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by

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IN THE TRAC-P STANDARD TEST MATRIX**

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A DESCRIPTION OF THE EXPANDED TEST PROBLEMS IN THE TRAC-P STANDARD TEST MATRIX

ABSTRACT

This report describes the expanded set of test problems that were created to augment the existing Transient Reactor Analysis Code (TRAC)-P standard matrix of test problems. The expanded test problems were created to support the TRAC-P modernization effort. In most cases, these test problems were modified or expanded versions of problems in the TRAC Standard Test Matrix. A problem description is included for each problem added to the Standard Test Matrix. In this description, the details regarding modifications of the original test problem are included, as well as the observed problem results. This expanded test set will be used to verify that the predicted results for the modernized version of TRAC-M/f90 are "null" relative to the archival version of TRAC-P/MOD2 (Ver. 5.4.25), the latter being the base version on which work on the modernized code began. The problems described in this document increase the percentage of executable source coding that is activated when the Standard Test Matrix is run from 71% to 83.5%. A brief review of the characteristics of the portions of the source code that are not activated when running the expanded Standard Test Set also is provided. With a few exceptions, we have concluded that the cost to increase the fraction of coding activated by the Standard Test Set further is high relative to the increased coverage that can be attained. Therefore, we recommend that this activity be concluded.

1. INTRODUCTION

To support the modernization effort for the pressurized water reactor (PWR) version of the Transient Reactor Analysis Code (TRAC)-P, the TRAC-P Standard Test Matrix has been expanded. The current Standard Test Matrix contains 42 problems that are described in Ref. 1. A primary use of the current Standard Test Matrix is to verify that the results predicted by the modernized Fortran90 (f90) TRAC (TRAC-M/f90) are "null" relative to TRAC-P/MOD2, Ver. 5.4.25, the base code from which the TRAC-M/f90 derives. The results of the base and modernized code are declared to be null if the predicted results are identical. The null success metric is the primary success metric for modernization of TRAC-P. If the null success metric is to be meaningful, the test problems used to determine nullness must activate a high percentage of the lines of source code in both TRAC-P/MOD2, Ver. 5.4.25 and TRAC-M/f90.

As we began the enhancement of the Standard Test Matrix, 71% of the executable lines of source coding in TRAC-P/MOD2, Ver. 5.4.25 were activated collectively by the problems in the Standard Test Matrix. This was deemed to be inadequate coverage of TRAC-P/MOD2, Ver. 5.4.25 for validating, i.e., null testing, the modernized code. Therefore, an effort was made to expand the problem set in the Standard Test Matrix to provide increased null testing.

PureCoverage[®] software was used to determine the lines of coding exercised by the Standard Test Matrix and the expanded test matrix. PureCoverage is a software development tool that provides coverage statistics, i.e., lines of coding exercised on a subroutine basis and a line-by-line basis. This is a test coverage product intended to aid in code development and testing. PureCoverage provides some valuable information,² such as

1. identifying portions of coding that tests have not exercised,
2. accumulating coverage data over multiple runs, and
3. merging data from different programs sharing a common source code.

PureCoverage was used to identify areas in the code where further assessment was necessary. With study, important deficiencies that have been identified are code input options associated with unexercised coding, code bugs, dead coding, and unsupported coding.

We began with the Standard Test Matrix described in Ref. 1. This standard test set then was expanded to exercise the coding further in TRAC-P/MOD2, Ver. 5.4.25. Additional problems were created by modifying the current Standard Test Matrix or adding to the test set input decks created previously for other analyses.

This document is divided into four sections. The first section describes the expanded test matrix. The second section describes areas of the code where code bugs and dead coding were discovered. The next section lists coding that is no longer supported. We conclude with the characteristics of the remaining portions of the code, which are not tested by the expanded Standard Test Matrix.

2. PROBLEM DESCRIPTION

The following is the list of problems added to the test set. These problems were created for other analytical or code development efforts at Los Alamos National Laboratory (LANL) but were not included in the Standard Test Matrix. We have determined that these problems increase the coverage of the code by exercising previously unexercised coding. We recommend that these problems be added to the Standard Test Matrix.

- short and long problem sets in English units (ptracc.units and ptraccl.units);
- radiation problems (tracinG and tracinH);

- LOFTK (loftk and loftkr);
- AP600 (sbinss.14, sbintr200, and sgcasea);
- D2O problem (mss2.d2o);
- ZIONPWR modified;
- FLECHT-SEASET;
- CCTF (cctf14 and cctf54);
- Akimoto (inmist.new, inplug.new, and intrans.new);
- H. B. Robinson (inrenode.61); and
- FXKILL (errinopts, errinteger, erreval, errcomma, errcomment, errelev, errduelev, errcont, errrend, errfill, errrepeat, and errrepeat1).

A description of each of these problems follows.

2.1. Short and Long Problem Sets in English Units

The short and long problem sets in English units comprised the following problems. The problems in the short problem set are drain, hcond1, hcond2, hcond3, hcond4, hcond5, marvik, mscl, mscv, msp2, mspl, mspv, msr2, msrl, msrv, mss2, mssl, mssv, mst2, mstl, mstv, msv2, msvv, rod2, tindwn, tinup, utube, ZIONPWR, w4loopn, and w4loopnr. For a detailed description of these problems, see Ref. 1. However, the problems differ from those described in Ref. 1 because these problems exercise the English unit option for iogrf, iolab, and ioout in the namelist. The long problem set in English units is made up of loftl26n and loftl26rn. For a complete description of these problems, see Ref. 1; the only modification to these problem descriptions is the use of the English unit option for the outputs in the trcgrf, trcout, and trcmsg files.

2.2. Radiation Test Problems

The radiation test problems G and H were used to test the radiation enclosure model.³ These problems were created to test the implementation of the radiation heat-transfer model into TRAC-P/MOD2. A total of nine problems for code verification are described in detail in Ref. 3. Problems G and H test the effects of convection, and a participating medium is included.

In problem G there are two enclosures formed by three concentric cylinders. The participating medium is steam at 1 atm and 373.15 K. This problem was added to the expanded test matrix because it exercises subroutines "sfa22v" and "ssl22v". The upper-level tree diagram of subroutines added for the radiation enclosure model is

shown on page 15 of Ref. 3 and includes radems, radmap, radfp, radsol, radchyd, and radchts. These subroutines are exercised by all of the radiation test problems.

Problem H consists of four surfaces of an enclosure that is infinitely long and has a square cross section. The participating medium again is steam at 1 atm and 373.15 K. Problem H was included in the expanded test set because it exercises subroutines "sfa44a" and "ssl44a".

The remaining seven problems were not added to the expanded test problem set because they do not expand the coverage of TRAC-P/MOD2. These problems exercise the upper-level subroutines shown on page 15 of Ref. 3 but do not improve the code coverage.

2.3. AP600 Plant Models

The problems sbinss.14 and sbintr200 are two-theta core Westinghouse AP600 PWR plant models. These decks test small-break (SB) loss-of-coolant-accidents (LOCAs) and intermediate-break (IB) LOCAs. Problem sbinss.14 is a steady-state test, whereas sbintr200 is a combined transient restart model for the SBLOCA.

The sgcasea is a stand-alone AP-600 steam generator model that uses the time-dependent fill boundary option. In the standard problem matrix, the table input was not exercised in numerous components. The coding for reading the table input was repeated in numerous components, and this problem inputs the fill boundary tables in the form of a control block.

2.4. Heavy-Water Coolant Model

The problem mss2.d2o uses heavy-water fluid properties, which are initiated in the input deck by selecting id20 = 1. This input deck consists of three components: two breaks and a pipe. The pipe is made up of 22 cells and is a mirror image, with a pressure boundary condition on each end.

Numerous TRAC-P/MOD2 subroutines are used specifically for an analysis with heavy water. Without this problem, the following subroutines are not exercised: thermd, seteod, viscvd, fpropd, rholid, sattmd, cpvv1d, satded, satprd, labeld, thcl, viscl, and cplld. These subroutines account for 454 lines of coding, and adding the mss2.d20 problem exercises 65% of the heavy-water-related lines of coding.

2.5. ZIONPWR Modified Problem

A modified ZIONPWR input deck named ZIONPWRN is similar to the ZIONPWR included in the Standard Test Matrix.¹ The ZIONPWRN deck is a Zion PWR core containing a simple pump and valve model. For further details regarding the ZIONPWRN input deck, see Section 2.10 of Ref. 1. The significant difference between this deck and the deck in the Standard Test Matrix is the expansion of the control system. In this problem, the Zion PWR plant model is used to test all aspects of the control-system signal variables, control blocks, and trips. There are 132 control

blocks added to the ZIONPWR standard test problem to evaluate 66 different control-block operations and to evaluate both the user-specified and internal TRAC-P/MOD2 initialization procedures.¹ There are an additional nine trips that test all trip-related features one or more times. The control-procedure signal variables and control blocks are in this test problem for the purpose of testing whether they are initialized and evaluated correctly. This problem improves the coverage of the conblk subroutine significantly by exercising an additional 200 lines of coding.

2.6. FLECHT-SEASET

The Full-Length Emergency Cooling Heat Transfer-Separate Effects and Systems Effects Test (FLECHT-SEASET) is a forced reflood for a 17 x 17 unblocked rod bundle.⁴ The test number for the FLECHT-SEASET problem is 31504. The FLECHT-SEASET problem exercises coding that models the reflood heat-transfer process.

2.7. CCTF

Two problems, run 14 and run 54, have been added to the expanded test matrix from the Cylindrical Core Test Facility (CCTF) and are integral effect test problems.⁵ These problems are multiple tests of refill and reflood phases of LBLOCAs.⁴

The cctf14 problem is from the CCTF run 14 reflood case. The model in this input deck consist of six components, which include a fill, inlet pipe, vessel, outlet pipe, break, and heat structure. The vessel is one dimensional (1D).

The cctf54 problem was used for the analysis of the CCTF run 54. In this problem, there is a vessel nodalized into 2 azimuthal zones, 4 radial rings, and 16 axial levels. This deck is a two-loop model, where one of the loops is broken and each loop consists of a vessel, steam generator, and emergency core cooling (ECC) injection.

2.8. AKIMOTO Test Problems

Inmist.new, inplug.new, and intrans.new are models of the Akimoto Test Facility. At this facility, the condensation of steam on subcooled water in a horizontal test section of a rectangular cross section was studied.⁶ The inmist.new problem tests the TRAC-P condensation model,⁵ which predicts the rate of condensation for mist flow regimes. The problem inplug.new models a plug of water in a horizontal channel. The intrans.new problem examines the flow rate in a stable flow region; as the flow rate is increased, the flow starts to show oscillations. This models the oscillatory flow that occurs during the transition. The input decks for these three problems are modeled with two tee components, one for the test section and one modeling the outlet tank, a break, and three fill components. These three input decks were created by LANL for the Akimoto Condensation Experiments and are described further in Ref. 6.

2.9. H. B. ROBINSON MODEL

Inrenode.61 is a coarsely noded H. B. Robinson plant model, which consists of a two-dimensional (2D) reactor vessel. In the vessel there are two heat structures, a powered rod and an unpowered slab. The key feature of this model is the use of two-phase homologous pump curves. This problem further exercises the pump component.

2.10. FXKILL Update Test Problems

The input decks errinopts, errinteger, erreal, errcomma, errcomment, errelev, errduelev, errcont, errrend, errfill, errrepeat, and errrepeat1 were created to test for user input errors. These problems can be used only when the update fxkill is added to the archival code. Table 1 lists the problem names, input error, and results.

2.11. Modified Test Problems

To exercise the code further, the problems in the standard matrix and those described in Sections 2.1 to 2.10 have been modified slightly. Areas of the code that have not been tested sufficiently include the decay models, invalid or inconsistent user input, the heat-structure and vessel components, and table inputs. The following problems were created from one of the Standard Test Matrix problems or from one of the problems described above. The base deck is specified, and the changes to the deck are noted in the explanation of the problem.

The subroutine "namlst" performs input data checks on all of the namelist variables. This subroutine contained 511 lines of untested coding after running the standard test problems. To test this section of coding, a few problems were created with intentional namelist errors. There are 7 problems that improve the coverage of the "namlst" subroutine from 25% to 86%, or over 400 lines of coding. These problems exercise the error messages that correspond to improper input in the namelist. A description of the problems, including the errors introduced and the warning messages, is shown in Table 2. For each invalid namelist input, an out-of-range value output is produced as a warning message shown in column three of Table 2.

These problems represent simple tests. A large portion of the unexercised TRAC-PF1/MOD2 is from unexercised warning messages, which are displayed and exercised when a user inputs invalid or inconsistent data. In some cases we have tried to exercise this coding, but overall, this coding makes up the majority of the still unexercised coding.

The subroutine "decay" was not exercised by the original test problems. A few problems were created to exercise this subroutine. Table 3 lists the decay problems and the options selected for the each problem. A problem that uses the ANS-79 decay-heat standard and a problem using the ANS-79 decay-heat standard with heavy element decay were created.⁷ When these input decks were run, the decay

TABLE 1
FXKILL ERROR-CHECKING DECKS

Problem Name	Input Options	Results
errinopts	Misspelled namelist variable ikfac	Incorrect variable name: core dump
errinteger	Main data card-4 "stdyst" was input as real instead of integer	Error not detected
erreal	Main data card-5 "epso" was input as integer instead of real	Error not detected
errcomma	Heat-transfer coefficient on pipe component was input as 0,0 not 0.0	*preinp* input error detected in tracin. card number 127
errcomment	On main-cell array "vol" used vol *, not * vol *	*preinp* input error detected in tracin. card no. 139, *load* input error detected, rest of input skipped
errelev	On FILL entered 6.0 instead of 7.0 for "felv"	No error found on reading input, but trcout shows felv = 6.0 and grav = 2.0 (should be 1.0)
errduelev	On FILL entered 8.0 instead of 7.0 for "felv" (same as cell-1, Pipe)	No error found on reading input, but trcout shows felv = 8.0 and grav = 0.0 on cell-1 Pipe (should be 1.0)
errcont	On ARRAY entered "c" instead of "s" for continuation line	*preinp* input error detected in tracin. card number 142
errend	On ARRAY info line did not input an "e" to indicate "end of array"	No differences, TRAC did not catch error
errfill	On ARRAY info line input 2 "f" instead of 1 to indicate "fill array"	No differences, TRAC did not catch error
errrepeat	On ARRAY info line input less values then were needed	Error was not detected
errrepeat1	On ARRAY info line input 2 "r" instead of 1 to indicate "repeat values"	*preinp* input error detected in tracin. card number 141 rest of component skipped

TABLE 2
NAMELIST WARNING MESSAGE PROBLEMS

Problem Name	Input Options	Results
namelist.a	<ul style="list-style-type: none"> • istopt, fdhfl, icflow = 3 • dtstrt = -2.0 • iadded, icdelt, = -1 • idiag, igas = 5 • iconht, idiags, ielv, ieeeg = 2 • invan = 1 	<ul style="list-style-type: none"> • Warning message for each of the variables • *namlst* <i>variable</i> has out-of-range value
namelist.b	<ul style="list-style-type: none"> • istopt = 1 • alp = 3 	<ul style="list-style-type: none"> • Warning message • *namlst* <i>variable</i> has out-of-range value
namelist.c	<ul style="list-style-type: none"> • htcwl = -1.0 • iconht = 1 	<ul style="list-style-type: none"> • Warning message • *namlst* <i>variable</i> has out-of-range value
namelist.d	<ul style="list-style-type: none"> • cfz3, hd3, hstn, qppp, tw, htcwv = -1.0 • igeom3, iofftk, ikfac, iogrf, ioinp, iolab, ipowr = 2 • iblaus, nfrc1, nfrc3, nifsh = 3 • imfr, ihor, inlab = 4 	<ul style="list-style-type: none"> • Warning message • *namlst* <i>variable</i> has out-of-range value
namelist.e	<ul style="list-style-type: none"> • ioout, ireset, isolcn, isscv, ithd, iunout, levstg, mhtli, mhtlo, mhtvi, mhtvo, mwfl, mwfv, newrfd = 2 • istopt, ndia1 = 3 • nencl, iunlab = -1 	<ul style="list-style-type: none"> • Warning message • *namlst* <i>variable</i> has out-of-range value
namelist.f	<ul style="list-style-type: none"> • nhtstr, ccif, nlt = -1 • nifsh, ieos = 1 • noair, nrslv = 2 • nsend = -2 • nosets = 3 	<ul style="list-style-type: none"> • Warning message • *namlst* <i>variable</i> has out-of-range value
namelist.g	<ul style="list-style-type: none"> • nsdl, nspl = -1 • tpowr, timdu = -1 • nsdu, nspu, timdl = -2 • nvgrav = 2 • idiag = 3 	<ul style="list-style-type: none"> • Warning message • *namlst* <i>variable</i> has out-of-range value

TABLE 3
DECAY PROBLEMS

Problem Name (base deck)	Options Tested	Results
decay.1	<ul style="list-style-type: none"> • ndhx = 69 • irpwty = 11 • nsend = 3 	Exercise subroutine decay
decay.2	<ul style="list-style-type: none"> • ndhx = 71 • irpwty = 11 	Exercise subroutine decay
decay.3	<ul style="list-style-type: none"> • ipwrad = 1 • nfbpwt = 4 	<ul style="list-style-type: none"> • Exercise subroutine rrod2 • Core dump
decay.4	<ul style="list-style-type: none"> • ipwrad = 1 	<ul style="list-style-type: none"> • Exercise subroutines rrod1, rrod2, rhtstr • Core dump
decay.5	<ul style="list-style-type: none"> • irpwty = 11 • nhist = 1 	Exercise subroutine rrod2
decay.6	<ul style="list-style-type: none"> • iprwty = 11 • nhist = 1 • ndhx = -11 	Exercise subroutine rrod2
decay.7	<ul style="list-style-type: none"> • irpwty = 11 • nhist = 2 • ndhx = -11 	Exercise subroutine rrod2
decay.8	<ul style="list-style-type: none"> • irpwty = 11 • nhist = 2 • ndhx = 69 	Exercise subroutine rrod2

subroutine was completely exercised. Including these problems in the expanded test matrix improved the coverage in "rrod2" and completely tested subroutine "decay".

The base deck for the decay model problems is the modified ZION-PWR plant model. The first problem, decay.1, uses the ANS-79 decay-heat standard by assigning ndhx = 69 and irpwty = 11. The variable ndhx is the number of decay-heat groups, and irpwty is the option for neutronic point-reactor kinetics. The second problem assigns ndhx = 71, which defines the ANS-79 decay-heat standard plus heavy-element decay for ^{239}U and ^{239}Np . A third input deck was created to test the 2D axial power-shape table setting ipwrad = 1, and the various options for nfbpwt were exercised. The variable nfbpwt is the option for replacing the radial, axial, and/or the horizontal plane power shapes with another user-defined shape volume averaging the reactivity feedback parameter over the core region.

The variable `nhist` allows the user three options for power history. Option zero is selected when the user inputs the delayed neutron precursor concentration (`cdgn`) and the decay-heat precursor concentration (`cdhn`). Option `nhist = 0` is the selection used in all Standard Test Matrix problems. To exercise the code further, the other options for `nhist` are input. When `nhist` is assigned a value of 1, `cdgn` and `cdhn` are calculated assuming an infinite history of operation at the user input power level of `rpowri`. If `nhist` is ≥ 2 , a power history table will be input with the number of data pairs being the value of `nhist`; this is then used to calculate `cdgn` and `cdhn`.

Problems `decay.5`, `decay.6`, `decay.7`, and `decay.8` test the `nhist` options with a variety of other variables to exercise subroutine "rrod2".

Two problems were created from the base deck of `w4loopn` from the Standard Test Matrix to test the subroutine "dtdiag". The subroutine "dtdiag" is a timestep-size diagnostic used for the `trcmsg` file. The first deck assigns the namelist variables `tsdls = 1` and `tsdus = 20`. The second problem assigns `tsdlt = 1.0` and `tsdut = 200.0`. These two problems improve the coverage of `dtdiag` from 0% to 68%. Table 4 lists the problem names and the input options for the timestep diagnostic problems.

Numerous problems were created to test the heat-structure and vessel components further. Table 5 lists the problems, options, and results of the new test problems. Problems `core.1`, `core.2`, and `core.3` test the 2D power-shape option `ipwrad = 1` with various other parameters, as listed in Table 5. The variable `ipwdep` is the power-shape table-dependence option. This option is set to -1, which exercises the power-shape table dependence defined for each node by a signal-variable or control-block identification number. The node power density and the resulting power shape are not normalized by TRAC-P/MOD2 to a spatially averaged value of unity in problems `core.2` and `core.3`. In problem `core.1`, `ipwdep` is set to 1, which exercises the power-shape table dependence defined for each node by a signal-variable or control-block identification number. The node power density and the resulting power shape are normalized by TRAC-P/MOD2 to a spatially averaged value of unity. Also, in problems `core.2` and `core.3`, the option `nrpwr` is set to 2, which defines the number of rod axial or slab thickness locations for the 2D axial-r or axial-x power shape. In

TABLE 4
TIMESTEP DIAGNOSTIC PROBLEMS

Problem Name	Input Options	Results
<code>dtdiag.1</code>	<ul style="list-style-type: none"> • <code>tsdls = 1</code> • <code>tsdus = 20</code> 	Exercise subroutine <code>dtdiag</code>
<code>dtdiag.2</code>	<ul style="list-style-type: none"> • <code>tsdlt = 1.0</code> • <code>tsdut = 200.0</code> 	Exercise subroutine <code>dtdiag</code>

TABLE 5
CORE PROBLEMS

Problem Name	Options Tested	Results
core.1	<ul style="list-style-type: none"> • ipwrad = 1 • ipwdep = 1 • nrpwr = 2 	Exercise subroutines irod, core1, and rrod2
core.2	<ul style="list-style-type: none"> • ipwdep = -1 • nrpwr = 2 • ipwrad = 1 	Exercise subroutines irod, core1
core.3	<ul style="list-style-type: none"> • ipdwep = -1 • nfbpwt = 1 	Exercise subroutines rrod2

problems core.1 and core.2, the ipwrad option, which is the spatial power shape, is assigned a value of 1, which uses a 2D axial-r or axial-x power-shape table. These problems exercise subroutines "irod", "core1", and "rrod2". The problems shown in Table 5 are based on the ZIONPWR test problem, with the key differences in the decks shown in the Options Tested column.

The 13 heat-structure problems test a variety of options in the heat-structure components that had not been exercised. These options include invalid input, hot patches, multiple 1D hydraulic component coupling, adiabatic boundary conditions, and external thermocouples. The majority of these problems are based on the ZIONPWR, except where noted in Table 6 (the problem is described in Ref. 1). A listing of the heat-structure problems and the options exercised, along with the results, is shown in Table 6.

Heatstructure.1 is from the ZIONPWR problem. In this problem, the reflood option is not activated by assigning newrfd = 0, but the hotpatch is initiated with ipatch = 1. The goal was to confirm that the proper error was displayed. In Heatstructure.2, the reflood model was turned on in the namelist options (newrfd = 1). This problem is based on cctf54 and tests the coding for the hotpatch modeling. Problem heatstructure.4 turns on the namelist option ithd, which allows the input of heat-transfer diameters through variables hdri and hdro for heat-structure components. Problem heatstructure.10 turns on the heat-structure option for multiple 1D component coupling. This option was not exercised in the other test problems. Problem heatstructure.11 sets ittc = 1, which is the specification of an external thermocouple on the ROD or SLAB element surface. In addition, the tc array card 48 of the heat-structure component is added.

Problems heatstructure.3, 5, 6, 7, 8, 9, and 12 test input error and warning message coding. These problems intentionally input improper data to check the warning messages.

TABLE 6
HEAT-STRUCTURE PROBLEMS

Problem Name	Options Selected	Results
heatstructure.1	<ul style="list-style-type: none"> • newrfd = 0 • ipatch = 1 • slab 	<ul style="list-style-type: none"> • Error messages • *rhtstr* newrfd.eq.1 models hot patches
heatstructure.2 cctf54	<ul style="list-style-type: none"> • newrfd = 1 • ipatch = 1 • slab 	Hot-patch modeling
heatstructure.3	<ul style="list-style-type: none"> • idbci = 0 • idbco = 0 	<ul style="list-style-type: none"> • Warning • *rhstr* either idbco or idbci must be 2
heatstructure.4	<ul style="list-style-type: none"> • hdri = 0 • idbci = 0 • idbco = 2 • ithd = 1 	Namelist option to input heat-transfer diameters through variable HDRI
heatstructure.5	<ul style="list-style-type: none"> • idbco = 0 • idbci = 2 • hdri = 0.000 • ithd = 1 	<ul style="list-style-type: none"> • Warning • *rhstr* hdri must be .gt. 0 • When ithd = 1 and idbci = 2, then hdri = 0.000 must be >0
heatstructure.6	<ul style="list-style-type: none"> • hdro = 0 • idbci = 0 • idbco = 2 • ithd = 1 	<ul style="list-style-type: none"> • Warning • *rhstr* hdro must be >0
heatstructure.7	nodes = 28	<ul style="list-style-type: none"> • Warning • *rhstr* dimension nzfmx .lt. nodes
heatstructure.8	<ul style="list-style-type: none"> • nzmax = 250 • ncrz = 400 	<ul style="list-style-type: none"> • Warning • *rhstr* dimension nzfmx .lt. ncrz+1
heatstructure.9	<ul style="list-style-type: none"> • q235 = 0 • q239 = 0 • q238 = 0 • qavg = 0 • r239pf = 0 • fishpi = -.1 • rans = -.1 	<ul style="list-style-type: none"> • *rrod1 bad input q235 • *rrod1 bad input q238 • *rrod1 bad input q239 • *rrod1 bad input qavg • *rhtstr* q235 cannot be.le.zero • *rhtstr* q238 cannot be.le.zero • *rhtstr* q239 cannot be.le.zero • *rhtstr* qavg cannot be.le.zero • *rhtstr* r239pf cannot be.le.zero • *rhtstr* rans cannot be.le.zero • *rhtstr* fishpi cannot be.le.zero
heatstructure.10	mld = 1	Option for multiple 1D hydraulic component coupling
heatstructure.11	<ul style="list-style-type: none"> • ittc = 1 • array tc 	Model thermocouple on slab or rod option
heatstructure.12	<ul style="list-style-type: none"> • mhtli = 1 • mhtlo = 1 • mhtvi = 1 • mhtvo = 1 • htmi = 1.4000 • htmlo = 1.4000 	<ul style="list-style-type: none"> • Warning • *rhtstr* htmi is outside range (0.9,1.1) • *rhtstr* htmlo is outside range (0.9,1.1)
heatstructure.13	nencl = 1	Warning

There was some concern with the control system regarding the ability of the test problems to exercise. A detailed investigation of the control system resulted in the creation of five short problems.

We examined each of the subroutines included in the control system and found that the vast majority of the unexercised coding in these subroutines is for invalid input tests and warning messages. In the control system subroutines, there were approximately 700 lines of coding for valid input data tests and the corresponding user warning messages.

To improve the coverage of subroutine "conblk", five short problems were created. These problems test a few of the invalid user input warning messages in conblk. Problem conblock.5 tests coding, which evaluates xout when xtau1 and xtau2 are complex valued roots. Table 7 lists the problem names, the input options, and the results of the problems.

A significant portion of the unexercised coding tests the input and if the input is invalid displays a warning message. Ten test problems with invalid input were created to improve the code coverage in subroutine "input" and subroutine "rvssl". Table 8 lists the problem name, the input options, and the problem results.

The namelist options mwfl and mwfv allow input of the wall-to-liquid wall-friction multiplicative design factors and the wall-to-gas wall-friction multiplicative design factors, respectively. Initiating this option requires that mwfl = 1 or mwfv = 1 in the namelist; additional array input is required by the pipe, pump, tee, valve, and vessel components. A problem was created to exercise the coding for mwfl = 1 and mwfv = 1. The problem name, input options, and results are shown in Table 9. The problems in Table 9 are based on utube3d, which is described in Ref. 1. The modifications to the problem are shown in Table 9 in the input options column. The problems mwfl and mwfv further exercise the subroutine "rvssl".

TABLE 7
CONBLK TEST PROBLEMS

Problem Name	Input Options	Results
conblock.1	icbn = 71	*conblk* bad cntl-block operation number
conblock.2	cbcon2 = -4.000	*conblk* invalid dead function constants
conblock.3	cbcon1 = 1.000e-20	Exercise conblk subroutine
conblock.4	cbgain = 0.000	Exercise conblk subroutine
conblock.5	<ul style="list-style-type: none"> • cbcon1 = 1.000e-10 • cbcon2 = 5.500e-21 	Exercise conblk subroutine

TABLE 8
INPUT ERROR PROBLEMS

Problem Name	Input Options	Results
input.1	no namelist data	*input* inopts namelist data not found
input.2	nccfl = 15	*input* nccfl is out of bounds
input.3	matb = 45	*input* illegal material ID number
input.4	tp = -0.0762	*load* not enough data to fill array
input.5	isolut = 0	*input* isolut = 0 instead of 1
vessel.1	ivssbf = 1	*rvssl* illegal value for ivssbf
vessel.2	<ul style="list-style-type: none"> • iconc = 1 • isolut = 0 	*rcomp* iconc and isolut are inconsistent
vessel.3	nsgrid = -1	*rvssl* nsgrid must .ge.0
vessel.4	<ul style="list-style-type: none"> • nsgrid = 1 • newrfd = 0 	*rvssl* newrfd = 1 to model spacer grids
vessel.5	iext = 1	Core dump

TABLE 9
MWFL AND MWFV PROBLEMS

Problem Name	Input Options	Results
mwfl	<ul style="list-style-type: none"> • mwfl = 1 • array wfmfl 	Exercise subroutine rvssl
mwfv	<ul style="list-style-type: none"> • mwfv = 1 • array wfmfv 	Exercise subroutine rvssl

In subroutine "rvssl", there were various areas of coding that were not exercised. Problems to exercise rvssl further are shown in Table 10. Problem cfz3g is based on the utube3d problem, and rvssl is based on the msr2 problem described in Ref. 1.

Problem rvssl.2 is based on utube3d, which is described in Ref. 1. There is an option in the namelist variables to input the data for certain parameters only once in the namelist. Default values can be assigned to alp, cfz3, hd3, hstn, p, pa, qppp, vl, vv, tv, and tl when istopt is 1 or 2. Istopt is set to 2 so that the input data cards for the arrays above remain but are overridden by the namelist values.

Problems napcss, napcss.1, and napcss.2 are based on the loftk input deck described in Ref. 1. The parameter napcss is the controller type used in the CSS controller card. Various controller types are not exercised in the Standard Test Matrix. To exercise

TABLE 10
RVSSL PROBLEMS

Problem Name	Input Options	Results
cfz3g	<ul style="list-style-type: none"> • istopt = 2 • cfz3 = 2.2 • nfrc3 = 2 	Exercise subroutine rvssl
rvssl	<ul style="list-style-type: none"> • gytc = 3.0 • gxrc = 4.0 • igeom = 0 • ntsx = 3 	Exercise subroutine rvssl *Fatal Error*
rvssl.2	<ul style="list-style-type: none"> • istopt = 2 • hd3, alp, vv, vl, tv, tl, p, pa input in namelist 	Exercise subroutine rvssl
rvssl.3	nvent = 1	Exercise subroutine rvssl
napcss	napcss = 7, 8, 10, 12	Exercise subroutine rvssl
napcss.1	napcss = 9, 14	Exercise subroutine rvssl
napcss.2	napcss = 6, 13, 14	Exercise subroutine rvssl

the coding in subroutine "rvssl", the values of the variable napcss are modified, as shown in Table 10.

The subroutines "femom", "femomx", "femomy", and "femomz" contained a large portion of unexercised coding. An investigation to exercise this coding resulted in the creation of one problem and the discovery of numerous lines of dead coding, which are described in the Code Issues section of this document. Table 11 lists the femom problems, input options, and results. The problem in Table 11 is based on the msr2 problem, which is described in Ref. 1.

There is an option in the pipe and tee components for allowing power to the fluid and an option in the pump to allow wall heat transfer. In the Standard Test Matrix,

TABLE 11
FEMOM PROBLEM

Problem Name	Input Options	Results
femom	<ul style="list-style-type: none"> • ivssbf = 2 • igeom = 0 	Exercise TRAC-P/MOD2

these options are not adequately tested. The power-to-the-wall option in the pump component was not sufficiently exercised. The table input for these options is a key feature that must be exercised for the pipe, pump, and tee components. Initiating this option then requires the user to input various cards and arrays for the components, which further exercises the subroutines.

Four problems were created to exercise the subroutines "rtee", "rpipe", and "rpump". The problem name, options tested, and results are listed in Table 12; these problems are based on the inrenode.61 problem described in Section 2.9 of this document. These problems improve the coverage of the pipe, pump, and tee components and test the qppp component options.

TABLE 12
QPPP PROBLEMS

Problem Name	Input Options	Results
Tee.1	<ul style="list-style-type: none"> • ipow1 = 1 • npwtb1 = 2 • npwrf1 = 2 • nqptb1 = 2 • nqprf1 = 2 • qp1n1 = 1.0 • additional arrays powrf1, qp3tb1, and qp3rf1 	Exercise qppp option on primary side in subroutine rtee
Tee.2	<ul style="list-style-type: none"> • ipow2 = 1 • npwtb2 = 2 • npwrf2 = 2 • nqptb2 = 2 • nqprf2 = 2 • qp1n2 = 1.0 • additional arrays powrf2, qp3tb2, and qp3rf2 	Exercise qppp options on secondary side in subroutine rtee
Pipe	<ul style="list-style-type: none"> • ipow = 1 • npowtb = 2 • npowrf = 2 • arrays qp3tb and qp3rf 	Exercise subroutine rpipe
Pump	<ul style="list-style-type: none"> • nqp3rf = 2 • array qf3rt 	Exercise subroutine rpump

3. CODE ISSUES

During this investigation, code bugs and areas of dead coding were discovered. To expand the coverage of the code, subroutines that contained large sections of untouched coding were identified; problems then were created to meet the conditions that should exercise the coding. In a few instances, the response of the code to input decks was not as expected, which led to the discovery of code bugs.

One of these cases was unexercised coding for a three-dimensional (3D) vessel undergoing reflood. In two subroutines, "htif" and "cif3", a conditional of these options had to be met to exercise large sections of coding. Various input decks were added to the expanded test set to exercise these coding sections, such as FLECHT-SEASET and cctf54. However, the problems were unsuccessful in exercising these sections of coding. It was determined that both of these subroutines contained a code bug that has been resolved in Ver. 5.4.29+ of TRAC-P/MOD2. This code bug was brought to the attention of the TRAC-M/f90 development team, and flags were placed in the code to ensure that the bug would be fixed later.

Areas of dead and developer coding exist in TRAC-P/MOD2, Ver. 5.4.25, which were identified during this investigation. Dead coding is code that cannot be exercised through input deck options. In some situations, the dead coding can be considered developer coding. The developer coding was added to TRAC-P/MOD2, Ver. 5.4.25 for the use of the code developers, but it is not an option for the users to initiate. This coding may be considered dead coding or developer coding; however, it is not coding that can be exercised without modifying the source code. Two areas of dead coding were found. One section was discovered in "femom" and another in the subroutines "sgeev", "hqr2t", "ortrant", and "balbakt". In addition to these two areas, many subroutines are platform dependent and are not called anywhere in TRAC-P/MOD2.

Over 100 lines of dead coding were found in the subroutine "femom". This coding is initiated with a test on a variable iepri. The variable iepri is fixed in the Ver. 5.4.25 coding. The only way to test this section of coding would be to modify the Ver. 5.4.25 source code. This item also has been brought to the attention of the TRAC-M/f90 development team, and flags were placed in the code to ensure that the dead coding will be fixed later.

In the subroutine "sgeev", there is a variable named job that must not be equal to zero to initiate calls to "hqr2t", "balbakt", "scopyt", "scopym", and "ortrant". The variable job is defined in the call to "sgeev" as zero, and therefore, these subroutines will not be called. The variable job is also used in "dgbsl" as a condition for calling "ddot". These unexercised subroutines account for 450 lines of coding.

Other sections of dead coding were found in subroutines "femomx", "femomy", "femomz", and "stbme3". In each of these subroutines, there are conditionals for igbcyt, igbcxr, and igbcz. The variables igbcxr and igbcyt always will be equal to zero, whereas igbcz can be equal to zero or one. In subroutines "femomx", "femomy",

"femomz", and "stbme3", there are 175 lines that can never be exercised because it is not possible for igbcyt or igbcxr to be any value but zero.

There are many platform-dependent subroutines that are seen by the PureCoverage software and compiled but are not called for certain platforms. These subroutines include "sgbfat", "sgbslt", and "clrint", which are replaced by the subroutines "dgbfa", "dgbsl", and "ipack", respectively, depending on the platform. The subroutines "sgbfat", "sgbslt", "isamaxt", and "clrint" are called for specific platforms but should not be counted in the coverage statistics. These four subroutines account for 145 lines of executable coding.

Many subroutines are included in the source coding but have no calls from any other subroutine in the code. The list of routines that have no calls in the code and a description of the routine are shown below:

- **vdpcss** defines the two signal variables for inlet and outlet pressure and defines the two control blocks for the subtract and pi controller needed to adjust flow resistance through the vessel.
- **ring0** initializes variables for the inner-ring radial boundary to allow more general loops.
- **unpkrit** unpacks data packed by packit.
- **rsperr** is a support routine for IBM.
- **switch** moves one level of vessel data starting at IADD1 to IADD2 and vice versa.
- **movlev** is called by the switch to copy n elements from array A to array B.
- **setic** is a routine that is not currently used.
- **modify** is the control program for the interactive modification capability.

These routines are not called and account for another 100 lines of executable coding.

Overall, the dead coding and code bugs account for a significant portion of unexercised coding. The items listed above account for 2.8% of TRAC-P/MOD2, Ver. 5.4.25.

4. UNSUPPORTED CODE

The archival version of TRAC-P/MOD2 contains models and components that are no longer supported. These components include the turbine, containment, and steam separator. A listing of the subroutines for unsupported coding is shown in Table 13, along with the number of lines of unexercised executable coding. The

TABLE 13
UNSUPPORTED TRAC-P/MOD2 CODING

Subroutine	Number of Unused Executable Code Lines
ssepor	303
rturb	189
sepdi	137
sgecot	96
returb	86
trpow	86
turb1	83
returb	86
sgefat	60
iturb	57
sgeflt	51
wturb	46
sepdx	35
igturb	34
turb3	22
loctrb	13
turb2	12
dturb	10
trbpre	68
trbpst	23
ctain1	3
ctain2	3
ctain3	3

subroutines in Table 13 account for 2.7% of the TRAC-P/MOD2, Ver. 5.4.25 executable coding.

Numerous subroutines contain conditional tests for types equal to either sepdh, ctainh, or turbh. The coding following these conditionals is not tested. The subroutines that contain unsupported coding include the following subroutines: tee1, tee2, tee3, rtee, icomp, ihpss1, dmpit, xtvd, outld, prep1d, post, rdcomp, rdrest, srt1p, tf1ds1, and tf1ds.

There are certainly numerous other subroutines that contain further unsupported coding and that have yet to be identified. Overall, the executable coding for the separator, containment, and turbine make up >3% of TRAC-P/MOD2, Ver. 5.4.25.

5. REMAINING CODE CHARACTERISTICS

In almost every subroutine containing unexercised coding, there are numerous warning messages. These messages account for approximately five lines of coding each. The number of unexercised messages is especially heavy in subroutines "rtee", "rpump", "rvlv", "rhstr", "rvssl", "rpipe", and "rfill". Each of these subroutines reads input data for specific TRAC-P/MOD2 components. Some warning messages are similar for each of these subroutines. Figure 1 is an example of the unexercised error message coding that is seen; this message is repeated in each of the previously mentioned subroutines. Figure 1 is extracted from subroutine "rvlve" from the PureCoverage file. The numbers in the left-hand column are the number of times the line has been executed; in this section of coding, the error message has not been hit, as indicated by the zeros in the left-hand column beside the coding.

In Appendix A, there is a listing of the PureCoverage results after running the Expanded Standard Test Matrix. In the PureCoverage file, the total number of executable lines of coding in each subroutine is shown, and the number of lines that

```

590 | if(lenvlt.le.lendim) go to 5
0 |   newlim=lenvlt+3
0 |   write(imout,3) lendim,lenvlt,newlim,newlim
0 |   write( iout,3) lendim,lenvlt,newlim,newlim
0 |   write( itty,3) lendim,lenvlt,newlim,newlim
|   3 format(/' current value of lendim ='i6,' and lenvlt ='i6/
|   1 ' increase lendim to'i6,' in blkdat and dimension',
|   2 ' vlt to'i6,' in genvlt')
0 |   jflag=1
0 |   call error(2,'rvlve* vlt size exceeds its limit',4)
590 | 5 continue

```

Fig. 1. Example of an error message seen throughout the TRAC-P/MOD2, Ver. 5.4.25 source coding. This coding is from subroutine "rvlve" and is in the format produced by PureCoverage.

are exercised, along with the percentage of the subroutine exercised, is listed. From a cursory examination of the results, it might be thought that significant gains could be made in some of the subroutines. At this point, we have concluded that the cost of increasing the code coverage is high relative to the improvements to the code coverage.

We have determined that a significant portion of the remaining untested coding is warning or error messages. To give an example of the number of code lines that are error or warning messages for invalid or inconsistent user input data, a few of the subroutines that contained a significant number of unused lines of coding were examined and the error and warning message code lines were tallied. In the following routines, there are a total of 531 lines of unexercised warning or error message coding: *rvlve*, *choke*, *rtee*, *rrod2*, *ihpss3*, *rhstr*, *core1*, *rvssl*, *rcntl*, and *ihpss1*. This is a significant portion of the subroutines' unexercised coding.

Numerous options were added to the expanded test problems to exercise areas of the code that were not exercised by the Standard Test Matrix. Numerous code bugs, dead or developer coding, and unsupported coding were discovered during this investigation. There is, with only a few exceptions, a limited number of problems that can be developed to exercise the physics and the models of TRAC-P/MOD2 further. The cost to create these problems is high relative to the additional coverage to TRAC-P/MOD2. The majority of the unexercised coding remaining in TRAC-P/MOD2 is in response to invalid or inconsistent user-input data. After careful examination of the code, we recommend that this activity be concluded.

6. REFERENCES

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APPENDIX A

Adjusted lines	unused	unused	used	used %	unused	used	used %
=====	=====	=====	=====	=====	=====	=====	=====
Total Coverage	52		534	91%	9094	45857	83%
ssepor.f	1		0	0%	303	0	0%
hqr2t.f	1		0	0%	263	0	0%
htif.f	0		1	100%	256	467	64%
cif3.f	0		1	100%	250	587	70%
recntl.f	0		1	100%	219	476	68%
rturb.f	1		0	0%	189	0	0%
choke.f	0		1	100%	176	383	68%
rtee.f	0		1	100%	172	206	54%
rvlve.f	0		1	100%	171	160	48%
femom.f	0		1	100%	159	1066	87%
ihpss3.f	0		1	100%	149	510	77%
rhtstr.f	0		1	100%	149	762	83%
ihpss1.f	0		1	100%	143	785	84%
sepdi.f	1		0	0%	137	0	0%
sfa55v.f	1		0	0%	136	0	0%
core1.f	0		1	100%	132	898	87%
femomy.f	0		1	100%	114	321	73%
rcntl.f	0		1	100%	110	721	86%
ivssl.f	0		1	100%	108	362	77%
dtdiag.f	0		1	100%	107	228	68%
trpset.f	0		1	100%	101	474	82%
rvssl.f	0		1	100%	100	713	87%

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load.f	0	1	100%	96	216	69%
sgecot.f	1	0	0%	96	0	0%
namlst.f	0	1	100%	94	590	86%
aivssl.f	0	1	100%	91	61	40%
conblk.f	0	1	100%	89	413	82%
htvssl.f	0	1	100%	87	602	87%
zcore.f	0	1	100%	87	297	77%
returb.f	1	0	0%	86	0	0%
trbpow.f	1	0	0%	86	0	0%
thermd.f	0	1	100%	85	143	62%
turb1.f	1	0	0%	83	0	0%
rpump.f	0	1	100%	80	208	72%
tf3ds3.f	0	1	100%	70	546	88%
icomf.f	0	1	100%	69	252	78%
trbpre.f	0	1	100%	68	7	9%
tf3ds1.f	0	1	100%	65	514	88%
offtke.f	0	1	100%	64	54	45%
rbreak.f	0	1	100%	64	133	67%
rrod2.f	0	1	100%	63	448	87%
tfplbk.f	0	1	100%	63	164	72%
fillx.f	0	1	100%	62	178	74%
femomx.f	0	1	100%	61	372	85%
sgbfat.f	1	0	0%	60	0	0%
iturb.f	1	0	0%	57	0	0%
prefwd.f	0	1	100%	56	186	76%
tf1ds1.f	0	1	100%	55	567	91%
input.f	0	1	100%	51	902	94%

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sgbslt.f	1	0	0%	51	0	0%
srtlp.f	0	1	100%	51	182	78%
svset.f	0	1	100%	51	114	69%
breakx.f	0	1	100%	50	61	54%
rdrest.f	0	1	100%	49	375	88%
rpipe.f	0	1	100%	49	80	62%
pumpsr.f	0	1	100%	48	107	69%
rcomp.f	0	1	100%	48	270	84%
femomz.f	0	1	100%	46	452	90%
vdpcss.f	1	0	0%	46	0	0%
wturb.f	1	0	0%	46	0	0%
retee.f	0	1	100%	44	110	71%
sfa33v.f	1	0	0%	43	0	0%
vlvex.f	0	1	100%	42	90	68%
sound.f	0	1	100%	41	478	92%
tflds.f	0	1	100%	41	853	95%
fbrcss.f	0	1	100%	40	147	78%
refill.f	0	1	100%	40	96	70%
cbset.f	0	1	100%	38	141	78%
sgeev.f	0	1	100%	38	18	32%
velbc.f	0	1	100%	38	16	29%
cfiles.c	3	11	78%	37	36	49%
scopym.f	1	0	0%	37	0	0%
ssl55v.f	1	0	0%	37	0	0%
ecomp.f	0	1	100%	36	195	84%
aiplen.f	0	1	100%	35	26	42%
sepdx.f	1	0	0%	35	0	0%

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htcor.f	0	1	100%	34	609	94%
igturb.f	1	0	0%	34	0	0%
saxpyt.f	1	0	0%	34	0	0%
svset3.f	0	1	100%	34	387	91%
rebrk.f	0	1	100%	33	94	74%
break1.f	0	1	100%	32	69	68%
prep1d.f	0	1	100%	32	134	80%
rerod1.f	0	1	100%	32	262	89%
rfill.f	0	1	100%	32	215	87%
sdott.f	1	0	0%	32	0	0%
sgefst.f	1	0	0%	31	0	0%
teel.f	0	1	100%	30	61	67%
svset1.f	0	1	100%	29	337	92%
ddot.f	1	0	0%	28	0	0%
svseth.f	0	1	100%	28	292	91%
evltab.f	0	1	100%	26	54	67%
edit.f	0	1	100%	25	90	78%
hout.f	0	1	100%	25	144	85%
irodl.f	0	1	100%	25	104	80%
isamaxt.f	1	0	0%	25	0	0%
stbme3.f	0	1	100%	25	259	91%
viscvd.f	0	1	100%	25	14	35%
ortrant.f	1	0	0%	24	0	0%
revssl.f	0	1	100%	24	361	93%
volfa.f	0	1	100%	24	71	74%
aicomp.f	0	1	100%	23	91	79%
bkspln.f	0	1	100%	23	119	83%

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sssalt.f	1	0	0%	23	0	0%
trbpst.f	0	1	100%	23	7	23%
sasumt.f	1	0	0%	22	0	0%
turb3.f	1	0	0%	22	0	0%
vsssr.f	0	1	100%	22	95	81%
balbakt.f	1	0	0%	21	0	0%
dgbst.f	0	1	100%	21	30	58%
ring0.f	1	0	0%	21	0	0%
sgeslt.f	0	1	100%	21	28	57%
revlve.f	0	1	100%	20	60	75%
unsvcb.f	0	1	100%	20	50	71%
trans.f	0	1	100%	19	110	85%
irod.f	0	1	100%	18	260	93%
post3d.f	0	1	100%	18	121	87%
repipe.f	0	1	100%	18	62	77%
timchk.f	0	1	100%	18	30	62%
unpkst.f	1	0	0%	18	0	0%
chf.f	0	1	100%	17	79	82%
getcrv.f	0	1	100%	17	27	61%
itee.f	0	1	100%	17	150	89%
readi.f	0	1	100%	17	133	88%
readr.f	0	1	100%	17	377	95%
rkin.f	0	1	100%	17	198	92%
scopyt.f	0	1	100%	17	20	54%
ssl33v.f	1	0	0%	17	0	0%
evfxxx.f	0	1	100%	16	45	73%
radmap.f	0	1	100%	16	42	72%

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renc1.f	0	1	100%	16	66	80%
tmsfb.f	0	1	100%	16	11	40%
wbreak.f	0	1	100%	16	21	56%
linint.f	0	1	100%	15	36	70%
zpwrci.f	0	1	100%	15	133	89%
bksstb.f	0	1	100%	14	212	93%
loctrb.f	1	0	0%	13	0	0%
mwrxf.f	0	1	100%	13	20	60%
rrod1.f	0	1	100%	13	137	91%
elgr.f	0	1	100%	12	101	89%
igraf.f	0	1	100%	12	227	94%
post.f	0	1	100%	12	212	94%
rholid.f	0	1	100%	12	16	57%
rholi.f	0	1	100%	12	13	52%
rplen.f	0	1	100%	12	96	88%
thermh.f	0	1	100%	12	235	95%
trac.f	0	1	100%	12	111	90%
turb2.f	1	0	0%	12	0	0%
bfgrf.f	0	1	100%	11	53	82%
ivlve.f	0	1	100%	11	57	83%
rdcomp.f	0	1	100%	11	48	81%
rsperr.f	1	0	0%	11	0	0%
seteod.f	0	1	100%	11	42	79%
seteoh.f	0	1	100%	11	53	82%
wir.f	0	1	100%	11	40	78%
zpwrm.f	0	1	100%	11	97	89%
daxpy.f	0	1	100%	10	18	64%

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dmpit.f	0	1	100%	10	111	91%
dturb.f	1	0	0%	10	0	0%
expand.f	0	1	100%	10	92	90%
hash.f	0	1	100%	10	23	69%
idamax.f	0	1	100%	10	13	56%
iplen.f	0	1	100%	10	98	90%
linint0.f	0	1	100%	10	55	84%
mfuel.f	0	1	100%	10	22	68%
mstrct.f	0	1	100%	10	56	84%
pump2.f	0	1	100%	10	15	60%
pumpd.f	0	1	100%	10	41	80%
pumpx.f	0	1	100%	10	18	64%
rerad.f	1	0	0%	10	0	0%
setlcm.f	0	1	100%	10	9	47%
tee2.f	0	1	100%	10	71	87%
trip.f	0	1	100%	10	16	61%
vssl2.f	0	1	100%	10	157	94%
wtee.f	0	1	100%	10	39	79%
outld.f	0	1	100%	9	69	88%
preinp.f	0	1	100%	9	213	95%
prep3d.f	0	1	100%	9	121	93%
sattmd.f	0	1	100%	9	7	43%
sfa44v.f	0	1	100%	9	73	89%
bkstb3.f	0	1	100%	8	211	96%
chkbd.f	0	1	100%	8	92	92%
renc.f	0	1	100%	8	96	92%
repump.f	0	1	100%	8	134	94%

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unnumb.f	0	1	100%	8	40	83%
vssl1.f	0	1	100%	8	196	96%
bits.f	1	0	0%	7	24	77%
chen.f	0	1	100%	7	35	83%
fpropd.f	0	1	100%	7	30	81%
locv1v.f	0	1	100%	7	19	73%
mfrod.f	0	1	100%	7	62	89%
rehtst.f	0	1	100%	7	76	91%
shrink.f	0	1	100%	7	47	87%
clrint.f	1	0	0%	6	0	0%
core3.f	0	1	100%	6	88	93%
find.f	0	1	100%	6	17	73%
findh.f	0	1	100%	6	24	80%
fwall.f	0	1	100%	6	121	95%
graf.f	0	1	100%	6	130	95%
igprzr.f	0	1	100%	6	41	87%
igvssl.f	0	1	100%	6	496	98%
iwall3.f	0	1	100%	6	153	96%
justlr.f	0	1	100%	6	35	85%
rprizr.f	0	1	100%	6	35	85%
tee3.f	0	1	100%	6	100	94%
vssl3.f	0	1	100%	6	143	95%
wcomp.f	0	1	100%	6	212	97%
wmxytb.f	0	1	100%	6	88	93%
delay.f	0	1	100%	5	29	85%
dscal.f	0	1	100%	5	18	78%
htstrp.f	0	1	100%	5	210	97%

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ifset.f	0	1	100%	5	2	28%
ipipe.f	0	1	100%	5	50	90%
ipump.f	0	1	100%	5	55	91%
j3d.f	0	1	100%	5	143	96%
plen3.f	0	1	100%	5	54	91%
switch.f	1	0	0%	5	0	0%
tf1ds3.f	0	1	100%	5	551	99%
viscvh.f	0	1	100%	5	38	88%
bansol.f	0	1	100%	4	44	91%
ciradh.f	0	1	100%	4	37	90%
civssl.f	0	1	100%	4	60	93%
cpvv1d.f	0	1	100%	4	8	66%
fwkf.f	0	1	100%	4	35	89%
hvwebb.f	0	1	100%	4	38	90%
ibrk.f	0	1	100%	4	71	94%
junsol.f	0	1	100%	4	21	84%
lchpip.f	0	1	100%	4	5	55%
lcmtrn.f	0	1	100%	4	32	88%
movlev.f	1	0	0%	4	0	0%
out3d.f	0	1	100%	4	59	93%
replen.f	0	1	100%	4	94	95%
rfdbk.f	0	1	100%	4	122	96%
satded.f	0	1	100%	4	7	63%
satprd.f	0	1	100%	4	7	63%
sclmom.f	0	1	100%	4	75	94%
scmlcm.f	0	1	100%	4	26	86%
trips.f	0	1	100%	4	27	87%

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value.f	0	1	100%	4	67	94%
xtvdr.f	0	1	100%	4	49	92%
astpln.f	0	1	100%	3	54	94%
ctain1.f	1	0	0%	3	0	0%
ctain2.f	1	0	0%	3	0	0%
ctain3.f	1	0	0%	3	0	0%
evaldf.f	0	1	100%	3	77	96%
indel.f	0	1	100%	3	18	85%
jfind.f	0	1	100%	3	8	72%
lchvss.f	0	1	100%	3	10	76%
locpmp.f	0	1	100%	3	16	84%
loctee.f	0	1	100%	3	4	57%
mgap.f	0	1	100%	3	33	91%
order.f	0	1	100%	3	92	96%
rddim.f	0	1	100%	3	54	94%
rttr.f	0	1	100%	3	18	85%
sfa44.f	0	1	100%	3	72	96%
sfa55.f	0	1	100%	3	114	97%
split.f	0	1	100%	3	8	72%
steady.f	0	1	100%	3	158	98%
timstp.f	0	1	100%	3	185	98%
wrcomp.f	0	1	100%	3	32	91%
bfaloc.f	0	1	100%	2	15	88%
chbset.f	0	1	100%	2	34	94%
ciradr.f	0	1	100%	2	29	93%
deltar.f	0	1	100%	2	24	92%
dgbfa.f	0	1	100%	2	58	96%

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ff3d.f	0	1	100%	2	123	98%
findnum.f	0	1	100%	2	10	83%
getcenc.f	0	1	100%	2	9	81%
getradm.f	0	1	100%	2	10	83%
igplen.f	0	1	100%	2	95	97%
igsvcb.f	0	1	100%	2	58	96%
matsol.f	0	1	100%	2	86	97%
modify.f	1	0	0%	2	0	0%
nxtcmp.f	0	1	100%	2	16	88%
poster.f	0	1	100%	2	164	98%
putradm.f	0	1	100%	2	10	83%
rdcrds.f	0	1	100%	2	8	80%
recomp.f	0	1	100%	2	57	96%
scltbl.f	0	1	100%	2	21	91%
setic.f	1	0	0%	2	0	0%
sgefat.f	0	1	100%	2	32	94%
stbme.f	0	1	100%	2	376	99%
tee1x.f	0	1	100%	2	35	94%
vlve1.f	0	1	100%	2	25	92%
warray.f	0	1	100%	2	64	96%
wpipe.f	0	1	100%	2	42	95%
xtvinit.f	0	1	100%	2	119	98%
blkdat.f	1	0	0%	1	0	0%
blkdat2.f	1	0	0%	1	0	0%
fceinfo.f	0	1	100%	1	9	90%
frod.f	0	1	100%	1	31	96%
fthex.f	0	1	100%	1	7	87%

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getrdm1.f	0	1	100%	1	7	87%
hqrt.f	0	1	100%	1	127	99%
ltopp.f	0	1	100%	1	16	94%
manage.f	0	1	100%	1	46	97%
mzirc.f	0	1	100%	1	26	96%
pipe3.f	0	1	100%	1	26	96%
pntrod.f	0	1	100%	1	210	99%
ptrspl.f	0	1	100%	1	43	97%
pump3.f	0	1	100%	1	28	96%
sfa22v.f	0	1	100%	1	16	94%
teemet.f	0	1	100%	1	14	93%
teemf1.f	0	1	100%	1	14	93%
teemom.f	0	1	100%	1	9	90%
vlve3.f	0	1	100%	1	26	96%
vssrod.f	0	1	100%	1	100	99%
wprizr.f	0	1	100%	1	42	97%
allblk.f	0	1	100%	0	4	100%
assign.f	0	1	100%	0	14	100%
auxpln.f	0	1	100%	0	76	100%
bacit.f	0	1	100%	0	31	100%
bakup.f	0	1	100%	0	18	100%
balanct.f	0	1	100%	0	79	100%
bdplen.f	0	1	100%	0	71	100%
bfclos.f	0	1	100%	0	11	100%
bfin.f	0	1	100%	0	20	100%
bfout.f	0	1	100%	0	16	100%
bits.o	1	4	80%	0	0	--

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bkmom.f	0	1	100%	0	49	100%
bksmom.f	0	1	100%	0	33	100%
break2.f	0	1	100%	0	14	100%
break3.f	0	1	100%	0	19	100%
cbedit.f	0	1	100%	0	29	100%
cdthex.f	0	1	100%	0	11	100%
cella3.f	0	1	100%	0	125	100%
cellav.f	0	1	100%	0	42	100%
chbd.f	0	1	100%	0	14	100%
chbsav.f	0	1	100%	0	12	100%
chf1.f	0	1	100%	0	19	100%
chksr.f	0	1	100%	0	14	100%
cihtst.f	0	1	100%	0	39	100%
cirad.f	0	1	100%	0	57	100%
clean.f	0	1	100%	0	10	100%
clear.f	0	1	100%	0	6	100%
compi.f	0	1	100%	0	66	100%
concf.f	0	1	100%	0	9	100%
constb.f	0	1	100%	0	64	100%
copya.f	0	1	100%	0	4	100%
cournof	0	1	100%	0	7	100%
cp11.f	0	1	100%	0	7	100%
cp11d.f	0	1	100%	0	4	100%
cp11h.f	0	1	100%	0	4	100%
cpvv1.f	0	1	100%	0	7	100%
cpvv1h.f	0	1	100%	0	12	100%
cvmgt.f	0	1	100%	0	4	100%

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cwvssl.f	0	1	100%	0	5	100%
cylht.o	0	1	100%	0	0	--
dater.f	0	1	100%	0	19	100%
dbrk.f	0	1	100%	0	9	100%
dcodf.f	0	1	100%	0	18	100%
dcomp.f	0	1	100%	0	106	100%
decays.f	0	1	100%	0	155	100%
dfill.f	0	1	100%	0	9	100%
dhtstr.f	0	1	100%	0	46	100%
dlevel.f	0	1	100%	0	5	100%
dpipe.f	0	1	100%	0	9	100%
dplen.f	0	1	100%	0	42	100%
dpump.f	0	1	100%	0	15	100%
drad.f	0	1	100%	0	6	100%
drod1.f	0	1	100%	0	115	100%
dtee.f	0	1	100%	0	20	100%
dvlve.f	0	1	100%	0	10	100%
dvpscl.f	0	1	100%	0	15	100%
dvssl.f	0	1	100%	0	120	100%
enddmp.f	0	1	100%	0	6	100%
endgrf.f	0	1	100%	0	6	100%
error.f	0	1	100%	0	48	100%
etee.f	0	1	100%	0	78	100%
faxpos.f	0	1	100%	0	39	100%
fceinfl.f	0	1	100%	0	12	100%
fill1.f	0	1	100%	0	20	100%
fill2.f	0	1	100%	0	3	100%

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fill3.f	0	1	100%	0	4	100%
finder.f	0	1	100%	0	23	100%
fltom.f	0	1	100%	0	52	100%
flux.f	0	1	100%	0	44	100%
fluxes.f	0	1	100%	0	44	100%
fnmesh.f	0	1	100%	0	111	100%
fprop.f	0	1	100%	0	7	100%
fproph.f	0	1	100%	0	37	100%
gapht.f	0	1	100%	0	16	100%
getbit.f	0	1	100%	0	5	100%
glevel.f	0	1	100%	0	9	100%
grfget.f	0	1	100%	0	5	100%
grfput.f	0	1	100%	0	26	100%
gvssl1.f	0	1	100%	0	69	100%
gvssl2.f	0	1	100%	0	34	100%
hev.f	0	1	100%	0	7	100%
hevd.f	0	1	100%	0	5	100%
hevh.f	0	1	100%	0	5	100%
hlfilm.f	0	1	100%	0	31	100%
hlflmr.f	0	1	100%	0	33	100%
htpipe.f	0	1	100%	0	47	100%
htstr1.f	0	1	100%	0	88	100%
htstr3.f	0	1	100%	0	60	100%
htstrv.f	0	1	100%	0	70	100%
hunts.f	0	1	100%	0	18	100%
hvfilm.f	0	1	100%	0	8	100%
hvnb.f	0	1	100%	0	15	100%

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icmpr.f	0	1	100%	0	4	100%
idel.f	0	1	100%	0	12	100%
idiff.f	0	1	100%	0	3	100%
ieeecvt.f	0	1	100%	0	5	100%
ifill.f	0	1	100%	0	65	100%
igbrak.f	0	1	100%	0	89	100%
igcomp.f	0	1	100%	0	211	100%
igfill.f	0	1	100%	0	83	100%
ighstr.f	0	1	100%	0	195	100%
igpipe.f	0	1	100%	0	49	100%
igpump.f	0	1	100%	0	73	100%
igte.f	0	1	100%	0	39	100%
igvlve.f	0	1	100%	0	29	100%
ilevel.f	0	1	100%	0	4	100%
init.f	0	1	100%	0	17	100%
initbc.f	0	1	100%	0	127	100%
inner.f	0	1	100%	0	34	100%
ipack.f	0	1	100%	0	8	100%
iprizr.f	0	1	100%	0	47	100%
iprop.f	0	1	100%	0	36	100%
isort.f	0	1	100%	0	18	100%
iunpack.f	0	1	100%	0	8	100%
jld.f	0	1	100%	0	75	100%
jbd4.f	0	1	100%	0	12	100%
jvalue.f	0	1	100%	0	12	100%
labeld.f	0	1	100%	0	5	100%
labelh.f	0	1	100%	0	5	100%

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labelp.f	0	1	100%	0	7	100%
ldchar.f	0	1	100%	0	3	100%
lentab.f	0	1	100%	0	6	100%
level.f	0	1	100%	0	10	100%
leveli.f	0	1	100%	0	9	100%
levelr.f	0	1	100%	0	9	100%
lint4d.f	0	1	100%	0	61	100%
mbn.f	0	1	100%	0	8	100%
mhtr.f	0	1	100%	0	8	100%
mix3d.f	0	1	100%	0	19	100%
mixprp.f	0	1	100%	0	12	100%
movinfo.f	0	1	100%	0	8	100%
mprop.f	0	1	100%	0	11	100%
newdlt.f	0	1	100%	0	137	100%
orthest.f	0	1	100%	0	44	100%
outer.f	0	1	100%	0	132	100%
packit.f	0	1	100%	0	39	100%
pipe1.f	0	1	100%	0	16	100%
pipe1x.f	0	1	100%	0	20	100%
pipe2.f	0	1	100%	0	12	100%
piprod.f	0	1	100%	0	73	100%
plen1.f	0	1	100%	0	67	100%
plen2.f	0	1	100%	0	43	100%
pntvss.f	0	1	100%	0	93	100%
powint.f	0	1	100%	0	28	100%
prep.f	0	1	100%	0	13	100%
preper.f	0	1	100%	0	161	100%

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prizr1.f	0	1	100%	0	16	100%
prizr2.f	0	1	100%	0	8	100%
prizr3.f	0	1	100%	0	31	100%
przr1x.f	0	1	100%	0	29	100%
pstepq.f	0	1	100%	0	28	100%
ptrsa.f	0	1	100%	0	286	100%
pump1.f	0	1	100%	0	12	100%
pumpi.f	0	1	100%	0	13	100%
putrdm1.f	0	1	100%	0	3	100%
rlmacht.f	0	1	100%	0	4	100%
radchts.f	0	1	100%	0	12	100%
radchyd.f	0	1	100%	0	7	100%
radems.f	0	1	100%	0	6	100%
radfp.o	0	1	100%	0	0	--
radmodl.f	0	1	100%	0	25	100%
radpt.f	0	1	100%	0	83	100%
radsol.o	0	1	100%	0	0	--
rdcom3.f	0	1	100%	0	3	100%
rdcrvs.f	0	1	100%	0	80	100%
rdlcm.f	0	1	100%	0	5	100%
rdzmom.f	0	1	100%	0	63	100%
reecho.f	0	1	100%	0	86	100%
reprzr.f	0	1	100%	0	29	100%
rholiq.f	0	1	100%	0	7	100%
rlevel.f	0	1	100%	0	15	100%
rodht.o	0	1	100%	0	0	--
rrdlcm.f	0	1	100%	0	18	100%

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rrdlcm.o	0	1	100%	0	0	--
rsvlcm.f	0	1	100%	0	17	100%
rsvlcm.o	0	1	100%	0	0	--
sldptr.f	0	1	100%	0	214	100%
satdeh.f	0	1	100%	0	19	100%
satder.f	0	1	100%	0	7	100%
satprh.f	0	1	100%	0	19	100%
satprs.f	0	1	100%	0	7	100%
sattmh.f	0	1	100%	0	25	100%
sattmp.f	0	1	100%	0	7	100%
savbd.f	0	1	100%	0	23	100%
scputm.f	0	1	100%	0	2	100%
sedit.f	0	1	100%	0	84	100%
setbd.f	0	1	100%	0	8	100%
setbdt.f	0	1	100%	0	17	100%
seteos.f	0	1	100%	0	7	100%
seterr.f	0	1	100%	0	3	100%
setnet.f	0	1	100%	0	63	100%
setva.f	0	1	100%	0	4	100%
sgedit.f	0	1	100%	0	25	100%
shift.f	0	1	100%	0	8	100%
shiftb.f	0	1	100%	0	30	100%
shiftr.f	0	1	100%	0	8	100%
sigma.f	0	1	100%	0	4	100%
ssl22v.f	0	1	100%	0	10	100%
ssl44.f	0	1	100%	0	30	100%
ssl44v.f	0	1	100%	0	26	100%

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ssl55.f	0	1	100%	0	43	100%
stbmpl.f	0	1	100%	0	40	100%
stdir.f	0	1	100%	0	77	100%
tbc1.f	0	1	100%	0	16	100%
tcputm.f	0	1	100%	0	4	100%
teemf2.f	0	1	100%	0	7	100%
teex.f	0	1	100%	0	23	100%
tf1d.f	0	1	100%	0	58	100%
tf3ds.o	0	1	100%	0	0	--
tfpln.o	0	1	100%	0	0	--
thcl.f	0	1	100%	0	7	100%
thcld.f	0	1	100%	0	5	100%
thclh.f	0	1	100%	0	6	100%
thcv.f	0	1	100%	0	11	100%
thermo.f	0	1	100%	0	7	100%
timed.f	0	1	100%	0	4	100%
timupd.f	0	1	100%	0	18	100%
tmpptr.f	0	1	100%	0	133	100%
trac.o	0	1	100%	0	0	--
trisl.f	0	1	100%	0	14	100%
uncrvt.f	0	1	100%	0	70	100%
vfwall3.f	0	1	100%	0	17	100%
viscl.f	0	1	100%	0	7	100%
viscld.f	0	1	100%	0	5	100%
visclh.f	0	1	100%	0	15	100%
viscv.f	0	1	100%	0	7	100%
vlve2.f	0	1	100%	0	10	100%

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vmcell.f	0	1	100%	0	5	100%
volv.f	0	1	100%	0	16	100%
vpoint.f	0	1	100%	0	295	100%
vrbdf.f	0	1	100%	0	31	100%
wand.f	0	1	100%	0	5	100%
wdrag.f	0	1	100%	0	21	100%
wfill.f	0	1	100%	0	16	100%
whtstr.f	0	1	100%	0	392	100%
wiarr.f	0	1	100%	0	12	100%
wjcell.f	0	1	100%	0	4	100%
wlabi.f	0	1	100%	0	38	100%
wlabr.f	0	1	100%	0	42	100%
wlevel.f	0	1	100%	0	14	100%
wor.f	0	1	100%	0	5	100%
wplen.f	0	1	100%	0	89	100%
wpump.f	0	1	100%	0	49	100%
wrlcm.f	0	1	100%	0	5	100%
wvlve.f	0	1	100%	0	40	100%
wvssl.f	0	1	100%	0	170	100%
wxor.f	0	1	100%	0	5	100%
xtvld.f	0	1	100%	0	30	100%
xtvbi3e.f	0	1	100%	0	3	100%
xtvbuf.f	0	1	100%	0	26	100%
xtvcb.f	0	1	100%	0	23	100%
xtvht.f	0	1	100%	0	68	100%
xtvpipe.f	0	1	100%	0	9	100%
xtvpplen.f	0	1	100%	0	28	100%

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xtvpump.f	0	1	100%	0	9	100%
xtvsig.f	0	1	100%	0	21	100%
xtvtee.f	0	1	100%	0	9	100%
xtvvalv.f	0	1	100%	0	9	100%
xtvvsl.f	0	1	100%	0	62	100%
zerov.f	0	1	100%	0	32	100%
zpwhci.f	0	1	100%	0	57	100%