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USER'S MANUAL FOR IRPREP

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13. ABSTRACT *(Maximum 200 words)*

Irprep is a set of eight interactive programs. Three were developed to extract information from a Ballistic Research Laboratory Computer Aided Design (BRL-CAD) three dimensional model and create inputs for use in PRISM and other thermal models. The information is extracted using raytracing. The other five programs are used to display thermal information obtained from PRISM and other thermal models. The image may be displayed in an X-Windows environment or on an SGI workstation. This manual explains how to use the eight interactive programs of **irprep**.

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1. INTRODUCTION

Irprep is a collection of eight programs. Three extract information from the BRL-CAD (Ballistic Research Laboratory Computer Aided Design) three dimensional models and create input files for use in different thermal models. The other five programs are used to display the output from thermal models. The BRL-CAD models are developed using the multi-device graphics editor (mged) and use three dimensional combinatorial solid geometry (CSG). These models are built by combining different primitives (e.g., spheres, cylinders, and boxes) using boolean operations. These models are then evaluated using ray-tracing programs that fire rays at the target and extract geometric data at each intersection of the rays with the primitives in the model [1,2].

The eight different programs in **irprep** are **firpass**, **secpass**, **shapefact**, **display**, **see**, **see2**, **pictx**, and **pictsgi**. All eight are interactive programs. **Firpass** must be run before **secpass**, **shapefact**, and **display**; since **firpass** creates files used by these programs. **Display** creates a file used by **see** and **see2**.

Firpass, **secpass**, and **shapefact** are the three programs in **irprep** that are designed to extract geometric data from BRL-CAD models. **Firpass** creates several different types of files: a diagnostic file, an error file, two intermediate files, and a primary file. There are three different types of primary files that **firpass** may create: the facet records for PRISM (Physically Reasonable Infrared Signature Model) [3,4], a generic file, and a geometric properties file. PRISM is a thermal model developed at Keweenaw Research Center (KRC) under contract to the Tank Automotive Command (TACOM). **Secpass** creates a diagnostic file, an error file, an intermediate file, and a primary file. The primary file is either the conductivity table for PRISM or a generic file. **Shapefact** finds the shape factors between regions in the engine and creates one of two types of primary files, a regular or generic file as well as an error file. These shape factors may be used with the engine compartment radiation models developed by Jim Rapp at the Ballistic Research Laboratory (BRL) [5] or in conjunction with other thermal models.

The other five programs in **irprep** are used for post processing. **Display** takes a temperature output file (either from PRISM or a generic file), the three dimensional geometry file, and an intermediate file from **firpass** and creates an output file that can be displayed by Analyzer2 [6,7], **see**, or **see2**. **Display** uses ray-tracing and the temperature output file from a thermal model to create temperature maps. Analyzer2 is a program to display temperature information written by Glenn Durfee a Science and Engineering Apprentice Program (SEAP) student with the System Engineering and Concepts Analysis Division (SECAD). Analyzer2 uses X-Windows with Motif. **See** and **see2** both produce a color display of the target where the color represents the temperature of the region. **See** displays the image using X-Windows, **see2** displays the image using Silicon Graphics (SGI) graphics. **Pictx** and **pictsgi** combine the programs **display** and **see** or **display** and **see2** respectively.

2. MODIFICATIONS TO GEOMETRY FILE

If the geometry file being used with **firpass** and **secpass** was not built specifically for heat flow analysis it will probably needs to be modified. Geometric models may be built for any number of purposes: vulnerability evaluation, radar signature analysis, optical signatures determination, and infrared (IR) signature simulation. For each of these uses, the models may be built differently and must be adapted for an unintended use. Any regions that do not have the same thermal properties over the entire region will need to be changed. These regions must be split into smaller regions such that each region has the same thermal properties over the entire region. Similarly, any large region may require subdivision into smaller regions if large temperature variations can occur within the region. Also, any region having more than one surface normal needs to be broken into smaller regions. For example, if the geometric model of a tank turret is one region or even several large regions it probably needs to be broken into smaller regions so that there is more than one normal associated with the turret. PRISM needs one normal per region and if a large region is broken into smaller regions the normal will be averaged over a smaller area. Another example is toolboxes made from one solid or two solids (where one is the inside subtracted from the other). Assuming these boxes are placed with the bottom on a surface they will have a surface normal pointing straight up. Surface normals are used in PRISM for solar loading, and appropriate solar loading is needed on the sides as well as the top of the box. It might be appropriate to model each of these sides as a separate region so that each side has its own normal vector.

When **firpass** finds the centroid of a region it will not necessarily be within that region, for example, a turret ring. A turret ring is often made by subtracting two concentric cylinders from each other. **Firpass** will calculate the centroid as being at the center of the cylinders not taking into account that the center is not part of the region. If the user does not want the centroid to be outside of the region, some regions will need to be remodeled.

Any region that is almost totally surrounded by exterior air, such as the gun tube will need to be examined. The average normal vector to the exterior surface of a gun tube should be (0, 0, 0) (where this notation denotes vector components in the x, y, and z directions). **Firpass** will do unpredictable things to a zero normal vector when normalizing it. What happens is that the normals do not cancel each other out completely and when a vector is normalized it's length must be equal to one. One possibility for solving this problem is to split the gun tube cylinder into an inside and outside cylinder and then splitting these cylinders lengthwise into quarters or eighths. If there is just one cylinder split into quarters there is still the problem that there is exterior air on both sides of the guntube (on the outer surface and on the interior of the barrel) and it would be expected that the normal would be near (0, 0, 0). Or the user could also designate the air inside the gun barrel to be interior air.

Any region not attached to something will need to be modified. Often for vulnerability modeling toolboxes will not get placed exactly on a fender, instead they will be floating slightly above the fender. These toolboxes will need to be moved down or exterior air will be detected below them. Any interior components not necessary for thermal modeling may be stripped out, such as, crew, ammunition, or computers. The engine components should be left in the file.

Appropriate air must also be placed in the model. When **irprep** finds the exterior surface area of a region, any surface bounded by exterior air or a gap will be considered an exterior surface. For example, if a box is hollowed out and no air is put in this hollow space the **irprep** programs will assume this is exterior air. In the mged geometry file an air region must have a region identification number (id) of zero and an air code greater than zero. The region id indicates what type of material the region is composed of when used with a material data base. The region id and air code are defined using mged and may be checked by listing the region (l region name) while using the mged editor. They may be changed by using regdef or edcodes. The following air codes are used in **irprep**.

1 => exterior air
2 => crew compartment air
5 => engine compartment air
6 => closed compartment air
7 => exhaust air
8 => generic air 1
9 => generic air 2

Closed compartment air is used to include air in toolboxes, this is air that is interior air but not crew compartment air, engine compartment air, or exhaust air. Generic airs one and two have been added for future use or if the user is interested is areas surrounded by other air. It has also been suggested that the material and line of sight for an air region be set to zero.

One suggestion when building these three dimensional models is to group all groups except air in one big group (such as all). All air should be in one group (such as air). The model must have air in it for **firpass** and **secpass** to run correctly. PRISM does not want air in the vehicle file. If the groups and regions are grouped this way it is much easier to delete unwanted air regions from the PRISM vehicle file. This will be discussed in more detail later.

The geometry to be used with **shapefact** should be the engine compartment consisting of engine components and surrounding walls only. All interior air in this part of the description must be modeled as engine air. There must be engine air in this model for **shapefact** to work correctly.

The mged file that is used as an example throughout this user's manual is test.veh.g. This is a very simple vehicle (21 regions including three air regions). See Figure 1 for an optical rendering of this vehicle. This geometry file is not appropriate for thermal modeling. It contains some long plates, for example, the side of the hull is six meters long. If this entire side does not have the same thermal properties over it's entire length it should be broken into smaller regions. A wheel has also been designed as being one region, a cylinder. The normal vector of a cylinder is (0, 0, 0); as mentioned before **firpass** will do unpredictable things when a region has a normal vector of (0, 0, 0). The wheel should be split into smaller pieces. Regions for this example were not subdivided in order to keep the number of regions small.

3. FIRPASS

3.1. **Firpass** Input Files

Firpass interrogates an mged file to obtain the facet records for either a PRISM-ready file, a generic file, or a geometric properties file. In order to run **firpass** the user will need a compiled copy of firpass, an mged geometry file, and a material properties file. The geometry file should have all the necessary changes made to it (see section 2).

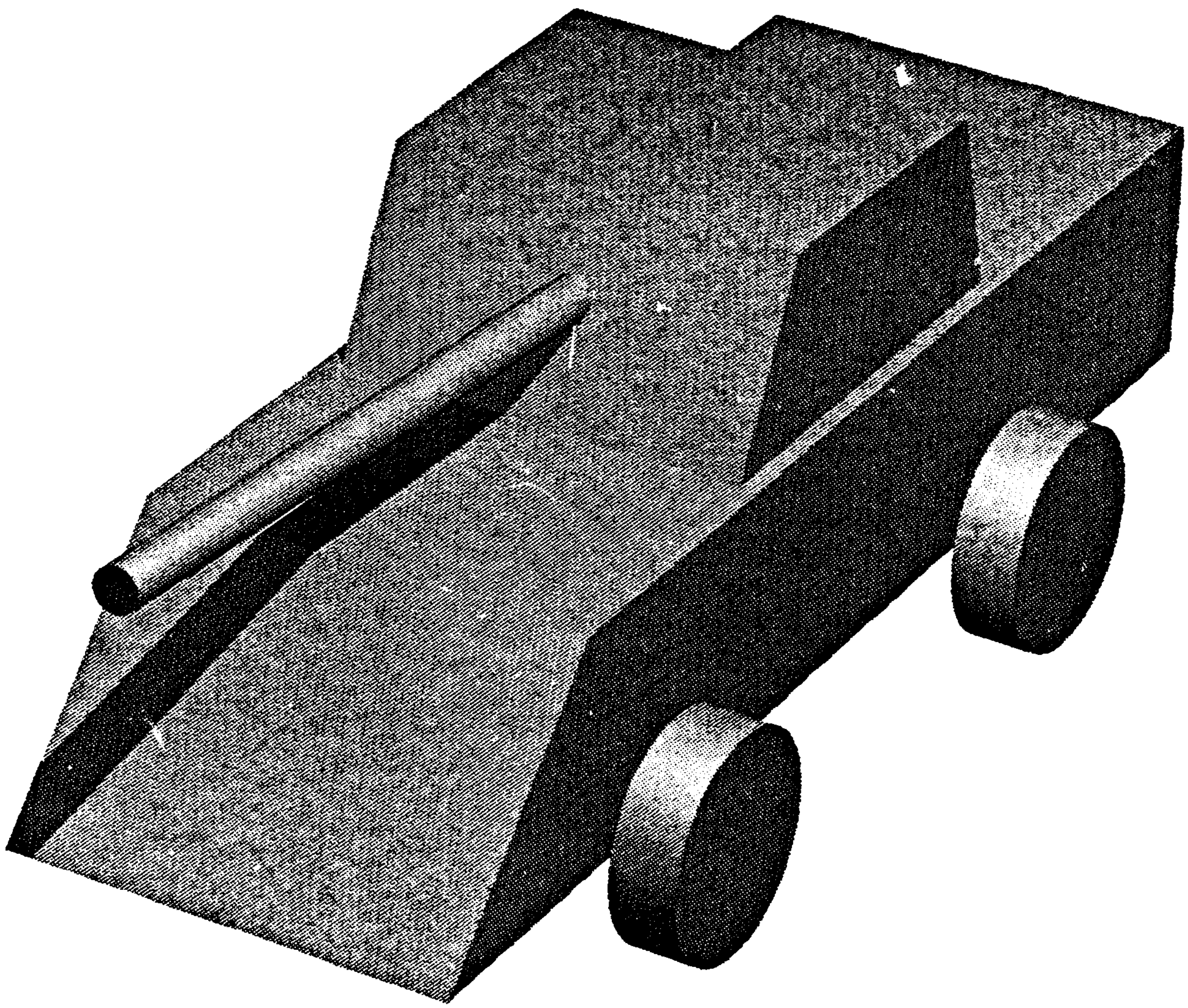

Figure 1. Optical Rendering of Simple Vehicle

The material properties file is a list of forty-one different materials that could be contained in the mged file. There are seven columns in the file. Each column is described below.

column 1 - material code
column 2 - density (kg/m^3)
column 3 - specific heat (J/kgC)
column 4 - absorptivity
column 5 - emissivity
column 6 - thermal conductivity (W/mK)
column 7 - description of material

Material zero must be air and entries for columns two through six will be zero. The last material must be number forty and all materials between zero and forty must exist. They may be filled in with zeroes. A sample material properties file is located in appendix A. In this material properties file absorptivity and emissivity have been set to a default value (1.0). Since these properties depend on the surface coating of the material, they should be changed to appropriate values for specific models. For our example absorptivity was set to 0.60 and emissivity was set to 0.94.

3.2. **Firpass** Output Files

There will be four or five output files generated when running **firpass**: a diagnostic file (optional), an error file, two intermediate files (to be used with **secpass**, **shapefact**, and **display**), and a primary file. The diagnostic file is an optional file used mainly for debugging purposes. The user may choose to have this information written to a file, the screen, or not at all. The average user probably does not need to see this information, it contains intermediate steps in getting the information he is interested in finding.

The error file will contain records describing any region overlaps found in the course of ray-tracing the geometric model and a list of the number of adjacent regions for each region. Provision is also made for listing to this file any large variances between surface areas and volumes of regions when these quantities are redundantly calculated by firing rays in different directions. A planned future revision of the **firpass** code would include the capability to fire sets of rays in three orthogonal directions, whereas in the current version only one set of rays are fired from a single direction.

The intermediate file created for use with **secpass** contains the total number of regions in the model. For each region in the model the file contains the centroid of the region, material identification, and the shared surface area for each adjacent region. The intermediate file created for use with **shapefact** and **display** contains the region number and name. This file allows the engine components to have the same region numbers as the corresponding items found with **firpass** and **secpass**. This file also makes it possible to look at a PRISM temperature output file and have a region number correspond to a region name.

The user may create any one of three different primary files: facet records for PRISM, a generic file, or a geometric properties file. The PRISM file will contain the facet records needed by PRISM. When this file is combined with the conductivity table created by **secpass** it becomes a PRISM-ready vehicle data file. The information in the PRISM file for each region is listed below.

- region number
- region name
- region type
- exterior surface area (m^2)
- mass (kg)
- specific heat (J/kgC)
- emissivity
- surface normal unit vector
- convection coefficient
- region number seen by back surface
- region number seen by front surface
- shape factor
- hub radius
- bearing friction constant

The facet records for PRISM are written in the format specified for PRISM's vehicle data file. (See the PRISM User's Manual [3,4] for the format that this file is written.) The PRISM file may be written so that it can be read by PRISM 2.0 or PRISM 3.0. There are some very slight differences between the files read by these two releases [3,4].

A number is arbitrarily assigned by the ray tracer to each region and one is added to it to get the PRISM number. (PRISM numbers must start at one and the numbers assigned by the ray tracer start at zero.) The name is the twenty-five right-most characters of the region path name [1]. PRISM only accepts twenty-five characters but the region path name may be greater than twenty-five. The surface normal unit vector is the normalized average of the individual normals computed at the intersections of rays with the exterior free surface area of the region. The exterior surface area is computed by adding over the entire exterior surface area the small area associated with each ray that hits the region. The volume is computed by adding over the entire region the volume tube (rectangular tube) associated with each ray that hits the region. Once the volume of a region is known, its mass may be found by multiplying its volume by its density (from the material properties file). The specific heat and emissivity are dependent on the material type and are assigned from the material properties file. The hub radius will be set to zero unless that region is bounded by engine air in which case the area bounded by engine air will be assigned to this data field, (this field is available because the radius is only used for suspension components). Region type and convection coefficient are both set to one; region number seen by the back and front surfaces, shape factor, and bearing friction constant are set to zero. These variables are only used for special cases and it is up to the user to change them where necessary. See the PRISM User's Manual [3,4] for a description of when the special conditions prevail.

The user may choose the second option for the primary file to create a generic file that has the required information for use in other thermal models. The user then can re-format the information in the desired format for use in another thermal model. The information contained in this file for each region is listed below.

1 region_number name volume_(m^3) density_(kg/m^3) thermal_conductivity_(W/mK) specific_heat_(J/kgC) region_material

2 region_number number_of_exterior_convection_surfaces number_of_interior_convection_surfaces area_of_all_exterior_convection_surfaces_(m^2) area_of_all_interior_convection_surfaces_(m^2)

3 region_number number_of_solar_loaded_surfaces surface_area_(m^2) surface_normal_components absorptivity

The first digit of each main line indicates the type of information in the succeeding line. 1 indicates geometric and material properties of the region, all of which is contained on one line. A 2 indicates convection heat transfer information. There may be one to three lines of this information. The digit 3 indicates solar heat transfer and there will be two lines to contain this information.

The user can, for a third choice, create a geometric properties file. Two formats are possible for this file. In the first format, the data are spaced so that they are easily readable by the user. In the second format, the data are pushed together and there are no columns. This format provides a data file that is easily read using a computer program for use elsewhere. The first format is presented below.

region_number name x-component_of_centroid_(m) y-component_of_centroid_(m) z-component_of_centroid_(m) volume_(m^3) mass_(kg) (both lines appear on same line)
region_number external_surface_area_(m^2) engine_surface_area_(m^2) crew_surface_area_(m^2) closed_compartment_surface_area_(m^2) exhaust_surface_area_(m^2) generic_1_surface_area_(m^2) generic_2_surface_area_(m^2) (all lines on one)
region_number material_code density_(kg/m^3) specific_heat_(J/kgC) absorptivity emissivity thermal_conductivity_(W/mK) material_description (both lines on one)
region_number all_adjacent_regions (separated by commas)

A maximum of twenty adjacent regions may be listed.

All of the data in the second format are in a single string separated by commas only. For each region, the following information is printed.

region_number, name, x-component_of_centroid_(m), y-component_of_centroid_(m), z-component_of_centroid_(m), volume_(m^3), mass_(kg), exterior_surface_area_(m^2), crew_surface_area_(m^2), engine_surface_area_(m^2), closed_compartment_surface_area_(m^2), exhaust_surface_area_(m^2), generic_1_surface_area(m^2),generic_2_surface_area_(m^2),material_code, density_(kg/m^3), specific_heat_(J/kgC), absorptivity, emissivity, thermal_conductivity_(W/mK), all_adjacent_regions

3.3. **Firpass** Examples

3.3.1. PRISM File Example

In the following examples the mged file test.veh.g will be used as input to **firpass**. This file pertains to the model of a simple vehicle developed for use in the following examples. The following is an example where the facet records of a PRISM file are created using this mged file. Program prompts and messages are printed in italics. User response is printed in an upright font.

$ firpass test.veh.g vehicle air
Write output to standard out (0) or a file (1) or not at all (2)? 1
Enter name of file output is to be written to (15 char max). veh.f.out
Enter name of error file to be created (15 char max). veh.f.err
Enter name of second pass file to be created (15 char max). veh.f.2nd
Enter name of region # & name file to be created (15 char max). veh.f.rnn
Enter name of material id file to be read (15 char max). prp
Enter type of file to be written.
0 - PRISM file
1 - Generic file
2 - Geometric properties file
0
Enter name of facet file to be created. (15 char max) veh.f.fac
Which release of PRISM is being used, 2.0 (2) or 3.0 (3)? 3
File Used: test.veh.g
Material ID File: prp
Database Title: test vehicle for use with irprep programs
Mallocing arrays.
Zeroing variables.
Center of bounding rpp (356.500000, 0.000000, 1250.000000)
Length of diagonal of bounding rpp: 3829.051456
Minimums & maximums
x: -3472.551456 - 4185.551456
y: -3829.051456 - 3829.051456
z: -2579.051456 - 5079.051456
Model minimum & maximum.
X: -3001.000000 to 3714.000000
Y: -1350.000000 to 1350.000000
Z: 0.000000 to 2500.000000

Enter grid spacing (mm) for fired rays.
10

SHOOTING DOWN X-AXIS

SUMMARY OF FILES USED & CREATED
.g file used: test.veh.g

regions used:

vehicle

air

material id file used: prp

output file created: veh.f.out

second pass file created: veh.f.2nd

error file created: veh.f.err

region # & name file created: veh.f.rnn

facet file created: veh.f.fac

(format is PRISM 3.0)

Freeing memory.

$

The command line for using **firpass** is

firpass model.g objects...

where model.g is the mged geometry to be used (test.veh.g) and objects are all the groups to be interrogated (vehicle and air). Note that for this particular run the objects vehicle and air were used in that order. This will allow the air to be stripped out easily where it is not needed. The objects are ray-traced in the order they are given; therefore, air will appear at the end of the file and less renumbering of regions will need to be done. For this particular run the user chose to create an output file, naming it veh.f.out. The .f.out suffix means that it is the output file created by firpass. This convention for naming files will be used throughout the manual. The user also needed to enter the name of an error file (.f.err implies the error file created by **firpass**). The user then entered veh.f.2nd for the second pass file. This file will be used with **secpass**, while veh.f.rnn will be used with **shapefact** and **display**. The type of file to be created is the "facet" records for PRISM; therefore, the user chooses 0 (PRISM file). A facet file will now be created. The version of PRISM to be used must be chosen. In this example version 3.0 was selected. The formatting between the 2.0 and 3.0 version of PRISM is slightly different. The name of a material file needed to be entered, prp. In this particular material properties file absorptivity was set to 0.60 and emissivity was set to 0.94. The name (including path information) must be less than or equal to fifteen characters. Information about the file and the size of the geometry is printed out in millimeters and the user must choose a grid spacing. The geometry example is approximately six meters long, two meters wide, and two and a half meters high. A grid spacing of 10 millimeters was chosen as being an appropriate spacing. Since the run took less than 10 minutes this spacing could be made smaller and still run in a reasonable period of time. The program prints SHOOTING DOWN X-AXIS as rays are fired even though the rays are actually being fired in an arbitrary direction. **Firpass** ends with a summary of the files used and created. A copy of veh.f.fac created by running this sample case may be found in Appendix B.

Let's look at one region in the mged file and examine the values computed. Region r.hull03 is the back wall of the hull, it is bounded on the rear by exterior air (nothing) and on the front by engine air (air type 5).

The region number of r.hull03 is three, this can be found in file veh.f.fac. This region is rectangular and ranges from -3000 to -2980 in the x-direction, -980 to 980 in the y-direction, and 550 to 1650 in the z-direction (units are millimeters). The material id is 1. With this information the exterior surface area may be computed by hand ($2.156m^2$) and the mass may be computed by hand (335kg). The surface unit normal should be (-1, 0, 0). These values match very well with the values found by **firpass** as seen in veh.f.fac.

3.3.2. Generic File Example

The following is a run of **firpass** where a generic file is created using the same vehicle as before.

```
$ firpass test.veh.g vehicle air
Write output to standard out (0) or a file (1) or not at all (2)? 2
Enter name of error file to be created (15 char max). veh.f.err
Enter name of region # & name file to be created (15 char max). veh.f.rnn
Enter name of second pass file to be created (15 char max). veh.f.2nd
Enter name of material id file to be read (15 char max). prp
Enter type of file to be written.
        0 - PRISM file
        1 - Generic file
        2 - Geometric properties file
1
Enter name of generic file to be created. (15 char max) veh.f.gen
File Used: test.veh.g
Material ID File: prp
Database Title: test vehicle for use with irprep programs
Mallocing arrays.
Zeroing variables.
Center of bounding rpp ( 356.500000, 0.000000, 1250.000000 )
Length of diagonal of bounding rpp: 3829.051456
Minimums & maximums
 x: -3472.551456 - 4185.551456
 y: -3829.051456 - 3829.051456
 z: -2579.051456 - 5079.051456
Model minimum & maximum.
        X: -3001.000000 to 3714.000000
        Y: -1350.000000 to 1350.000000
        Z: 0.000000 to 2500.000000

Enter grid spacing (mm) for fired rays.
10

SHOOTING DOWN X-AXIS
```

SUMMARY OF FILES USED & CREATED

.g file used: test.veh.g

regions used:

vehicle

air

material id file used: prp

second pass file created: veh.f.2nd

error file created: veh.f.err

region # & name file created: veh.f.rnn

generic file created: veh.f.gen

Freeing memory.

$

The only difference between this and the previous example is that the user chose to create a generic file. The generic file, veh.f.gen, may be found in Appendix B.

3.3.3. Geometric Properties File Example

Below is a sample session where the geometric properties file is to be written by **firpass**, using the same geometry as in the last two sections.

$ firpass test.veh.g vehicle air

Write output to standard out (0) or a file (1) or not at all (2)? 2

Enter name of error file to be created (15 char max). veh.f.err

Enter name of second pass file to be created (15 char max). veh.f.2nd

Enter name of region # & name file to be created (15 char max). veh.f.rnn

Enter name of material id file to be read (15 char max). prp

Enter type of file to be written.

0 - PRISM file

1 - Generic file

2 - Geometric properties file

2

Do you want a readable (0) or non-readable (1) geometric file? 0

Enter name of geometric properties file to be created (15 char max). veh.f.geo

File Used: test.veh.g

Material ID File: prp

Database Title: test vehicle for use with irprep programs

Mallocing arrays.

Zeroing variables.

Center of bounding rpp (356.500000, 0.000000, 1250.000000)

Length of diagonal of bounding rpp: 3829.051456

Minimums & maximums

x: -3472.551456 - 4185.551456

y: -3829.051456 - 3829.051456

z: -2579.051456 - 5079.051456

Model minimum & maximum.

X: -3001.000000 to 3714.000000

Y: -1350.000000 to 1350.000000

Z: 0.000000 to 2500.000000

Enter grid spacing (mm) for fired rays

10

SHOOTING DOWN X-AXIS

SUMMARY OF FILES USED & CREATED

.g file used: test.veh.g

regions used:

vehicle

air

material id file used: prp

second pass file created: veh.f.2nd

error file created: veh.f.err

region # & name file created: veh.f.rnn

geometric file created: veh.f.geo

Freeing memory.

$

The geometric properties file, veh.f.geo, may also be found in Appendix B.

4. SECPASS

4.1. **Secpass** Input Files

Secpass interrogates an mged file to obtain the conductivity table (conduction factors for adjacent regions) for a PRISM-ready file or a generic file. When the "facet" records from **firpass** are combined with the conductivity table of **secpass**, a PRISM-ready file can be made. A compiled copy of **secpass**, the same mged file used with **firpass**, the same material properties file used with **firpass**, and the second pass file created by **firpass** for use with **secpass** are needed to run **secpass**. A second pass file from **firpass** is generated regardless of which output file one selects. The second pass file contains the total number of regions in the model. An error will occur if this number of regions does not equal the number of regions in the mged geometry file named in the command line. For each region listed in the second pass file there will be a region number, centroid, material id, and shared surface area for each adjacent region.

4.2 **Secpass** Output Files

There will be three or four output files generated by **secpass**: an optional diagnostic file, an error file, an intermediate file, and a primary file. The diagnostic file is optional, used mainly for debugging purposes. It may be written to a file, written to the screen, or not written at all. The error file will contain information on any adjacent regions for which the number of calculations (number of rays that hit these two regions) to determine the conductance is less then the minimum number set in **secpass**.c. The intermediate file contains the four conductance values between each adjacent region calculated using four types of conduction path length approximations. The four conduction path length approximations are: average, root mean squared (rms), minimum, and maximum. The user may compare the conductance values between adjacent regions for different conduction path lengths and determine which is the most appropriate.

The user creates one primary file: a conductance file or generic file. The conductance file contains the information needed by PRISM. The format of this file may be found in the PRISM User's Manual [3,4]. The information contained in this file for use with PRISM is the region number, the adjacent region number, the conductance between the two regions, and the shared surface area. The shared surface area is not actually needed by PRISM but is printed so that the user may see what the area is. This file is written out in a triangular format, herein the conductance between regions m and n is not printed again as a conductance between regions n and m.

The user may choose to create a generic file instead of the conductance file. The generic file option is used in conjunction with other thermal models. The user must extract and format the information needed by his thermal model. For each region in the mged geometry model the following information will be printed in the generic file.

```
4  region_number  number_of_adjacent_regions
   adjacent_region_number  shared_area_(m^2)  conduction_distance_(m)
```

The number four indicates that the following lines will contain information on conduction between two adjacent regions. The number of adjacent regions defines how many lines of information follow the current line.

4.3. **Secpass** Examples

4.3.1 PRISM File Example

The following example uses the same mged model as before.

$ secpass test.veh.g vehicle air
Write output to standard out (0) or a file(1) not at all (2)? 1
Enter name of output file (15 char max). veh.s.out
Enter name of file that has second pass information
in it (15 char max). veh.f.2nd
Enter type of output file to be generated.
0 - PRISM File
1 - Generic File
0
Enter name of file to be created for PRISM conductivity
information (15 char max). veh.s.con
Which release of PRISM is being used, 2.0 (2) or 3.0 (3)? 3
Which length calculation should be used when
computing conduction
between regions?
1 - average length
2 - rms length
3 - minimum length
4 - maximum length
3
Enter name of file to be created for conductivity
table (15 char max). veh.s.tbl
Enter name of material file (15 char max). prp
Enter name of error file to be created (15 char max). veh.s.err
Database title: test vehicle for use with irprep programs
Number of regions in mged file: 21
Mallocing arrays.
cond malloced
loop malloced
All variables zeroed.
second pass file opened
The number of regions read was 21
Center of bounding rpp (356.500000, 0.000000, 1250.000000)
Length of diagonal of bounding rpp: 3829.051456
Minimums & maximums of grid:
-3472.551456 - 4185.551456
-3829.051456 - 3829.051456
-2579.051456 - 5079.051456

Model minimum & maximum.
X: -3001.000000 to 3714.000000

Y: -1350.000000 to 1350.000000
Z: 0.000000 to 2500.000000

Enter spacing (mm) between fired rays. 10

grid spacing: 10.000000

Shooting down x-axis.

SUMMARY OF FILES USED & CREATED
.g file used: test.veh.g
regions used:
vehicle
air
file containing second pass information: veh.f.2nd
material file used: prp
output file created: veh.s.out
conductivity file created: veh.s.con
(format is PRISM 3.0)
conductivity table file created: veh.s.tbl
error file created: veh.s.err

Freeing memory.
$

The command line for using **secpass** is

secpass model.g objects...

where model.g is the mged geometry file to be used, and objects are all groups to be interrogated. The user must list the objects in the same order as the objects were listed when using **firpass**. If the objects are not listed in the same order, the region numbers will not correspond to the region numbers in the files created with **firpass**. For this particular run the user chose to create an output file, naming it veh.s.out (.s.out implies the output file created by **secpass**). The user now decides to create a conductance PRISM file and must enter a name for the file, veh.s.con (.s.con implies the conductance file for PRISM created by **secpass**). The user is now asked which version of PRISM is to be used, 2.0 or 3.0. There is a slight difference in the format of these two files [3,4]. In this particular example the user is using PRISM 3.0. The user selects the conduction path length form to be used when computing the conductance between regions. The average length is the average length of ray segments traced between the centroid and shared surface. The rms length is the root mean squared length of these ray segments between the centroid and shared surface, and the minimum and maximum lengths are the minimum and maximum lengths of the ray segments. In this particular example the minimum length was chosen. The user now enters a file name for the intermediate file, veh.s.tbl (.s.tbl implies intermediate conductance table created by **secpass**). This table will contain all four conduction path lengths and conductances between adjacent regions for all regions in the geometry file to assist the user in choosing a conduction path length form. Next the user enters the material properties file, the same file used with **firpass**. Again, an error file is created containing information on regions where the conduction path length was calculated using fewer than a minimum number of values. Currently this minimum number of values (variable MINCAL) in **secpass**.c is set to ten which represents the number of rays intersecting the shared surface. Next, information about the database is given such as the title and number of regions. The next five statements simply tell where the program is in its execution and are probably of little interest to the user. The next line indicates the number of regions in the file created by **firpass**. If this number does not agree with the number of regions in the BRL-CAD geometry file, an error will occur. The next lines are information on the dimensions of the model in millimeters. The user needs to enter the grid spacing for the rays that are to be fired. This spacing should be the same as that used in **firpass**. When the run is finished, a summary of the files used and created will be printed. The file veh.s.con may be found in Appendix C.

The conductance between two regions may be checked by hand. Regions r.hull03 (region number 3) and r.hull04 (region number 4) are next to each other. They are both rectangular regions. r.hull04 is the bottom plate of the hull and r.hull03 is the back plate of the hull. The x-component of r.hull04 extends from -3000 to 3000, the y-component extends from -980 to 980, and the z-component extends from 550 to 570 (millimeters). The x-component of r.hull03 extends from -3000 to -2980, the y-component extends from -980 to 980, and the z-component extends from 570 to 1630. The centroid of r.hull03 is (-2990, 0, 1100) and the centroid of r.hull04 is (0, 0, 560). Both these centroids agree with what was found in **firpass**. The minimum distance from the centroid of r.hull04 to the shared surface area is the distance from the centroid to where the right shared surface area of r.hull03 meets r.hull04 (2.98m). The minimum distance from the centroid of r.hull03 to the edge of r.hull04 is the distance straight down fro the centroid to the top of r.hull04 (0.53m). Both of these agree with what was found using **secpass**. The shared surface area is 0.04 m^2. Both regions are mild steel and have a thermal conductivity of 52.000 W/mK. Now the equation from the PRISM manual may be used [3,4].

$$RK_{i,j} = \left(\frac{L_i}{K_i A} + \frac{L_j}{K_j A} \right)^{-1}$$

$RK_{i,j}$: conductance between regions i and j
L_i : conduction path length of region i
L_j : conduction path length of region j
K_i : thermal conductivity of region i
K_j : thermal conductivity of region j
A: shared surface area between region i and j

When these values are substituted in the equation above, the conductance between regions r.hull03 and r.hull04 is found to be 0.593 which agrees with the value calculated by **secpass**.

4.3.2. Generic File Example

The following is the same run as in the last section except that a generic file was created instead of a PRISM file.

$ secpass test.veh.g vehicle air
Write output to standard out (0) or a file(1) not at all (2)? 2
Enter name of file that has second pass information
in it (15 char max). veh.f.2nd
Enter type of output file to be generated.
    0 - PRISM File
    1 - Generic File
1
Enter name of generic file to be created (15 char max). veh.s.gen
Which length calculation should be used when
computing conduction
between regions?
    1 - average length
    2 - rms length
    3 - minimum length
    4 - maximum length
3
Enter name of file to be created for conductivity
table (15 char max). veh.s.tbl
Enter name of material file (15 char max). prp
Enter name of error file to be created (15 char max). veh.s.err
Database title: tled MGED Database
Number of regions in mged file: 21
Mallocing arrays.
cond malloced
loop malloced
All variables zeroed.
second pass file opened
The number of regions read was 21
Center of bounding rpp (356.500000, 0.000000, 1250.000000)
Length of diagonal of bounding rpp: 3829.051456
Minimums & maximums of grid:
  -3472.551456 - 4185.551456
  -3829.051456 - 3829.051456
  -2579.051456 - 5079.051456

Model minimum & maximum.
    X: -3001.000000 to 3714.000000

Y: -1350.000000 to 1350.000000
Z: 0.000000 to 2500.000000

Enter spacing (mm) between fired rays. 10

grid spacing: 10.000000

Shooting down x-axis.
Opened generic file.

SUMMARY OF FILES USED & CREATED
.g file used: test.veh.g
regions used:
vehicle
air
file containing second pass information: veh.f.2nd
material file used: prp
generic file created: veh.s.gen
conductivity table file created: veh.s.tbl
error file created: veh.s.err

Freeing memory.
$

The user chose to create a generic file this time. All the other answers to the questions are as before. The file veh.s.gen may be found in Appendix C.

5. SHAPEFACT

5.1. **Shapefact** Input Files

Shapefact interrogates an mged file to find the shape (intervisibility) factors between regions, primarily for Jim Rapp's engine compartment radiation models [5]. In order to run **shapefact** the user will need a compiled copy of **shapefact**, an mged geometry file of engine components, and a region number and name file created by **firpass**. This geometry file must have engine air correctly placed and labeled. **Shapefact** only uses rays for finding the shape factor if they leave a region and enter engine air. In general **shapefact** finds the shape factors of an engine which is a subset of a larger mged geometry file. Usually the mged geometry file used with **firpass** and **secpass** is an entire vehicle including the engine. Therefore, the region number and name file created by firpass is needed so that the regions of the engine being interrogated by **shapefact** have the same region numbers as the engine regions in the original model.

5.2. **Shapefact** Output Files

There will only be one of two types of primary files and an error file generated: a regular or generic file. The regular file is for use with Jim Rapp's engine compartment radiation models [5]. In this file the first line contains the number of forward rays fired. The succeeding lines will contain information about each region. The format is below.

> region_number region_name engine_area_(m^3)
>   region_number shape_factor
> sum_of_hits
> sum_of_shape_factors

The sum of hits and the sum of shape factors is provided for error checking. For an enclosed engine the sum of the shape factors should sum to 1.0. The generic file has been written to be used with other engine models. It's format is shown below.

> 5 region_number radiation_surface_area_(m^2) number_of_viewable_regions
>   viewable_region_number shape_factor

The 5 indicates the data will be radiation heat transfer data. The number of viewable regions indicates how many regions the current region has shape factors with, this also indicates the number of data lines to follow.

5.3. **Shapefact** Examples

5.3.1. Example One: Sphere and Disk

The geometry file in this example consists of a sphere and disk enclosed in a hollow box. Any empty space will be filled with engine air.

Below is the script for running this particular example.

$ shapefact sph.dsk.g all.air
Enter type of file to be written (0=>regular or 1=>generic). 0
Enter name of output file (15 char max).
    sd.sh.reg
Enter the name of the error file (15 char max).
    sd.sh.err
Enter region # & name file to be read (15 char max).
    sd.f.rnn
Do you want to dump interm shape factors to screen (0-no, 1-yes)? 0
Enter number of rays to be fired. 5000000

Do you wish to enter your own seed (0) or use the default of 1 (1)? 1
seed initialized
Database Title: sphere & disk for use with shape
Number of regions: 4
1000000.000000 rays have been fired in forward direction.
2000000.000000 rays have been fired in forward direction.
3000000.000000 rays have been fired in forward direction.
4000000.000000 rays have been fired in forward direction.
5000000.000000 rays have been fired in forward direction.
Finding correct region numbers.
Finished finding correct region numbers.
$

Shapefact is started by typing the following line.

```
shapefact model.g objects...
```

The first information requested is the type of file to be created and the name of the output file where all the information on shape factors will be recorded as well as the name of an error file to be created. The user also needs to enter a region number and name file that was created by **firpass**. This is done so the region numbering of the engine corresponds to the numbering of the entire vehicle file. If the user so chooses, intermediate shape factors may be printed out. If the user chooses to print out intermediate shape factors, they will be printed every million rays. Columns one and two contain region numbers and column three contains the shape factor between the two regions. Next the user needs to enter the number of rays to be fired. This will be a VERY large number since the majority of the rays will miss the model altogether. Then the user may choose to enter his own seed for the random number generator. The regular file sd.sh.reg may be found in Appendix D. The questions and answers for creating a generic file are exactly the same except the user must provide an answer of 1 for the first question. A generic file sd.sh.gen may also be found in Appendix D.

The sphere in this example has a radius of 500mm and is centered at (0, 0, 500). The disk has a radius of 1000mm and the top face is centered at (0, 0, -500). The shape factor for this geometry may be computed using the following equation [8].

$$F_{sd} = \frac{1}{2}\left(1 - \left(1 + \left(\frac{r_d}{h}\right)^2\right)^{\frac{-1}{2}}\right)$$

F_{sd} : shape factor from sphere to disk
r_d : radius of disk
h: distance from center of sphere to top face of disk

Hand computation of the shape factor from the sphere to the disk yields 0.146, which agrees with the output from **shapefact**. From this output, one infers that the shape factor from region number two (r.sph, sphere) to region number one (r.disk, disk) is 0.146196.

5.3.2. Example Two: Concentric Spheres

This example finds the shape factors for two concentric spheres enclosed in a sphere. The two concentric spheres are enclosed in a sphere so that rays leaving the spheres are not taken into account.

```
$ shapefact con.sph.g all.air
Enter type of file to be written (0=>regular or 1=>generic). 0
Enter name of output file (15 char max).
        cs.sh.reg
Enter the name of the error file (15 char max).
        cs.sh.err
Enter the region # & name file to be read (15 char max).
        cs.f.rnn
Do you want to dump interm shape factors to screen (0-no, 1-yes)? 0
Enter number of rays to be fired. 5000000
Do you wish to enter your own seed (0) or use the default of 1 (1)? 1
seed initialized
Database Title: concentric spheres for use with
Number of regions: 4
1000000.000000 rays have been fired in forward direction.
2000000.000000 rays have been fired in forward direction.
3000000.000000 rays have been fired in forward direction.
4000000.000000 rays have been fired in forward direction.
5000000.000000 rays have been fired in forward direction.
Finding correct region numbers.
Finished finding correct region numbers.
$
```

The regular file, cs.sh.reg, may be found in Appendix D along with cs.sh.gen, a generic file. Again, this calculation may be checked by hand using the following equation [8].

r_d : radius of disk. 257text: S12 <- 12; b=0,h=42,lf=1,rf=1

$$F_{12}=1$$

$$F_{21}=\left(\frac{r_1}{r_2}\right)^2$$

$$F_{22}=1-\left(\frac{r_1}{r_2}\right)^2$$

F_{12} : shape factor from sphere one to sphere two

F_{21} : shape factor from sphere two to sphere one

F_{22} : shape factor from sphere two to sphere two

r_1 : radius of sphere one

r_2 : radius of sphere two

Sphere one is the inside sphere and sphere two is the outside sphere. The radius of sphere one is 1000 mm and of sphere two is 2000 mm. The shape factor from sphere one to sphere two is 1.0, the shape factor from sphere two to sphere one is 0.25, and the shape factor from sphere two to itself is 0.75. These values agree fairly well with **shapefact**. The output from **shapefact** states that the shape factor from sphere one (region 1, r.sph1) to sphere two (region 2, r.sph2) is one. The shape factor from sphere two to sphere one is 0.249554. And the shape factor from sphere two to itself is 0.750446. If closer agreement is needed, more rays may be fired. However, since the method of calculation involves Monte Carlo sampling, to increase the accuracy of the current answer by one more significant digit required 100 times more ray-tracing!

6. CREATING A PRISM VEHICLE FILE FROM **IRPREP** OUTPUT FILES

6.1. Modifications to **Irprep** Output Files

A PRISM vehicle file is created by combining the facet file created by **firpass** and the conductivity file created by **secpass** into a vehicle file. PRISM does not accept air regions; therefore, all air regions must be removed from the facet records and any reference to them must be removed from the conductivity table. The file must be renumbered so the region numbers are consecutive. This is why it is recommended that the air be a separate group placed last when running **firpass** and **secpass**. At the very least the last line of the facet records, indicating the end must be renumbered. The first line of the conductivity table indicating this file is for use with PRISM must be removed. **Firpass** labels all region types one. Any special regions such as tracks and wheels need to be relabled. (See references 3 and 4 for a complete listing of special regions.) Any track regions must be labeled right or left, also [3,4]. And wheels need to have a radius and if the vehicle is moving a friction associated with them. Any regions that were not divided correctly should have their normals altered. For example, if the gun tube was one region the normal should probably be pointing straight up, (0,0,1). Any wheels that are one region should probably have a normal of (0,1,0) or (0,-1,0) depending whether they are on the left or right.

6.2. An Example

First veh.f.fac and veh.s.con are combined to create a PRISM vehicle file, veh.veh. Remove the first line of what was veh.s.con, "Conductivity file for use with PRISM." This line was just printed to let the user know how the file was to be used.

Next remove all lines in the facet records that deal with air. For this example that is regions nineteen through twenty-one. The last line of the facet records needs to be renumbered nineteen. In the conductivity table part of the file all references to regions nineteen through twenty-one (air regions) need to be removed.

Now any special region types need to be identified. The only special regions in this file are the wheels, regions fourteen through seventeen. These regions are of type eleven; therefore, type one must be changed to eleven. Regions twelve and thirteen are part of the group wheels but they are axles not wheels; therefore, the type does not need to be changed. When a region is identified as a wheel it must have an associated radius. The radius variable for this example needs to be set to 0.5 since the wheel radius is a half meter. The friction variable was not changed since in this scenario the vehicle will not be moving.

Any normals that need to be adjusted may be changed now. Since the wheels are all one region the left wheels will get a normal of (0,1,0) and the right wheels will get a normal of (0,-1,0). The guntube was also modeled as one region so the normal was chosen to be (0,0,1).

The vehicle file is now ready to be run through PRISM with a set of files that were supplied with PRISM: sc071984, statdrv, w071984, and tr071984. These are a scenario file, a stationary driver file, a weather file, and a terrain file.

A temperature output file, veh.prm, was created. This file contains the temperature of each region at different time steps. See the PRISM manual [3,4] for the format of this file. The vehicle file, veh.veh; the temperature output file, veh.prm; and the PRISM input files may be found in Appendix E.

7. DISPLAY

7.1. **Display** Input Files

Display ray-traces a BRL-CAD geometry file. As a ray hits a region, the temperature of that region is looked up in the PRISM file and a temperature is assigned to the pixel corresponding to that ray. In order to run **display** a compiled copy of **display**, the BRL-CAD geometry file, the temperature output file from PRISM (or a generic temperature output file), and the region number and name file created by **firpass** must be available. In addition to this the user must know the number of regions (if using a PRISM output file), the elapsed time, the grid size, the viewing azimuth, and the viewing elevation.

7.2. **Display** Output Files

Display will create one file that is readable by Analyzer2 [6,7], **see**, and **see2**. This file contains a temperature for each pixel of the file just ray-traced. The first line of this file contains two integers that are the width and height of the grid. They should be the same since **display** uses a square grid. Each succeeding line will contain a floating point number that is a temperature of a pixel. The first temperature is for the top, left pixel. The pixels move to the right and then down.

7.3. **Display** Example

This example again uses the mged file test.veh.g. Note that only one object, vehicle, was used. The air regions were removed from the PRISM file; therefore, the air should not be ray-traced.

```
$ display test.veh.g vehicle
Type of output file to be read 0=>PRISM, 1=>generic.
        0
Enter name of the PRISM output file to be read (26 char max).
        veh.prm
Enter the number of regions in the PRISM file, must be more
than eight (not including the background).
        18
Enter name of region # & name file to be read (26 char max).
        veh.f.rnn
Enter name of output file (26 char max).
        veh.dis
Enter the elapsed time to create graphical representation of.
        4
Number of regions (including the background): 19
7/19/1984 7.000000:0.000000
Prism out file read.
Region # & name file opened.
The number of regions read from the output file and the region # & name
file was the same, 18 (does not include background in number).
Building directory.
File: test.veh.g
Database Title: test vehicle for use with irprep programs
        vehicle loaded.
The number of regions read from the output
file, the region # & name file, and the .g
file are all equal. The number of regions
read, including the background is 19
Preparation started.

Minimum & maximum X: -3001.000000 - 3714.000000
Minimum & maximum Y: -1350.000000 - 1350.000000
Minimum & maximum Z: 0.000000 - 2500.000000
Center of bounding sphere: 356.500000, 0.000000, 1250.000000
Radius of bounding sphere: 3829.551456
Enter multiplication factor for radius.
        .75
Enter grid size.
        512
Enter azimuth & elevation.
        35 25
gridsize: 512 x 512
azimuth: 35.000000 degrees
elevation: 25.000000 degrees
```

The command line for using **display** is

display model.g objects...

where model.g is the mged geometry (test.veh.g) and objects are all the groups except air (vehicle). A file needs to be read that contains the temperature information. This may be a PRISM or generic file. In this case a PRISM file (veh.prm) is read. When a PRISM output temperature file is used the number of regions needs to be entered since this is not contained in the PRISM temperature output file. The user will also need to enter the region number and name file that was created by **firpass**. The user than needs to enter the name of the file to be created (veh.dis) and what the elapsed time is for ray-tracing. Once this has been done information about the file is printed out. The user is then asked to enter a multiplication factor. This makes the vehicle smaller or larger. Often 1.0 will work, but this is something the user needs to experiment with. Next the user needs to enter the grid size for ray-tracing, 256 and 512 are good choices. At this time **see** and **see2** which actually display the image are not set up to handle any file larger than 512. The user also needs to enter the viewing angles, azimuth and elevation. Now **display** will create a file readable by Analyzer2, **see**, and **see2**. This file does not appear in an appendix due to its length. If a grid spacing of 512 is used there are 262145 lines of data.

8. SEE

8.1. **See** Input File

See takes advantage of X-Windows; therefore, when running **see** the user must be using X-Windows. **See** reads the file that was created by **display** and draws a picture on the screen giving an appropriate color to each pixel based on the temperature of that pixel. In order to run **see** the user must have a compiled copy of **see** and a file created by **display**.

8.2. **See** Output

See generates an image in one of the four color scales listed below.

gray
red
black-blue-cyan-green-yellow-white
black-blue-magenta-red-yellow-white

8.3. **See** Example

See is run by typing **see** (while in an X-Windows environment) and answering the questions as they are asked.

```
$ see
Enter name of file to be read (26 char max).
        veh.dis
Indicate type of color shading to use.
        0 - gray
        1 - red
        2 - black-blue-cyan-green-yellow-white
        3 - black-blue-magenta-red-yellow-white
0
Do you wish to create a pix file (0-no, 1-yes)?
        0
Zeroing color info array - finished zeroing
Setting up color scale -shades of gray - finished.
Reading file - file read.
Width: 512
Height: 512
Finding min & max.
Minimum: 22.590000
Maximum: 46.830000
Finding pixel bins - found pixel bins.
Putting color info in arrays - color info in arrays.
$
```

First the user enters the name of the file created by **display** (veh.dis) and then which color scale is to be used. The user is asked if a pix file should be created. If 1 (yes) is entered the user is prompted for the name of the pix file. This file can be used in conjunction with other routines in the BRL-CAD package. Next the program prints out statements indicating the stage of the program. It will take a little time to read the file. Then the image is displayed on the screen (Figure 2).

9. SEE2

9.1. See2 Input File

The difference between **see** and **see2** is that **see2** takes advantage of the SGI graphics instead of X-Windows. Again, this program uses the file created by **display** and creates an image using one of the color scales listed below.

gray
black-blue-cyan-green-yellow-white
black-blue-magenta-red-yellow-white

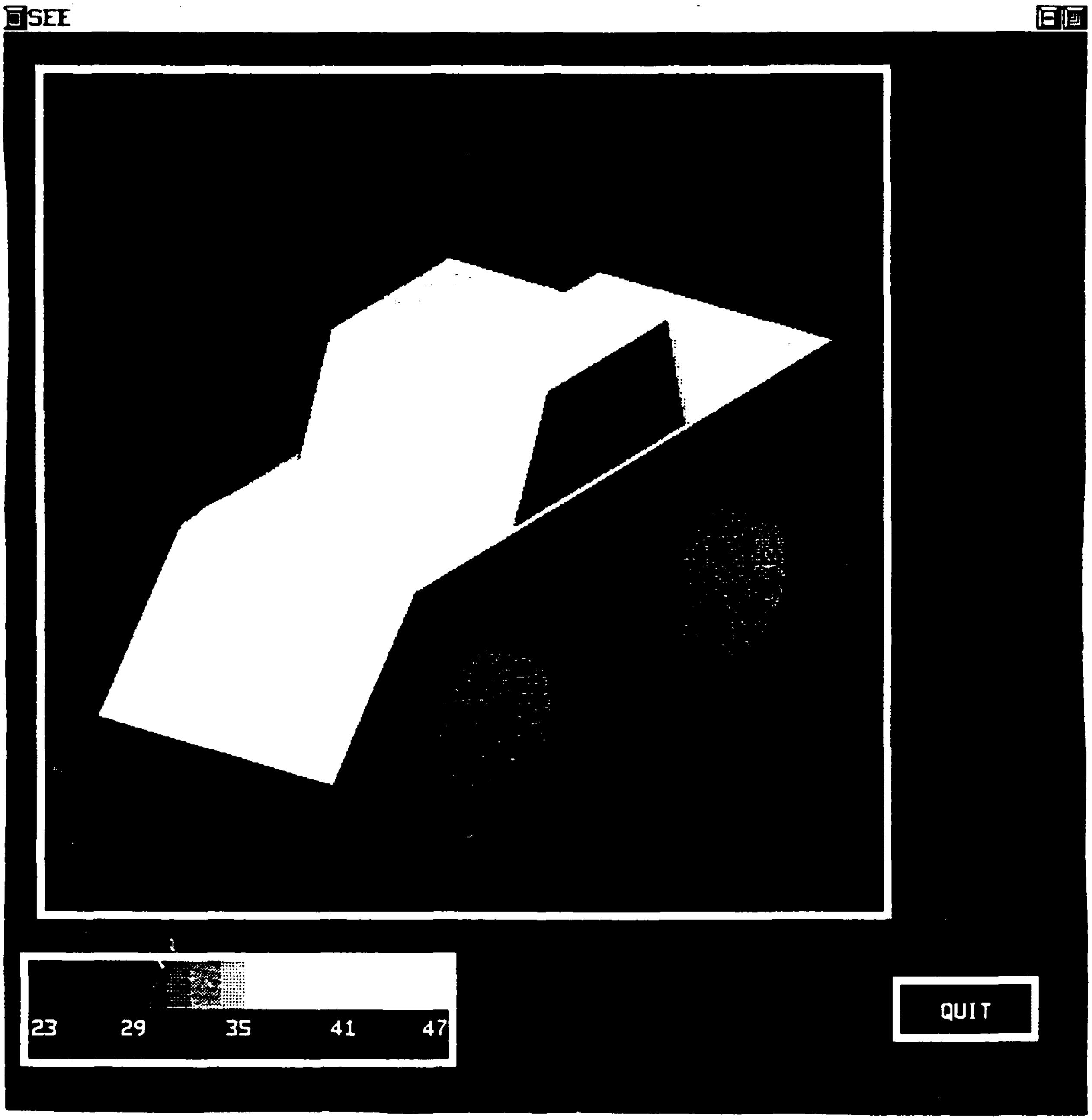

Figure 2. Image Displayed by **See**

The user will need a compiled copy of **see2** and the file created by **display**.

9.2. **See2** Output

The output of **see2** is an image in one of the color scales listed above.

9.3. **See2** Example

See2 is run by typing **see2** (on an SGI) and answering the questions.

```
$ see2
Enter name of file to be read (26 char max).
      veh.dis
Indicate color scale to be used.
      0 - gray
      1 - black-blue-cyan-green-yellow-white.
      2 - black-blue-magenta-red-yellow-white.
0
Print scan line number (0-yes, 1-no)?
      1
Do you wish to create a pix file (0-no, 1-yes)?
0
Setting color scale - gray scale - set.
Reading file - file read.
Width: 512
Height: 512
Finding min & max.
Minimum: 22.590000
Maximum: 46.830000
Finding pixel bins - pixel bins found.
Setting color for each pixel - colors found.
Press 'z' return to end. z
THE END

$
```

First the user enters the name of the file created by **display** (veh.dis) and then selects a color scale (gray). Then the user is asked if the scan lines should be printed, the answer should probably be no since printing scan lines slows the process down. The printing of the scan lines was only added for diagnostic purposes. The user then entered 0 to indicate a pix file was not to be created. If the user had entered 1 there would have been a prompt to enter the pix file name. The image will be displayed and the user presses z and return to end the process. See figure 3 for the image created by **see2**.

10. PICTX AND PICTSGI

Pictx and **pictsgi** combine **display** and **see** or **see2** together into one program. **Pictx** combines **display** and **see** and needs to be run in an X-Windows environment. **Pictsgi** combines **display** and **see2** and runs on an SGI. **Pictx** simply calls **display** and **see** while **pictsgi** calls **display** and **see2**. Start **pictx** by typing **pictx** and **pictsgi** by typing **pictsgi**. The user only needs to answer the questions as they appear.

ACKNOWLEDGMENT

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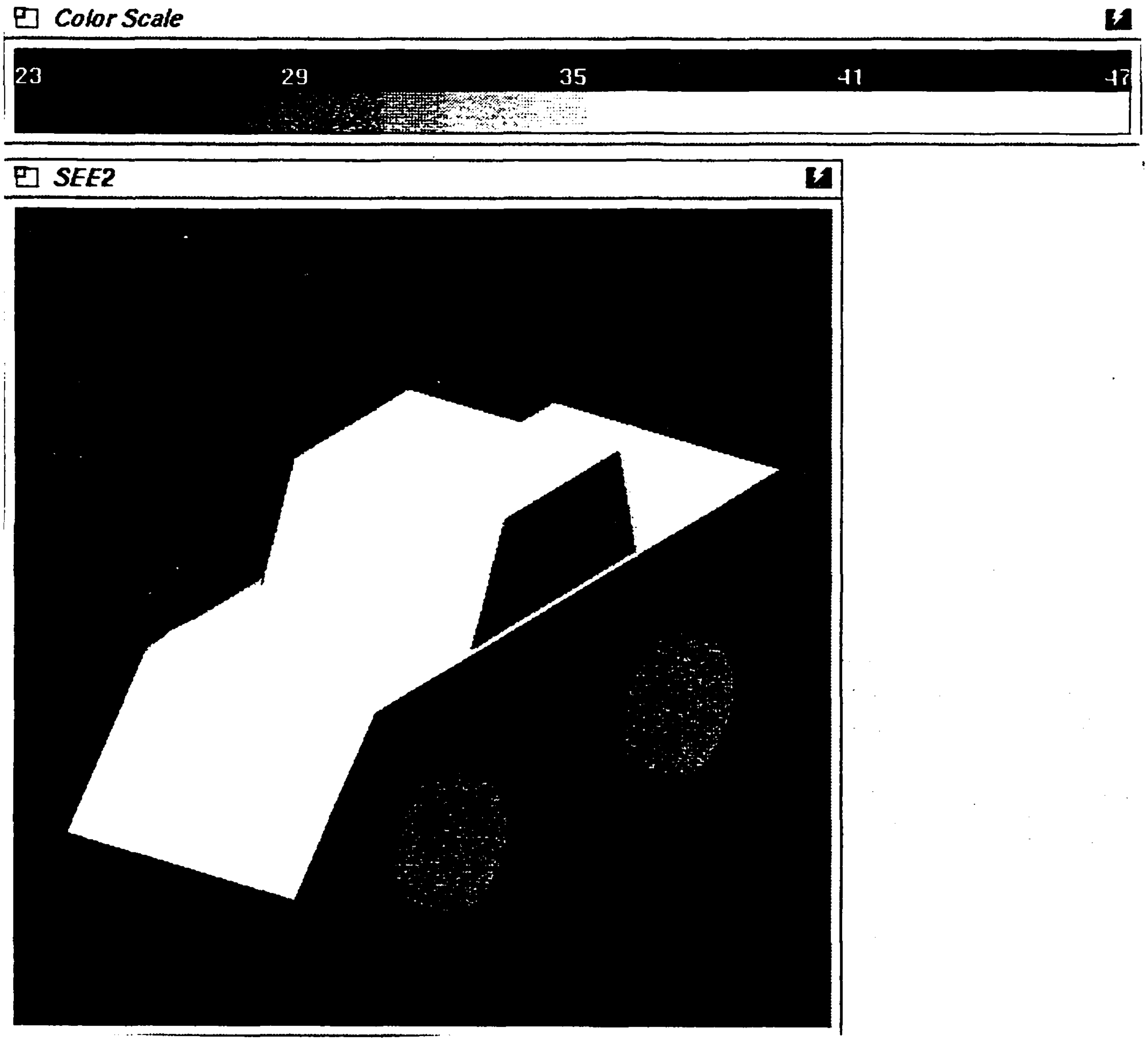

Figure 3. Image Displayed by **See2**

APPENDIX A - Materials Properties File

(See section 3.1 for a description of this file.)

0	0.0	0.0	0.0	0.0	0.0	Air
1	7764.10	460.20	1.0	1.0	52.000	Mild Steel
2	7764.1	448.00	1.0	1.0	100.00	Rolled Homogeneous Armor
3	7764.1	460.20	1.0	1.0	17.300	Face-hardened Steel Armor
4	7203.80	460.20	1.0	1.0	52.000	Cast Iron
5	2769.5	883.0	1.0	1.0	201.0	Aluminum 2024
6	1793.0	1000.00	1.0	1.0	159.000	Magnesium
7	8900.70	384.92	1.0	1.0	385.790	Copper
8	10997.8	129.00	1.0	1.0	34.600	Lead
9	4482.4	523.00	1.0	1.0	30.00	Titanium
10	18681.9	130.0	1.0	1.0	50.00	Tuballoy
11	744.4	1500.	1.0	1.0	0.300	Nylon, Unbonded
12	928.5	1500.	1.0	1.0	0.300	Nylon, Bonded
13	1199.0	1500.	1.0	1.0	0.300	Lexan
14	1216.6	1464.4	1.0	1.0	0.300	Plexiglass, Cast
15	1216.6	1464.4	1.0	1.0	0.300	Plexiglass, Stretched
16	2001.1	1000.	1.0	1.0	0.400	Doron
17	2465.3	753.12	1.0	1.0	1.172	Glass
18	935.6	2008.30	1.0	1.0	0.156	Rubber
19	650.0	1757.0	1.0	1.0	.112	Wood, Hard
20	1000.	4184.00	1.0	1.0	0.606	Water
21	902.40	1799.09	1.0	1.0	0.113	Oil, Lube or Hydraulic
22	797.20	1800.	1.0	1.0	0.14	Fuel, Diesel
23	1690.	1088.	1.0	1.0	0.400	Propellant
24	1650.	1088.	1.0	1.0	0.400	High Explosive
25	680.9	1800.00	1.0	1.0	0.1	Gasoline
26	1320.	1500.	1.0	1.0	0.300	Fiberglass
27	80.3	1800.	1.0	1.0	0.300	Foam rubber
28	1099.	4000.	1.0	1.0	0.600	Personnel
29	5200.	130.0	1.0	1.0	50.00	Radiation Shielding Material
30	19300.	134.00	1.0	1.0	178.00	Tungsten
31	2769.50	883.0	1.0	1.0	201.00	Aluminum Armor 5083
32	2769.50	883.0	1.0	1.0	201.00	Aluminum Armor 7039
33	2769.5	883.0	1.0	1.0	201.0	Aluminum Armor, other
34	157.	1870.	1.0	1.0	0.400	Canvas
35	1960.	950.0	1.0	1.0	18.00	Ceramic Armor
36	190.	1046.	1.0	1.0	0.040	Celotex
37	2450.	1000.00	1.0	1.0	0.400	Boron
38	930.	1680.	1.0	1.0	0.260	Polyethylene/Kevlar
39	1300.	1000.	1.0	1.0	0.200	Red Fuming Nitric Acid
40	18700.	117.0	1.0	1.0	25.00	Uranium

Key:

column 1 - material code
column 2 - density (kg/m3)
column 3 - specific heat
column 4 - absorptivity
column 5 - emissivity
column 6 - thermal conductivity (W/mK)
column 7 - material

This list is designed for our purposes. Prepare your material file appropriate for you work. We have set all absorptivities and emissivities to 1.

APPENDIX B - Output Files from **firpass**

(See section 3.3 for a description of these files.)

```
02      Facet file for use with PRISM.
 FN DESCRIPTION                  TY     AREA     MASS  SPHEAT       E1        E2   ABSOR
   SN(X)    SN(Y)    SN(Z)     CONV        K        L   SHAPE
     1    /vehicle/hull/r.hull01  1    6.320 939.456 460.200   0.940    0.940    0.600
   0.000   1.000    0.000    1.000       0        0  0.000   1.176   0.000
     2    /vehicle/hull/r.hull02  1    6.321 939.461 460.200   0.940    0.940    0.600
   0.000  -1.000    0.000    1.000       0        0  0.000   1.175   0.000
     3    /vehicle/hull/r.hull03  1    2.077 322.612 460.200   0.940    0.940    0.600
  -1.000   0.000    0.000    1.000       0        0  0.000   2.078   0.000
     4    /vehicle/hull/r.hull04  1   11.8281823.356 460.200   0.940    0.940    0.600
   0.000   0.000   -1.000    1.000       0        0  0.000   2.174   0.000
     5    /vehicle/hull/r.hull05  1    6.211 991.056 460.200   0.940    0.940    0.600
   0.000   0.000    1.000    1.000       0        0  0.000   2.175   0.000
     6    /vehicle/hull/r.hull06  1    2.809 436.001 460.200   0.940    0.940    0.600
   0.740   0.000    0.673    1.000       0        0  0.000   0.000   0.000
     7      /vehicle/tur/r.tur01  1    1.509 224.396 460.200   0.940    0.940    0.600
   0.000   1.000    0.028    1.000       0        0  0.000   0.000   0.000
     8      /vehicle/tur/r.tur02  1    1.508 224.385 460.200   0.940    0.940    0.600
   0.000  -1.000    0.028    1.000       0        0  0.000   0.000   0.000
     9      /vehicle/tur/r.tur03  1    1.659 252.542 460.200   0.940    0.940    0.600
   0.905   0.000    0.426    1.000       0        0  0.000   0.000   0.000
    10      /vehicle/tur/r.tur04  1    1.572 238.981 460.200   0.940    0.940    0.600
  -0.973   0.000    0.229    1.000       0        0  0.000   0.000   0.000
    11      /vehicle/tur/r.tur05  1    2.520 391.311 460.200   0.940    0.940    0.600
   0.000   0.000    1.000    1.000       0        0  0.000   0.000   0.000
    12   /vehicle/wheels/r.whl05  1    0.640 128.038 460.200   0.940    0.940    0.600
   0.018   0.000   -1.000    1.000       0        0  0.000   0.000   0.000
    13   /vehicle/wheels/r.whl06  1    0.657 128.041 460.200   0.940    0.940    0.600
   0.158   0.000   -0.987    1.000       0        0  0.000   0.000   0.000
    14   /vehicle/wheels/r.whl01  1    2.4851829.327 460.200   0.940    0.940    0.600
  -0.336   0.925   -0.179    1.000       0        0  0.000   0.000   0.000
    15   /vehicle/wheels/r.whl02  1    2.4951829.330 460.200   0.940    0.940    0.600
  -0.321  -0.915   -0.244    1.000       0        0  0.000   0.000   0.000
    16   /vehicle/wheels/r.whl03  1    2.4921829.356 460.200   0.940    0.940    0.600
  -0.525   0.736   -0.428    1.000       0        0  0.000   0.000   0.000
    17   /vehicle/wheels/r.whl04  1    2.4971829.332 460.200   0.940    0.940    0.600
  -0.560  -0.736   -0.380    1.000       0        0  0.000   0.000   0.000
    18      /vehicle/gun/r.gun01  1    3.786 307.322 460.200   0.940    0.940    0.600
   0.233  -0.924   -0.303    1.000       0        0  0.000   0.000   0.000
    19          /air/r.crw.air01  1   31.12270064.243 460.200   0.940    0.940    0.600
   0.000   0.000    0.000    1.000       0        0  0.000   0.000   0.000
    20          /air/r.crw.air02  1   12.23619780.950 460.200   0.940    0.940    0.600
   0.000   0.000    0.000    1.000       0        0  0.000   0.000   0.000
    21          /air/r.eng.air01  1   10.85617895.872 460.200   0.940    0.940    0.600
   0.000   0.000    0.000    1.000       0        0  0.000   0.000   0.000
    22 END OF REGIONS           999
```

```
1      1    /vehicle/hull/r.hull01 1.210e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      2    /vehicle/hull/r.hull02 1.210e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      3    /vehicle/hull/r.hull03 4.155e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      4    /vehicle/hull/r.hull04 2.348e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      5    /vehicle/hull/r.hull05 1.276e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      6    /vehicle/hull/r.hull06 5.616e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      7      /vehicle/tur/r.tur01 2.890e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      8      /vehicle/tur/r.tur02 2.890e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1      9      /vehicle/tur/r.tur03 3.253e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     10      /vehicle/tur/r.tur04 3.078e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     11      /vehicle/tur/r.tur05 5.040e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     12  /vehicle/wheels/r.whl05 1.649e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     13  /vehicle/wheels/r.whl06 1.649e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     14  /vehicle/wheels/r.whl01 2.356e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     15  /vehicle/wheels/r.whl02 2.356e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     16  /vehicle/wheels/r.whl03 2.356e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     17  /vehicle/wheels/r.whl04 2.356e-01 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     18      /vehicle/gun/r.gun01 3.958e-02 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     19          /air/r.crw.air01 9.024e+00 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     20          /air/r.crw.air02 2.548e+00 7.764e+03 5.200e+01 4.602e+02   Mild Steel
1     21          /air/r.eng.air01 2.305e+00 7.764e+03 5.200e+01 4.602e+02   Mild Steel
2      1    1            2
  6.320e+00
  4.605e+00 1.176e+00
2      2    1            2
  6.321e+00
  4.604e+00 1.175e+00
2      3    1            1
  2.077e+00
 2.078e+00
2      4    1            2
  1.183e+01
  9.458e+00 2.174e+00
2      5    1            2
  6.211e+00
  4.369e+00 2.175e+00
2      6    1            1
  2.809e+00
  2.809e+00
2      7    1            1
  1.509e+00
  1.380e+00
2      8    1            1
  1.508e+00
  1.381e+00
2      9    1            1
  1.659e+00
  1.619e+00
2     10    1            1
  1.572e+00
  1.535e+00
2     11    1            1
  2.520e+00
  2.469e+00
2     12    1            0
  6.398e-01
```

```
2      13      1            0
  6.565e-01
2      14      1            0
  2.485e+00
2      15      1            0
  2.495e+00
2      16      1            0
  2.492e+00
2      17      1            0
  2.497e+00
2      18      1            1
  3.786e+00
  1.765e-01
2      19      0            0
2      20      0            0
2      21      0            0
3       1    1
  6.320e+00 +2.650e-05 +1.000e+00 +4.174e-05 6.000e-01
3       2    1
  6.321e+00 -8.700e-05 -1.000e+00 -1.424e-06 6.000e-01
3       3    1
  2.077e+00 -1.000e+00 +0.000e+00 +0.000e+00 6.000e-01
3       4    1
  1.183e+01 +3.326e-05 +0.000e+00 -1.000e+00 6.000e-01
3       5    1
  6.211e+00 -5.162e-05 +0.000e+00 +1.000e+00 6.000e-01
3       6    1
  2.809e+00 +7.399e-01 +0.000e+00 +6.727e-01 6.000e-01
3       7    1
  1.509e+00 +1.387e-04 +9.996e-01 +2.775e-02 6.000e-01
3       8    1
  1.508e+00 -2.637e-04 -9.996e-01 +2.763e-02 6.000e-01
3       9    1
  1.659e+00 +9.048e-01 +0.000e+00 +4.258e-01 6.000e-01
3      10    1
  1.572e+00 -9.734e-01 +0.000e+00 +2.290e-01 6.000e-01
3      11    1
  2.520e+00 +0.000e+00 +0.000e+00 +1.000e+00 6.000e-01
3      12    1
  6.398e-01 +1.822e-02 +0.000e+00 -9.998e-01 6.000e-01
3      13    1
  6.565e-01 +1.584e-01 +0.000e+00 -9.874e-01 6.000e-01
3      14    1
  2.485e+00 -3.359e-01 +9.248e-01 -1.789e-01 6.000e-01
3      15    1
  2.495e+00 -3.206e-01 -9.153e-01 -2.438e-01 6.000e-01
3      16    1
  2.492e+00 -5.247e-01 +7.358e-01 -4.280e-01 6.000e-01
3      17    1
  2.497e+00 -5.601e-01 -7.362e-01 -3.799e-01 6.000e-01
3      18    1
  3.786e+00 +2.333e-01 -9.241e-01 -3.027e-01 6.000e-01
3      19    1
  0.000e+00 +0.000e+00 +0.000e+00 +0.000e+00 6.000e-01
3      20    1
  0.000e+00 +0.000e+00 +0.000e+00 +0.000e+00 6.000e-01
```



```
3      21    1
  0.000e+00 +0.000e+00 +0.000e+00 +0.000e+00 6.000e-01
```

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GEOMETRIC FILE - from firpass

```
.gfile used:  test.veh.g
      regions used:
            vehicle
            air
```

region number	region name	centroid X	Y	Z	volume (m**3)	mass (kg)
1	/vehicle/hull/r.hull01	-2.425e+02	+9.900e+02	+1.083e+03	1.210e-01	9.395e+02
2	/vehicle/hull/r.hull02	-2.424e+02	-9.900e+02	+1.083e+03	1.210e-01	9.395e+02
3	/vehicle/hull/r.hull03	-2.990e+03	-6.897e-03	+1.100e+03	4.155e-02	3.226e+02
4	/vehicle/hull/r.hull04	-4.533e+00	-2.337e-03	+5.600e+02	2.348e-01	1.823e+03
5	/vehicle/hull/r.hull05	-5.998e+02	-2.166e+00	+1.640e+03	1.276e-01	9.911e+02
6	/vehicle/hull/r.hull06	+2.486e+03	-2.320e-02	+1.100e+03	5.616e-02	4.360e+02
7	/vehicle/tur/r.tur01	-3.471e+02	+9.100e+02	+2.050e+03	2.890e-02	2.244e+02
8	/vehicle/tur/r.tur02	-3.471e+02	-9.100e+02	+2.050e+03	2.890e-02	2.244e+02
9	/vehicle/tur/r.tur03	+4.931e+02	-4.325e-02	+2.066e+03	3.253e-02	2.525e+02
10	/vehicle/tur/r.tur04	-1.192e+03	+3.218e-02	+2.066e+03	3.078e-02	2.390e+02
11	/vehicle/tur/r.tur05	-4.000e+02	+2.895e-02	+2.490e+03	5.040e-02	3.913e+02
12	/vehicle/wheels/r.whl05	+1.400e+03	+9.272e-02	+5.000e+02	1.649e-02	1.280e+02
13	/vehicle/wheels/r.whl06	-1.400e+03	-1.114e-01	+5.000e+02	1.649e-02	1.280e+02
14	/vehicle/wheels/r.whl01	+1.400e+03	+1.200e+03	+5.000e+02	2.356e-01	1.829e+03
15	/vehicle/wheels/r.whl02	+1.400e+03	-1.200e+03	+5.000e+02	2.356e-01	1.829e+03
16	/vehicle/wheels/r.whl03	-1.400e+03	+1.200e+03	+5.000e+02	2.356e-01	1.829e+03
17	/vehicle/wheels/r.whl04	-1.400e+03	-1.200e+03	+5.000e+02	2.356e-01	1.829e+03
18	/vehicle/gun/r.gun01	+1.962e+03	-1.229e-03	+2.246e+03	3.958e-02	3.073e+02
19	/air/r.crw.air01	+3.101e+02	+6.454e-05	+1.080e+03	9.024e+00	7.006e+04
20	/air/r.crw.air02	-3.476e+02	+1.091e-01	+2.030e+03	2.548e+00	1.978e+04
21	/air/r.eng.air01	-2.425e+03	+1.805e-04	+1.100e+03	2.305e+00	1.790e+04

region number	exterior sur area (m**2)	engine sur area (m**2)	crew sur area (m**2)	closed compartment sur area (m**2)	exhaust sur area (m**2)	generic 1 sur area (m**2)	generic 2 sur area (m**2)
1	6.320e+00	1.176e+00	4.605e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
2	6.321e+00	1.175e+00	4.604e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
3	2.077e+00	2.078e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
4	1.183e+01	2.174e+00	9.458e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
5	6.211e+00	2.175e+00	4.369e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
6	2.809e+00	0.000e+00	2.809e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
7	1.509e+00	0.000e+00	1.380e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
8	1.508e+00	0.000e+00	1.381e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
9	1.659e+00	0.000e+00	1.619e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
10	1.572e+00	0.000e+00	1.535e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
11	2.520e+00	0.000e+00	2.469e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
12	6.398e-01	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
13	6.565e-01	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
14	2.485e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
15	2.495e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
16	2.492e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
17	2.497e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
18	3.786e+00	0.000e+00	1.765e-01	0.000e+00	0.000e+00	0.000e+00	0.000e+00
19	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00

20	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00
21	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00

region number	material code	density (kg/m3)	specific heat	absorptivity	emissivity	thermal conductivity (W/mK)	material
1	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
2	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
3	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
4	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
5	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
6	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
7	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
8	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
9	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
10	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
11	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
12	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
13	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
14	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
15	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
16	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
17	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
18	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
19	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
20	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel
21	1	7.764e+03	4.602e+02	6.000e-01	9.400e-01	5.200e+01	Mild Steel

region number	adjacent regions									
1	3,	4,	5,	6,	12,	13,	19,	21,		
2	3,	4,	5,	6,	12,	13,	19,	21,		
3	1,	2,	4,	5,	21,					
4	1,	2,	3,	6,	12,	13,	19,	21,		
5	1,	2,	3,	6,	7,	8,	9,	10,	19,	20,	21,
6	1,	2	4,	5,	19,					
7	5,	9,	10,	11,	20,					
8	5,	9,	10,	11,	20,					
9	5,	7,	8,	11,	18,	20,				
10	5,	7,	8,	11,	20,					
11	7,	8,	9,	10,	20,					
12	1,	2,	4,	14,	15,					
13	1,	2,	4,	16,	17,					
14	12,									
15	12,									
16	13,									
17	13,									
18	9,	20,								
19	1,	2,	4,	5,	6,	20,	21,			
20	5,	7,	8,	9,	10,	11,	18,	19,		
21	1,	2,	3,	4,	5,	19,				

APPENDIX C - Output Files from **secpass**

(See section 4.3 for a description of these files.)

Apr 23 13:34 1992 veh.s.con Page 1

```
Conductivity file for use with PRISM.
   3     1   0.288 2.061e-02
   4     1   4.148 1.193e-01
   5     1   3.406 1.005e-01
   6     1   0.446 2.834e-02
  12     1   0.005 2.573e-04
  13     1   0.003 1.316e-04
  19     1 241.770 4.605e+00
  21     1  23.431 1.176e+00
   3     2   0.319 2.282e-02
   4     2   4.158 1.196e-01
   5     2   3.378 9.939e-02
   6     2   0.453 2.871e-02
  12     2   0.002 1.269e-04
  13     2   0.003 1.268e-04
  19     2 241.323 4.604e+00
  21     2  23.411 1.175e+00
   4     3   0.583 3.933e-02
   5     3   0.697 3.903e-02
  21     3 190.876 2.078e+00
   6     4   0.749 5.287e-02
  12     4   0.444 1.241e-02
  13     4   0.447 1.241e-02
  19     4 941.731 9.458e+00
  21     4  47.165 2.174e+00
   6     5   0.831 5.274e-02
   7     5   1.593 3.995e-02
   8     5   1.596 3.995e-02
   9     5   1.193 3.981e-02
  10     5   1.734 3.694e-02
  19     5 161.735 4.133e+00
  20     5   7.492 2.357e-01
  21     5  62.718 2.175e+00
  19     6  81.651 2.809e+00
   9     7   0.589 1.877e-02
  10     7   0.524 1.730e-02
  11     7   1.103 2.834e-02
  20     7  78.712 1.380e+00
   9     8   0.565 1.804e-02
  10     8   0.524 1.730e-02
  11     8   1.102 2.834e-02
  20     8  78.672 1.381e+00
  11     9   2.668 5.876e-02
  18     9   0.390 1.129e-02
  20     9 103.153 1.619e+00
  11    10   3.028 6.464e-02
  20    10  95.852 1.535e+00
  20    11 278.521 2.469e+00
  14    12   0.367 8.467e-03
  15    12   0.351 8.099e-03
  16    13   0.319 7.362e-03
  17    13   0.319 7.362e-03
  20    18   4.086 1.610e-01
  20    19 188.183 3.435e+00
  21    19  39.504 2.078e+00
```

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```
4     1      8
      3  2.061e-02  2.740e+00
      4  1.193e-01  5.152e-01
      5  1.005e-01  5.520e-01
      6  2.834e-02  2.322e+00
     12  2.573e-04  1.724e+00
     13  1.316e-04  1.274e+00
     19  4.605e+00  1.039e-02
     21  1.176e+00  1.630e+00
4     2      8
      3  2.282e-02  2.738e+00
      4  1.196e-01  5.160e-01
      5  9.939e-02  5.522e-01
      6  2.871e-02  2.312e+00
     12  1.269e-04  1.725e+00
     13  1.268e-04  1.276e+00
     19  4.604e+00  1.206e-02
     21  1.175e+00  1.631e+00
4     3      5
      1  2.061e-02  9.801e-01
      2  2.282e-02  9.801e-01
      4  3.933e-02  5.300e-01
      5  3.903e-02  5.300e-01
     21  2.078e+00  1.138e-02
4     4      8
      1  1.193e-01  9.800e-01
      2  1.196e-01  9.800e-01
      3  3.933e-02  2.977e+00
      6  5.287e-02  2.961e+00
     12  1.241e-02  1.402e+00
     13  1.241e-02  1.393e+00
     19  9.458e+00  1.183e-02
     21  2.174e+00  1.867e+00
4     5     11
      1  1.005e-01  9.822e-01
      2  9.939e-02  9.779e-01
      3  3.903e-02  2.381e+00
      6  5.274e-02  2.591e+00
      7  3.995e-02  9.040e-01
      8  3.995e-02  9.016e-01
      9  3.981e-02  1.279e+00
     10  3.694e-02  6.818e-01
     19  4.133e+00  6.728e-01
     20  2.357e-01  6.704e-01
     21  2.175e+00  1.273e+00
4     6      5
      1  2.834e-02  9.800e-01
      2  2.871e-02  9.800e-01
      4  5.287e-02  7.087e-01
      5  5.274e-02  7.083e-01
     19  2.809e+00  1.923e-02
4     7      5
      5  3.995e-02  4.000e-01
      9  1.877e-02  7.573e-01
     10  1.730e-02  8.182e-01
     11  2.834e-02  4.361e-01
```

```
      20  1.380e+00  1.181e-02
4      8      5
       5  3.995e-02  4.000e-01
       9  1.804e-02  7.589e-01
      10  1.730e-02  8.173e-01
      11  2.834e-02  4.376e-01
      20  1.381e+00  1.279e-02
4      9      6
       5  3.981e-02  4.562e-01
       7  1.877e-02  9.001e-01
       8  1.804e-02  9.000e-01
      11  5.876e-02  4.571e-01
      18  1.129e-02  5.009e-02
      20  1.619e+00  4.984e-02
4     10      5
       5  3.694e-02  4.262e-01
       7  1.730e-02  9.000e-01
       8  1.730e-02  9.000e-01
      11  6.464e-02  4.245e-01
      20  1.535e+00  1.242e-02
4     11      5
       7  2.834e-02  9.000e-01
       8  2.834e-02  9.001e-01
       9  5.876e-02  6.883e-01
      10  6.464e-02  6.856e-01
      20  2.469e+00  1.057e-02
4     12      5
       1  2.573e-04  9.816e-01
       2  1.269e-04  9.820e-01
       4  1.241e-02  5.005e-02
      14  8.467e-03  1.050e+00
      15  8.099e-03  1.050e+00
4     13      5
       1  1.316e-04  9.877e-01
       2  1.268e-04  9.865e-01
       4  1.241e-02  5.028e-02
      16  7.362e-03  1.050e+00
      17  7.362e-03  1.050e+00
4     14      1
      12  8.467e-03  1.504e-01
4     15      1
      12  8.099e-03  1.502e-01
4     16      1
      13  7.362e-03  1.501e-01
4     17      1
      13  7.362e-03  1.501e-01
4     18      2
       9  1.129e-02  1.456e+00
      20  1.610e-01  1.475e+00
4     19      7
       1  4.605e+00  9.800e-01
       2  4.604e+00  9.800e-01
       4  9.458e+00  5.104e-01
       5  4.133e+00  6.562e-01
       6  2.809e+00  1.769e+00
      20  3.435e+00  5.496e-01
```



```
      21  2.078e+00  2.181e+00
4     20      8
       5  2.357e-01  9.653e-01
       7  1.380e+00  8.999e-01
       8  1.381e+00  9.001e-01
       9  1.619e+00  7.663e-01
      10  1.535e+00  8.202e-01
      11  2.469e+00  4.503e-01
      18  1.610e-01  5.738e-01
      19  3.435e+00  3.997e-01
4     21      6
       1  1.176e+00  9.801e-01
       2  1.175e+00  9.801e-01
       3  2.078e+00  5.547e-01
       4  2.174e+00  5.300e-01
       5  2.175e+00  5.300e-01
      19  2.078e+00  5.547e-01
```

INTENTIONALLY LEFT BLANK.

APPENDIX D - Output Files from **shapefact**

(See section 5.3 for a description of these files.)

```
Apr 23 15:42 1992  sd.sh.reg Page 1

Number of forward rays fired:  5000000.000000

1       /all.air/r.disk 3.170418e+00
   1    0.000000e+00
   2    1.454059e-01
   3    8.545941e-01
   4    0.000000e+00
  sum of hits:  885693.000000
  sum of shape factors:  1.000000

2       /all.air/r.sph  3.144167e+00
   1    1.467304e-01
   2    0.000000e+00
   3    8.532696e-01
   4    0.000000e+00
  sum of hits:  877698.000000
  sum of shape factors:  1.000000

3       /all.air/r.box  1.689831e+01
   1    1.604804e-01
   2    1.587852e-01
   3    6.807344e-01
   4    0.000000e+00
  sum of hits:  4716515.000000
  sum of shape factors:  1.000000

4       /all.air/r.air  0.000000e+00
   1    0.000000e+00
   2    0.000000e+00
   3    0.000000e+00
   4    0.000000e+00
  sum of hits:  0.000000
  sum of shape factors:  0.000000
```

```
Apr 23 15:48 1992  sd.sh.gen Page 1

 5  1  3.170411e+00  2
    2  1.454051e-01
    3  8.545949e-01
 5  2  3.144167e+00  2
    1  1.467293e-01
    3  8.532707e-01
 5  3  1.689831e+01  3
    1  1.604801e-01
    2  1.587854e-01
    3  6.807345e-01
 5  4  0.000000e+00  0
```

```
Apr 23 14:37 1992  cs.sh.reg Page 1

Number of forward rays fired:  5000000.000000

1       /all.air/r.sph1 1.255002e+01
   1    0.000000e+00
   2    1.000000e+00
   3    0.000000e+00
   4    0.000000e+00
  sum of hits:  629142.000000
  sum of shape factors:  1.000000

2       /all.air/r.sph2 5.028985e+01
   1    2.495538e-01
   2    7.504462e-01
   3    0.000000e+00
   4    0.000000e+00
  sum of hits:  2521068.000000
  sum of shape factors:  1.000000

3       /all.air/r.sph3 0.000000e+00
   1    0.000000e+00
   2    0.000000e+00
   3    0.000000e+00
   4    0.000000e+00
  sum of hits:  0.000000
  sum of shape factors:  0.000000

4       /all.air/r.air  0.000000e+00
   1    0.000000e+00
   2    0.000000e+00
   3    0.000000e+00
   4    0.000000e+00
  sum of hits:  0.000000
```

```
Apr 23 14:38 1992  cs.sh.gen Page 1

 5  1  1.255002e+01  1
    2  1.000000e+00
 5  2  5.028985e+01  2
    1  2.495538e-01
    2  7.504462e-01
 5  3  0.000000e+00  0
 5  4  0.000000e+00  0
```

APPENDIX E - PRISM Files

(See section 6.2 for a description of these files.)

```
02      Facet file for use with PRISM.
 FN DESCRIPTION                TY    AREA     MASS  SPHEAT       E1        E2    ABSOR
   SN(X)    SN(Y)   SN(Z)     CONV       K         L   SHAPE
     1    /vehicle/hull/r.hull01  1   6.320 939.456 460.200   0.940    0.940    0.600
   0.000   1.000   0.000   1.000      0         0  0.000   1.176   0.000
     2    /vehicle/hull/r.hull02  1   6.321 939.461 460.200   0.940    0.940    0.600
   0.000  -1.000   0.000   1.000      0         0  0.000   1.175   0.000
     3    /vehicle/hull/r.hull03  1   2.077 322.612 460.200   0.940    0.940    0.600
  -1.000   0.000   0.000   1.000      0         0  0.000   2.078   0.000
     4    /vehicle/hull/r.hull04  1  11.8281823.356 460.200   0.940    0.940    0.600
   0.000   0.000  -1.000   1.000      0         0  0.000   2.174   0.000
     5    /vehicle/hull/r.hull05  1   6.211 991.056 460.200   0.940    0.940    0.600
   0.000   0.000   1.000   1.000      0         0  0.000   2.175   0.000
     6    /vehicle/hull/r.hull06  1   2.809 436.001 460.200   0.940    0.940    0.600
   0.740   0.000   0.673   1.000      0         0  0.000   0.000   0.000
     7      /vehicle/tur/r.tur01  1   1.509 224.396 460.200   0.940    0.940    0.600
   0.000   1.000   0.028   1.000      0         0  0.000   0.000   0.000
     8      /vehicle/tur/r.tur02  1   1.508 224.385 460.200   0.940    0.940    0.600
   0.000  -1.000   0.028   1.000      0         0  0.000   0.000   0.000
     9      /vehicle/tur/r.tur03  1   1.659 252.542 460.200   0.940    0.940    0.600
   0.905   0.000   0.426   1.000      0         0  0.000   0.000   0.000
    10      /vehicle/tur/r.tur04  1   1.572 238.981 460.200   0.940    0.940    0.600
  -0.973   0.000   0.229   1.000      0         0  0.000   0.000   0.000
    11      /vehicle/tur/r.tur05  1   2.520 391.311 460.200   0.940    0.940    0.600
   0.000   0.000   1.000   1.000      0         0  0.000   0.000   0.000
    12  /vehicle/wheels/r.whl05  1   0.640 128.038 460.200   0.940    0.940    0.600
   0.018   0.000  -1.000   1.000      0         0  0.000   0.000   0.000
    13  /vehicle/wheels/r.whl06  1   0.657 128.041 460.200   0.940    0.940    0.600
   0.158   0.000  -0.987   1.000      0         0  0.000   0.000   0.000
    14  /vehicle/wheels/r.whl01 11   2.4851829.327 460.200   0.940    0.940    0.600
   0.000   1.000   0.000   1.000      0         0  0.000   0.500   0.000
    15  /vehicle/wheels/r.whl02 11   2.4951829.330 460.200   0.940    0.940    0.600
   0.000  -1.000   0.000   1.000      0         0  0.000   0.500   0.000
    16  /vehicle/wheels/r.whl03 11   2.4921829.356 460.200   0.940    0.940    0.600
   0.000   1.000   0.000   1.000      0         0  0.000   0.500   0.000
    17  /vehicle/wheels/r.whl04 11   2.4971829.332 460.200   0.940    0.940    0.600
   0.000  -1.000   0.000   1.000      0         0  0.000   0.500   0.000
    18      /vehicle/gun/r.gun01  1   3.786 307.322 460.200   0.940    0.940    0.600
   0.000   0.000   1.000   1.000      0         0  0.000   0.000   0.000
    19 END OF REGIONS           999
     3        1    0.288 2.061e-02
     4        1    4.148 1.193e-01
     5        1    3.406 1.005e-01
     6        1    0.446 2.834e-02
    12        1    0.005 2.573e-04
    13        1    0.003 1.316e-04
     3        2    0.319 2.282e-02
     4        2    4.158 1.196e-01
     5        2    3.378 9.939e-02
     6        2    0.453 2.871e-02
    12        2    0.002 1.269e-04
    13        2    0.003 1.268e-04
     4        3    0.583 3.933e-02
     5        3    0.697 3.903e-02
     6        4    0.749 5.287e-02
    12        4    0.444 1.241e-02
```



```
    13        4    0.447 1.241e-02
     6        5    0.831 5.274e-02
     7        5    1.593 3.995e-02
     8        5    1.596 3.995e-02
     9        5    1.193 3.981e-02
    10        5    1.734 3.694e-02
     9        7    0.589 1.877e-02
    10        7    0.524 1.730e-02
    11        7    1.103 2.834e-02
     9        8    0.565 1.804e-02
    10        8    0.524 1.730e-02
    11        8    1.102 2.834e-02
    11        9    2.668 5.876e-02
    18        9    0.390 1.129e-02
    11       10    3.028 6.464e-02
    14       12    0.367 8.467e-03
    15       12    0.351 8.099e-03
    16       13    0.319 7.362e-03
    17       13    0.319 7.362e-03
```

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7 19 1984	7. 0.						
0.00	18.80	34.00	34.00	34.00	34.00	34.00	34.00
34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00
34.00	34.00	34.00	34.00				
1.00	18.93	25.97	25.46	25.71	26.27	25.70	26.99
25.95	25.44	27.12	25.47	25.56	27.67	27.50	31.86
31.73	31.86	31.73	21.60				
2.00	20.95	25.01	22.58	22.75	23.53	27.38	36.55
25.28	22.79	37.14	22.79	27.50	25.01	24.80	30.88
30.16	30.88	30.16	27.37				
3.00	21.99	23.04	22.32	21.70	22.49	31.09	42.53
23.67	23.12	42.26	22.38	31.47	23.73	23.52	29.60
29.07	29.59	29.07	33.73				
4.00	24.86	22.60	25.31	21.76	22.59	36.02	46.83
23.69	26.69	45.41	23.25	36.51	23.45	23.27	28.61
28.91	28.60	28.91	40.36				
5.00	27.80	23.13	29.71	22.49	23.28	40.98	48.94
24.69	31.48	46.43	24.85	41.39	23.76	23.61	27.92
29.53	27.91	29.53	45.72				
6.00	28.40	23.92	33.63	23.39	24.05	44.58	48.34
25.81	35.51	44.91	26.42	44.78	24.23	24.10	27.39
30.55	27.39	30.55	48.54				
7.00	30.82	24.85	36.95	24.38	25.02	47.68	46.94
27.00	38.86	42.65	29.64	47.67	24.94	24.83	27.07
31.82	27.06	31.82	51.59				
8.00	30.37	25.97	39.06	27.81	26.13	49.60	44.27
28.32	40.96	39.32	35.57	49.45	25.85	25.76	26.95
33.08	26.94	33.09	52.80				
9.00	29.29	26.56	39.03	33.37	26.76	49.38	39.75
28.98	40.87	34.70	41.18	49.16	26.44	26.35	26.84
33.93	26.84	33.94	51.28				
10.00	30.54	26.90	37.77	39.49	27.33	48.21	34.54
29.35	39.60	32.23	46.10	48.03	26.99	26.88	26.76
34.29	26.75	34.29	49.59				
11.00	28.79	26.66	34.68	44.08	27.36	45.19	30.24
29.05	36.50	30.54	48.74	45.13	27.13	27.00	26.59
33.94	26.59	33.95	45.35				
12.00	25.73	26.23	30.68	45.92	26.90	40.84	27.60
28.59	32.43	29.10	48.47	40.95	26.85	26.70	26.39
33.00	26.38	33.01	39.53				
13.00	23.01	26.41	27.43	43.64	25.90	35.13	25.32
28.54	29.01	27.23	44.30	35.37	26.10	25.92	26.35
31.91	26.34	31.91	32.16				
14.00	18.03	24.82	24.10	37.06	24.19	28.50	22.35
26.48	25.46	24.26	36.33	28.79	24.73	24.49	25.96
30.65	25.95	30.65	23.47				
15.00	12.46	19.80	19.29	27.18	21.06	20.62	17.52
20.87	20.24	19.18	25.73	20.82	22.18	21.83	24.65
28.84	24.64	28.84	13.30				
16.00	11.42	15.57	15.26	20.23	18.16	14.65	13.39
16.13	15.77	14.71	18.51	14.77	19.71	19.27	23.19
26.95	23.17	26.95	7.06				
17.00	10.72	12.62	12.42	15.69	16.01	10.59	10.46
12.77	12.56	11.46	13.85	10.66	17.79	17.31	21.83
25.22	21.81	25.22	4.03				
18.00	11.27	10.85	10.73	12.87	14.68	8.16	8.74

10.69	10.57	9.47	11.02	8.21	16.50	16.00	20.63
23.70	20.62	23.70	3.33				
19.00	11.38	9.70	9.63	10.99	13.80	6.56	7.60
9.30	9.23	8.13	9.19	6.59	15.56	15.06	19.54
22.31	19.52	22.31	3.08				
20.00	10.65	8.83	8.78	9.63	13.04	5.44	6.77
8.27	8.23	7.16	7.92	5.45	14.73	14.23	18.48
20.99	18.46	20.99	2.83				
21.00	10.82	8.25	8.23	8.73	12.44	4.77	6.25
7.60	7.59	6.54	7.13	4.78	14.00	13.51	17.47
19.72	17.45	19.72	2.94				
22.00	9.10	7.46	7.44	7.75	11.70	3.88	5.46
6.74	6.73	5.70	6.19	3.88	13.21	12.72	16.48
18.52	16.46	18.51	2.10				
23.00	9.33	6.83	6.82	7.00	11.08	3.21	4.85
6.07	6.07	5.04	5.48	3.20	12.51	12.03	15.54
17.38	15.52	17.38	1.63				
24.00	11.11	7.67	6.75	6.83	10.84	3.38	6.26
6.89	5.98	6.68	5.38	3.39	12.14	11.79	14.97
16.45	14.95	16.44	2.50				

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01
XXXXXXXXXXXXXXX  KRC ktank test July 19, 1984
LAT=            0.823359
LONG=           1.544471
MON=            07
DAY=            19
YR=             1984
HR=             07.
MIN=            00.
VEHAZ=          90.
TDIFF=          +4.
DURATN=         24.
DTIME=          0.01
LAPTIM=         0.0
ELEV=           334.
MMOD=           100
SWMOD=          OFF
LWMOD=          ON
INIT=           34.0
INITMPFILSW=    OFF
ENGSW=          OFF
THREED=         OFF
FREDSW=         OFF
```

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05
TERRAIN FILE    July 7, 1984.
TABSOR          0.65
TEMIS           0.94
KA              2.64
DX              .0254
SC              .208
CABSOR          .74
CEMIS           .95
LW              .0025
LL              .900
PBS             0.20
PCR             0.60
NNODE           09
TTEMPi  ALPHAi  300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
                300.     8.2E-07
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03              Stationary vehicle.
  ETIME   MPH    ENGSTATE
  25.00   00.0   0
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4

TIME	AIRT	SOLAR	WIND	HUMID	CLOUD	LWIR	WINDIR
0610	18.800	0.000	1.299	78.833	5.000	0.000	155.808
0615	18.900	2.000	0.828	78.250	6.000	0.000	150.912
0620	18.700	4.000	0.903	77.667	6.000	0.000	151.920
0625	18.600	6.000	1.532	77.083	6.000	0.000	180.216
0630	18.700	10.000	1.055	76.500	7.000	0.000	169.704
0635	18.400	20.000	1.630	75.917	7.000	0.000	162.720
0640	18.400	24.000	1.016	75.333	7.000	0.000	171.936
0645	18.400	34.000	1.390	74.750	8.000	0.000	159.408
0650	18.500	50.000	1.131	74.167	8.000	0.000	149.184
0655	19.700	116.000	2.397	73.583	8.000	0.000	137.088
0700	18.800	94.000	1.633	73.000	7.000	0.000	163.512
0705	18.500	34.000	0.467	72.583	7.000	0.000	182.232
0710	18.400	26.000	1.758	72.167	7.000	0.000	147.456
0715	18.000	14.000	2.811	71.750	6.000	0.000	161.280
0720	17.800	16.000	1.647	71.333	6.000	0.000	142.056
0725	17.800	14.000	0.659	70.917	6.000	0.000	170.928
0730	17.900	12.000	3.116	70.500	5.000	0.000	157.248
0735	17.800	10.000	1.309	70.083	5.000	0.000	214.848
0740	18.000	10.000	1.679	69.667	4.000	0.000	148.464
0745	18.200	28.000	2.012	69.250	4.000	0.000	166.320
0750	18.500	70.000	2.727	68.833	4.000	0.000	152.496
0755	18.800	160.000	2.131	68.417	4.000	0.000	168.480
0800	19.500	282.000	2.072	68.000	4.000	0.000	156.528
0805	20.000	306.000	2.419	67.917	3.000	0.000	153.792
0810	19.700	260.000	1.402	67.833	3.000	0.000	144.432
0815	20.000	294.000	1.2[illegible]	67.750	3.000	0.000	176.544
0820	19.900	308.000	2.516	67.667	3.000	0.000	172.368
0825	19.900	310.000	1.515	67.583	3.000	0.000	182.232
0830	19.800	292.000	1.483	67.500	3.000	0.000	147.528
0835	19.900	286.000	2.031	67.417	3.000	0.000	151.776
0840	20.200	354.000	1.293	67.333	2.000	0.000	237.168
0845	20.300	352.000	1.631	67.250	2.000	0.000	173.448
0850	20.100	368.000	1.807	67.167	2.000	0.000	159.480
0855	20.100	384.000	1.446	67.083	2.000	0.000	140.472
0900	20.300	400.000	1.967	67.000	2.000	0.000	148.464
0905	20.100	398.000	1.504	66.917	2.000	0.000	164.160
0910	20.100	414.000	1.030	66.833	2.000	0.000	160.416
0915	20.100	430.000	2.862	66.750	2.000	0.000	189.936
0920	20.100	440.000	1.435	66.667	2.000	0.000	159.048
0925	20.100	450.000	1.752	66.583	1.000	0.000	132.552
0930	20.400	462.000	2.231	66.500	1.000	0.000	125.352
0935	20.300	480.000	0.707	66.417	1.000	0.000	172.008
0940	20.400	510.000	2.117	66.333	1.000	0.000	160.344
0945	20.300	520.000	1.520	66.250	1.000	0.000	163.368
0950	20.400	526.000	2.134	66.167	1.000	0.000	169.992
0955	20.200	542.000	1.522	66.083	1.000	0.000	169.272
1000	20.300	554.000	3.271	66.000	1.000	0.000	167.328
1005	20.800	564.000	1.010	66.083	1.000	0.000	159.984
1010	20.600	578.000	1.016	66.167	1.000	0.000	124.344
1015	20.800	590.000	1.779	66.250	1.000	0.000	170.208
1020	20.400	600.000	2.040	66.333	1.000	0.000	154.944
1025	20.600	606.000	1.791	66.417	0.000	0.000	168.264
1030	20.400	624.000	3.125	66.500	0.000	0.000	169.920
1035	20.600	632.000	1.561	66.583	0.000	0.000	175.824

1040	20.600	644.000	2.837	66.667	0.000	0.000	174.888
1045	21.200	650.000	0.753	66.750	0.000	0.000	186.840
1050	20.700	658.000	0.916	66.833	0.000	0.000	192.816
1055	21.200	672.000	1.224	66.917	0.000	0.000	163.440
1100	20.400	690.000	1.726	67.000	0.000	0.000	158.688
1105	21.100	700.000	1.956	66.917	0.000	0.000	171.936
1110	21.100	708.000	1.387	66.833	0.000	0.000	198.792
1115	21.600	710.000	0.884	66.750	0.000	0.000	192.672
1120	21.400	722.000	1.577	66.667	0.000	0.000	159.552
1125	21.800	734.000	1.431	66.583	0.000	0.000	211.824
1130	21.200	740.000	2.232	66.500	0.000	0.000	170.352
1135	20.700	748.000	2.599	66.417	0.000	0.000	188.856
1140	21.400	762.000	0.714	66.333	0.000	0.000	203.760
1145	21.300	770.000	2.549	66.250	0.000	0.000	186.912
1150	21.500	772.000	0.992	66.167	0.000	0.000	155.232
1155	21.100	782.000	1.933	66.083	0.000	0.000	207.144
1200	21.500	790.000	1.344	66.000	0.000	0.000	201.384
1205	21.000	798.000	2.328	65.750	0.000	0.000	176.976
1210	21.700	802.000	1.727	65.500	0.000	0.000	189.216
1215	21.200	810.000	2.532	65.250	0.000	0.000	176.472
1220	21.300	820.000	1.106	65.000	0.000	0.000	152.496
1225	22.400	824.000	1.661	64.750	0.000	0.000	210.888
1230	21.500	830.000	2.452	64.500	0.000	0.000	190.584
1235	21.600	834.000	1.366	64.250	0.000	0.000	188.280
1240	21.900	840.000	1.851	64.000	0.000	0.000	219.600
1245	22.100	844.000	1.342	63.750	0.000	0.000	192.960
1250	21.800	848.000	2.102	63.500	0.000	0.000	153.576
1255	22.200	850.000	3.257	63.250	0.000	0.000	157.536
1300	22.200	850.000	1.933	63.000	0.000	0.000	161.136
1305	21.900	856.000	1.944	63.167	0.000	0.000	148.248
1310	21.800	862.000	2.694	63.333	0.000	0.000	184.176
1315	21.700	868.000	1.807	63.500	0.000	0.000	167.544
1320	21.800	872.000	1.839	63.667	0.000	0.000	172.584
1325	22.200	874.000	1.284	63.833	0.000	0.000	163.656
1330	21.900	876.000	2.331	64.000	0.000	0.000	189.936
1335	22.300	880.000	1.232	64.167	0.000	0.000	168.408
1340	22.400	880.000	1.541	64.333	0.000	0.000	163.728
1345	23.100	880.000	1.550	64.500	0.000	0.000	198.936
1350	22.800	880.000	1.375	64.667	0.000	0.000	170.928
1355	22.500	880.000	2.155	64.833	0.000	0.000	167.544
1400	22.700	880.000	1.243	65.000	0.000	0.000	171.072
1405	23.100	880.000	1.073	65.833	0.000	0.000	186.192
1410	22.800	880.000	1.734	66.667	0.000	0.000	153.792
1415	23.300	880.000	3.066	67.500	0.000	0.000	198.288
1420	22.900	880.000	2.306	68.333	0.000	0.000	147.168
1425	22.900	878.000	1.891	69.167	0.000	0.000	143.136
1430	23.900	874.000	0.649	70.000	0.000	0.000	139.464
1435	23.800	866.000	1.251	70.833	0.000	0.000	151.920
1440	23.600	860.000	1.179	71.667	0.000	0.000	201.744
1445	23.500	860.000	1.489	72.500	0.000	0.000	166.104
1450	23.400	860.000	1.439	73.333	0.000	0.000	189.072
1455	23.000	852.000	2.124	74.167	0.000	0.000	191.520
1500	23.300	850.000	1.720	75.000	0.000	0.000	196.344
1505	23.600	850.000	1.198	73.833	0.000	0.000	157.032
1510	23.800	842.000	1.814	72.667	0.000	0.000	227.088
1515	22.900	838.000	3.068	71.500	0.000	0.000	163.800

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1520	23.300	832.000	0.935	70.333	0.000	0.000	188.784
1525	23.300	828.000	2.096	69.167	0.000	0.000	144.936
1530	23.700	820.000	0.808	68.000	0.000	0.000	166.032
1535	23.200	814.000	1.257	66.833	0.000	0.000	175.896
1540	23.300	808.000	1.646	65.667	0.000	0.000	162.648
1545	23.800	802.000	1.209	64.500	0.000	0.000	199.008
1550	23.700	798.000	0.746	63.333	0.000	0.000	190.584
1555	23.900	788.000	3.028	62.167	0.000	0.000	190.368
1600	23.700	780.000	2.494	61.000	0.000	0.000	164.880
1605	24.000	772.000	1.487	59.000	0.000	0.000	186.984
1610	23.800	766.000	1.950	57.000	0.000	0.000	176.328
1615	24.100	758.000	2.375	55.000	0.000	0.000	176.472
1620	24.200	750.000	0.931	53.000	0.000	0.000	156.672
1625	24.200	744.000	1.568	51.000	0.000	0.000	187.560
1630	24.300	738.000	1.750	49.000	0.000	0.000	218.592
1635	24.700	714.000	1.078	47.000	0.000	0.000	154.944
1640	24.400	708.000	1.027	45.000	0.000	0.000	158.256
1645	24.400	700.000	1.411	43.000	0.000	0.000	151.488
1650	24.600	692.000	0.788	41.000	0.000	0.000	192.240
1655	24.800	684.000	1.224	39.000	0.000	0.000	220.176
1700	25.000	674.000	1.247	37.000	0.000	0.000	156.744
1705	24.400	662.000	1.431	37.083	0.000	0.000	193.032
1710	24.000	650.000	2.481	37.167	0.000	0.000	183.456
1715	24.000	640.000	1.322	37.250	0.000	0.000	163.080
1720	24.600	626.000	2.553	37.333	0.000	0.000	164.232
1725	24.300	618.000	1.084	37.417	0.000	0.000	177.480
1730	24.400	604.000	0.714	37.500	0.000	0.000	173.592
1735	24.200	594.000	1.370	37.583	0.000	0.000	215.928
1740	24.700	582.000	0.757	37.667	0.000	0.000	139.176
1745	24.700	568.000	0.693	37.750	0.000	0.000	184.608
1750	24.800	552.000	1.349	37.833	0.000	0.000	180.360
1755	24.600	542.000	1.225	37.917	0.000	0.000	194.112
1800	24.400	530.000	0.968	38.000	0.000	0.000	196.344
1805	24.200	516.000	1.418	38.417	0.000	0.000	194.256
1810	25.100	502.000	0.554	38.833	0.000	0.000	179.784
1815	24.300	488.000	0.860	39.250	0.000	0.000	176.976
1820	24.300	474.000	0.981	39.667	0.000	0.000	168.840
1825	24.700	460.000	0.941	40.083	0.000	0.000	204.768
1830	24.400	444.000	0.824	40.500	0.000	0.000	201.168
1835	24.100	434.000	1.095	40.917	0.000	0.000	223.200
1840	23.900	418.000	0.870	41.333	0.000	0.000	185.760
1845	23.800	400.000	0.973	41.750	0.000	0.000	201.528
1850	23.700	386.000	1.339	42.167	0.000	0.000	178.632
1855	23.900	374.000	1.111	42.583	0.000	0.000	190.152
1900	23.900	358.000	1.211	43.000	0.000	0.000	209.448
1905	23.900	344.000	1.674	43.000	0.000	0.000	164.952
1910	23.900	328.000	0.624	43.000	0.000	0.000	178.200
1915	23.700	316.000	1.223	43.000	0.000	0.000	212.472
1920	23.300	300.000	0.753	43.000	0.000	0.000	199.440
1925	23.600	286.000	0.791	43.000	0.000	0.000	181.080
1930	23.400	272.000	0.482	43.000	0.000	0.000	183.960
1935	23.300	260.000	0.622	43.000	0.000	0.000	140.904
1940	23.700	240.000	0.626	43.000	0.000	0.000	181.224
1945	23.400	230.000	0.505	43.000	0.000	0.000	167.544
1950	23.400	216.000	0.303	43.000	0.000	0.000	204.912
1955	23.000	202.000	0.783	43.000	0.000	0.000	186.768

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2000	22.400	184.000	0.200	43.000	0.000	0.000	198.648
2005	22.000	176.000	0.337	44.167	0.000	0.000	216.360
2010	21.900	168.000	0.200	45.333	0.000	0.000	141.912
2015	21.800	154.000	0.202	46.500	0.000	0.000	186.768
2020	21.600	144.000	0.388	47.667	0.000	0.000	207.288
2025	21.500	126.000	0.290	48.833	1.000	0.000	236.736
2030	21.400	120.000	0.201	50.000	1.000	0.000	174.024
2035	21.400	104.000	0.238	51.167	1.000	0.000	190.728
2040	21.300	84.000	0.201	52.333	1.000	0.000	191.016
2045	20.900	78.000	0.200	53.500	1.000	0.000	176.472
2050	20.700	66.000	0.200	54.667	1.000	0.000	180.432
2055	20.100	54.000	0.256	55.833	1.000	0.000	185.184
2100	19.800	46.000	0.225	57.000	1.000	0.000	186.768
2105	19.100	36.000	0.200	57.259	1.000	0.000	183.816
2110	18.400	24.000	0.200	57.519	1.000	0.000	186.768
2115	17.200	20.000	0.201	57.778	1.000	0.000	166.464
2120	16.400	18.000	0.200	58.037	1.000	0.000	178.056
2125	16.000	16.000	0.200	58.296	1.000	0.000	182.880
2130	15.500	10.000	0.200	58.556	1.000	0.000	174.024
2135	15.000	10.000	0.200	58.815	1.000	0.000	167.832
2140	14.800	10.000	0.200	59.074	1.000	0.000	167.328
2145	14.600	6.000	0.200	59.333	1.000	0.000	161.352
2150	14.400	6.000	0.200	59.593	1.000	0.000	134.568
2155	14.300	8.000	0.200	59.852	1.000	0.000	119.088
2200	13.900	0.000	0.200	60.111	1.000	0.000	119.088
2205	13.900	2.000	0.201	60.370	1.000	0.000	119.880
2210	13.800	0.000	0.200	60.630	1.000	0.000	119.664
2215	13.500	0.000	0.200	60.889	1.000	0.000	135.576
2220	13.400	0.000	0.200	61.148	1.000	0.000	122.616
2225	13.500	2.000	0.199	61.407	1.000	0.000	123.624
2230	13.600	2.000	0.200	61.667	1.000	0.000	123.624
2235	13.400	2.000	0.201	61.926	1.000	0.000	123.192
2240	13.400	0.000	0.201	62.185	1.000	0.000	122.616
2245	13.400	0.000	0.200	62.444	1 000	0.000	122.832
2250	13.500	4.000	0.200	62.704	1.000	0.000	129.024
2255	13.500	2.000	0.200	62.963	1.000	0.000	120.888
2300	13.400	0.000	0.200	63.222	1.000	0.000	120.888
2305	13.500	0.000	0.200	63.481	1.000	0.000	138.888
2310	13.400	0.000	0.200	63.741	1.000	0.000	138.456
2315	13.400	4.000	0.200	64.000	1.000	0.000	139.752
2320	13.300	0.000	0.200	64.259	1.000	0.000	139.968
2325	13.200	2.000	0.200	64.519	1.000	0.000	138.960
2330	13.300	0.000	0.200	64.778	1.000	0.000	141.696
2335	13.200	2.000	0.200	65.037	1.000	0.000	121.608
2340	13.200	0.000	0.200	65.296	1.000	0.000	126.000
2345	13.000	0.000	0.200	65.556	1.000	0.000	146.880
2350	13.100	0.000	0.250	65.815	1.000	0.000	146.016
2355	13.000	0.000	0.200	66.074	1.000	0.000	146.880
0000	13.100	0.000	0.200	66.333	1.000	0.000	155.448
0004	13.100	2.000	0.200	66.541	1.000	0.000	149.616
0009	13.300	0.000	0.264	66.800	1.000	0.000	158.472
0014	13.200	0.000	0.200	67.059	1.000	0.000	154.512
0019	13.300	0.000	0.200	67.319	1.000	0.000	176.760
0024	13.700	0.000	0.200	67.578	1.000	0.000	166.968
0029	14.300	0.000	0.200	67.837	1.000	0.000	172.584
0034	14.400	4.000	0.704	68.096	1.000	0.000	175.752

0039	14.600	0.000	0.200	68.356	1.000	0.000	180.648
0044	14.600	0.000	0.336	68.615	1.000	0.000	176.976
0049	14.700	0.000	0.227	68.874	1.000	0.000	184.248
0054	14.600	0.000	0.302	69.133	1.000	0.000	180.144
0059	14.800	0.000	0.218	69.393	0.000	0.000	183.600
0104	14.500	0.000	0.252	69.652	0.000	0.000	177.192
0109	14.500	0.000	0.205	69.911	0.000	0.000	170.208
0114	14.200	2.000	0.200	70.170	0.000	0.000	187.488
0119	14.600	2.000	0.421	70.430	0.000	0.000	191.664
0124	14.500	0.000	0.290	70.689	0.000	0.000	225.792
0129	14.400	0.000	0.369	70.948	0.000	0.000	214.848
0134	13.900	0.000	0.199	71.207	0.000	0.000	187.704
0139	14.600	0.000	0.266	71.467	0.000	0.000	188.208
0144	14.600	0.000	0.291	71.726	0.000	0.000	182.808
0149	14.600	0.000	0.531	71.985	0.000	0.000	182.880
0154	14.800	0.000	0.887	72.244	0.000	0.000	190.080
0159	14.800	0.000	0.415	72.504	0.000	0.000	206.424
0204	14.900	0.000	0.498	72.763	0.000	0.000	187.200
0209	14.800	0.000	0.304	73.022	0.000	0.000	206.784
0214	14.800	4.000	0.514	73.281	0.000	0.000	195.336
0219	14.600	0.000	0.855	73.541	0.000	0.000	193.248
0224	14.200	0.000	0.344	73.800	0.000	0.000	193.896
0229	13.800	0.000	0.747	74.059	0.000	0.000	159.768
0234	13.300	2.000	0.213	74.319	0.000	0.000	167.760
0239	13.300	0.000	0.200	74.578	0.000	0.000	178.128
0244	13.200	2.000	0.529	74.837	0.000	0.000	168.768
0249	13.300	0.000	0.938	75.096	0.000	0.000	173.160
0254	13.600	4.000	0.423	75.356	0.000	0.000	165.024
0259	13.800	0.000	0.572	75.615	0.000	0.000	175.752
0304	13.900	0.000	0.599	75.874	0.000	0.000	188.640
0309	13.300	0.000	0.280	76.133	0.000	0.000	201.168
0314	13.300	0.000	0.352	76.393	0.000	0.000	179.136
0319	13.300	0.000	0.640	76.652	0.000	0.000	179.784
0324	13.000	4.000	1.227	76.911	0.000	0.000	162.072
0329	13.300	0.000	0.761	77.170	0.000	0.000	175.248
0334	13.300	0.000	0.627	77.430	0.000	0.000	187.272
0339	13.200	0.000	0.689	77.689	0.000	0.000	169.632
0344	13.300	0.000	1.235	77.948	0.000	0.000	191.304
0349	13.900	0.000	0.551	78.207	0.000	0.000	193.392
0354	13.900	0.000	1.011	78.467	0.000	0.000	194.688
0359	14.100	0.000	0.877	78.726	0.000	0.000	207.648
0404	13.800	0.000	1.102	78.985	0.000	0.000	191.880
0409	13.200	2.000	0.341	79.244	0.000	0.000	182.304
0414	12.600	0.000	0.397	79.504	0.000	0.000	192.168
0419	12.600	0.000	0.595	79.763	0.000	0.000	194.040
0424	12.400	0.000	0.432	80.022	0.000	0.000	180.144
0429	12.300	0.000	0.911	80.281	0.000	0.000	181.728
0434	12.200	0.000	0.573	80.541	0.000	0.000	170.928
0439	12.100	4.000	0.283	80.800	0.000	0.000	190.728
0444	12.100	0.000	0.259	81.059	0.000	0.000	191.016
0449	12.400	0.000	0.323	81.318	0.000	0.000	189.360
0454	12.300	0.000	0.904	81.578	0.000	0.000	183.384
0459	11.700	0.000	0.980	81.837	0.000	0.000	187.560
0504	11.700	0.000	0.464	82.096	0.000	0.000	183.816
0509	12.000	0.000	0.601	82.356	0.000	0.000	184.464
0514	12.400	0.000	0.474	82.615	0.000	0.000	179.352

0519	12.300	0.000	0.640	82.874	0.000	0.000	190.800
0524	11.800	0.000	0.254	83.133	0.000	0.000	179.856
0529	11.900	0.000	0.553	83.393	0.000	0.000	180.576
0534	12.100	0.000	0.984	83.652	0.000	0.000	169.632
0539	12.000	0.000	1.041	83.911	0.000	0.000	168.984
0544	11.900	4.000	0.271	84.170	0.000	0.000	174.024
0549	11.900	2.000	0.938	84.430	0.000	0.000	166.752
0554	12.200	4.000	0.423	84.689	0.000	0.000	163.656
0559	12.300	2.000	0.812	84.948	0.000	0.000	164.016
0604	12.300	0.000	0.556	85.207	0.000	0.000	165.384
0609	12.300	10.000	0.699	85.467	0.000	0.000	166.392
0614	12.200	10.000	0.492	85.726	0.000	0.000	169.272
0619	12.300	10.000	0.698	85.985	0.000	0.000	162.792
0624	12.300	10.000	0.627	86.244	0.000	0.000	167.112
0629	12.200	12.000	0.581	86.504	0.000	0.000	168.048
0634	12.200	18.000	0.207	86.763	0.000	0.000	182.160
0639	12.100	20.000	0.570	87.022	0.000	0.000	174.816
0644	12.800	26.000	0.245	87.281	0.000	0.000	166.824
0649	13.000	48.000	0.696	87.541	0.000	0.000	181.728
0654	13.200	60.000	0.254	87.800	0.000	0.000	176.616
0659	13.600	68.000	0.875	88.059	0.000	0.000	177.264
0704	13.900	82.000	0.345	88.318	0.000	0.000	166.608
0709	14.300	96.000	0.877	88.578	0.000	0.000	165.600
0714	14.300	106.000	0.600	88.837	0.000	0.000	169.272
0719	14.700	120.000	0.810	89.096	0.000	0.000	162.504
0724	15.000	132.000	0.305	89.356	0.000	0.000	171.216
0729	15.100	142.000	1.043	89.615	0.000	0.000	165.096
0734	15.600	154.000	0.539	89.874	0.000	0.000	157.392
0739	15.800	168.000	0.570	90.133	0.000	0.000	166.896
0744	15.900	178.000	1.420	90.393	0.000	0.000	172.152
0749	16.300	192.000	0.948	90.652	0.000	0.000	180.144
0754	16.700	206.000	1.574	90.911	0.000	0.000	169.992
0759	16.900	220.000	0.471	91.170	0.000	0.000	172.368
0804	17.200	230.000	0.997	91.430	0.000	0.000	170.784
0809	17.400	240.000	0.935	91.689	1.000	0.000	180.072
0814	17.600	262.000	0.850	91.948	1.000	0.000	181.224
0819	17.700	280.000	1.625	92.207	1.000	0.000	173.664
0824	17.900	286.000	0.243	92.467	1.000	0.000	170.928
0829	18.200	308.000	0.510	92.726	1.000	0.000	169.704
0834	18.400	324.000	0.924	92.985	1.000	0.000	202.752
0839	18.700	336.000	1.342	93.244	2.000	0.000	189.792
0844	19.200	350.000	0.519	93.504	2.000	0.000	190.368
0849	19.100	366.000	1.182	93.763	2.000	0.000	191.664
0854	19.200	376.000	1.207	94.022	2.000	0.000	205.704
0859	19.300	390.000	1.113	94.281	2.000	0.000	162.072

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