086 -0.0304  1.0000
343     8  0.0296 -0.0774 -0.0290  0.0096  0.0868  0.0048 -0.4666  1.0000
344     9 -0.0293  0.0053  0.0298  0.0341 -0.0144 -0.0239 -0.4819 -0.4549  1.0000
345    10 -0.0034 -0.0301  0.0048  0.0149  0.0431 -0.0327 -0.0128 -0.0103  0.0197  1.0000
346 !       1       2       3       4       5       6       7       8       9      10
```

5.4 Description of LHS Output Debug file

The LHS output debug/diagnostics file is an ASCII text file that contains descriptions of each parameter, the raw and rank sampled distribution outcomes, histogram plots of each sampled distribution, and the raw and rank correlation tables for the sampled distributions. Most of the output is optional and is controlled by the OUTPUT command in the input control file.

The format of the LHS output debug/diagnostics file is described briefly below. Appendix C contains a sample of LHS's output debug/diagnostics file, lhs2_300_t3.dbg. The sample file contains raw data for each of the 10 distributions, for each of the 75 outcome vectors.

Except the banner information (banner of code name, build date, authors, run date and platform), the first data block of LHS's output debug file contains an echoed listing of the LHS input file, rearranged somewhat to be more understandable to the user. Included in the "echoed input" section are the LHS execution keywords, input execution-parameter data specifications, a recapitulation of the input information for the various distributions sampled, and information concerning the correlation matrix.

The next data block of the output debug file is a group of tables showing resulting values over all outcomes for each of the distributions sampled. The table heading "RUN NO." identifies the outcome vector number, there being 1 - 75 in the case of the sample problem in Appendix C. The headers "X(1) X(2) X(3) ...X(10)" identify each of the 10 distributions sampled, with the sampled values listed under these headings on a vector by vector basis. For the example in Appendix C, there were 75 outcome vectors and 10 sampled distributions. Since an LHS sample table can contain up to 10 distributions, a single table is sufficient to present the entire sample. The table contains 75 outcome vectors, each containing sampled results for distributions 1 - 10.

Once the *raw data* table has been presented, a similar table is written for the ranks of the Latin-hypercube sample values. This table shows the rank of a given distribution's sampled value in comparison to all the other values for that particular distribution over the entire 75-outcome vector sample. For example, in sampled distribution number "X(1)", which is a normal distribution, outcome vector number 6 is ranked first. That means the actual sampled value for outcome vector number 6 of that distribution is the smallest of the entire 75-outcome sample (in this case it is -5.458E-02). At the other end of the spectrum, outcome vector number 69 is the largest value for

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that distribution (ranked 75th at a value of 1.904E-01). The minimum to maximum range for sample variable number 1 is 5.458E-02 ~ 1.904E-01. Correlations called for in LHS's input file are implemented on the basis of ranked data rather than raw data.

Since the OUTCOME keyword HIST was specified in the LHS input file (Appendix A), histogram density function plots, together with applicable statistical data, are presented for each of the 10 distributions generated in the example file given in Appendix C. A header at the top of each histogram identifies the distribution being displayed. The graphical plot gives a rough outline of the distribution shape and shows where the sampled values fall between the function's upper and lower bounds. For density, the distance between the function's bounds is subdivided into segments, and the sampled outcomes are allocated to their associated segment, depending on their value. Statistical data located directly beneath the histogram plots show the actual minimum and maximum values sampled for a given distribution, the mean and median values of the sampled distribution, and the associated variance. These statistical measures can assist users endeavoring to assure that a sampled distribution is correct.

The last data block found on the LHS output debug/diagnostics file listed in Appendix C gives correlation tables for the raw sampled data, including ranks. These tables give the correlations between each distribution and all of the other distributions present in the sample. Positive correlations indicate that high values in one variable correlate with high variables in the other. Negative correlations indicate that high values in one variable correlate with low values in the other. The user should assure the suitability of the correlations by inspecting the rank-correlation table and determining whether the correlations specified in the LHS input file were implemented. The user *should* scour the entire table for spurious correlations. To accomplish that, users must have prior knowledge of the distributions being generated and their interrelationships.

5.5 Allowable/Prescribed Ranges for Input and Output

LHS can sample 19 distribution types, although only 12 of those are contemplated for use in the WIPP PA certification calculations. The chosen 12 are: NORMAL, LOGNORMAL, UNIFORM, LOGUNIFORM, CUMULATIVE USER, DATA USER, DELTA USER, STUDENT, LOGSTUDENT, TRIANGULAR, STUDENTMSD and LOGSTUDENTGGD distributions. The other seven distribution types (which LHS can sample, but which are *not* contemplated for WIPP-PA certification calculations) are BETA, UNIFORM*, LOGUNIFORM*, HISTOGRAM USER, EXPONENTIAL, RAYLEIGH, and RAYLEXP.

For purposes of the WIPP PA certification calculations, sampled values for NORMAL and LOGNORMAL distributions are constrained to be no smaller than the smallest input value and no larger than the largest input value, even though those values represent 1st an 99th quantiles.

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STUDENT and LOGSTUDENT distributions are also constrained to the values representing the 1st and 99th quantiles.

At present, LHS is limited to the generation of 100 parameter distributions, 10,000 outcome vectors for a single sampling run, and 50 distribution correlations specified in the input file. These limits may be increased, but the code would need to be recompiled.

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6.0 REQUIRED USER TRAINING AND/OR BACKGROUND

To exercise LHS, users should have basic knowledge of the Linux operating system and, optionally, Python and Shell scripts. The users should have an overall understanding of the WIPP PA results database, which is used in virtually every WIPP code set (Rechard, 1992; Rechard et al. 1993). In addition, the users should have access to the WIPP cluster of Dell PowerEdge C6420 with CentOS 7 or their equivalent.

To manipulate and/or interpret the results of LHS, users should have (1) a basic understanding of introductory probability theory, and especially sampling theory and probability distribution functions, (2) a fairly complete, if basic, overview understanding of the WIPP PA process, and especially of, the uncertain physical parameters that are used, the data distributions they lead to, how distributions for different physical parameters are either related or not related, the rational basis of uncertainty sampling methods, and the use of input-data vectors in WIPP PAs (WIPP PA, 1992a-e), and (3) an operational familiarity with and general understanding of LHS's preprocessor code, PRELHS (Feng, 2021c).

7.0 CAPABILITIES AND LIMITATIONS

To execute, LHS reads the ASCII text output transfer file exactly as it was produced by PRELHS (see the User's Manual for PRELHS, Feng, 2021c). Contained in that file are input records describing the various types of distributions to be generated and keywords used to control the run, including, for example: TITLE, NOBS, RANDOM SEED, and OUTPUT.

LHS is capable of generating a correlation matrix of sampled distribution data as directed by input from PRELHS's ASCII text transfer file. Specific keywords that can be read and acted upon by LHS, but will not be used for the certification calculation, are: NREPS, RANDOM PAIRING, and RANDOM SAMPLE.

LHS produces three ASCII output files during each run. (i) The ASCII output date file; (ii) The output diagnostics/debug file; and (iii) The random number stream file (optional; existing random number stream file can be used as an input file; see Sections 5.2.3 and 5.2.4 for details).

The diagnostics/debug file contains echoed input file information, the raw values for the sampled distribution outcomes in tabular format for each distribution type, and tables of rank values for the sampled distribution outcomes. Depending on the keywords provided, additional output tables may be present showing raw and rank correlation tables for the sampled distributions, and

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histogram plots of each sampled distribution. Included with the distribution histograms is a listing of statistical information applicable to the distribution portrayed in the plot.

At present, LHS is limited to the generation of 100 parameter distributions, 10,000 outcome vectors for a single sampling run, and 50 distribution correlations specified in the input file. These limits may be increased, but the code would have to be recompiled.

8.0 USER INTERACTIONS WITH THE SOFTWARE

LHS Version 3.00 executes on a Linux platform. To execute LHS, the executable name (*lhs*) must be in the user's current PATH or referenced by its path name.

LHS expects a number of command line arguments. The program arguments may either be positional (provided in order) or flagged (preceded by the appropriate flag). Flags always start with "–"; they may be abbreviated. All positional arguments must be listed before any flagged arguments. The only difference between using positional and flagged arguments is that optional arguments may be omitted for flagged arguments.

Interactive users may request that the program prompt for any missing command line arguments by appending "?" to the command line.

LHS expects the following command line arguments. LHS Version 3.00 writes its results to a database for post-processing.

–input	The input transfer file from PRELHS.
–output	The output data file. This file contains descriptions of each parameter, the values of the sampled parameters of which the Latin hypercube sample consists, and the rank correlation matrix. See Section 5.3 of this document for more information on this file.
–debug	The output diagnostics file. This file may contain descriptions of each parameter, the raw and rank sampled distribution outcomes, histogram plots of each sampled distribution, and the raw and rank correlation tables for the sampled distributions. See Section 5.4 of this document for more information on this file.
–analysis	The analysis name for the database.

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–revision	The analysis revision for the database. It defaults to 0.
–replicate	The replicate number for the database.
–database	The database type or name. Regulatory calculations should request "PROD" to use database PA_Results. For informal runs, "TEST" requests the test database PA_Results_test, PA_Results_xxx for a PA user's database or "NONE" requests no database output. See Section 5.1.3 of this manual for more information on the database.
-random	The random number control file. It defaults to ./ran_cntrl.txt.

9.0 ERROR MESSAGES

Detailed error detection is implemented in LHS through an assortment of error-checking subroutines. Errors detected during execution result in the generation of corresponding error messages written to the diagnostics/debug file. If the code regards the error as serious, and that is generally the case, the run will abort after an error message has been written.

LHS's error messages are numerous and specific in nature. In most cases, the error message describes the subroutine where the error occurred, and is accompanied by text describing the error. Often that is sufficient to track the problem down, especially if a "debug" version of the code is available. "Debug" versions of LHS allow interaction with the code during its execution and facilitate tracking down errors. However, the user should always perform a detailed visual inspection of the entire debug file to assure (i) the output looks as it should and (ii) that no error messages have appeared.

LHS error messages fall into several categories. Numerous error messages are devoted to improperly specified input data records. All of the execution keywords, problem size specifications, and distribution input data are checked for proper form. LHS is unable to determine whether a particular data distribution accurately reflects the physical information it is supposed to portray in the real world, but it is quite able to determine whether that information is entered in a syntactically correct way. LHS easily detects errors such as the maximum range being smaller than the minimum range for a given distribution.

Once the input file information has been successfully read, LHS checks to see if parameters set in the input file (such as the number of distributions to be sampled, the number of outcome vectors to be generated, and the number of distribution parameter correlations specified) exceed the limits

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imposed by maximum-value parameters specified internally. LHS also checks to see that at least a minimum number of distributions and sample outcome vectors have been specified.

As the code creates the sample for the various distributions, error checks are invoked that are internal to the subroutines used to calculate the distributions. This type of error checking is most prevalent in the generation of BETA distributions, distributions that will not be used in regulatory calculations. Lastly, LHS utilizes numerous error-checking routines to assure that the correlation table calculated during a run meets the mathematical tests it must pass to be deemed acceptable.

The error messages are listed below. This list is not comprehensive, but it contains the most common error messages associated with the input data records. Most of these error messages are proceeded by "*ERROR*". The input distribution information or the input card that contains the error is usually listed directly above or below the error. This information and the error message should be sufficient to allow the user to identify and fix the input error.

ADDNEWVAR subroutine:

The number of variables requested exceeds the maximum allowed = *num*
Invalid distribution type *distr*

CHKDIM subroutine:

The *parameter* = *num* is zero or invalid
The *parameter* = *num* exceeds maximum= *num*

RDPAR subroutine:

No VARIABLES have been specified
The following distribution did not have the correct parameter data card
The number of *parameter* requested= *num* exceeds maximum= *num*
The *parameter* requested is zero or invalid
Distribution parameters ABOVE violate *condition* where A= *value* B= *value* ...
LOG Distribution parameters ABOVE should be > 0.0
Number of observations requested for distribution ABOVE = *num* does not match NOBS= *num*

SCANPAR subroutine:

The number of *parameter* requested= *num* exceeds maximum= *num*
Invalid option *text* requested
The number of OBSERVATIONS has not been specified or is invalid
The number of REPETITIONS is invalid
RANDOM SEED has not been specified

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10.0 REFERENCES

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11.0 APPENDIX A: EXAMPLE OF LHS INPUT CONTROL FILE

Listed below is an example LHS input control file, as produced by PRELHS, and described in detail in Section 5.2.

```
TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
TITLE CMS Test Input File for the LHS Code
NOBS                75
RANDOM SEED    933090934
NORMAL                  GLOBAL    DISPPERC
    5.00000E-02    2.00000E-01
LOGNORMAL               COLLOID   CONC
    1.00000E-02    1.00000E+02
UNIFORM                 WAS_AREA  TAUFAIL
    4.80000E-02    9.60000E+00
LOGUNIFORM              WAS_AREA  SPPERM
    1.00000E-17    1.00000E-12
USER DISTRIBUTION  (CUMULATIVE)       BOREHOLE  DOMEGA
        20          SPECIFIED    CONTINUOUS
    4.20000E+00   0.00000
    4.20000E+00   0.15000
    6.30000E+00   0.00000
    6.30000E+00   0.50000
    8.40000E+00   0.00000
    8.40000E+00   0.15000
    1.05000E+01   0.00000
    1.05000E+01   0.10000
    1.26000E+01   0.00000
    1.26000E+01   0.05000
    1.47000E+01   0.00000
    1.47000E+01   0.02000
    1.68000E+01   0.00000
    1.68000E+01   0.01000
    1.88000E+01   0.00000
    1.88000E+01   0.01000
    2.09000E+01   0.00000
    2.09000E+01   0.01000
    2.30000E+01   0.00000
    2.30000E+01   0.00000
USER DISTRIBUTION  (DATA)          CULEBRA   POROSITY
        21          EQUAL        CONTINUOUS
  5.80563E-02  9.55000E-02  1.03330E-01  1.07400E-01  1.15000E-01  1.20500E-01
  1.22250E-01  1.23500E-01  1.29000E-01  1.38500E-01  1.44330E-01  1.46500E-01
  1.61600E-01  1.61800E-01  1.65170E-01  1.78000E-01  1.78400E-01  1.79600E-01
  2.02500E-01  2.07750E-01  2.52500E-01
USER DISTRIBUTION  (DELTA)           BOREHOLE  DIAMMOD
        14          SPECIFIED    DISCRETE
    5.08000E-02   0.07143
    1.01600E-01   0.07143
    1.52400E-01   0.07143
    1.93680E-01   0.07143
    2.19080E-01   0.07143
```

Information Only

```
    2.28600E-01    0.07143
    2.50830E-01    0.07143
    2.79400E-01    0.07143
    3.04800E-01    0.07143
    3.49250E-01    0.07143
    3.81000E-01    0.07143
    4.44500E-01    0.07143
    5.58800E-01    0.07143
    6.09600E-01    0.07144
TRIANGULAR              WAS_AREA   GRATCORI
    0.00000E+00     3.20000E-09    6.40000E-07
STUDENT                 S_MB139    POROSITY
        16
  4.00000E-03  5.00000E-03  5.00000E-03  8.00000E-03  1.00000E-02  1.10000E-02
  1.30000E-02  1.30000E-02  1.60000E-02  1.60000E-02  1.60000E-02  1.70000E-02
  1.80000E-02  1.90000E-02  2.10000E-02  2.70000E-02
LOGSTUDENT              STULMAT1   STULPRP1
        20
  9.55000E-07  1.03330E-06  1.57400E-06  2.15000E-06  4.20500E-06  8.22250E-06
  2.23500E-05  4.29000E-05  7.38500E-05  9.44330E-05  1.46500E-04  3.61600E-04
  5.61800E-04  7.65170E-04  9.78000E-04  1.78400E-03  2.79600E-03  5.02500E-03
  7.07750E-03  9.52500E-03
CORRELATION MATRIX
    7
    1    3 -0.999
    2    5 -0.950
    4    6 -0.800
    5    2 -0.950
    7    8 -0.650
    7    9 -0.650
    8    9 -0.650
OUTPUT CORR HIST DATA
TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
```

12.0 APPENDIX B: EXAMPLE OF LHS OUTPUT DATA FILE

```
   1    !file version
TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
LHS300_T3       0       2    !Analysis name, revision, replicate
11/17/2021 08:05:42
```

Information Only

```
   933090934     !Random seed
          10     !Number of variables
          75     !Number of observations
     1      0   GLOBAL     DISPPERC   NORMAL              5.00000000E-02  2.00000000E-01
0.00000000E+00  0.00000000E+00
     2      0   COLLOID    CONC       LOGNORMAL           1.00000000E-02  1.00000000E+02
0.00000000E+00  0.00000000E+00
     3      0   WAS_AREA   TAUFAIL    UNIFORM             4.80000000E-02  9.60000000E+00
0.00000000E+00  0.00000000E+00
     4      0   WAS_AREA   SPPERM     LOGUNIFORM          1.00000000E-17  1.00000000E-12
0.00000000E+00  0.00000000E+00
     5     20   BOREHOLE   DOMEGA     CUMULATIVE                    20.               2.
-1.  0.00000000E+00
  4.20000000E+00  0.00000000E+00
  4.20000000E+00  1.50000000E-01
  6.30000000E+00  0.00000000E+00
  6.30000000E+00  5.00000000E-01
  8.40000000E+00  0.00000000E+00
  8.40000000E+00  1.50000000E-01
  1.05000000E+01  0.00000000E+00
  1.05000000E+01  1.00000000E-01
  1.26000000E+01  0.00000000E+00
  1.26000000E+01  5.00000000E-02
  1.47000000E+01  0.00000000E+00
  1.47000000E+01  2.00000000E-02
  1.68000000E+01  0.00000000E+00
  1.68000000E+01  1.00000000E-02
  1.88000000E+01  0.00000000E+00
  1.88000000E+01  1.00000000E-02
  2.09000000E+01  0.00000000E+00
  2.09000000E+01  1.00000000E-02
  2.30000000E+01  0.00000000E+00
  2.30000000E+01  0.00000000E+00
     6     21   CULEBRA    POROSITY   DATA                  21.               1.
-1.  0.00000000E+00
  5.80563000E-02
  9.55000000E-02
  1.03330000E-01
  1.07400000E-01
  1.15000000E-01
  1.20500000E-01
  1.22250000E-01
  1.23500000E-01
  1.29000000E-01
  1.38500000E-01
  1.44330000E-01
  1.46500000E-01
  1.61600000E-01
  1.61800000E-01
  1.65170000E-01
  1.78000000E-01
  1.78400000E-01
  1.79600000E-01
  2.02500000E-01
  2.07750000E-01
  2.52500000E-01
     7     14   BOREHOLE   DIAMMOD    DELTA                 14.               2.
1.  0.00000000E+00
  5.08000000E-02  7.14300000E-02
  1.01600000E-01  7.14300000E-02
  1.52400000E-01  7.14300000E-02
```

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```
  1.93680000E-01  7.14300000E-02
  2.19080000E-01  7.14300000E-02
  2.28600000E-01  7.14300000E-02
  2.50830000E-01  7.14300000E-02
  2.79400000E-01  7.14300000E-02
  3.04800000E-01  7.14300000E-02
  3.49250000E-01  7.14300000E-02
  3.81000000E-01  7.14300000E-02
  4.44500000E-01  7.14300000E-02
  5.58800000E-01  7.14300000E-02
  6.09600000E-01  7.14400000E-02
     8      0   WAS_AREA   GRATCORI   TRIANGULAR          0.00000000E+00   3.20000000E-09
6.40000000E-07  0.00000000E+00
     9     16   S_MB139    POROSITY   STUDENT                        15.   1.36875000E-02
1.58566167E-03  6.34264666E-03
  4.00000000E-03
  5.00000000E-03
  5.00000000E-03
  8.00000000E-03
  1.00000000E-02
  1.10000000E-02
  1.30000000E-02
  1.30000000E-02
  1.60000000E-02
  1.60000000E-02
  1.60000000E-02
  1.70000000E-02
  1.80000000E-02
  1.90000000E-02
  2.10000000E-02
  2.70000000E-02
    10     20   STULMAT1   STULPRP1   LOGSTUDENT                     19. -9.15701141E+00
6.91232871E-01  3.09128737E+00
 -1.38615545E+01
 -1.37827530E+01
 -1.33618904E+01
 -1.30500427E+01
 -1.23792363E+01
 -1.17086363E+01
 -1.07086842E+01
 -1.00566387E+01
 -9.51347455E+00
 -9.26761997E+00
 -8.82848513E+00
 -7.92497193E+00
 -7.48436464E+00
 -7.17541253E+00
 -6.93000089E+00
 -6.32889724E+00
 -5.87956545E+00
 -5.29332983E+00
 -4.95083454E+00
 -4.65383536E+00
     1    10
  9.500259254406300E-02          1.833462417566156E+01          8.149024458160401E+00
3.500045610758840E-16  6.382973371028900E+00
  2.026792339086531E-01          2.286000000000000E-01          2.595930688173129E-07
1.400753306213971E-02  9.200959445714469E-05
     2    10
  1.577137857840651E-01          2.054968669694798E+00          1.609475160865784E+00
1.301527353397215E-16  7.983987920045851E+00
```

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```
  2.179183440744863E-01           4.445000000000000E-01           8.276741951418272E-08
1.340362694975296E-02  1.103685645777620E-04
     3    10
  6.957847212170133E-02           3.463398409625599E+00           9.232903134722710E+00
7.916380432060293E-14  5.941572175820669E+00
  1.446198091634076E-01           3.492500000000000E-01           5.790454210832484E-07
1.031622233174444E-02  6.147058028568506E-05
     4    10
  1.068306231282150E-01           3.901298889846980E-02           6.920956252403259E+00
8.263752085871514E-16  1.730940481821668E+01
  1.617506960741679E-01           6.096000000000000E-01           2.273112087144309E-08
1.325063277747902E-02  2.917698299173254E-05
     5    10
  1.612978691934403E-01           1.511450135335808E+00           1.131908213157654E+00
6.634006631553939E-14  7.530740042090414E+00
  1.213745002945264E-01           5.588000000000000E-01           1.085085372525259E-07
1.185987946385247E-02  4.894526386721092E-05
     6    10
  5.458080894418260E-02           7.649484257631214E-02           9.576991171569825E+00
3.095035597253103E-14  1.209509083032606E+01
  1.223506022890409E-01           6.096000000000000E-01           9.257374671872421E-08
1.160705322297247E-02  1.547010368721344E-04
     7    10
  1.346753839842474E-01           1.667410632485043E-01           3.491282317957878E+00
3.256837664469179E-16  1.086490128397939E+01
  1.400822021767298E-01           2.190800000000000E-01           3.108267123536646E-08
1.698512373218876E-02  1.449077825670657E-04
     8    10
  1.035376306500530E-01           8.184292740368122E+00           7.214806480426788E+00
1.775440223877032E-14  6.446658516883850E+00
  1.277860183139642E-01           5.080000000000000E-02           1.267432522067796E-07
1.649158595548850E-02  8.462745085872405E-05
     9    10
  1.554993927951053E-01           2.746472258138257E+00           1.487406829757691E+00
7.380771855955414E-17  7.345477713584899E+00
  1.975582950369511E-01           3.492500000000000E-01           2.213367364413485E-07
1.310603376130676E-02  1.865465004539919E-04
    10    10
  1.843481036228658E-01           6.994231159451106E-01           1.999301639652252E-01
1.215331990988930E-14  9.248932219346353E+00
  1.630311056452194E-01           1.936800000000000E-01           4.295729128908109E-07
1.264748445966444E-02  7.101638119085061E-05
    11    10
  1.706463652200956E-01           3.500729803503642E-01           7.871652632522583E-01
7.605709584800258E-13  8.162591876029966E+00
  1.043460623092651E-01           4.445000000000000E-01           1.142669089736872E-07
1.282419440751898E-02  1.786108803739772E-04
    12    10
  1.317619256939080E-01           1.110626224216331E+00           4.077339009857178E+00
7.157107429656271E-15  7.361610182285308E+00
  1.616936854998271E-01           1.524000000000000E-01           5.634039661766912E-07
1.300715429644939E-02  4.297673091802182E-05
    13    10
  1.358126360722833E-01           2.179700871201038E-02           3.736169146308899E+00
2.879046622338684E-14  1.249747928321359E+01
  1.180791251887878E-01           1.936800000000000E-01           4.514964509108484E-07
1.177444208586117E-02  1.338912102724001E-04
    14    10
  1.252315953386917E-01           9.238874979561018E-01           4.967820155220032E+00
5.643980742937717E-15  7.767633240222930E+00
```

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  1.461362253678639E-01           1.016000000000000E-01           1.212805365703705E-07
1.595553629712816E-02  2.958390381003707E-04
    15    10
  1.277001911064829E-01           8.188898261472903E-01           4.527380439319611E+00
1.017964478730378E-14  9.905846948623644E+00
  9.009721109934529E-02           3.492500000000000E-01           2.473356229058495E-07
1.226880573842089E-02  2.364943859857206E-04
    16    10
  8.376466882583683E-02           2.784168178285288E-01           8.738841168041230E+00
1.401383068895218E-17  1.023563510417937E+01
  1.915097736295059E-01           1.524000000000000E-01           3.485328928088422E-07
1.392840365531641E-02  6.474255623096095E-05
    17    10
  1.087419864995996E-01           1.035035712982397E-01           6.537747433891297E+00
1.384368355262359E-14  1.537440595626817E+01
  1.234150370756785E-01           3.048000000000000E-01           2.375360370899728E-07
1.314516661670974E-02  6.065815264244895E-05
    18    10
  1.427566364545217E-01           2.703667211036532E+01           2.803330987892151E+00
2.405768656448214E-17  4.477688387235006E+00
  2.044642329573630E-01           1.016000000000000E-01           3.258373692088565E-07
1.458514264519565E-02  2.528928702374962E-04
    19    10
  1.378194575382964E-01           2.118359893304111E+01           3.358193862915039E+00
9.816186455531516E-13  4.921177264849345E+00
  7.373346579290867E-02           3.048000000000000E-01           1.936239512024595E-07
1.367279614345391E-02  1.184630261248901E-04
    20    10
  1.399312582381632E-01           4.816689767804520E-02           3.044831141510010E+00
5.854763077677858E-17  1.308066642522807E+01
  2.073361208677290E-01           2.794000000000000E-01           1.778897281659109E-08
1.619936337669669E-02  4.231730906248038E-05
    21    10
  1.666519195569210E-01           6.639473865352934E+00           8.947214595413208E-01
1.872578067092328E-14  6.817565620899201E+00
  1.050576515805920E-01           2.794000000000000E-01           3.289173934941466E-07
1.215187386492423E-02  7.979746916516926E-05
    22    10
  9.942838685039646E-02           5.627389049999622E-01           7.486638279724120E+00
4.038362930252351E-17  9.170048398971547E+00
  1.792546379280090E-01           5.080000000000000E-02           3.924137835944076E-07
1.412607433405639E-02  1.082160385367472E-04
    23    10
  9.141468938499969E-02           4.869680430712842E+01           8.317382136878967E+00
4.706353234807414E-15  5.164572761058808E+00
  9.980406903028488E-02           1.016000000000000E-01           2.817127097913842E-07
1.511249311283288E-02  1.895822094558097E-04
    24    10
  1.790710197705789E-01           5.145362584475019E-01           4.176975517272949E-01
2.910021376174972E-15  8.630275909105926E+00
  1.225194344023863E-01           2.508300000000000E-01           1.767965949992411E-07
1.423647372810614E-02  8.311754005536264E-05
    25    10
  1.333649847815049E-01           2.256029124129779E+00           3.884863203191757E+00
1.123805156489536E-13  7.705035841226576E+00
  1.351790127078692E-01           2.190800000000000E-01           2.038330331769824E-07
1.461835675045660E-02  2.422217047602818E-05
    26    10
  9.658697575789207E-02           2.894292032384719E+00           7.960209192819596E+00
7.165227527516459E-13  6.870938651561737E+00
```

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  1.228703417479992E-01           2.508300000000000E-01           1.581740263494739E-07
1.431120022242432E-02  3.282418364355798E-05
    27    10
  1.300817587343149E-01           4.133936044530964E+00           4.371963776664734E+00
2.157916014953623E-13  6.739146442472935E+00
  8.108283557572524E-02           4.445000000000000E-01           2.281096259844060E-07
1.192063284621572E-02  1.274011836074605E-04
    28    10
  1.027371180207744E-01           3.048754089165049E-01           7.428773775062561E+00
1.660528511361716E-16  8.783113029797862E+00
  1.753601351657706E-01           3.048000000000000E-01           2.713072083638026E-07
1.297448561974356E-02  2.157709437476081E-04
    29    10
  6.095363192188574E-02           3.960221806895650E-01           9.427754251289368E+00
2.391701783782990E-15  8.371522817015645E+00
  1.114600163427989E-01           2.508300000000000E-01           1.347728502572142E-07
1.447807847521332E-02  8.202546470561660E-05
    30    10
  1.154891937362676E-01           1.050274902657357E+00           5.942978186511993E+00
1.259644235835264E-13  7.645085570573805E+00
  1.070245894759496E-01           1.524000000000000E-01           5.302376489659155E-08
1.647969364243078E-02  3.749314065468203E-05
    31    10
  8.630047854383330E-02           1.782414219656909E+00           8.576326886291504E+00
4.373202602670938E-13  6.502920435428619E+00
  1.141547526868184E-01           3.048000000000000E-01           2.753916595458748E-07
1.276197886383964E-02  1.050379614193607E-04
    32    10
  1.623523774716383E-01           4.304759611158256E-01           1.217889590454102E+00
5.484953146162247E-16  8.071537722587584E+00
  1.242795245647430E-01           5.080000000000000E-02           3.383711499522091E-07
1.525571409696367E-02  1.923442239634600E-05
    33    10
  1.324072199819734E-01           8.950545631955696E-01           3.856082785301208E+00
1.675456434996758E-17  7.831841956138609E+00
  1.775928265543379E-01           4.445000000000000E-01           6.238287665897761E-08
1.380389103229650E-02  4.522168532951905E-05
    34    10
  1.387999199215709E-01           1.342689045499697E+00           3.224626393508911E+00
3.813490161195979E-17  7.042366470336914E+00
  2.093075360119329E-01           1.936800000000000E-01           6.682743210736664E-08
1.554396702157713E-02  1.001003492203097E-04
    35    10
  1.476303039723672E-01           2.443066300161172E-01           2.292613297424317E+00
5.932006803391417E-13  1.040984282970427E+01
  1.006756189658642E-01           2.190800000000000E-01           1.844644478644502E-07
1.474181357361321E-02  1.992885394228212E-04
    36    10
  1.234632684991001E-01           3.686878834779887E+00           4.759897167510986E+00
3.378328752138224E-15  6.310808681964874E+00
  1.456644284736315E-01           6.096000000000000E-01           8.789301127231410E-08
1.138791890366132E-02  1.399141154158508E-04
    37    10
  1.295680090191933E-01           7.343199081736342E+00           4.240803681640625E+00
4.167194098034226E-14  5.093461403846741E+00
  1.071554724481006E-01           1.524000000000000E-01           3.057530197976138E-07
1.414446980532439E-02  7.333146755938439E-05
    38    10
  1.195071279140705E-01           3.393587082325496E-01           5.728921542892456E+00
3.225734201870089E-17  9.505405896504708E+00
```

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  1.699958253000575E-01           5.080000000000000E-02           4.525916959848831E-08
1.721390752400591E-02  1.374086482833334E-04
    39    10
  1.532683474267568E-01           2.085966431759214E-01           1.811122714729309E+00
1.761898567704331E-13  1.073167993545530E+01
  1.090424076728026E-01           1.524000000000000E-01           3.591433997659661E-07
1.433023677657968E-02  4.820353523369200E-04
    40    10
  1.098150263915075E-01           6.022255361448179E+01           6.546347776973247E+00
1.083375356789081E-15  4.343165804545085E+00
  1.839996052304898E-01           3.810000000000000E-01           9.356214134023591E-08
1.358389295924947E-02  1.479874252877615E-04
    41    10
  1.597225801685994E-01           5.529454957812162E+00           1.439896490707398E+00
1.450191622088286E-15  6.588664183616638E+00
  1.783260193061829E-01           2.286000000000000E-01           5.919281561945201E-08
1.542420668222833E-02  1.680784965415149E-04
    42    10
  8.841627107922008E-02           8.807114077264229E+00           8.449122878837585E+00
3.789314765479865E-15  6.070020279735327E+00
  1.167689043362935E-01           2.794000000000000E-01           1.032517469292712E-07
1.471045981682460E-02  2.065534868778827E-04
    43    10
  1.510789038513422E-01           9.726796896564790E-01           2.001934278907776E+00
2.860926767113274E-16  7.858436601459978E+00
  1.444189941452344E-01           2.286000000000000E-01           3.668529105504280E-07
1.263282422928450E-02  2.254508172006764E-04
    44    10
  1.162415849068455E-01           1.174963109796474E+01           5.649349577369691E+00
8.667294896503013E-14  5.822022382418314E+00
  1.508646222225823E-01           1.936800000000000E-01           7.517858745974870E-08
1.564347549539508E-02  5.822793241592132E-05
    45    10
  1.440249524215666E-01           2.434515306145649E+00           2.611742446241379E+00
4.297869069428031E-16  6.565385600090027E+00
  1.206996429413557E-01           3.810000000000000E-01           2.455583329935905E-08
1.497223377152874E-02  4.921349044338026E-05
    46    10
  7.778410516545359E-02           4.515737084767415E+00           8.970316091921330E+00
2.116442554827593E-15  6.632220318198204E+00
  1.371219543218612E-01           3.048000000000000E-01           3.372506416523216E-08
1.535881487491795E-02  9.444802082703713E-05
    47    10
  1.221365094430791E-01           8.103939862345191E-02           5.175067453575134E+00
2.499685289928783E-14  1.151085057258604E+01
  1.273094325939814E-01           5.080000000000000E-02           4.977636296953715E-07
1.486263836826914E-02  1.295800593632085E-04
    48    10
  1.775981118623112E-01           3.062482029350194E-02           4.425571149253845E-01
8.696565022858087E-16  1.768745419184340E+01
  1.648048594930370E-01           5.588000000000000E-01           1.597257043136438E-09
1.568060423770617E-02  1.644410249351697E-04
    49    10
  9.719512949263402E-02           1.329407772151730E+01           7.592650389690399E+00
5.360619847732038E-13  4.598456797202428E+00
  9.684496109485627E-02           3.492500000000000E-01           3.981578618638453E-08
1.505397819654666E-02  1.531812243353112E-04
    50    10
  1.062822652767366E-01           1.174854222094707E-01           6.946887193040848E+00
3.830024319083109E-13  1.450479449748988E+01
```

Information Only

```
  5.954949440596302E-02           3.810000000000000E-01           1.055633482125659E-07
1.373624412803790E-02  6.691664551207289E-05
    51    10
  1.204615524049941E-01           7.749565795235740E-01           5.440359943466187E+00
9.591036705375732E-17  8.339687945365903E+00
  1.789039849662780E-01           2.190800000000000E-01           4.147531470605748E-07
1.208231827318284E-02  3.359993639143672E-04
    52    10
  1.233727088968489E-01           5.766364664536664E-01           5.130083754997253E+00
1.257568344856834E-17  7.291378668308258E+00
  2.412573874182985E-01           1.016000000000000E-01           4.029208543226448E-07
1.388522568218313E-02  7.030072295506368E-05
    53    10
  1.468460931570627E-01           1.190751768209571E+00           2.171712743110657E+00
2.072958459341377E-17  7.589662648200988E+00
  1.640625085628032E-01           3.048000000000000E-01           3.744717700286596E-07
1.102180981970851E-02  3.577528291599396E-04
    54    10
  1.420071646499597E-01           4.741792582613802E+00           2.870698489532471E+00
2.685034145915706E-17  7.105188886165618E+00
  1.780906753277778E-01           3.492500000000000E-01           3.128466028808774E-07
1.148671603488228E-02  1.038349992077599E-04
    55    10
  1.181637268008500E-01           6.037697790888866E-02           5.392693611869812E+00
1.848647723292878E-13  1.361270074844355E+01
  1.035162061149279E-01           1.524000000000000E-01           4.647890282012216E-07
1.247313183072786E-02  5.604443758209771E-05
    56    10
  1.449687038016549E-01           1.536736016508157E-02           2.398631567687988E+00
3.719547540363576E-14  2.101062678098649E+01
  1.332335380951563E-01           3.492500000000000E-01           1.885661427609229E-07
1.352286330333436E-02  7.755961747682277E-05
    57    10
  1.258802245055774E-01           2.545261601173134E+00           4.863026823844910E+00
6.620735071444187E-17  7.007320658206940E+00
  1.782337277094523E-01           5.588000000000000E-01           7.097246511781032E-08
1.320646438140125E-02  8.879101337680908E-05
    58    10
  1.267342469125002E-01           1.396165311264233E-01           4.466318831405640E+00
4.848641357339605E-17  1.010932332356770E+01
  1.784175030481815E-01           2.286000000000000E-01           1.658425966643345E-07
1.437172605086354E-02  5.352447906653529E-05
    59    10
  1.173279418575061E-01           1.317069845560460E+00           5.872417468338013E+00
2.104560751737857E-16  8.250906151592730E+00
  1.795616433143616E-01           2.508300000000000E-01           2.500342027672841E-07
1.362300984981698E-02  9.735278258385232E-05
    60    10
  1.136354428472447E-01           4.359448485903403E-01           6.225790156059265E+00
2.382571864266483E-16  8.111477515220640E+00
  2.403595455884920E-01           2.286000000000000E-01           2.927918812612538E-07
1.345436959055422E-02  1.120465921289377E-04
    61    10
  7.989981173588477E-02           1.968162062802861E-01           8.877301557083129E+00
1.016471483626056E-17  8.883970528443644E+00
  2.049729184150694E-01           6.096000000000000E-01           1.370935019185435E-08
1.239958921935413E-02  2.463347564856782E-04
    62    10
  1.372091076295474E-01           2.191483321815764E-01           3.408559494113922E+00
8.944723428710179E-15  1.189277690410612E+01
```

Information Only

```
  1.552876938422520E-01           2.508300000000000E-01           2.304987018853880E-07
1.386286450813377E-02  4.453505451276520E-04
    63    10
  1.489266733049232E-01           6.333713717269708E-01           2.566578613052368E+00
8.266554532950502E-15  7.442655024528502E+00
  1.589837699596086E-01           4.445000000000000E-01           4.887111953402860E-07
1.007158215148246E-02  6.541074273976165E-05
    64    10
  1.520177383346520E-01           1.654624861891482E+00           1.838359026844502E+00
1.573021155636031E-13  6.681719311594963E+00
  1.160427635828654E-01           5.588000000000000E-01           6.362268976158124E-09
1.454592645457535E-02  1.578623963200801E-04
    65    10
  1.140125572349607E-01           2.674440911307204E-01           6.043353991589546E+00
7.038364493615560E-16  8.221650360584256E+00
  1.431743209745089E-01           1.936800000000000E-01           5.231840394704534E-07
1.125791640167147E-02  7.522000082186597E-05
    66    10
  8.607166525156362E-02           1.199015109920395E-01           8.616765583496093E+00
1.238612262724458E-15  1.233635479688642E+01
  1.623062036259968E-01           1.936800000000000E-01           4.333585424727298E-07
1.249920851580250E-02  1.222829954851165E-04
    67    10
  1.106011841605194E-01           6.582435629539493E-01           6.688705823278427E+00
5.177973488146106E-14  7.929916271924971E+00
  1.616168835687637E-01           2.286000000000000E-01           1.319400490039070E-07
1.489166435691964E-02  1.747632772552674E-04
    68    10
  1.656997178609521E-01           1.006352897435368E+01           1.035549349937439E+00
1.811816866189361E-15  6.935822149276733E+00
  1.620222471488316E-01           2.794000000000000E-01           2.986565295850495E-07
1.233670372048897E-02  3.727058592633917E-05
    69    10
  1.903973651027788E-01           3.240230453523307E+00           1.537907226181030E-01
3.999524813254778E-15  5.462044995625813E+00
  1.252806657552719E-01           3.810000000000000E-01           1.451692538185036E-07
1.334868027296906E-02  1.147781682286689E-04
    70    10
  1.124626220341657E-01           1.887725728279077E+00           6.391677316398621E+00
4.815002055655810E-16  7.196298217773437E+00
  1.464732744773229E-01           6.096000000000000E-01           1.708622528146480E-07
1.086432262490276E-02  9.645598669483431E-05
    71    10
  1.715503906222907E-01           1.659374857210902E+01           6.096308290100099E-01
1.483210213140069E-16  5.550379608074824E+00
  1.304532377640406E-01           3.810000000000000E-01           1.554314908580177E-07
1.329816553819292E-02  8.720070202237848E-05
    72    10
  1.045004917099043E-01           1.541137000741800E-01           7.077411714658737E+00
3.188465152889027E-13  1.123635962724683E+01
  1.217274201432864E-01           1.016000000000000E-01           2.054547196226355E-07
1.583626003568942E-02  2.721844091309483E-04
    73    10
  7.185068992983373E-02           5.887988710464730E+00           9.167078758163452E+00
1.032547265576019E-16  7.133606701970100E+00
  1.727512061117488E-01           4.445000000000000E-01           1.472721694542681E-07
1.291498760965278E-02  5.174114817139881E-05
    74    10
  1.005460789859716E-01           1.609778287186916E+00           7.792388095741273E+00
5.471497499279528E-14  7.499552431583403E+00
```

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```
  1.405796891745329E-01           5.588000000000000E-01           4.624000734525745E-08
1.287646966703346E-02  1.249860092941885E-04
    75    10
  9.318309654409919E-02           4.754947756645417E-01           7.924174635696411E+00
2.793219868491982E-13  9.587649053335179E+00
  1.198340254624685E-01           2.508300000000000E-01           2.130735455227069E-07
1.407075668003678E-02  3.076174346089193E-04
!RANK correlation matrix
!       1       2       3       4       5       6       7       8       9      10
   1  1.0000
   2  0.0249  1.0000
   3 -0.9991 -0.0231  1.0000
   4 -0.0478  0.0054  0.0468  1.0000
   5 -0.0124 -0.9477  0.0108 -0.0232  1.0000
   6 -0.0009 -0.0100  0.0053 -0.8032  0.0337  1.0000
   7  0.0576  0.1072 -0.0578  0.0183 -0.1086 -0.0304  1.0000
   8  0.0296 -0.0774 -0.0290  0.0096  0.0868  0.0048 -0.4666  1.0000
   9 -0.0293  0.0053  0.0298  0.0341 -0.0144 -0.0239 -0.4819 -0.4549  1.0000
  10 -0.0034 -0.0301  0.0048  0.0149  0.0431 -0.0327 -0.0128 -0.0103  0.0197  1.0000
!       1       2       3       4       5       6       7       8       9      10
```

Information Only

13.0 APPENDIX C: EXAMPLE OF LHS OUTPUT DEBUG FILE

```
                              LL       HH   HH   SSSSSS
                              LL       HH   HH  SS
                              LL       HH   HH  SS
                              LL       HHHHHHH   SSSSS
                              LL       HH   HH       SS
                              LL       HH   HH       SS
                              LLLLLLL  HH   HH  SSSSSS

                                   LHS Version 3.00
                                PRODUCTION Built 11/01/2021
                          Written by R.L. Iman and M.J. Shortencarier

                                Run on 11/17/2021 at 08:05:42
                             Run on x86_64 cb001 Linux 3.10.0-957

    TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27

    RANDOM SEED =   933090934

    NUMBER OF VARIABLES =  10

    NUMBER OF OBSERVATIONS =   75

    ANALYSIS: LHS300_T3    REVISION:   0 REPLICATE:   2

    AN INPUT CORRELATION MATRIX HAS BEEN SPECIFIED

    THE SAMPLE INPUT VECTORS WILL BE PRINTED ALONG WITH THEIR CORRESPONDING RANKS

    HISTOGRAMS OF THE ACTUAL SAMPLE WILL BE PLOTTED FOR EACH INPUT VARIABLE

    THE CORRELATION MATRICES (RAW DATA AND RANK CORRELATIONS) WILL BE PRINTED
1

    TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27

    VARIABLE  DISTRIBUTION          RANGE                    LABEL
0       1     NORMAL       5.0000E-02 TO   0.2000          GLOBAL    DISPPERC
0       2     LOGNORMAL    1.0000E-02 TO    100.0          COLLOID   CONC
0       3     UNIFORM      4.8000E-02 TO    9.600          WAS_AREA  TAUFAIL
0       4     LOGUNIFORM   1.0000E-17 TO   1.0000E-12      WAS_AREA  SPPERM
0       5     USER SUPPLIED DISTRIBUTION (CUMULATIVE)      BOREHOLE  DOMEGA
                            20 DATA PAIRS
                   4.200000E+00  0.0000
                   4.200000E+00  0.1500
                   6.300000E+00  0.0000
                   6.300000E+00  0.5000
                   8.400000E+00  0.0000
                   8.400000E+00  0.1500
                   1.050000E+01  0.0000
                   1.050000E+01  0.1000
                   1.260000E+01  0.0000
                   1.260000E+01  0.0500
                   1.470000E+01  0.0000
                   1.470000E+01  0.0200
                   1.680000E+01  0.0000
                   1.680000E+01  0.0100
                   1.880000E+01  0.0000
```

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```
                  1.880000E+01  0.0100
                  2.090000E+01  0.0000
                  2.090000E+01  0.0100
                  2.300000E+01  0.0000
                  2.300000E+01  0.0000
0       6     USER SUPPLIED DISTRIBUTION (DATA)            CULEBRA   POROSITY
                             21 DATA POINTS
                  5.805630E-02  9.550000E-02  1.033300E-01  1.074000E-01  1.150000E-01
                  1.205000E-01  1.222500E-01  1.235000E-01  1.290000E-01  1.385000E-01
                  1.443300E-01  1.465000E-01  1.616000E-01  1.618000E-01  1.651700E-01
                  1.780000E-01  1.784000E-01  1.796000E-01  2.025000E-01  2.077500E-01
                  2.525000E-01
0       7     USER SUPPLIED DISTRIBUTION (DELTA)           BOREHOLE  DIAMMOD
                             14 DATA PAIRS
                  5.080000E-02  0.0714
                  1.016000E-01  0.0714
                  1.524000E-01  0.0714
                  1.936800E-01  0.0714
                  2.190800E-01  0.0714
                  2.286000E-01  0.0714
                  2.508300E-01  0.0714
                  2.794000E-01  0.0714
                  3.048000E-01  0.0714
                  3.492500E-01  0.0714
                  3.810000E-01  0.0714
                  4.445000E-01  0.0714
                  5.588000E-01  0.0714
                  6.096000E-01  0.0714
0       8     TRIANGULAR  WITH PARAMETERS BELOW            WAS_AREA  GRATCORI
                             A=       0.000
                             B=      3.2000E-09
                             C=      6.4000E-07
0       9     STUDENT  WITH PARAMETERS BELOW               S_MB139   POROSITY
                              15 DEGREES OF FREEDOM     16 INPUT POINTS
                             MEAN=    1.3687E-02
                             STDERR=  1.5857E-03      STDDEV=  6.3426E-03
                  4.000000E-03  5.000000E-03  5.000000E-03  8.000000E-03  1.000000E-02
                  1.100000E-02  1.300000E-02  1.300000E-02  1.600000E-02  1.600000E-02
                  1.600000E-02  1.700000E-02  1.800000E-02  1.900000E-02  2.100000E-02
                  2.700000E-02
0      10     LOGSTUDENT  WITH PARAMETERS BELOW            STULMAT1  STULPRP1
                              19 DEGREES OF FREEDOM     20 INPUT POINTS
                             LOG MEAN=    -9.157
                             LOG STDERR=  0.6912          LOG STDDEV=   3.091
                -1.386155E+01 -1.378275E+01 -1.336189E+01 -1.305004E+01 -1.237924E+01
                -1.170864E+01 -1.070868E+01 -1.005664E+01 -9.513475E+00 -9.267620E+00
                -8.828485E+00 -7.924972E+00 -7.484365E+00 -7.175413E+00 -6.930001E+00
                -6.328897E+00 -5.879565E+00 -5.293330E+00 -4.950835E+00 -4.653835E+00
1TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0INPUT                    RANK                      CORRELATION                    MATRIX
PAGE   1
0    1  1.0000
0    2  0.0000  1.0000
0    3 -0.9990  0.0000  1.0000
0    4  0.0000  0.0000  0.0000  1.0000
0    5  0.0000 -0.9500  0.0000  0.0000  1.0000
0    6  0.0000  0.0000  0.0000 -0.8000  0.0000  1.0000
0    7  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  1.0000
0    8  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.6500  1.0000
0    9  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.6500 -0.6500  1.0000
0            1       2       3       4       5       6       7       8       9
```

Information Only

```
0VARIABLES
0********* CAUTION USER PLEASE NOTE ********* CAUTION USER PLEASE NOTE ********* CAUTION
USER PLEASE NOTE **********

 THE INPUT RANK CORRELATION MATRIX IS NOT POSITIVE DEFINITE
 AN ITERATIVE PROCEDURE HAS BEEN USED TO PRODUCE A SUBSTITUTE RANK CORRELATION MATRIX
 THIS ADJUSTED RANK CORRELATION MATRIX APPEARS ON THE NEXT PAGE
 THE USER SHOULD EXAMINE THIS MATRIX TO MAKE SURE THAT THE CORRELATION REQUIREMENTS ARE
STILL SATISFIED


********************************************************************************************
****************************
1TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0ADJUSTED                  RANK                   CORRELATION                    MATRIX
PAGE   1
0     1  1.0000
0     2  0.0000  1.0000
0     3 -0.9990  0.0000  1.0000
0     4  0.0000  0.0000  0.0000  1.0000
0     5  0.0000 -0.9500  0.0000  0.0000  1.0000
0     6  0.0000  0.0000  0.0000 -0.8000  0.0000  1.0000
0     7  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  1.0000
0     8  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.4997  1.0000
0     9  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.4997 -0.4997  1.0000
0           1       2       3       4       5       6       7       8       9
0VARIABLES

 Values will NOT be written to Database

 Values will NOT be written to Database
1TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0LATIN HYPERCUBE SAMPLE INPUT VECTORS

 RUN NO.   X(1)        X(2)        X(3)        X(4)        X(5)        X(6)        X(7)
X(8)        X(9)       X(10)
0     1  9.500E-02  1.833E+01  8.149E+00  3.500E-16  6.383E+00  2.027E-01  2.286E-01
2.596E-07  1.401E-02  9.201E-05
0     2  1.577E-01  2.055E+00  1.609E+00  1.302E-16  7.984E+00  2.179E-01  4.445E-01
8.277E-08  1.340E-02  1.104E-04
0     3  6.958E-02  3.463E+00  9.233E+00  7.916E-14  5.942E+00  1.446E-01  3.493E-01
5.790E-07  1.032E-02  6.147E-05
0     4  1.068E-01  3.901E-02  6.921E+00  8.264E-16  1.731E+01  1.618E-01  6.096E-01
2.273E-08  1.325E-02  2.918E-05
0     5  1.613E-01  1.511E+00  1.132E+00  6.634E-14  7.531E+00  1.214E-01  5.588E-01
1.085E-07  1.186E-02  4.895E-05
0     6  5.458E-02  7.649E-02  9.577E+00  3.095E-14  1.210E+01  1.224E-01  6.096E-01
9.257E-08  1.161E-02  1.547E-04
0     7  1.347E-01  1.667E-01  3.491E+00  3.257E-16  1.086E+01  1.401E-01  2.191E-01
3.108E-08  1.699E-02  1.449E-04
0     8  1.035E-01  8.184E+00  7.215E+00  1.775E-14  6.447E+00  1.278E-01  5.080E-02
1.267E-07  1.649E-02  8.463E-05
0     9  1.555E-01  2.746E+00  1.487E+00  7.381E-17  7.345E+00  1.976E-01  3.493E-01
2.213E-07  1.311E-02  1.865E-04
0    10  1.843E-01  6.994E-01  1.999E-01  1.215E-14  9.249E+00  1.630E-01  1.937E-01
4.296E-07  1.265E-02  7.102E-05
0    11  1.706E-01  3.501E-01  7.872E-01  7.606E-13  8.163E+00  1.043E-01  4.445E-01
1.143E-07  1.282E-02  1.786E-04
0    12  1.318E-01  1.111E+00  4.077E+00  7.157E-15  7.362E+00  1.617E-01  1.524E-01
5.634E-07  1.301E-02  4.298E-05
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0    13   1.358E-01   2.180E-02   3.736E+00   2.879E-14   1.250E+01   1.181E-01   1.937E-01
4.515E-07   1.177E-02   1.339E-04
0    14   1.252E-01   9.239E-01   4.968E+00   5.644E-15   7.768E+00   1.461E-01   1.016E-01
1.213E-07   1.596E-02   2.958E-04
0    15   1.277E-01   8.189E-01   4.527E+00   1.018E-14   9.906E+00   9.010E-02   3.493E-01
2.473E-07   1.227E-02   2.365E-04
0    16   8.376E-02   2.784E-01   8.739E+00   1.401E-17   1.024E+01   1.915E-01   1.524E-01
3.485E-07   1.393E-02   6.474E-05
0    17   1.087E-01   1.035E-01   6.538E+00   1.384E-14   1.537E+01   1.234E-01   3.048E-01
2.375E-07   1.315E-02   6.066E-05
0    18   1.428E-01   2.704E+01   2.803E+00   2.406E-17   4.478E+00   2.045E-01   1.016E-01
3.258E-07   1.459E-02   2.529E-04
0    19   1.378E-01   2.118E+01   3.358E+00   9.816E-13   4.921E+00   7.373E-02   3.048E-01
1.936E-07   1.367E-02   1.185E-04
0    20   1.399E-01   4.817E-02   3.045E+00   5.855E-17   1.308E+01   2.073E-01   2.794E-01
1.779E-08   1.620E-02   4.232E-05
0    21   1.667E-01   6.639E+00   8.947E-01   1.873E-14   6.818E+00   1.051E-01   2.794E-01
3.289E-07   1.215E-02   7.980E-05
0    22   9.943E-02   5.627E-01   7.487E+00   4.038E-17   9.170E+00   1.793E-01   5.080E-02
3.924E-07   1.413E-02   1.082E-04
0    23   9.141E-02   4.870E+01   8.317E+00   4.706E-15   5.165E+00   9.980E-02   1.016E-01
2.817E-07   1.511E-02   1.896E-04
0    24   1.791E-01   5.145E-01   4.177E-01   2.910E-15   8.630E+00   1.225E-01   2.508E-01
1.768E-07   1.424E-02   8.312E-05
0    25   1.334E-01   2.256E+00   3.885E+00   1.124E-13   7.705E+00   1.352E-01   2.191E-01
2.038E-07   1.462E-02   2.422E-05
0    26   9.659E-02   2.894E+00   7.960E+00   7.165E-13   6.871E+00   1.229E-01   2.508E-01
1.582E-07   1.431E-02   3.282E-05
0    27   1.301E-01   4.134E+00   4.372E+00   2.158E-13   6.739E+00   8.108E-02   4.445E-01
2.281E-07   1.192E-02   1.274E-04
0    28   1.027E-01   3.049E-01   7.429E+00   1.661E-16   8.783E+00   1.754E-01   3.048E-01
2.713E-07   1.297E-02   2.158E-04
0    29   6.095E-02   3.960E-01   9.428E+00   2.392E-15   8.372E+00   1.115E-01   2.508E-01
1.348E-07   1.448E-02   8.203E-05
0    30   1.155E-01   1.050E+00   5.943E+00   1.260E-13   7.645E+00   1.070E-01   1.524E-01
5.302E-08   1.648E-02   3.749E-05
0    31   8.630E-02   1.782E+00   8.576E+00   4.373E-13   6.503E+00   1.142E-01   3.048E-01
2.754E-07   1.276E-02   1.050E-04
0    32   1.624E-01   4.305E-01   1.218E+00   5.485E-16   8.072E+00   1.243E-01   5.080E-02
3.384E-07   1.526E-02   1.923E-05
0    33   1.324E-01   8.951E-01   3.856E+00   1.675E-17   7.832E+00   1.776E-01   4.445E-01
6.238E-08   1.380E-02   4.522E-05
0    34   1.388E-01   1.343E+00   3.225E+00   3.813E-17   7.042E+00   2.093E-01   1.937E-01
6.683E-08   1.554E-02   1.001E-04
0    35   1.476E-01   2.443E-01   2.293E+00   5.932E-13   1.041E+01   1.007E-01   2.191E-01
1.845E-07   1.474E-02   1.993E-04
0    36   1.235E-01   3.687E+00   4.760E+00   3.378E-15   6.311E+00   1.457E-01   6.096E-01
8.789E-08   1.139E-02   1.399E-04
0    37   1.296E-01   7.343E+00   4.241E+00   4.167E-14   5.093E+00   1.072E-01   1.524E-01
3.058E-07   1.414E-02   7.333E-05
0    38   1.195E-01   3.394E-01   5.729E+00   3.226E-17   9.505E+00   1.700E-01   5.080E-02
4.526E-08   1.721E-02   1.374E-04
0    39   1.533E-01   2.086E-01   1.811E+00   1.762E-13   1.073E+01   1.090E-01   1.524E-01
3.591E-07   1.433E-02   4.820E-04
0    40   1.098E-01   6.022E+01   6.546E+00   1.083E-15   4.343E+00   1.840E-01   3.810E-01
9.356E-08   1.358E-02   1.480E-04
0    41   1.597E-01   5.529E+00   1.440E+00   1.450E-15   6.589E+00   1.783E-01   2.286E-01
5.919E-08   1.542E-02   1.681E-04
0    42   8.842E-02   8.807E+00   8.449E+00   3.789E-15   6.070E+00   1.168E-01   2.794E-01
1.033E-07   1.471E-02   2.066E-04
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0    43   1.511E-01   9.727E-01   2.002E+00   2.861E-16   7.858E+00   1.444E-01   2.286E-01
3.669E-07   1.263E-02   2.255E-04
0    44   1.162E-01   1.175E+01   5.649E+00   8.667E-14   5.822E+00   1.509E-01   1.937E-01
7.518E-08   1.564E-02   5.823E-05
0    45   1.440E-01   2.435E+00   2.612E+00   4.298E-16   6.565E+00   1.207E-01   3.810E-01
2.456E-08   1.497E-02   4.921E-05
0    46   7.778E-02   4.516E+00   8.970E+00   2.116E-15   6.632E+00   1.371E-01   3.048E-01
3.373E-08   1.536E-02   9.445E-05
0    47   1.221E-01   8.104E-02   5.175E+00   2.500E-14   1.151E+01   1.273E-01   5.080E-02
4.978E-07   1.486E-02   1.296E-04
0    48   1.776E-01   3.062E-02   4.426E-01   8.697E-16   1.769E+01   1.648E-01   5.588E-01
1.597E-09   1.568E-02   1.644E-04
0    49   9.720E-02   1.329E+01   7.593E+00   5.361E-13   4.598E+00   9.684E-02   3.493E-01
3.982E-08   1.505E-02   1.532E-04
0    50   1.063E-01   1.175E-01   6.947E+00   3.830E-13   1.450E+01   5.955E-02   3.810E-01
1.056E-07   1.374E-02   6.692E-05
0    51   1.205E-01   7.750E-01   5.440E+00   9.591E-17   8.340E+00   1.789E-01   2.191E-01
4.148E-07   1.208E-02   3.360E-04
0    52   1.234E-01   5.766E-01   5.130E+00   1.258E-17   7.291E+00   2.413E-01   1.016E-01
4.029E-07   1.389E-02   7.030E-05
0    53   1.468E-01   1.191E+00   2.172E+00   2.073E-17   7.590E+00   1.641E-01   3.048E-01
3.745E-07   1.102E-02   3.578E-04
0    54   1.420E-01   4.742E+00   2.871E+00   2.685E-17   7.105E+00   1.781E-01   3.493E-01
3.128E-07   1.149E-02   1.038E-04
0    55   1.182E-01   6.038E-02   5.393E+00   1.849E-13   1.361E+01   1.035E-01   1.524E-01
4.648E-07   1.247E-02   5.604E-05
0    56   1.450E-01   1.537E-02   2.399E+00   3.720E-14   2.101E+01   1.332E-01   3.493E-01
1.886E-07   1.352E-02   7.756E-05
0    57   1.259E-01   2.545E+00   4.863E+00   6.621E-17   7.007E+00   1.782E-01   5.588E-01
7.097E-08   1.321E-02   8.879E-05
0    58   1.267E-01   1.396E-01   4.466E+00   4.849E-17   1.011E+01   1.784E-01   2.286E-01
1.658E-07   1.437E-02   5.352E-05
0    59   1.173E-01   1.317E+00   5.872E+00   2.105E-16   8.251E+00   1.796E-01   2.508E-01
2.500E-07   1.362E-02   9.735E-05
0    60   1.136E-01   4.359E-01   6.226E+00   2.383E-16   8.111E+00   2.404E-01   2.286E-01
2.928E-07   1.345E-02   1.120E-04
0    61   7.990E-02   1.968E-01   8.877E+00   1.016E-17   8.884E+00   2.050E-01   6.096E-01
1.371E-08   1.240E-02   2.463E-04
0    62   1.372E-01   2.191E-01   3.409E+00   8.945E-15   1.189E+01   1.553E-01   2.508E-01
2.305E-07   1.386E-02   4.454E-04
0    63   1.489E-01   6.334E-01   2.567E+00   8.267E-15   7.443E+00   1.590E-01   4.445E-01
4.887E-07   1.007E-02   6.541E-05
0    64   1.520E-01   1.655E+00   1.838E+00   1.573E-13   6.682E+00   1.160E-01   5.588E-01
6.362E-09   1.455E-02   1.579E-04
0    65   1.140E-01   2.674E-01   6.043E+00   7.038E-16   8.222E+00   1.432E-01   1.937E-01
5.232E-07   1.126E-02   7.522E-05
0    66   8.607E-02   1.199E-01   8.617E+00   1.239E-15   1.234E+01   1.623E-01   1.937E-01
4.334E-07   1.250E-02   1.223E-04
0    67   1.106E-01   6.582E-01   6.689E+00   5.178E-14   7.930E+00   1.616E-01   2.286E-01
1.319E-07   1.489E-02   1.748E-04
0    68   1.657E-01   1.006E+01   1.036E+00   1.812E-15   6.936E+00   1.620E-01   2.794E-01
2.987E-07   1.234E-02   3.727E-05
0    69   1.904E-01   3.240E+00   1.538E-01   4.000E-15   5.462E+00   1.253E-01   3.810E-01
1.452E-07   1.335E-02   1.148E-04
0    70   1.125E-01   1.888E+00   6.392E+00   4.815E-16   7.196E+00   1.465E-01   6.096E-01
1.709E-07   1.086E-02   9.646E-05
0    71   1.716E-01   1.659E+01   6.096E-01   1.483E-16   5.550E+00   1.305E-01   3.810E-01
1.554E-07   1.330E-02   8.720E-05
0    72   1.045E-01   1.541E-01   7.077E+00   3.188E-13   1.124E+01   1.217E-01   1.016E-01
2.055E-07   1.584E-02   2.722E-04
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0    73   7.185E-02   5.888E+00   9.167E+00   1.033E-16   7.134E+00   1.728E-01   4.445E-01
1.473E-07   1.291E-02   5.174E-05
0    74   1.005E-01   1.610E+00   7.792E+00   5.471E-14   7.500E+00   1.406E-01   5.588E-01
4.624E-08   1.288E-02   1.250E-04
0    75   9.318E-02   4.755E-01   7.924E+00   2.793E-13   9.588E+00   1.198E-01   2.508E-01
2.131E-07   1.407E-02   3.076E-04
1TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0RANKS OF LATIN HYPERCUBE SAMPLE INPUT VECTORS

 RUN NO.      X(1)        X(2)        X(3)        X(4)        X(5)        X(6)        X(7)
X(8)        X(9)       X(10)
0    1         13.0        71.0        64.0        24.0        13.0        68.0        29.5
49.0        44.0        32.0
0    2         64.0        49.0        13.0        17.0        42.0        73.0        62.5
18.0        33.0        40.0
0    3          3.0        56.0        73.0        59.0        10.0        39.0        51.5
75.0         2.0        17.0
0    4         22.0         4.0        54.0        29.0        73.0        48.0        73.0
5.0         30.0         3.0
0    5         66.0        44.0         9.0        58.0        34.0        21.0        68.0
24.0        10.0        10.0
0    6          1.0         7.0        75.0        53.0        66.0        23.0        73.0
20.0         8.0        54.0
0    7         47.0        14.0        28.0        23.0        62.0        35.0        24.5
7.0         74.0        51.0
0    8         19.0        65.0        57.0        49.0        14.0        30.0         3.0
27.0        73.0        29.0
0    9         63.0        53.0        12.0        14.0        30.0        67.0        51.5
43.0        27.0        60.0
0   10         74.0        33.0         2.0        47.0        54.0        51.0        19.5
67.0        20.0        22.0
0   11         70.0        23.0         6.0        74.0        45.0         9.0        62.5
25.0        22.0        59.0
0   12         44.0        40.0        32.0        43.0        31.0        47.0        13.5
74.0        26.0         8.0
0   13         48.0         2.0        29.0        52.0        68.0        18.0        19.5
69.0         9.0        48.0
0   14         38.0        37.0        39.0        42.0        38.0        41.0         8.0
26.0        70.0        70.0
0   15         41.0        35.0        36.0        46.0        57.0         4.0        51.5
47.0        14.0        66.0
0   16          7.0        20.0        69.0         3.0        59.0        66.0        13.5
60.0        43.0        18.0
0   17         23.0         9.0        51.0        48.0        72.0        26.0        45.5
46.0        28.0        16.0
0   18         54.0        73.0        22.0         6.0         2.0        69.0         8.0
57.0        54.0        68.0
0   19         50.0        72.0        26.0        75.0         4.0         2.0        45.5
39.0        38.0        43.0
0   20         52.0         5.0        24.0        12.0        69.0        71.0        40.5
4.0         71.0         7.0
0   21         69.0        63.0         7.0        50.0        21.0        10.0        40.5
58.0        13.0        26.0
0   22         16.0        29.0        59.0        10.0        53.0        63.0         3.0
64.0        46.0        39.0
0   23         11.0        74.0        65.0        41.0         6.0         6.0         8.0
52.0        62.0        61.0
0   24         73.0        28.0         3.0        37.0        50.0        24.0        35.5
36.0        48.0        28.0
0   25         46.0        50.0        31.0        61.0        37.0        33.0        24.5
40.0        55.0         2.0
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0   26      14.0      54.0      63.0      73.0      22.0      25.0      35.5
33.0      49.0       4.0
0   27      43.0      58.0      34.0      66.0      20.0       3.0      62.5
44.0      11.0      46.0
0   28      18.0      21.0      58.0      19.0      51.0      56.0      45.5
50.0      25.0      64.0
0   29       2.0      24.0      74.0      36.0      49.0      14.0      35.5
29.0      52.0      27.0
0   30      29.0      39.0      47.0      62.0      36.0      11.0      13.5
12.0      72.0       6.0
0   31       9.0      47.0      67.0      70.0      15.0      15.0      45.5
51.0      21.0      38.0
0   32      67.0      25.0      10.0      27.0      43.0      27.0       3.0
59.0      63.0       1.0
0   33      45.0      36.0      30.0       4.0      39.0      57.0      62.5
14.0      40.0       9.0
0   34      51.0      43.0      25.0       9.0      25.0      72.0      19.5
15.0      66.0      36.0
0   35      58.0      18.0      18.0      72.0      60.0       7.0      24.5
37.0      57.0      62.0
0   36      37.0      57.0      37.0      38.0      12.0      40.0      73.0
19.0       6.0      50.0
0   37      42.0      64.0      33.0      55.0       5.0      12.0      13.5
55.0      47.0      23.0
0   38      33.0      22.0      45.0       8.0      55.0      54.0       3.0
10.0      75.0      49.0
0   39      62.0      16.0      14.0      64.0      61.0      13.0      13.5
61.0      50.0      75.0
0   40      24.0      75.0      52.0      31.0       1.0      65.0      57.0
21.0      36.0      52.0
0   41      65.0      61.0      11.0      33.0      17.0      60.0      29.5
13.0      65.0      57.0
0   42      10.0      66.0      66.0      39.0      11.0      17.0      40.5
22.0      56.0      63.0
0   43      60.0      38.0      16.0      22.0      40.0      38.0      29.5
62.0      19.0      65.0
0   44      30.0      68.0      44.0      60.0       9.0      43.0      19.5
17.0      67.0      15.0
0   45      55.0      51.0      21.0      25.0      16.0      20.0      57.0
6.0      60.0      11.0
0   46       5.0      59.0      71.0      35.0      18.0      34.0      45.5
8.0      64.0      33.0
0   47      35.0       8.0      41.0      51.0      64.0      29.0       3.0
72.0      58.0      47.0
0   48      72.0       3.0       4.0      30.0      74.0      53.0      68.0
1.0      68.0      56.0
0   49      15.0      69.0      60.0      71.0       3.0       5.0      51.5
9.0      61.0      53.0
0   50      21.0      10.0      55.0      69.0      71.0       1.0      57.0
23.0      39.0      20.0
0   51      34.0      34.0      43.0      15.0      48.0      62.0      24.5
66.0      12.0      72.0
0   52      36.0      30.0      40.0       2.0      29.0      75.0       8.0
65.0      42.0      21.0
0   53      57.0      41.0      17.0       5.0      35.0      52.0      45.5
63.0       4.0      73.0
0   54      53.0      60.0      23.0       7.0      26.0      58.0      51.5
56.0       7.0      37.0
0   55      32.0       6.0      42.0      65.0      70.0       8.0      13.5
70.0      17.0      14.0
```

Information Only

```
0    56        56.0         1.0        19.0        54.0        75.0        32.0        51.5
38.0        35.0        25.0
0    57        39.0        52.0        38.0        13.0        24.0        59.0        68.0
16.0        29.0        31.0
0    58        40.0        12.0        35.0        11.0        58.0        61.0        29.5
34.0        51.0        13.0
0    59        31.0        42.0        46.0        20.0        47.0        64.0        35.5
48.0        37.0        35.0
0    60        27.0        26.0        49.0        21.0        44.0        74.0        29.5
53.0        34.0        41.0
0    61         6.0        15.0        70.0         1.0        52.0        70.0        73.0
3.0        16.0        67.0
0    62        49.0        17.0        27.0        45.0        65.0        44.0        35.5
45.0        41.0        74.0
0    63        59.0        31.0        20.0        44.0        32.0        45.0        62.5
71.0         1.0        19.0
0    64        61.0        46.0        15.0        63.0        19.0        16.0        68.0
2.0        53.0        55.0
0    65        28.0        19.0        48.0        28.0        46.0        37.0        19.5
73.0         5.0        24.0
0    66         8.0        11.0        68.0        32.0        67.0        50.0        19.5
68.0        18.0        44.0
0    67        25.0        32.0        53.0        56.0        41.0        46.0        29.5
28.0        59.0        58.0
0    68        68.0        67.0         8.0        34.0        23.0        49.0        40.5
54.0        15.0         5.0
0    69        75.0        55.0         1.0        40.0         7.0        28.0        57.0
30.0        32.0        42.0
0    70        26.0        48.0        50.0        26.0        28.0        42.0        73.0
35.0         3.0        34.0
0    71        71.0        70.0         5.0        18.0         8.0        31.0        57.0
32.0        31.0        30.0
0    72        20.0        13.0        56.0        68.0        63.0        22.0         8.0
41.0        69.0        69.0
0    73         4.0        62.0        72.0        16.0        27.0        55.0        62.5
31.0        24.0        12.0
0    74        17.0        45.0        61.0        57.0        33.0        36.0        68.0
11.0        23.0        45.0
0    75        12.0        27.0        62.0        67.0        56.0        19.0        35.5
42.0        45.0        71.0
1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  1     NORMAL DISTRIBUTION

     MIDPOINT          FREQ.

   0.5780000E-01         2    XX
   0.6460000E-01         0
   0.7140000E-01         2    XX
   0.7820000E-01         2    XX
   0.8500000E-01         3    XXX
   0.9180000E-01         4    XXXX
   0.9860000E-01         4    XXXX
   0.1054000             6    XXXXXX
   0.1122000             6    XXXXXX
   0.1190000             6    XXXXXX
   0.1258000             6    XXXXXX
   0.1326000             7    XXXXXXX
   0.1394000             6    XXXXXX
   0.1462000             5    XXXXX
   0.1530000             4    XXXX
   0.1598000             4    XXXX
```

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```
   0.1666000             2    XX
   0.1734000             2    XX
   0.1802000             2    XX
   0.1870000             2    XX
0                       75

      MIN            MAX            RANGE           MEAN          MEDIAN        VARIANCE

   0.5458081E-01  0.1903974      0.1358166      0.1248657      0.1252316      0.9066446E-
03

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  2     LOGNORMAL DISTRIBUTION

     MIDPOINT          FREQ.

    1.500000            54    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    4.500000             8    XXXXXXXX
    7.500000             4    XXXX
    10.50000             2    XX
    13.50000             1    X
    16.50000             1    X
    19.50000             1    X
    22.50000             1    X
    25.50000             0
    28.50000             1    X
    31.50000             0
    34.50000             0
    37.50000             0
    40.50000             0
    43.50000             0
    46.50000             0
    49.50000             1    X
    52.50000             0
    55.50000             0
    58.50000             0
    61.50000             1    X
0                       75

      MIN            MAX            RANGE           MEAN          MEDIAN        VARIANCE

   0.1536736E-01   60.22255       60.20719       4.481191      0.9726797       95.60207

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  3     UNIFORM DISTRIBUTION

     MIDPOINT          FREQ.

   0.2350000             4    XXXX
   0.7050000             3    XXX
    1.175000             3    XXX
    1.645000             5    XXXXX
    2.115000             3    XXX
    2.585000             4    XXXX
    3.055000             3    XXX
    3.525000             4    XXXX
    3.995000             3    XXX
    4.465000             4    XXXX
    4.935000             4    XXXX
```

Information Only

```
    5.405000             3    XXX
    5.875000             5    XXXXX
    6.345000             4    XXXX
    6.815000             3    XXX
    7.285000             4    XXXX
    7.755000             4    XXXX
    8.225000             3    XXX
    8.695000             4    XXXX
    9.165000             3    XXX
    9.635000             2    XX
0                       75

      MIN            MAX            RANGE           MEAN          MEDIAN        VARIANCE

   0.1537907       9.576991       9.423200       4.830449       4.863027       7.597714

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  4     LOGUNIFORM DISTRIBUTION

     MIDPOINT          FREQ.

   0.2450000E-13        55    XXXX
```

```
    8.715000             5    XXXXX
    9.545000             5    XXXXX
    10.37500             4    XXXX
    11.20500             3    XXX
    12.03500             3    XXX
    12.86500             2    XX
    13.69500             1    X
    14.52500             1    X
    15.35500             1    X
    16.18500             0
    17.01500             1    X
    17.84500             1    X
    18.67500             0
    19.50500             0
    20.33500             0
    21.16500             1    X
0                       75

      MIN            MAX           RANGE           MEAN          MEDIAN        VARIANCE

    4.343166       21.01063       16.66746       8.625762       7.767633       9.746747

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  6     DATA DISTRIBUTION

     MIDPOINT          FREQ.

   0.5915000E-01         1    X
   0.6825000E-01         0
   0.7735000E-01         2    XX
   0.8645000E-01         1    X
   0.9555000E-01         2    XX
   0.1046500             7    XXXXXXX
   0.1137500             5    XXXXX
   0.1228500            11    XXXXXXXXXXX
   0.1319500             4    XXXX
   0.1410500             6    XXXXXX
   0.1501500             4    XXXX
   0.1592500             8    XXXXXXXX
   0.1683500             4    XXXX
   0.1774500             9    XXXXXXXXX
   0.1865500             1    X
   0.1956500             2    XX
   0.2047500             4    XXXX
   0.2138500             2    XX
   0.2229500             0
   0.2320500             0
   0.2411500             2    XX
0                       75

      MIN            MAX           RANGE           MEAN          MEDIAN        VARIANCE

   0.5954949E-01  0.2412574      0.1817079      0.1466039      0.1444190      0.1443193E-
02

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  7     DELTA DISTRIBUTION

     MIDPOINT          FREQ.
```

Information Only

```
   0.4200000E-01          5    XXXXX
   0.7000000E-01          0
   0.9800000E-01          5    XXXXX
   0.1260000              0
   0.1540000              6    XXXXXX
   0.1820000              6    XXXXXX
   0.2100000              4    XXXX
   0.2380000             12    XXXXXXXXXXXX
   0.2660000              4    XXXX
   0.2940000              6    XXXXXX
   0.3220000              0
   0.3500000              6    XXXXXX
   0.3780000              5    XXXXX
   0.4060000              0
   0.4340000              6    XXXXXX
   0.4620000              0
   0.4900000              0
   0.5180000              0
   0.5460000              5    XXXXX
   0.5740000              0
   0.6020000              5    XXXXX
0                        75

      MIN             MAX           RANGE           MEAN          MEDIAN        VARIANCE

   0.5080000E-01  0.6096000      0.5588000      0.2939637      0.2508300      0.2350708E-
01

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  8     TRIANGULAR DISTRIBUTION

     MIDPOINT          FREQ.

   0.1450000E-07          6    XXXXXX
   0.4350000E-07          6    XXXXXX
   0.7250000E-07          6    XXXXXX
   0.1015000E-06          7    XXXXXXX
   0.1305000E-06          4    XXXX
   0.1595000E-06          6    XXXXXX
   0.1885000E-06          4    XXXX
   0.2175000E-06          6    XXXXXX
   0.2465000E-06          4    XXXX
   0.2755000E-06          3    XXX
   0.3045000E-06          4    XXXX
   0.3335000E-06          3    XXX
   0.3625000E-06          4    XXXX
   0.3915000E-06          2    XX
   0.4205000E-06          3    XXX
   0.4495000E-06          1    X
   0.4785000E-06          2    XX
   0.5075000E-06          1    X
   0.5365000E-06          1    X
   0.5655000E-06          2    XX
0                        75

      MIN             MAX           RANGE           MEAN          MEDIAN        VARIANCE
```

Information Only

```
   0.1597257E-08  0.5790454E-06  0.5774482E-06  0.2143810E-06  0.1885661E-06  0.2257937E-
13

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO.  9     STUDENT DISTRIBUTION

     MIDPOINT          FREQ.

   0.9900000E-02         1    X
   0.1026000E-01         1    X
   0.1062000E-01         0
   0.1098000E-01         2    XX
   0.1134000E-01         3    XXX
   0.1170000E-01         3    XXX
   0.1206000E-01         3    XXX
   0.1242000E-01         5    XXXXX
   0.1278000E-01         6    XXXXXX
   0.1314000E-01         7    XXXXXXX
   0.1350000E-01         7    XXXXXXX
   0.1386000E-01         6    XXXXXX
   0.1422000E-01         7    XXXXXXX
   0.1458000E-01         6    XXXXXX
   0.1494000E-01         5    XXXXX
   0.1530000E-01         3    XXX
   0.1566000E-01         4    XXXX
   0.1602000E-01         2    XX
   0.1638000E-01         2    XX
   0.1674000E-01         0
   0.1710000E-01         2    XX
0                       75


      MIN             MAX           RANGE            MEAN          MEDIAN        VARIANCE

   0.1007158E-01  0.1721391E-01  0.7142325E-02  0.1368655E-01  0.1367280E-01  0.2417719E-
05

1   TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0  HISTOGRAM FOR VARIABLE NO. 10     LOGSTUDENT DISTRIBUTION

     MIDPOINT          FREQ.

   0.1150000E-04         1    X
   0.3450000E-04         8    XXXXXXXX
   0.5750000E-04        11    XXXXXXXXXXX
   0.8050000E-04        11    XXXXXXXXXXX
   0.1035000E-03        11    XXXXXXXXXXX
   0.1265000E-03         7    XXXXXXX
   0.1495000E-03         6    XXXXXX
   0.1725000E-03         4    XXXX
   0.1955000E-03         4    XXXX
   0.2185000E-03         2    XX
   0.2415000E-03         3    XXX
   0.2645000E-03         1    X
   0.2875000E-03         1    X
   0.3105000E-03         1    X
   0.3335000E-03         1    X
   0.3565000E-03         1    X
   0.3795000E-03         0
   0.4025000E-03         0
   0.4255000E-03         0
```

Information Only

```
   0.4485000E-03          1    X
   0.4715000E-03          1    X
0                        75


      MIN             MAX           RANGE           MEAN          MEDIAN        VARIANCE

   0.1923442E-04  0.4820354E-03  0.4628009E-03  0.1318590E-03  0.1050380E-03  0.8770832E-
08

1TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RAW DATA
PAGE   1
0    1  1.0000
0    2 -0.0824  1.0000
0    3 -0.9862  0.1008  1.0000
0    4 -0.0204  0.0413  0.0277  1.0000
0    5  0.0053 -0.4366 -0.0152 -0.0790  1.0000
0    6  0.0012 -0.0119  0.0050 -0.5145 -0.0532  1.0000
0    7  0.0124 -0.0699 -0.0364  0.0253  0.0709 -0.0287  1.0000
0    8  0.0165 -0.0638 -0.0153 -0.1051 -0.0066  0.0408 -0.4618  1.0000
0    9  0.0038  0.0946  0.0186  0.0592  0.0411 -0.0023 -0.4791 -0.4939  1.0000
0   10  0.0327  0.0277 -0.0465  0.0495  0.0249 -0.0268 -0.0895  0.0478  0.0176  1.0000
0           1       2       3       4       5       6       7       8       9      10
0VARIABLES
1TITLE SDB: wipp::wipp_copy    Calc: PRELHS       Ver: ING6.4   02/13/96 13:26:27
0CORRELATIONS AMONG INPUT VARIABLES CREATED BY THE LATIN HYPERCUBE SAMPLE FOR RANK DATA
PAGE   1
0    1  1.0000
0    2  0.0249  1.0000
0    3 -0.9991 -0.0231  1.0000
0    4 -0.0478  0.0054  0.0468  1.0000
0    5 -0.0124 -0.9477  0.0108 -0.0232  1.0000
0    6 -0.0009 -0.0100  0.0053 -0.8032  0.0337  1.0000
0    7  0.0576  0.1072 -0.0578  0.0183 -0.1086 -0.0304  1.0000
0    8  0.0296 -0.0774 -0.0290  0.0096  0.0868  0.0048 -0.4666  1.0000
0    9 -0.0293  0.0053  0.0298  0.0341 -0.0144 -0.0239 -0.4819 -0.4549  1.0000
0   10 -0.0034 -0.0301  0.0048  0.0149  0.0431 -0.0327 -0.0128 -0.0103  0.0197  1.0000
0           1       2       3       4       5       6       7       8       9      10
0VARIABLES
```

Information Only