NUCLEAR SAFETY GROUP

PROBABILISTIC RISK ASSESSMENT REPORT

PRA EVALUATION

OF

POPULATION DOSE RISK FROM SEVERE ACCIDENTS AT SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 AND 3

August 18, 1994

NSG/PRA REPORT PRA-2/3-94-012

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PURPOSE

The purpose of this evaluation is to determine the population dose risk from severe accidents initiated by internal events at San Onofre Nuclear Generating Station (San Onofre) Units 2 and 3. This type of evaluation is characterized in probabilistic risk assessment (PRA) terminology as a Level 3. The result of the evaluation is the estimation of the likelihood that the general population will be exposed to radioactivity from releases following a severe accident initiated by internal events at San Onofre Units 2 and 3.

BACKGROUND

A Level 1 and Level 2 PRA of internal events, identified as an Individual Plant Examination (IPE), was conducted for San Onofre Units 2 and 3 in response to NRC Generic Letter 88-20 (Ref. 1). The IPE was submitted to the NRC in May 1993. The Level 1 portion of the PRA determined the likelihood of core damage from internal initiating events. The Level 2 portion of the PRA determined the likelihood, magnitude, and timing of radioactive releases from the plant following the core damage events evaluated in the Level 1 PRA.

A Level 3 PRA determines the impact of radioactive releases evaluated in the Level 2 portion of the PRA on the population and land use. The results from the Level 3 PRA include estimates of the following parameters associated with each Level 2 release type: population doses, early fatalities, latent fatalities, land interdiction costs, and other impacts associated with the dispersion of radioactive material beyond the site boundary.

The inputs to the Level 3 PRA include: the likelihood, timing, and magnitude of radioactive releases from the units; the typical weather pattern for the site; the population distribution surrounding the site (up to 100 miles); the land use surrounding the site (up to 100 miles); the emergency declaration procedures; and the emergency evacuation plans. With the exception of the likelihood of each type of radioactive release, all the inputs are fed into a consequence analysis code which determines the average radiological impact of each release type from the Level 2 PRA. The MACCS (MELCOR Accident Consequence Code System) code was chosen for the calculation since it is was developed for and utilized by the NRC for consequence evaluation (Ref. 2).

The quantity of information required to generate the input to the MACCS code is enormous. A significant amount of effort is required to evaluate historical weather data from the site, determine population distributions in radial sectors around the site up to 100 miles, and determine land use up to 100 miles from

the site. Also a large number of parameters associated with each release type in the Level 2 PRA must be evaluated and reformatted for input in the MACCS code.

The development of a sample MACCS code input applicable to the SONGS site was performed in 1991 by NUS Corporation (Ref. 3). The sample code input utilized actual site weather data, 1990 land use information, and the 1990 population census to accurately reflect the characteristics of the SONGS site and the surrounding area. The sample code input also evaluated the SONGS emergency evacuation plan to determine the timing and directional factors affecting population evacuation and/or sheltering during an emergency. The only inputs in the sample code which were not determined were the characteristics of the radionuclide releases (magnitude, timing, energy of plumes), since the Level 2 portion of the SONGS PRA was not complete at that time.

Since the Level 2 portion of the San Onofre Units 2 and 3 PRA is now complete, all the information required to generate the MACCS input is now available. This report documents the development of the MACCS input files, performance of the MACCS runs, and review of the results.

METHODOLOGY

The Level 2 portion of the San Onofre Units 2 and 3 PRA resulted in the determination of the likelihood, timing, and magnitude of radioactive releases from severe accidents. Fifteen distinct source term release categories were specified in the Level 2 PRA. Each source term release category was evaluated using the MAAP (Modular Accident Analysis Program) code. The MAAP code simulates the accident conditions in the core, reactor coolant system, other plant systems, and the containment to determine how, when, and how much radioactive material would be released from the plant in a severe accident. The MAAP code was specifically developed by the nuclear industry for this use and was utilized by almost all utilities in the performance of their Level 2 PRAs in response to NRC Generic Letter 88-20.

The parameters from the MAAP runs which are used in the Level 3 MACCS code input include:

- cumulative radionuclide release fractions for each major fission product group over time (up to 48 hrs)
- sensible heat in the released radionuclides over time
- timing associated with the start and duration of major radioactive release plumes
- timing associated with conditions where a General Emergency would be declared

The definition of the radionuclide release groups in MAAP and MACCS differ slightly. MAAP uses 12 radionuclide release groups, whereas MACCS uses 9 radionuclide release groups. The differences between the release groups are summaried in Table 1.

Table 1
Radionuclide Release Groups

Radionuclide Type	MAAP Release Group	MACCS Release Group
Nobles Gases	Nobles	Xe/Kr
I	CsI	I
Cs	CsI, CsOH	Cs
Te	TeO_2, Te_2, Sb	Te
Sr	SrO	Sr
Ru, MO_2	MO_2	Ru
Ba	BaO	Ba
La	La_2O_3	La
Ce	CeO_2	Ce
UO_2	UO_2	None

There is a direct correspondence between all the radionuclide release groups except Cs and Te. For these two radionuclide release groups, mass balance equations in Appendix A correspondence from PLG were utilized. The release fractions and masses for each radionuclide type were taken from the MAAP analyses. Table 2 provides the masses used in the calculation:

Table 2
Radionuclide Type Masses From MAAP

Radionuclide Type	Mass (kg)	Applicable Source Term Sequence(s)
CsI	39.1	All
CsOH	331.35	All
TeO_2	0.0 1.9 40.38 1E-5 3.12 0.61	All except: MLO-4 PCS-35 SBO-17 LLO-4 ATWS-26
Te_2	0.0 33.83 3.03 34.45 32.88 34.9	All except: MLO-4 PCS-35 SBO-17 LLO-4 ATWS-26

ASSUMPTIONS

1. The start time and duration of radioactive material release plumes were determined by reviewing the cumulative radioactive release plots from each source term sequence MAAP run. Dr. Edward Fenstermacher of PLG, a consultant expert in consequence analysis, reviewed the cumulative release plots and recommended plume start times and durations (see Appendix A for correspondence).

2. The sensible heat associated with each plume segment for each source term sequence was calculated from the MAAP code. Mr. Cris Henry of FAI provided a minor modification to the MAAP code which would calculate the sensible heat of the radionuclide release (see Appendix A for correspondence). The average sensible heat during a release period (i.e., plume) was used in the MACCS input for each plume.

3. The time associated with the declaration of a General Emergency was determined based on the failure or imminent failure of all three fission product barriers (fuel cladding, reactor coolant system, and containment) per SONGS Emergency Plan Implementing Procedure SO123-VIII-1 (Ref. 4). Since the imminent failure of a fission barrier is subjective, the predicted failure time was used for conservatism. The failure times of the fission product

barriers were determined from Table 4.7-6 (Source-Term Analysis Results MAAP Run Summary Table) of the San Onofre Units 2 and 3 IPE submittal (Ref. 1). The assumed time when a General Emergency is declared for each source term sequence is provided in Table 3.

Table 3
Time Assumed When General Emergency Declared

Source Term Sequence	Time of Cladding Failure (hr)	Time of RCS or Vessel Failure (hr)	Time of Containment Failure (hr)	Time General Emergency Declared (hr)
PCS-4	1.7	2.5	*	**
MLO-4	1.3	0.0	*	**
LLO-4	1.2	0.0	*	**
ATWS-6	0.6	1.6	*	**
LOP-48	1.7	2.6	39.8	39.8
PCS-35	10.3	11.5	*	**
SLO-20	1.3	3.6	26.5	26.5
LLO-13	0.6	0.0	22.3	22.3
SBO-17	1.7	2.7	0.0	2.7
LLO-32	0.6	0.0	0.0	0.6
VSEQ-2	5.6	0.0	0.0	5.6
SGTR-20	10.4	0.0	0.0	10.4
SGTR-33	1.7	0.0	0.0	1.7
SGTR2-48	10.4	0.0	0.0	10.4
SGTR2-66	10.4	0.0	0.0	10.4

Notes:

* Denotes no containment failure predicted by MAAP within 48 hours.

** Denotes conditions not sufficient for declaration of General Emergency per SO123-VIII-1, Rev. 0. Time General Emergency declared is set to 7 days in MACCS input.

4. The radionuclide release height for each plume was assumed to be 10 meters, except for steam generator tube rupture events where is was assumed to be 30 meters. San Onofre Units 2 and 3 are situated below a bluff next to the ocean on the Southern California coast. Winds blowing in the direction of population centers (inland or along the coast) must in general pass up over the bluff surface unless released from the upper areas of the containment such as the main steam relief valve discharges. The most likely locations for containment failure during post-accident pressurization are associated with the penetrations located on the low portion of the containment. Due to the large number of bluffs, hills, and mountains between the site and the major population centers, the impact of the release height on the population dose is assumed small.

ANALYSIS

The sample MACCS input for SONGS was used as the basis for the analysis. The release information from the MAAP runs for each of the fifteen source term sequence analyses were incorporated into the MACCS sample input.

The fifteen source term sequence MACCS input files were analyzed using MACCS to determine the population dose consequences. The risk measure of interest in the MACCS outputs is the mean population dose (in units of sieverts) from 0 to 1609 kilometers (i.e., 100 miles) from the site using the combined emergency response cohorts (i.e., the "OVERALL RESULTS" section of output).

The total population dose risk was calculated by multiplying the frequency of each source term by its population dose consequence, and summing the risks for all fifteen source term sequences.

RESULTS

The results of the fifteen source term sequence MACCS runs are provided in Appendix B.

The frequency, mean population dose, and mean population dose risk (i.e., frequency time dose) for each of the fifteen source term sequence MACCS runs are provided in Table 4.

Table 4
Summary of Results from MACCS Runs

Source Term Sequence	Frequency (/yr)	Mean Population Dose to 100 Miles (man-rem)	Mean Population Dose Risk (man-rem/yr)
PCS-4	9.0E-6	3.27E+2	2.94E-3
MLO-4	6.8E-6	7.14E+2	4.86E-3
LLO-4	4.3E-6	5.37E+3	2.31E-2
ATWS-26	2.8E-6	5.12E+2	1.43E-3
LOP-48	2.1E-6	2.02E+4	4.24E-2
PCS-35	2.7E-6	1.40E+4	3.78E-2
SLO-20	6.9E-7	2.83E+6	1.95E+0
LLO-13	6.2E-8	1.60E+6	9.92E-2
SBO-17	1.9E-8	3.55E+6	6.75E-2
LLO-32	1.4E-9	1.78E+6	2.49E-3
VSEQ-2	6.5E-7	1.74E+7	1.13E+1
SGTR-20	7.9E-7	3.90E+6	3.08E+0
SGTR-33	2.2E-7	1.40E+4	3.08E-3
SGTR2-48	1.5E-7	4.78E+6	7.17E-1
SGTR2-66	2.8E-7	4.53E+6	1.27E+0
TOTAL	3.0E-5	NA	1.86E+1

CONCLUSION

The estimated mean population dose risk from severe accidents due to internal initiating events at San Onofre Units 2 and 3 is 19 man-rem /yr.

The accident initiators contributing over 98% to the total population dose risk at San Onofre Units 2 and 3 are:

- Interfacing System LOCA (61%)
- Steam Generator Tube Rupture (27%)
- Small LOCA (11%)

A comparison of population dose risk for San Onofre Units 2 and 3 with other nuclear plants is provided in Table 5. The population dose risk from San Onofre Units 2 and 3 is lower than all other plants in Table 5 with the exception of Grand Gulf.

Table 5
Comparison of Population Dose Risk

Plant	Population Dose Risk (man-rem/yr)
Grand Gulf	6
San Onofre 2 & 3	19
Peach Bottom	28
Surry	31
Sequoyah	80
Zion	136

Note: Population Dose Risk for other plants was taken from Draft NUREG-1493 (Ref. 5).

REFERENCES

1. "Individual Plant Examination Report for San Onofre Nuclear Generating Station, Units 2 and 3, in Response to Generic Letter 88-20", Southern California Edison, April 1993.

2. NUREG/CR-4691, "MELCOR Accident Analysis Consequence Code System," Sandia National Laboratories, Prepared for the Nuclear Regulatory Commission, February 1990.

3. "SONGS Consequence Analysis Using MACCS", Halliburton NUS Environmental Corporation, August 1991.

4. SONGS Emergency Plant Implementing Procedure SO123-VIII-1, "Recognition and Classification of Emergencies", Revision 0.

5. Draft NUREG-1493, "Performance-Based Containment Leak Test Program," Nuclear Regulatory Commission, Draft for Comment.

APPENDIX A

Technical Correspondence

PLG

ENGINEERS • APPLIED SCIENTISTS • MANAGEMENT CONSULTANTS

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August 8, 1994

Mr. Sam Chien
San Onofre Nuclear Generating Station
Southern California Edison Company
P.O. Box 126
San Clemente, CA 92674

Dear Sam:

I discovered after reading your fax of August 2, 1994 that there was indeed an error in the calculation of the Cs and Te release fractions from the release fractions in MAAP categories 2 and 6 (for Cs) and 3 and 11 (for Te), but it was in equation 3. The amended equations are presented below.

We first determine the fractions of Cs in the mass of CsI and CsOH. These are

$$f_2^{Cs} = \frac{\overline{w}_{Cs}}{\overline{w}_{Cs} + \overline{w}_I} \qquad (1)$$

$$f_2^{Cs} = \frac{\overline{w}_{Cs}}{\overline{w}_{Cs} + \overline{w}_O + \overline{w}_H} = \frac{\overline{w}_{Cs}}{\overline{w}_{Cs} + 17.0073\, g/gmol} \qquad (2)$$

where $\overline{w}_{Cs}$, $\overline{w}_I$, $\overline{w}_O$ and $\overline{w}_H$ are the average atomic weights of cesium, iodine, oxygen and hydrogen in the material released. Then define the fraction of Cs in each of the MAAP release categories:

$$\mu_2 = \frac{f_2^{Cs} m_2}{f_2^{Cs} m_2 + f_6^{Cs} m_6} \qquad (3)$$

$$\mu_6 = 1 - \mu_2 \qquad (4)$$

in MAAP categories 2 and 6 respectively, and where m_2 and m_6 are the total mass of CsI and CsOH available for release. The Cs release fraction is then

$$\ell_{Cs} = \mu_2 \ell_2 + \mu_6 \ell_6, \qquad (5)$$

where ℓ_2 and ℓ_6 are the release fractions for MAAP categories 2 and 6, respectively.

As we discussed, this operation needs to be performed for each fission product group at each phase of each release. The MAAP release fraction for the first phase is obtained by taking the release fraction from the graph (or printout) at a time equal to the beginning of the <u>second</u> phase. For each subsequent phase, the release fraction is taken at the beginning of the next phase (or the end of the release), and subtracting all prior phases.

I hope this error has not delayed your analysis. Also, Keith told me that you may not have the values for m_2 and m_6 needed. Please call me and we'll see if we can come up with a strategy for getting the values you need.

Keith indicated that you had gone back to Fauske for an explanation of the anomalous results of the sensitivity runs. Do we need to do anything additional about this, or has it bee resolved?

I have expanded the tables to include the last two release scenarios. These tables follow:

Start time for Phase, Variable RDPDELAY001 Values in seconds				
Sequence	Phase 1	Phase 2	Phase 3	Phase 4
PCS-4	8100	11700	47700	83700
LOP-48	7200	36000	72000	151200
MLO-4	7200	14400	21600	57600
SGTR-33	8100	9900	45900	81900
VSEQ2	5400	7200	10800	43200
PCS-35	38700	49500	61200	97200
SGTR2-48	39600	116100	148500	165600
SGTR2-66	39600	41400	72000	93600
LLO-34	2700	6300	18000	36000
SBO-17	8100	21600	39600	NONE
MLO-20	5400	81000	95400	136800
LLO-13	3600	18000	82800	97200
SGTR-20	39600	43200	57600	93600
LLO-4	4500	8100	55800	91800
ATWS26	2700	6300	8100	18000

Duration of Phase, Variable RDPLUDUR001 Values in seconds				
Sequence	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**
PCS-4	3600	36000	36000	89100
LOP-48	28800	36000	79200	21600
MLO-4	7200	7200	36000	115200
SGTR-33	1800	36000	36000	92700
VSEQ2	1800	3600	7200	10800
PCS-35	10800	11700	36000	75600
SGTR2-48	7200	32400	17100	7200
SGTR2-66	1800	30600	21600	79200
LLO-34	3600	11700	18000	136800
SBO-17	13500	18000	133200	NONE
MLO-20	27000	14400	41400	36000
LLO-13	14400	64800	14400	10800
SGTR-20	3600	14400	18000	79200
LLO-4	3600	47700	36000	81000
ATWS26	1800	1800	2700	9000

RDNUMREL001, the number of plume segments, will be 4, except as noted. The risk dominant segment, RDMAXRSK001, is indicated by having the start time in bold face type. The representative time point, RDREFTIM001, may be conservatively set to zero for all segments of all plumes.

Very truly yours,

T. Edward Fenstermacher

T. Edward Fenstermacher

Fauske & Associates, Inc.

DATE: July 25, 1994

TO: Sam Chien, San Onofre Nuclear Generating Station

FROM: Christopher E. Henry, FAI, MAAP Maintenance Group C.E.H

SUBJECT: MAAP variables representing mass and sensible energy flow to the environment from a containment leak or breach

I believe that I have acquired the requested information regarding MAAP variables which represent mass and energy flow from a containment leak or breach to the environment. While there may not be a direct correspondence between these variables and the required input parameters for the MACCS code, the following information should be sufficient to generate the appropriate input parameters.

The first part will focus on energy transport to the environment via sensible heat transfer of gaseous plume emanating from either a containment leak or breach. Note that a containment breach can reside in either the upper compartment (A compartment) or the annular compartment (D compartment). Containment leakage is confined to the D compartment. The second part will then focus on energy transfer to the environment via transport of fission product gases and aerosols, and their associated fraction of decay power, within the plume.

Plume Sensible Heat Transfer: Normal Leakage in the D Compartment

As noted above, normal containment leakage to the environment is assumed to occur in the D compartment, presumably due to the fact that most containment penetrations are located at this elevation. As shown in Attachment 1, the gas mass flow rate through the leakage, WGLK, is calculated via a call to GFLOW within subroutine EQUIL. Notice that the input parameter of normal leakage area, ALKNOM, which is an argument within the call to GFLOW, is used to compute WGLK.

Attachment 1 then shows a section of coding from regional subroutine DCOMPT. The sensible heat transfer associated with WGLK is included as part of the calculation of FUGD, which is the rate of change of gas internal energy within the D compartment control volume. Specifically, the gas sensible heat transfer is the first circled term within the rate equation. A breakdown of the term shows that it is simply the product of WGLK and the summation of each constituent's mass fraction multiplied by its specific enthalpy. (Note, for noncondensable gas constituents, the specific enthalpy is the product of the gas temperature, TGLK, and the constituent's specific heat (CPH2 for hydrogen, for instance). For steam, the specific enthalpy, HSTLK, is known directly.)

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In addition to the gas sensible heat transfer, a second component to plume sensible heat transfer is suspended water, which constitutes a fog resulting from steam condensation in the D compartment atmosphere that is also transported within the plume. As shown in the EQUIL coding within Attachment 1, the suspended water mass flow rate, WSWLK, is calculated from WGLK in the line immediately following the call to GFLOW. The sensible heat term for the suspended water is shown as the second circled term in the DCOMPT coding within Attachment 1, immediately after the noted gas sensible term.

Plume Sensible Heat Transfer: Containment Failure in the D Compartment

In the case of a containment failure in addition to the normal leakage in the D compartment, calculation of sensible heat transfer via gas and suspended water transport through the containment breach is performed in essentially the same manner as that for normal leakage. The gas and suspended water flow rates, WGCFD and WSWCF respectively, are calculated in subroutine EQUIL, as shown by the section of coding in Attachment 2. The respective terms for sensible heat transfer are shown as the two circled terms in the section of coding from subroutine DCOMPT in Attachment 2. Like the corresponding leakage terms, both gas and suspended water flow through the containment breach contribute to the calculation of the rate of gas internal energy change in the D compartment, symbolized by FUGD.

Plume Sensible Heat Transfer: Containment Failure in the A Compartment

The containment failure can also be specified as occurring in compartment A rather than D. As shown in Attachment 3, gas and suspended water flow rates, WGCFA and WSWCF respectively, are also calculated in subroutine EQUIL. The respective sensible heat transfer terms are circled in the included section of subroutine ACOMPT coding. Like the sensible heat terms in the D compartment, these terms contribute to the rate of change in the gas internal energy for the A compartment, symbolized by FUGA.

Plot File Output of Desired MAAP Parameters

The noted sections of coding reveal that the desired sensible heat terms have not cast in terms of discrete parameters that can be easily added to user-defined plot files, such as Plot File 77. It is possible to add all contributing parameters, such as flow rates, constituent mass fractions and specific heats, temperature, enthalpy, etc., to the plot file and then perform the sensible heat transfer calculations external to MAAP.

However, a much more efficient method entails making assignments of the sensible heat transfer to elements of the PLT array. For instance, suppose that leakage and containment failure occur in the D compartment. To utilize the PLT array for plotting, the named common /XPLTX/, which contains array declaration PLT(500), must be added to subroutine DCOMPT, as shown by the first "CREV SONGS" code modification in Attachment 4. (Note, the sections of DCOMPT coding in Attachment 4 are essentially the same as those shown in Attachment 2.) As shown, this line is added adjacent to the other common declarations at the top of DCOMPT.FOR.

In the latter "CREV SONGS" code modification, PLT(1) and PLT(2) are assigned the plume sensible heat transfer through the normal leakage and the containment breach, respectively. PLT(1) and PLT(2) can then be added to a user-defined plot file, yielding the desired data in

terms of two discrete parameters. Of course, since the DCOMPT.FOR has been modified, a new MAAP executable must be generated by recompiling DCOMPT and linking it to the MAAP object library. This limited amount of code modification will render a code that is tailored to your specific needs.

If you need further assistance on any of the points discussed above, please contact me.

Attachment 1

MAAP coding corresponding to plume sensible heat transfer from normal leakage in the D compartment

EQUIL.FOR CODING

```
                .
126   CALL GFLOW(0,1.D0,PFINL,TGD,VOLGT,CFD,PE,TGE,1.D6,1.D0,TD,
     2VGLK,MFSTLK,MFH2LK,MFO2LK,MFCOLK,MFC2LK,MFN2LK,ALKNOM,0.D0,WGLK)
      WSWLK=WSWLK*WGLK
      WAWLK=WAWLK*WGLK
                .
                .
```

DCOMPT.FOR CODING

```
                .
                .
      FUGD=QFLD-QDIFD+QBRND-QGOW-QGIW+
CREV P16.04 RAA/MAM 11/30/90 END
     1WGBD*(MFSTBD*HSTBD+TGBD*(MFH2BD*CPH2+MFO2BD*CPO2+MFCOBD*CPCO+
     2MFC2BD*CPC2+MFN2BD*CPN2))+
     1WGAD*(MFSTAD*HSTAD+TGAD*(MFH2AD*CPH2+MFO2AD*CPO2+MFCOAD*CPCO+
     2MFC2AD*CPC2+MFN2AD*CPN2))-
     3WGCFD*(MFSTCF*HSTCF+TGCF*(MFH2CF*CPH2+MFO2CF*CPO2+MFCOCF*CPCO+
CREV P16.04 FJD 11/01/90 START
C     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFN*IFCD+QGFPD+WSTFP*HSTW-
C     7LAMSD*MSWD*HWSTD+WSWBD*HWSTBD+WSWAD*HWSTAD+
C     8WGFNA/MGA*MSWA*IFCD*HWSTA-WSTAW*HWSTD-
CREV P16.05 FJD 1/7/91 START
C     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFPD+WSTFP*HSTW+QTNODE*QGRD-
     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFPD+WSTFP*HSTW+NQT*QGRD-
CREV P16.05 FJD 1/7/91 END
     7LAMSD*MSWD*HWSTD+WSWBD*HWSTBD+WSWAD*HWSTAD-WSTAW*HWSTD-
CREV P16.04 FJD 11/01/90 END
     3WGLK*(MFSTLK*HSTLK+TGLK*(MFH2LK*CPH2+MFO2LK*CPO2+MFCOLK*CPCO+
     6MFC2LK*CPC2+MFN2LK*CPN2))-WSWLK*HWSTLK
```

GAS SENSIBLE HEAT*

SUSPENDED WATER SENSIBLE HEAT*

*FAI GUIDANCE TO MODIFY MAAP TO ENSURE COMPATIBILITY WITH MACCS.

Attachment 2

MAAP coding corresponding to plume sensible heat transfer from a containment breach in the D compartment

EQUIL.FOR CODING

```
              .
116   CALL GFLOW(0,1.D0,PFINL,TGD,VOLGT,CFD,PE,TGE,1.D6,1.D0,TD,
     2VGCF,MFSTCF,MFH2CF,MFO2CF,MFCOCF,MFC2CF,MFN2CF,CD*ACF,0.D0,WGCFD)
      WSWCF=WSWCF*WGCFD
      WAWCF=WAWCF*WGCFD
              .
              .
```

DCOMPT.FOR CODING

```
              .
              .
      FUGD=QFLD-QDIFD+QBRND-QGOW-QGIW+
CREV P16.04 RAA/MAM 11/30/90 END
     1WGBD*(MFSTBD*HSTBD+TGBD*(MFH2BD*CPH2+MFO2BD*CPO2+MFCOBD*CPCO+
     2MFC2BD*CPC2+MFN2BD*CPN2))+
     1WGAD*(MFSTAD*HSTAD+TGAD*(MFH2AD*CPH2+MFO2AD*CPO2+MFCOAD*CPCO+
     2MFC2AD*CPC2+MFN2AD*CPN2))
     (3WGCFD*(MFSTCF*HSTCF+TGCF*(MFH2CF*CPH2+MFO2CF*CPO2+MFCOCF*CPCO+
CREV P16.04 FJD 11/01/90 START
C    6MFC2CF*CPC2+MFN2CF*CPN2))+QGFN*IFCD+QGFPD+WSTFP*HSTW-
C    7LAMSD*MSWD*HWSTD+WSWBD*HWSTBD+WSWAD*HWSTAD+
C    8WGFNA/MGA*MSWA*IFCD*HWSTA-WSTAW*HWSTD-
CREV P16.05 FJD 1/7/91 START
C    6MFC2CF*CPC2+MFN2CF*CPN2))+QGFPD+WSTFP*HSTW+QTNODE*QGRD-
     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFPD+WSTFP*HSTW+NQT*QGRD-
CREV P16.05 FJD 1/7/91 END
     7LAMSD*MSWD*HWSTD+WSWBD*HWSTBD+WSWAD*HWSTAD-WSTAW*HWSTD-
CREV P16.04 FJD 11/01/90 END
     3WGLK*(MFSTLK*HSTLK+TGLK*(MFH2LK*CPH2+MFO2LK*CPO2+MFCOLK*CPCO+
     6MFC2LK*CPC2+MFN2LK*CPN2))-WSWLK*HWSTLK
              .
              .
              .
      IF (WGCFD.EQ.0.D0) GO TO 1111
      FMSWD=FMSWD-WSWCF
      FMAWD=FMAWD-WAWCF
      FMWG=FMWG-WSWCF-WAWCF
      FUGD=FUGD WSWCF*HWSTCF              SUSPENDED WATER
1111  IF(ISORT.EQ.1) THEN                 SENSIBLE HEAT*
              .
```

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Attachment 3

MAAP coding corresponding to plume sensible heat transfer from a containment breach in the A compartment

EQUIL.FOR CODING

```
                .
114    CALL GFLOW(0,1.D0,PFINL,TGA,VOLGT,CFA,PE,TGE,1.D6,1.D0,TD,
      2VGCF,MFSTCF,MFH2CF,MFO2CF,MFCOCF,MFC2CF,MFN2CF,CD*ACF,0.D0,WGCFA)
       WSWCF=WSWCF*WGCFA
       WAWCF=WAWCF*WGCFA
                .
                .
```

ACOMPT.FOR CODING

```
                .
                .
       FUGA=QFLA-QDIFA-QGSP1A-QGSP2A+QBRNA+
CREV P16.04 RAA/MAM 11/30/90 END
      1WGBA*(MFSTBA*HSTBA+TGBA*(MFH2BA*CPH2+MFO2BA*CPO2+MFCOBA*CPCO+
      2MFC2BA*CPC2+MFN2BA*CPN2))-
      1WGAD*(MFSTAD*HSTAD+TGAD*(MFH2AD*CPH2+MFO2AD*CPO2+MFCOAD*CPCO+
      2MFC2AD*CPC2+MFN2AD*CPN2))+
      3WGUA*(MFSTUA*HSTUA+TGUA*(MFH2UA*CPH2+MFO2UA*CPO2+MFCOUA*CPCO+
      4MFC2UA*CPC2+MFN2UA*CPN2))-
CREV P16.04 FJD 10/23/90 START
C      5WGFNA*(MFSTA*HSTA+TGA*(MFH2A*CPH2+MFO2A*CPO2+MFCCA*CPCO+
C      6MFC2A*CPC2+MFN2A*CPN2))-
CREV P16.04 FJD 10/23/90 END
      5WGCFA*(MFSTCF*HSTCF+TGCF*(MFH2CF*CPH2+MFO2CF*CPO2+MFCOCF*CPCO+   GAS SENSIBLE
      6MFC2CF*CPC2+MFN2CF*CPN2)) QGFPA+WSTFP*HSTW+QSTA+QGCNA-           HEAT*
      7QGUW=QGIWT-QGIWU-QGDCH.-QGEQ-LAMSA*MSWA*HWSTA+WSWBA*HWSTB+
CREV P16.04 RAA/MAM 11/30/90 START
CCREV P16.04 FJD 10/23/90 START
CC     8WSWUA*HWSTUA-WSWAD*HWSTAD-WGFNA/MGA*MSWA*HWSTA-WSTAW*HWSTA+QGDCH
C      8WSWUA*HWSTUA-WSWAD*HWSTAD-WSTAW*HWSTA+QGDCH
CCREV P16.04 FJD 10/23/90 END
      8WSWUA*HWSTUA-WSWAD*HWSTAD-WSTAWA*HWSTA+QGDCHA
                .
                .
                .
        IF (WGCFA.EQ.0.D0) RETURN
        FMSWA=FMSWA-WSWCF
        FMAWA=FMAWA-WAWCF
        FMWG=FMWG-WSWCF-WAWCF
        FUGA=FUGA-WSWCF*HWSTCF          SUSPENDED WATER
        RETURN                          SENSIBLE HEAT*
                .
                .
```

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Attachment 4

Sample DCOMPT code modification for utilizing PLT( )
array assignments as a means of retrieving
sensible heat transfer data from D compartment
leakage and containment failure plumes

DCOMPT.FOR CODING

```
      .
      .
      COMMON/D3/TFOWDO,TFOWBO,TFIWDO
CREV SONGS ** NEW CODING FOR SENSIBLE HEAT OUTPUT ** START
C ADD /XPLTX/ COMMON TO SUBROUTINE                              NEW CODING*
C
      COMMON/XPLTX/PLT(500)
C
CREV SONGS ** NEW CODING FOR SENSIBLE HEAT OUTPUT ** END
      .
      .
      FUGD=QFLD-QDIFD+QBRND-QGOW-QGIW+
CREV P16.04 RAA/MAM 11/30/90 END
     1WGBD*(MFSTBD*HSTBD+TGBD*(MFH2BD*CPH2+MFO2BD*CPO2+MFCOBD*CPCO+
     2MFC2BD*CPC2+MFN2BD*CPN2))+
     1WGAD*(MFSTAD*HSTAD+TGAD*(MFH2AD*CPH2+MFO2AD*CPC2+MFCOAD*CPCC+
     2MFC2AD*CPC2+MFN2AD*CPN2))-
     3WGCFD*(MFSTCF*HSTCF+TGCF*(MFH2CF*CPH2+MFO2CF*CPO2+MFCOCF*CPCO+
CREV P16.04 FJD 11/01/90 START
C     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFN*IFCD+QGFPD+WSTFP*HSTW-
C     7LAMSD*MSWD*HWSTD+WSWBD*HWSTBD+WSWAD*HWSTAD+
C     8WGFNA/MGA*MSWA*IFCD*HWSTA-WSTAW*HWSTD-
CREV P16.05 FJD 1/7/91 START
C     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFPD+WSTFP*HSTW+QTNODE*QGRD-
     6MFC2CF*CPC2+MFN2CF*CPN2))+QGFPD+WSTFP*HSTW+NQT*QGRD-
CREV P16.05 FJD 1/7/91 END
     7LAMSD*MSWD*HWSTD+WSWBD*HWSTBD+WSWAD*HWSTAD-WSTAW*HWSTD-
CREV P16.04 FJD 11/01/90 END
     3WGLK*(MFSTLK*HSTLK+TGLK*(MFH2LK*CPH2+MFO2LK*CPO2+MFCOLK*CPCO+
     6MFC2LK*CPC2+MFN2LK*CPN2))-WSWLK*HWSTLK

CREV SONGS ** NEW CODING FOR SENSIBLE HEAT OUTPUT ** START
C     PLT(1) - SENSIBLE HEAT TRANSFER THROUGH CONT. LEAK IN D COMPT
C     PLT(2) - SENSIBLE HEAT TRANSFER THROUGH CONT. BREACH IN D COMPT    NEW CODING*
C
      PLT(1)=WGLK*(MFSTLK*HSTLK+TGLK*(MFH2LK*CPH2+MFO2LK*CPO2+MFCOLK*CPCO+
     . MFC2LK*CPC2+MFN2LK*CPN2))+WSWLK*HWSTLK

      PLT(2)=WGCFD*(MFSTCF*HSTCF+TGCF*(MFH2CF*CPH2+MFO2CF*CPO2+MFCOCF*CPCO+
     . MFC2CF*CPC2+MFN2CF*CPN2))+WSWCF*HWSTCF
CREV SONGS ** NEW CODING FOR SENSIBLE HEAT OUTPUT ** END
      .
      .
      .
      IF (WGCFD.EQ.0.D0) GO TO 1111
      FMSWD=FMSWD-WSWCF
      FMAWD=FMAWD-WAWCF
      FMWG=FMWG-WSWCF-WAWCF
      FUGD=FUGD-WSWCF*HWSTCF
1111  IF(ISORT.EQ.1) THEN
      .
      .
```

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August 8, 1994

Mr. Sam Chien
San Onofre Nuclear Generating Station
Southern California Edison Company
P.O. Box 126
San Clemente, CA 92674

Dear Sam:

I discovered after reading your fax of August 2, 1994 that there was indeed an error in the calculation of the Cs and Te release fractions from the release fractions in MAAP categories 2 and 6 (for Cs) and 3 and 11 (for Te), but it was in equation 3. The amended equations are presented below.

We first determine the fractions of Cs in the mass of CsI and CsOH. These are

$$f_2^{Cs} = \frac{\overline{w}_{Cs}}{\overline{w}_{Cs} + \overline{w}_I} \qquad (1)$$

$$f_6^{Cs} = \frac{\overline{w}_{Cs}}{\overline{w}_{Cs} + \overline{w}_O + \overline{w}_H} = \frac{\overline{w}_{Cs}}{\overline{w}_{Cs} + 17.0073\, g/gmol} \qquad (2)$$

where $\overline{w}_{Cs}$, $\overline{w}_I$, $\overline{w}_O$ and $\overline{w}_H$ are the average atomic weights of cesium, iodine, oxygen and hydrogen in the material released. Then define the fraction of Cs in each of the MAAP release categories:

$$\mu_2 = \frac{f_2^{Cs} m_2}{f_2^{Cs} m_2 + f_6^{Cs} m_6} \qquad (3)$$

$$\mu_6 = 1 - \mu_2 \qquad (4)$$

in MAAP categories 2 and 6 respectively, and where m_2 and m_6 are the total mass of CsI and CsOH available for release. The Cs release fraction is then

$$\ell_{Cs} = \mu_2 \ell_2 + \mu_6 \ell_6, \qquad (5)$$

A-16

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August 25, 1994

Mr. Sam Chien
San Onofre Nuclear Generating Station
Southern California Edison Company
P.O. Box 126
San Clemente, CA 92674

Dear Sam:

I received your fax this morning, and thought I should extend the equations I gave you earlier to include three components for the TeO_2-Te_2-Sb group. The equations for cesium I sent you on August 8 still hold.

We first determine the fraction of Te in the mass of TeO_2. This is:

$$f_3^{Te} = \frac{\overline{w}_{Te}}{\overline{w}_{Te} + 2 \cdot \overline{w}_O} = \frac{\overline{w}_{Te}}{\overline{w}_{Te} + 31.9988} \quad (1)$$

where $\overline{w}_{Te}$ and $\overline{w}_O$ are the average atomic weights of tellurium and oxygen in the material released. Then define the fraction of Te/Sb in each of the MAAP release categories:

$$\mu_3 = \frac{f_3^{Te} m_3}{f_3^{Te} m_3 + f_{10}^{Sb} m_{10} + f_{11}^{Te} m_{11}} = \frac{f_3^{Te} m_3}{f_3^{Te} m_3 + m_{10} + m_{11}} \quad (2)$$

$$\mu_{10} = \frac{m_{10}}{f_3^{Te} m_3 + m_{10} + m_{11}} \quad (3)$$

$$\mu_{11} = \frac{m_{11}}{f_3^{Te} m_3 + m_{10} + m_{11}} \quad (4)$$

in MAAP categories 3, 10 and 11 respectively, and where m_3, m_{10} and m_{11} are the total masses of TeO_2, Sb, and Te_2 available for release. The Te/Sb release fraction is then

$$\ell_{Te} = \mu_3 \ell_3 + \mu_{10} \ell_{10} + \mu_{11} \ell_{11}, \quad (5)$$

where ℓ_3, ℓ_{10} and ℓ_{11} are the release fractions for MAAP categories 3, 10 and 11, respectively.

This gives the release fractions in terms of the <u>mass</u> released. If we want it in terms of the activity released, we need to modify equations 2-5 as follows:

$$\mu'_3 = \frac{f_3^{Te} m_3 A_{Te}^{Sp}}{\left(f_3^{Te} m_3 + f_{11}^{Te} m_{11}\right) A_{Te}^{Sp} + f_{10}^{Sb} m_{10} A_{Sb}^{Sp}} = \frac{f_3^{Te} m_3 A_{Te}^{Sp}}{\left(f_3^{Te} m_3 + m_{11}\right) A_{Te}^{Sp} + m_{10} A_{Sb}^{Sp}} \qquad (2')$$

$$\mu'_{10} = \frac{m_{10} A_{Sb}^{Sp}}{\left(f_3^{Te} m_3 + m_{11}\right) A_{Te}^{Sp} + m_{10} A_{Sb}^{Sp}} \qquad (3')$$

$$\mu'_{11} = \frac{m_{11} A_{Te}^{Sp}}{\left(f_3^{Te} m_3 + m_{11}\right) A_{Te}^{Sp} + m_{10} A_{Sb}^{Sp}} \qquad (4')$$

$$\ell_{Te} = \mu'_3 \ell_3 + \mu'_{10} \ell_{10} + \mu'_{11} \ell_{11}, \qquad (5')$$

where A_{Te}^{Sp} and A_{Sb}^{Sp} are the specific activities (in Ci/g) of the tellurium and antimony available for release. Of course, this could be extended to include not just activity, but some measure of the relative dose-effectiveness of antimony and tellurium.

The discrepancies I found extended to the other groups as well. I don't know the cause, but the symptom I see is that some of the total release fractions used in the MACCS runs are not the same as the corresponding release fractions at the end of 48 hours from the graphs you sent me last month. For instance, in the case of LLO-34, we have:

Group	MACCS Total	Graph at 48 hours	MACCS/Graph Ratio
I	8.2E-3	6.3E-3	1.30
Cs	8.1E-3	6.4E-3	1.27
Te	2.3E-3	1.6E-3	1.44
Sr	2.3E-4	1.6E-4	1.44
Ru	8.5E-6	<1E-5	?
La	3.0E-5	1.7E-5	1.76
Ce	1.3E-4	8.0E-5	1.62
Ba	1.2E-4	8.6E-5	1.40

The root of this discrepancy may not be in your computer program. It might just be that I was sent graphs from a MAAP run that was later changed. Nonetheless, you need to have a consistent audit path for the calculations before you sent this report out.

I am proceeding with the review of the remaining 6 cases I haven't checked yet, and will let you know any inconsistencies that appear. Please call if you have any other questions.

Very truly yours,

T. Edward Fenstermacher

T. Edward Fenstermacher

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August 25, 1994

Mr. Tom Hook
San Onofre Nuclear Generating Station
Southern California Edison Company
P.O. Box 126
San Clemente, CA 92674

Dear Mr. Hook:

I have completed my review of the reports "PRA Evaluation of Population Dose Risk from Severe Accidents at San Onofre Nuclear Generating Station Units 2 and 3" (referred to herein as the Base Case Report) and "PRA Evaluation of Risk Impact of Proposed One-Time Exemption form the Requirement of 10CFR50, Appendix J for ILRT Testing at San Onofre Nuclear Generating Station Units 2 and 3" (referred to herein as the ILRT Report).

I found the methodology employed in both reports to be sound. I have sent you minor corrections to several of the source terms employed in the Base Case Report, based on a comparison of the integral release fraction of each isotope group as a function of time implied by the release fractions, the start time and the duration of each phase with the graphical data sent to me by Sam Chien from July 22, 1994 to August 2, 1994. A corrected set of data is enclosed with this report. Subject to the revision of the Base Case Report to include these results, the resulting mean population dose should be correct within the type of uncertainty limits characteristic of consequence analysis methodology.

Since no corresponding curves were available to me for the MAAP results for the ILRT report, I was unable to check the input for this report in detail. However, a careful internal consistency check, along with a comparison of the ILRT Report source terms to the Base Case Report source terms, should reveal any problems which may be present.

If I can be of any further assistance to you, please feel free to call.

Very truly yours,

T. Edward Fenstermacher

T. Edward Fenstermacher

Enclosure

(AVAILABLE UPON REQUEST)

APPENDIX B
MACCS Output File Listings

(AVAILABLE UPON REQUEST)