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AUTH.NAME   AUTHOR AFFILIATION
BASKIN,K.P.   Southern California Edison Co.
RECIP.NAME   RECIPIENT AFFILIATION
MIRAGLIA,F.   Licensing Branch 3

SUBJECT: Forwards revisions to FSAR,in response to Siting Analysis Branch 810327 request for addl info re offsite toxic gas hazards & "Analysis of Probability of Toxic Gas Hazard for San Onofre Station As Result of Truck Accidents Near Plant."

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Southern California Edison Company

P. O BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

K. P. BASKIN
MANAGER OF NUCLEAR ENGINEERING, SAFETY, AND LICENSING

TELEPHONE
(213) 572-1401

April 6, 1981

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U.S. NUCLEAR REGULATORY COMMISSION

Director, Office of Nuclear Reactor Regulation
Attention: Mr. Frank Miraglia, Branch Chief
Licensing Branch No. 3
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket Nos. 50-361 and 50-362
San Onofre Nuclear Generating Station
Units 2 and 3

Enclosed are sixty-three (63) copies of the revised FSAR sections responding to Siting Analysis Branch (SAB) questions concerning offsite toxic gas hazards. The revisions provide the additional information requested by the SAB during a meeting on March 27, 1981. Also enclosed are seven (7) copies of the report "Analysis of the Probability of a Toxic Gas Hazard for the San Onofre Nuclear Generating Station as a Result of Truck Accidents Near the Plant" which describes the detailed methodology and analysis results (Mail Code B028).

Direct distribution of these revised FSAR sections will be made as part of the Amendment 24 distribution which will be in accordance with the service list provided by SCE's letter of October 29, 1979. An affidavit attesting to the fact that distribution has been completed will be provided within ten (10) days of docketing of Amendment 24.

If you have any questions or comments concerning this information, please contact me.

Very truly yours,

K P Baskin

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2.2.3 EVALUATION OF POTENTIAL ACCIDENTS

The accidents considered in this section include: explosions of hazardous materials, delayed ingnition of flammable vapor clouds, liquid spills and release of toxic vapors, fires, and accidents at sea. 21

2.2.3.1 Determination of Design Basis Events

Standard Review Plan 2.2.3 defines design basis events external to the station as those accidents for which a realistic estimate of the annual probability of exceeding 10EFR100 exposure guidelines is in excess of approximately 10^{-7} or for which a conservative estimate of this probability is in excess of approximately 10^{-6}.

Available statistical data were analyzed to determine the probability of occurrence of potential accidents based upon their historical frequency of occurrence. In those cases where data relating to particular classes of accidents were not available, conservative assumptions were used to evaluate order-of-magnitude accident probabilities. A description of data sources, assumptions, and computational methods is presented in the following paragraphs. The containment can withstand a 7.0 lb/in.^{2} differential pressure and maintain containment integrity. The other safety-related buildings can withstand 7.0 lb/in.^{2} also. In the following analysis, the peak positive normal reflected explosion overpressure of 7.0 lb/in.^{2} was used as design basis for evaluating probabilities. 24

2.2.3.1.1 Transportation Accidents on Interstate 5

Hazardous materials transported past San Onofre on Interstate 5 are tabulated in paragraph 2.2.2.2. The hazardous materials include military ordnance, flammable and explosive chemicals, toxic chemicals, and pressurized non-combustible gases.

2.2.3.1.1.1 Accident Rates for Motor Carriers of Hazardous Cargoes. The probability of transportation accidents on Interstate 5 (I-5) involving hazardous materials was estimated from statistical data on the frequency of truck accidents on I-5 within a 5-mile radius of the San Onofre plant site and nationwide accident rates.

Accident rates for all trucks[a] and commodities are determined for a 10 mile segment of I-5 extending approximately equidistant in both directions from the SONGS site. California State Department of Transportation supplied data is summarized in table 2.2-3A. From this data, an observed truck accident rate of 0.566 x 10^{-6} accidents per truck mile is evaluated. The data given in table 2.2-3A is for I-5 from mile post R61.38 to mile post R71.38. Truck traffic rates are based on weighted sample counting and extrapolated to annual counts. Northbound and southbound data are combined. 24

a. Truck is defined as any vehicle 5000 pounds or more excluding pickup trucks, vans and buses.

Table 2.2-3A

SUMMARY OF DATA SUPPLIED BY
CALIFORNIA DEPARTMENT OF TRANSPORTATION

Calendar Year	Truck Miles on I-5	Number of Accidents	Accidents per 10^6 Miles
1974	20.38×10^6	12	0.589
1975	19.88×10^6	9	0.453
1976	21.83×10^6	15	0.687
1977	22.65×10^6	12	0.530
Combined	84.74×10^6	48	0.566

Table 2.2-3B

U.S. DOT INTERCITY HIGHWAY TRUCK ACCIDENT RATES PER MILE

24

Year	Accident Reported If Over[a]	Accident Rate $\times 10^{-6}$	Injury Rate $\times 10^{-6}$	Fatality Rate $\times 10^{-6}$
1971	$ 250	2.19	1.00	0.083
1972	$ 250	2.31	0.996	0.081
1973	$ 2000	0.952	1.02	0.071

a. Accident also reported if there was an injury or fatality.

Traffic accidents are reported to the state if property damage is $200.00 or greater or there has been personal injury or death.

In this analysis, I-5 accident rates are combined with U.S. Department of Transportation (U.S. DOT) data where the property damage threshold for reporting accidents has been increased from $250.00 to $2,000.00. To correct for the data base inequities, U.S. DOT experience before and after the reporting threshold change is used to generate a correction factor. Table 2.2-3B presents data covering the transition period.[27] [28]

$$\text{Correction factor} = \frac{\text{1973 accident rate}}{\text{1971-72 accident rate}} = \frac{0.952 \times 10^{-6}}{2.25 \times 10^{-6}}$$

$$= 0.423 \, \frac{\$2000 \text{ accidents}}{\$250 \text{ accidents}}$$

The 2.25×10^{-6} rate is the average of 1971 and 1972 rates.

This factor is applied to the I-5 accident rates based on the assumption that California accident rates would be reduced by the same proporation as that observed on the national level. The fact that the California threshold is \$200.00 vs. \$250.00 for the U.S. DOT would make the correction factor a conservative assumption.

The accident rate corrected to the \$2,000.00 death or injury reporting criteria for all trucks on I-5 is:

$$0.423 \times 0.566 \times 10^{-6} = 0.239 \times 10^{-6} \text{ accidents/truck-mile}$$

The bulk of hazardous commodities carried on I-5 past the San Onofre Site are in tank trucks.

Therefore, the I-5 tank-truck accident rates are assessed by applying a correction factor based on nationwide experience. An Authur D. Little, Inc. Report(29) evaluated a national tank-truck accident rate of 1.33×10^{-6} per loaded tank truck mile.

This accident rate is based on data from 1968 through 1972 (5 years). The average number of loaded tank-truck accidents was 1650 accidents per year and the average loaded tank-truck usage was 1.24×10^9 miles per year. During the same 5-year period, the Bureau of Motor Carrier Safety published(27) data yielding an inter-city truck accident rate of 2.41×10^{-6} accidents per truck-mile. This accident rate is the ratio of 160,347 accidents and $66,389 \times 10^6$ truck miles. 24

Nationwide truck accident statistics show that loaded tank trucks have a lower accident rate than all types of trucks combined. (1.33×10^{-6} vs. 2.41×10^{-6} for years 1968 through 1972 with the same reporting criteria). Therefore, the I-5 accident rate for all types of trucks (0.239×10^{-6}) is corrected to loaded tank-truck accident rate by assuming the same relative improvement exists in California (I-5) as observed nationwide.

$$\text{Loaded tank truck accident rate on I-5} = 0.239 \times 10^{-6} \frac{1.33 \times 10^{-6}}{2.41 \times 10^{-6}} = 0.132 \times 10^{-6} \text{ accidents/mile}$$

Table 2.2-3C[27]

NATIONAL TRUCK ACCIDENT RATES

24

Calendar Year	Total Intercity Vehicle Miles	Total Intercity Accidents	Accident Rate per 10^6 Miles
1968	11704 x 10^6	29209	2.50
1969	12461 x 10^6	30672	2.46
1970	12390 x 10^6	33203	2.68
1971	13951 x 10^6	30581	2.19
1972	15883 x 10^6	36682	2.31
Combined	66389 x 10^6	160347	2.41

2.2.3.1.1.2 Explosions Due to Transportation Accidents on Interstate 5

2.2.3.1.1.2.1 Military Ordnance. The average number and size of the explosive shipments past the San Onofre plant site were provided by the Office of the Commandant, Eleventh U.S. Naval District.[31] The average shipment size is 700 pounds equivalent TNT with the maximum single shipment being 5000 pounds of Class 7 explosive (1 pound of Class 7 explosive is equivalent to 1 pound of TNT).[32] Present analysis conservatively assumes that there were 10 annual shipments of 5000 pounds of equivalent TNT explosives.

Based on physical constraints, the minimum distance along I-5 is approximately 560 feet from the nearest safety-related structure (the fuel handling building). The peak positive normal reflected overpressure at the plant site produced by the surface detonation of 700 pounds of TNT at a distance of 560 feet is approximately 1.3 lb/in.^{2}.[33] The surface detonation of 5000 lbs TNT at 560 feet from the station will produce an overpressure of approximately 3.2 lb/in.^{2}. Therefore, since the design basis overpressure is 7.0 lb/in.^{2}, the detonation of 700 pounds or 5000 pounds of TNT on any portion of I-5 will not exceed the design basis value. 24

The probability that an accident would result in an explosion was determined by data provided by the Institute of Makers of Explosives[34] on the accident statistics for commercial shipments of explosives. During the 4-year period of 1972-1975, there were 70 accidents reported of which 3 involved explosions. From this information, it is estimated that the conditional probability of an explosion due to an accident is 3/70 or 0.043. Accident Reports are filed when an explosive shipment accident results in (1) fire, (2) death or injury, (3) property damage exceeding $1000.

The minimum shipment size of explosives which will cause a 3.0 lb/in.^{2} overpressure is approximately 4470 equivalent pounds of TNT. Based on a distribution of 216 shipments with an average weight of 700 pounds and a maximum weight of 5000 pounds, it is conservative to assume that there are 10 annual shipments of 5000 pounds. Based on the assumed 10 annual shipments of 5000 pounds equivalent TNT with a probability of a truck accident of 4.24×10^{-7} per truck mile, and 0.043 probability of an explosion, the annual probability of ordnance detonations on a 0.173-mile length of I-5 causing an overpressurization of 3.0 lb/in.^{2} at the plant site is 3.15×10^{-8}. Therefore military shipments of explosives on I-5 are not considered to be a hazard insofar as overpressures experienced at the plant are concerned. 24

All other explosive shipments past the plant are Class B explosives which are defined as those explosives which in general function by rapid combustion rather than detonation and therefore[35] do not pose an explosion hazard to the plant.

2.2.3.1.1.2.2 Explosive Chemicals. There are two classifications[35] of hazardous materials, detailed in table 2.2-1, being shipped on I-5 past the San Onofre site, which can pose an explosion hazard, flammable liquids and flammable compressed gasses.

A. Flammable liquids are shipped at ambient temperature and pressure and would not pose an explosion hazard unless vaporized. To calculate the probability of hazardous flammable liquids to explode due to a truck accident, it is necessary to determine the conditional probabilities of a spill and an explosion occurring due to a spill. Since the bulk of the flammable materials move by tank truck, the probability of a tank truck accident per mile
24 of I-5 is 1.32×10^{-7}. The probability of a spill is estimated to be 0.02 since fewer than 2% of the accidents result in a spill.[29]

The probability of an explosion resulting from an in-transit tank truck spill of flammable liquid is 0.0113, as determined from the accident reports of the Department of Transportation, Office of Hazardous Materials.[37] These reports covered the period from July, 1973, to December, 1975, and included a total of 442 spills of flammable liquids from tank trucks, of which 5 resulted in explosions. It was conservatively assumed that all of these explosions were fuel-air detonations which yield the maximum possible overpressure. These incident reports are required by federal law for all unintentional spills of hazardous materials. Starting in July, 1973, these reports were classified according to the results of the spill. The total probability of an in-transit explosion of a tank truck carrying a flammable
24 liquid on I-5 is calculated to 2.98×10^{-11} ($1.32 \times 10^{-7} \times 0.02 \times .0113$) tank truck explosions/tank truck mile.

The effect of the explosion for the flammable liquids listed in table 2.2-1 is dependent on the chemical and physical properties of the materials. These chemicals are liquids at ambient temperature and pressure, and, in general, they have low vapor pressures and high vapor densities. Thus, the vapor formed tends to hug the ground, and only a thin vapor interface exists between the air and the liquid. Therefore, spilled fuels are unlikely to produce an explosion with a strong blast wave but will produce a simple flash-over flame igniting the remainder of the fuel.[38][39] To be extremely conservative, it is assumed that 10% of the liquid is vaporized to form an explosive cloud for all flammable liquids, except for formaldehyde where 37% is used to correspond to the amount of formaldehyde in solution. It is assumed that the explosion occurs at the point of the accident. Delayed denotations of vapor clouds are discussed in paragraph 2.2.3.1.2.2.3.

The enthalpy of combustion of a stoichiometric fuel-air mixture for each of the flammable liquids[40] is equated to the enthalpy of detonation of TNT (500 k cal/lb).[41] In accordance with empirical observations of blast damage in unconfined vapor cloud explosions, it is assumed that the maximum fraction of the fuel in the combustion range or the maximum yield of the TNT equivalent weight is calculated based upon a probability distribution.
24 The given values of the yield are applied to the total quantity of material released, rather than the flash fraction.

Since the average shipment size is almost equal to the maximum size,
the maximum shipment size for each chemical listed in table 2.2-1
is used to calculate the peak positive normal reflected overpres-
sure at the plant site for a surface detonation.(33) At the minimum
distance of 560 feet, only formaldehyde, gasoline, and xylene are
capable of causing a peak overpressure which exceed 3.0 lb/in.^{2}. 24

Using the value of 600 feet for the length of the plant parallel
to I-5, the total length of I-5 that can produce an overpressure
of 3.0 for a tank truck explosion of formaldeyhde is 3,240 feet
(0.61 miles), gasoline is 1078 feet (0.204 miles), and xylene is
952 feet (0.18 mile). These values are multiplied by the proba-
bility of an explosive spill of 2.98×10^{-11} tank truck explosion/ 24
tank truck mile and the annual shipments (14 for formaldehyde,
17,000 for gasoline, and 24 for xylene) to yield an annual proba-
bility of explosions causing an overpressure in excess of
3.0 lb/in.^{2} is 2.55×10^{-10} for formaldehyde, 1.03×10^{-7} for 24
gasoline and 1.29×10^{-10} for xylene. The analysis for gasoline is
conservative since it is assumed that all explosions were fuel-
air detonations, that the entire cargo was available for flashing,
and that the maximum shipment size was used in the analysis.
Gasoline has a high vapor density and low vapor pressure(44)
in comparison with most other hazardous materials and therefore
a spill will actually result in a very small amount of vapor.
In addition, the value of 3.0 lb/in.^{2} is significantly below the 24
design overpressure value of 7.0 lb/in.^{2}. Therefore, shipments of
flammable liquids by tank truck are not considered to be a hazard
insofar as plant overpressures are concerned.

B. Flammable gasses are shipped by the plant site as compressed
liquids and compressed gas. Propane (LPG), butane, liquified
natural gas (LNG), and hydrogen are shipped in tank trucks as
compressed liquids, and hydrogen and acteylene are shipped as
compressed gasses. The compressed liquids are shipped by tank
trucks, and the conditional probability of a spill is 2.64×10^{-9} 24
tank truck spill/tank truck mile ($1.32 \times 10^{-7} \times 0.02$). The
probability of a liquified compressed gas-air detonation was
determined from the Department of Transportation (DOT), Office
of Hazardous Materials, Incident Reports for July 1973, to
December 1975,(37) and the University of Southern California
study(45) of DOT propane tank truck accidents from January 1970,
through August 1972. In each of these reports, there was 1
explosion out of 17 spills of the cargo. Using 0.06 as the con-
ditional probability of an explosion per spill, the total
probability for a tank truck carrying compressed flammable
liquified gas is 1.58×10^{-10} explosions/tank truck mile of I-5. 24

The magnitude and resulting effect of explosions on I-5 is
dependent on the chemical and physical properties of the material.

For LPG, LNG, and liquified hydrogen, the amount of flashing of liquid to vapor was calculated from the enthalpy differences at the cryogenic shipping condition and at atmospheric pressure.[46][47][48] The enthalpy of combustion of a stoichiometric fuel-air mixture for each of the flammable gasses was equated to the enthalpy of detonation of TNT.[41] For the unconfined vapor cloud explosions of LPG and LNG it is assumed that the maximum yield of the TNT equivalent weight is based upon the probability
24 distribution discussed above. For hydrogen and acetylene, it is conservatively assumed that the maximum yield is 100% of the TNT equivalent weight.

The maximum shipment weights given in table 2.2-1 for LPG, LNG and liquid hydrogen were used for the shipment size. At the minimum distance of 560 feet, the fuel-air detonation of LPG will produce an overpressure of 5.4 lb/in.^{2} and liquid hydrogen will produce an overpressure of 4.0 lb/in.^{2}. LNG will produce a 1.6 lb/in.^{2} overpressure. Therefore, since the design basis
24 overpressure is 7.0 lb/in.^{2}, detonation of these shipments along any portion of I-5 will not exceed the design basis value.

Hydrogen gas is shipped in 219 cubic feet cylinders with a maximum shipment size of 75 cylinders reported. Even in the case of assuming that all 75 cylinders rupture to form a vapor cloud, the fuel air detonation of this cloud will not exceed the design pressure of the plant. Hydrogen gas is also shipped in a tank trailer consisting of 10 cylinders having a total capacity of 640 pounds or 114,000 standard cubic feet. Instantaneous rupture of all 10 cyclinders could produce a vapor cloud which, if detonated, could produce a 6.0 lb/in.^{2} overpressure. Similarly the shipment of 10 - 198 pound, (gross weight) acetylene cylinders containing 330 cubic feet will not cause an overpressure even if all cylinders rupture to produce a vapor cloud. This analysis is extremely conservative since it assumed total release of all hydrogen and acetylene gas from all cylinders in an accident. 24

Another possible cause of damage to the plant is a fireball generated by the explosion of tank trucks on I-5. The maximum size of a fireball generated by the explosion of an LPG tank truck on I-5 was determined by using the technique described in reference 42. Ignition of a 10,100 gallon LPG tank consuming the entire contents would result in a fireball with a radius of 156 feet with a duration of 7.4 seconds. Since the outer dimension of the fireball is 400 feet away from the nearest safety-related building, a fireball caused by the explosion of an LPG tank truck will not be a hazard to the plant.

2.2.3.1.1.2.3 Flammable Vapor Clouds (Delayed Detonation). The delayed detonation of vapor clouds that result from spills of compressed liquids and gasses on I-5 are a possible hazard to the plant. No flammable liquids except formaldehyde (which is shipped as a gas in solution) are capable of forming a vapor cloud of significant proportions that could drift toward the plant. This is due to the fact that the flammable liquids form a thin vapor level between the air and liquid.[38][39]

Flammable gasses in liquid or gaseous state can form a vapor cloud which could drift toward the plant. To analyze this effect the puff release of the contents of these cargoes in the amounts stated in the previous section was assumed to occur on I-5 anywhere within the 5-mile radius of the plant. The potential consequences of an explosion involving these releases is dependent on the location of the release relative to the direction of the prevailing wind. Table 2.2-4 gives the relative frequency with which the wind blows towards the San Onofre site from each of sixteen 22 1/2° wind rose sectors. The unrestricted vapor cloud is assumed to move downwind from the release point under very stable atmospheric conditions (Pasquill Stability G).

The effective length of I-5 for which the detonation of a drifting puff release of the tank truck cargo would cause an overpressure of greater than 3.0 lb/in.^{2} at the plant site was determined. The drifting cloud's capability of exploding was based on its concentration being above the lower explosive limit concentration for the material being released. For conservatism it was assumed that vapor release within the distance calculated to produce overpressurization at the plant from an explosion at the accident site would not drift away from the plant.

Table 2.2-4

TABULATION OF THE RELATIVE FREQUENCY WITH WHICH WINDS BLOW TOWARDS THE SAN ONOFRE SITE FROM EACH OF THE 22-1/2 DEG WIND ROSE SECTORS, AND THE LENGTH OF INTERSTATE 5 LYING WITHIN EACH SECTOR AREA[a]

Wind Direction Sector	Frequency of Winds Blowing Toward the Site from Sector[a]	Estimated Length of Interstate 5 Included within the Sector Area (miles)
NW	0.0614	4.85
NNW	0.0320	0.27
N	0.0343	0.10
NNE	0.1092	0.07
NE	0.1404	0.07
ENE	0.0289	0.10
E	0.0163	0.25
ESE	0.0220	1.84
SE	0.0485	2.84
SSE	0.0698	0
S	0.0652	0
SSW	0.0607	0
SW	0.0533	0
WSW	0.0639	0
W	0.0857	0
WNW	0.1078	0

a. Wind direction probabilities are derived from table 2.3-22.

Using the value of 600 feet for the length of the plant parallel to I-5, the effective length of I-5 that could produce an overpressure greater than 3.0 psi due to a drifting unconfined vapor cloud explosion are for LPG (0.51 mile), LNG (0.16 mile), Hydrogen-liquid (0.36 mile) and formaldehyde (0.8 mile). The maximum explosive yields for LPG and LGN were 10% of the TNT equivalent weights (39)(41)(42)(43) and assumed to be 100% for hydrogen and formaldehyde. These values were multiplied by the probability of an explosion and number of annual shipments given in table 2.2-1. The annual probabilities of a plant site overpressurization explosion due to a drifting cloud from an I-5 tank truck spill are for LPG (1.79×10^{-7}), LNG (1.06×10^{-8}), hydrogen-liquid (2.94×10^{-9}) and formaldehyde (3.40×10^{-10}). 24

The annual probability of a plant site overpressurization explosion resulting from a release of LPG was further analyzed. This realistic analysis is an extension of the previous analysis using the following modified inputs:

A. The peak reflected overpressures required to cause release which could lead to consequences in excess of 10CFR100 guidelines is 7 lb/in.^{2}.

B. The single value of possible accident locations on I-5 has been replaced by a distribution across the southbound lanes and shoulder.

C. Sixty percent of the LPG shipments on I-5 are in tandem trailers with a maximum of 5,000 gallons available for involvement in a vapor cloud detonation. 24

D. The single yield of explosion has been replaced by a distribution of yields which is applied to the entire quantity of material released.

E. The probability of a significant explosion per train mile is reduced by a factor of two to account for the effects of improved couplers and head shields.

A review of LPG shipment data on I-5 shows that most shipments are southbound or on the side of the highway nearest the plant. The possible accident locations used in the realistic analysis were derived from actual truck accident locations along the ten-mile stretch of I-5 near the plant. The resulting locations and the assigned relative probabilities are:

• West edge of right-of-way	0.21
• West edge of roadway	0.37
• Center of roadway	0.26
• East edge of roadway	0.16

Finally, a probability distribution for the yield of an explosion was derived. The results of this realistic analysis show that the probability of exceeding the 10 CFR 100 guidelines are as follows:

- Due to LPG on I-5 0.57×10^{-7}/year
24
- Due to LPG on ATSF 0.53×10^{-7}/year
- Total 1.1×10^{-7}/year

which meets the acceptance criteria of SRP 2.2.3 of not exceeding approximately 10^{-7} per year.

The delayed detonation of hydrogen and acetylene was analyzed due to ruptures of gas cylinders containing these substances. However there are no results available on the probability of cylinder failure in an accident.[49-55] To obtain a probability of this type of failure, it is possible to relate the probability of steel drum failure to the probability of gas cylinder failure. Brobst[56] estimated that the probability of breaching a 55-gallon drum in an accident is 0.125. Clarke[57] has also noted that for containers about the size of 55-gallon drums about 6.8% of the containers are damaged in puncture accidents.

The probability of breaching a cylinder or drum is assumed to be inversely proportional to the cube of the wall thickness.[58] The wall thickness for the 219 cubic ft. hydrogen gas cylinders is a nominal
2 0.24 inches[59], for the 10 large cylinders it is a minimum of 0.375 inches[60], and for the acetylene cylinders it is a nominal 0.15 inches.[59] The wall thickness for the steel drum is a nominal 0.0478 inches.[61] Using the conservative value of 0.125 for the failure probability of steel drums, the probabilities of rupturing each type of cylinders per accident is 1.0×10^{-3} (219 cubic ft. hydrogen cylinders), 2.6×10^{-4} (large hydrogen cylinders) and 4.05×10^{-3} (acetylene
2 cylinders).

The probabilities of failing one or more cylinders in an accident are
2 0.07 (shipment size of 75 hydrogen cylinders of 219 cubic ft.), 0.0026 (shipment size of 10 large hydrogen cylinders) and 0.04 (shipment size of 10 acetylene cylinders). For conservatism it is assumed that the entire cargo is released. This is extremely conservative since the probability of failing more than 3 cylinders per accident is essentially zero. Using the value of 600 feet for the plant, the effective lengths of I-5 capable of causing an overpressure of 3.0 or greater are 0.18 miles (219 cubic
2 ft. hydrogen cylinders), 0.54 miles (large hydrogen cylinders) and 0.17 miles (acetylene). The annual probabilities of a plant overpressure of 3.0 psi or greater due to the detonation of a drifting cloud from an I-5 release of flammable gas are 8.3×10^{-8} (for 260 shipments of 219 cubic
2 ft. cylinders), 8.5×10^{-10} (for 24 shipments of large hydrogen cylinders) and 8.9×10^{-9} (for 52 shipments of acetylene).

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The analysis for delayed detonation of vapor clouds is conservative since it is very probable that escaping vapors will find an ignition source near the accident site. Car and truck traffic along I-5 would provide ample heat sources from hot manifolds and mufflers. James(61) has reported that for 81 vapor releases from tank cars 58% were ignited within 50 feet of the accident and all leaks found sources of ignition within 300 feet. In addition, the maximum size was used with the assumption that the entire contents of the tank truck was capable of forming the vapor cloud. The
24 effect of bouyancy was neglected in the analysis. Finally, exceeding the design bases overpressure of 7.0 lb/in.^{2} by the amounts calculated will not cause gross failure of the structures nor activity releases sufficient to lead to exceeding 10CFR100 guidelines. It is therefore concluded that overpressure due to fuel air detonation of vapor clouds resulting from accidents on I-5 do not pose a hazard to the plant.

2.2.3.1.1.3 <u>Release of Toxic Gasses Due to Transportation Accidents on Interstate 5</u>. Toxic chemicals are transported along Interstate 5 on a regular basis. Tables 2.2-1 and 2.2-2 list the observed materials transported past the site and their estimated frequency of shipment.

Based on a survey of Hazardous Materials Incident Reports on file with the Department of Transportation within a 10-mile radius of the site, no release of toxic chemicals has been reported. Reports are required by federal law if any hazardous material, regardless of quantity, has been released. This survey covered the calendar years through 1975, and corresponds to an estimated 1.34 x 10^8 truck-miles of traffic along the segment of Interstate 5.(23)

Based on tables 2.2-1 and -2, the predominant number of shipments past the site are asphyxiants. The effect on control room habitability of the release of compressed gasses which are classified as simple asphyxiants (i.e., helium, nitrogen, et cetera) was analyzed for the case of an instantaneous release of the entire shipment, and for the case of a continuous release of an entire shipment. The analysis of continuous releases considered the full spectrum of release rates and release durations. Based on these analyses the peak concentration of any asphyxiant in the control room is estimated to be 4.7% by volume. This is well below the concentration (10%) at which asphyxiants displace enough oxygen to become dangerous.

The remainder of toxic chemicals shipped past the site includes specific commercial products for which individual accident statistics are not readily available. In order to conservatively estimate the probability of an accidental release, it is necessary to estimate the probability for a loss of lading given that an accident has occurred. Compressed
24 gases in the liquified state, propane (LPG) and butane in particular, have been shown to pose a toxic hazard to plant operators.[91] The Bureau of Motor Carrier Safety (BMCS) of the U.S. Department of Transportation accident reporting system was consulted in efforts to determine the loss of lading fraction for these toxic materials. An analysis of the magnetic tape records of the accident report

forms for calendar years 1973 through 1977 indicated that 7 out of 109 accidents (6.4%) involving compressed gases, were on divided highway but were not on an entrance or exit ramp when the accident occurred resulted in loss of lading. [90] . From the accident rate derived in paragraph 2.2.3.1.1.1 above; the estimated probability for an accident along Interstate-5 which results in a loss of lading per truck-mile is 8.5×10^{-9} (1.32×10^{-7} accidents/mile x .064 spills/accident). The fraction of spills per truck accident is primarily dependent upon the type of material container used in shipment. In the case of gasoline, this fraction presented in the literature varies from .02(29) to values up to .3(90). Large variations in the assumed spill fraction will not significantly affect the results of the probabilistic risk with respect to meeting Standard Review Plan 2.2.3 guidelines. The following four substances have been identified as a result of the probabilistic risk assessment with their associated probabilities:

- Chlorine 1×10^{-6}/yr
- Butane 1×10^{-6}/yr 24
- Propane (LPG) 2×10^{-6}/yr
- Gasoline 1×10^{-6}/yr

Although realistic, this analysis does not take credit for the following factors: the section of I-5 adjacent to the site can be expected to have a lower than average accident rate for the State of California due to controlled access, lack of severe grades or turns, year-round nonfreezing conditions, and raised reflector lane markings. Other factors not utilized are included in the release statistics which do not discriminate between the more likely mechanism of a small puncture or crack resulting in a minimal leakage and/or leak rate and the less likely severe rupture which presents the more significant hazard to the plant. Finally, it is estimated that a realistic appraisal of dilution at the site (including the effects of ground roughness and topography) from a potential release along I-5 would result in a significantly reduced effective length of highway for consideration. It is therefore concluded that the potential for inadvertent release for each of the remaining toxic chemicals is negligible and does not present a hazard to the plant.

2.2.3.1.2 Transportation Accidents on the Atchison, Topeka, and Santa Fe Railroad Track Adjoining the San Onofre Nuclear Generating Station

Hazardous materials transported past San Onofre on the AT&SF railroad track are identified in subsection 2.2.2. The hazardous materials are military ordnance and LPG. The AT&SF Railway Company does not anticipate any other hazardous materials being shipped through the San Onofre area.(64)

2.2.3.1.2.1 Accident Rates for Atchison, Topeka, and Sante Fe Railroad. Railroad accident rates are determined from the statistical data published by the Office of Safety, Federal Railroad Administration, U.S. Department of Transportation. Data was obtained from the Accident Bulletins, Summary and Analysis of Accidents on Railroads in the United States for the calendar years of 1968 - 1974.[65] During this period there were 59,894 accidents nationwide with a total train mileage of over 5.8 billion miles. The average accident rate is 10.3 accidents per million train miles. During this same period the Atchison, Topeka and Santa Fe (AT&SF) Railroad had 2007 accidents in 379,391,000 train miles for an average of 5.29 accidents per million train miles.[65]

Using these accident rates for the stretch of AT&SF Railroad past the plant site are conservative since these rates include all train accidents including yard switching operations. Yard switching operations generally account for over 75% of the collision accidents that occur on railroads.[65]

2.2.3.1.2.2 Explosions Due to Collisions and Derailment Accidents on the AT&SF Railroad Track.

2.2.3.1.2.2.1 Military Ordnance. The Atchison, Topeka, and Santa Fe Railway Company reports hauling 74 carloads of ammunition past the San Onofre site during the first 11 months of 1975.[64] Shipments occur with a frequency of about 7 carloads per month. Commander Hatcher, U.S. Navy,[32] states that the 1975 shipments had the following distribution by net explosive weight [a]:

1 boxcar/yr at 37,000 pounds net explosive weight[a]

1 boxcar/yr at 25,500 pounds net explosive weight

82 boxcars/yr at less than 25,500 pounds but more than 400 lbs. averaging 13,000 pounds.

To predict the overpressures that might be produced by the explosion of ordnance boxcars on the AT&SF track, assumptions are required about the weight of explosive in the 82 boxcars shipments where the value was not specified, and also about the number of ordnance boxcars which are carried in a single train.

Table 2.2-5 gives the assumed frequency distribution of net explosive weight per boxcar vs. the number of boxcars/yr hauling this quantity of explosive. The mean net explosive weight for the 82 boxcar loads of 25,000 pounds and less is approximately 13,000 pounds, which agrees well with the mean net explosive weight reported for these shipments by Commander Hatcher of the U.S. Navy.[32]

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a. One pound of net explosive weight equals one pound of TNT[32]

Table 2.2-5
ASSUMED BOX CAR WEIGHT DISTRIBUTION OF ORDNANCE
TRANSPORTED BY RAIL PAST THE SAN ONOFRE SITE

Boxcar Shipments/yr	Net Explosive Weight/Boxcar (lb)
1	37,000
1	25,500
4	25,000
10	20,000
15	15,000
25	13,000
15	10,000
10	6,000
2	3,000
1	400
84 boxcars/yr	

It is assumed that all ordnance train shipments involve two loaded boxcars.(64) For conservatism, the boxcar net explosive weights given in table 2.2-5 were combined such as to maximize the weight of explosive per train shipment. It is further conservatively assumed that if either of the boxcars in a shipment detonates, the second will also detonate. The total weight and number of each size shipment is given in table 2.2-6.

No data were found from which the conditional probability of a munitions car explosion, given a munitions car accident could be derived. However a report by the IIT Research Institute(66) gives a compilation of data from which the probability of an explosion in a munitions train accident can be estimated.

The IIT Research Institute study estimated that there were 1.98×10^7 explosive train-miles per year based on statistics for a 57 year period from 1917 to 1973. The annual average train miles during this same period was 1.36×10^9. During this 57-year period there were 35 explosions involving in-transit shipments of explosives. The national annual probability of an explosion due to a train accident involving explosives is 3.1×10^{-8} explosions per explosive train mile. The accident rate for the Santa Fe Railroad is significantly less than the national average and therefore using the ratio of Santa Fe Railroad accident rate to the national railroad rate, the probability of an explosion on the Santa Fe Railroad involving explosives is 1.59×10^{-8} explosions per explosive train mile.

The probability that a munitions train explosion on the Santa Fe Railroad will cause a peak positive normal reflected pressure at the station which

Table 2.2-6
ASSUMED SHIPMENT WEIGHT DISTRIBUTION OF ORDNANCE
TRANSPORTED BY RAIL PAST THE SAN ONOFRE SITE

Munitions Train Shipments/Yr N_i	Total Net Explosive Weight/Shipment W_i (lbs)
1	62,500
2	50,000
5	40,000
7	30,000
1	28,000
12	26,000
7	20,000
1	16,000
4	12,000
1	9,000
1	3,400
42 shipments/yr	

exceeds the design basis overpressure is estimated by the following equation:

$$P_{op} = P_{ex} \times SF \times \sum_{i=1}^{42} N_i L_i$$

where

24 P_{op} = the annual probability of an overpressure at the station exceeding the design basis overpressure of 7.0 lb/in.^{2}

P_{ex} = probability of an explosive Santa Fe Railroad per explosive train mile (1.59×10^{-8})

SF = significance factor (0.154)[66]

N_i = the number of munitions train shipments/yr which carry a total of W_i pounds net explosive weight past the San Onofre site

L_i = the critical length of track over which the detonation on W_i pounds of TNT would produce an overpressure at the
24 station exceeding the design basis overpressure of 7.0 lb/in.^{2}

The significance factor was determined by the IIT Research Institute study[66] to eliminate those explosions that did not result in an explosive blast. Values for W_i and N_i assumed for the calculation are given in table 2.2-6. Peak explosion overpressures are based upon standard scaling laws for surface, hemispherical burst of TNT at sea level.[33] Assuming the entire explosive cargo of a train detonates in-mass, the annual probability of a peak positive normal reflected overpressure at the station exceeding 3.0 $lb/in.^2$ overpressure, caused by ordnance detonations on the AT&SF track, is 4.59×10^{-8}. 24

This number can be considered to be conservative, and the actual probability of occurrence is expected to be much lower for the following reasons:

A. The number of accidents involving explosives included large number of shipments that were made during both World Wars and the Korean and Vietnam conflicts.

B. Commander R. E. Hatcher, U.S. Navy, states that if an explosion would occur in a boxcar of ordnance of the type normally shipped past San Onofre (small arms ammunition) it is more likely to detonate in small individual bursts rather than as a single large blast.[32] Overpressures experienced at San Onofre site would be correspondingly lower.

2.2.3.1.2.2.2 LPG Tank Cars. There are two types of accidents involving LPG cars which could lead to an explosion:

- Accidental puncture of a LPG tank car
- Exposure of a LPG tank car to fire

A comprehensive data base developed by the Association of American Railroads and the Railway Progress Institute (AAR-RPI)[67] provides statistics from which the frequency of occurrence of loss-of-lading accidents from type 112A pressure noninsulated tank cars (the type used to transport LPG by the San Onofre site) can be estimated. During the 6-year period 1965 to 1970, there were 63 mechanical damage-induced loss-of-lading accidents involving type 112A cars carrying flammable compressed gases. The AAR-RPI[67] study estimates that the fleet of 112A cars loaded with flammable compressed gases traveled a total of 5.38×10^7 car-miles/yr during this period. Therefore, the national rate of loss-of-lading accidents per shipment mile was 1.95×10^{-7} loss-of-lading accidents caused by mechanical damage/LPG tank car mile. The accident rate for the Santa Fe Railroad is significantly less than the national average and therefore by using the ratio of the Santa Fe Railroad and national average, the Santa Fe rate of loss-of-lading accidents per shipment mile is 1.0×10^{-7} loss-of-lading accidents by mechanical damage/LPG tank car mile.

The AAR-RPI Final Phase 02 report(67) cites 40 incidents in which 50 cars experienced loss-of-lading from type 112A and 114A tank cars carrying LPG propane, and butane that were caused by mechanical puncture. In 24 of these cases, the release caused a fire, and in 26 cases the gas escaped without incident (as inferred from the fact that no property damage to neighboring cars or other structures occurred). These cases will be broken down into various categories according to their severity. Jones et al,(45) in their evaluation of the risks of propane rail car shipments, have categorized the severity of propane tank car accidents by the following scheme:

A. Type I - This type of incident could be caused by a major rupture of the containment vessel resulting in a gross spill without ignition. The result would be that a very large vapor cloud would be formed. If this cloud would be ignited after an explosive fuel/air mixutre had been formed, a maximum incident explosion would result. This type of incident is characterized by an unconfined fuel/air detonation.

B. Type II - This type of incident would be caused by a separate fire or a tank puncture resulting in a fire that would overheat the punctured propane tank or another propane tank in the near vicinity. The result would be an explosive pressure rupture of the heated tank, causing nearby overpessure damage and possible shrapnel damage from the ruptured tank. This type of incident is characterized by a propane tank explosion.

C. Type III - This type of incident would result from a leak or a tank puncture resulting in a large spill with ignition occurring immediately or shortly after the incident. The propane would burn uncontrollably in a large, intense fireball. No tank explosion would occur since the tank puncture would be large enough to relieve the pressure. This type of incident is characterized by a large uncontrollable fireball with no explosion.

D. Type IV - This type of incident would be caused by a leak, a tank puncture, a released safety valve or a burst transfer line or valve resulting in a controllable fire. The fire may be of considerable time duration and does not result in tank rupture, either due to fire control measures or protective insulation. This type of incident is characterized by a controllable fire with no explosion.

E. Type V - This type of incident would involve a leak or a puncture, either small or large, in a propane tank of loading lines which does not result in fire. If no source of ignition occurs, the propane will be dispersed in the atmosphere in a relatively short time. This type of incident is characterized by loss of lading, but no fire.

Reviewing the information available about these accidents,[42][68][69] it is concluded that these 50 tank car accidents can be classifed as follows:

Type	Number of Accidents
I	0
II	2
III	20
IV	2
V	26

No tank car Type I severity accidents involving either LPG or propane have been reported[45] in the period from 1965 to 1970. However, there was one such incident resulting from the puncture of a propylene car (January 22, 1972, St. Louis, Missouri)[45] and a second due to the puncture of a car laden with isobutane (July 19, 1974, Decatur, Illinois).[70] To be conservative, these incidents are included in the data base to obtain the following relative frequency of occurrence per tank car for each type of accident due to mechanical damage to LPG tank cars:

Type	Relative Frequency of Occurrence
I	0.038
II	0.038
III	0.385
IV	0.038
V	0.500

In addition to the mechanical damage, exposure of LPG cars to fire can lead to explosions. Review of the University of Southern California report[45] and the AAR-RPI reports[68][69] show that there were 17 incidents involving 49 LPG tank cars during the period of 1965-1970. These accidents can be classified as follows:

Type	Number	Frequency of Occurrence
I	0	0.0
II	39	0.796
III	2	0.041
IV	7	0.143
V	1	0.020

Although fuel-air detonations from fire-induced loss-of-lading accidents are conceivable, it is not credible that the escaping gas would fail to detonate very near the car (the heat from the fire which caused the tank car failure would also be available to initiate the detonation). The probability of a delayed detonation for these cases is accordingly assumed to be zero.

One hundred thirteen carloads of LPG were shipped past the San Onofre site during the first 11 months of 1975 (refer to subsection 2.2.2). The annual frequency of shipments is taken to be 124 LPG cars/yr., based upon the opinion of the Atchison, Topeka and Santa Fe Railway Company[64] that there will be minimal future growth in LPG haulage. The Company has also stated that no more than two or three LPG tank cars are included in the consist of any train.[64]

There are three possible hazards that could adversely affect the plant from an explosion of an LPG tank car; overpressurization, fireball, and missiles generated by tank car explosion. Detonations and resulting shock wave would occur only for Type I events. For Type II events, the overpressure failure of the tank car results in an explosive energy release but not detonation. A very conservative analysis of this yielded a maximum overpressure at the plant of approximately 1.0 lb/in.^{2}.[33]

A realistic analysis of the overpressurization potential to the plant site from LPG tank cars has been performed using the following outputs:

A. The peak reflected overpressures required to cause release which could lead to consequences in excess of 10CFR100 guidelines as 7 lb/in.^{2}.

B. The single yield of explosion has been replaced by a distribution
24 of yields which is applied to the entire quantity of
312.46 released.

C. The probability of a significant explosion per train mile is reduced by a factor of 2 to account for the effects of improved couplers and head shields.

The results of this realistic analysis show that the probability of exceeding 10CFR100 guidelines from an LPG explosion on ATSF railroad is $.53 \times 10^{-7}$/year.

A second possible cause of plant damage is the detonation resulting in a fireball causing damage to the plant. The maximum size fireball would be the result of a Type III accident. A considerably smaller fireball could result from a Type II accident. The analysis of the size and duration of this fireball is based on the technique described in reference 42. Ignition of 30,000-pound tank car of LPG would result in a fireball with a radius of 221 feet with a duration of 10.4 seconds. A fireball of this duration at a distance of about 240 feet from the plant will not casue damage to concrete buildings.

The final potential hazard to the plant is the generation of self propelled (or rocketing) missiles due to Type II ruptures of the tank car. A fragment from an LPG tank car explosion was hurled 2640 feet[71] while the great majority of the rocketing tank car fragments generated by exploding tank cars have a range of less than 1000 feet.[69] The largest range of

83. Deleted 16-312.36

84. Letter from Col. J. R. Aichele, Assistant Chief of Staff, Facilities, U.S. Marine Corps., Camp Pendleton, California, to Mr. D. R. Poole, Southern California Edison Company, December 7, 1978. 14

85. Sax, Irving N., "Dangerous Properties of Industrial Chemicals," Chapter 1.

86. Sokolik, A. S., "Self-Ignition Flame and Detonation in Gases." Translated from Russian. Published by the Israel Program for Scientific Translations for the NSF and NASA. Moskva: 1960. Jerusalem: 1963, pp 240-241. 16-312.36

87. Windholds, Martha, et al., ed. "Merk Index: An Encyclopedia of Chemicals and Drugs," Merk and Co., 1976.

88. British Gas Data Book, vol. 1, British Gas Corporation, 1974.

89. Fox, R. W., and Kline, S. J., "Flow Regime Data and Design Methods for Curved Subsonic Diffusers," TASME, Jour. Basic Engrg., vol. 84, Series D, September 1962.

90. Analysis of Explosive Vapor Cloud and Missile Hazards for Rail and Highway Transportation Routes Near the San Onofre Nuclear Generating Station Units 2 and 3; NUS Report 3367, July 1979. 24

91. Analysis of the Probability of a Toxic Gas Hazard for the San Onofre Nuclear Generating Station as a Result of Truck Accidents Near the Plant; Power Engineering Services, February, 1981.

pressurized during normal operation. Equipment in the makeup air supply system is designed to pressurize the control room and is sized to deliver 1000 ft^3/min flowrate into the control room. Based on the rate of outleakage, this flowrate is adequate to maintain a 1/4-inch positive pressure in the control room envelope. 9

6.4.2.4 Shielding Design

The design basis loss-of-coolant accident (LOCA) dictates the shielding requirements for the control room. Control room shielding design bases are discussed in paragraph 12.3.2.2.7. Descriptions of the design basis LOCA source terms and control room shielding parameters, and evaluation of design basis accident doses to control room personnel are presented in paragraph 15.6.3.3.5.

Drawings of the control room and its location in the plant, identifying distances, and shield thicknesses with respect to each radiation source discussed in paragraph 15.6.3.3.5 are shown in figures 12.3-3 and 12.3-4.

6.4.3 SYSTEM OPERATIONAL PROCEDURES

6.4.3.1 Normal Mode

Control room HVAC system operation in the normal mode is described in subsection 9.4.2.

6.4.3.2 Emergency Mode

Upon receipt of a control room isolation signal (CRIS), actuated by an SIAS signal or an outside air intake high radiation signal, the control room HVAC system is automatically shifted to the emergency mode of operation. Transfer to the emergency mode may also be initiated manually from the control room. 1-312.15

Transfer to the emergency mode consists of automatically closing the outside air isolation dampers from the normal supply air handling unit and all exhaust isolation dampers, stopping the control building supply and exhaust fans, activating both train A and train B outside air isolation dampers to the emergency ventilation units, and starting the emergency air conditioning units, opening the outside air isolation damper to the emergency filtration trains, and starting the fans. The emergency ventilation supply train fans discharge into the emergency recirculation type air conditioning units, which are started by the emergency mode transfer. Thus, each emergency ventilation supply train fan draws outside air through HEPA filters and carbon adsorbers, and discharges into the respective emergency recirculation air handling unit. Since there is no control room exhaust, the control room atmosphere exfiltrates to the outside of the control room. The development of the CRIS signal, including the quantity and setpoints of parameters sensed and actuation logic, is discussed in section 7.3. 21 1-312.15

The control room is supplied at a rate of 35,485 ft^3/min with cooled air from the operating emergency air conditioning unit by processing a mixture of 1000 ft^3/min of outside air through the emergency ventilation supply unit and 34,485 ft^3/min of recirculated air from the control room. The temperature of the control room is maintained between 70F and 85F.

6.4.3.3 Smoke Removal Mode

Should the control room fill with smoke, the control room normal HVAC system is shifted automatically to the smoke removal mode to clear the atmosphere. The operation of smoke removal mode is not safety related and, therefore, the capability to shift to the control room isolation mode is unaffected by smoke removal mode. The 100%-capacity smoke removal fan is started, the smoke isolation damper mounted in the smoke exhaust duct is opened, the outside air inlet isolation valve is opened, and the recirculating damper is closed. The airflow regime, thus established, changes control room air at a rate of 6.53 changes per hour or 31,800 ft^3/min.

6.4.3.4 Isolation Mode

The system operational procedure will be the same as the emergency mode
11 described in paragraph 6.4.3.2, with the exception that the emergency ventilation supply fans are not started.

6.4.4 DESIGN EVALUATION

6.4.4.1 Radiological Protection

The ability of the control room habitability system to provide radiological protection for the control room operator is demonstrated by the control room accident dose analyses presented in chapter 15 and the implementation of design bases discussed in paragraph 6.4.4.3.

6.4.4.2 Toxic Gas Protection

24 6.4.4.2.1 Determination of Offsite Chemicals Requiring Analysis

6.4.4.2.1.1 Introduction. An analysis of potentially hazardous chemicals shipped past the site has been performed to determine which hazardous chemicals should be considered as credible design basis accidents. NRC Regulatory Guide 1.78 provides generic frequency and size guidelines as to the shipment that should be included in the analysis.

11 The guidelines are further discussed in Standard Review Plan Section 2.2.3, which states that "judgement must be used as to the acceptability of the overall risk presented by an event", and that "guidelines should be estimated using assumptions which are as realistic as is practicable." Accordingly, a site specific evaluation has been performed to determine which potentially hazardous chemicals should be considered.

The potentially hazardous chemicals that are shipped on Interstate 5 (I-5)
past the site are listed in section 2.2. Several of the chemicals shipped
past the plant can be eliminated on the basis that they are not inhalation
hazards or that they are not volatile. Simple asphyxiants have been
analyzed in subsection 2.2.3 and found not to be a hazard.

For the analysis of the remaining chemicals, a probabilistic model for the 24
sequence of events involved in an accidental release was developed. Based
on this model, the probability of equaling or exceeding the toxic chemical
concentration at the control room air intake, assuming an accident has
occurred in the vicinity of the site along Interstate 5, was calculated.
This probability is evaluated at the toxicity limit of the chemical, and 24
is compared with a conservatively low value of 10^{-7} per year.

6.4.4.2.1.2 <u>Results</u>. For those chemicals analyzed using the methodology 24
discussed below, butane, propane, chlorine and gasoline have a probability
of exceeding their toxic concentration limits at the control room intake
greater than the 10^{-7} criterion of Standard Review Plan 2.2.3.

6.4.4.2.1.3 <u>Method of Analysis</u>. The starting point in the method of
analysis is the occurrence of an accident in that portion of I-5 within a
5-mile radius centered at the control room air intake. The liquid chemical
is spilled on the road and proceeds to evaporate or boil (for liquid
gases). The resulting plume may be carried toward the control room air 24
intake. The basis for estimating the potential hazard included determin-
ing the likelihood of a release and the likelihood for each substance that
a toxic concentration would reach the control room intake. Parameters
affecting the likelihood of achieving a toxic concentration were proba-
bilistically combined in a dispersion model. In this way, the total
probability for exceeding the concentrations is determined for the site.

Table 6.4-2

PROBABILITY OF EXCEEDING TOXICITY LIMIT
FOR OBSERVED FREQUENCY

Hazardous Chemicals	Probability (per year)
Chlorine	1×10^{-6}
Propane	2×10^{-6}
Butane	1×10^{-6}
Gasoline	1×10^{-6}
Anhydrous Ammonia	9×10^{-7}
Jet Fuel	5×10^{-8}
Diesel Fuel	3×10^{-8}
Benzene	6×10^{-8}
Formaldehyde	5×10^{-8}

6.4.4.2.1.3.1 Toxic Aerosol Model. Subsequent to the accident within the segment of I-5 defined above, the plume resulting from a release of any hazardous material would travel with the prevailing wind. If the plume is drawn such that the plume boundary defines a level of toxic concentration, χ_m, the hazardous condition would be that condition whereby the plume "foot-print" overlaps the control room air intake. This foot-print is defined as the projected area of the plume in which a concentration of the substance greater than the toxic limit exists. For a chronic release this foot-print would remain fixed in time. For a puff-release over an area, the foot print is the area enclosing a toxic concentration for a sufficient period of time to constitute an incapacitating dose during the passage of the plume. The situation of the plume foot-print overlapping the air intake could therefore result should the wind be blowing from the accident site at an angle between θ_1 and θ_2 as shown on figure 6.4-3. Let P_m be the probability that the wind is blowing between these angles; then the probability that the concentration exceeds χ_m at the air intake is

$$P(\chi \geq \chi_m) = P_R P_m$$

where P_R is the probability of the release which caused the foot-print.

An accident producing a toxic gas release could occur at any point along Interstate -5; therefore it is convenient to segment the road and consider each segment separately as a release point. For a given road segment, it is necessary to calculate the wind angle that would cause the foot-print to cover the air intake. The plume foot-print itself is a function of many variables: and therefore the exposure concentration

$$\chi = \chi(\bar{r}, D, p, h, R, Q, t)$$

where $\bar{r}$ is a vector from the source to the observer, $\bar{U}$ is the average wind direction vector, p represents the atmospheric stability usually expressed as Pasquill category F, h is the height of release, and R is the ground roughness that results in additional mixing. Q is the quantity of material released, if the material is released in a short time duration (a puff). The value of χ is a function of time. If, however, the release occurs slowly so that a release rate Q is constant, the plume for constant meteorological conditions will reach equilibrium and the contour will appear as a static foot-print.

In general, the probability that the plume contour, χ, exceeds a critical concentration, χ_m is

$$P(\chi \geq \chi_m) = \sum_{\substack{\text{sum over} \\ i, Q, P, \bar{U}}} P_i P_Q P_P P_{\bar{U}}$$ 24

where $P_{\bar{U}}$ is the probability that the wind will blow at an angle between θ_1 and θ_2, at a wind speed $\bar{U}$, given Pasquill condition F. P_P is the probability of this Pasquill condition, P_Q is the probability of releasing a quantity of material Q given an accident, and P_i is the probability of an accident in the ith segment of the highway. In this problem the effect of bouyancy is treated conservatively by modifications to the standard deviations in the generalized diffusion equation developed below. The release can be treated as either a puff release in which χ is the time integrated dose or a continuous release in which χ is the maximum allowable concentration.

6.4.4.2.1.3.2 Gaussian Plume Model

It has been found experimentally that the dispersion of aerosols into the atmosphere may be modeled as a Gaussian distribution. Qualitatively this indicates that there are many uncorrelated forces causing the dispersion, so that the mean value theorem is applicable and the result may be characterized by experimental parameters for the Gaussian distribution. In this model, for a puff release,

$$\chi(t) = \frac{2Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z}\exp\left[-\frac{1}{2}\left(\frac{x - \bar{U}t}{\sigma_x}\right)^2 - \frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where x is a distance downwind from the release, y is a horizontal distance from the head of the x vector, and z is a vertical distance from the head of the vector. σ_x, σ_y, σ_z, are parameters in the x, y, and z directions respectively that characterize the dispersion, $\bar{U}$ is the average wind speed in the x direction, Q is the puff release quantity and $\dot{Q}$ is the continuous release source term (mg/sec).

A measure of the consequences of a toxic material spill is the dose or exposure

$$\bar{X} = \int_0^\infty X(t)\,dt$$

Or

24

$$\bar{X} = \frac{Q}{\pi\sigma_y\sigma_z\bar{U}}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

The same form is obtained for a continuous release, except that for the chronic release $\bar{X}$ is replaced by $\dot{X}$ and Q by $\dot{Q}$.

Many of the substances considered here, because of their high molecular weight and the coldness of the vapor, do not rise as rapidly as mor bouyant materials. An example of such a material is chlorine. Experiments conducted by the Bureau of Mines showed that the dispersion of chlorine vapor may be adequately described by a Gaussian plume model such as those used for air pollutants (C). However, they found that the vertical dispersion is less than that observed for the usual air pollutants. Their data indicated that the vertical standard deviation (for concentration versus distance) is approximately 20 percent of the horizontal standard deviation.

To allow for the effects of heavy gases and vapors, a constant multiplicative scaling parameter is introduced adjusting σ_z for negative bouyancy. This scaling factor is approximately the ratio of the density of the aerosol to the density of the ambient air. The data is digitized into 21 logarithmically spaced points and interpolated to provide the values of σ_y and σ_z appropriate for the x distance.

Returning to FSAR figure 6.4.3, certain geometric relationships may be obtained:

$$\phi = 180^\circ - \phi_r + \tan^{-1}\frac{d}{\ell}$$

where ϕ_r is the angle of the highway with respect to north, and d and ℓ are defined in FSAR figure 6.4-3. The allowable angular variations are

$$\phi_1 = \phi - \Delta\phi + 180^\circ$$

$$\phi_2 = \phi + \Delta\phi + 180^\circ$$

The 180° is added to correct for the fact that the wind rose data are for wind direction and the theory requires wind bearing to be used. If ϕ_1 or ϕ_2 are defined for each wind direction:

$$\Delta\phi = \tan^{-1}\frac{y}{x}$$

where 24

$$x = d^2 + \ell^2.$$

The probability of the wind blowing between ϕ_1 and ϕ_2 is obtained as

$$P_m(\lambda,Q,X) = \sum_{\substack{\text{Sum over all values} \\ \text{of } \bar{U} \text{ and } P}} \left| P_{\phi_1}(\bar{U},P) - P_{\phi_2}(\bar{U},P) \right|$$

P_m is for one specific accident site, for quantity of material Q released, having toxicity $\bar{X}$.

Then, for a given toxic substance, the probability of exceeding its toxicity limit, X_m, is

$$P(\chi \geq \chi_m) = P_x P_T \Delta\ell \sum_{Q,\ell} P_Q P_m(\ell,Q,x)$$

24

where it is assumed that there is a constant accident probability, P_T, per unit length of highway and $\Delta\ell$ is the length of the highway segment used in the analysis. P_x is the annual frequency of shipment of toxic material characterized by the toxic limit, χ_m.

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24 Atmospheric dispersion, and the resultant concentration at the control room air intake were calculcated for Pasquill stability category F and site specific wind rose data.

6.4.4.2.1.3.3 Atmospheric Release Models. Following a spill, the rate at which the chemical is released to the atmosphere depends on the physical properties of the chemical, the geometry of the pool of liquid formed, the

24 meteorological conditions at the time of the spill, the nature of the surface on which the chemical is lying and on the solar radiation. The release rate for materials that have a boiling point greater than the ambient temperature is limited by mass transfer considerations. Those materials with boiling points at or below the ambient temperature have their continuous release rate governed by heat transfer considerations.

The size of pool of liquid formed by the spill is estimated by assuming a square shaped pool with a depth of one centimeter. The lateral extent of the pool is limited by the topography of the highway to a maximum of 60 feet on a side.

For materials with boiling points at or below the ambient temperature, the

24 evaporation rate was determined as the average rate for concrete road surface temperatures of 70F and 150F (day and night average), and the air temperature 70F. Solar radiation was taken to be 365 Btu/h-ft^2, and the concrete thermal conductivity used was .54 Btu/h-ft-°F.

6.4.4.2.2 Toxic Gas Analysis

6.4.4.2.2.1 Chemicals Analyzed. The methodology described in paragraph 6.4.4.2.1 was used to identify those offsite chemicals requiring further analysis. These offsite chemicals, along with chemicals stored onsite, were then analyzed to determine the effects of a chemical release upon the plant operators. Necessary design provisions to mitigate the consequences of such chemical releases were then identified.

24 Offsite chemicals analyzed were butane, propane, gasoline and chlorine. The onsite chemicals analyzed were nitrogen, hydrogen, carbon dioxide, diesel oil, aqueous ammonia, hydrazine, sulfuric acid, and holon 1301. Three onsite chemicals were excluded from consideration; NaOH, NaOCL, and lubricating oil. NaOH was excluded because it is non-volatile, NaOCL on the basis that it is nonhazardous, and lubricating oil on the basis it is non-volatile and relatively non-toxic.

6.4.4.2.2.2 Analysis Assumptions. All releases were postulated to occur at an ambient air temperature of 14.1C (the annual average temperature of the San Onofre 2 and 3 site, FSAR table 2.3-6) and Pasquill Stability Category F. In accordance with Regulatory Guide 1.78, it was assumed that the wind blows directly toward the control room. For those chemicals located on the intake side of the control room, the chemical was assumed to be blown directly from the point of spillage to the fresh air intake of the control room without dilution in the building wake. Table 6.4-3 lists the onsite chemical storage methods, methods of connection to the system service, and distance from the control room air intake. Offsite chemicals were assumed to be released on I-5 at the point of closest approach to the control room (850 feet). Inleakage into the control room was modeled assuming normal control room fresh air makeup of 4770 ft^3/min. 24

6.4.4.2.2.3 Analysis Results. The results of this analysis (FSAR table 6.4-4) determined that for carbon dioxide, aqueous ammonia, chlorine, butane, and propane design provisions are necessary to isolate the control room to protect the inhabitants. These design provisions are Seismic Category I toxic gas detectors in the control room normal ventilation intake that sample, alarm, and then isolate the control room when setpoints are exceeded. Emergency portable breathing apparatus are also provided for the control room operators.

In the case of gasoline, the large number of annual shipments overrides other factors in contributing to the magnitude of the probabilistic risk. However, in this analysis, the low vapor pressure yields dispersion characteristics which do not allow the material to build up to its respective toxicity limit inside the control room and isolation protection is not required. 24

For propane and butane, a large variation in the toxicity limits is provided in the literature. Utilizing a conservative toxicity limit of 1750 milligrams per cubic meter for both materials, control room isolation is required in both cases. The detector used for these materials is a general hydrocarbon detector which detects the mole fraction of carbon in the sample mixture. The mole fraction of carbon for propane and butane is similar (approximately .8) and the detector setpoint is 100 ppm (butane or propane).

The above analysis was then rerun incorporating the design provision discussed above to verify that toxicity limits were not exceeded in the control room. Inleakage into the control room after isolation is discussed in FSAR paragraph 6.4.2.3 (Leak Tightness). The results of this analysis demonstrate that toxicity limits are not exceeded in the control room during the 2-minute period following a toxic chemical alarm and that the San Onofre 2 and 3 design meets the requirements of Regulatory Guide 1.78.

6.4.4.3 Implementation of Design Basis

These evaluations are listed to correspond with the design basis of subsection 6.4.1.

A. Control room habitability system components discussed in paragraph 6.4.2.2.2 are arranged in redundant safety-related ventilation trains, as shown in figure 9.4-8. The location of components and ducting within the control room envelope ensures an adequate supply of filtered air to all areas requiring access as shown in figure 6.4-1.

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Table 6.4-3
ONSITE CHEMICAL STORAGE FACILITIES AND DISTANCE
FROM CONTROL ROOM INTAKE

Chemical	Storage Facility	Method of Connection to System Serviced	Distance From Control Room Air Intake in Feet
Nitrogen	Compressed, liquified gas in 91,800 lb capacity tank @-320F and 245 lb/in^2.g	See FSAR figure 3.6-1	394 feet
Hydrogen	Compressed gas stored in 7620 scf cylinders @ 2450 lb/in.^{2}g, 70F	See FSAR figures 3.6-1 and 9.3-9	341 feet
Carbon Dioxide	Compressed, liquified gas stored in 13-ton capacity storage tank @300 lb/in.^{2}g, 0^{o}F	See FSAR figure 9.5-2	112 feet
Diesel Oil	350 gal tank, ambient temperature and pressure	See FSAR figure 9.5-1	495 feet
11 Ammonia (aqueous)	29.4% aqueous solution, 3000 gal tank, ambient temp. and press.	See FSAR figure 10.4-3	230 feet
Hydrazine (aqueous)	35% aqueous sol- ution, 55 gal drum, ambient temp. & press.	55 gallon drums stored on ground floor of turbine bldg at el. + 7.0 ft.	72 feet
Sulfuric acid	66^{o}Be in 10,000 gal tank, ambient temperature and pressure	See FSAR figure 9.2-2	220 feet
Halon 1301	Compressed gas stored in 140 lb capacity cylinders	See FSAR figure 9.5-2	Release inside control building

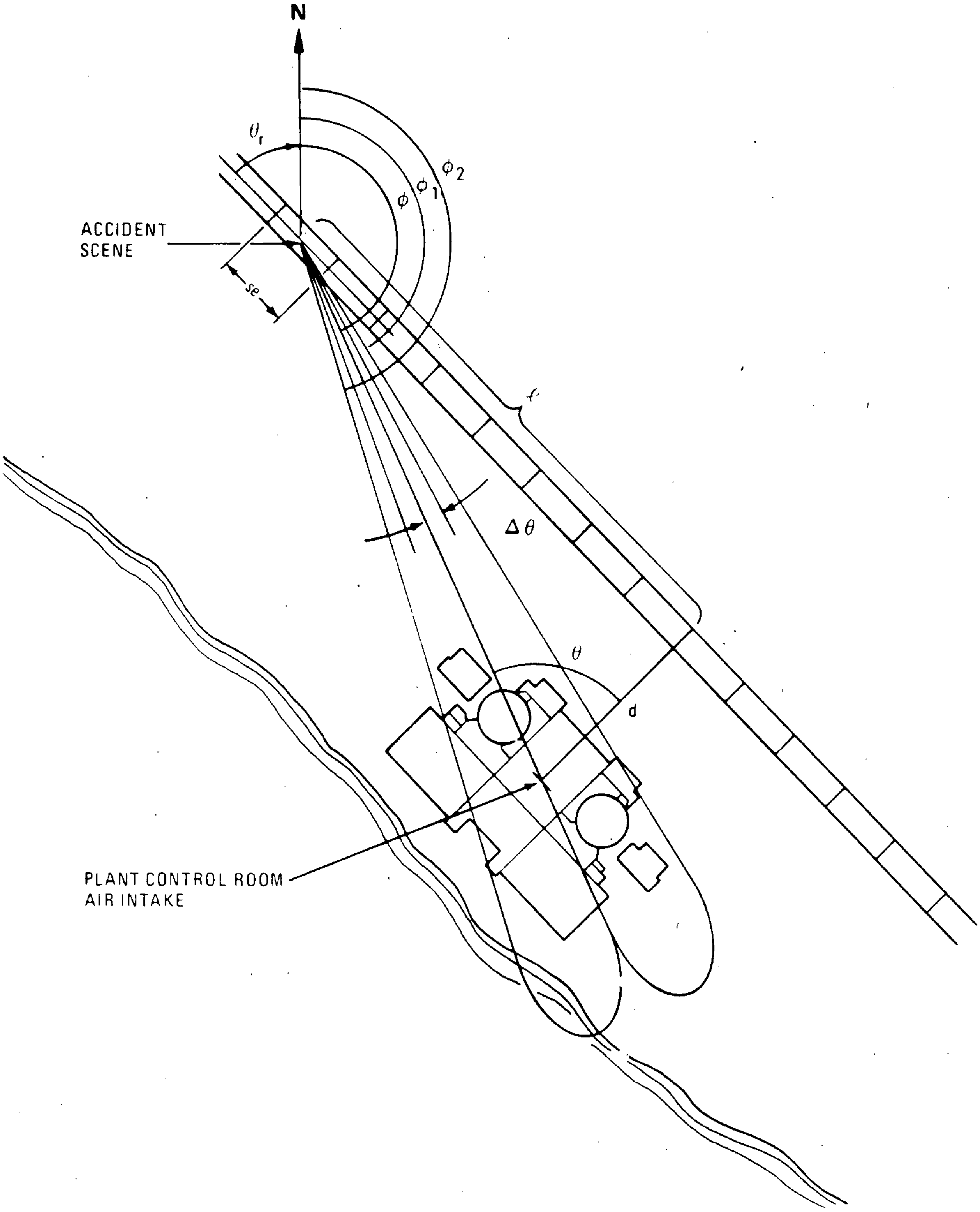
Table 6.4-4
SUMMARY OF RESULTS
EFFECT OF POSTULATED TOXIC GAS RELEASES ON THE HABITABILITY OF
THE SAN ONOFRE UNITS 2 AND 3 CONTROL ROOM

Hazardous Chemical	Postulated Accident	Toxicity Limit For Gas or Vapor (ppm by vol)	Objectives of Reg. Guide 1.78 Met Without Toxic Gas Protection	Effectiveness of Detection and Control Room Isolation as a Mitigating Measure				C=Continuous Release P=Puff release
				Set Point (ppm)	Detector Response Time (sec)	Isolation Time (sec)	χ_{cr}[(1)] @ 120 sec	Either P or C
Nitrogen	Rupture of 91,800 lb onsite tank	143,000	Yes		(No Protection Required)			
Hydrogen	Rupture of 7,620 scf onsite cylinder	143,000						
Diesel Oil	Rupture of 350 gal fire pump day tank	200						
Hydrazine	Rupture of 55 gal onsite drum	5						
Sulfuric Acid	Rupture of 10,000 gal onsite tank	0.09						
Halon 1301	Discharge of 140 lb cylinder in control room	70,000						
Gasoline	Rupture of 4,500 gal cargo tank I5	780						
Propane	Rupture of 8,485 gal cargo tank I5	1000[(2)]	No	100[(3)]	30	6	52	P
Carbon dioxide	Rupture of 13 ton onsite tank	50,000		5000	30	6	8,437	P+C
Butane	Rupture of 8,485 gal cargo tank, I5	750[(2)]		100[(3)]	30	6	50	P+C
Chlorine	Rupture of 2000 lb cylinder, I5	15		5	10	6	9	P
Chlorine	Rupture of 2000 lb cylinder, I5	15		5	10	6	12	C
Aqueous ammonia	Rupture of 3000 gal onsite tank	100		50	30	6	7	C

1. χ_{cr} = The toxic gas concentration inside the control room 120 seconds following an alarm from the detector.

2. 1750 mg/m^3 = 1000 ppm propane
   = 750 ppm butane

3. Mole fraction carbon for butane and propane is .8; 100 ppm butane setpoint is equivalent to 100 ppm propane setpoint.



SAN ONOFRE
NUCLEAR GENERATING STATION
Units 2 & 3

SITE GEOMETRY

Figure 6.4-3