UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SEP 4 1975

PROJECT NO.: 558

LICENSEE: SAN DIEGO GAS & ELECTRIC COMPANY (SDGE)

FACILITY: SUNDESERT SITE

SUMMARY OF MEETING HELD ON AUGUST 27, 1975

A meeting was held with representatives of the San Diego Gas & Electric Company (SDGE) and their consultants on August 27, 1975. The purpose of the meeting was to discuss the following items:

A) Planned response to NRC question on aircraft activities in the vicinity of the site (Q310.10)

B) SDGE's decision to request USGS participation in the Sundesert review

C) Hydrology Question 321.1

A) Aircraft Activities

The applicant proposes to describe all aircraft activities within 15 miles of the site. This will be done by grouping aircraft activities into four categories, described below. In obtaining data about aircraft activities within the 15 mile area surrounding the site, a number of persons have been contacted. These contacts were identified and include representatives of the Department of Defense, the Navy, the Air Force, and the Federal Aviation Agency.

Aircraft activities within 15 miles of the site have been grouped into the following four categories:

1. Activities within five miles of an airport (low-level)

The nearest airport is at Blythe, CA, 13 miles away, thus there are no takeoffs or landings within 5 miles of the site. The site was described as meeting the Regulatory Guide 1.70 limits of less than 1.69×10^5 operations per year since only 5.4×10^4 operations per year occur at the Blythe Airport. No probability analysis will be performed for this category of activity.

2. High altitude airways

The nearest high altitude airway was described to be 11 miles north of the site. No probability analysis will be performed for this category.

3. Low altitude airways (>5 miles from airport)

Low altitude airway V135 was described to be 3 miles east of the site. The minimum altitude allowed for this airway is 5000 feet. About 47 flights per day operate on the airway. Most of these are general aviation. Two commercial flights per day operate. No probability analysis will be performed for this category.

4. Military

Intensive military aircraft training takes place in the area within 15 miles of the site. A significant amount of this training currently takes place over the area within 5 miles of the site. The training was described as primarily low-level, high-speed terrain following missions. The pilots flying these missions navigate visually while flying the missions and apparently are under no electronic control or surveillance. The total number of operations last year passing within 15 miles of the site was about 2300. About 1500 of these passed within 5 miles of the site. The military has verbally indicated to SDGE that they would adjust the training paths so that none pass within 5 miles of the site.

SDGE has concluded that a probability analysis will be performed for category 4 activities. Some difficulty has been experienced in obtaining information needed for the analysis. The types of aircraft which fly the missions have been determined but not the frequency for each type. Another area of difficulty has been in determining where a distressed aircraft following one of the training paths might crash. It is believed that for low-level flights (<500 feet) the impact will be within one mile of the training flight path and within three miles for higher altitudes. Data to support this remains to be obtained. Another area of difficulty has been in obtaining pilot experience for aircraft training in this area. The military only indicates that pilots of all experience levels use the training paths. Thus it appears to SDGE that a minimum experience factor will have to be used.

Comments made by the NRC include:

Path of distressed aircraft enroute between airport and training areas should be addressed

Who is responsible for control of trajectory or training path; is plane under control of radar while on training mission or free to wander

Consider how visible the site will appear to a pilot

Type of aircraft and its accident rate/crash statistics should be considered

Future operations should be considered

B) SDGE announced the decision to request USGS participation in the Sundesert review. A letter has already been mailed to H. Denton expressing this desire. NRC promised to consider the request and make a decision within 10 days. SDGE requested that a three party meeting be held with USGS if they were brought in on the review. The desirability of such a meeting as described by SDGE would be to allow them to describe the benefit they hope to gain by USGS participation and explain why an expedited review by USGS would be desirable.

C) A brief meeting was held to discuss the applicant's answer[1] to round one question 321.1 (Hydrology). The answer was not responsive to NRC comments made in a prior meeting (7/30/75) and in a conference call (8/5/75). The discussions of this meeting were aimed at assuring that NRC needs in this area were understood by the applicant. A followup conference call was agreed to, desired by the applicant, with the applicant to initiate the call.

William C. Gilbert

William C. Gilbert, Project Manager
Gas Cooled Reactors Branch
Division of Reactor Licensing

Attachments:
List of Attendees

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[1] filed in Amendment 4 to the ESRR

Sundesert

Attendence List

August 27, 1975

NRC

W. Gilbert
H. Fontecilla
J. Read

SDG&E

G. D. Cotton

S&W

W. G. Culp
G. E. Carver

Lowenstein, Newman, Reis & Axelrad

K. H. Shea

Pickard & Lowe

K. Woodward

SUNDESERT NUCLEAR PROJECT

Contacts on Aircraft Activity

Date	Type	Name	Affiliation	Comments
11/22/74	letter	E. J. Sheridan	DOD	Reference to Reg. Guide 1.70.8 and requesting information no response
2/4/75	letter	Col. P.S. Frappolo	USMC	Request for information on Yuma Marine Corps Air Station response from Lt. Col. R. C. Conway, dated 2/27/75
2/14/75	letter	Col. H.H. Patillo	USA	Request for information on Yuma Proving Ground response referred to report from DOD which is in the ESRR
4/3/75	telecon	V. Finch	DOD	Request for general military information which is in the ESRR
4/3/75	telecon	R. Green	USA	Request for information on Yuma Proving Ground which is in the ESRR
4/6/75	telecon	-	FAA Blythe	Request for information on hig altitude route which is in the ESRR
4/10/75	telecon	V. Finch	DOD	Request for aircraft type usin Chocolate Mountain Aerial Gunning Range. A-4, A-6, A-7, F-4, F-8, F-14
5/13/75	telecon	R. Flower	USN	Request for information on US Naval Impact Range which is in the ESRR
5/28/75	telecon	R. Flower	USN	Request for information on Range 2532 - this Range was deactivated.

Date	Type	Name	Affiliation	Comments
5/29/75	telecon	R. Green	USA	Request for use of Zone E Yuma Proving Ground - used to detonate shells - this information is in the ESRR
6/17/74	letter.	R. Green R. Flower	USA USN	Either confirming previous telecons
6/24/75	telecon	W. Jones	FAA Blythe	General discussion of aircraft activity
7/29/75	telecon	Cdr. Jones	USN	Request for information on "sandblower routes" #365 - 90 flights 1975 #394 - 366 flights 1975 #362 - 522 flights 1975 8 crashes at Choc. Mts. Aerial Gunnery Range involving 9 aircraft (one mid-ai 3-F1's, 1-F3, 2-F8's, 2-A4's, 1-A7
7/29/75	telecon	M.S. Williamson	FAA-Yuma	Request for information on V-135 no records on number of operations. VFR pilots are not required to file flight plans.
8/4/75	letter	R. Green	USA	Request for information to answer NRC question 310.10. Response dated 8/14/75 from I.V. Faucon, Facilities Engineer
8/4/75	letter	R. Flower	USN	Same as letter sent to R. Green dated 8/4, no response as of 8/25/75
8/4/75	letter	W. Jones	FAA Blythe	Same as letter sent to R. Green dated 8/4, response dated 8/14/75.
8/13/75	telecon	T. Benzak	FAA Los Angeles	Request for information on V-135 Peak daily use of V-135 is 47 aircraft below 18,000 ft, most light general aviation.
8/25/75	telecon	R. Lund	FAA Los Angeles	Request for information on V-135 Mr. Lund will supply a one day sample of aircraft type using V-135.

Date	Type	Name	Affiliation	Comments
8/13/75	letter	Capt. R. Lewis	USN	Request for aircraft incident statistics
8/14/75	letter	Maj. Gen. Ranald T. Adams	USAF	Request for aircraft incident statistics
8/14/75	letter	Chief of Naval Operations	USN	Request for aircraft flight frequency data
8/14/75	letter	Maj. R. J. Maurer	FAA-USAF	Request for aircraft flight frequency data

K. M. CAMPE

CONF 770708

SAFETY DESIGN OF NUCLEAR POWER PLANTS AGAINST AIRCRAFT IMPACTS

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INTRODUCTION

A nuclear power plant is considered adequately designed against aircraft hazards if the probability of aircraft accidents resulting in radiological consequences greater than 10 CFR part 100 guidelines is less than about 10^{-7} per year.[1] Otherwise an aircraft accident is considered a design basis event and the plant must be hardened up to the point at which the above criterion is met. In many cases it has been sufficient to demonstrate that the probability of an impact on a safety-related building is less than 10^{-7} per year. In other cases, it is necessary to take into account the intrinsic hardness of buildings and structures designed to withstand tornado, seismic, and manmade hazards in order to demonstrate that an aircraft impact presents an acceptable risk. In some cases, however, it is necessary to consider aircraft impacts as design basis events and to specify the level of hardening required to satisfy the design criterion.

This paper presents a number of techniques which may be utilized to accomplish the above objectives. Firstly, a re-evaluation is made of aircraft crash probabilities. Secondly, methods are described for calculating aircraft impact forcing functions, for obtaining probability distributions for the impact parameters. Thirdly, evaluations are made for assessing the probability that an impact on a given structure will result in consequences exceeding those listed in 10 CFR 100 and recommendations are made for treating lower consequence events. Finally, other effects such as fires, explosions and secondary missiles are examined briefly.

AIRCRAFT ACCIDENT STATISTICS

The most common method for evaluating the probability P of an aircraft impact on an area A of a nuclear plant located at a distance R from an airfield is that suggested by Eisenhut.[2] The basic equation is

$$P = \Sigma\, q_i\, A\, N_i \qquad (1)$$

where N_i is the annual number of aircraft operations (takeoff or landing) at the airfield for the ith class of aircraft, and q_i is the associated accident rate (per square mile per year), obtained from actual experience. Most accidents occur within a sixty degree zone surrounding the extended runway centerline. Accident rates are usually calculated for this high risk region and then assumed to be isotropic for other angles.[2,3] Other methods are used for areas isolated from airports.[1,4] Eisenhut has obtained accident rates (for accidents in which a fatality has occurred) for air carriers, military aircraft and General Aviation.[1] Air carriers have a well deserved reputation for safety. The mean accident rate for air carriers during 1966-1970 for the continental United States is less than 4×10^{-6} per square mile per year.[5] Because the design penalty for hardening against an air carrier is extreme, there is a tendency to locate nuclear plants away from airports having large amounts of air carrier traffic. Thus, in most cases design levels will be set by General Aviation aircraft.

GENERAL AVIATION ACCIDENT RATES

In the subsequent material, a critical accident is taken to be any accident which resulted in a destroyed aircraft or in a fatality. The primary data base consists of listing of the characteristics of all critical accidents of Civil Aviation aircraft occurring within five miles of an airport in the period 1966-1970.[6] (The ratio of critical accidents to fatal is 1.6.)

Table I provides a breakdown of critical accidents by class of aircraft. In this paper, we will use the Eisenhut statistics for large fixed wing aircraft, and assume that gliders will be most unlikely to damage a plant and that the rotor aircraft will be able to avoid a damaging impact; therefore the primary interest lies in the accident statistics of small (under 12,500 lb), fixed wing aircraft.

Table II provides a detailed breakdown of crashes as a function of type of operation, distance from airport and type of airport. Data on the number of operations were obtained from a number of sources, both indirect and direct.[6-10] The smallest class of aircraft consists of those not covered in the 1972 National Airport System Plan and are assigned a nominal 500 annual operations per airport.[8] It can be seen that the overall accident rate depends strongly upon class of airport. This is no doubt due to the better aircraft control, maintenance and physical facilities present at the larger airports, as well as the greater average level of skill of the pilots and the more sophisticated safety equipment of aircraft utilizing the larger class of airport. These data suggest that the accident rate $q_i(R)$ be written as

$$q_i(R) = K(R)\ J_{ij} \tag{2}$$

where K(R) is the spacial distribution function (fraction of accidents per unit area) and J_{ij} is the accident rate for the jth type of airport and ith class of aircraft. K(R) is calculated by assuming that accidents occurring within the traffic pattern have the same distance distribution as the other accidents and that the distribution is independent of airport type.

Table III provides a comparison of these data with those of Eisenhut. The line marked "Present Model-Adjusted" excludes non-fatal accidents and accidents occurring within the traffic pattern and thus is directly comparable to Eisenhut. The agreement is satisfactory. It is suggested that for

TABLE I

CIVIL AVIATION AIRCRAFT ACCIDENTS WITHIN 5 MILES OF AN AIRPORT (1966-1970)

Type of Aircraft	No. of Accidents
Large Fixed Wing Aircraft (more than 12500 lb)	35
Small Fixed Wing Aircraft - jet	20
Small Fixed Wing Aircraft - 2 propeller	260
Small Fixed Wing Aircraft - 1 propeller	1640
Helicopters	68
Gyrocopters	17
Gliders	24
Balloon	1
Total	2065

TABLE II

NATURE OF SMALL FIXED WING AIRCRAFT ACCIDENTS (1966-1970)

Airport Type	Flight Mode	Frequency of Accidents								Accident Rate per 10^6 ops
		Distance from Airport (miles)								
		Traffic Pattern	0-1	1-2	2-3	3-4	4-5	Total	Mode Fract.	Jij
< 2000 ops/ yr B=6632 ($33.2x10^6$ ops)	TO	113	65	9	5	1	0	193	.269	
	IF	29	109	70	61	55	17	341	.476	
	IL	1	1	2	1	1	0	6	.008	
	OL	124	40	3	5	3	2	177	.247	
	Total	267	215	84	72	60	19	717	1.000	21.6
2000-10000 ops/yr B=1702 ($28.4x10^6$ ops)	TO	33	17	3	2	3	1	59	.210	
	IF	8	39	42	34	27	10	160	.569	
	IL	0	1	0	0	0	0	1	.004	
	OL	39	14	3	1	2	2	61	.217	
	Total	80	71	48	37	32	13	281	1.000	9.9
10,000-40,000 ops/yr B=1047 ($78.1 x10^6$ ops)	TO	44	28	7	0	0	1	80	.196	
	IF	16	48	48	39	41	15	207	.507	
	IL	3	3	2	1	0	1	10	.025	
	OL	82	21	1	4	2	1	111	.272	
	Total	145	100	58	44	43	18	408	1.000	5.2
Non-FAA > 40,000 ops/ yr B=299 ($85.4x10^6$ ops)	TO	25	20	1	1	0	0	47	.215	
	IF	12	19	29	22	12	8	102	.468	
	IL	3	2	0	2	0	0	7	.032	
	OL	38	17	5	0	0	1	62	.284	
	Total	78	58	35	25	13	9	218	1.000	2.6
FAA > 40,000 ops/ yr B=330 ($192.5x10^6$ ops)	TO	22	19	1	4	1	0	47	.159	
	IF	7	26	26	18	30	7	114	.385	
	IL	20	3	9	4	1	1	38	.128	
	OL	65	17	11	2	1	1	97	.328	
	Total	114	65	47	28	33	9	296	1.000	1.5
Any B=10010 (418×10^6 ops)	TO	237	149	21	12	5	2	426	.222	
	IF	72	241	215	174	165	57	924	.481	
	IL	27	10	13	8	2	2	62	.032	
	OL	348	109	23	12	9	7	508	.265	
	Total	684	509	272	206	181	68	1920	1.000	4.6
Fraction of aircraft crashes			.412	.220	.167	.146	.055			
Fraction of aircraft crashes per square miles(inside 60°) K(R)			.393	.0700	.0319	.0199	.0058			

B = No. air airports

Flight Modes:

TO = Take Off
IF = In Flight
IL = Instrument Landing
OL = Other Landing

TABLE III

MEAN ACCIDENT RATES VS DISTANCE FROM AIRPORT: SMALL FIXED WING AIRCRAFT (PER MILLION OPERATIONS PER SQUARE MILE)

	Distance From Airport (mi)				
	0-1	1-2	2-3	3-4	4-5
Present Model	1.81	.32	.15	.092	.027
Present Model-adjusted	.72	.13	.059	.037	.011
Eisenhut Model	.84	.15	.062	.038	.012

TABLE IV

LOCATION OF SMALL FIXED WING AIRCRAFT ACCIDENTS (1966-1970)

	Type of Power Plant			
Type of Airport	Jet	2 Propeller	1 Propeller	Any
Less than $2x10^3$ ops/yr.	4	52	661	717
$2x10^3$-10^4 ops/yr.	2	38	241	281
10^4-$4x10^4$ ops/yr.	5	57	346	408
More than $4x10^4$ ops/yr-Non FAA	2	38	178	218
More than $4x10^4$ ops/yr-FAA	7	75	214	296
Total	20	260	1640	1920

TABLE V

ACCIDENT RATE FOR SMALL FIXED WING AIRCRAFT

Accident Location	Billions of Miles Travelled	Number of Critical Acc.	Critical Acc./ 10^6 miles
On Airport	0	435	
0-1 miles	.4	948.7	2.37
1-2 miles	.4	381.7	.95
2-3 miles	.4	274.6	.69
3-4 miles	.4	222.2	.56
4-5 miles	.4	92.8	.23
Over 5 miles	15.6	2571	.16
Total	17.6	4926	.28

sites outside the 60° reference angle mentioned above, the factor K(R) be replaced by K(R)/3.

Table IV provides a breakdown of the location of accidents as a function of type of aircraft. It is likely that many of the jet and twin propeller accidents occurring at the smaller airports are the results of emergency landing attempts and hence not really associated with normal operations at that airport. It is recommended that the accident rates shown in Table II be applied for single engine aircraft and that the accident rates for multiple engine aircraft be taken to be the logarithmic mean of the accident rate at large FAA airports and the rate at the type of airport under examination.

Table V shows the accident rates as a function of distance travelled. The asymptotic rate of 1.6×10^{-7} accidents per mile travelled is reached shortly after 5 miles and may be used in Hornyik evaluations of airways (victors) or in extrapolation of the accident rate associated with an airport beyond 5 miles, as shown in Equation (3).

$$P = (N_i \; A \; K'_{ij}) \; / \; 2\pi R \qquad (3)$$

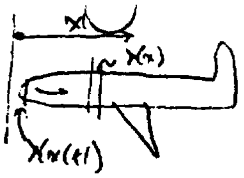
with

$$K'_{ij} = K_o \; J_{ij} \qquad (4)$$

where $K_o = 1.6 \times 10^{-7}/4.6 \times 10^{-6} = .35$. Note that the data in Table II may be utilized in a Hornyik evaluation of traffic patterns in the vicinity of an airport, also.[4] Finally, it should be noted that the mean accident rate for small, fixed wing aircraft occuring more than 5 miles from an airport during the reference 5 year period is 2.3×10^{-4} accidents/ square mile-year. Unless a plant is quite isolated from air travel lanes, the probability of an impact on a safety related building is likely to be greater than 10^{-7} per year, independent of proximity to any airport. Most of these impacts, however, will not cause unacceptable damage.

CHARACTERISTICS OF SMALL, FIXED WING AIRCRAFT

The characteristics of small, fixed wing aircraft produced by three major manufacturers are shown in Tables VI and VII, for single and twin engine aircraft. It can be seen that the empty weights of single engine aircraft range from 900 to 2200 lb, while the twin engine aircraft range from 2800 lb on up. The most interesting feature of this table, however, is that the important characteristics such as length, maximum takeoff weight, stalling velocity and maximum horizontal velocity (at least for single engine aircraft) all "scale" with "size", that is with empty weight, w_o. These are the parameters which determine the magnitude of the forcing function. The scaling phenomenon thus is useful in determining the probability distributions for the forcing function. Table VIII provides recommended values of the parameters to be used in devising a scaled aircraft.



λv = linear momentum density
v = rate of delivery of momentum to wall

$\therefore R = \lambda v^2 + P$ ↑ force upon [illegible] aircraft

AIRCRAFT IMPACT DYNAMICS

The forcing function R(t) for an impact on a rigid structure of an aircraft may be written as:[12]

$$R(t) = \lambda(x(t))\ v^2(t)/g + P_b(x(t)) \tag{5}$$

where $P_b(x)$ is the load necessary to crush the aircraft at a distance from the nose, λ the weight of aircraft per unit length, v the velocity if the uncrushed portion of aircraft and

$$x(t) = \int_0^t v(t')\ dt' \tag{6}$$

$$w(x) = w_0 - \int_0^x \lambda(x')\ dx' \quad = \text{live mass} \tag{7}$$

X $$v^2 = v_0^2 - 2g \int_0^x \frac{P_b\ (x')dx'}{w\ (x')} \tag{8}$$

no, conservation of energy says:
$$\int_x^L \lambda dx\, v^2 = \frac{M}{2} v_0^2 - \int_0^x P(x)\, dx \left(-\int_0^{x'} R\, dx'\right)$$ ↑ yield [illegible]

The above formulation is for normal incidence on a wall or roof by an aircraft with total weight w_0 and initial velocity v_0. Non-normal incidence can easily be incorporated into the above formulation by making the substitutions

$$\begin{aligned} \lambda &\rightarrow \lambda/\cos\alpha \\ v &\rightarrow v\cos\alpha \\ P_b &\rightarrow P_b\cdot\cos\alpha \end{aligned} \tag{9}$$

In some cases it may be desirable to evaluate the effects of a specific aircraft. Weight distribution information can usually be obtained from the manufacturer, but little information on the crushing load is available. For most problems the forcing function is not sensitive to changes in P_b. An approximate method is to scale the crushing load curve provided in Reference 12 for the Boeing 720. An alternate method is to use

$$P_b = K\ \lambda c \tag{10}$$

where λc is the weight distribution for the compressible portion of the aircraft and $K = 876\ \text{ft}^{-1}$ is a material property assumed constant for all aircraft and obtained from the crushing load distribution in Reference 12. Equation (5) may be rewritten as

$$R = \lambda v_0^2/g \ + \ K(\lambda c - 2\lambda \int_0^x \frac{\lambda c\ (x')dx'}{w\ (x')}) \tag{11}$$

Provided that the impacting velocity is not too low, a reasonably accurate approximation to the peak forcing function, R_p is

$$R_p = \lambda p\ v_0^2/g \tag{12}$$

where λp is the peak value of the weight per unit length. Because aircraft of a given class scale, for an aircraft of length L,

$$\lambda p \approx \frac{cw}{L} \tag{13}$$

where c is a constant, typical of the class of aircraft. For the smaller aircraft considered herein, $c \approx 3.0$. Equation (12) becomes

$$R_p = \frac{3\ w v_o{}^2}{gL} \tag{14}$$

Equation (14) along with the scaling laws of Table VIII, provide the basis for developing the probability distribution for the forcing function. A possible technique is to use equation (14) to select a design basis aircraft and to use the formulation of equations (5)-(11) to determine the time dependent forcing function. An alternate method is to assume a triangular pulse with a peak of R_p and the time scale fixed to conserve momentum. Relatively little accuracy is lost by the latter technique.

IMPACT PARAMETERS

From the formulations of the previous section it is known that the important impact parameters are aircraft velocity, weight and angle of incidence. It is reasonable to assume that the aircraft weight and velocity have uniform probability distributions over the limits provided in tables VI and VII (for known aircraft types) or over the limits suggested by scaling (for unknown aircraft types). In the latter case, it is necessary to obtain the number of aircraft in a given weight class. During the period 1966-1970 a total of 63000 general aviation fixed wing aircraft were shipped, with the mean airframe weight being 1209 lb.[7] The equivalent figures for transport-type aircraft were 2344 and 93000 lb, respectively.[7] Engine weights constitute approximately 25% of the empty weight for single engine aircraft, approximately 35% of the empty weight for twin engine aircraft. These figures indicate that the mean empty weight for general aviation fixed wing aircraft is of the order of 1600-1700 lb. Assuming that the probability distribution for the aircraft empty weight obeys an inverse power law, the exponent is found to be approximately 3.0. This indicates that perhaps 7 times as many single engine aircraft are sold as twin engine aircraft (for general aviation). (The ratio was no doubt considerably lower for aircraft flying during the 1966-1970 period). Refering back to Table I, it is seen that single engine aircraft constitute 85% of the accidents and 87% of the population. It must be concluded, therefore, that twin engine aircraft have a much greater utilization factor. Therefore, in those cases in which the the type of aircraft is not known, it will be assumed that the fraction of operations has a uniform distribution over the empty weight of the aircraft. Finally, it has been suggested that the mean angle of crash for loading operations is 10° and that for takeoff is 45°.[12] It is possible to treat the angle of incidence as a random variable in both the probability of impact and the forcing functions calculations. It is more convenient, however, to use a simplified technique. One method is to assume that the projected ground area is the roof area plus the mean value of the vertical area of a building not shielded by other buildings. A second method is to increase

TABLE VI

CHARACTERISTICS OF SINGLE ENGINE AIRCRAFT [11]

Manufacturer	Model	Weight (lb) Empty	Weight (lb) Max T.O.	Fuel	Length (ft)	Max. Cabin Cross-Sect. Area (ft^2)	Velocity (ft/sec) Min.	Velocity (ft/sec) Max.
Piper	Supercub 170	930	1750	238	22.6		63	191
Cessna	150	1000	1600	172	23.9		81	183
Piper	Cherokee	1331	2325	330	23.8	14.0	95	198
Cessna	Skyhawk	1363	2300	343	26.9		95	211
Beechcraft	Sport 150	1433	2150	343	25.7	15.2	84	186
Piper	Pawnee D	1479	2900	257	24.7		89	166
Beechcraft	Sundowner	1500	2450	343	25.7	15.2	87	202
Mooney	Ranger	1525	2575	343	24.1	12.6	84	258
Cessna	Skywagon 180	1617	2800	429	25.6		89	249
Cessna	Cardinal	1707	2800	330	27.3	14.8	97	264
Beechcraft	Sierra 200	1711	2750	343	25.7	15.2	92	236
Piper	Cherokee 6	1766	3400	554	27.7	16.4	92	241
Cessna	Stationair	1785	3600	429	28.0	15.2	106	264
Cessna	Skywagon 207	1964	3800	383	31.8	15.2	111	254
Cessna	Agwagon	1985	3300	244	26.3		89	221
Piper	Pawnee Brave	2050	3900	594	27.4		91	221
Beechcraft	Bonanza	2051	3400	426	26.4	14.7	109	308
Cessna	Centurion	2170	3800	594	28.1	14.0	110	296

TABLE VII

- CHARACTERISTICS OF TWIN ENGINE AIRCRAFT[11]

Company	Model	Weight (lb) Empty	max. t.o.	fuel	Length (ft)	Max. Fuselage Cross-Sectional Area (ft^2)	Velocity ft/sec min.	max.
Piper	Seneca	2788	4570	845	28.6		101	264
Beechcraft	Baron 95, B55	3156	5100	660	28.0	14.7	123	346
Piper	Aztec	3180	5200	950	31.2		100	315
Cessna	310	3337	5500	1370	32.0		113	349
Cessna	402	3864	6300	1370	36.1	19.8		360
Cessna	340A	3868	5990	1370	34.3	15.6		360
Piper	Navajo	3930	6500	1254	32.6		107	360
Beechcraft	Baron 58p	3985	6140	1135	29.8	14.7	129	360
Cessna	414	4126	6350	1370	33.8	19.6		330
Beechcraft	Duke B60	4275	6775	937	33.8	18.1	138	360
Cessna	421	4501	7450	1406	36.4	18.1		330
Piper	Cheyenne	4870	9000	2574	34.7		129	360
Cessna	441	5045	9500	2970	39.0	18.1		410
Beechcraft	Queen Air	5277	8800	1412	35.5	21.4	142	360
Beechcraft	King Air A100	5640	9650	2534	35.5	21.4	150	400
Beechcraft	Airliner	5722	10400	2429	44.5	21.9	154	340
Beechcraft	King Air	6759	11500	3102	40.0	21.4	155	440
Beechcraft	Super King	7315	12500	3590	43.8	21.4	167	
Cessna Jet	500	6454	11850	3793	43.5	21.9	154	340
Learjet	24E	7025	12900	4719	43.3	21.4	145	
Learjet	25D	7640	15000	4719	47.6	21.4	167	

TABLE VIII

IDEALIZED AIRCRAFT PARAMETERS

Parameter	Type of Aircraft Single Engine	Twin Engine
Empty Weight (lb)	$1000 \leq w_o \leq 2200$	$2800 \leq w_o \leq 8000$
Maximum Takeoff Weight (lb)	$(1.75 \pm .15)\ w_o$	$(1.70 \pm .12)\ w_o$
Length (ft)	$(2.24 \pm .13)\ w_o^{1/3}$	$(2.16 \pm .16)\ w_o^{1/3}$
Minimum Velocity (ft/sec)	$(.0582 \pm .0059)\ w_o$	$(.0283 \pm .0056)\ w_o$
Maximum Velocity (ft/sec)	$(.145 \pm .025)\ w_o$	$\sim .08\ w_o$
Maximum Cross sectional Area (ft^2)	15	20

Error Bands are ± standard deviation

the roof area by 50% to take into account wall strikes, slide in collisions, etc. Both methods assume all impacts have normal incidence and are generally conservative.

SECONDARY EFFECTS

The secondary effects of aircraft impacts are usually not severe and are susceptible to the same general probability analysis as are the impactive effects. Fires occur in approximately one half of all crashes and may be analyzed using the methods of Pinkel, once a design basis aircraft has been established.[14] Explosions occur less frequently and will produce only moderate blast and missile effects. Upper bound methods will usually prove satisfactory for the treatment of explosion phenomena.

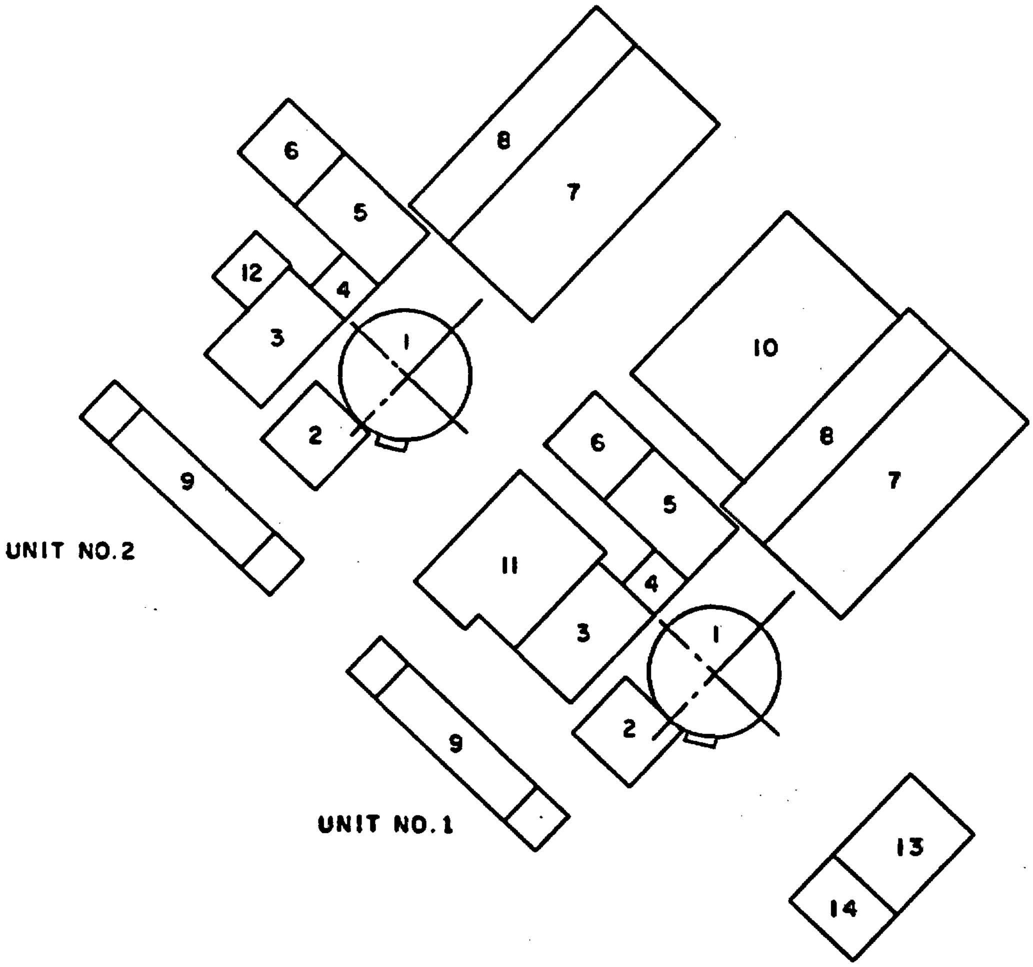
PROBABILITY OF UNACCEPTABLE CONSEQUENCES

It is convenient to devide a nuclear plant into grouping of structures with similar vulnerabilities. A catastrophic strike on initial structures such as the containment, the fuel storage building and the control room may, through different mechanisms, result in off-site radiological releases greater than those listed in 10 CFR 100. Although only a fraction of the strikes may result in massive releases, in order to aviod complex analysis, it is assumed that impacts on the containment, fuel storage building and control room have a probability of 1.0 of producing unacceptable consequences provided barrier penetration, spall or building collapse has occurred. Certain parts of the plant such as the PCCW System are vulnerable during refueling but not otherwise or are vulnerable perhaps 10% of the time. The waste processing building is vulnerable to certain penetrating impacts but the off-site consequences are generally not severe. On a risk balancing basis it is reasonable to assign a probability of .01 to unacceptable damage, given an impact. Finally, other safety-related buildings are very unlikely to be required during an aircraft impact. For example, the fraction of time that a site will be without off-site power is in the range 10^{-3} to 10^{-4}; it is only at such times that the diesel generators are necessary. Similarly, coincident occurrences of aircraft impact and LOCA have extremely low probabilities. Hence, aircraft impacts on these types of buildings are extremely unlikely to cause unacceptable damage and are assigned a nominal weight of 1%.

The above discussion should not be taken as an assessment of the "risk" presented by an aircraft impact, but only as a method of providing bases for conservative design.

AIRCRAFT IMPACT DESIGN OF A TYPICAL PLANT

The layout of a typical two unit plant is shown in Figure 1. The effective ground area of this plant is taken to be 1.5 times the roof area times the utilization factors of the previous section. Table IX provides the areas of the safety related buildings at this site. It is of interest to calculate the probability of an impact on a safety related building assuming only normal background air traffic is in the vicinity (i.e. the plant is located far from any airport). The results are shown in Table X. It can be seen that the



1. CONTAINMENT
2. FUEL STORAGE BLDG.
3. PRIMARY AUX. BLDG.
4. EQUIP. VAULT
5. CONTROL BLDG.
6. DIESEL GEN. BLDG.
7. TURBINE BLDG.
8. HEATER BAY
9. COOLING TOWER
10. ADM. & SERVICE BLDG.
11. WASTE PROCESSING BLDG.
12. REFUELING WATER STORAGE TANK
13. CIRC. WATER PUMP HOUSE
14. SERVICE WATER PUMP HOUSE

FIGURE — 1
PLOT PLAN OF A TYPICAL
NUCLEAR POWER STATION

TABLE IX

AREAS OF SAFETY RELATED STRUCTURES IN A TYPICAL NUCLEAR POWER PLANT

Class of Target	Structure	Weighting Factor	A_p ($X10^4 mi^2$)	A_{eff} ($X10^4 mi^2$)
(Probability/Release)				
High/High	1	1.0	19	19
High/High	2,5	1.0	23	23
Moderate/Low	3,4	0.1	13	1
High/Low	11	0.01	14	
Low/High	6,9,12, 13,14	0.01	51	24
Total (w/o Containment)			91	24
Total (with Containment)			110	43

A_p = Total Projected Area
A_{eff} = Roof Area X Number of Structures X Weighting Factor

TABLE X

PROBABILITY OF AN AIRCRAFT IMPACT ON A TYPICAL PLANT FROM NORMAL BACKGROUND

	Probability Per Unit (Events per year x 10^7)		
	On Safety Related Structure	On Critical Structure	
Type of Aircraft		With Cont.	w/o Cont.
Air Carrier	.2	.1	.1
Small Fixed Wing, 2 Engine	2	.7	.4
Small Fixed Wing, 1 Engine	11	4	2.3
Any	13	5	2.8

probability of an impact on a safety related structure is of the order 10^{-6} per year, but since small aircraft are unlikely to damage the containment, the probability of striking a potentially vulnerable structure reduces to 2.8×10^{-7} per year or somewhat over the guideline value of 10^{-7} per year. Normally this is acceptable because of the inherent conservative nature of the calculations. To illustrate the technique, however, this point is ignored. Assuming that all twin engine aircraft impacts will cause unacceptable damage, the problem is reduced to selecting a design basis angle engine aircraft such that more severe collisions will occur less than 0.5/2.3 or 22% of the time. The peak value of the forcing functions would be of the order of 3.4×10^5 lb corresponding, for example, to a fully loaded Cessna Skywagon travelling at 182 ft./sec.

Assume now that a small, private airfield is located one mile from this site, and has 500 operations per year of small aircraft, of which 100 consist of operations of a Piper Aztec, and the remainder of small single engine aircraft. The plant is assumed to lie within 30° of the extended runway. The accident rate for the Piper Aztec is 5.7×10^{-6} per operation or 2.2×10^{-4} accidents per square mile per year. Because aircraft is unlikely to damage the containment, the probability of a strike in a critical structure is 2.6×10^{-7} per year per unit. Assuming that the background count remains the same, it is necessary to eliminate all but 19% of the accidents. For this aircraft, the weight will range between 3180 and 5200 lb, the velocity between 100 and 315 ft/sec. The peak value for the forcing function satisfying the condition that 81% of the collisions will be excluded is 9.3×10^5 lb., corresponding, for example to a velocity of 244 ft/sec and a weight of 5200 lb. Note that the probability of an impact by a single engine aircraft on a critical structure (excluding the containment) is 4.1×10^{-6} per year. Perhaps 2% of single engine aircraft impacts will result in a peak forcing function greater than 9.3×10^5 lb. Unless, therefore, it is possible to establish that the remaining operations do not include any of the larger single engine aircraft, it will be necessary to increase the peak forcing function slightly to reduce the risk to an acceptable level.

CONCLUSIONS

A conservative method is presented for establishing a design basis aircraft for a nuclear power plant site. It has been shown that the threat of a crash by General Aviation aircraft at small airports is an order of magnitude higher than previously thought. Though this may appear to be excessively conservative, indications are that other types of flying (such as crop dusting) may be even more hazardous. The method of extrapolating the accident rate at distances between five miles and the position at which the aircraft have entered segregated traffic lanes is different from that suggested in USNRC Regulatory Guide 1.70 (Rev.2), Section 2.2.3. Also, the accident rate of 1.6×10^{-7} per mile for small aircraft is useful in evaluating the effect of a victor route on a plant. Note that this rate is 50 times that of any air carrier.[1] The approximate expression for estimating the forcing function is useful for zeroing in on a design basis aircraft.

An underlying theme of the above techniques is that there exists a rigid cutoff point of acceptability. This appears to be an arbitrary position since, after all, the basic criterion reads "radiological consequences greater than 10 CFR part 100 guids is less than about 10^{-7} per year".[1] (Emphasis added) In other similiar problems such as design for tornado or seismic event, a gain of a factor of two in probability of unacceptable consequences causes relatively small design penalties. In the present case, the design penalty may be linear with probability. The only reasonable alternative, however, are to introduce arbitrariness elesewhere, such as in the design phase, or to design for whole classes of aircraft (all single engine, fixed wing aircraft, all small twin engine aircraft, etc).

Finally, it can be seen that the bulk of the problems is caused by relatively few buildings and areas. Thus it is reasonable to provide a greater degree of protection for the control room and fuel storage areas than for the Primary Auxiliary Building which is vulnerable for relatively short periods of time. This concept of differential hardening is already utilized, in that the containment is much "harder" than the other structures on site. The cost savings of using this type of approach may be substantial.

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MAY 1 1 1971

Mr. Edward J. Bauser
Executive Director
Joint Committee on Atomic Energy
Congress of the United States

Dear Mr. Bauser:

Recent discussions between representatives of the AEC regulatory staff and the Department of Defense have developed additional information on low-level military training flights. This information concerns events following the recent B-52 crash near the Big Rock Point nuclear power station in northern Michigan both with respect to the Bayshore training route near the Big Rock Point plant and the more general possibility of low-level military flights near nuclear installations throughout the country.

Subsequent to the crash of a B-52 bomber about six miles from Big Rock Point a series of meetings with DOD representatives was initiated through the office of the Military Liaison Committee to explore the question of low-level flights by military aircraft near nuclear installations. A letter to Chairman Seaborg dated March 1, 1971, from Mr. Ralph Nader and Chairman Seaborg's reply dated March 22, 1971, with respect to this matter and with respect to the proximity of commercial airports to nuclear power plant sites were previously transmitted to you by letter dated April 1, 1971. As noted in our reply to Mr. Nader, the proximity of the Air Force's Bayshore bomb scoring site to the Big Rock Point plant near Charlevoix, Michigan, and the associated use of the plant in connection with training flights, came to the attention of the AEC in 1963. At that time it was the AEC's understanding that the plant was being used as a practice target and the AEC requested the Air Force to remove the plant from their practice target list. The AEC's Division of Military Application determined from the Air Force that the plant would not be used for this purpose. We were subsequently informed by DOD that the use of the plant as a practice target had been discontinued in 1963 but that low-level flights near the plant continued with the targets for these runs being in Lake Michigan, several miles offshore.

Subsequent to the January 7, 1971 crash, low-level training flights on the Bayshore route were suspended and SAC formally closed the route to low-level training missions on January 15, 1971.

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The regulatory staff met with DOD representatives on February 3, 1971, and April 6, 1971, and in the latter meeting Air Force representatives proposed, for AEC and Consumers Power Company concurrence, an alternate flight path in the Bayshore area that would route low-level flights along a centerline about 5-1/2 miles east of the plant, with a return path to the entrance of the bomb-scoring run passing about 12 miles west of the plant. (The centerline of the previous route was 3000 feet west of the plant with the planes at an altitude of about 1750 feet as they left the off-shore scoring area.) The proposed flight path zone would be 8 miles wide (4 miles on either side of the centerline); therefore planes could approach to within 1-1/2 miles of the Big Rock Point plant. However, we understand that the Air Force proposes to abort and redirect any training flights approaching the zone boundary in the Bayshore target area.

We have asked the Air Force representatives for a letter which would provide information on this alternate route, including statistics on the deviation of aircraft from the nominal flight path during such training missions. On the basis of this information we hope to be in a position to agree with the Air Force that the probability of a crash at the Big Rock Point plant as a result of low-level training flights on this alternate route would be negligible.

We understand that because of a loss of target flexibility associated with the alternate route that this change of route would be only an interim measure and that a new scoring area more than 10 miles west of the plant would be required to restore adequate target flexibility. This long-range proposal requires clearance from the FAA and would entail movement of radar tracking facilities from the present Bayshore location.

With regard to the general problem of low-level military flights, the staff has provided Air Force representatives with a list of site coordinates for licensed nuclear power plants and test reactors. We have received DOD Flip Low Altitude High Speed Training Route Charts for the contiguous States and Puerto Rico. On the basis of a preliminary examination of these charts, it appears that only one other nuclear facility site, Arkansas Nuclear One in northwestern Arkansas, is near a low-level bomber training route similar to the Bayshore route. This facility is more than 5 miles from the nearest edge of the flight zone and should therefore not be subject to regular overflights.

The DOD charts also indicate about 250 other low-level military training flight paths for aircraft in the United States. Our preliminary examination of these routes indicates that about one-third of the nuclear power reactor sites are within about 10 miles of one or more of these routes. After receiving statistical information from the Air Force on the deviation of aircraft from the nominal flight path on these routes, the frequency of use of these routes, and relevant crash statistics, we will be in a better position to evaluate changes, if any, which may be desirable in current military training routes. (A simple instruction from DOD to all flying commands to instruct air crews to avoid the locations of nuclear power plant sites may be sufficient action in this matter.) The DOD has indicated that if formal route changes are required, the FAA will necessarily have to be consulted.

We plan later to notify all power and test reactor licensees of the ultimate results of these efforts and ask that they notify us of any unusual overflight conditions that arise in the future at their plants.

Of course military overflights are not the sole consideration in evaluating potential aircraft hazards. Commercial and general aviation overflights and the proximity of airports are also of concern. In the course of our past evaluations of nuclear power facilities we have not considered that the hazards from these aircraft overflights warrant special measures when the facilities are not in the immediate vicinity of airports since statistics available on civilian and general aviation crashes indicated a very low probability of striking any given point near air corridors. We have concluded, however, that the area immediately around airports has a significantly higher crash probability, especially within the first two miles, and have had under development for some time explicit criteria concerning the design and location of nuclear power plants in relation to nearby airports. A copy of these criteria will be sent to you before publication for comment. As noted in Chairman Seaborg's letter to Mr. Nader, the Commission will also consider holding public hearings on the criteria at the time they are ready for publication.

Sincerely,

Harold L. Price
Director of Regulation

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