Docket 50-289
Supplement No. 4
December 22, 1967

Supplement No. 4

Emergency Core Cooling System

Changes have been made to the emergency core cooling system to provide independence between the subsystems. These changes are presented schematically in Figures 6-1, 9-8, and 9-10.

The changes may be summarized as follows:

1. Two 100 percent capacity low pressure injection pumps (3000 gpm each) are used to inject and recirculate coolant after an accident through each of two decay heat coolers and into two separate reactor vessel nozzles.

2. A separate sump suction line is provided to each of two low pressure pumps. These lines are jacketed from the reactor building out through the sump isolation valve.

3. Three 100 percent capacity high pressure injection pumps are provided to assure subsystem independence following an accident. Each of these pumps is capable of pumping 500 gpm at a total developed head of 1400 feet. Each emergency core cooling subsystem will contain one of these pumps. Either the third pump or one of the two emergency pumps may be used to supply seal water flow and reactor coolant system makeup during normal plant operation. The four injection lines are brought individually outside the reactor building with separate remotely operated isolation valves.

4. The decay heat cooler outlet can be cross connected to the high pressure pump suction to provide high pressure injection after entering the recirculation mode should the reactor coolant pressure be above the maximum discharge pressure of the core flooding tanks and low pressure pumps.

5. To provide independence between the reactor building cooling system and the core cooling systems, the cooling water for these two functions has been completely separated. This has been accomplished by installing a separate set of pumps to circulate river wate directly through the reactor building coolers. Additional pumps and coolers are included to provide separate open and closed loop cooling systems for the decay heat coolers.

6. The criterion for separation of the system is as follows: Each subsystem will be arranged and physically separated to permit detection and isolation of leakage from a given subsystem. Leakage detection will be provided by separate auxiliary sump level detectors. Wall or equipment shields will assure that leakage from a given subsystem wil reach the appropriate sump.

   The independence that is described above is reflected throughout the auxiliary systems and extends to the ultimate heat sink.

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ETROPOLITAN EDISON COMPAN

THREE MILE ISLAND
NUCLEAR STATION

PRELIMINARY SAFETY ANALYSIS REPORT

AMENDMENT NO. 8

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Docket No. 50-289
February 23, 1968

AMENDMENT NO. 8

METROPOLITAN EDISON COMPANY

THREE MILE ISLAND NUCLEAR STATION

Amendment NO. 8 to the Metropolitan Edison Company's Preliminary Safety Analysis Report consists of Supplement No. 5. Supplement No. 5 should be placed directly behind Supplement No. 4 in Volume 4.

Also included are four copies of the Table of Contents, page vii. One of these revised pages should be placed in each of the four volumes.

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MEMO ROUTE SLIP
AEC-93 (Rev. May 14, 1947) AECM 0240

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Docket No. 50-289
Supplement No. 5
February 23, 1968

SUPPLEMENT NO. 5

The following information is submitted in response to an oral inquiry by the AEC regulatory staff regarding what possibility there is for an airplane hitting the Three Mile Island station while arriving or departing from Olmsted State Airport and regarding the capability of the station to safely withstand such an unlikely event.

Section A presents a discussion of the probability of such an event and concludes that there is less than about one chance in one million per year that it could occur.

Section B presents a discussion of the capability of vital areas of the station to safely withstand a hypothetical aircraft incident.

SECTION A - PROBABILITY OF AN AIRPLANE STRIKE

The Three Mile Island Station is two and one-half miles (straight line distance) from the eastern end of the single runway of Olmsted State Airport. The station is about one and one-half miles to the southwest of the extended runway center line. The respective location of the station and the airport and its runway are shown in Figure 2-2 of the PSAR, which is also included as Figure A-1 of this supplement.

Air traffic in the site area is discussed briefly in Section 2.2.3 of the PSAR and flight patterns in and out of Olmsted Airport are described in Supplement 1 (dated October 2, 1967) in answer to the AEC Staff's question numbered 2.6.3.

Those responsible for planning and operations for the Olmsted Airport, formerly the Olmsted Air Force Base, have indicated that there are no plans for additional runways and that present flight patterns are well established.

The probability of crashes into the plant by aircraft arriving or departing Olmsted has been approximated by examining 10 years of records in the annual statistical summaries of U. S. air carrier accidents (1) and individual aircraft accident reports

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(1) U. S. Air Carrier Accidents, Statistical Review and Resume of Accidents; annual edition, 1956-65, inclusive; Civil Aeronautics Board, Bureau of Safety.

available from the Bureau of Safety of the Civil Aeronautics Board. These records cover about eighty million aircraft movements (landings plus take-offs). The accident occurrences related to them are summarized in Tables A-1, A-2, A-3 and Figure A-2.

Using these data as a basis and the approximations described below, it is estimated that for each aircraft movement (landing and take off) at Olmsted there is about one chance in 5×10^{10} of a crash into the plant. This is equivalent to a recurrence interval of about one strike in 5×10^{10} years for each aircraft movement per year.

If it is assumed that there are about eighty thousand aircraft movements per year at Olmsted, (about four times the present movement rate) the chance of a crash into the plant in any one year is less than one in a million (i.e., is equivalent to a strike recurrence interval of once in more than a million years).

The types of air carrier aircraft which now use Olmsted airport in terms of approximate percent of total air carrier movements are:

Convair 580	67%
DC-9	10
Fairchild F-27	10
Boeing 707	3
Other	10
	100

Because it is served primarily by local service carriers and by shorter flights of trunk carriers, there is a higher portion of smaller aircraft than at major airports and this relative pattern will probably continue in the future.

In addition to air carrier movements there are small civilian and executive aircraft flights (probably less than 10% of total flights), some Air National Guard flights from a unit stationed at Olmsted (probably less than 10% of total flights and using C-121 type aircraft) and some small percentage of transient military flights including helicopters. Of all of the aircraft presently using the airport, the Boeing 707 is the largest type.

As indicated above, most of the aircraft movements at Olmsted are of the air carrier type. This proportion is likely to increase in the future, particularly if traffic increases to about four times the present rate as has been assumed in the probability analysis. Therefore, the use of air carrier accident statistics is appropriate.

As indicated in Section B, hereto, protection is afforded in the plant against a crash by an airplane of about 300,000 lb. weight (which is typical of the Boeing 707 class or against the worst missile likely to result therefrom). Presently, about three percent of movements at Olmsted involve this class of airplane. If this ratio is maintained for the projected 80,000 movements per year and if it is assumed that crash frequency for 300,000 lb. class airplanes is the same as for all those considered, the chance of such an airplane hitting the plant would be about one in 30 million per year.

There are aircraft which may be used in the future which are larger than the 300,000 lb. class (e.g., the Boeing 747.) If, as seems reasonable, they do not comprise more than 1 to 10% of air traffic at Olmsted and if they have similar crash frequencies as present air carrier aircraft, the chances of their hitting the plant should be less than one in 10 to one in 100 million per year, assuming there are about 80,000 movements per year.

The estimated chance of a crash into the plant (i.e. about one chance in a million per year) is in the order of a hundred times less likely than other types of extreme environmental effects (i.e., from tornadoes and floods) for which the plant is designed

Aircraft Accident Statistics

The Bureau of Safety of the Civil Aeronautics Board publishes annual statistical reports on U. S. Air Carrier accidents. Table 1 summarizes data contained in these reports for the period 1956 through 1965, inclusive, based on about 80 million aircraft movements.

Individual accident reports were examined to determine the portion of the total fatal accidents (roughly comparable to high energy accidents) which occurred in the proximity of airports (i.e., within a 5 mile radius of the end of the runway being used). The results are summarized in Table A-2 for operations in Continental U. S. The types of aircraft involved in these accidents are listed in Table A-3.

Probability of Airplane Strikes on Three Mile Island

In order to get an approximation of the probability of an airplane crash into the plant, the geographical distribution of crash impact locations with respect to the runway being used was plotted for all fatal crashes listed in Tables A-2 and A-3 for the chosen ten-year period. Then the relative location of the plant and the ends of the Olmsted runway were sumperimposed on a plot. The results are given in Figure A-2 for both arrival and departure crashes.

Examination of Figure A-2 indicates that 15 of the 17 landing accidents were within ± one-half mile of the extended runway centerline. Only two of them were outside the ± one-half mile runway width. Thus, it is clear that there is not an equal probability of a landing accident strike in the area near an airport. To provide some adjustment for this situation, it is assumed for purposes of estimation that 15 of the arrival accidents strike within ± one-half mile of the runway centerline and that the other two have an equal probability of striking anywhere else within a four mile radius circle. Thus, there are two crashes which have some probability of being superimposed on the station location.

The fatal departure accidents numbered 10 over the 10 year period and 5 of them were within a 1 mile radius of the end of a runway To provide for the non-uniform probability of takeoff accidents striking in the vicinity of the airport, it is assumed that 50% of them strike within a 1 mile radius of the end of the runway and the other 50% have an equal probability of striking anywhere else within a 4 mile radius. All accident locations plotted in Figure A-2 are assumed to be within the 4 mile radius even though one departure accident lies slightly outside this radius. Thus, there are 5 crashes which would have some probability of being superimposed on the station location.

During the 10 year period of record there were approximately 40 million aircraft arrivals and 40 million departures. Therefore, the applicable accident frequency (f) is about $5/40 \times 10^6$ or 1.25×10^{-7} per departure and $2/40 \times 10^6$ or 5×10^{-8} per landing

Using these numbers, the probability of a crash on the station for any one landing or takeoff was taken to be the applicable accident frequency times the ratio of the "target area" of the plant to the "total area" in which the applicable accidents are assumed to happen with random distribution. These areas were estimated as follows:

(1) The "target area" for arrival (landing) accidents was assumed to be approximately the horizontal area (on the ground) which would be covered by the plant plus the shadow cast by the largest vertical cross section of the plant (excluding cooling towers) assuming light rays emanate from the plane as it approaches the plant along a line inclined 10° above the horizontal. This

angle was chosen as being a typical descent line for airplanes crashing on landing. (If the angle were greater, the area would be less and the probability of a strike would be less). The area of the shadow so obtained was increased by 50% to account for airplanes which might crash in front of the plant and slide into it. The resulting target area for arrival accidents (here called A_a) is about 0.0225 square miles.

(2) The "target area" for departure (take-off) accidents was similarly estimated using a 45° approach angle believed typical of departure crashes. This area (here called A_d) was estimated to be 0.0066 square miles.

(3) The "total area" for random distribution of departure accidents (here called A_{td}) is $\pi(4)^2 - \pi(1)^2$ or 47.1 square miles. Simalarly, the "total area" for arrival accidents (A_{ta}) is about $\pi(4)^2 - 1 \times 8 = 42.2$ square miles.

For any one arrival, the probability (P_a) of hitting the plant is:

$$P_a = f_a\ A_a/A_{ta} = 5 \times 10^{-8} \times \frac{0.0225}{42.2} = 2.66 \times 10^{-11}$$

Similarly, for any one departure, the probability of hitting the plant is:

$$P_d = f_d A_d/A_{td} = 1.25 \times 10^{-7} \times 0.0066/47.1 \cong 1.75 \times 10^{-11}$$

and for both departures and arrivals the average probability is

$$\frac{Pa + Pd}{2} = 2.2 \times 10^{-11}$$

This is equivalent to a recurrence interval of one strike every 4.5×10^{10} (or, say, 5×10^{10}) years per aircraft movement per year.

If it is assumed that there are about 80,000 aircraft movements a year at Olmsted and that half of the take-offs (20,000) and half the landings (20,000) are from the end of the runway nearest the plant and therefore could affect it, the chance for the plant being hit is:

$$P = 20{,}000\ (Pa + Pd) = .88 \times 10^{-6}$$

This is equivalent to a recurrence interval for a crash on the plant of about once in 1.13 million years and indicates that there is less than one chance in a million that an airplane will crash into the plant in any one year.

TABLE A-1

SUMMARY OF U. S. AIR CARRIER ACCIDENTS(1,2)

ALL OPERATIONS

Year	Total Accidents	Fatal Accidents(3)
1956	107	9
1957	113	14
1958	90	15
1959	102	18
1960	90	17
1961	84	11
1962	70	10
1963	77	13
1964	79	13
1965	83	9

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(1) From *U. S. Air Carrier Accidents, Statistical Review and Resume of Accidents*, annual editions 1956-65, Civil Aeronautics Board, Bureau of Safety.

(2) A "U. S. Air Carrier" is defined in the referenced report as "those operators who have been issued a Certificate of Public Convenience and Necessity by the Civil Aeronautics Board."

(3) Fatal accidents are those in which one or more human fatalities occurred.

TABLE A-2

FATAL ACCIDENTS IN THE PROXIMITY OF AIRPORTS(1,2)

CONTINENTAL U. S.

Year	NUMBER Total	Arriving	Departure
1956	1	0	1
1957	3	2	1
1958	3	2	1
1959	4	3	1
1960	2	0	2
1961	2	1	1
1962	3	2	1
1963	4	3	1
1964	3	2	1
1965	2	2	0
	27	17	10

TABLE A-3

TYPES OF AIRCRAFT INVOLVED IN THE FATAL ACCIDENTS LISTED IN TABLE A-2

Year	Aircraft
1956	Martin 404
1957	Convair, DC6, DC3
1958	DC7, Convair, Viscount
1959	Electra, DC3, M202, L1049
1960	Electra, C46
1961	Electra, L049
1962	B707, DC7, L1049
1963	Viscount, L1049, Martin 404, DC3
1964	DC4, DC3, L1049
1965	B727, B727

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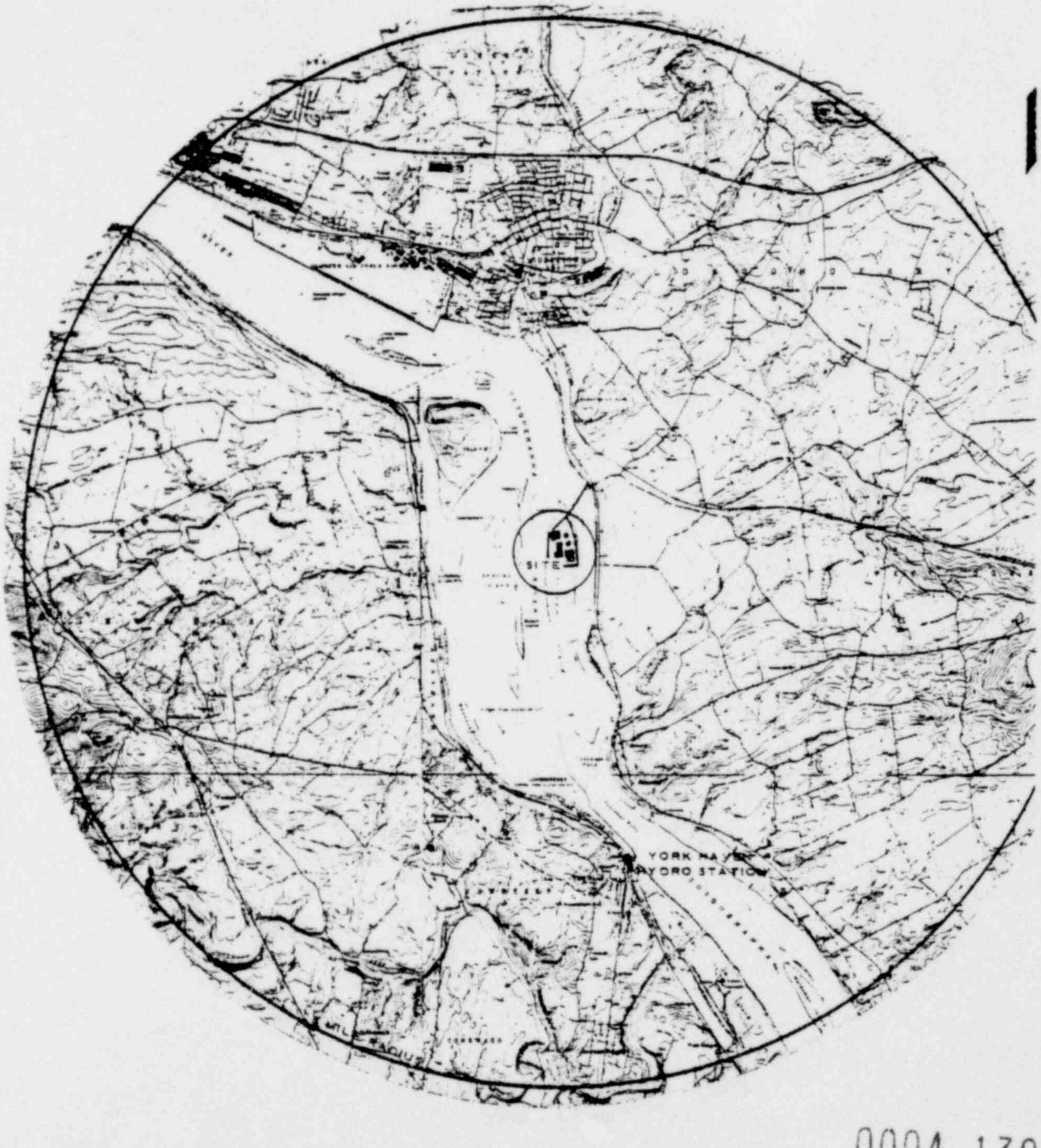
(1) Source: Aircraft Accident Reports, National Transportation Safety Board, Department of Transportation.

(2) Within a five-mile radius of the end of the runway being used.



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THREE MILE ISLAND NUCLEAR ST

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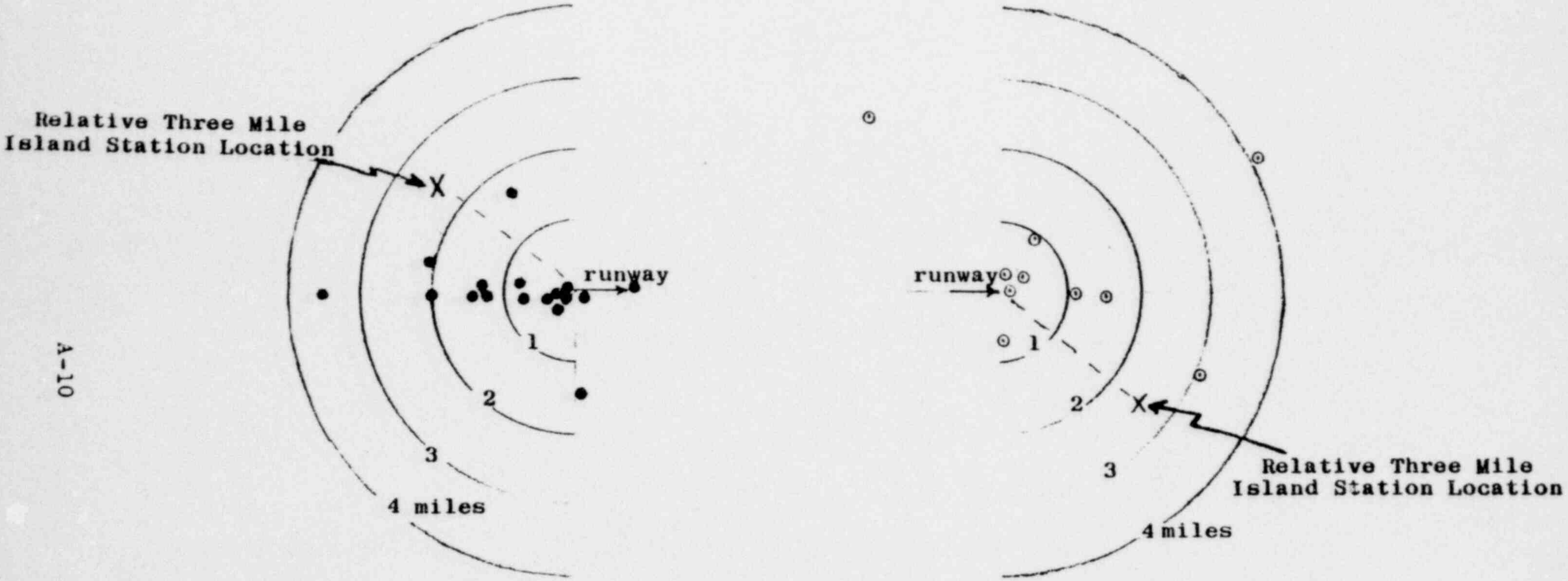

Arriving (17)

Departing (10)

APPROXIMATE CRASH LOCATIONS OF FATAL ACCIDENTS OF U. S. AIR CARRIERS, WITHIN CONTINENTAL U. S., IN PROXIMITY OF AIRPORT, IN TAKEOFF AND LANDING OPERATIONS

TEN YEARS: 1956 - 65

Note:
Locations are relative

Figure A-2

HYPOTHETICAL AIRCRAFT INCIDENT

Section B - Design Objective

Capability to Withstand Air Strike

Although the probability of an aircraft incident at the Three Mile Island Nuclear Station is extremely remote, the principle structures and component of the plant, set forth below, will have the capability of withstanding hy thetical aircraft strike related loadings such as:

Case	Item	Weight	Velocity	Effective
A	Object	6,000 lbs.	200 knots	5 ft. diame
B	Object	4,000 lbs.	200 knots	3 ft. diame
C	Total Aircraft	300,000 lbs.*	200 knots	16 ft. diame
D	Total Aircraft	200,000 lbs.	200 knots	19 ft. diame

and thereby preclude the occurrence of any accident condition not previousl evaluated. These loadings are typical of those which may be associated with an incident involving commercial, multi-engine, jet aircraft traveling at a maximum speed of 200 knots or 334 ft/sec. Other loadings such as the consequences of an exploding fuel tank will be considered if such an accide is found to be possible. Collateral effects of the loadings, such as the generation of secondary missiles, fire, and pressure and temperature effect will be considered to assure the capability of bringing the plant to a safe shutdown condition.

1. Reactor Building - The impact of the loadings described as Cases A, B, C, and D will be evaluated on the apex of the dome and at a sign ficant location on the cylinder to assure that the hypothetical objects are prevented from penetrating the external reactor containment structure or causing it to collapse. The interior structures and major components are supported from the base mat independent of the containment shell. Consequently their response due to the hypothetical aircraft strike is minimal (i.e. less than that associated with the seismic disturbance). The only other significant items attached to the containment shell include the polar crane and the spray header piping. The trolley and trucks of the crane

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*The analytical check on the basis of this loading considered a high uniform collapse resistance of the fuselage, which further investigation indicated was not conservative. Because of the extremely remote probability of such an aircraft impacting at the most unfavorable location and altitude, the structures of the plant will be designed to have the capability of withstanding a hypothetical strike of a 300,000 lb aircraft with the load-time description described in Appendix B.

will be tied down during plant operation to ensure no overturning or sliding will occur due to the most severe disturbance resulting from either the maximum seismic load or the hypothetical aircraft strike. The spray header piping will similarly be checked to ensure collapse will not occur. It can therefore be concluded that loss-of-coolant accident will not occur due to the disturbance associated with the hypothetical aircraft strike and there will be no release of radioactive material to the environment.

2. Control Building - The impact of the aforementioned loadings on the roof at approximately Elevation 385'-0" and side walls will be evaluated. The area to be protected is depicted on Figure B-1. This check will be with the objectives of ensuring that:

    a. No penetration or collapse of the structure will occur.

    b. Instrumentation and controls necessary to shut down the reactc plant and maintain it in a safe condition will be available.

    c. Access provisions and ventilation systems are designed to prevent ingress of aircraft fuel, fire, smoke, or pieces of the aircraft which could cause unacceptable damage.

    d. The Control Room remains habitable during and after the incident.

3. Fuel Handling Building - The impact of the aforementioned loadings the roof and side walls will be evaluated with the objective of sat fying Items "a" and "c" listed under paragraph "2" above. The openings for railroad entrance will be sized and located such that the possible trajectories would not include one which would result in the objects falling into the Spent Fuel Pool. The roof and walls of the structure will afford protection against missile impingement. This is depicted on Figure B-1 and provides protectic of the Spent Fuel Pool.

4. Auxiliary Building - The impact of the aforementioned loadings on the roof and side walls will be evaluated with the objective of satisfying Items "a" and "c" listed under paragraph "2" above. The floors of the structure at Elevation 329'-0" or 305'-0" depending upon the location will afford missile protection for equipment located below these elevations. This is depicted on Figure B-1 and provides protection of critical items of the radioactive waste treatment systems.

5. Intermediate Building - The impact of the aforementioned loadings c an enclosure surrounding the main steam lines to a location downstr of the isolation valves and surrounding the emergency feedwater pumps will be evaluated with the objective of providing protection below the floor at approximately Elevation 340'-0". This is depict on Figure B-1.

C. Summary of Studies

A preliminary study was made to determine if a containment vessel of essentially the same geometry and design used for the Three Mile Island Nuclear Station provides protection against the impingement of those missiles described as Cases "A" and "B" (i.e. the 6,000 lb. and 4,000 lb. objects traveling at 200 knots). This study which is described more completely in Appendix A, indicates that the upper bound of displacement due to a direct central missile impingement on the spherical dome does not correspond to a condition of collapse.* The study further indicates that penetration will not occur due to local material failure.

*This preliminary analysis is admittedly grossly conservative and assumes plastic response which the dynamic elastic analyses described hereafter indicates will not occur.

A study of Case "C" was made to determine the response due to the direct central impingement of a 300,000 lb aircraft on the dome. This study, which was a dynamic elastic analysis more completely described in Appendix B, indicates that the impingement of the total aircraft should not jeopardize the integrity of the dome. It was assumed for this analysis that the impinging aircraft would have a constant load time curve as shown in Figure 1 of Appendix B. This analysis considered a high collapse resistance of the fuselage which further investigation indicates is not conservative.

A second study was made to determine the response due to a direct central impingement of a 200,000 lb aircraft on the dome. This was also a dynamic elastic solution as described in Appendix B. The results of this analysis indicate that the impingement of the 200,000 lb aircraft should not jeopardiz the structural integrity of the dome. The load time curve for this aircraft is the result of a more intensive investigation of the phenomena associated with an airplane crash. The results of this investigation and a plot of the load time curve is in Appendix C.

The potential pressure increase external to the critical structures caused by the rapid combustion of the jet fuel is anticipated to pose no problem in that all critical structures consist of significant thickness of structural concrete and no confining space exists to produce high local pressures. Aircraft crash fire experience has not indicated that the vapor clouds release coincident with the deceleration of an aircraft will produce serious blast hazards. The vapor clouds that can be formed by the bulk release of fuel from aircraft tanks can and do create large balls of fire, but since these release into open air where there is no confinement problem, no blast damages are anticipated. Nevertheless, a study will be made including use of the same analytical technique used to determine primary cavity pressure due to primary coolant breaks, as reported in the answer to Question 5.8 contained in Supplement No. 1 to the PSAR. Conservative assumptions on confining volume and vent area will provide data as to credible over-pressure conditions.

The numbers of openings to the outside, from within areas housing vital components or systems required for the shutdown and maintaining the reactor plant in a safe condition, will be held to a minimum and essentially will be only those required for operator access and ventilation. A more complete study regarding capability to be provided for fire detection and protection following the hypothetical aircraft strike is included in Appendix "D". Shielding will be provided for critical openings to prevent direct aircraft strikes upon the openings. Examples of use of both fixed and movable shields are shown in Appendix D, Figures 1 and 2.

The concrete structures will also be designed taking into consideration the development of secondary missiles and potential loss of structural capability due to scabbing or spalling of concrete.

Where objectionable secondary missiles may occur due to the scouring action of the reflected shock wave in the impact face or the scabbing effect of the propagated wave in the opposite face special systems of reinforcement will be used to provide the needed tensile strength. This reinforcement will consist of either rebar trusses or anti-scabbing plates. The containment liner will of course provide this reinforcement.

The extension of all buildings designed to withstand the hypothetical aircraft strike will be constructed of reinforced or prestressed concrete. The walls and roofs of these buildings will be of significant concrete thickness as required for radiation, missile, and/or aircraft protection. The mild steel reinforcement for these buildings will have a concrete cover of 2 in. or more. The tendon conduit for the reactor building will have a minimum cover of 6 in. as specified in the answer to question 7.12.1 in Supplement #1.

Slabs and walls with 2 in. of concrete cover for the reinforcement and a thickness of 6 in. has a 2 hour fire rating.[1] The two hour fire rating indicates that the 6 in. slab or wall will support its design load while exposed to temperatures up to 1850 F for two hours. However, two hours is considered adequate time to extinguish any fire produced by an aircraft crash at this plant.

Spalling of concrete is considered to be of two types.[1] The "explosive" spalling is produced when there is high relative humidity in the concrete and the free moisture changes to steam producing small pockets of pressure. This spalling starts at the surface exposed to the high temperatures and propagates inward. In the unlikely event that the necessary ingredients are present (high relative humidity and high temperatures) it is possible that some of the concrete could be spalled off. The only structural members that would be exposed to high temperature would be the walls. The protective structures are designed such that a fuel fire would not occur inside the structure. Burning fuel could be puddled on the roof slabs, however the concrete would not be exposed to high temperatures because the flame would be burning on the top of the slab and also on top of the fuel. There would be no damage due to spalling of roof slabs. The walls could be exposed to flames and possible high temperatures in which under the ideal condition one could expect to lose concrete due to spalling. However, the walls are sized for radiation, missile, and/or aircraft protection and from a structural consideration; a loss of 2 in. of concrete would not jeopardize the structural integrity of the building.

The "sloughing off" type of spalling is produced when high temperatures tend to shrink the cement paste and at the same time expand the aggregate. The sloughing spalling is experienced when aggregates containing more than 30 percent free silica are used. Concrete using this type of aggregate is given a reduced fire endurance rating by The National Board of Fire Underwriters.[1] The aggregate used in all vital structures for this plant is a limestone aggregate containing little or no fire silica or other ingredients that would cause sloughing.

D. System Studies

The plant layout provides significant physical separation between the off-site and emergency power supply of approximately 500 feet and located at opposite corners of the main building complex as shown on Figure B-2. This separation is considered to be sufficient to ensure that one of the power supplies will b available following a hypothetical aircraft incident. If; however, the situation is postulated that both power sources are lost the expected results will be as analyzed in section 14.1.2.8.3 and the answer to Question 4.10.

In the unlikely event that the emergency diesel generators are temporarily removed from service due to a deficiency of oxygen caused by aircraft related fires simultaneously surrounding the diesels and filling the intermediate building, the station batteries will enable the plant to remain in a safe condition until the situation is corrected.

The emergency feedwater supply can be obtained from either one of the two condensate storage tanks or the condenser hot well. In addition to the redundant dispersed water supplies, an emergency river make-up pump will also be provided, as shown on Figure 9-8 to pump directly from the nuclear services cooling water system to the suction of the emergency feed pumps. Protection will be provided to ensure operability of the emergency feedwater pumps including the energy sources for driving power. The emergency feedwater pump arrangement will be modified so that one 5 percent capacity steam-driven pump and two 2-1/2 percent capacity motor-driven pumps will be provided in lieu of the two 5 percent capacity steam-driven pumps originall described elsewhere in the PSAR. With this arrangement the plant can experience the complete loss of all main steam lines and still retain the capaci to deliver feedwater to the steam generators. The plant layout provides

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[1] Symposium on Fire Resistance of Concrete - American Concrete Institute - Publication SP-5.

significant physical separation between the various feedwater sources as shown on Figure B-2. This separation is considered to be sufficient to ensure that at least one feedwater source will be available following a hypothetical aircraft incident.

The fire protection features will include redundant dispersed water supplies, automatic fire pumps and a piping system to supply yard hydrants, interior fire hose stations, various automatic deluge water spray systems (including coverage of emergency diesel generators and station transformers). Activation of transformer fire protection systems would cause, at the most, a brief interruption of off-site power. In addition appropriate portable fire extinguishers will also be included. All will be in accordance with recognized standards.

Employees will be trained to handle fire emergencies.

E. Blowdown of Steam Generators

The simultaneous rupture of four steam lines and the subsequent blowdown of both steam generators will cause the reactor system coolant temperature to decrease to about 515 degrees F in less than 20 seconds. Immediately following the blowdown, the reactor system coolant will heat up because decay heat generation is greater than emergency feedwater heat removal capacity. Reactor trip is initiated by the low primary system pressure caused by the initial cooldown.

The tripping of the reactor results in tripping of the turbine. This causes the main feedwater isolation and control valves to close, thereby stopping normal feedwater flow. The abnormally low pressure in both steam lines also causes the feedwater startup isolation valves to close, thereby stopping feedwater flow through the startup control valve. One of the two motor-driven emergency feedwater pumps, will be started to supply feedwater. The turbine trip also causes the steam line isolation valves to close, thereby preventing further flow of steam from the steam generators to the atmosphere through the broken line. These valves are in an area protected from aircraft impingement and, therefore, will not be affected by an aircraft accident. After the steam line isolation valves have been closed, the primary system will heat up to the normal 540 degrees F shutdown temperature as a result of the decay heat being generated in the reactor. Thereafter, this temperature will be maintained by removal of steam from the steam generator through the turbine bypass valve which is also located in the protected area. The secondary relief valves provide an alternate means for removing steam from the steam generator by discharging directly to the atmosphere.

In the event that one of the steam line isolation valves fails to close, feedwater to that steam generator would be stopped as a result of the differential pressure between the steam generators. Further decay heat removal would be through the isolated steam generator.

To demonstrate that the consequences of the accident are not sensitive to the operation of the isolation valves, an analysis was carried out in which both steam generators continue to discharge steam to the atmosphere through the ruptured lines. The initial cooldown will cause the pressure in the reactor coolant system to drop to approximately 800 psig. This is below the setpoint.

For actuation of the high pressure injection system, therefore, at the time of the accident, one high pressure injection pump will begin adding borated water to the reactor coolant system. Subsequent decrease of the reactor system coolant temperature due to the addition of the colder borated high pressure injection water and removal of heat by the steam generators will reduce the reactor system pressure to 600 psi. This results in the actuation of the core flooding tanks. The borated water added is more than sufficient to compensate for the reactivity added by cooldown of the reactor coolant. The reactor will remain subcritical throughout the transient, even for the case of having a 1 percent shutdown margin at 540 degrees F with one rod stuck out of the core.

The doses which result from the rupture of a steam line have been presented in section 14.1.2.9 of the Three Mile Island Nuclear Station PSAR. In that analysis, it was assumed that the plant had been operating with steam generator tube leakage and 1 percent failed fuel. The total integrated doses at the site boundary were 0.88 rem thyroid and 0.004 rem whole body. Rupture of all four steam lines will not change these doses.

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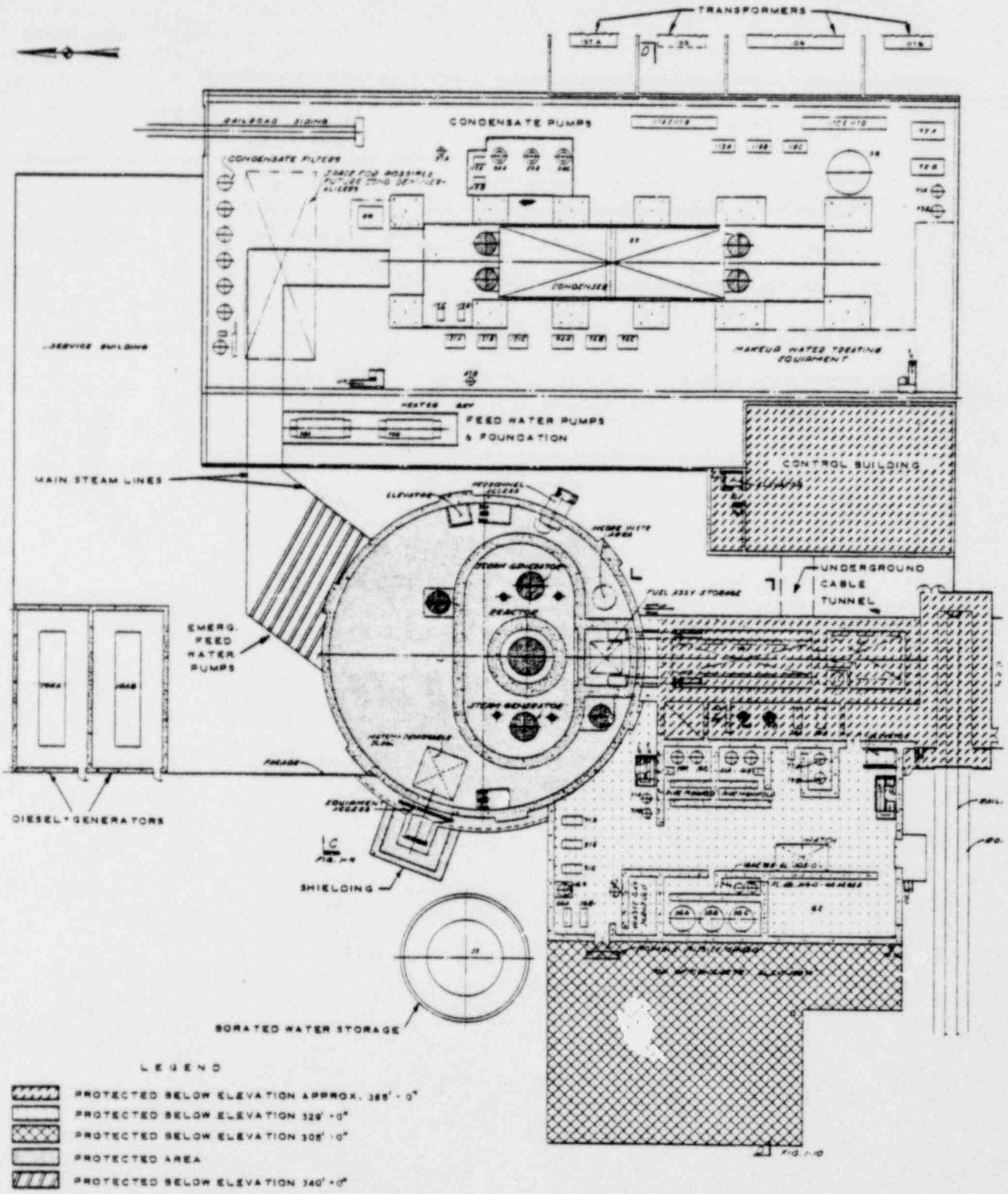
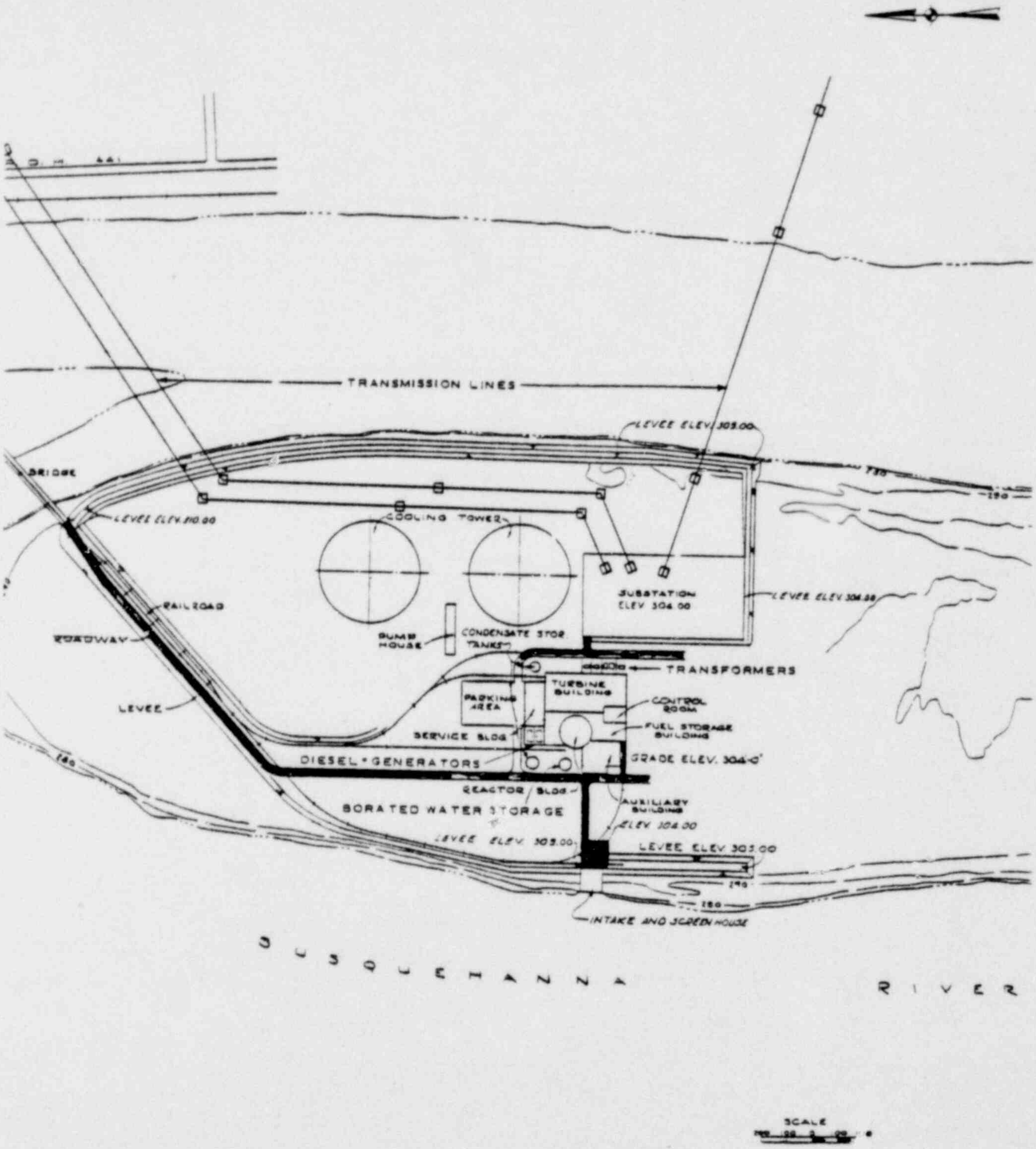


SAFEGUARDS PROTECTION FOR AIRCRAFT IMPING
SUPPLEMENT 5
FIGU



ERSION OF WATER AND POWER SOURCES
PLEMENT 5 FIGURE B-2

Appendix A

1. GENERAL

A preliminary study was made to determine if a containment vessel of essentially the same geometry and design used for the Three Mile Island Nuclear Station provides protection against prescribed missiles resulting from a hypothetical aircraft impingement. In this study the hypothetical missiles were defined as having the following properties:

Case	Weight	Velocity	Impact Surface
A	6,000 lb.	200 knots	5 ft. diameter
B	4,000 lb.	200 knots	3 ft. diameter

This preliminary study consisted of an investigation of the overall structı response due to central impact of the missile on a spherical dome as well ε the resistance to penetration due to a local material failure.

2. STRUCTURAL RESPONSE

A. Introduction

An upper bound of permanent displacements was determined resulting from direct central aircraft impingement on a spherical dome. The basic tool used was the displacement bound theorem for rigid-plastic continua.(1) The initial velocity distribution is determined on the basis of an inelastic collision between the missile and the structure.

B. Limit Analysis for Ring Loads

First we considered a simply supported spherical cap under a ring load (See Figure 1). The intensity of the load is "P" per unit length (i.e. the total load = 2 πPa). A lower bound on the limiting value of "P" is found by determining a stress field which satisfies equilibri condition and which nowhere violates the yield condition.

To obtain a lower bound, we assumed that for $r \geq a$

$$N_\phi = 0, \quad M_\theta = M_o$$

where "M_o" is the fully plastic moment per unit length. On this basis it can be then determined that

$$2\pi Pa = \frac{4\pi M_o \sin\alpha}{\cos\bar{\phi}} \quad \frac{1}{\ln\left(\frac{(1+\sin\alpha)\ (1-\sin\bar{\phi})}{(1+\sin\bar{\phi})\ (1-\sin\alpha)}\right)}$$

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where "2 π Pa" is the total ring load.

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(1) J. Martin, "Impulsive Loading Theorem for Rigid-Plastic Continua," J. Engineering Mechs. Div., ASCE, EM5, October 1964, pp. 27-42.

For this condition where $\frac{\text{"a"}}{R}$ approaches zero.

$$\frac{2\pi Pa}{M_o} = 1.81\pi$$

C. Determination of the Initial Velocity Field

From the elastic solution for a concentrated load at the apex of a shell investigators have determined that "r_e" the length over which the initial velocity distribution is felt is approximately $2\sqrt{hR}$ where "h" is the shell thickness.(2) (3) Therefore the initial velocity is sensibly zero for $r = r_e$.

The initial velocity distribution is considered proportional to the elastic static deflection due to a concentrated load at the apex. Because it is difficult to determine these deflections in closed form for a spherical shell it was necessary to approximate the deflection by several functions each one of which were used to determine λM which is the fraction of the responding dome mass attaining the same velocity as the missile immediately after contact. These functions included the following:

1. Linear variation
2. Simple triogonometric variation
3. Variation suggested by a simply supported circular plate under a central concentrated load.
4. Variation suggested by a clamped circular plate under a central concentrated load.

For these cases the numerical values of "λ", v_o and T_o are as shown on the attached Table 1.

where λ = fraction of responding dome mass as described before

V_o = velocity of λM immediately after contact

T_o = initial kinetic energy of the dome

D. Application of the Displacement Bound Theorem

Using the displacement bound theorem it can be shown that:

$$W_o^{\,U.B.} = \frac{T_o}{1.81\pi M_o}$$

where $W_o^{U.B.}$ is the upper bound of the deflection at $r = 0$.

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(2) K. Forsberg and W. Flügge, "Point Load on a Shallow Elliptic Parabaloid," to appear in Journal of Applied Mechanics.

(3) A. Kalnins and P. M. Naghdi, "Propagation of Axisymmetric Waves in an Unlimited Elastic Shell," Journal of Applied Mechanics, 27, 1960, pp. 690-695.

"M_o", the totally plastic moment per unit length, is conservatively developed considering that at plastic collapse the tendons are not carrying any load and that only the 3/8" steel liner acts as reinforcement with a yield strength of 30,000 psi. Therefore M_o = 393,000 lb. ft/ft which results in a conservative lower bound. Considering the previous cases for distribution of initial velocity, the upper bou of displacements are therefore as shown on the attached Table 2.

The average value of 0.97 inches for $W_o^{U.B.}$ is considered to be a reasonable and representative number for an upper bound deflection. It should be noted that this analysis provides only an order of magnitude determination of the upper bound of displacement and based upon comparison with actual displacement of a flat circular plate with "a/R = 0", that is a concentrated in lieu of a ring load, the upper bound errs on the high side.

The conclusion can be drawn on the basis of this analysis that the structural response of the dome does not produce a condition of collapse. This solution does not consider the problem of local material failures which could lead to a more serious problem than the overall structural response.

3. LOCAL MATERIAL FAILURE

A study was made of the problem of local penetration making use of the modified Petry formula, wherein:

$$D = k\ Ap\ V'$$

where D = depth (in feet) of penetration

k = experimentally obtained material's coefficient for penetration

Ap = sectional pressure obtained by dividing the weight of the missile by its maximum cross-sectional area (expressed as pounds per square foot)

V' = velocity factor expressed as $\log_{10} \left(1 + \frac{V^2}{215,000}\right.$

where "V" represents the terminal or striking velocity in feet per second.

On the basis of "k" of 0.0023 the penetrations are as follows:

Case A D = 0.128' = 1.54"
Case B D = 0.237' = 2.85"

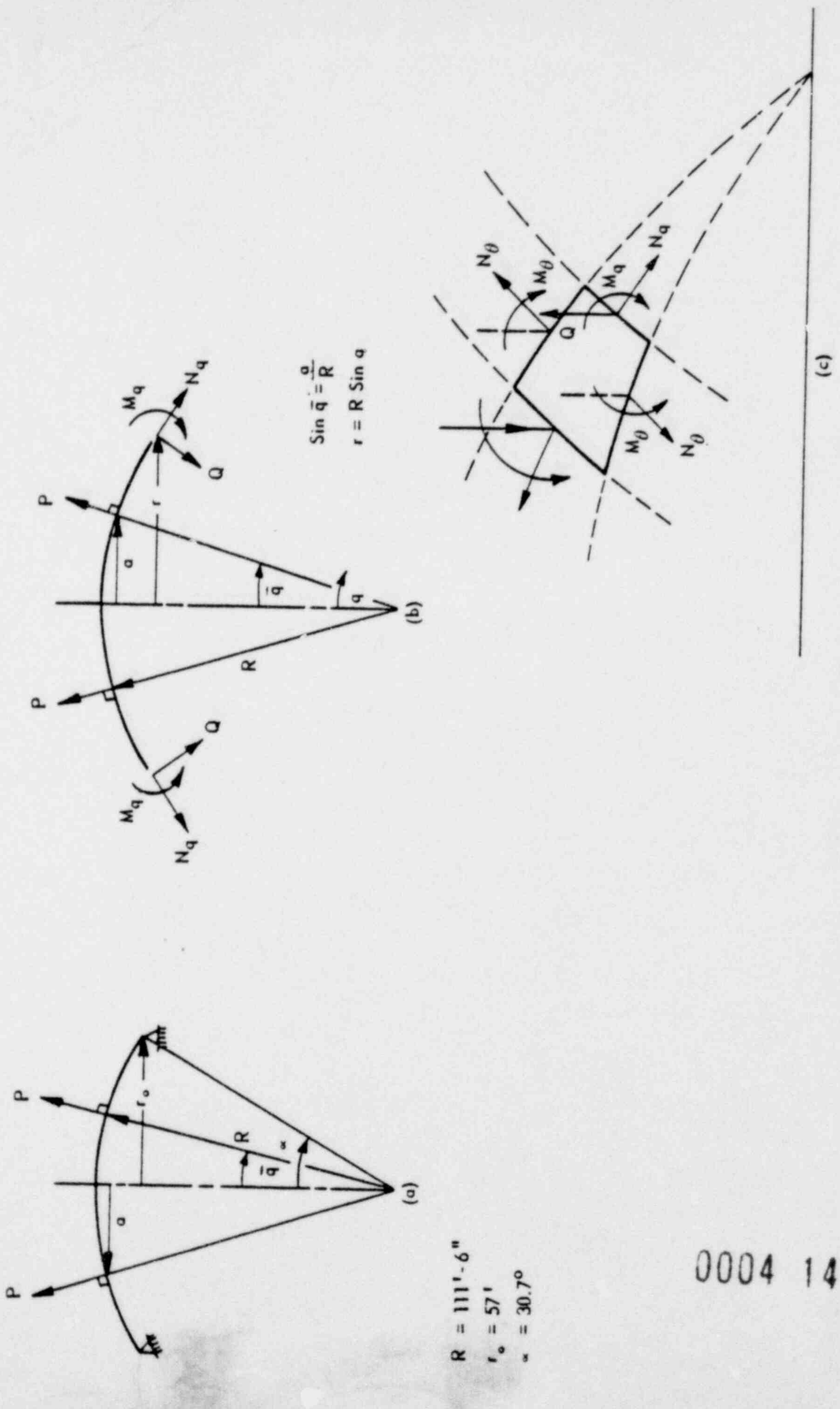
both of which are less than the limit established for valid use of this equation.

TABLE 1

	r_e = 37.0'		
	λ	v_o (fps)	T_o (ft-lbs)
Case 1	0.1667	5.8	0.182×10^6
Case 2	0.172	5.6	0.172×10^6
Case 3	0.228	4.3	0.133×10^6
Case 4	0.130	7.4	0.23×10^6

TABLE 2

	r_e = 37.0'
Case	$W_o^{U.B.}$ (inches)
1	0.995
2	0.925
3	0.715
4	1.245
Average	0.97



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SPHERICAL CAP UNDER A RING
APPENDIX A FIGU

Appendix B

The stability of the reactor containment structure will be verified by means of dynamic elastic analyses for the impingement of the total aircraft.

For the initial dynamic elastic analysis, it is considered that the most unfavorable area of impact is centered around the apex of the dome. Consequently the effect of a large aircraft impingement against the apex of the reinforced concrete dome is being studied by calculating the dynamic response of an elasti solid of revolution to time-dependent forces acting on the area of impact, as shown in Figure 1. The magnitude and duration of the impact forces are determined according to the mass, structural characteristics, and vertical component of the velocity of the aircraft. The grid for the finite-element idealization of the dome is given in Figure 2. Based on virtual work, the equilibri equations for the entire structure are formulated as follows:

$$(m)\ddot{\vec{d}} + \left[\alpha\,(k) + 2\beta(m)\right]\dot{\vec{d}} + (k)\,\vec{d} = \vec{f}$$

where:

(m) = mass matrix

$\alpha(k) + 2\beta(m)$ = damping matrix

(k) = stiffness matrix

$\vec{d}$ = displacement vector

Dots indicate time derivatives. These equations are integrated by means of a Predictor-Corrector method with a Runge-Kutta-Gill starting procedure using a computer program developed at Franklin Institute Research Laboratories. FIRL is acting as Consultant to GAI in connection with this problem.

Evaluation of the results, in conjunction with a procedure previously proposed by Dr. Steven Batterman and utilized in the study decribed in Appendix "B" to calculate limit (final) displacements in a rigid-perfectly plastic shell will lead to safe estimates of the size and velocity of the largest aircraft that may impinge upon the containment building without jeopardizing its structural integrity.

An analysis was performed considering the following loading condition (Refer to Figure 1 of Appendix B for nomenclature):

P_n = 200 psi

t_1 = 0

$t_2 = t_3 > 0.16$ sec.

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The diameter of the impact area was considered to be 16 feet. In order to obtain a preliminary indication of displacements, this analysis was performed on the basis of the conservative assumption of no internal damping. Also to simplify the solution, the steel liner was not considered.

The equivalent diameter of the fuselage of the B707 type aircraft is approximately 13.3 ft. The assumed impact area is considered to be reasonably indicative of the impact area of such an aircraft considering the significant distortion which will occur to the fuselage as well as the load distribution afforded by the concrete to the middle surface of the dome. 9

The loading pressure of the 300,000 lb aircraft without impact would be 10.4 psi. Therefore the loading considered represents a constant deceleration of the impacting aircraft of 20g. That means that the entire aircraft remains intact and all elements decelerate at 20g. This represents an equivalent load on the fuselage of the aircraft of 5,800,000 lb, which it is estimated would result in gross collapse of the aircraft. Therefore, this analysis is considered to be based upon a conservative evaluation of the hypothetical loading.

The analysis indicates that the maximum displacements and stresses both of which occur at the center of impact (i.e. the apex of the dome) are as follows:

	Displacement (in.)	Stress (psi)
Maximum	-0.98	-2264 + 354
Static	-0.66	-1832 + 346

The displacement at the apex of the dome as a function of time is depicted on Figure 3. This graphical representation of displacements indicates that the most severe duration of the loading is equal to or greater than 0.16 seconds. The static displacement is that produced by the 200 psi loading applied for an infinite period. Figure 4 depicts the displacements and stresses which occur at time 0.16 seconds after impact which is the instant of maximum displacement at the dome apex.

The loading considered in this analysis represents the case where the aircraft with all its engines, fuel tanks, and wings remains intact and the total resulting load is applied on the nose of the aircraft. It has been concluded that the resultant load due to one or both wings shearing off the fuselage and impacting against the dome will result in a less critical condition than that previously considered. The static displacement of the dome at the point of impact of one engine is approximately 0.1 inches. The displacement results from a loading equivalent to a 200g deceleration 1
applied for an infinite period. The physical separation of engines is sufficient to produce only a minimal increase in displacements due to the impact of multiple engines. This conclusion is further reinforced by the fact that the wings or engines upon separation from the remainder of the aircraft would be traveling at a significantly reduced speed. A further analysis will be performed to determine the dynamic response due to the impact of multiple objects representing the engines to confirm the foregoing conclusion.

The conclusion can therefore be safely drawn that the dome will not collapse due to the conservatively established loading even if no consideration is given to the significant damping which would obviously occur. 9

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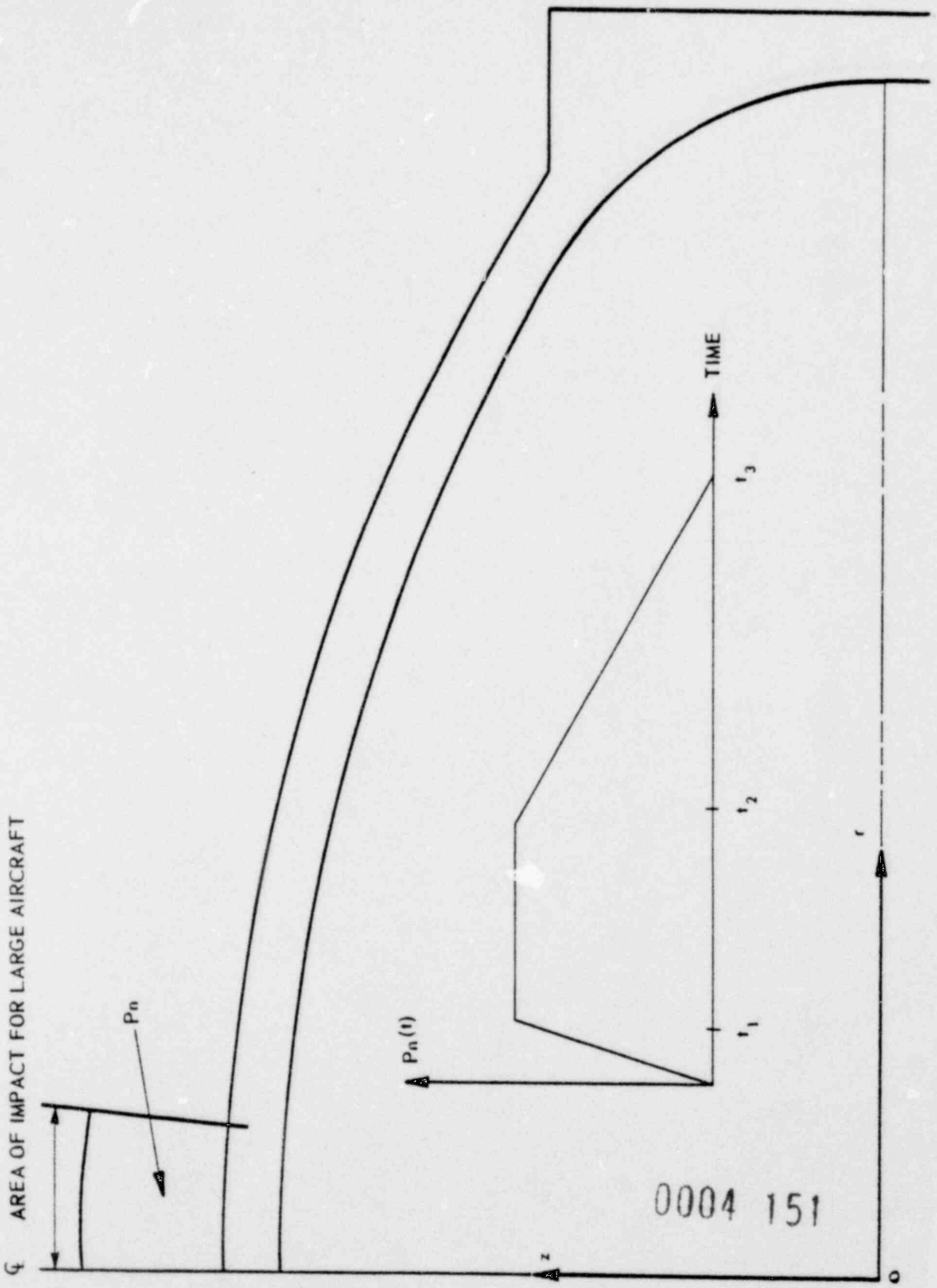
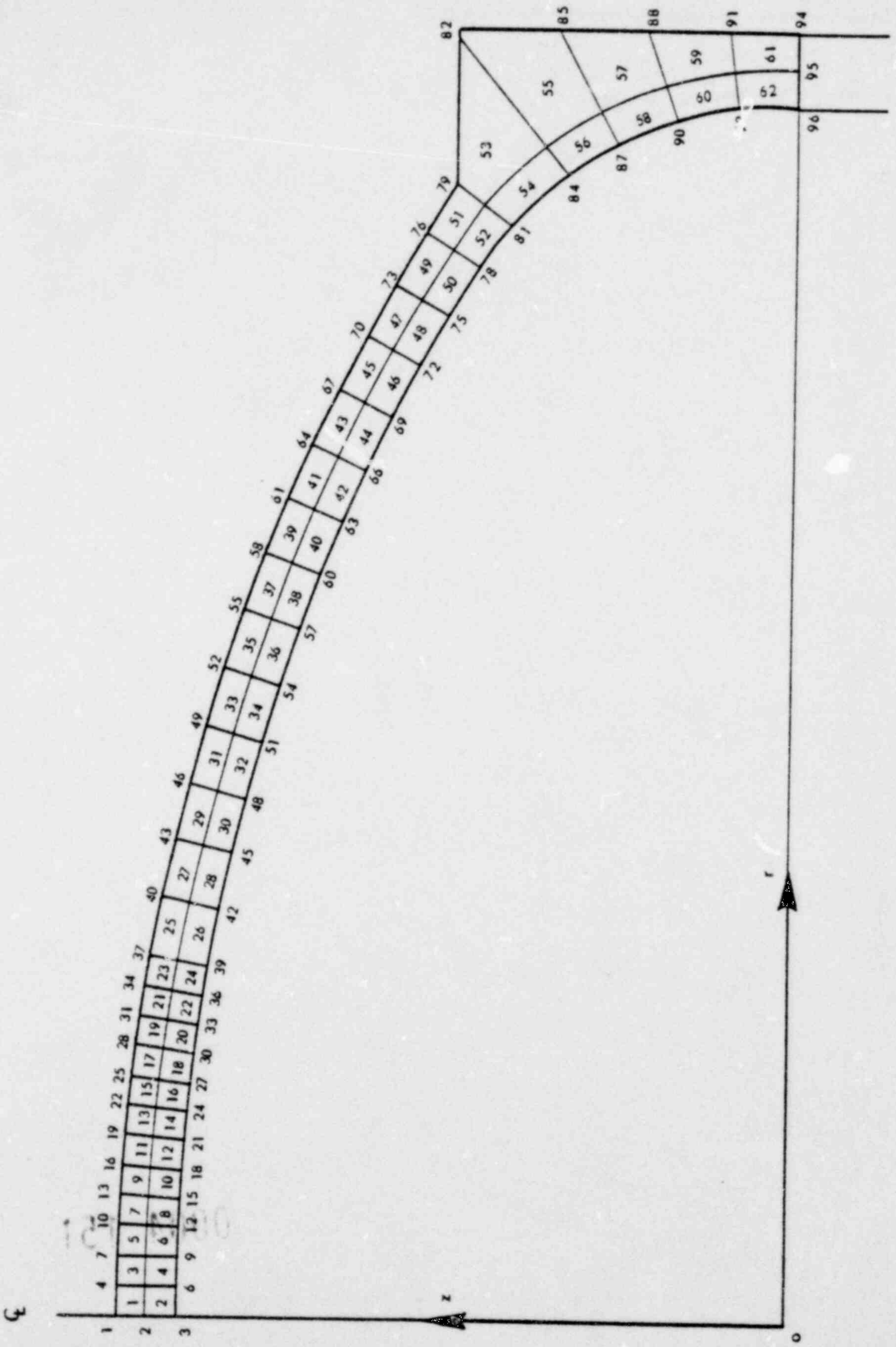
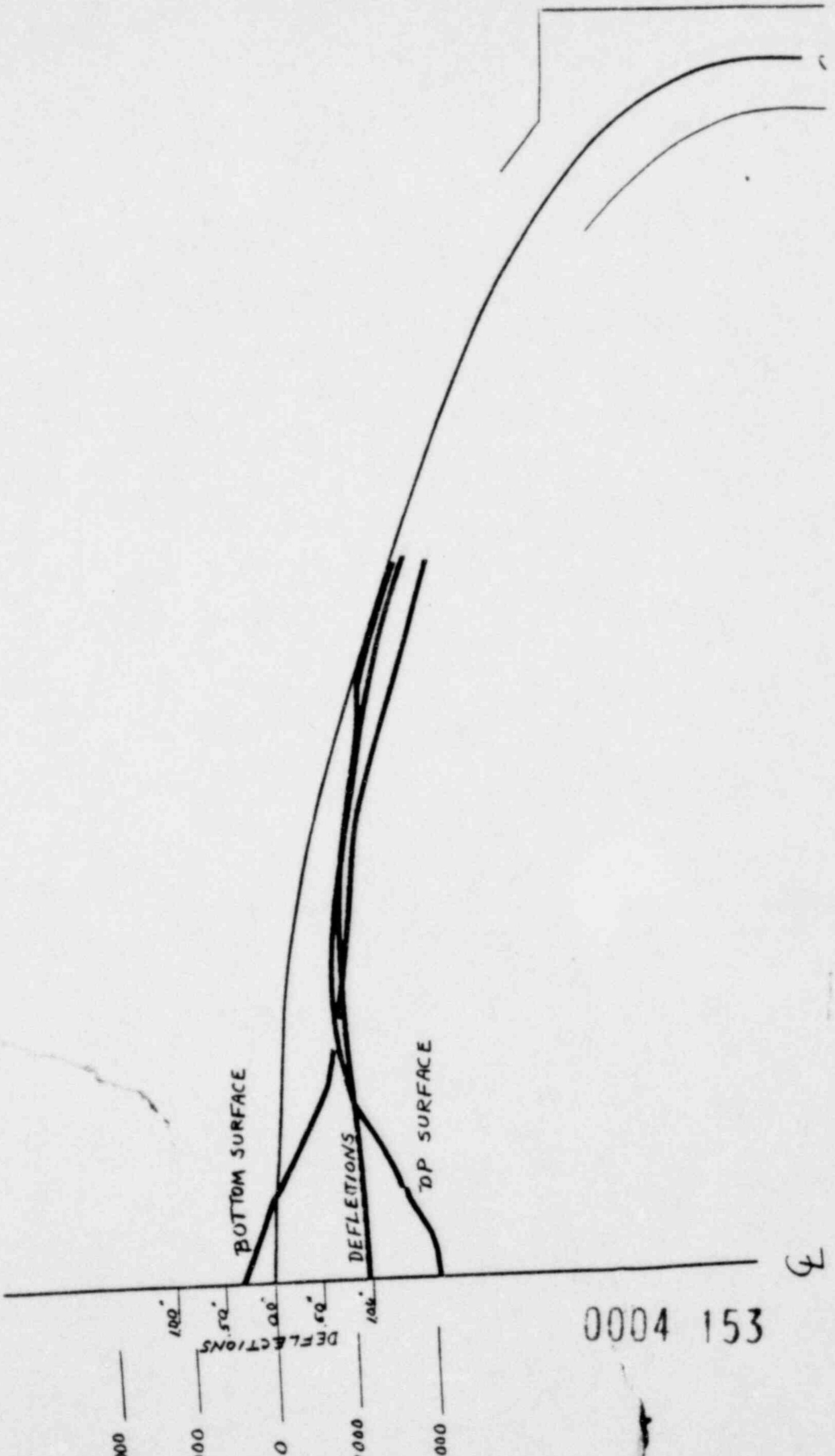


SPATIAL AND TIME DISTRIBL
OF LOAD ON SHELL
APPENDIX B FIGL



RID FOR DYNAMIC FINITE ELEMENT ANALYSIS OF
AIRCRAFT IMPINGEMENT ON DOME

PPENDIX B FIGURE 2



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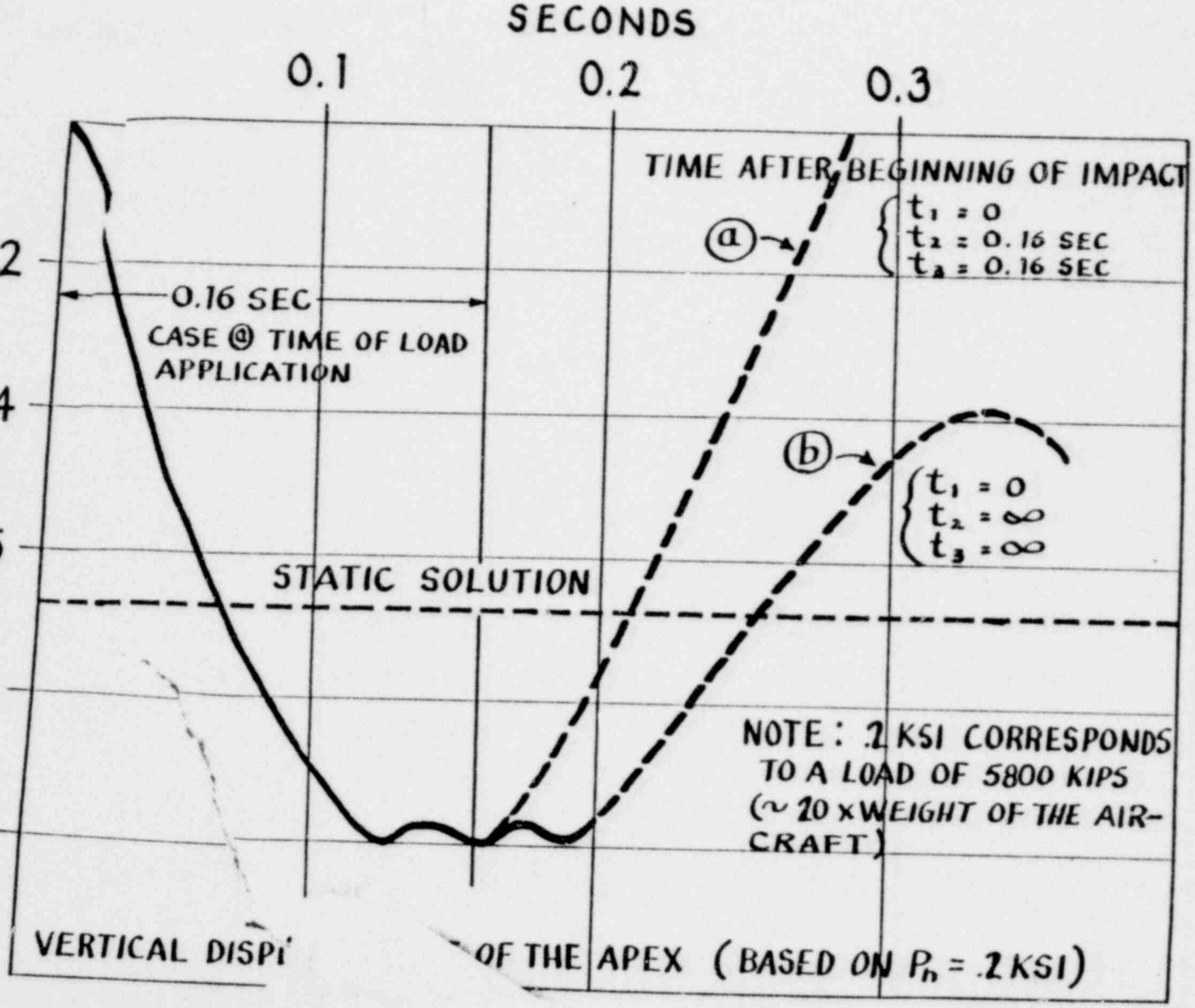
TIONS AND STRESSES FOR AIRCRAFT
GEMENT FOR TIME = 0.16 SECONDS

FIGURE 4

IX B



EFFECT OF AIRCRAFT IMPINGEMENT
DOME OF CONTAINMENT STRUCTUR
APPENDIX B

FIGUR

AMEND. 9 (3-6-68)