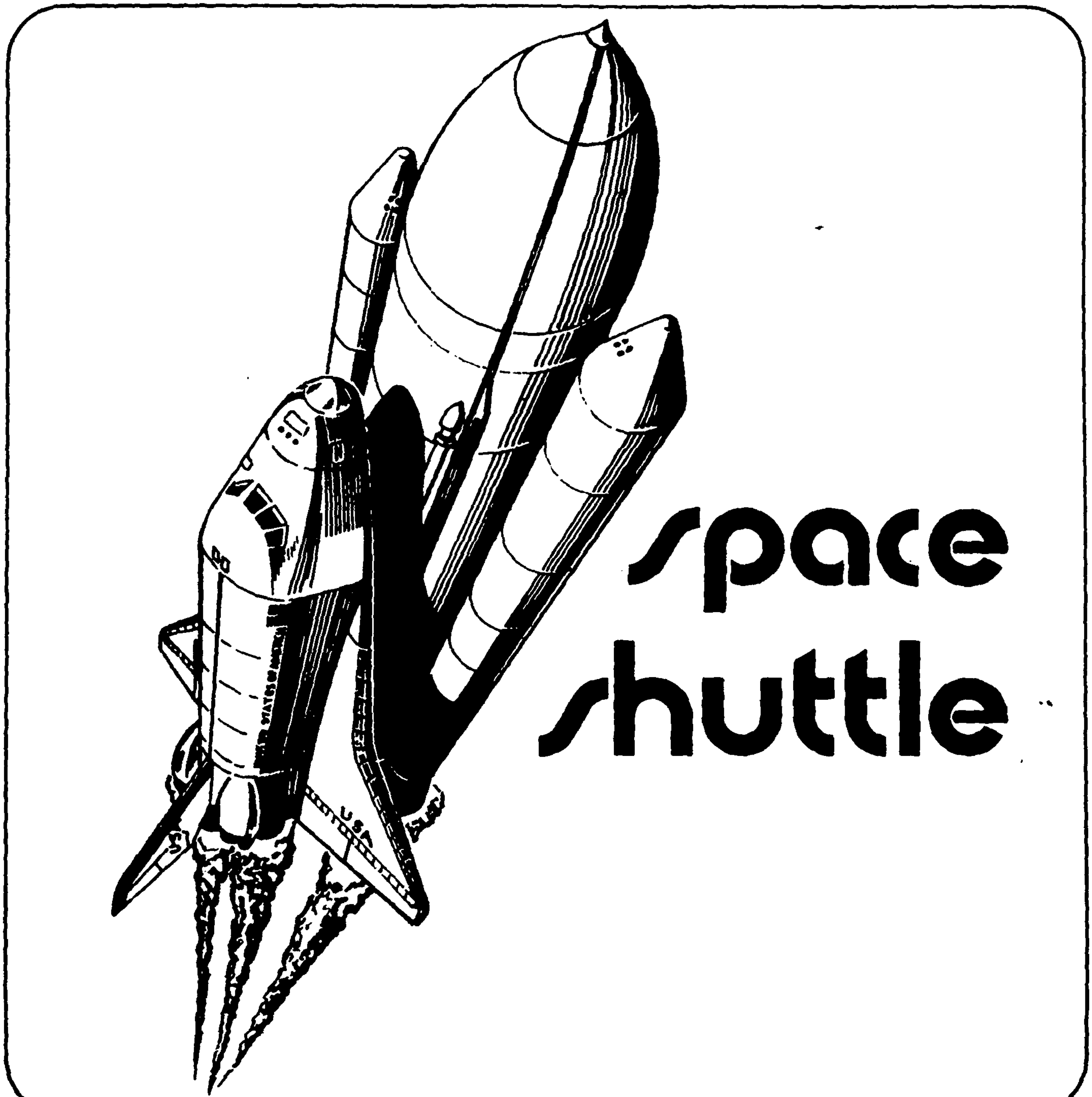
NASA
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

FINAL ENVIRONMENTAL STATEMENT FOR THE SPACE SHUTTLE SOLID ROCKET MOTOR DDT&E PROGRAM AT THIOKOL/WASATCH DIVISION PROMONTORY, UTAH

JANUARY, 1977



MSFC - Cover 5 (March 1976)

SUMMARY

ENVIRONMENTAL STATEMENT
FOR THE
SPACE SHUTTLE SRM DDT&E PROGRAM

( ) Draft (X) Final Environmental Statement

Responsible Federal Agency: National Aeronautics and Space Administration
Marshall Space Flight Center (MSFC),
Solid Rocket Booster Project Office

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National Aeronautics and Space Administration
Marshall Space Flight Center
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AC-205, 453-3651 (FTS 872-3651)

1. Type of Action: (X) Administrative ( ) Legislative Action

2. Brief Description of Action and Purpose: The proposed action is to process, test, and deliver Solid Rocket Motors (SRMs) in support of the National Aeronautics and Space Administration (NASA) Space Shuttle Program. Accomplishment of the proposed action involves the processing of nineteen (19) and static testing of seven (7) SRMs at Thiokol/Wasatch Division, Promontory, Utah; the delivery of twelve (12) SRMS to NASA/Kennedy Space Center, Florida; and the delivery of two (2) inert and three (3) empty SRMs to NASA/Marshall Space Flight Center, Alabama.

   The Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) Program at Thiokol/Wasatch Division is scheduled for completion in mid-1980. The timely completion of the DDT&E activity is necessary for NASA to meet the Space Shuttle Program objective of the first manned orbital flight in 1979. The processing, test functions, and facilities are essentially identical to those used by Thiokol in previous solid rocket motor programs.

3. Summary of Environmental Impacts and Adverse Environmental Effects: Normal Solid Rocket Motor (SRM) test firings, and possibly abnormal, will result in the release of air pollutants, which will cause a temporary, localized small degradation of air quality downwind from the test site. The predicted change in air quality is not expected to have any significant adverse effects on the flora, fauna or human population. Test firing activities will subject a large area to moderate sound levels of predominately low frequencies. No adverse effects are anticipated to the environment or to human health or safety. The SRM processing and testing activities to be performed at the Thiokol/Wasatch facility are similar to those of past programs. The performance of the proposed action at the Thiokol facility will have a stabilizing economic effect on the local communities.

4. Summary of Major Alternatives Considered: The Space Shuttle Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) activity is a weighted optimum, considering the overall Space Shuttle Program. The

alternatives are: no action, alternate methods of solid propellant waste disposal, choice of an alternate solid propellant, alternate SRM static test firing plans, the use of an HCl washout scrubber device, and alternate transportation methods and routes. None of these alternatives are currently considered technically, economically, or environmentally superior.

5. <u>Comments requested from:</u>

Council on Environmental Quality (CEQ)
Department of Agriculture (DoA)
Department of Air Force
Department of Commerce (DoC)
Department of Defense (DoD)
Department of Interior (DoI)
Department of Transportation (DoT)
Energy Research and Development Administration (ERDA)
Environmental Protection Agency (EPA)
Regional Administrator VIII U.S. Environmental Protection Agency
Office of Management and Budget (OMB)

Utah Air Conservation Committee
Utah Department of Natural Resources

Mayor's Office, Brigham City, Utah
Mayor's Office, Tremonton, Utah
Bear River Migratory Bird Refuge
Four Corner Environmental Research Institute
Golden Spike National Historic Site Office

Alabama Clearing House
Arkansas Clearing House
Florida Clearing House
Georgia Clearing House
Kansas Clearing House
Louisiana Clearing House
Mississippi Clearing House
Missouri Clearing House
Nebraska Clearing House
Tennessee Clearing House
Utah Clearing House
Wyoming Clearing House

6. <u>Comments received from:</u>

Department of Agriculture (DoA)
Department of Air Force
Department of Interior (DoI)
Energy Research and Development Administration (ERDA)
Environmental Protection Agency (EPA)
State of Georgia
State of Mississippi
State of Nebraska
State of Wyoming

7. Draft Statement Published September, 1976
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1.0 DESCRIPTION OF PROPOSED ACTION AND STATEMENT PURPOSE

1.1 Background and Purpose

On January 5, 1972, the President announced that the United States should proceed at once with the development of a new Space Transportation System (STS). The STS primary vehicle, better known as the Space Shuttle, is piloted and reusable with the capability of carrying large payloads to and from Earth Orbit.

The Space Shuttle (Figure 1) consists of a manned reusable Orbiter, expendable-propellant hydrogen/oxygen External Tank (ET), and two recoverable and reusable Solid Rocket Boosters (SRBs). It will have three main liquid fueled rocket engines, an Orbital Maneuvering System, and a cargo bay 18.3m (60 ft) long by 4.6m (15 ft) in diameter with a payload capability up to 29,500 kg (65,000 lb).

At launch, both the Solid Rocket Boosters (SRBs) and the Orbiter liquid rocket engines will burn simultaneously. When the complete vehicle attains an altitude of about 50 km (30 mi) the SRBs will be separated, and subsequently recovered from the ocean. The External Tank is jettisoned before the Space Shuttle Orbiter goes into orbit. The Orbital Maneuvering System of the Orbiter is then used to obtain the desired orbit. The Orbiter with its crew and payload will remain in orbit to carry out its mission, normally about seven days, but when required, as long as 30 days. When the mission is completed, the Orbiter will return to Earth for reuse.

Each Solid Rocket Booster (SRB) consists of several subsystems: the Solid Rocket Motor (SRM), structures, separation motors, electrical and instrumentation, thrust vector control and recovery. The SRM is composed of the segmented motor case, solid propellant, ignition system, and nozzle. The Solid Rocket Boosters (SRBs) operate in parallel with the Orbiter liquid engines during the boost phase of flight. They provide impulse and thrust vector control capability in conjunction with the Orbiter liquid engines until SRM burnout. Following burnout, the two SRBs are separated from the vehicle and reenter the Earth's atmosphere. Initial deceleration forces are created by aerodynamic drag. Parachutes are ultimately deployed to provide additional deceleration forces which reduce the SRB velocity to acceptable water impact conditions and, therefore, permit recovery, refurbishment, and reuse of a majority of the SRB subsystems.

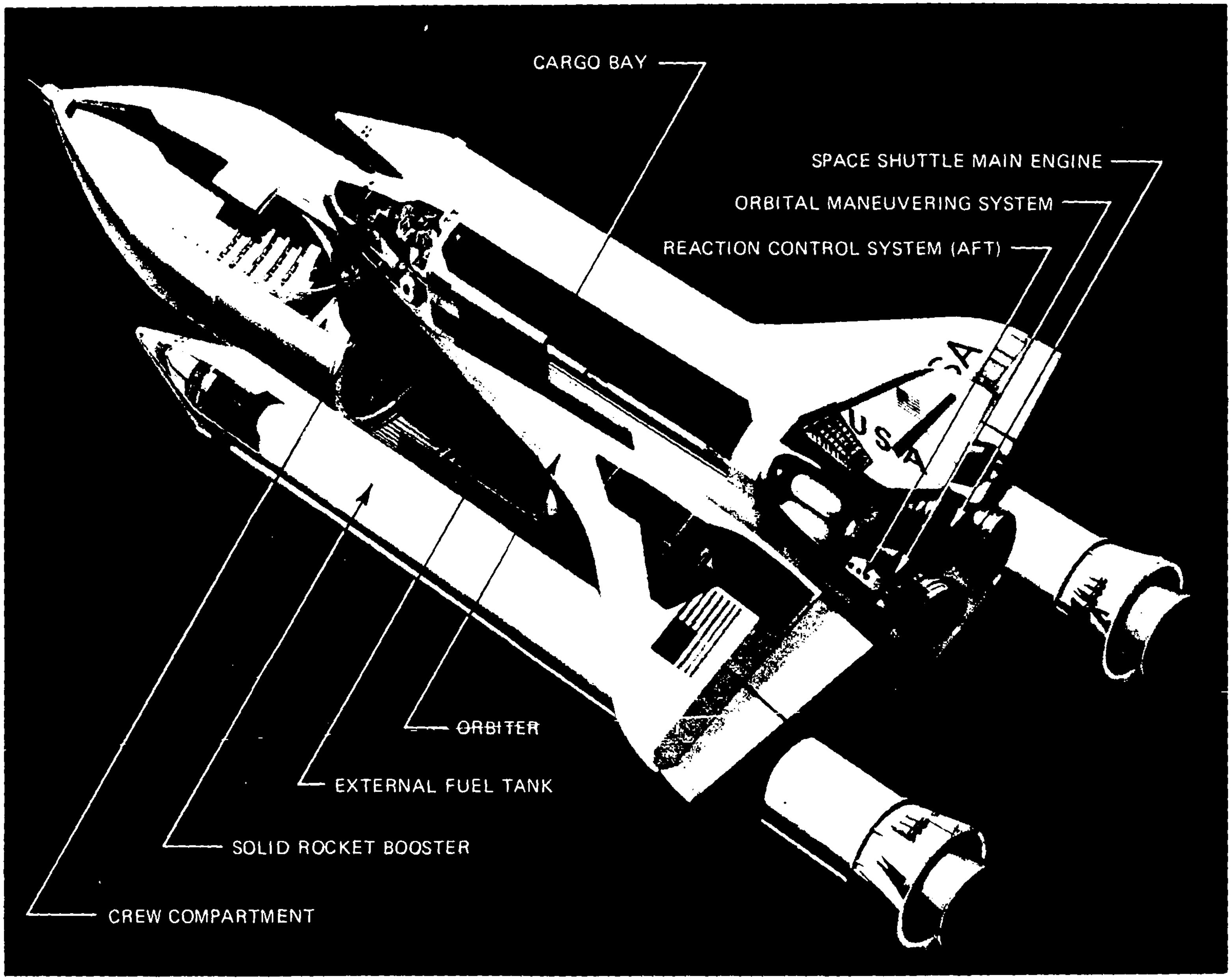


FIGURE 1. SPACE SHUTTLE VEHICLE

The Environmental Statement(1)* for the Space Shuttle Program was issued in July 1972, by the National Aeronautics and Space Administration (NASA) as required by the National Environmental Policy Act (NEPA) of 1969 and the April 23, 1971, guidelines (then in force) of the Council on Environmental Quality (CEQ) on statements covering proposed major Federal actions that might have a significant effect on the quality of the human environment. The Environment Statement for the Space Shuttle Program addressed both development and operational aspects of the launch systems without regard for the location of those activities, many of which were not then known. Since then, specific locations for particular development and operational activities have been identified and, where necessary, environmental impact statements prepared and circulated for comment.

The environmental statement submitted herein addresses the Space Shuttle Solid Rocket Motor (SRM) Processing, Static Test Firings, and Delivery activities. These are the major activities of the Space Shuttle SRM Design, Development, Test and Evaluation (DDT&E) Program at the Thiokol/Wasatch Division, Promontory, Utah. The other activities in the SRM DDT&E Program which are considered environmentally insignificant include facilities activation support, flight test and ground operations support, logistics support and sustaining engineering for demonstrating initial operational capability.

Marshall Space Flight Center (MSFC) of the National Aeronautics and Space Administration (NASA) has overall responsibility for the development of the Space Shuttle SRM. The Shuttle SRM DDT&E Program was awarded to the Thiokol Corporation, Wasatch Division, Promontory, Utah.

1.2 Proposed Action

The proposed action is to process, test, and deliver Solid Rocket Motors (SRMs) in support of the National Aeronautics and Space Administration (NASA) Space Shuttle Program. Accomplishment of the proposed action involves the processing of nineteen (19) and static testing of seven (7) SRMs at Thiokol/Wasatch Division, Promontory, Utah; the delivery of twelve (12) SRMs to NASA/Kennedy Space Center (KSC), Florida; and the delivery of two (2) inert and three (3) empty SRMs to NASA/Marshall Space Flight Center (MSFC), Alabama.

*Superscript numbers refer to References, which are shown in Appendix A. Also, note that abbreviations used herein are given in Appendix B, and Appendix C lists metric/English unit conversion factors.

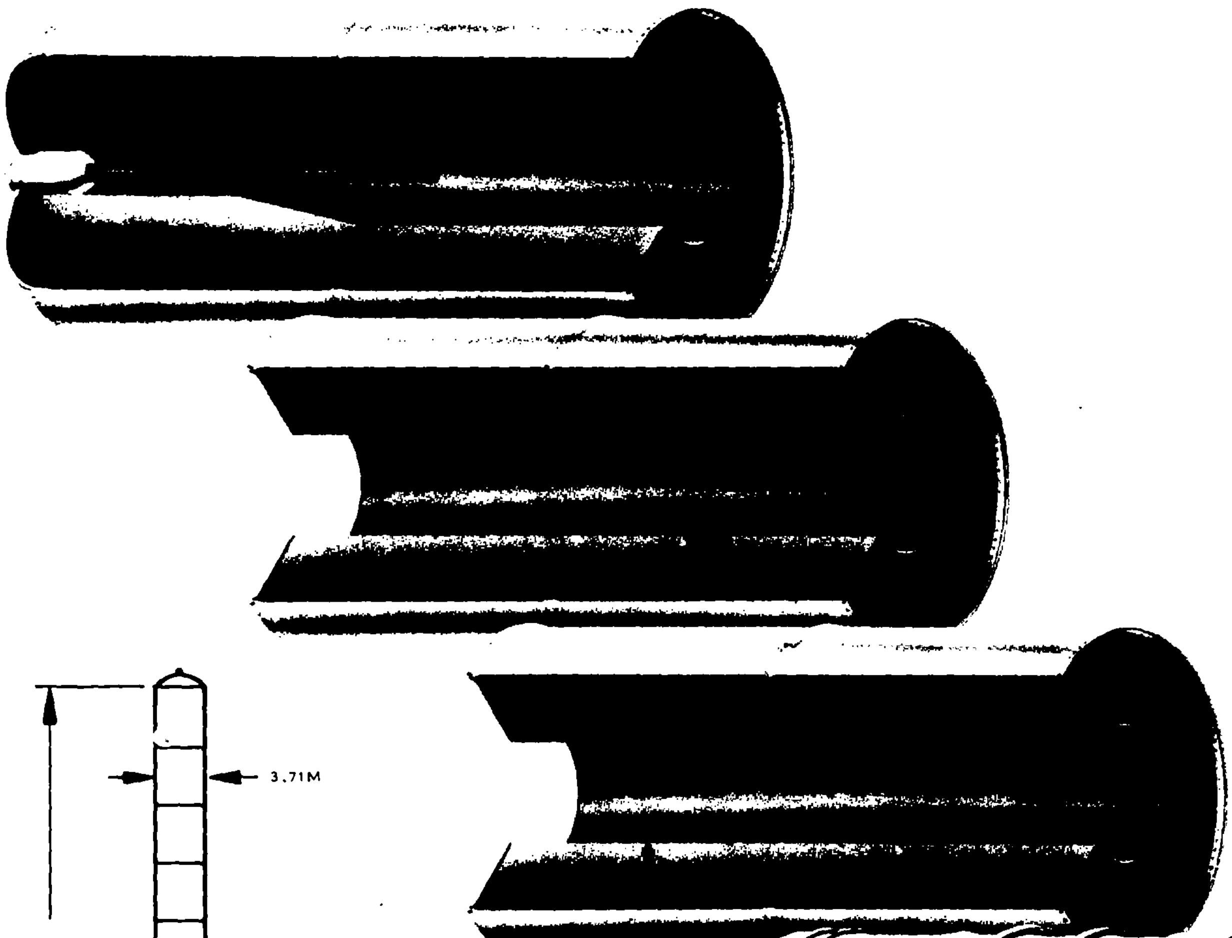
The processing of the first Solid Rocket Motor (SRM) case at Thiokol is scheduled to begin in the later part of 1976, followed by the first static test firing in July 1977. The SRM Design, Development, Test and Evaluation (DDT&E) Program at Thiokol/Wasatach is scheduled for completion in mid-1980. The timely completion of the SRM DDT&E Program is necessary for NASA to meet the Space Shuttle Program objective of the first manned orbital flight in 1979. The SRM processing and static test operations are essentially identical to those used by Thiokol in previous solid rocket motor programs at the Wasatch Division.

1.2.1 SRM Design Characteristics

The SRM design is illustrated in Figure 2; a thrust-time profile and a summary mass breakdown also are presented. The design reflects knowledge and experience gained in the fabrication and processing of large SRMs and their components. Conservative design margins have been incorporated in areas where past failure modes indicate potential uncertainties. The design is comprised of a segmented, weld-free case, water impact stiffening and ET/SRB attach rings; a single movable nozzle; case bonded polybutadiene acrylic acid acrylonitrile (PBAN) composite propellant; an igniter; elastomeric internal insulating materials; liner; inhibitor; and instrumentation. Refer to Appendix D for details of the SRM design.

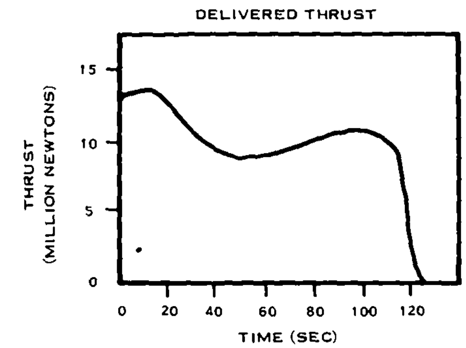
The steel cases are assembled into four casting and shipping segments (Figure 2). The motor consists of: a forward segment, two interchangeable cylindrical segments, and an aft segment incorporating provisions for nozzle attachment and attachment to the External Tank. The nozzle (less the aft extension) will be assembled to the aft segment for shipment, as will the igniter (less initiating squibs) to the forward segment. The segments are readily transportable by rail. This approach will result in transportation and launch site operation cost savings. Launch site receiving, handling, subassembly, and final assembly in the KSC Vertical Assembly Building (VAB) are simplified and expedited.

The motor has a nominal outside diameter of 3.7m (12.2 ft) and is 38m (125 ft) long. It produces a total vacuum impulse of $\sim 1300 \times 10^6$ N-sec (290×10^6 lb-sec) over a burn time of 122 sec. Initial sea level thrust is $\sim 11.6 \times 10^6$ N (2.6×10^6 lb). Vacuum specific impulse (thrust/mass flow rate) is ~2570 m/sec (262 sec) with a nozzle expansion ratio (exit area/throat area) of 7.16:1. The total loaded motor mass is ~570,000 kg (1.26×10^6 lb), with ~504,000 kg (1.1×10^6 lb) being solid propellant. The maximum expected operating chamber pressure is ~660 N/cm^2 (960 psi).



TYPICAL MASS DATA (KG)

	FORWARD SEGMENT	CENTER SEGMENT (2 REQ)	AFT SEGMENT
IGNITER	300	--	--
CASE	11,805	10,119	13,477
PROPELLANT	135,941	123,803	121,538
INSULATION	2,266	577	3,005
INHIBITOR	72	247	121
LINER	178	166	192
RACEWAY	73	73	56
NOZZLE	--	—	7,262
	150,635	134,985	145,651
		566,256	
ATTACH PROVISIONS		138	
TRANSDUCER		1	
INERT CONTINGENCY		1,718	
TOTAL SRM MASS		568,113	



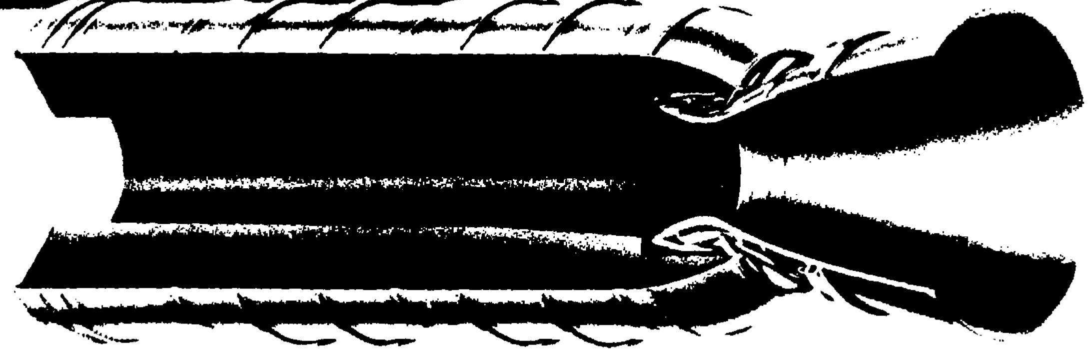


FIGURE 2. SOLID ROCKET MOTOR (SRM)

1.2.2 SRM Processing Facilities

The Space Shuttle Solid Rocket Motor DDT&E Program will be conducted utilizing existing facilities at Thiokol's Wasatch Division plantsite, Promontory, Utah. These facilities are contained on a 77-km^2 (30 mi^2) site approximately 18 km (11 mi) from the northern-most portion of the Great Salt Lake and about 32 km (20 mi) from Brigham City, Utah (see Figure 3). Most SRM processing and testing activities will be performed in two of the three major plantsite areas; namely, the R&D Area (Figure 4) and the Testing Area (Figure 5). Facilities in the third major area, Air Force Plantsite Number 78 (Figure 6), will be employed for SRM ammonium perchlorate grinding (oxidizer ingredient in the SRM propellant - see Appendix D).

In accordance with present practice, a preventative maintenance schedule for facilities used in the Shuttle SRM DDT&E Program will be established to assure continued reliability. Industrial practice, manufacturers' recommendations, government regulations, and in-plant history are used to determine preventative maintenance requirements. Maintenance personnel comply with the Maintenance Manual and the preventative maintenance checklists in performing designated tasks.(2) Facility engineers are cognizant of OSHA and EPA regulations. Thiokol/Wasatch facilities have been reviewed and all requirements have been met.(3) Facilities housing hazardous operations are properly identified and sited according to safety regulations.(4) All facilities, where required, are equipped with adequate control devices to prevent deleterious discharges to the atmosphere or to the ground water and meet the requirements of State and Federal agencies having jurisdiction. Appendix E briefly describes processing facilities that will be used in the Space Shuttle SRM DDT&E Program.

1.2.3 SRM Processing Operations

The SRM processing operations are illustrated within one overall SRM manufacturing flow chart presented in Figure 7. The overall manufacturing plan employs state-of-the-art techniques; such techniques are currently used on two major ICBM programs and were previously used on the 156-inch diameter SRM program. The Space Shuttle SRM processing operations begin with receipt of the case segments at Thiokol/Wasatch. The case is prepared, insulated, lined, and cast with propellant; then, the propellant is cured and the motor is finished to the planned

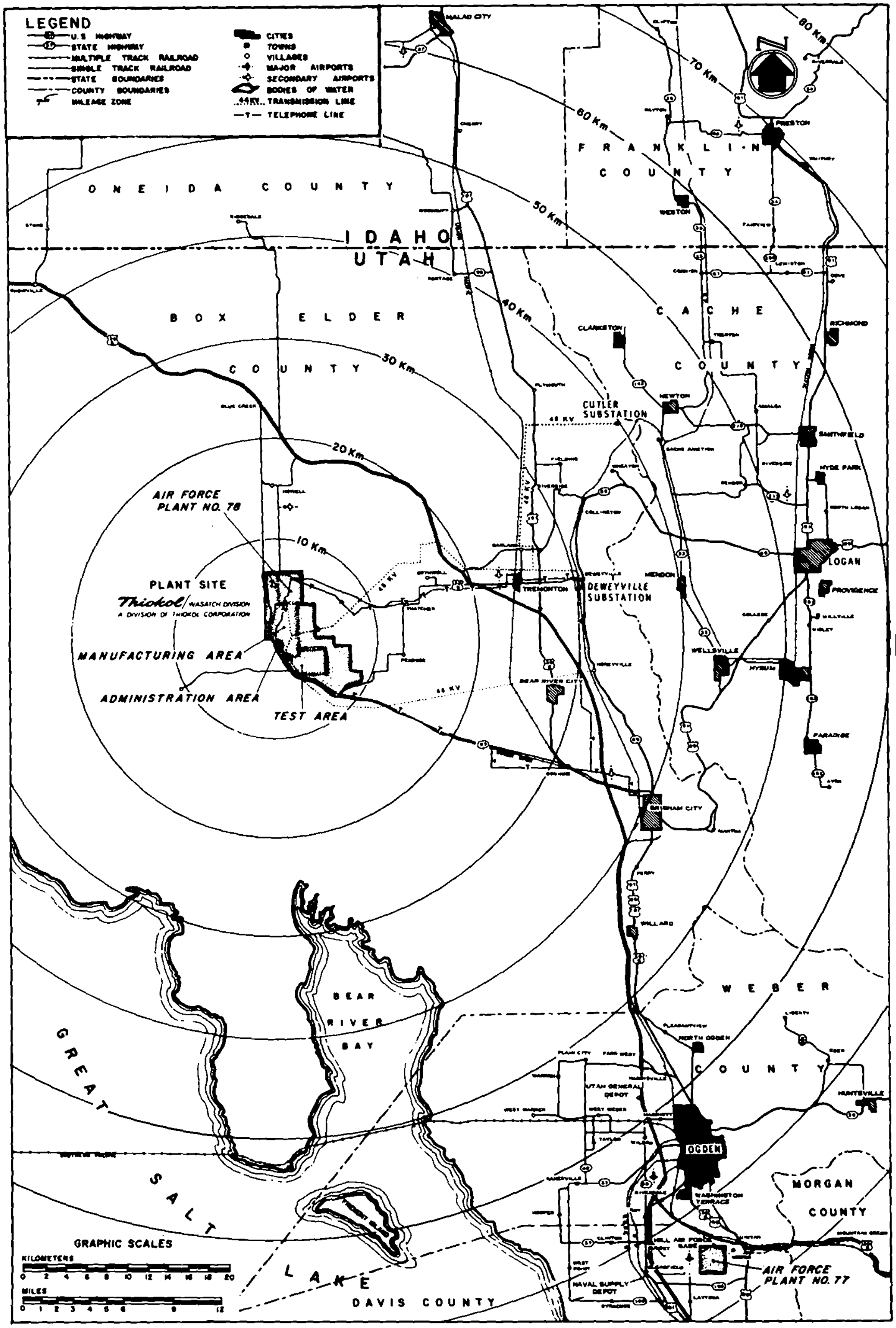


FIGURE 3. THIOKOL/WASATCH PLANTSITE AREA

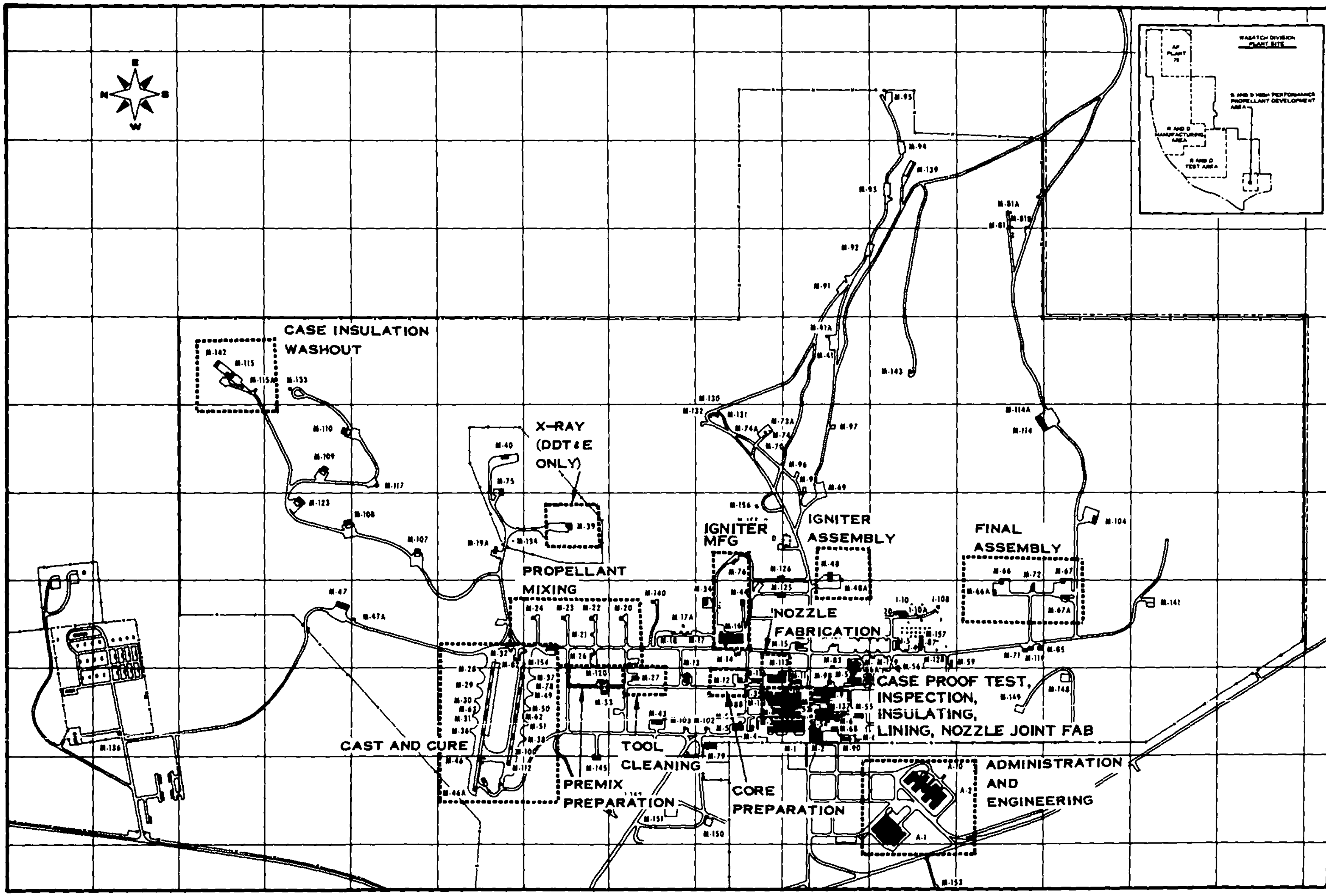


FIGURE 4. THIOKOL/WASATCH R&D AREA

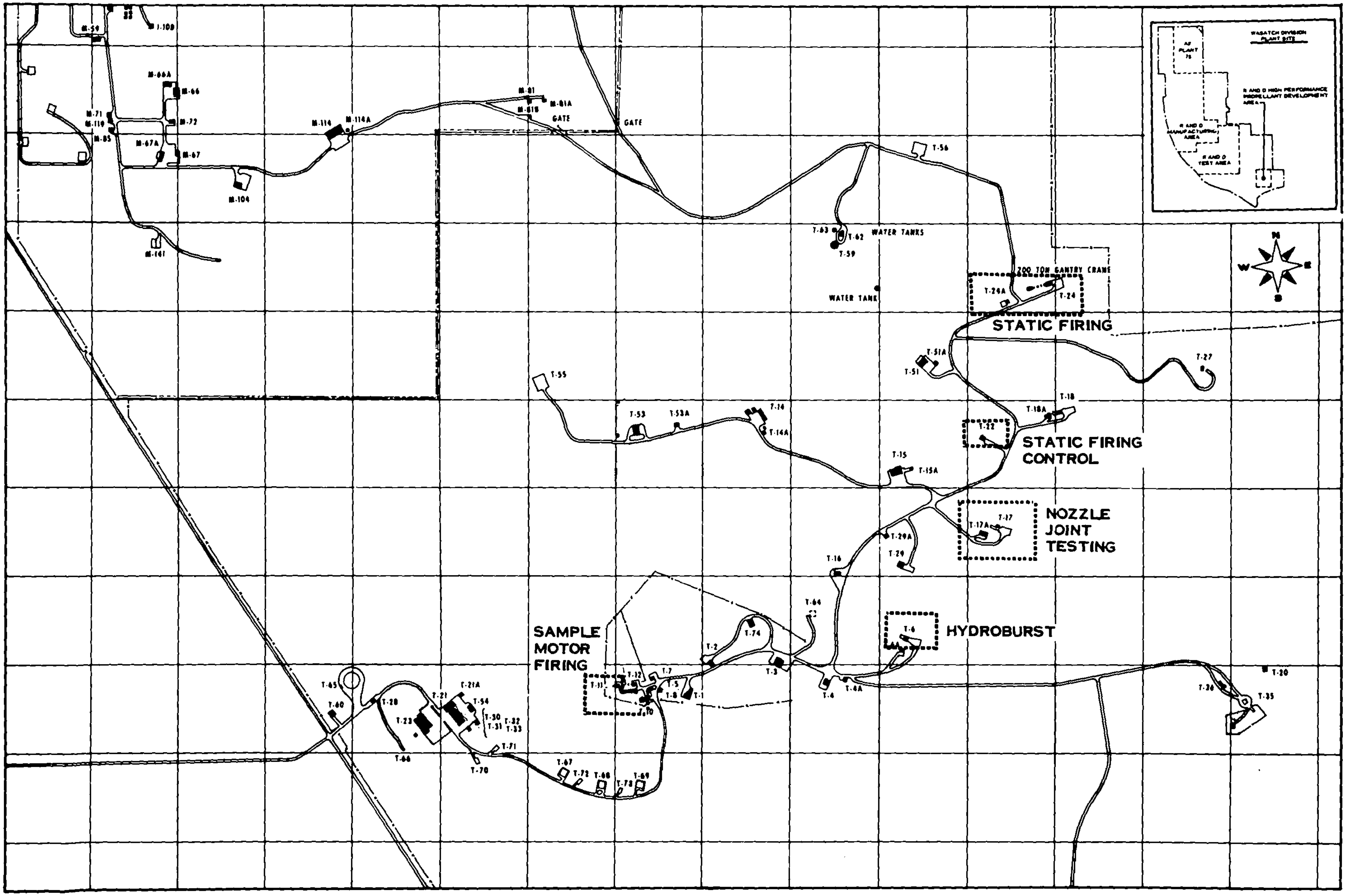


FIGURE 5. THIOKOL/WASATCH TEST AREA

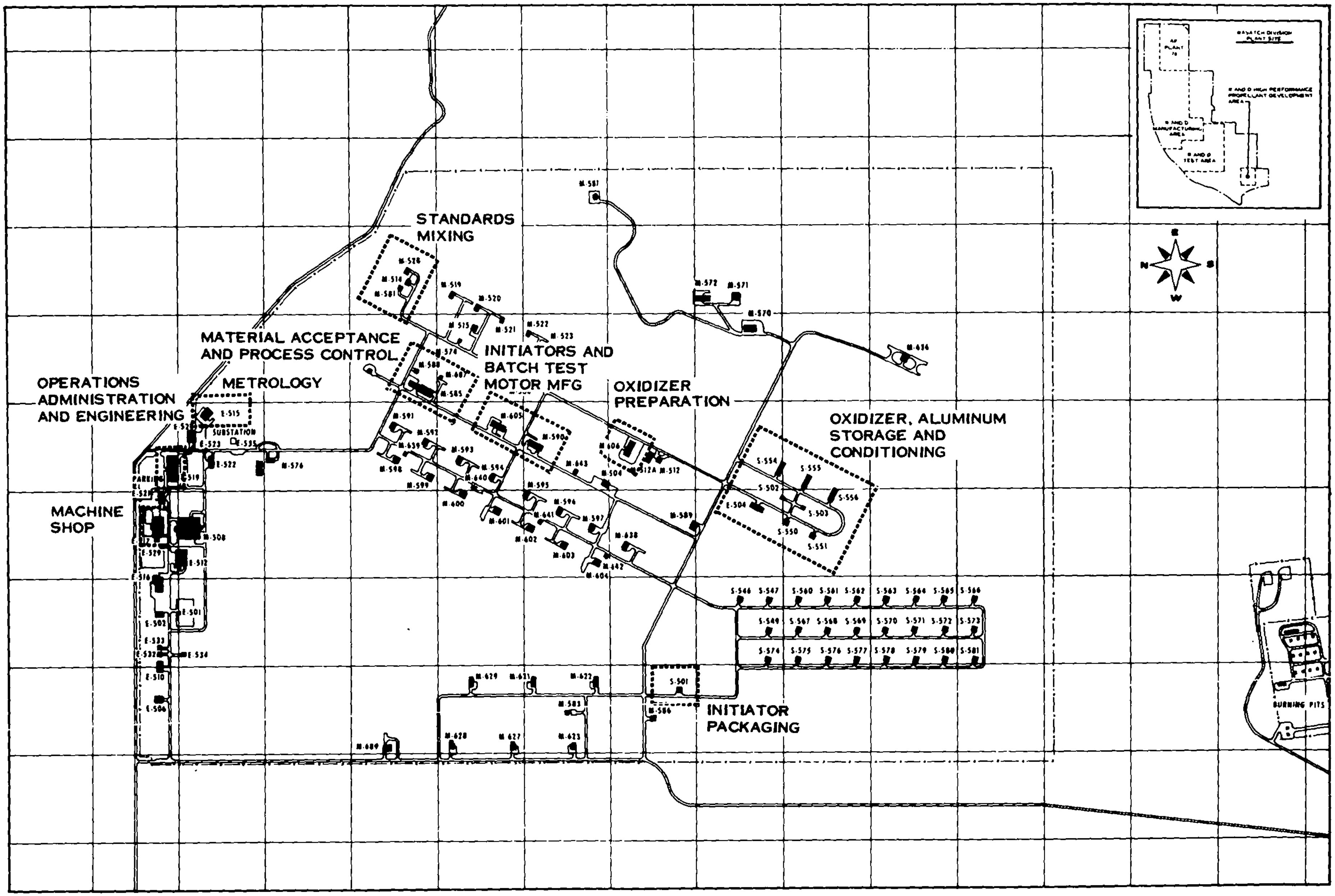


FIGURE 6. THIOKOL/WASATCH AIR FORCE PLANT 78

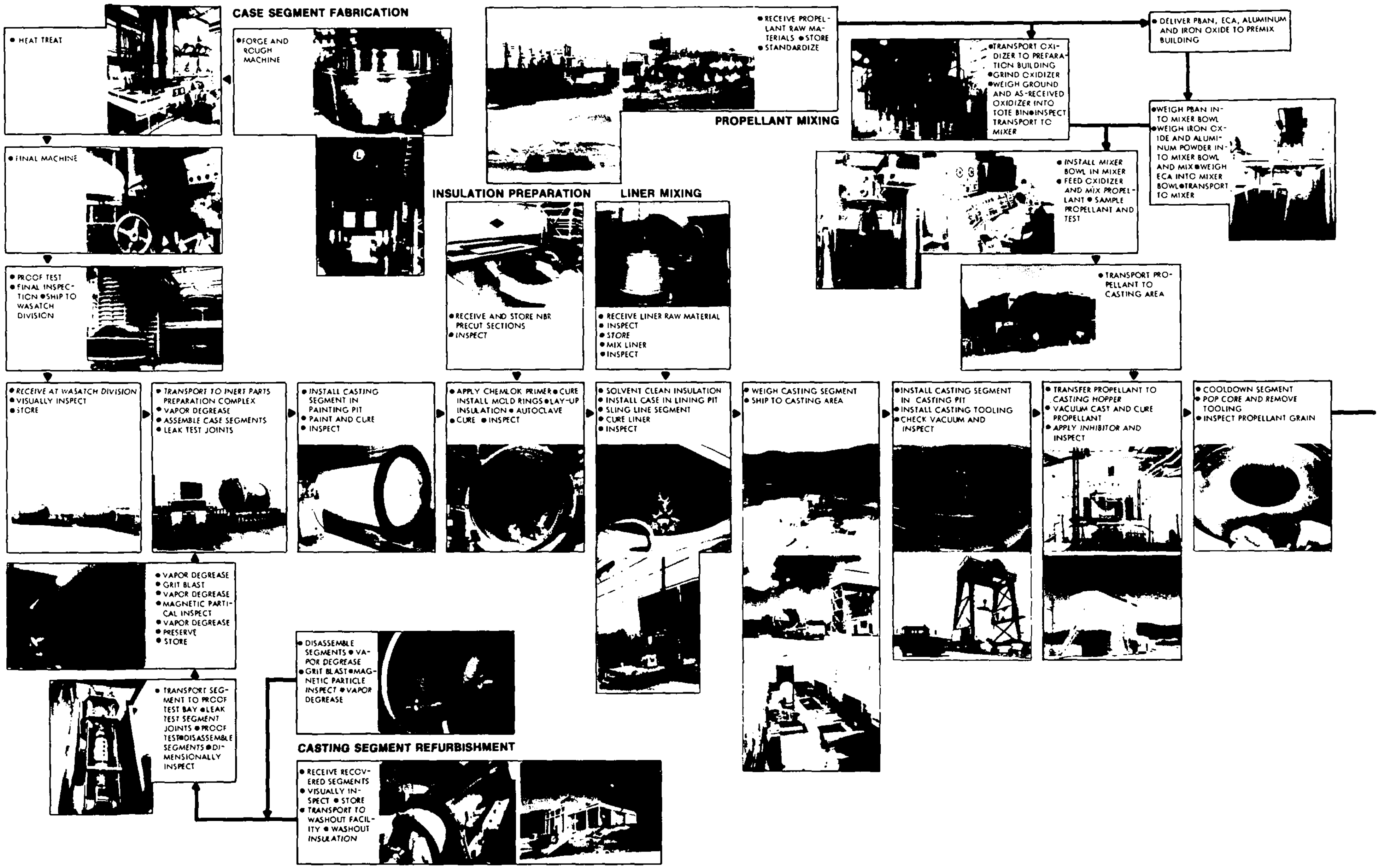


FIGURE 7. SRM MANUFACTURING FLOW CHART (Sheet 1 of 2)

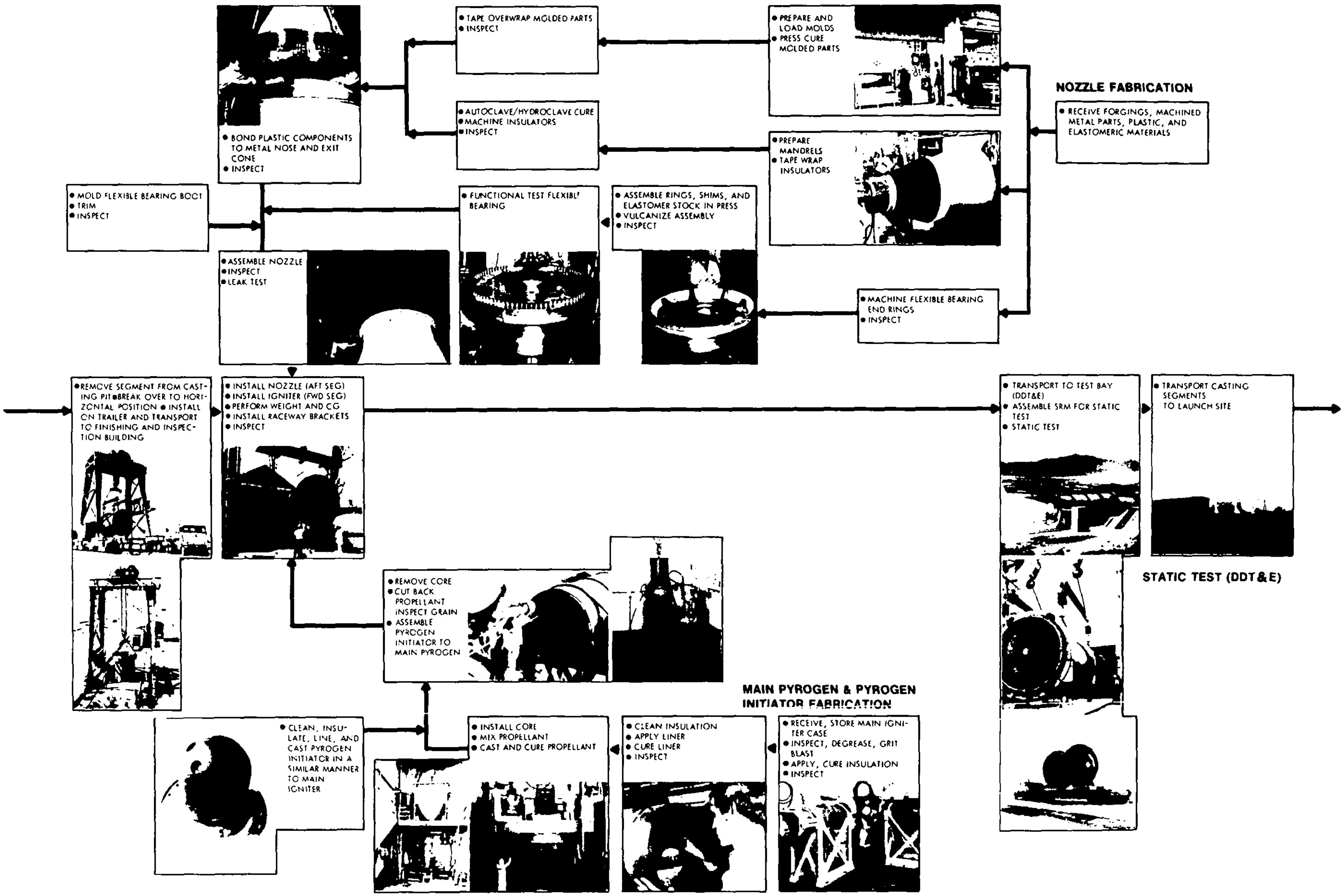


FIGURE 7. SRM MANUFACTURING FLOW CHART (Sheet 2 of 2)

assembly configuration. Fabrication of the nozzle and the ignition system complete the SRM processing activities. The major process characteristics unique to the Space Shuttle SRM are the handling requirements due to their size.

Figure 8 shows an aerial view of that portion of the plant which will be used primarily for SRM processing. SRM nozzle and case preparation operations, refurbishment and inspection, insulating, lining, propellant manufacture, casting, motor finishing, and subassembly operations will be completed in the area depicted. Appendix F briefly describes the supplier manufacturing and Thiokol processing activities required for the SRM DDT&E Program.

1.2.3.1 SRM Waste Propellant Disposal

Inherent to the normal propellant processing operations, waste propellant is accumulated from rejected mixes and equipment cleanup. It is estimated that approximately 70,000 kg (150,000 lb) of waste propellant will require disposal as a result of the SRM propellant processing activities. Currently, the only safe and economical method to dispose of this waste propellant is by burning in large open pits. Thiokol/Wasatch Division has utilized this disposal method since propellant mixing operations began in 1957.

1.2.4 SRM Static Test Firings

Static test firings are required as a part of the Space Shuttle SRM DDT&E Program to demonstrate and qualify the Space Shuttle SRM for manned Space Shuttle flights which will begin in 1979. Seven (7) static motor test firings have been scheduled for an 18-month test period beginning in July, 1977, and lasting through December, 1978. These test firings could occur in any month during the test period; however, it is anticipated that they will occur mostly in summer months. Currently, four tests are scheduled for the July-September period, one in April, one in February, and one in December. The minimum time between any two firings would be approximately 45 days (typically, 60 days).

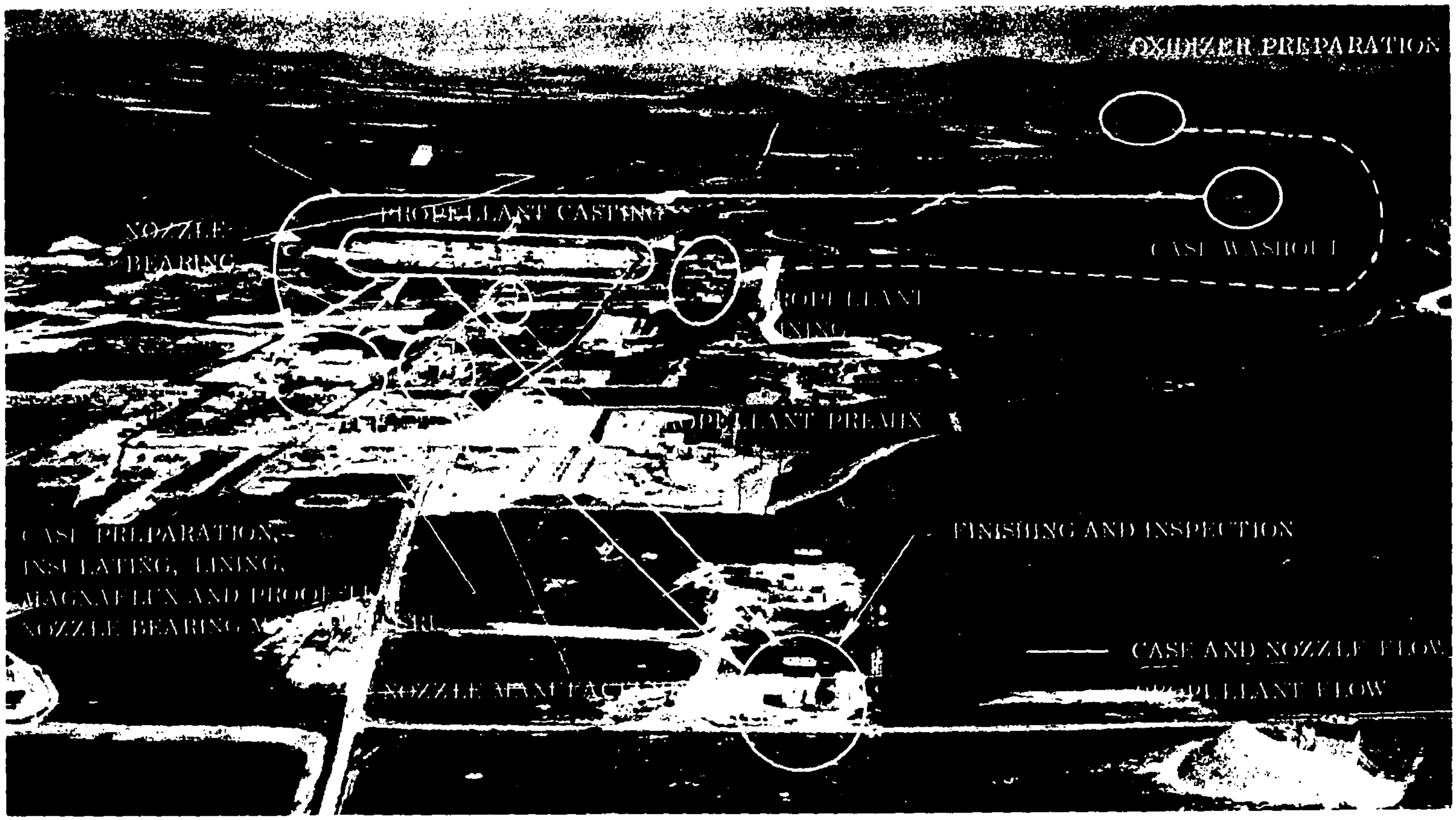


FIGURE 8. AERIAL VIEW OF PROCESSING AREA

The facility to be used for the static tests is T-24 (Figure 5). This facility was used extensively in the 1960's for static test firings of 156-inch diameter motors. SRM segments will be moved to this facility using an in-house transporter and assembled in the horizontal firing position.

Prior to the receipt and assembly of the SRM in the test bay at T-24, the axial thrust transducers will be calibrated, installed and aligned in the test bay. Also all lifting and handling equipment will be proof tested to verify structural integrity. A complete check of the ignition system, electrical circuitry, data acquisition system, and thrust vector control (TVC) system will be performed on the assembled SRM. After acceptance of the final assembly and checkout, and the assurance that the proper meteorological conditions exist in the vicinity, the motor will be test fired.

Immediately following static test of the motor, an automatic CO_2 quench system will be actuated. The purpose of the post-test CO_2 quench is to prevent the remaining nozzle and case insulation material from burning and charring. As the SRM is disassembled, a photographic record of component condition will be made before the segments are transported to the refurbishment area. Post-test operations will include determination of insulation char depth, insulation erosion, virgin insulation material remaining, segment and nozzle post-test weight and center of gravity, nozzle erosion, nozzle ablative material char, ignition component system condition, and the condition of the case. A post-test analysis of motor performance and hardware condition will also be conducted. Critical parameters such as chamber pressure, thrust, and thrust vector control (TVC) angle will be made available for engineering analysis.

1.2.5 SRM Transportation

Transportation of Space Shuttle SRM segments for static test firings will be via an in-house transporter. The SRM segment will be loaded on the in-house transporter at the R&D Area, and transported to the T-24 test facility along State Highway 83 for a distance of approximately 7 km (4.4 mi).

The twelve SRMs, which will be delivered to Kennedy Space Center (KSC), Florida, for the six Shuttle DDT&E orbital flights, will be transported via rail as individual casting motor segments. The closest railroad load point is located at Corinne, 33 km (21 mi) from the R&D Area. The segments will be transported to Corinne along State Highway 83 on flatbed trailers and loaded on specially designed flatbed railroad cars of the Union Pacific Railroad. The segments will have covers over the open ends of the grain and each segment will be encapsulated by a shroud. The shroud is designed to protect the segment from the elements. Upon recovery of spent SRMs at Cape Kennedy, the empty case segments will be returned, via rail, to Thiokol for subsequent refurbishment and future reuse. The railroad route to Cape Kennedy is shown in Figure 9. SRM segments would travel through such states as: Wyoming, Nebraska, Kansas, Missouri, Arkansas, Tennessee, Alabama, Georgia, and Florida.

The shipment of three empty and two inert propellant SRMs between Marshall Space Flight Center, Alabama, and Thiokol/Wasatch will be via railroad. This route is also shown in Figure 9.

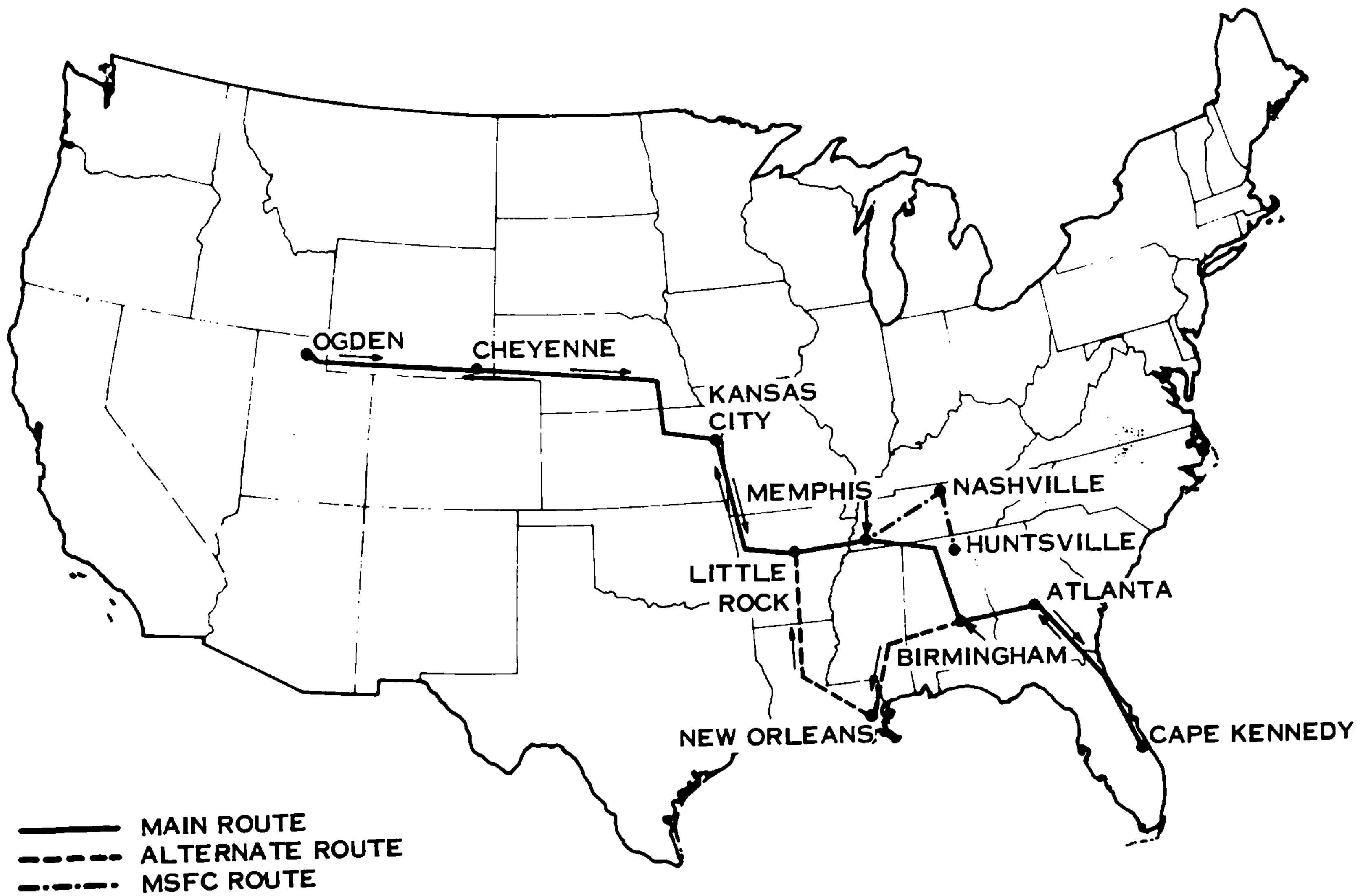


FIGURE 9. RAILROAD ROUTES FOR THE TRANSPORTATION OF SRM SEGMENTS BETWEEN THIOKOL/WASATCH, CAPE KENNEDY, AND HUNTSVILLE, ALABAMA

2.0 DESCRIPTION OF EXISTING CONDITIONS

2.1 Existing Thiokol/Wasatch Plant and Programs

The Space Shuttle Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) Program will be conducted utilizing existing facilities located at the Thiokol/Wasatch Division plantsite, Promontory, Utah. Operations at the Thiokol/Wasatch Division began in late 1956. From that beginning until the present time, plant activity has encompassed a wide range of programs requiring the processing of solid propellants, rocket motor testing, and the industrial support necessary to achieve program goals. Solid rocket motors manufactured and tested during this period vary from motors containing 3-4 kg (7-9 lb) of propellant to 156-inch diameter space boosters containing 318,000 kg (700,000 lb) of propellant. More recent programs include: Trident, SRAM, HARM, Genie, Minuteman, and Poseidon. Much of the technology developed in these programs will be applied to the Shuttle SRM DDT&E Program.

The 77-km^2 (30-mi^2) plantsite is remote from any major population center and is also reasonably isolated from ranches located at varying distances from the area boundaries (Figure 10). Secondary State Highway 83, which leads to the "Golden Spike" historic site, is located near the boundaries of the Thiokol/ Wasatch plantsite. This highway is also part of a plant periphery road, south and west of the plant area, and serves as an access means for plant personnel.

Currently, the plantsite is composed of three major areas in which processing and testing activities take place. These are the Test Area, the R&D Area, and the Air Force Plantsite Number 78. These areas are shown in Figure 11. The locations of existing processing, testing and support facilities are shown in Figures 4, 5, and 6. Appendix E describes the processing facilities that will be utilized.

2.2 Physical Features

2.2.1 Topographic Features

The Thiokol/Wasatch plantsite lies in the northern end of the Great Salt Lake Basin. The Wasatch Mountains rim the Basin to the east and the

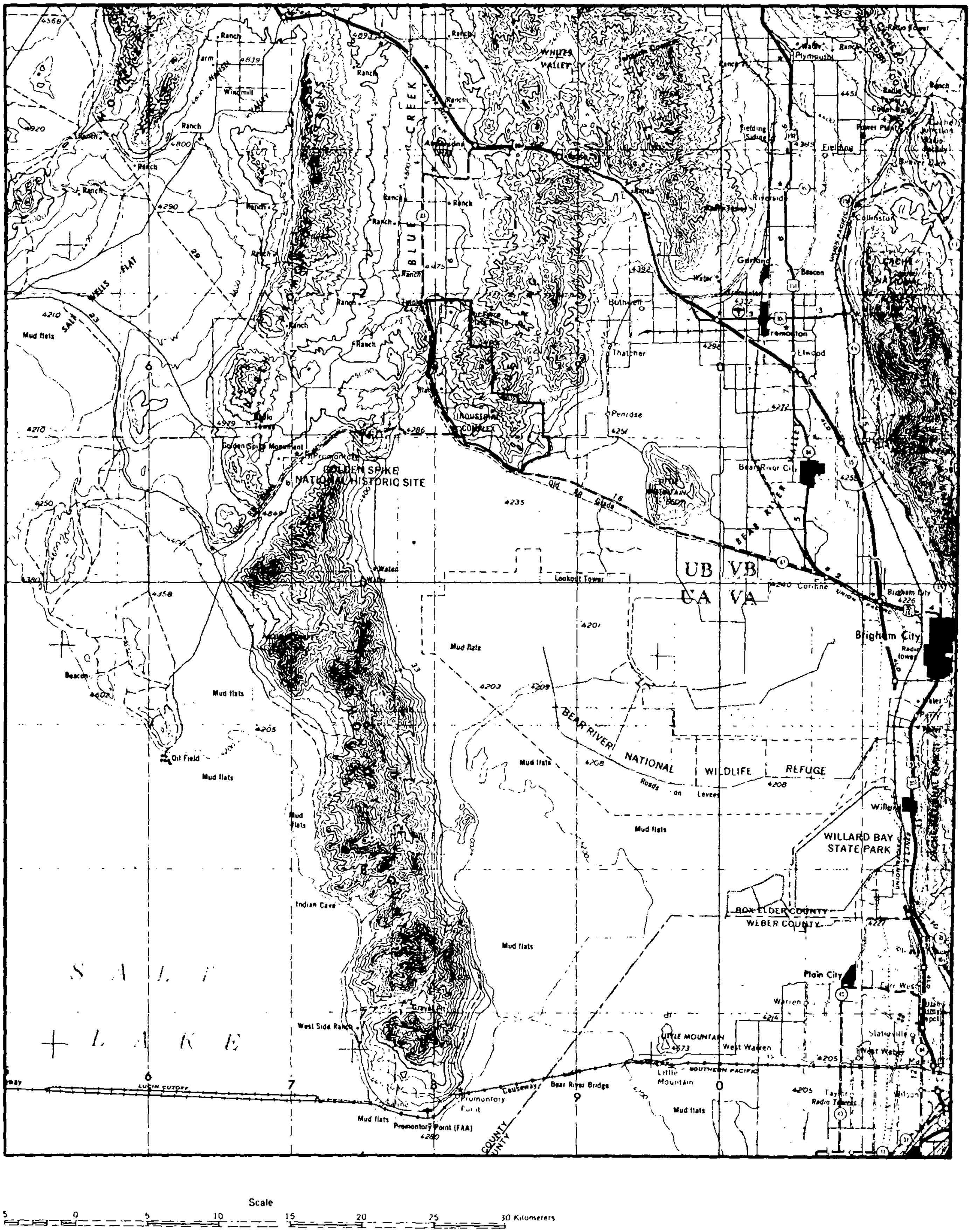


FIGURE 10. MAP OF IMPORTANT LOCAL FEATURES SURROUNDING THIOKOL/WASATCH PLANTSITE

Note: Elevations given in feet, distances in miles. Conversion factors are: meters = feet x 0.3048 and km = miles x 1.609.

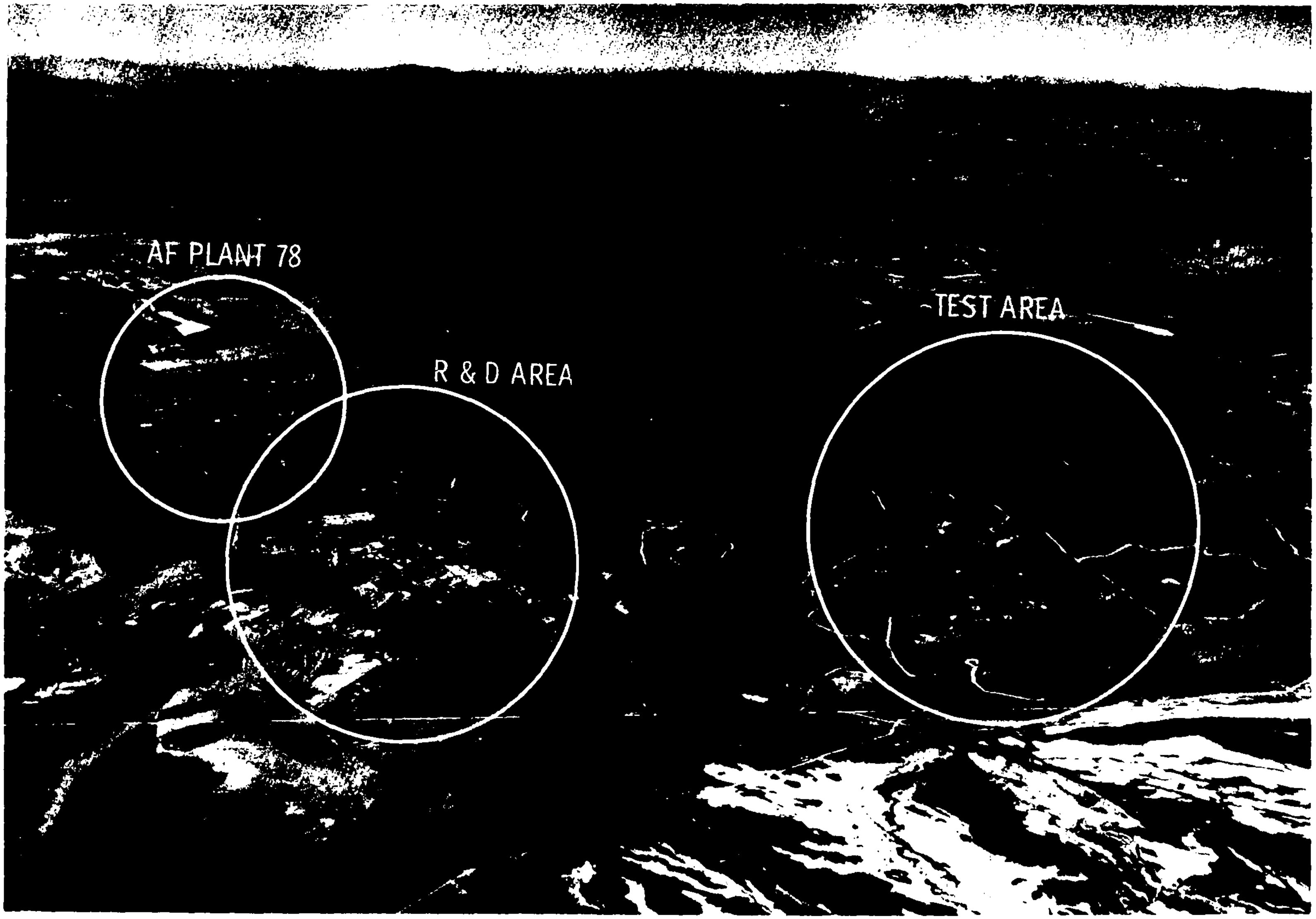


FIGURE 11. PRINCIPAL THIOKOL/WASATCH DIVISION AREAS

Promontory Mountains to the west. This area is within the Basin and Range Physiographic Province, with the Wasatch Mountains being the boundary between the Basin and Range Province and the Colorado Plateau to the east and south.

Elevations within the Great Salt Lake Basin range from ~1,280 m (4,200 ft) at the salt flats and lake to peaks within the local area rising to ~1,700 m (5,600 ft) above sea level (Blue Springs Hills). Isolated peaks of the Wasatch Range east of Thiokol rise from 2,750 to 3,050 m (9,000 to 10,000 ft). The Promontory Mountains form a range between 6.5 to 13 km (4 to 8 mi) wide which extends into the northeastern portion of the Great Salt Lake, forming Promontory Point. These mountains have comparatively low relief, rising to a maximum of 980 m (3,200 ft) above lake level (Mount Tarpey).

At a closer level the Thiokol/Wasatch site is located to the northwest of the Bear River Delta and is inclusive of portions of the Blue Springs Creek Valley and Blue Springs Hills (Figure 10). The topography of this area consists of a series of relatively low, rounded mountains that extend from north to south and are separated by broad intervening valleys. These valleys include the major drainageways of the area, which are the Bear River, Malad River, and Blue Creek, all of which drain southward into Great Salt Lake. The outstanding topographic characteristic of the area is a series of old Lake Bonneville terraces that appear as well-worn, giant steps up the sides of the mountains. The "treads" of these steps and the valley floors constitute the larger part of the cultivated land in the area.

2.2.2 Geological Features

2.2.2.1 Surficial Geology

Surficial geology of the Thiokol/Wasatch site is dominated by the past intermittent rise and fall of Lake Bonneville, a large prehistoric inland lake of Pleistocene time. This lake is the prehistoric predecessor of the Great Salt Lake. The islands of the Great Salt Lake and the bordering ranges and peaks display more than 21 km (13 mi) of sedimentary rock ranging in age from old Precambrian to Recent. This represents a span of about 1.7 billion years.[5] Limestone, quartzite, dolomite, and shale comprise the greater portion of the strata; metamorphosed sediments account for the remainder. Elevated topographic features, predominantly isolated peaks or series of peaks oriented in a north-south line, have resulted from compressive and directional earth forces. These thrust and fault block mountains are dated to the Laramide orogeny.[5]

2.2.2.2 Soils

The types of soils occupying the general area of the site correspond very closely to the topography. Well-drained soils occupy the mountain foot slopes and associated alluvial fans and high lake terraces. They are predominantly silt loams and cobbly silt loams. The slope of these soils is moderate to steep.

Blue Creek drainage is characterized by soils which are generally poorly drained. These areas are occupied by soils common to flood plains and low lake terraces in the region.

A detailed soils map and data for the eastern part of Box Elder County, Utah, have been prepared by the Soil Conservation Service and are available for detailed activity planning.[6]

2.2.3 Hydrological Features

The plantsite is located about 18 km (11 mi) north of the Great Salt Lake among terraces formed by fluctuating water levels of old Lake Bonneville. It is adjacent to the mudflats and wetlands of the Bear River Delta formed by the confluence of the Bear and Malad Rivers. Surface water hydrology in the area is rather simple; groundwater hydrology is complex.

2.2.3.1 Surface Waters

There is only one stream which flows through the plantsite, Blue Springs Creek. It is a first order stream which originates ~40 km (25 mi) north of the plantsite, and has formed the Blue Creek Valley running southward into the Bear River Delta. It has been impounded ~20 km (12 mi) north of the plantsite to form Blue Creek Reservoir, the outflow of which flows through the western portion of the plantsite. No gauging stations are located along Blue Springs Creek, and so information on the quantitative discharge regime of the stream is not available. Like all small streams in the area, the predominant discharge occurs in the spring in the aftermath of snowmelt. Due to the impoundment of the stream north of the plantsite, summer discharge is small to nonexistent, and in winter months the stream's discharge is so low that it freezes solid on occasion. The discharge of Blue Springs Creek into wetlands south of the plantsite is regulated for management of waterfowl habitat.

Since 1966, the Wasatch Division of Thiokol Corporation has been monitoring selected water quality parameters at various stations on Blue Springs Creek to determine the nature and extent of effects, if any, of its operations on stream water quality. The location of monitoring stations is shown on Figure 12; station #4 is located upstream from the plantsite; station #2 is located just south of the open pit burning area on the plant premises; and station #1 is located downstream from the plant premises. Selected water quality monitoring data are provided in Table 1. The quality of the water as it enters the plantsite is rather poor due to its high content of dissolved solids; this is typical of most other streams in the area.[7]

The climatology of the area is the chief factor responsible for the paucity and relatively poor quality of surface waters in the region. Precipitation in the area typically amounts to ~30 cm (12 in) per year. Evaporation potential, however, is on the order of 130 cm (51 in) per year. Given the seasonal variation in precipitation, with highs in the spring months, natural stream channels tend to go virtually dry during the summer.

There are several arroyos on the plantsite which carry snowmelt runoff during the spring, but are devoid of surface water during the rest of the year. These lead into the Blue Creek Valley, and so can be considered as intermittent tributaries to Blue Springs Creek.

Blue Springs Creek flows into the lowlying wetlands north of the Bear River Delta, and disperses throughout the Playas-Saltair soil association[6] along with influxes from other sources, such as the Bear River, the Great Salt Lake, and groundwater discharge.

2.2.3.2 Groundwater

In contrast to the paucity and simple hydrology of surface waters, the area surrounding the plantsite is characterized by a complex pattern of groundwater hydrology. This is typical of semiarid regions with moderate relief

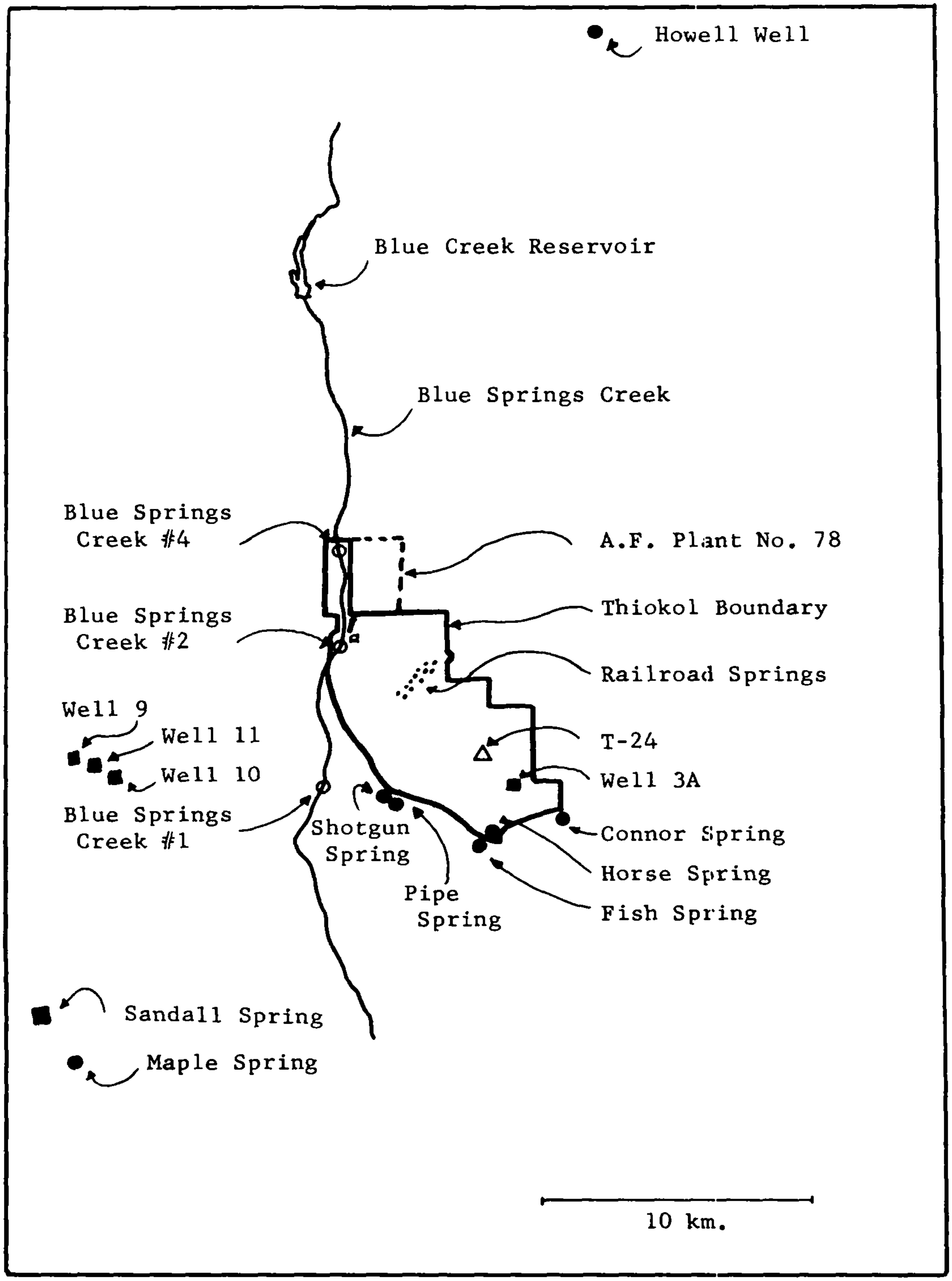


FIGURE 12. SURFACE WATERS, SPRINGS, AND WELLS IN THE VICINITY OF THE THIOKOL/WASATCH PLANTSITE

TABLE 1. SELECTED WATER QUALITY DATA FROM BLUE SPRINGS CREEK

		Blue Creek #1		Blue Creek #2		Blue Creek # 4	
		1968	1975	1968	1975	1968	1975
Total Solids	Min	3,881	1,109	4,111	3,100	3,941	2,769
	Mean	6,791	3,646	7,033	4,275	6,416	4,002
	Max	9,188	5,147	11,600	5,611	9,058	5,187
Conductivity	Min	5,800	1,720	6,300	5,170	5,700	4,500
	Mean	10,477	5,961	10,065	6,802	10,131	6,287
	Max	13,900	8,650	14,000	8,850	15,500	7,100
Chloride	Min	1,756	291	1,925	1,288	1,856	1,300
	Mean	3,267	1,675	3,188	1,979	3,110	1,852
	Max	4,582	2,425	4,566	2,706	4,429	2,356
Sodium	Min	1,220	240	1,220	800	1,340	860
	Mean	2,151	1,140	2,141	1,335	2,063	1,260
	Max	3,000	1,600	2,980	1,820	3,060	1,600
Calcium Carbonate	Min	222	110	204	127	175	124
	Mean	317	203	286	232	322	222
	Max	443	293	383	368	462	330
Magnesium Carbonate	Min	163	138	212	121	203	125
	Mean	341	197	341	198	339	199
	Max	505	255	545	266	599	275
Copper	Min	0.05	0.03	0.05	0.03	0.06	0.06
	Mean	0.15	0.11	0.11	0.125	0.16	0.16
	Max	0.31	0.20	0.18	0.43	0.50	0.34
Titanium	Min	0.12	-	0.10	-	0.12	-
	Mean	0.22	-	0.24	-	0.25	-
	Max	0.49	-	0.40	-	0.70	-

NOTE: All units except conductivity (micromhos/cm) are in mg/liter.

topography. The hills and valleys on and around the plantsite contain both recharge and discharge areas for groundwater. Springs occur usually at the bases of hills; most of them are artesian and saline, but a few feed freshwater to the surface at a rate ranging from 10 to 1000 liters (2.6 to 260 gal) per minute. A few "hot" springs, discharging from much greater depths, also occur in the area.

The springs which occur at the base of the hills on or close to the Thiokol plantsite are almost all salty or have a chloride content in excess of 1,000 mg/liter. The one exception is the Sandall Spring on the Thiokol Ranch. The fresh springs (Maple Spring on Promontory, and the Railroad Springs on the plantsite) are mountain springs and their flow is derived from local precipitation above the valley floor.

2.2.3.3 Water Use

Groundwater from wells and springs is the only supply used by Thiokol Wasatch Division in any direct sense. Thiokol's water supply (see Figure 12) is derived from one well on the plantsite (Well 3A), 12 springs on the plantsite (Railroad Springs), 4 wells at the Thiokol Ranch on Promontory and one spring on Promontry (Maple). The Howell Well located 15 km (9 mi) north of Air Force Plant 78 is yet to be connected to the Thiokol water system (see Figure 12). The present wellfield can supply ~2250 liters (600 gal) per minute to the plantsite. The influx is stored in a 190,000-liter (50,000 gal) headbox and distributed through on-site lines. Figure 13 indicates the relationships between water demand and wellfield supply, and the potential of the new wellfield located about 15 km (9 mi) north of the plantsite. Current water use and projected water use is well within the capacities of present and planned wellfields. Thiokol's primary intent in developing the new wellfield is to take appropriate precaution against excessive withdrawals within present wellfields which could conceivably cause salt water intrusion into the freshwater layer. Selected water quality data from well supplies and springs are listed in Table 2. These data indicate that well water is typically less saline than spring waters, but both have characteristically high sodium and chloride contents and high specific conductivity.

Currently, the plant's facilities use about 2.5×10^6 liters (0.7×10^6 gal) per day. The biggest uses involve "bleedwater" to eliminate stagnation in feeder lines, steam production, sanitary waste discharge, and cooling water.

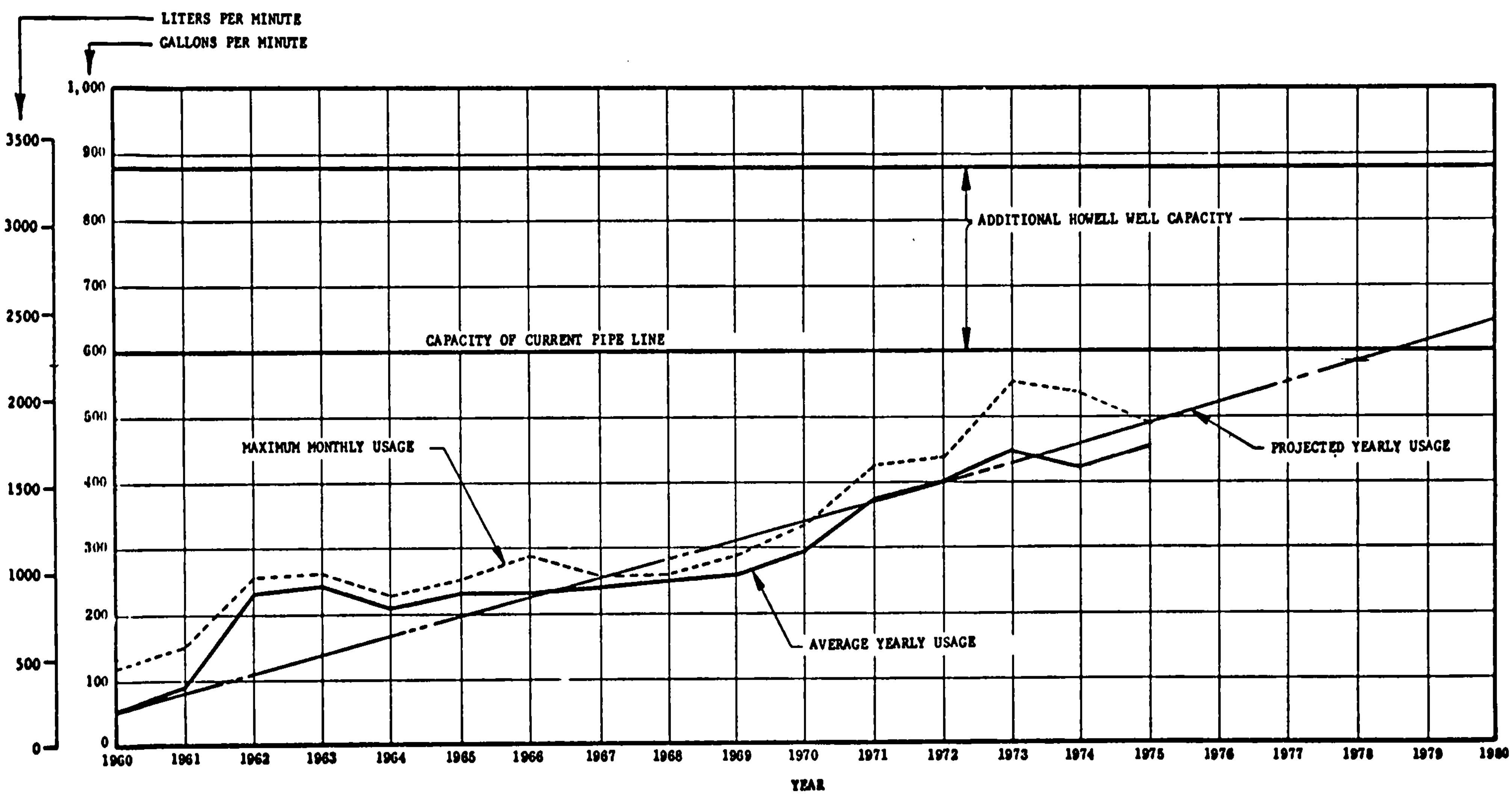


FIGURE 13. WATER USE AND WELLFIELD CAPACITIES AT THE THIOKOL/WASATCH PLANTSITE

The surface waters of Blue Springs Creek are not used by Thiokol for any direct purpose. Surface water from Blue Springs Creek and all of the salty springs south and west of the plantsite are used for wildlife habitat (waterfowl). Local gun clubs have the water rights. Data shown in Table 2 for the salt springs indicate that Thiokol operations are not downgrading the quality of water in the springs, which could affect the waterfowl.

TABLE 2. SELECTED WATER QUALITY MONITORING DATA FROM GROUNDWATER DISCHARGES IN THE VICINITY OF THE THIOKOL/WASATCH PLANTSITE

		Well No. 3A		Connor Spring		Horse Spring		Fish Spring		Pipe Spring		Shotgun Spring	
		1968	1975	1968	1975	1968	1975	1968	1975	1968	1975	1968	1975
Total Solids	Min	636	636	2,088	2,067	5,969	5,561	6,452	7,070	5,423	5,351	4,199	5,215
	Mean	724	724	2,530	2,479	6,400	6,151	6,875	7,132	5,843	5,608	4,998	5,816
	Max	974	983	2,938	2,837	6,957	7,202	7,178	7,341	6,133	5,903	5,440	6,545
Conductivity	Min	1,030	1,200	3,600	3,650	8,850	8,950	9,550	9,900	8,350	8,600	7,250	7,350
	Mean	1,398	1,430	4,300	4,100	10,825	10,159	11,175	11,031	9,800	9,040	8,358	8,904
	Max	1,690	1,630	4,850	5,150	12,550	12,600	12,700	12,900	10,850	10,050	9,700	11,250
Sodium	Min	154	152	520	700	2,040	1,820	2,120	2,020	1,780	1,640	1,360	1,600
	Mean	165	163	700	729	2,203	2,098	2,332	2,363	1,910	1,789	1,676	1,847
	Max	188	174	750	760	2,400	2,560	2,540	2,460	2,080	1,920	1,840	2,060
Copper	Min	0.02	0.01	0.02	0.03	0.05	0.10	0.04	0.07	0.05	0.06	0.04	0.05
	Mean	0.03	0.03	0.06	0.08	0.18	0.29	0.12	0.15	0.13	0.18	0.15	0.17
	Max	0.08	0.07	0.11	0.29	0.46	0.54	0.20	0.48	0.23	0.64	0.42	0.34
Silicon	Min	1.40	0.73	3.13	1.70	3.20	1.90	3.70	2.36	3.11	3.08	5.04	3.18
	Mean	4.59	2.02	6.33	3.98	7.16	6.77	9.51	7.78	10.39	8.03	13.78	8.44
	Max	7.71	3.68	11.91	11.73	16.64	17.78	21.32	17.54	20.70	15.93	27.80	21.31

NOTE: All units except conductivity (micromhos/cm) are in mg/liter.

2.2.4 Meteorology

The climate of the Great Salt Lake Basin is to a large extent dominated by the Sierra Nevada, 800 km (500 mi) to the west and the Rockies, 500 km (300 mi) to the east. The Sierras and other mountain ranges forming the west coast chain modify the character of winter storms which move across the Great Salt Lake Basin. Most of the moist Pacific air which brings winter precipitation to the basin must move across these mountain barriers with consequent loss of moisture. This partially accounts for the aridity of the Salt Lake Basin. The Rocky Mountains to the east also have a marked moderating influence on the climate of the lake basin. The mountains prevent the westward penetration of all but exceptionally strong outbreaks of cold continental air.

The Salt Lake Valley has several unique features that are most important to the dispersion of airborne materials. First, it is frequently under the influence of the Great Basin high-pressure area with its characteristic light winds and good weather. The circulation and terrain features apparently favor the development of unusual vertical wind structures in the valley, in which the increase of wind speed with height is much less than that observed in open, well-ventilated regions. This effect is most pronounced in the summer months, when Salt Lake City shows a nearly constant mean wind in the first 900 meters (3,000 ft) above the surface.

The Salt Lake City radiosonde data provide a valuable general indication of thermal stability. In the summer, there are very few daytime inversions (1 to 2 percent) and even the December-January peak is less than 20 percent, with a typical base of 600 meters (2,000 ft) or more above the surface.

Local wind patterns show a strong tendency for predominantly thermal circulations. The relation between the wind direction and time of day at the Thiokol installation leaves little doubt that there are favored wind directions with a strong diurnal pattern. At T-24, for example, there is evidence of a downslope drainage wind from the east at night, followed by a well-developed upslope wind from the south to southwest during the midday hours. Figure 14 shows the wind roses for 8:00 a.m. and 4:00 p.m. (constructed from surface wind data recorded at Building M-11 located in the R&D Area). The implication of these circulations is that there is a strong tendency for daytime upslope winds on either side of the ridge in the center of the Thiokol site, and very probably

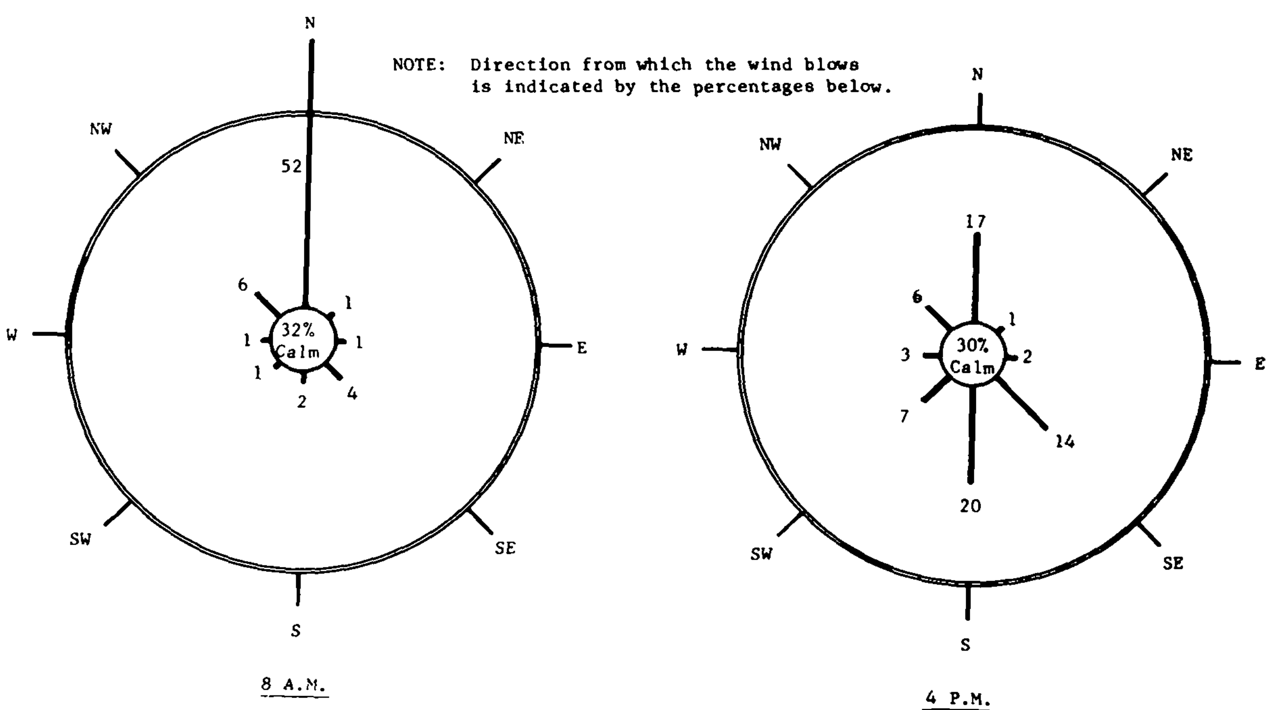
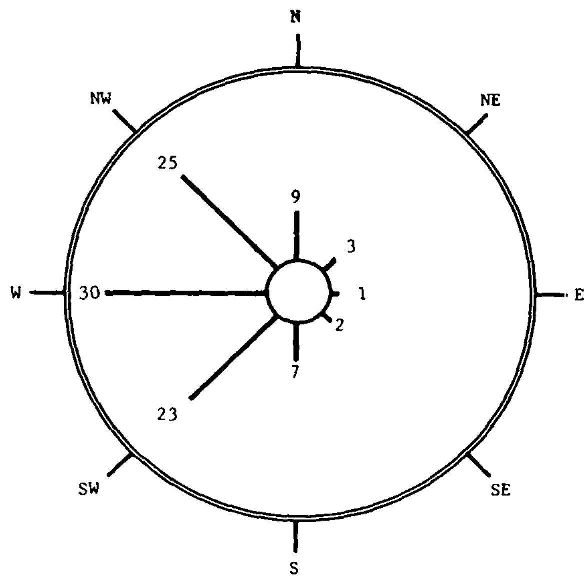


FIGURE 14. SURFACE WIND ROSES FOR 8 A.M. AND 4 P.M. AT THIOKOL/WASATCH PLANTSITE

these converging winds produce a general ascending motion during the day. Data indicate that the strongest and more frequent thermal circulations will be found during the warmer half of the year. Also, two definitive afternoon seasonal surface wind patterns predominate - northerly in the winter and southerly in the summer.

Winds aloft dictate a mean east-southeasterly flow over the area every month of the year. Figure 15 presents the wind rose, constructed using 1974 Salt Lake City radiosonde data, for the general wind pattern at 600 mb pressure (2-3 km above the surface). These data indicate the predominate ground tracks of the SRM exhaust cloud that results from static test firings.



NOTE: Wind data for altitudes where the pressure equals 600 mb. Direction from which the wind blows is indicated by the percentages above.

FIGURE 15. 1974 SALT LAKE CITY WIND ROSE FOR WINDS ALOFT

In the mid-1960's wind profiles to 700 mb were constructed for the Thiokol/Wasatch site, by employing slow-rising pibols on a routine basis. Sufficient data were recorded to show that the test site wind velocity gradients aloft, like those of Salt Lake City, were much lower than normal, averaging less than 1 m/sec (3 ft/sec) per 300 m (1000 ft) for the first 900 m (3000 ft) above the surface (Figure 16). This condition is considered one of the basic advantages for carrying out large rocket motor test firings in this area, as this condition allows rocket motor exhaust clouds to rise to great heights, minimizing potential impacts at the surface.

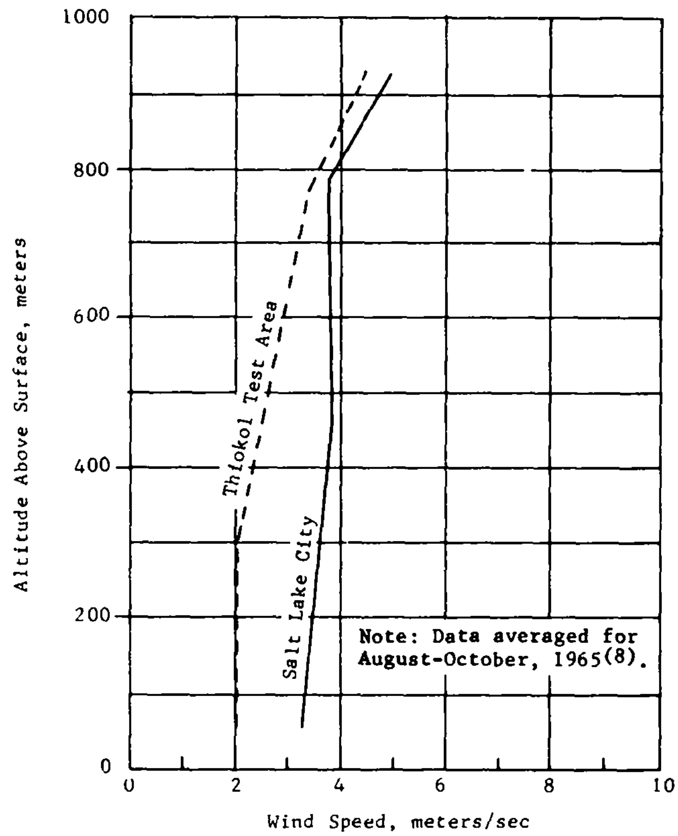


FIGURE 16. COMPARATIVE WIND PROFILES FOR THIOKOL/WASATCH AND SALT LAKE CITY

Climatological data are recorded three times daily at the Thiokol/Wasatch plantsite (Building M-11, located in the heart of the Thiokol R&D Area). Surface data measured include: temperature, pressure, relative humidity, wind velocity and direction, precipitation, and cloud conditions. Surface data, recorded for the 1971-1975 period, were used to generate the yearly averages, as presented below.

The area of the Thiokol/Wasatch plantsite is classified as semiarid, with an average annual total precipitation of ~30 cm (12 in). During the winter months, the average total snowfall amounts to ~60 cm (24 in). Precipitation typically occurs on 95 days out of the year (includes trace precipitation). During the year, it would be expected that: 35 percent of the days would be clear, 30 percent of the days would be partly cloudy, 34 percent would be cloudy, and fog would be expected to occur about 1 percent of the time. Figure 17 presents the average minimum and maximum surface temperature and relative humidity data for the various months of the year.

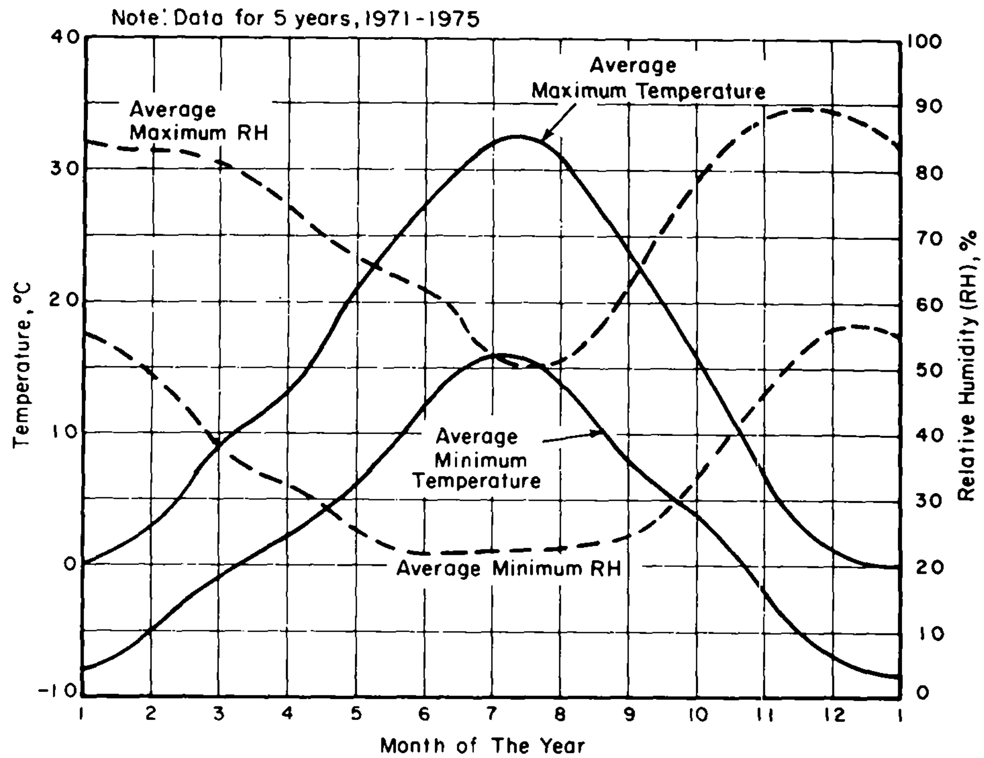


FIGURE 17. AVERAGE EXTREME TEMPERATURE AND RELATIVE HUMIDITY DATA FOR THIOKOL/WASATCH PLANTSITE

2.2.5 Ecological

2.2.5.1 Upland Habitats

The Thiokol/Wasatch plantsite is entirely composed of upland habitat, with the following exceptions: (1) developed areas occupying approximately 25 percent of the 77-km^2 (30-mi^2) area and (2) wetland habitats along Blue Springs Creek occupying less than one percent of the area.

The semiarid climate and well-drained soils of the area support a vegetation type dominated by bluebunch wheatgrass (Agropyron spicatum) and sagebrush (Atriplex sp.). Lists of common plant and mammal species are presented in Tables 3 and 4.

Historically, the sagebrush rangelands have supported an abundance of big game animals, particularly the bison and antelope. However, occupation by white settlers and the construction of the railroad led to the disappearance of these species from the area from overhunting, but also from reduced and/or interrupted range. The use of unimproved rangeland, including the Thiokol/Wasatch plantsite, for grazing domestic beef herds continues today.

TABLE 3. COMMON PLANT SPECIES IN THE VICINITY OF THE THIOKOL/WASATCH PLANTSITE

Common Name	Scientific Name	Habitat	Soil Associations[6]
Bluebunch wheatgrass	*Agropyron spicatum*	u	M,S,H,Sp
Sagebrush (Shadscale)	*Atriplex* sp.	u	M
Big Sagebrush (Sagebrush)	*Artemisia tridentata*	u	S,H,Sp
Bitterbrush (Antelope brush)	*Purshia tridentata*	u	M,S
Sandberg bluegrass	*Poa secunda*	u	M,H
Cheatgrass	*Bromus tectorum*	u	S,H
Juniper	*Juniperus osteosperma*	u	S
Snowberry	*Symphoricarpos* sp.	u	M
Yellowbrush (Rabbit brush)	*Chrysothamnus* sp.	u	H
Wiregrass	*Aristida* sp.	w	W
Sedges	*Cyperus* sp.	w	W
Kentucky bluegrass	*Poa pratensis*	w	W
Inland saltgrass	*Distichlus spicata stricta*	w	W
Foxtail	*Setaria* sp.	w	W

Habitat

u = upland

w = wetland

Soil Associations (Classification by Soil Conservation Service) [6]

M = Middle-Broad Association

S = Sandall

H = Hupp-Abela Association

Sp= Sanpete

W = Wood Cross

TABLE 4. MAMMALS IN THE VICINITY OF THE THIOKOL/WASATCH PLANTSITE

Common Name	Scientific Name	Habitat Preference	Abundance
Masked Shrew	Sorex cinereus	u	u
Merriam's Shrew	Sorex merriami	u	u
Vagrant Shrew	Sorex vagrans	u	c
Little Brown Myotis	Myotis lucifugus	u	c
Cave Myotis	Myotis velifer	u	u
Fringed Myotis	Myotis thysanodes	u	u
Long-earred Myotis	Myotis evotis	u	u
California Myotis	Myotis californicus	u	u
Yuma Myotis	Myotis yumanensis	u	u
Small-footed Myotis	Myotis leibii	u	u
Hoary Bat	Lasiurus cinereus	u	u
Western Pipistrel	Pipistrellus hesperus	u	u
Big Brown Bat	Eptesicus fuscus	u	u
Spotted Bat	Euderma maculatum	u	u
Townsend's Big-eared Bat	Plecotus townsendii	u	u
White-tailed Jack Rabbit	Lepus townsendii	u	u
Black-tailed Jack Rabbit	Lepus californicus	u	u
Nuttall's Cottontail	Sylvilagus nuttallii	u	u
Pigmy Rabbit	Sylvilagus idahoensis	u	u
Least Chipmunk	Eutamias minimus	u	u
Cliff Chipmunk	Eutamias dorsalis	u	u
Yellow-bellied Marmot	Marmota flaviventris	u	u
White-tailed Antelope Squirrel	Ammospermophilus leucurus	u	u
Uinta Ground Squirrel	Spermophilus armatus	u	u
Rock Squirrel	Spermophilus variegatus	u	u
Northern Pocket Gopher	Thomomys talpoides	u	u
Botta's Pocket Gopher	Thomomys bottae	u	u
Great Basin Pocket Mouse	Perognothus parvus	u	c
Ord's Kangaroo Rat	Dipodomys ordii	u	c
Beaver	Castor canadensis	w	u
Western Harvest Mouse	Reithrodontomys megalotis	w	c*
Deer Mouse	Peromyscus maniculatus	u	c
Northern Grasshopper Mouse	Onychomys leucogaster	u	u
Meadow Vole	Microtus pennsylvanicus	u	u
Montane Vole	Microtus montanus	w	u*
Long-tailed Vole	Microtus longicaudus	w	u*
Sagebrush Vole	Lagurus curtatus	u	u
Muskrat	Ondatra zibethica	w	c*
Porcupine	Erethizon dorsatum	u	u
Norway Rat	Rattus norvegicus	u	u
House Mouse	Mus musculus	u	u
Coyote	Canis latrans	u	c
Red Fox	Vulpes vulpes	u	u
Long-tailed Weasel	Mustela frenata	w	u*
Ermine	Mustela ermina	u	u
Mink	Mustela vison	w	u*
Badger	Taxidea taxus	u	u
Western Spotted Skunk	Spilogale gracilis	u	u
Striped Skunk	Mephitis mephitis	u	c
Bobcat	Lynx rufus	u	u
Mule deer	Odocoileus hemionus	u	u

Habitat Preference: u - upland, w - wetland

Abundance: u - uncommon, c - common

***Occurs primarily in the Bear River Delta marches.**

Source: References 9 and 10.

Numerous mammal species continue to inhabit the area. The largest is the mule deer, a small herd of which inhabits the plantsite. Small mammals, including several rabbit and small rodent species, are fairly common (see Table 4).

Upland bird species may be found on the plantsite, though not in large numbers. Upland game bird species include sage grouse (Centrocercus urophasianus), blue grouse (Dendragapus obscurus), sharp-tailed grouse (Pedioecetes phasianellus) and Chukar partridge (Alectoris chukar).

The cottontail rabbit is a commonly hunted species occupying this area. However, hunting is not permitted nor are firearms permitted within the 77-km^2 (30-mi^2) boundary of Thiokol/Wasatch. Hunting is allowed in adjacent rangelands and public and private hunting areas (predominantly for waterfowl) at the Bear River Delta.

2.2.5.2 Wetlands

On-site wetlands are very limited. The floodplain of Blue Springs Creek which flows along the western boundary is occupied by several species of sedges and grasses (Table 5) which require and/or have more tolerance of water. These areas cannot be classified as characteristic wetlands because of their limited extent and the minimal surface water season. Small areas of similar vegetation occupy the perimeters of the isolated springs found near the plantsite (Figure 12).

Small "wet" areas such as these are typically important to wildlife, as they represent a permanently available source of water. Even in low water periods when surface waters may be nearly or entirely dried up, the more abundant, lusher vegetation with its inherent increased seed and/or fruit production continues to provide cover, moisture, and food for small mammals and birds.

The delta of the Bear River, where it empties into Great Salt Lake, is located 18 km (11 mi) southeast of Thiokol/Wasatch. The delta is the site of the 260-km^2 (100-mi^2) Bear River Migratory Bird Refuge, administered by the U. S. Fish and Wildlife Service. Additional areas of the delta are committed to waterfowl management through State lands and private gun clubs. The Bear River Delta occupies an important position on both the Pacific and Central Migratory Flyways. Beyond the utilization of the Refuge during spring and fall migration by millions of waterfowl, approximately 60 species, out of the 200

TABLE 5. COMMON PLANTS OF THE BEAR RIVER MIGRATORY BIRD REFUGE

Common Name	Scientific Name	Important Season
Cattail	*Typha latifolia*	Y
Reed	*Phragmites communis*	Y
Bulrush	*Scirpus* spp.	Y
Glasswort	*Salicornia rubra*	Y
Sago Pondweed	*Potamogeton* sp.	Y
Peppergrass	*Lepidium perfoliatum*	Sp
Dyer's Woad	*Isatis tinctoria*	Sp
Foxtail Barley	*Hordeum jubatum*	Sp
Brome Grass	*Bromus* sp.	Sp
Willow	*Salix* spp.	Sp
Wood's Rose	*Rosa woodsii*	ES
Stinging Nettle	*Urtica dioica*	ES
Milkweed	*Asclepias* spp.	ES
Sweetclover	*Melilotus* spp.	ES
Indian Tobacco (Curley dock)	*Rumex crispus*	ES
Sunflower	*Helianthus annuus*	MS
Curlyleaf Gumweed	*Grindelia squarrosa*	MS
Intermediate Wheatgrass	*Agropyron intermedium*	MS
Teasel	*Dipsacus sylvestris*	LS
Wild Aster	*Aster* spp.	LS
Thistle	*Cirsium* sp	Pest
Tamarisk (Salt Cedar)	*Tamarix pentandra*	Pest

Legend

Y = All Year

Sp = Spring

ES = Early Summer

MS = Mid Summer

LS = Late Summer

Source: References 11 and 12.

species of birds recorded on the refuge, nest there annually. The refuge produces approximately 45,000 ducks and 2,500 geese annually.[13] Canada geese are the only nesting goose species. Principal nesting ducks, in order of abundance, are the gadwall, cinnamon teal, mallard, pintail, and redhead. Egrets, herons, ibises, and numerous shorebird species commonly nest in the lower marshes and along dikes of the Refuge. Seasonal abundance data for bird species in the Bear River Migratory Bird Refuge are presented in Appendix G.

Noise from large rocket test firings at Thiokol and sonic booms (3 to 4 per week) created by military aircraft flying in the area (Hill A.F. Base) have been reported[14] to cause birds in the Refuge to momentarily take wing and then soon settle back to land. No exhaust plume has been visibly detected over the Refuge, although plumes have been seen rising above the test site.[14]

2.2.5.3 Streams

Only a few streams flow through the area between Brigham City and the plantsite. The aridity of the climate and the relatively small watersheds of these streams result in extremely unstable flow conditions. The Bear and Malad rivers are the largest streams in the area, but are far removed from the plantsite, coming no closer than 30 km (19 mi) from its eastern boundary. Sulphur Creek and Salt Creek, smaller streams located between these rivers and the plantsite, are still well removed from the plantsite. The only stream in the vicinity is Blue Springs Creek, which flows through the western extremity of the plantsite.

The larger streams which are well removed from the plantsite contain flowing water throughout the year, and have pools which do not freeze solid during the winter months. No known biological studies have been conducted on any of these streams.

The smaller streams, including Blue Springs Creek, do not necessarily contain flowing water throughout the entire year, and may, on occasion, freeze solid during the winter months. Consequently, the fauna and flora are expected to be much more depauperate. The only fish which would be expected to inhabit these streams is the western speckled dace (Rhinichthys osculus). Benthic macroinvertebrates such as stonefly (Plecoptera), mayfly (Ephemeroptera), and dragonfly (Odonata) larvae typically inhabit intermittent and small streams such as these, and would likewise be expected to occur. The base of the food chain is expected to be almost entirely derived from attached filamentous algae and periphyton.[15]

2.2.5.4 Springs

A variety of springs are known to exist in the vicinity of the plantsite. Their locations are indicated on Figure 12. In most cases, they are small, but are manifested by permanent water-filled holes. Although no specific data have been collected relative to animal and plant inhabitants of these springs, it has been reported that similar springs in the area do contain an abundance of plant and animal life, including Gambusia sp. (fish), Tendipes sp. (midge fly larvae), corixid and dytiscid beetles, and periphyton, forming the predominant base of the food chain.[15] Although these springs are fairly small, they probably permit a more stable and balanced existence of plants and animals than in the case of the nearby streams.

2.2.5.5 Lakes

Because of the low precipitation and fairly rugged topography, only a few lakes exist in the region surrounding the plantsite. Of these, the largest and best known is the Great Salt Lake, located 18 km (11 mi) south of the plantsite. The salinity of the Great Salt Lake approaches saturation, and thus the lake supports a very atypical fauna and flora. The construction of a rock-filled railroad causeway across the lake in the late 1950's resulted in the creation of two ecologically distinct basins due to salinity imbalances. The northern basin, nearest the plantsite, contains a saturated brine with a depauperate biota consisting of Dunaliella salina (algae) plus unidentified protozoa and bacteria. The southern basin contains two major energy flow sequences: a planktonic sequence in which Artemia salinus (brine shrimp) feeds upon D. salina; and a benthic sequence in which Ephydra sp. (brine fly larvae) feed upon detritus and a blue green benthic alga, Coccochloris clabens.[16] No fish live in either basin due to the hypersalinity of the waters. Fish-eating birds such as the white pelican, california gull, and double breasted cormorant inhabit many of the small islands which rise above the lake's surface, but feed exclusively on fish derived from other locations.

Portions of the Bear River Migratory Bird Refuge can also be considered as a discontinuous lake, since the Bear River flows into the Refuge, which is diked to prevent saltwater intrusion from the Great Salt Lake.[17] This body of water is located 18 km (11 mi) southeast of the plantsite, and contains a more typical freshwater fauna; fish such as bass (*Micropterus* sp), pike (*Esox* sp), carp (*Cyprinus carpio*), chub (*Leuciscus* sp), and sucker (*Catostomus ardens*) are known to inhabit the area and probably feed upon benthic macroinvertebrates such as insect larvae and oligochaete worms. Detritus flowing in from the Bear River and adjacent wetlands undoubtedly forms the most important base of the food chain, along with contributions from periphyton, blue green algae, and aquatic macrophytic vegetation.

The only other body of water that can be considered a lake in the vicinity of the plantsite is Blue Creek Reservoir, an impoundment of Blue Springs Creek, located about 15 km (9 mi) north of the plantsite. No known ecological or biological studies have been conducted on Blue Creek Reservoir, and so the ecological features of this body of water are at this point unknown.

2.2.5.6 Rare and Endangered Species

There are no officially listed rare, endangered, or threatened species which are known to inhabit the Thiokol/Wasatch plantsite. Several endangered and status undetermined bird species, however, make extensive use of the Bear River Migratory Bird Refuge at least during some seasons of the year (Table 6). Because of the proximity of the Refuge to the Thiokol/Wasatch plantsite, and the flight capability of these organisms, these species could, on occasion, pass over the area.

2.3 Cultural Features

2.3.1 Demographic Features

The facilities of the Wasatch Division of Thiokol Corporation are located in the eastern half of Box Elder County, Utah. Box Elder County occupies an area of 14,600 km^2 (5,640 mi^2). A population of 31,000 represents a population density of 2 individuals per km^2 (5 individuals per mi^2). Urban population is approximately 18,000, or 58 percent of the total. Urban areas are considered those with 2,500 or more residents. The population of rural areas of the county is 13,000.

The county seat is Brigham City, with a population of 14,000. Tremonton, with 2,800 residents, is the second largest population center.

TABLE 6. RARE AND ENDANGERED SPECIES USING THE BEAR RIVER MIGRATORY BIRD REFUGE*

Common Name	Latin Name	Status
Peregrine Falcon	Falco peregrinus anatum	Endangered

Note: There are no endangered or threatened mammal, amphibian, fish, or plant species reported in the Thiokol/Wasatch plantsite area. No Peregrine Falcon eyries are known on the site.

Five bird species listed as status undetermined are known to occur on the Bear River Refuge. These include the Snowy Plover (Charadrius alexandrinus), Long-billed Curlew (Numenius americanus parvis), Burrowing Owl (Speotyto cunicularia hypugaea), White-faced Ibis (Plegadis chihi), and the Feruginous Hawk (Buteo regalis),

*Based on References 18, 89 and 90.

Figure 18 shows the distribution of population within various distances and directions from Thiokol. The distribution of home residences for Thiokol employees is also shown. Employees commute from a maximum of 100 km (62 mi) with most averaging a distance of 50 km (31 mi). Brigham City is home for 1,000 employees; Ogden, 300; Tremonton, 270; and Logan, 140. Other communities in which more than 15 employees live are Howell, Garland, Deweyville, Fielding, Honeyville, Corinne, Willard, Hyrum, Roy, Wellsville, and Clarkston, Utah, and Malad City, Idaho.

2.3.2 Social

Family groups living in the area of the Thiokol/Wasatch facility can be classified into two general groups: (1) ranchers and/or farmers, and (2) externally employed heads of households who commute long distances. Services and facilities of the region are widely spaced, except within the population center of Brigham City.

There are no schools, hospitals, or churches located near the Thiokol/Wasatch plantsite. Inasmuch as the churches and schools tend to be the social focal points of the communities, it can be stated that these centers are distant from Thiokol.

The community of Tremonton holds an annual fall fair and rodeo. Other festivals in the region include: (1) a 2-day Pioneer Day or "Mormon Day" during which most cities have parades and other activities, and (2) Peach Days in Brigham City recognizing the peach, cherry and, to a lesser extent, apricot and apple production in the Willard/Perry area.

Beyond the church-oriented social focus for the region, other activities may center on fraternal lodges such as Elks and Eagles. Utah is a dry liquor state and thus there are no "bars" per se, though private clubs are common in population centers. Other seasonal social foci are skiing areas, and boat and flying clubs.

As the largest single employer in the region, recreational activities sponsored by the Thiokol/Wasatch Division have some bearing upon the total social picture of the area. Thiokol maintains a recreational facility in Brigham City. A gym, meeting rooms, kitchen facilities, and a radio room are included. The facilities are used both by individual employees and the more than 20 interest clubs sponsored by Thiokol. These clubs include, among others, a ski club, radio club, photography club, and travel club.

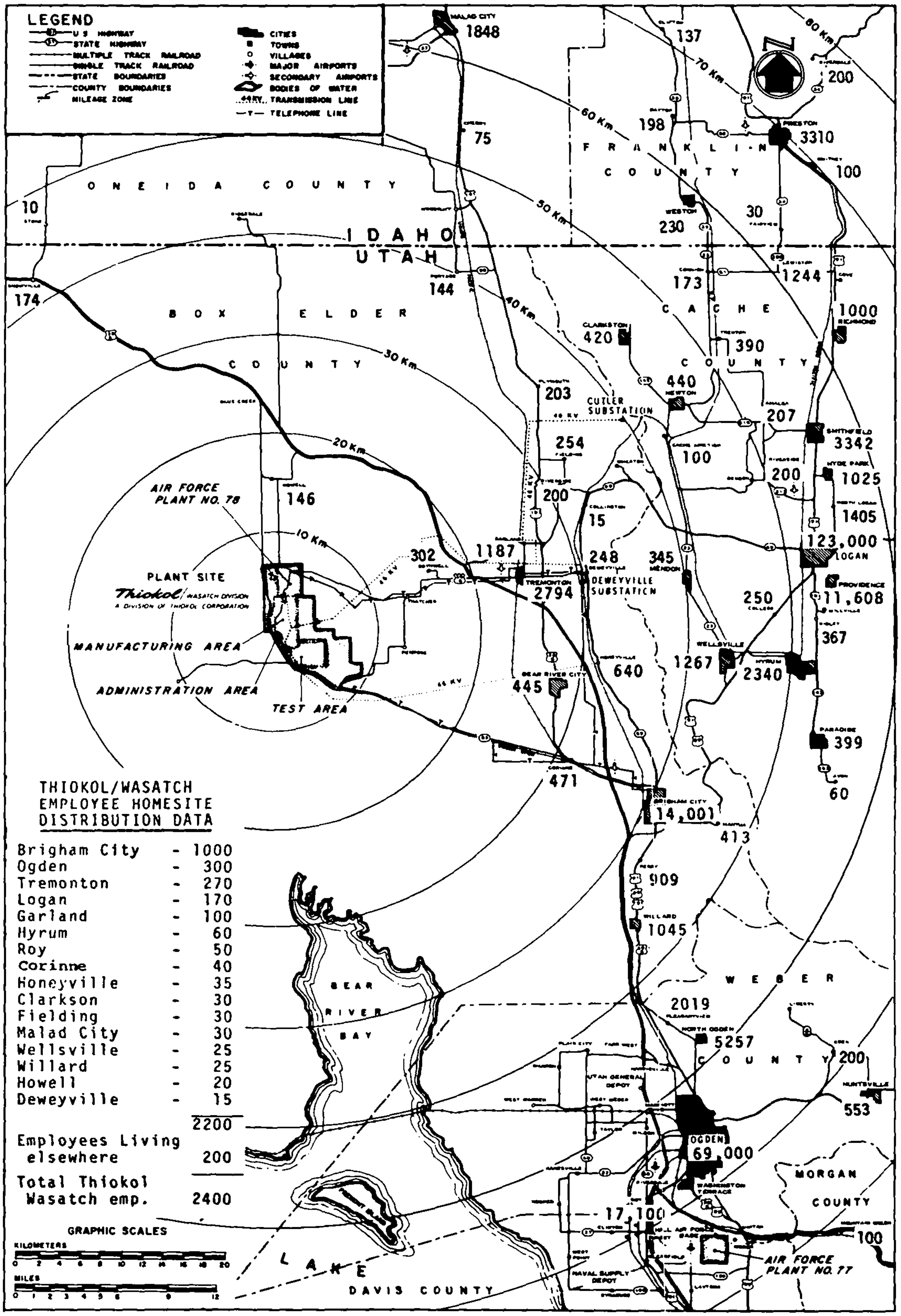


FIGURE 18. POPULATION DISTRIBUTION FOR THIOKOL/WASATCH VICINITY

Thiokol contributes annually to a large number of charitable organizations in the region. Numerous college-level courses conducted by the University of Utah and Utah State University are sponsored in Brigham City through cooperative agreements with Thiokol.

2.3.3 Historical

The early inhabitants of the Great Salt Lake Basin were desert-culture Indians who subsisted on seeds, roots, berries, and small game. The Navaho Indians were among the first distinct cultures to occupy the area, but Shoshoni and Ute later occupied and used the area as a hunting ground.

The first white men to visit the area were fur trappers. A party from the Rocky Mountain Fur Company trapped beaver in the Bear River Valley in the winter of 1824. Jim Bridger, a member of this party, followed the Bear River to the Great Salt Lake. Upon tasting the water, he believed that he had discovered an arm of the Pacific Ocean. John C. Fremont and company were the first white men known to explore the islands of the lake.

In 1851, eight families formed a settlement at Brigham City. These colonizing families were of the Mormon faith, members of the Church of Jesus Christ of Latter-Day Saints. In 1854, a colony of 50 families led by Lorenzo Snow came to the area. In the next several years the communities of Corinne, Bear River City, and Tremonton were settled. The farming communities continued to grow and prosper. The Methodist Episcopal Church, located in Corinne, has recently been declared a National Historic Site.

The region received a boost in 1869 with the completion of the Transcontinental Railroad through the area. The highlight of the building of the Transcontinental Railroad was its completion at 12:47 p.m., May 10, 1869, at Promontory Summit. This spot, now declared a National Historic Site, is located 41 km (25 mi) from Brigham City and 10 km (6 mi) from Thiokol. The driving of the Golden Spike by Leland Stanford of the Central Pacific Railroad and Thomas Durant of the Union Pacific Railroad culminated the completion of 2900 km (1800 mi) of rail across wilderness lands in less than 4 years. The railroad connected Omaha, Nebraska, terminus of the eastern railroads, to Sacramento, California. This line served until the completion of the Lucin cutoff across the Great Salt Lake in March, 1904 (see Figure 10). This cutoff shortened transcontinental time by eliminating the extra engine and switching requirements for crossing the Promontory Mountains.

In 1928, Congress established a 260-km^2 (100-mi^2) refuge on the delta of the Bear River. Considered one of the outstanding waterfowl areas of North America, the Bear River Migratory Refuge was originally created to safeguard waterfowl against serious losses from botulism.

2.3.4 Recreational

Recreational opportunities within the area are numerous and varied. Two foci of activity are (1) the Great Salt Lake approximately 18 km (11 mi) south of Thiokol and (2) the Wasatch Mountains 30 km (19 mi) east of Thiokol.

Upland game hunting particularly for birds and deer is common throughout the area, but is prohibited within the plant boundary. The marshes of the Bear River Delta are the site of several public and private hunting clubs. The duck season in Box Elder County is typically late October through the end of December. Canadian and white geese are also hunted.

Fishing is a year round sport in the region but is concentrated in the May to October season. There are no fish in the Great Salt Lake and consequently no fishing. The streams running into it and nearby freshwater lakes do, however, support a recreational fishery resource.

Snow skiing is an important recreational resource of the region. Beaver Mountain near Logan and Snow Basin, Nordic Valley, and Powder Mountain near Ogden are nearby. Park City, Brighton, Alta, and Snowbird are ski areas around Salt Lake City. Sundance is located north of Provo on Mt. Timpanogos.

Several golf courses are available in the area in Brigham City, Logan, and Ogden. There is a 9-hole course in Tremonton.

Ice skating, tennis, boating, and flying clubs are other recreational opportunities available in the area. Boating activities, predominantly on Utah Lake and the Great Salt Lake, include water skiing and fishing on Utah Lake and brine shrimping on the Great Salt Lake.

Picnicing, camping, hiking, climbing, and numerous other active recreational opportunities are available in the region. The Golden Spike National Monument is the focus of visitor recreation in the immediate vicinity of Thiokol. Approximately 55,000 visitors per year utilize this recreational resource.

2.3.5 Archeological

The northeastern Great Basin abounds with evidence of inhabitation by early man. Approximately 30 sites registered by the Utah Division of State History are either on or lie within 30 km (19 mi) of the Thiokol/Wasatch plantsite. Reference materials concerning these sites are presented in Appendix H.

Earliest occupations of the Great Basin are tied to the wetland, marsh habitats surrounding Lake Bonneville. These habitations are generally dated from 10,000 to 5500 B.P. (before present). An adaptive cultural shift is believed to have occurred late in this period. Early Archaic populations were primarily tied to the marshlands, with some limited seasonal exploitation of upland habitats. The fluctuating but slowly regressing lake prompted a gradual reduction in available marsh area and necessitated an increased dependence on upland zones by human inhabitants. This transition was culminated in Late Archaic (6000 to 4000 B.P.) with a shift to upland exploitation supported by intermittent marshland utilization.[19]

While much of the detail of prehistoric occupation of the region has not been worked out as yet, it is apparent that the Fremont and Nunic cultures greatly influenced the local inhabitants. Because of the proximity of the lake, the local cultures at all times retain some unique characteristics, though the lake never played a dominant role in cultural patterns after the Early Archaic periods.

By the time white cultures entered the region in the early 19th century, the modern Shoshoni Indian Tribe ruled the area of concern and much of a large region around this. The Shoshoni have their origins in the desert-plains cultures described above.

The Thiokol Corporation recognizes the archeological resource of its land holdings. Several petroglyphs have been preserved and are displayed to the public at the entrance, where they are coordinated with the rocket motor displays. All archeological resources of the plantsite are protected, and studies of the plantsite have been made by Utah State University.

2.3.6 Paleontology

Sediments composing the Blue Springs Hills are predominantly late Paleozoic in origin. The fossil component of these sediments is largely invertebrate organisms which are of minimal paleontological importance. Any vertebrate fossils in the area would be confined to the Blue Springs Creek bottom, but these resources have not been surveyed at this time. The area occupied by the Thiokol/Wasatch Division is generally a low paleontological resource area.[20]

2.3.7 Aesthetics

The value of aesthetical impressions to an individual is a highly personal thing. In consideration of this, the description of the existing aesthetics of the Thiokol/Wasatch facility will be presented from two general points of view: (1) a visitor to the area, perhaps a vacationer stopping by the Golden Spike National Monument, and (2) an area resident not directly employed at the facility.

The normal access route to the area for visitors is along State Route 83 (SR 83) from Brigham City (see Figure 10). The Blue Springs Valley can be characterized by its vast openness. The towering (to 3000 meters east of Brigham City) Wasatch Range would be to the back of the visitor with only small hills in view to the west and north, and with almost unlimited visibility (controlled by air quality) to the south across the Salt Lake Basin. The Wasatch Range is snow-peaked much of the year. Vegetation is limited to grasses and small shrubs over the area, contributing to a feeling of vastness and/or desolation. The muted colors of the desert are virtually unbroken by natural or manmade intrusions. Roughly 35 km (22 mi) from Brigham City SR 83 turns to the north-northwest. Rounding this turn, the visitor is confronted with a group of randomly spaced, one- and two-story multicolored buildings; primary colors predominate on these buildings. The buildings are a part of the Thiokol/Wasatch R&D area. A similar area (Plant 78) can be seen from SR 83 further north along the road after the Promontory Point cutoff.

The perimeters of all major facilities are fenced and guarded. This is necessary for public safety, company proprietary reasons, and government security. The public is, however, allowed to visit and spend time in a display area which is located outside the strict security area. Mock-ups of rocket motors designed, processed, and tested at the Thiokol/Wasatch facility are displayed. These include Minuteman, Genie, Poseidon, Bomarc, Mace, and a 120-inch booster segment, among others. Along with the technological display, several petroglyphs found on the plantsite have been displayed within this same area. A visitor is thus exposed to both man's earliest records through the petroglyphs and some of his most recent technological accomplishments in the form of solid rocket motors for space and defense.

Most local residents who are not directly employed at Thiokol or involved in service support are engaged in farming and/or ranching. Dry (nonirrigated) wheat farming predominates in the vicinity, with most farms additionally supporting small cattle herds. There are approximately 20 farms in the vicinity. Historically, as well as presently, there has been a resentment by ranchers toward "government" intervention (land-holding). Because the Thiokol facility has been present for over 20 years and because grazing permits were included in original land purchase agreements for the facility, this resentment does not seem to be an influence in the area. The Utah culture is basically pro-industry, where industry does not compete or conflict with ranching. Because the Thiokol facility does not conflict with and does contribute to the prosperity of the area, the local residents have a generally positive aesthetic opinion of the Thiokol/Wasatch operation.

The test firing of rocket motors at Thiokol is not new to the area. Both large and small motors are test fired at an average of 10 to 15 per year for larger motors (156-inch and Minuteman first stage class) and 100 to 200 per year for smaller motors (Genie, Harm, etc.). Large motors, however, such as the 156-inch motors, have not been tested for the past 8 years. The larger rocket motor test firings are accompanied by loud, though not painful at facility boundaries, noises with a duration of up to 2 minutes. A plume of gray-white smoke rises rapidly and vertically over the test site to the altitude at which it dissipates to invisibility. The exhaust cloud altitude varies with the size of the motor but may be from 1000 to 4000 m (3000 to 12,000 ft) high. Such exhaust clouds would be highly visible in clear skies.

Open pit burning of waste propellant and other hazardous materials is also accompanied by gray-white smoke which drifts slowly, rises, and dissipates. Open burning activities are not accompanied by loud noises.

These activities are a part of the background activity of the area. The attitudes of a visitor may range from dislike to intrigue at being able to observe a part of the space program. Local residents would associate these activities with the industry to such a degree as to have the same attitude about test firings as they do of the facility in general.

2.4 Economic Features

2.4.1 Farming

Approximately 13 percent of the total land mass in Box Elder County is in cultivation. Table 7 reports the major crops and area of each.

TABLE 7. MAJOR CROPS AND AGRICULTURAL LAND USAGE OF BOX ELDER COUNTY

Category	Area, km^2
Total Cultivated	1,552
Winter wheat	304
Spring wheat	32
Oats	6
Corn	40
Sugar beets	81
Hay	16
Alfalfa	162
Pasture, range	526
Irrigated (not included above)	385
Open Range	4,454
Pasture (noncultivated)	445
Orchard Land	636

The main source of irrigation water for Box Elder County is the Bear River. The water is impounded by Cutler Dam, which is owned by the Utah Power and Light Company, and is used for generating power. The power company assures 25,500 liters/sec (6,740 gal/sec) of water during the irrigation season. Most of the main water-delivery canals are owned and maintained by the Utah-Idaho Sugar Company. Water is delivered to the farmers on a turn basis.

Sugar beets are the most important irrigated crop. Sugar beets produced in Utah and southern Idaho are processed at the Utah-Idaho Sugar Company's Garland plant. Tomatoes are another important irrigated crop.

A short average growing season in the valleys limits many crops which can be grown. Suitable crops are irrigated alfalfa, alfalfa seed production, irrigated pasture, and some silage corn along with several small grains, predominantly wheats.

Contrasted to the prevailing arid conditions over much of the county, many areas of the Bear River Valley are too wet for maximum crop production without water level control. Tile draining is extensive in these soils.

2.4.2 Industrial Employment

Thiokol/Wasatch Division is the largest employer north of the Ogden metropolitan area. Thiokol is one of the fifteen largest employers in Utah.

In Box Elder County, other employers of over 100 and their locations are: American Greeting Card Company, Brigham City; Brigham Apparel Corporation, Brigham City; Fife Rock Products Co., Inc. (ready-mix concrete), Brigham City; Western Fruit Packers, Inc., Brigham City; and Utah-Idaho Sugar Co., Garland. There are numerous firms employing from 10 to 100 individuals, with most located in Brigham City or Tremonton. Others are located at Promontory Point (salt production) and Perry (fruit and vegetable canning).

The Wasatch Division of Thiokol Corporation has an average work force of 2400. Historical employment patterns at Thiokol/Wasatch have been rather consistent over the years, reaching a peak during maximum Minuteman motor production. Of the total employment skills, breakdowns are as follows: 255 management, 350 clerical and support, 565 engineering and research, 1230 trades and/or skilled labor.

The employment situation in Box Elder County can be generally described at the present time as "substantial unemployment".

2.4.3 Local Goods and Services

Major goods and services which support the total Thiokol/Wasatch plantsite operation, and are provided by locally based companies or organizations, are those for food, energy, and computer services. The Prophet Company provides a catering service to support cafeteria and vending machines located on the Thiokol premises. Electrical energy is provided by the Utah Power and Light Company. Gasoline and diesel fuel used for land-based plant vehicles and fuel oil for space and process heating are supplied by the American Oil and Hatch Fuel Oil companies. On occasion, the use of the University of Utah's (Salt Lake City) UNIVAC 1108 computer is required, as Thiokol's computer is not adequate to handle all computer needs.

2.4.4 Nonlocal Vendors

Government space and/or military hardware contracts typically involve major subcontracts for support materials. A typical solid rocket motor program at Thiokol/Wasatch involves the fueling, finishing, assembly, and testing of the motor. The forging and machining of casing segments along with numerous other hardware components are typically done under subcontract. Propellant ingredients are also supplied by nonlocal vendors.

Due to the sophistication and/or size of most of these orders most must be undertaken by nonlocal vendors. Each vendor is chosen by competitive bid and is subject to all applicable Federal regulations.

3.0 RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS, POLICIES AND CONTROLS

Thiokol/Wasatch Division is located in rural Box Elder County, Utah. This land is subject to no municipal planning authorities. The County does have zoning ordinances covering limited areas, but does not have any existing or planned zoning ordinances in the area of Thiokol.

Due to existing facilities and the absence of comprehensive planning in the area, no land use conflicts are anticipated in accomplishing the processing, static test firing and transportation of the Solid Rocket Motors (SRMs) in support of the Space Shuttle SRM Design, Development, Test and Evaluation (DDT&E) Program.

3.1 Facilities Location

Conduct of the Space Shuttle Solid Rocket Motor (SRM) Program at Thiokol/Wasatch will be accompanied by minor modification and/or refurbishment of some existing facilities. No major facility construction will be required at Thiokol. A description of buildings and other facilities which will be used in support of the program is outlined in Appendix E.

3.2 Railroad

The Union Pacific Railroad will serve the Solid Rocket Motor (SRM) Program through its facilities at Corinne. In-bound and out-bound case segments will be handled by rail and other major hardware shipments will be handled by truck. The Union Pacific has plans to upgrade the facilities at Corinne, in part to support the activities of the Space Shuttle SRM Program. Planned activities include construction of a new siding and concrete support pad at Corinne. No significant environmental effects are anticipated as a result of this action.

3.3 Agriculture

Agriculture activities and land uses will be unaffected by conduct of the Space Shuttle Solid Rocket Motor (SRM) Program. No additional land is required for industrial activity. Grazing leases on Thiokol lands will be maintained. Planned testing activities will not affect off-site agricultural uses of land.

4.0 ENVIRONMENTAL EFFECTS OF PROPOSED ACTION

4.1 Introduction

The potential environmental effects of the Space Shuttle Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) Program activities are discussed in detail in this section. In Sections 4.2 through 4.6, physical effects relating to air quality, noise, water quality, solid wastes, and pesticides are described. The resulting implications of induced changes in the physical environment to human beings and to flora and fauna are discussed in Sections 4.7 and 4.8, respectively. Section 4.7 also treats the implications to humans of accidents associated with transportation of the SRM segments. Cultural and economic effects of the DDT&E Program are covered in Sections 4.9 and 4.10, respectively. Commitments of manpower, materials, energy, water, and certain lands and facilities are discussed in Section 8.0.

4.2 Air Quality

This section considers possible effects to air quality which could occur from Space Shuttle Solid Rocket Motor (SRM) DDT&E Program activities. Effects upon man, flora and fauna resulting from possible degradation in air quality are discussed in Sections 4.7 and 4.8.

The SRM DDT&E Program activities which may degrade air quality are:

- Work force transportation
  - automobile emissions
- SRM processing
  - process-chemical releases
  - emissions resulting from energy utilization
- Combustion of SRM propellant
  - open burning of waste propellant
  - normal SRM static test firings
  - abnormal SRM static test firings
  - accidental ignition of a SRM casting segment.

Possible effects of these activities upon air quality are presented in the following subsections.

4.2.1 Work Force Transportation

The total work force that supports all programs at the Thiokol/ Wasatch plantsite has remained approximately 2400 over the last few years and is not expected to change significantly over the next five-year period. Approximately 75 percent of the total work force of 2400 (see Figure 37) work the first shift (07:30 to 16:00). The remaining work the second and third shifts. Roughly 600 vehicles, nearly all of which are automobiles, transport the work force to and from work on a given work day. Because of the remoteness of the plantsite, almost everyone uses car pools. The average daily round-trip distance traveled by a typical Thiokol/Wasatch worker is ~100 km (62 mi).

The estimated total daily automobile emissions resulting from the transportation of the total Thiokol work force are estimated in Table 8 for the years 1975 and 1978. Also shown are the estimated contributions from the Space Shuttle SRM DDT&E Program and other Thiokol programs. Emission data reflect expected changes resulting from EPA automobile emission standards for new automobiles.[21]

TABLE 8. TOTAL DAILY AUTO EMISSIONS RESULTING FROM THIOKOL/WASATCH WORK FORCE TRANSPORTATION

Emission	1975 SRM DDT&E (kg)	1975 Other (kg)	1975 Total (kg)	1978 SRM DDT&E (kg)	1978 Other (kg)	1978 Total (kg)
Carbon Monoxide	360	1460	1820	225	905	1130
Hydrocarbons	45	185	230	30	110	140
Nitrogen Oxides	35	145	180	25	110	135
Particulates	3	11	14	3	11	14
Sulfur Dioxide	1	6	7	1	6	7

The majority of the Thiokol employees use State Route 83 (SR 83) for access to the plant. From the work force homesite distribution data (Figure 18), the total Thiokol work force vehicular traffic along SR 83 between Thiokol and Corinne has been estimated at 350 two-way trips per workday. Of this 350, 70 to 80 are estimated to be associated with the SRM DDT&E Program.

During the summer months, May through August, approximately 100 cars per day will also pass along SR 83 as tourists visit the Golden Spike historic site. Other local traffic is considered insignificant. Therefore, the total peak traffic along SR 83 would be expected to be about 450 two-way trips, or 900 one-way trips. The estimated peak 1975 daily auto emissions along SR 83 between Corinne and the Thiokol plantsite are shown in Table 9, below:

TABLE 9. ESTIMATED 1975 DAILY AUTO EMISSIONS ALONG SR 83 BETWEEN CORINNE AND THIOKOL PLANTSITE

Daily Emissions (kg/km)		Percentage Breakdown by Time of Day						Total %
Carbon Monoxide	28	Emission Period (MST)	06:30 to 07:30	07:30 to 15:30	15:30 to 16:30	16:30 to 20:00	23:30 to 0:30	
Hydrocarbons	3.6							
Nitrogen Oxides	2.7	SRM DDT&E Program	7	0	7	0	2	16
Particulates	0.2	Other Thiokol Programs	27	0	27	0	8	62
Sulfur Dioxide	0.1	Golden Spike Visitors	0	13	2	7	0	22
		Total →	34	13	36	7	10	100

The estimated emissions from automobiles which transport the SRM DDT&E work force to the Thiokol/Wasatch plantsite are small compared to the total auto emissions in the area. Also, the emissions which will result from automobiles which transport the Space Shuttle SRM DDT&E Program work force to and from the plantsite will not be measurable and are considered insignificant.

4.2.2 SRM Processing

SRM processing operations are in compliance with Utah State restrictions on the emission or discharge of pollutants to the atmosphere. Required sampling of stack discharges is conducted by plant analytical specialists and records are maintained for review. On a selected basis, recovery equipment necessary to certain operations involving organic solvents, etc., is monitored and evaluated for efficiency. Installations of selected atmospheric discharge equipment require approval by State and Federal agencies. All equipment in this category is designed to the agency specification and approved by them prior to use.

4.2.2.1. Process Chemical Releases

Space Shuttle SRM processing activities during the DDT&E Program will result in the release of various process chemicals into the atmosphere. Most of these chemicals perform the roles of solvents and cleaning agents (see Table 10). 1,1,1-trichloroethane is used to clean SRM case segments in the vapor degreaser facility. It is anticipated that most of the 68,000 kg (150,000 lb) of this substance will be emitted into the atmosphere. Current estimates indicate that up to 270 kg (600 lb) per day during full-scale production would be lost. Various amounts of toluene, xylene, and methylethyl ketone will be used as cleaning agents during the five-year performance of the SRM DDT&E Program. Xylene and methyl cellosolve are released into the atmosphere as a result of the application of drying of primers and paints, which are applied to SRM case segments. Carbon dioxide is used as an inert pressurant in the curing of insulation and liners in the autoclave. The use of vented hoods, vent lines, and fans aids in minimizing the exposure of plant employees to these chemicals. The estimated maximum rates of release of these chemicals, under normal operations, as shown in Table 10, are considered to be small, and resulting concentrations of these chemicals in the air immediately surrounding the R&D Area are expected to be minute.

TABLE 10. ESTIMATED PROCESS CHEMICAL ATMOSPHERIC EMISSIONS FOR THE SPACE SHUTTLE SRM DDT&E PROGRAM

Chemical Name	Formula	Function	Total Amount Emitted (kg)	Maximum Release Rate* (kg/hr)
Trichloroethane	CH_3CCl_3	Cleaning Solvent(degreaser)	68,000	11
Toluene	$C_6H_5CH_3$	Cleaning Solvent	4,500	< 2
Xylene	$C_6H_4(CH_3)_2$	Paint & Cleaning Solvent	3,100	2.6
Methyethyl Ketone	$CH_3C(O)CH_2CH_3$	Cleaning Solvent	2,300	< 2
Methyl Cellosolve	$HOCH_2CH_2OCH_3$	Paint Solvent	900	3
Carbon Dioxide	CO_2	Inert Pressurant Gas	205,000	6,600

*Note: Release rates are continually varying. The maximum value would rarely be attained.

The proper handling of such other chemicals as magnesium silicate (asbestos - used in liner and inhibitor), zirconium silicate (used as grit in grit blaster), and aluminum powder and ammonium perchlorate (used in SRM propellant) is accomplished such that no measurable particulate releases of these chemicals into the atmosphere will take place during SRM processing. An elaborate filtering system is employed when processing the asbestos used in the SRM liner and inhibitor to eliminate the exposure of workers to asbestos particulates. Spray painting of the SRM cases and components is performed under controlled conditions and is generally carried out automatically in a sealed room, equipped with a filtering system. The emission of chemical process particulates into the atmosphere is not anticipated and, therefore, will not impact air quality.

4.2.2.2 Emissions Resulting from Energy Utilization

At the Thiokol/Wasatch plantsite, several types of petroleum products are consumed to produce various forms of energy. The combustion of these products results in the release of chemical species into the atmosphere. The major products consumed are: Numbers 2, 4 and 5 fuel oils and motor gasoline. Fuel oil is used for process and space heating; motor gasoline is used for powering process equipment and surface transport vehicles.

Electrical energy consumed at the plant does not impact the local environment.

4.2.2.2.1 Emissions from Oil-Fired Boilers

Various oil-fired steam boilers, that have been or are now being used for other programs, will be employed to provide domestic hot water and process and space heating in support of the Space Shuttle SRM DDT&E Program. Currently, in support of all programs at Thiokol/Wasatch, 43 oil-fired boilers are used. Plant 78 has two large boilers, each capable of consuming over 4×10^6 liters (1×10^6 gal) of Number 5 fuel oil, annually. The R&D Area has two main boiler houses (four boilers in each) with a combined consumption capacity of 1720 liters/hr (450 gal/hr) and burn Number 5 fuel oil. The remaining boilers are relatively small units (400-3000 kw), strategically located to support facilities heating requirements. In many areas, the boilers are connected to a main steam line and do not, therefore, support individual facilities.

In 1975, the total consumption for Number 2 and Numbers 4 and 5 fuel oil was: 1.5×10^6 liters (0.40×10^6 gal) and 13.7×10^6 liters (3.62×10^6 gal), respectively. These data are typical of previous years' consumptions (see Figure 40). The increase in Shuttle SRM DDT&E Program activity is not expected to cause the total fuel oil consumption to increase, as other programs will be phased out. The consumption related to Shuttle SRM activities is expected to be approximately one-fifth of the Thiokol/Wasatch total. The estimated total annual emissions from Thiokol's boilers are shown in Table 11. These data were obtained by considering that: the sulfur content is 1.3% for oil burned; typical annual oil consumption rates; anticipated peak Shuttle SRM activity; and fuel oil combustion emission factor data from Reference 21. It is estimated that during winter months approximately 1.32 kg (2.91 lb)/minute of SO_2 is emitted at the plantsite as a result of total Thiokol program activity (see note on Table 11). Rates of other species would be lower.

It is concluded that the continued use of existing oil-fired boilers for the SRM DDT&E Program poses essentially no impact on air quality. Thiokol/Wasatch currently meets Utah Air Conservation Regulation and Federal Ambient Air Standards for emissions from oil-fired boilers.

TABLE 11. ESTIMATED ANNUAL EMISSIONS FROM OIL-FIRED BOILERS

Emissions	Total Programs (kg/yr)	Space Shuttle SRM DDT&E Program (kg/yr)
Sulfur Dioxide	335,000	67,000
Nitrogen Oxides	100,000	20,000
Particulates	38,000	7,600
Hydrocarbons	5,000	1,000
Sulfur Trioxide	4,300	860
Aldehydes	1,600	320
Carbon Monoxide	300	60

Note: Data are based on typical consumption data, peak SRM DDT&E activity, and emission data in Reference 21. Estimated peak monthly emissions can be obtained by multiplying yearly values above by 0.17.

4.2.2.2.2 Emissions From Gasoline Powered Vehicles

Typically, 1.4×10^6 liters (0.37×10^6 gal) of gasoline are consumed yearly at the Thiokol/Wasatch plantsite. This consumption rate is not expected to increase as a result of the Space Shuttle SRM DDT&E Program. In fact, consumption may decrease as a result of the energy conservation program now in effect. Currently, specific emission information is not available for the surface transportation vehicles. Total annual emissions for the plant vehicles would be similar to the total annual emissions resulting from work force transportation. No significant or measurable impact on air quality caused by consumption of the amount of gasoline needed to support the SRM DDT&E Program is anticipated.

4.2.2.2.3 Non-Local Emissions Due to Electrical Energy Consumption

During the 1977-1978 time period, the period when the Space Shuttle SRM DDT&E Program activity is expected to peak, it is estimated that a total of approximately 40×10^6 kwhr of electricity will be consumed annually at the Thiokol/Wasatch plantsite. This total annual estimated electrical energy consumption rate is typical of historical consumption rates, considers the current Thiokol energy conservation measures, and includes requirements from all programs. During the peak Shuttle SRM activity approximately 8×10^6 kwhr of electrical energy per year will be required for the Shuttle SRM DDT&E Program. Although the consumption of electricity at the plant will not result in local emissions of undesirable combustion products, non-local emissions of these products will occur.

Thiokol purchases electrical power from the Utah Power and Light Company (UPLC). The power generated by the UPLC comes from a network of power plants located throughout Utah and Wyoming. Approximately 92% of the total power is generated from coal-fired power plants, the remainder is supplied from network hydroelectric power stations. The coal burned in the coal-fired power plants has a low sulfur content, and particulate ash emissions are minimized by the use of electrostatic precipators. The Utah-based power plants are located ~160 km (100 mi) SSE of Salt Lake City, near Helper, Huntington, and Emery. The Wyoming-based power plant complex is located near Kemmerer.

The 1977 annual emissions for all UPLC coal-fired power plants are estimated in Table 12. These estimates are based upon data in References 21 and 22. When the total annual projected electrical energy requirements of the entire Thiokol plantsite (40 x 10^6 kwhr) and the Space Shuttle SRM DDT&E Program (8 x 10^6 kwhr) are compared to the projected energy output of UPLC, the contribution to the total emissions from total Thiokol and SRM activities can be estimated. These data are also shown below in Table 12.

TABLE 12. EMISSIONS DUE TO ELECTRICAL ENERGY CONSUMPTION

	Annual Estimated Emissions (1977)		
Emittants	Total for Utah Power & Light (kg)	Thiokol Total (kg)	Shuttle SRM DDT&E Contribution (kg)
Nitrogen Oxides	45,000,000	130,000	26,000
Sulfur Dioxide	38,000,000	110,000	22,000
Carbon Monoxide	2,500,000	7,400	1,480
Particulate Ash	1,180,000	3,400	680
Hydrocarbons	750,000	2,200	440
Aldehydes	13,000	40	8

Note: Based on References 21 and 22, and 1977 electric energy projections.

The prorated non-local emissions due to the SRM DDT&E Program are considered insignificant (1/1700) when compared to the total. Continued research efforts to remove sulfur from coal, potential use of coal gasification processes, and an improved power plant efficiency should reduce the percentage of undesirable exhaust products in the near future.

4.2.3 Combustion of SRM Propellant

The combustion of SRM propellant will result in the quasi-instantaneous release of various chemical species (e.g., HCl gas and Al_2O_3 particulate) into the atmosphere, thus potentially impacting air quality. Planned combustion of Space Shuttle SRM propellant will occur during the disposal of waste propellant from casting operations and seven SRM static test firings. Unplanned releases of SRM propellant combustion products could occur (extremely low probability) if an

SRM case were to fail during a static test firing (abnormal test) or a casting segment were to be accidentally ignited, as a result of acts of God, transportation accident, etc. Analyses of the planned and unplanned quasi-instantaneous releases will be presented in the subsections that follow.

The State of Utah Air Conservation Committee of the Division of Health has stated [23,24] that the open burning of waste propellant and the static test firings of the Space Shuttle SRM, which are performed during meteorological conditions where the Clearing Index (CI) is greater than or equal to 500, would comply with Utah Air Quality Standards [25] (see Appendix I for CI definition). The Clearing Index is an indication of the predicted clearance of ground level pollutants in a given area based on measured temperature lapse rate and wind speeds. Clearing Index data compiled for the Salt Lake Valley, including the Wasatch Division area, show that favorable Clearing Index conditions (CI $\geq$ 500) have prevailed for more than 80% of the time over a six year period. [26] Figure 19 presents maximum, minimum, and average monthly frequencies for the actual Clearing Index for the period March, 1968, through June, 1973. [26] It is evident from this figure that from mid-to-late fall through winter, the CI is, on the average, unfavorable ~40% of the time. Thiokol/Wasatch will comply with Utah Air Quality Standards including open burning exemptions for planned releases.

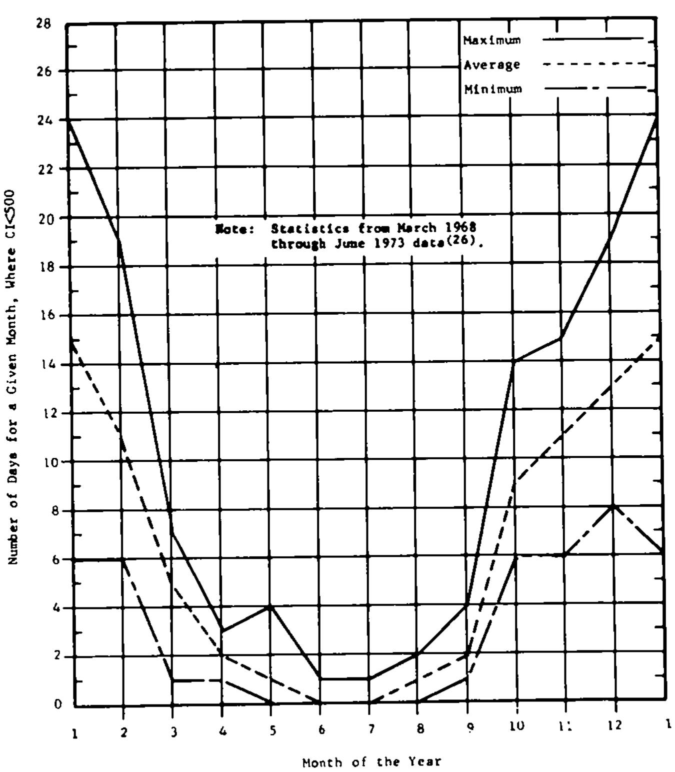


FIGURE 19. STATE OF UTAH CLEARING INDEX STATISTICS

The predicted magnitude and duration of the downwind ground-level concentrations of pollutants emitted from the SRM test firings and open burning, are necessary in the assessment of air quality impacts. Also of importance is the correlation of the CI to the peak downwind ground-level concentration and dose of a pollutant. Therefore, to determine the above, it is necessary to employ specific local meteorological conditions*, where the CI has been defined, as input to a dispersion model.

The dispersion model chosen in this assessment is Model 3 of the NASA/MSFC Multilayer Diffusion Program - Version 5 (see Appendix J for a description of Model 3).[27] This model has predicted HCl concentrations which correlated well with measurements taken for Titan launches at The Air Force Eastern Test Range, Florida. To date, the model has consistently predicted higher ground level concentrations than have been measured.[28]

Various meteorological parameters are required as input to the NASA/MSFC Diffusion Model. These parameters include: pressure, temperature, wind speed, wind direction, and relative humidity, as a function of altitude; and the depth of the surface mixing layer. Meteorological data of this type that have been obtained for the Thiokol/Wasatch plantsite are limited. However, it has been shown that various Thiokol data correlate closely with upper air data obtained from Salt Lake City soundings (see Figure 16).[29] Soundings taken at Logan, Utah, by the University of Utah Meteorology Department have correlated well with soundings taken at Salt Lake City. Inversion layers recorded at each location have typically been within 100 m (330 ft).[30] Low lying inversions at Logan are usually more severe because of local topographic effects (deep valley). Logan and Thiokol/Wasatch are both ~130 km (80 mi) north of Salt Lake City, Logan being slightly to the east and Thiokol/Wasatch slightly to the west of north. Therefore, for lack of better information, and because Salt Lake City upper air data are expected to be very similar to those at the Thiokol/Wasatch plantsite, Salt Lake City data were used in the prediction of concentrations and dosages of various pollutants resulting from the combustion of SRM propellant.

*The reader is referred to a discussion of the existing meteorological conditions, which is presented in Section 2.2.4. Note that exhaust clouds resulting from combustion of SRM propellant will have ground tracks dictated by local winds (see Figures 14 and 15).

The depth of the surface mixing layer is one of the prime meteorological factors in predicting downwind pollutant concentrations and dosages resulting from rocket tests or launches. By definition, the top of surface mixing layer is the height at which the vertical intensity of turbulence becomes effectively zero. Since direct measurement of the intensity of turbulence is not routinely made, indirect indicators such as wind speed or vertical temperature gradient must be used to estimate the surface mixing layer depth.

Over the past several years, G. C. Holzworth and others in the Meteorology Division of the Environmental Protection Agency have summarized mixing layer depths estimated from records of Salt Lake City radiosonde observations. Median afternoon surface mixing layer depth as a function of month is presented in Figure 20[31], and shows, as expected, a large seasonal variation which correlates well with Clearing Index data shown in Figure 19. The Holzworth method of predicting surface mixing layer depth is employed by the State of Utah in issuing the daily Clearing Index (defined in Appendix I).

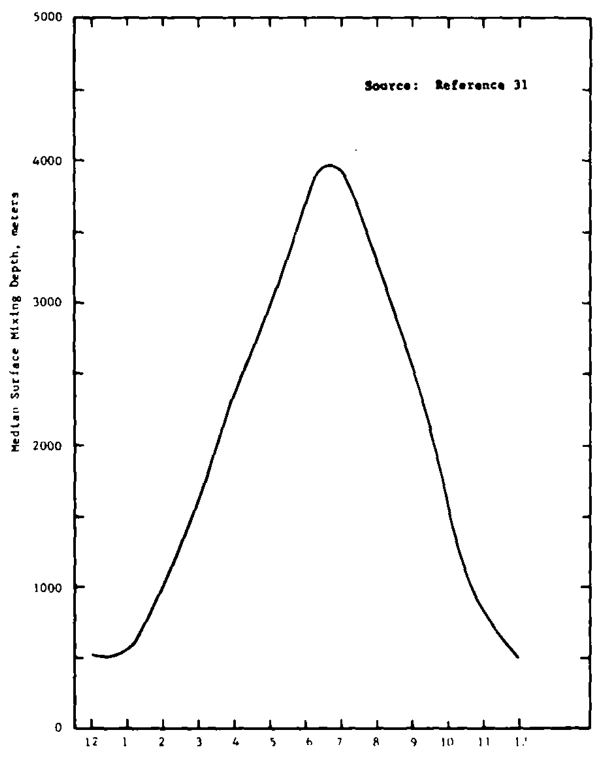


FIGURE 20. MEDIAN AFTERNOON MIXING LAYER DEPTHS FOR SALT LAKE CITY

If the Clearing Index is to be correlated to the downwind ground-level pollutant concentrations and dosages resulting from the quasi-instantaneous releases, then the Clearing Index for a given day must be compared to diffusion calculations which employ the meteorological conditions for that same day. Radiosonde data for Salt Lake City were obtained from the National Climatic Center, Asheville, North Carolina, for January, 1974, through September, 1975. Predicted and actual Clearing Index statistics were also obtained from the Salt Lake City Weather Station for the same period.[32] Since SRM static test firings are expected to occur when meteorological conditions more closely resemble the afternoon sounding at Salt Lake City, only afternoon meteorological data were selected for use with the diffusion model. A total of twenty-three soundings were selected. The soundings chosen represent days during various months of the year where the Clearing Indices varied from 30 to 4500. The selected dates are shown in Table 13, along with the predicted (a.m.) and actual (p.m.) Clearing Indices and surface mixing depths. The detailed meteorology for these dates is available in Reference 33.

TABLE 13. SELECTED METEOROLOGICAL CASES FOR DIFFUSION CALCULATIONS

Group	Case Number	Date*	Predicted[32] CI	Actual[32] CI	Surface Mixing Depth[32] (m)
CI<200	1	1/12/74	91	144	366
	2	1/13/74	192	60	180
	3	2/9/74	240	130	793
	4	2/10/74	60	60	710
	5	2/11/74	130	42	430
	6	10/18/74	175	160	610
	7	12/9/74	200	60	610
	8	1/14/75	100	30	91
200<CI<800	9	1/1/74	300	400	1280
	10	1/3/74	300	290	792
	11	1/9/74	650	600	366
	12	1/18/74	200	200	610
	13	8/21/74	480	500	3048
	14	9/28/74	500	300	1372
	15	2/18/75	350	340	1710
CI>800	16	1/26/74	1000+	840	1829
	17	1/28/74	1000+	900	1829
	18	4/8/74	1200	1280	1951
	19	5/11/74	1600	1300	3048
	20	6/19/74	2000	4500	4572
	21	6/20/74	1500	2400	3658
	22	8/9/74	880	800	2438
	23	2/21/75	1000+	1800	3048

*Note: Meteorological data for these dates are shown in Reference 33.

The following subsections describe both the planned and unplanned releases resulting from the combustion of SRM propellant, and present the results of dispersion calculations.

4.2.3.1 Open Burning of Waste Propellant

Presently, the only economical and safe method for disposing of waste propellant from solid rocket motor manufacturing operations is by burning in large open pits. The Thiokol/Wasatch Division has utilized this disposal method since propellant mixing operations began in 1957. The State of Utah Air Conservation Committee currently permits[23] this method of hazardous waste disposal, as there now is no other known practical method of disposal. Other methods of disposal have been under study by Thiokol[34], and a discussion of possible alternatives to open burning of waste propellant is presented in Section 6.0.

4.2.3.1.1 Burn Pit Operations

The burning pit area (M-136) currently used (see Figure 21) is strictly controlled to insure the safety of operation. On February 19, 1976, the Utah Air Conservation Committee granted the Thiokol/Wasatch Division an exemption from the Open Burning Regulations (Section 2.1 of Reference 25).[23] For several years the Thiokol/Wasatch Division has operated in accordance with an open burning variance.[35] The following conditions now apply:

(1) The exemption is for open burning of explosive material and is limited to that material which cannot be safely stored long enough to await favorable meteorological conditions as defined under the Clearing Index system.

(2) The exemption does not allow the open burning of any waste containing beryllium or other highly toxic materials except when meteorological conditions are such that the resulting products of combustion will traverse over unoccupied areas only. A description and evaluation of the quantities of highly toxic material to be emitted to the atmosphere must be submitted to the Executive Secretary (Utah Air Conservation Committee) prior to each burning.

(3) Records must be kept of the date, time, place, and quantity of each burn and the type of material burned during each year; these records must be submitted to the Utah Air Conservation Committee by January 15 of each year for the preceding year.

(4) A report of investigative efforts to eliminate open burning of hazardous materials of this type must be submitted to the Committee by January 15 of each year.

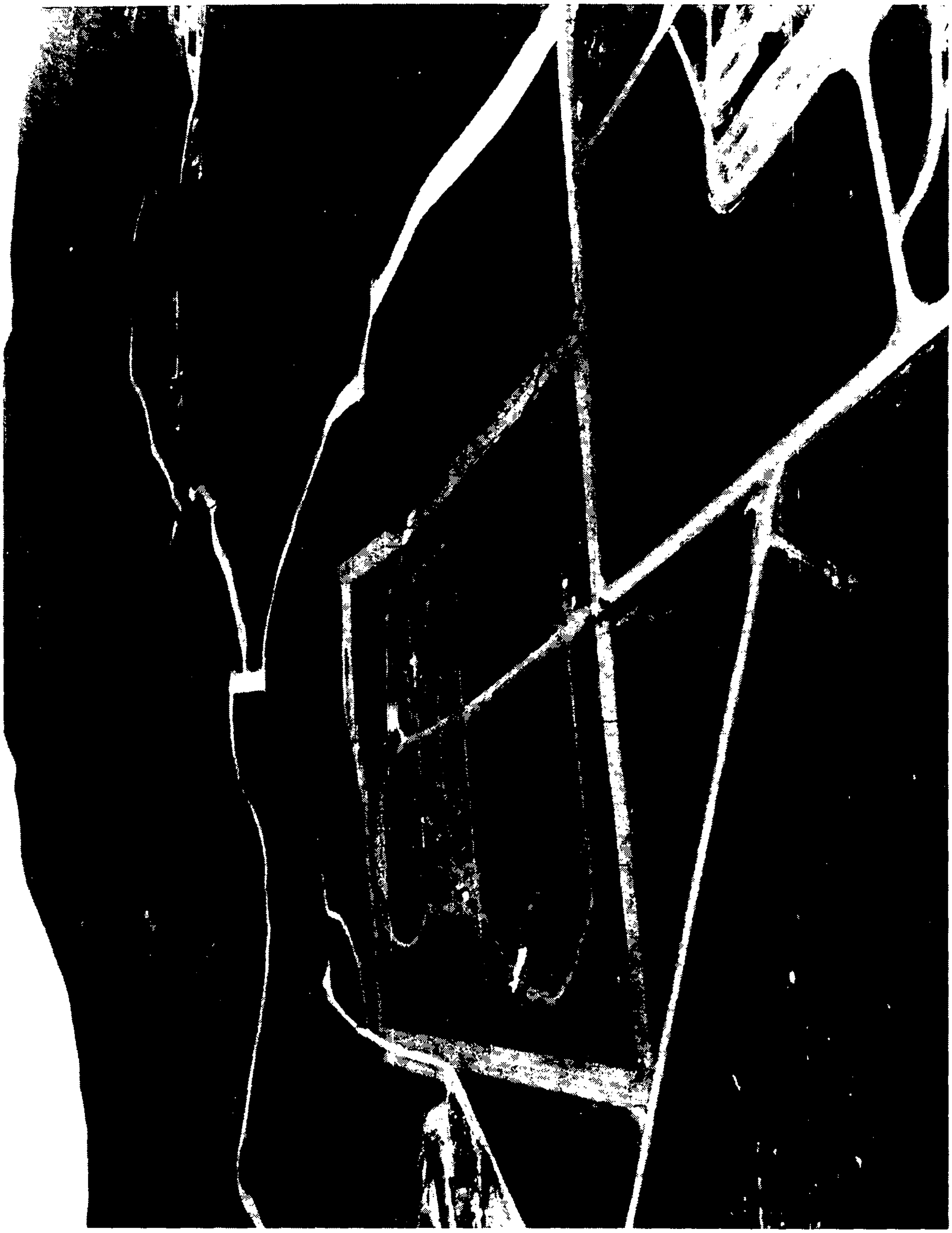


FIGURE 21. AERIAL VIEW OF WASTE PROPELLANT BURNING AREA

Open burning of waste SRM propellant at Thiokol/Wasatch will be carried out in accordance with this exemption.

Open burning of waste propellant at M-136 is currently accomplished via two different methods: (1) the "bag" disposal method, and (2) the "dump" disposal method. It is anticipated that both of these methods will also be used for SRM waste propellant disposal.

The "bag" disposal method is favored when the waste propellant has begun to cure. Basically, propellant remaining after the casting of a segment has been completed (tail endings) or propellant from the scrapedown of casting equipment is placed in plastic bags, which each hold ~30 kg (66 lb) of waste propellant. These bags are then transported to the M-136 facility where they are placed in a matrix slightly less than one meter apart. About 100 of these bags are placed in a 9 x 12-meter (30 x 40-ft) burn pit (Figure 21). A resistance wire is then placed in contact with propellant in one of the bags so that the propellant in that bag can be safely ignited from a remote location. It has been estimated that within approximately 60 seconds all 100 bags of propellant in the matrix will have burned.

The second method, the "dump" method, is prefered when a mix of propellant (3175 kg) has been rejected by Quality Control and has not begun to significantly cure. The bowl containing the rejected propellant mix is taken to the burn pit and dumped into the pit. The propellant is ignited using a method similar to the one mentioned above for the "bag" method. It has been estimated that the burn time for this method is about 120 seconds.

The basic difference between these two methods is that the burn time for an equal mass of waste propellant is shorter for the "bag" method, because more surface area is available for burning when the propellant is bagged.

4.2.3.1.2 Emissions From Open Pit Burning of Waste Propellant

Since January, 1970, and through December, 1975, approximately 7×10^6 kg (15×10^6 lb) of solid propellant waste have been disposed of via open burning in the M-136 burn pit area. Most of this waste, 90 to 95 percent, resulted from the Minuteman First Stage Reclamation Program, in which the propellant in 330 Minuteman ICBM first stages was replaced with new propellant. The remainder, 5 to 10 percent, resulted from the accumulation of waste propellant due to normal motor casting operations at the Thiokol/Wasatch plantsite.

The total amount of waste propellant expected to be disposed of between 1976 and 1980, for all Thiokol/Wasatch Programs, has been estimated at 0.39×10^6 kg (0.86×10^6 lb). About 18 percent of this total, or 0.07×10^6 kg (0.15×10^6 lb), would result from the SRM DDT&E Program casting activities.

The calculated annual emissions of HCl and Al_2O_3 from open pit burning at M-136 for the years 1970 through 1980 are shown on a semilogarithmic plot in Figure 22. The maximum annual emissions (1979) resulting from the Space Shuttle DDT&E Program are estimated to be quite small (~1/50th) when compared to the maximum annual total emissions of previous years.

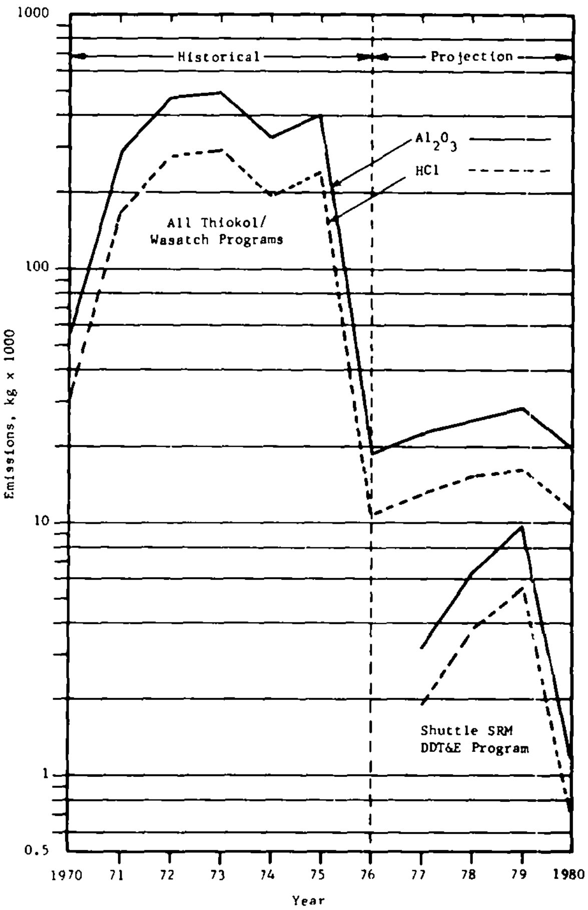


FIGURE 22. COMPARATIVE HCl AND Al_2O_3 EMISSION DATA FOR OPEN PIT BURNING AT M-136

Thermodynamic equilibrium calculations made by Thiokol for the low pressure burning of SRM propellant[36] indicate that, without afterburning effects (further reaction of the exhaust products with the air entrained in the hot exhaust cloud), the following quantities would be released as the result of a 3175 kg (7000 lb) burn of waste propellant:

Species	Amount, kg
Aluminum Oxide (Al_2O_3)	905
Carbon Monoxide (CO)	780
Hydrogen Chloride (HCl)	533
Water (H_2O)	317
Nitrogen (N_2)	276
Chlorine (Cl_2)	115
Carbon Dioxide (CO_2)	90
Hydrogen (H_2)	68
Other	91
	3175 kg

Of the major constituents, hydrogen chloride, chlorine and carbon monoxide, in high concentrations, can be potentially toxic (see Sections 4.7 and 4.8). Aluminum oxide is emitted as a particulate and may also be of concern.

As the hot buoyant cloud rises above the burn pit area (M-136) air is entrained into the bottom of the cloud and mixes with the hot exhaust products. Chemical reactions that can continue to take place should significantly reduce the CO concentration (afterburning $CO + 1/2\ O_2 \rightarrow CO_2$) and may redistribute the form of the chlorine content to some degree. Also, the heavier Al_2O_3 particulates should settle out of the cloud and fall to the ground, leaving only the smaller particles suspended in the air.

The peak instantaneous HCl and Al_2O_3 concentrations, assuming no afterburning or gravitational settling of Al_2O_3, as a function of distance from the burn pit are indicated in Figure 23. The instantaneous peaks for all 23 meteorological cases are shown and are represented as ● and ×, depending upon the CI value. An envelope has been constructed which presents the highest concentrations for cases where CI $\geq$ 500 and for cases where CI < 500, the highest peak instantaneous HCl concentration that would be expected is ~2.3 ppm (Al_2O_3 ~5.0 mg/m^3).

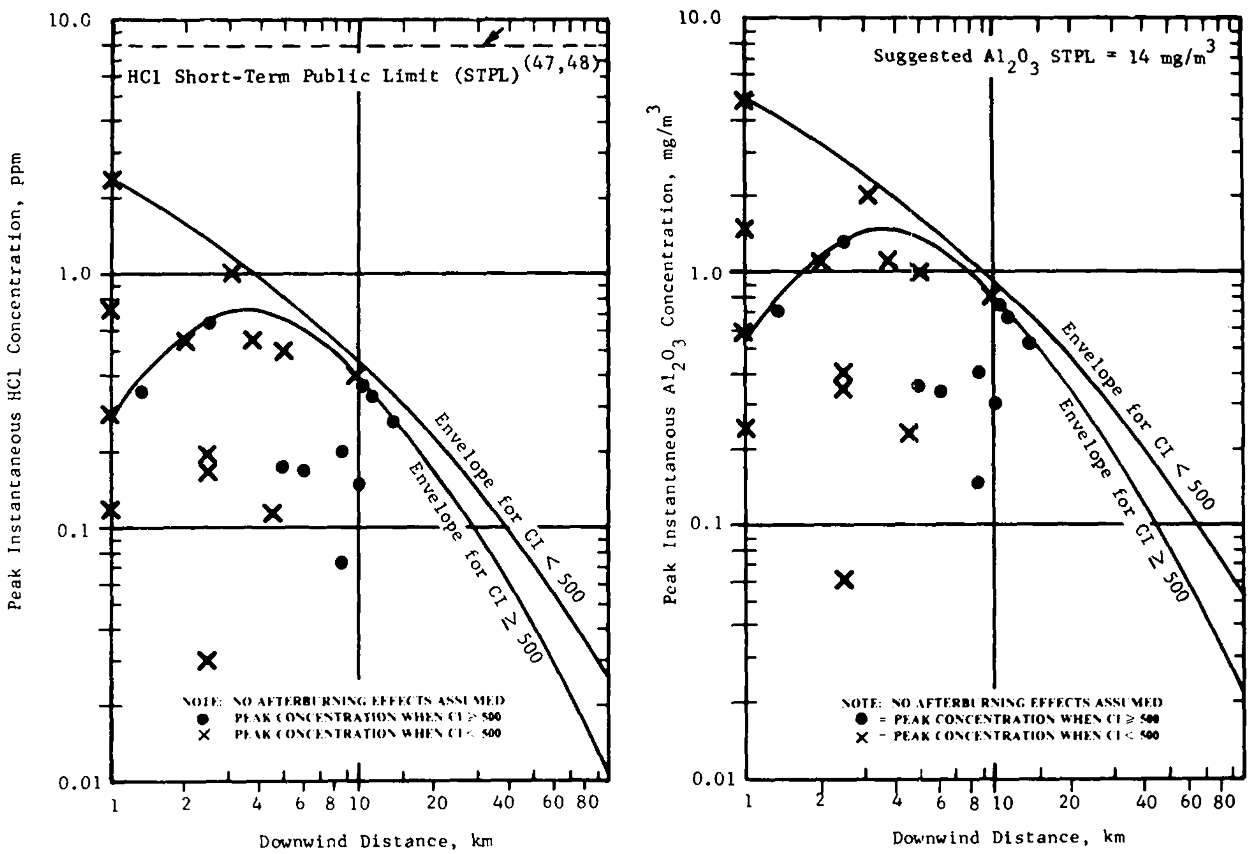


FIGURE 23. PEAK INSTANTANEOUS HCl AND Al_2O_3 CONCENTRATIONS EXPECTED FOR OPEN BURNING OF SPACE SHUTTLE SRM WASTE PROPELLANT AT M-136

Average, minimum, and maximum HCl and Al_2O_3 dosages are shown below in Table 14 for meteorological cases where CI $\geq$ 500 and CI < 500.

TABLE 14. HCl AND Al_2O_3 PEAK DOSAGE DATA FOR OPEN BURNING OF WASTE SRM PROPELLANT

	HCl (ppm·minute)			Al_2O_3 (mg/m^3·minute)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
CI < 500 (13 cases)	0.9	0.2	2.6	2.0	0.5	5.7
CI $\geq$ 500 (10 cases)	0.3	0.1	0.9	0.6	0.1	0.2

Note: For CI < 500, peaks occur inside of 10 km, usually 2.5 km; and for CI $\geq$ 500, peaks occur inside of 15 km, usually about 8 km downwind.

In conclusion, open burning of waste SRM propellant will produce a temporary, localized small degradation of air quality. However, the open burning of waste propellant for the SRM DDT&E Program will result in no change from current operations and will represent a significant reduction in the amount of waste propellant burned in previous years (see Figure 22). Possible effects due to SRM waste propellant disposal (degraded air quality) on man, flora, and fauna are discussed in Sections 4.7 and 4.8.

4.2.3.2 Space Shuttle SRM Static Test Firings

To develop and qualify the Space Shuttle Solid Rocket Motor for manned Space Shuttle flights beginning in 1979, seven SRMs have been scheduled to be horizontally static test fired during the DDT&E Program at the Thiokol/Wasatch T-24 test facility (Figure 24). The SRM static test firings have been scheduled for an 18-month period beginning in July, 1977, and lasting through December, 1978. The tentative schedule for these tests is shown below in Table 15.

TABLE 15. SRM STATIC TEST FIRING SCHEDULE

Motor Designation	Type of Test	Test Firing Date
DM-1	Development	July-August, 1977
DM-2	Development	September-October, 1977
DM-3	Development	February-March, 1978
DM-4	Development	April-May, 1978
QM-1	Qualification	June-July, 1978
QM-2	Qualification	August-September, 1978
QM-3	Qualification	December, 1978-January, 1979

Since 1964, roughly 5.2×10^6 kgs (11.5×10^6 lb) of propellant have been consumed in static test firings at Thiokol/Wasatch. These firings included: 147 Minuteman first stages (20,400 kg propellant each), five 156-inch diameter boosters (320,000 kg propellant each), two 120-inch diameter boosters (60,600

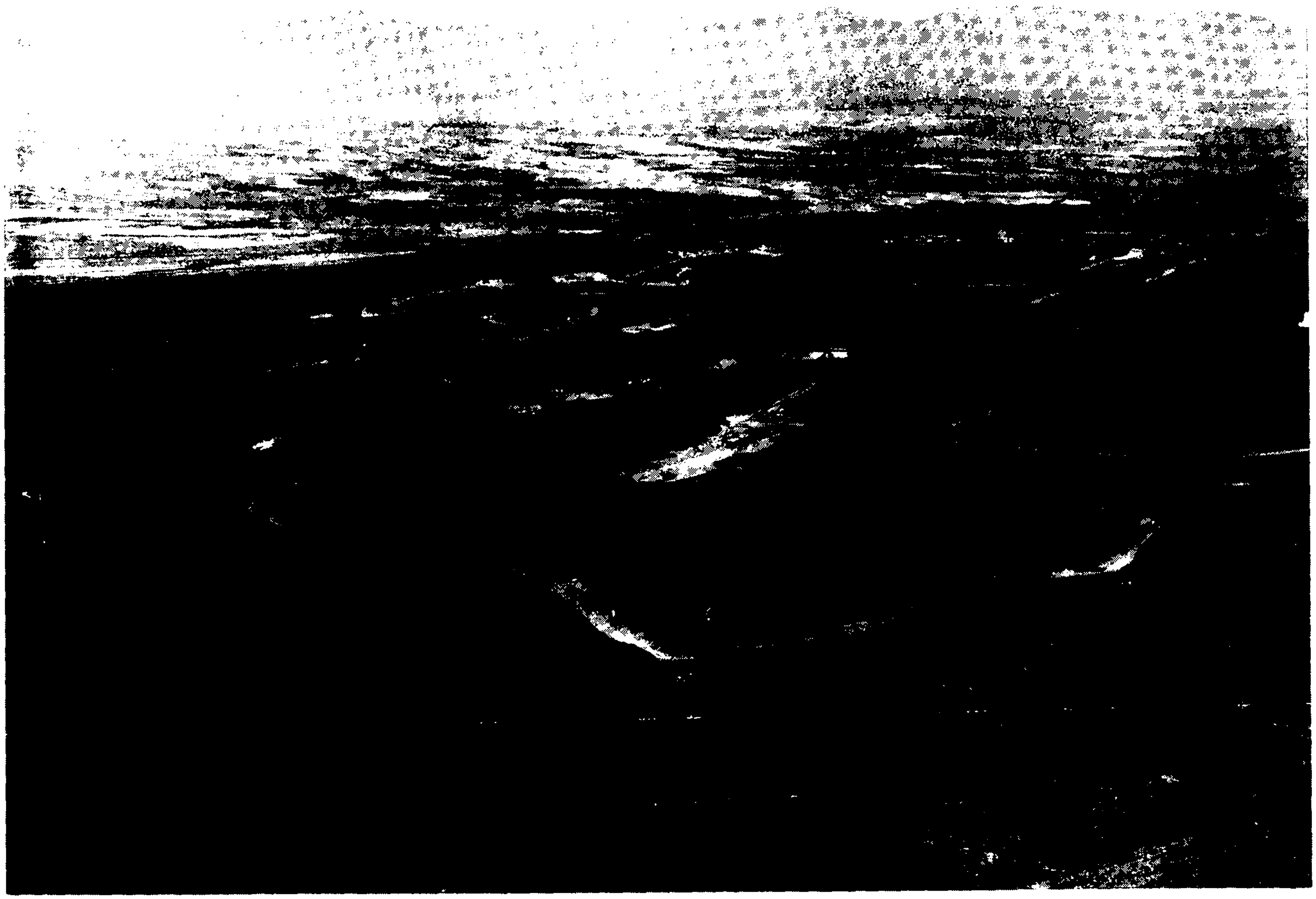


FIGURE 24. VIEW OVERLOOKING THIOKOL/WASATCH T-24 TEST FACILITY

kg propellant each), one 100-inch diameter booster (32,000 kg propellant), and many other smaller motors. With the seven Space Shuttle SRM test firings scheduled, the rate of propellant consumed in test firings will increase by a factor of 5 over the previous twelve-year average. However, when the SRM test firings are compared to periods when the 156-inch boosters were fired, this factor reduces to about 3. Solid propellant waste disposal activities of the early 1970's (Figure 22) alone emitted 25% more material into the atmosphere on an annual basis than will the static test and waste disposal activities of the SRM DDT&E Program.

As a result of a single motor test firing, $\sim 0.5 \times 10^6$ kg (1.1×10^6 lb) of solid rocket propellant will be consumed in a two-minute period, releasing hot gases and particulates into the atmosphere. A SRM exhaust cloud should rise above the test site and stabilize at an altitude of from 2 to 4 km (7,000 to 13,000 ft) within a 5 to 10-minute time period. Figure 25 presents a photograph of an exhaust cloud rising over the T-24 test area after a static test firing. As the exhaust cloud rises it will drift with the general motion of the upper air (see wind rose, Figure 15), while it spreads and dissipates. Insignificant ground level concentrations of various pollutants (e.g., HCl and Al_2O_3) are anticipated.

On July 17, 1973, the Utah Air Conservation Committee concluded that the static test firings of motors the size of the Space Shuttle SRM would not violate any of Utah's Air Quality Regulations if done when the Clearing Index is suitable (CI $\geq$ 500).[24] Static test firings of the Space Shuttle SRM will only be carried out when the Clearing Index is greater than or equal to 500, and when there is little chance of precipitation in the area (see Section 4.2.3.2.3).

4.2.3.2.1 Emissions From a Normal SRM Static Test Firing

A normal static test firing will expel a large amount of hot gaseous and particulate material from the SRM exhaust nozzle into the atmosphere. The local topographic features (see Figures 24 and 25) of the T-24 test site should aid in the upward deflection of the cloud as the buoyancy effects cause the exhaust cloud to rise to great heights. For the 10 meteorological cases where the CI $\geq$ 500, the average cloud rise (distance from cloud centroid above T-24) is ~2.7 km (8,900 ft); the extremes are 1.7 and 4.3 km (5,600 and 14,000 ft).

FIGURE 25. ROCKET EXHAUST CLOUD RISING ABOVE T-24 TEST SITE

The use of higher cloud heat content, which would be appropriate if afterburning is occurring, would result in higher cloud rise values (lower ground level concentrations) than those predicted here.

Approximately 504,000 kg (1,111,000 lb) of propellant will be consumed within a two-minute period. Thermodynamic equilibrium calculations of the exhaust gas composition at the SRM nozzle exit plane have been made by Thiokol.(37) One SRM firing is expected to release into the atmosphere, at the nozzle exit plane, the following:

Species	Amount, kg
Aluminum oxide (Al_2O_3)	152,000
Carbon monoxide (CO)	121,000
Hydrogen chloride (HCl)	107,000
Water (H_2O)	47,400
Nitrogen (N_2)	44,000
Carbon dioxide (CO_2)	18,100
Hydrogen (H_2)	10,600
Other	3,950
	504,050

As the exhaust products (species) leave the SRM exit plane, enter the high temperature plume and move horizontally toward the ridge (see Figure 36), surrounding air will be drawn into the exhaust. The exhaust cloud will begin to rise as buoyancy effects move the cloud up and away from the T-24 test site. The presence of entrained air (N_2 and O_2) in the high temperature exhaust cloud will undoubtedly result in the significant afterburning of CO, the possible repartitioning of chlorine between major amounts of HCl and smaller amounts of Cl_2, Cl and ClO and the formation of NO_x. NASA Langley Research Center, as a part of a continuing effort to assess the effects of solid rocket motor operations in the troposphere, has simulated the afterburning processes of the Space Shuttle SRM exhaust during the launch of the Space Shuttle vehicle.(38) The afterburning calculations include the effects of finite rate chemistry and turbulent mixing. Based upon data supplied in

Reference 38, an estimate of the amounts of major species, not including N_2, that would result if afterburning were to take place during an SRM static test firing is as follows:

Species	Amount, kg
Carbon dioxide (CO_2)	208,000
Aluminum oxide (Al_2O_3)	152,000
Water (H_2O)	145,000
Hydrogen chloride (HCl)	96,000
Chlorine (Cl_2)	11,000
Nitrogen oxides (NO_x)	7,000
Other	--

The comparison of the above data to the data in the previous table indicates that Al_2O_3 remains the same, CO is almost completely converted to CO_2*, HCl decreases about 10%, and both Cl_2 and NO_x increase above trivial levels.

The peak instantaneous HCl and Al_2O_3 concentrations, assuming no afterburning or gravitational settling of Al_2O_3, as a function of distance from the T-24 test site are shown in Figure 26. The instantaneous peaks for all 23 meteorological cases are shown, and are represented as • and ×, depending upon the CI value. An envelope has been constructed which represents the highest possible concentrations for cases where CI $\geq$ 500 and for cases where CI < 500. The effects of afterburning can be estimated by multiplying the nonafterburning HCl concentration data by various constants. These are 0.9 for HCl, 0.05 for Cl_2** and 0.08 for NO_x. As indicated in Figure 26, the peak concentrations are higher for cases where the CI $\geq$ 500, as compared to cases where CI < 500. This result is contrary to that of open burning. The apparent reason is that for normal test firings the cloud rises to such great heights that most of the cloud is kept from stabilizing within the surface

* The NASA measuring program has had little success in measuring CO concentrations downwind from Titan launches, apparently because it has afterburned to CO_2.

**The estimated half life of Cl_2 outside of the visible exhaust cloud is estimated at ~7 minutes, as atomic chlorine, formed from photochemical processes, will rapidly react with methane present in the atmosphere, thus reducing Cl_2 concentrations at ground level.(39)

mixing layer. Thus, under these conditions it is evident that deeper surface mixing layers should result in higher pollutant concentrations. Even though concentrations for cases where CI $\geq$ 500 are greater than those for CI < 500, all predicted concentrations are considerably lower than recommended guidelines (see Section 4.7). Therefore, there is no problem in testing when CI $\geq$ 500.

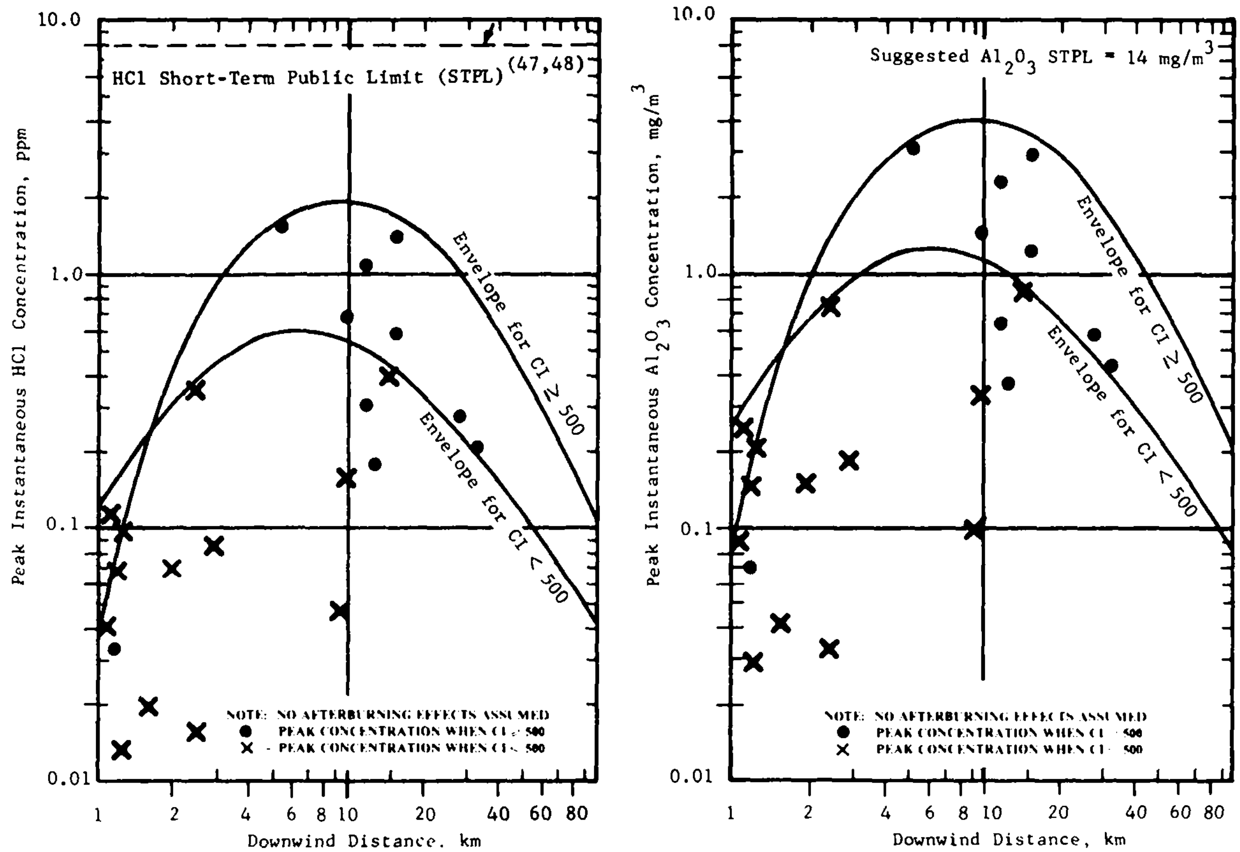


FIGURE 26. PEAK INSTANTANEOUS HCl AND Al_2O_3 CONCENTRATIONS EXPECTED FOR A STATIC TEST FIRING OF THE SPACE SHUTTLE SRM AT T-24

Since static test firings would only be carried out when CI $\geq$ 500[24], the highest peak instantaneous concentrations of the various species emitted with and without afterburning are:

	With Afterburning	Without Afterburning
Al_2O_3, mg/m^3	3.5	3.5
HCl, ppm	1.7	1.9
Cl_2, ppm	0.1	-
NO_x, ppm	0.15	-

Figures 27 and 28 present HCl isopleth plots for the two worst meteorological cases assumed here for a normal static firing. Figure 27 shows HCl isopleths for a test firing if it were to have occurred on 1/26/74 and Figure 28 shows HCl isopleths for a test firing if it were to have occurred on 2/21/75. Figure 28 gives insight as to how the Bear River Migratory Bird Refuge might be affected by impacts to air quality.

Average, minimum, and maximum dosage values with and without afterburning effects are shown in Table 16 for meteorological cases where CI $\geq$ 500 and CI < 500.

TABLE 16. PEAK DOSAGE DATA FOR NORMAL SRM STATIC TEST FIRINGS

	WITHOUT AFTERBURNING					
	HCl (ppm·minute)			Al_2O_3 (mg/m^3·minute)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
CI < 500	0.9	0.05	3.1	1.9	0.1	6.5
CI $\geq$ 500	1.8	0.3	4.0	3.7	0.7	8.0
	WITH AFTERBURNING					
	HCL (ppm·minute)			Al_2O_3 (mg/m^3·minute)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
CI < 500	0.8	0.04	2.8	1.9	0.1	6.5
CI $\geq$ 500	1.6	0.3	3.6	3.7	0.7	8.0
	WITH AFTERBURNING					
	NO_x (ppm·minute)			Cl_2 (ppm·minute)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
CI < 500	0.07	0.004	0.2	0.05	0.003	0.2
CI $\geq$ 500	0.15	0.02	0.3	0.1	0.02	0.2

Note: For CI < 500, peaks occur inside of 15 km, usually 2 km; and for CI $\geq$ 500, peaks occur inside of 35 km, usually about 12 km downwind.

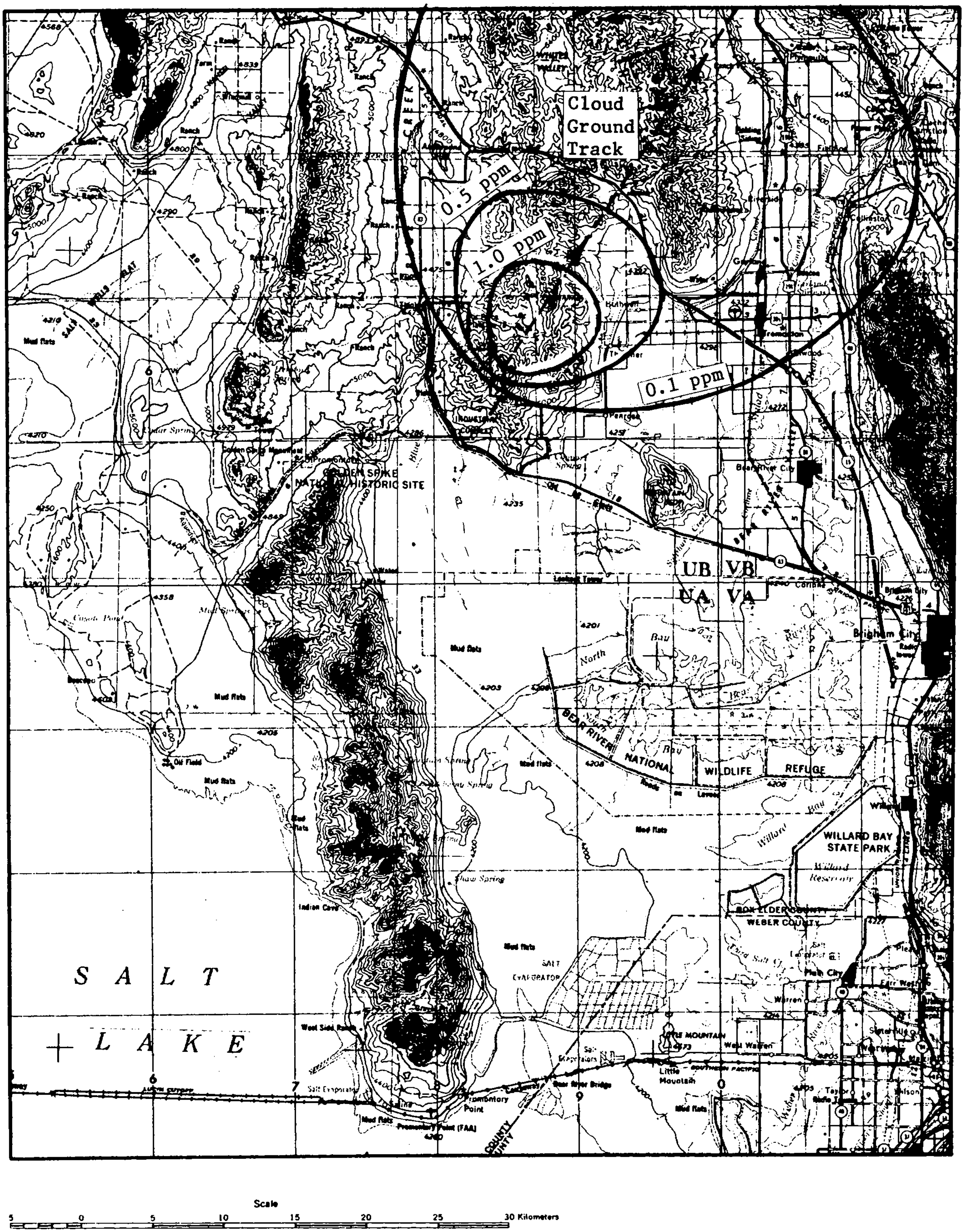


FIGURE 27. PREDICTED ISOPLETHS OF GROUND-LEVEL MAXIMUM HCl CONCENTRATION DOWNWIND FROM A SPACE SHUTTLE SRM STATIC TEST FIRING IF IT WERE TO HAVE OCCURRED ON THE AFTERNOON OF JANUARY 26, 1974 (CI = 840)

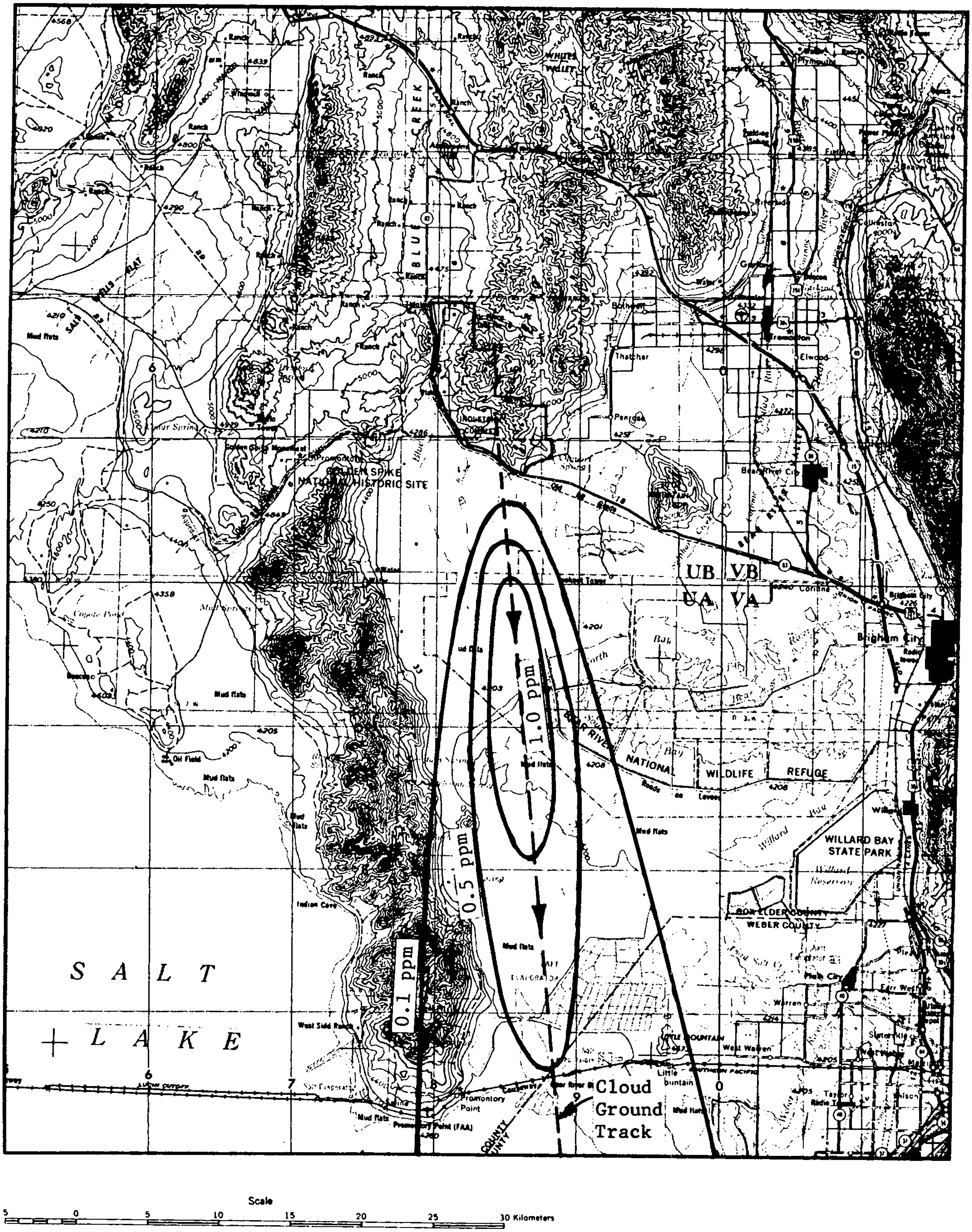


FIGURE 28. PREDICTED ISOPLETHS OF GROUND-LEVEL MAXIMUM HCl CONCENTRATION DOWNWIND FROM A SPACE SHUTTLE SRM STATIC TEST FIRING IF IT WERE TO HAVE OCCURRED ON THE AFTERNOON OF FEBRUARY 21, 1975 (CI = 1800)

In conclusion, the static test firings of the SRM will produce a temporary, localized small degradation of air quality. Possible effects on man, flora, and fauna as a result of SRM test firings (degraded air quality) are discussed in Sections 4.7 and 4.8.

4.2.3.2.2 Emissions From an Abnormal SRM Test Firing

An abnormal test firing is assumed to be one where the SRM case would rupture, due to an unexpected rise in chamber pressure, tossing the remaining propellant inside the motor out on to the ground. The propellant would then be consumed, but at a much lower rate. Although this situation is extremely unlikely to occur, the ground level concentrations and dosages are also predicted for this unplanned condition.

A worst case situation would be when a case would rupture early in firing. Because of the lower pressure, the solid propellant would burn slower and release slightly different amounts of effluent than in the normal test. The estimated total burn time is ~300 seconds, and the total estimated releases into the atmosphere, assuming no afterburning, are as follows:

Species	Amount, kg
Aluminum oxide (Al_2O_3)	144,000
Carbon monoxide (CO)	124,000
Hydrogen chloride (HCl)	84,600
Water (H_2O)	45,300
Nitrogen (N_2)	44,900
Chlorine (Cl_2)	18,200
Carbon dioxide (CO_2)	14,200
Hydrogen (H_2)	10,000
Other	18,850

The peak instantaneous HCl and Al_2O_3 concentrations, assuming no afterburning or gravitational settling of Al_2O_3, as a function of distance from the T-24 site, are shown in Figure 29. The instantaneous peaks for all 23 meteorological cases are shown and represented as ● and ×, depending upon the CI value. Figure 29 indicates that the concentration envelopes for

CI < 500 and CI ≥ 500 are very close to one another. However, this could be misleading because only one data point dictates the CI < 500 envelope at downwind distances greater than 5 km (3 mi).

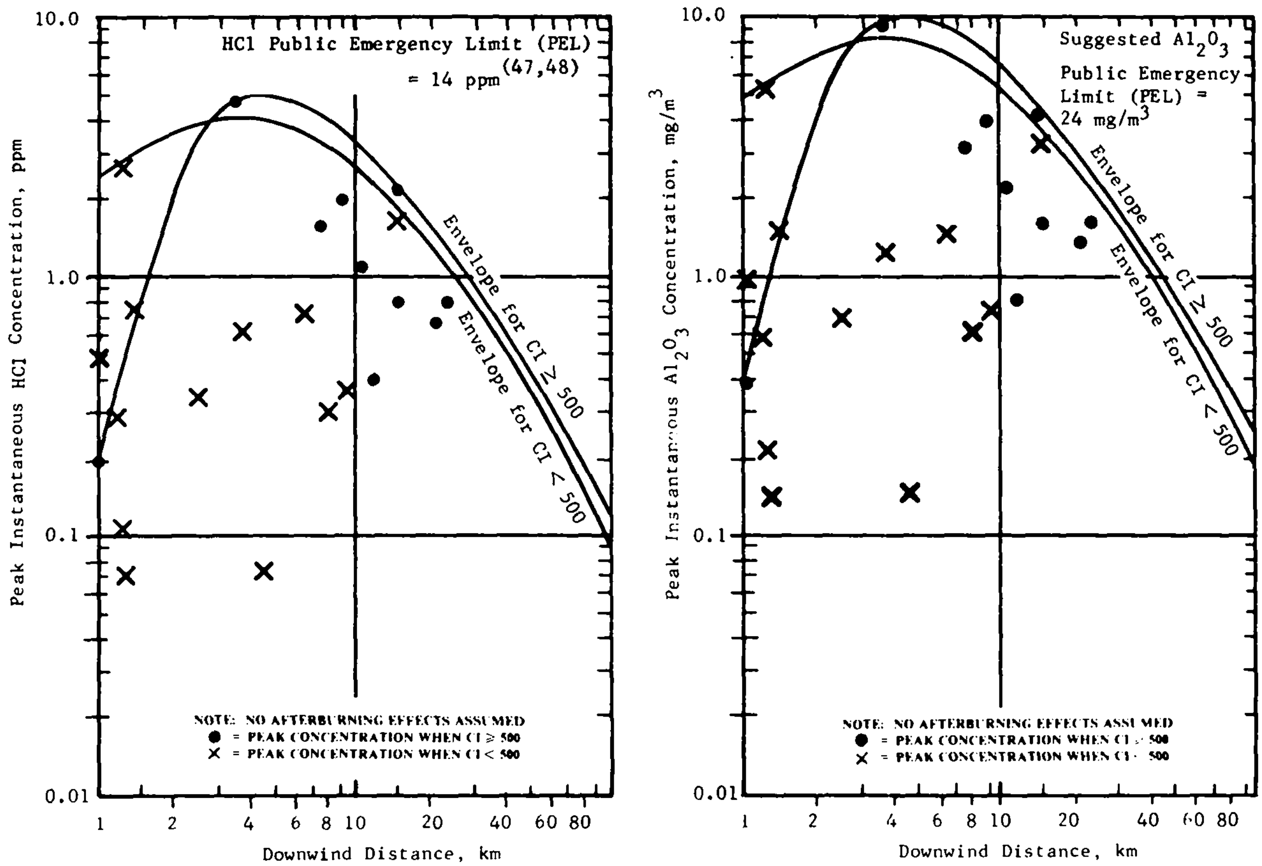


FIGURE 29. PEAK INSTANTANEOUS HCl AND Al_2O_3 CONCENTRATIONS EXPECTED FOR AN ABNORMAL TEST FIRING OF THE SPACE SHUTTLE SRM AT T-24

Average, minimum, and maximum dosage values assuming no afterburning are shown in Table 17 for meteorological cases where CI ≥ 500 and CI < 500.

TABLE 17. PEAK HCl AND Al_2O_3 DOSAGE DATA FOR ABNORMAL SRM STATIC TEST FIRINGS

	WITHOUT AFTERBURNING					
	HCl (ppm·minute)			Al_2O_3 (mg/m^3·minute)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
CI < 500	2.7	0.6	6.5	6.0	1.2	14.0
CI ≥ 500	3.3	1.0	8.6	7.3	2.2	19.0

Note: For CI < 500, peaks occur inside of 15 km, usually 2 km; and for CI ≥ 500, peaks occur inside of 25 km, usually about 12 km downwind.

In the unlikely event of a worst case abnormal test of the SRM, a temporary, localized small degradation of air quality would result. Possible effects on man, flora, and fauna are discussed in Sections 4.7 and 4.8.

4.2.3.2.3 Precipitation Scavenging of HCl

Possible precipitation (rain) scavenging of HCl from the SRM exhaust cloud may occur if the SRM is test fired during rain showers or if showers occur in the vicinity of the test area at the time of the test. The resulting acid rain from such an event may have localized affects on surface features. If the chance of rain exists, the SRM test firing will be postponed. Only two incidents have ever been reported which involved precipitation scavenging of HCl from solid rocket test firings or launches. One involved the static test of a large 260-inch diameter solid rocket motor in Florida. Rain showers were active in the area when the test was made. Some spotting of fruit in the area was observed. The other incident involved the September, 1975, launch of the Titan Centaur. Rain showers were again in the vicinity. A rain shower moved over the Titan exhaust cloud several minutes after the launch. pH values of 1 to 2 were measured by a NASA environmental monitoring team located within the controlled area of Kennedy Space Center, Florida.[28] There was some indication of vegetation spotting, but no permanent damage was reported. NASA personnel were also exposed to the acidified rain showers and reported no injury. Because the only two reported incidents occurred in a rather wet climatic region when it was well known that rain showers were present, it is concluded that the Utah test firings of the Space Shuttle SRM will not result in acid rain, since Utah is an arid climate where rain shower and snow storm activity is extremely predictable by front passages, and when a forecast exists for precipitation (rain or snow) within 2 hours after the test, the test will be postponed.

The process, proability, and implications of precipitation scavenging of HCl are not well understood at this time; several NASA studies have been made[40,41] and others are under way.

4.2.3.3 Accidental Ignition of a Casting Segment

It is unlikely that a Space Shuttle SRM casting segment would be accidentally ignited (see Section 4.7), during SRM processing, handling, or transportation operations. However, emissions from the occurrence of such an event have been predicted. The estimated burn times for each individual casting segment have been calculated to be: 900 seconds for the center and aft segments and 700 seconds for the forward segment.[36] Thermodynamic calculations predicting the species emitted from the low pressure combustion of the SRM propellant contained in these segments[36] allow the prediction of the total emissions and downwind peak concentrations and dosages.

Afterburning was not considered in these predictions. The total emissions are shown below:

Species	Amount, kg Forward	Center	Aft
Aluminum oxide (Al_2O_3)	38,700	35,300	34,600
Carbon monoxide (CO)	33,400	30,500	29,900
Hydrogen chloride (HCl)	23,100	21,000	20,700
Water (H_2O)	12,200	11,100	10,900
Nitrogen (N_2)	11,800	10,800	10,600
Chlorine (Cl_2)	4,900	4,500	4,400
Carbon dioxide (CO_2)	3,800	3,500	3,400
Hydrogen (H_2)	2,600	2,400	2,300

Afterburning effects would significantly reduce the CO concentration and modify the partitioning of HCl and Cl_2 to some extent. NO_x could be formed but the total amount would be small compared to other species.

Peak instantaneous HCl and Al_2O_3 concentrations (no afterburning or Al_2O_3 gravitational settling effects included) are shown in Figure 30 for the unplanned ignition of the forward and center segments. The aft segment would behave similarly to the center casting segment (open at both ends), and is not included. The curves shown in Figure 30 indicate, for the 23 meteorological cases used here, the maximum peak concentrations that would be expected.

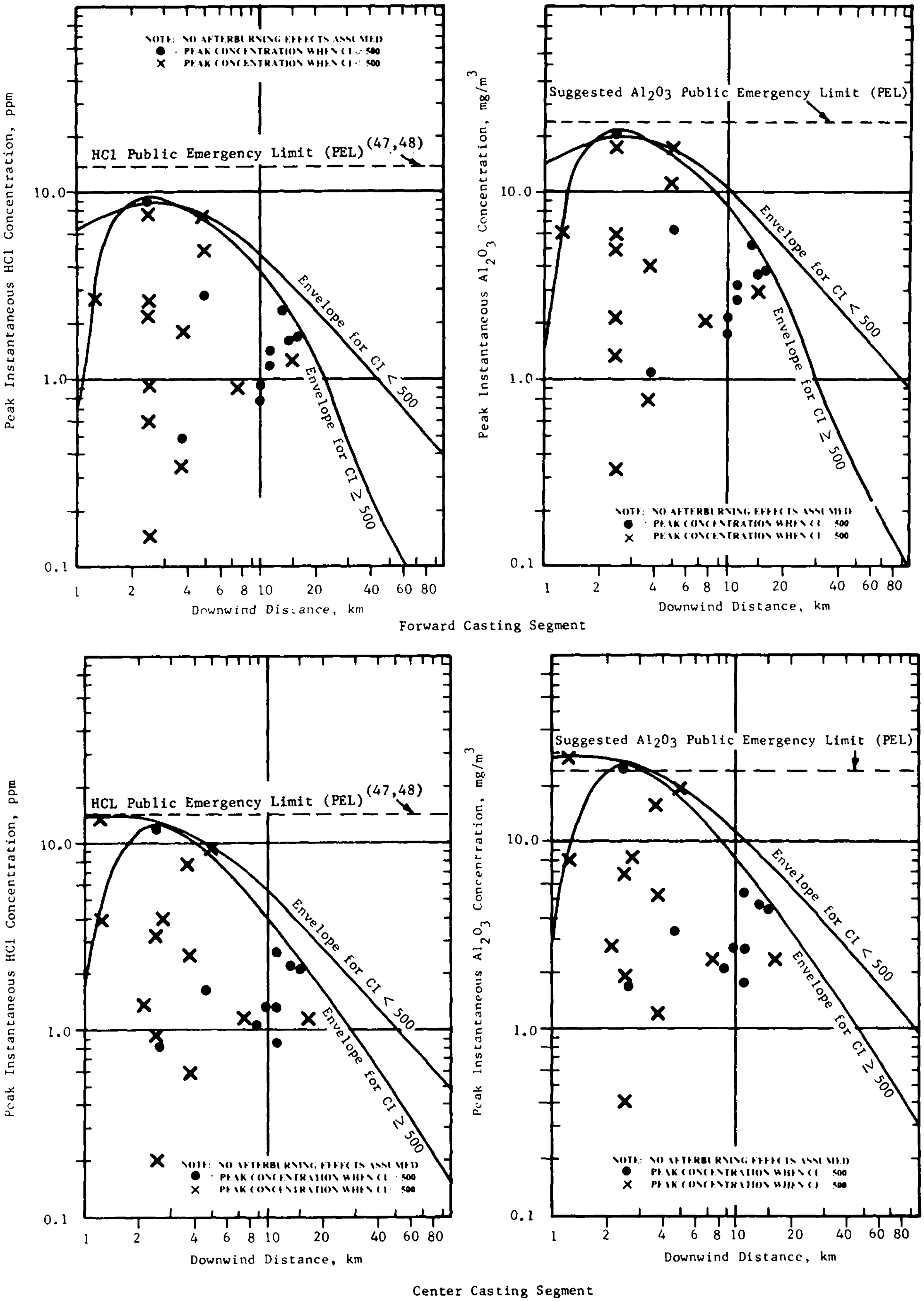


FIGURE 30. PEAK INSTANTANEOUS HCl AND Al_2O_3 CONCENTRATIONS EXPECTED FOR AN ACCIDENTAL IGNITION OF SPACE SHUTTLE SRM FORWARD AND CENTER CASTING SEGMENTS

Table 18 presents the HCl and Al_2O_3 dosages for accidental ignitions of casting segments.

TABLE 18. PEAK HCl AND Al_2O_3 DOSAGE DATA FOR THE ACCIDENTAL IGNITION OF A FORWARD AND CENTER CASTING SEGMENT

	WITHOUT AFTERBURNING					
	HCl (ppm·minute)			Al_2O_3 (mg/m^3·minute)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Forward Segment						
CI < 500	8.1	1.7	24.0	18.0	3.7	53.0
CI ≥ 500	2.8	1.1	5.9	6.1	2.4	13.0
Center Segment						
CI < 500	11.0	2.2	34.0	24.0	4.7	75.0
CI ≥ 500	3.0	0.6	7.5	6.6	1.3	17.0

Note: For cases where CI < 500, the peak dosages occur less than 15 km downwind, usually 4 km; cases where CI ≥ 500, the peak occurs less than 15 km downwind, usually 10 km.

Dispersion characteristics may vary with the different meteorological conditions which would exist during the rail transport of the 48 segments (12 motors) to Kennedy Space Center, Florida. Peak instantaneous concentrations predicted in the Wasatch area for this unlikely event may, in fact, be typical of what would be predicted for other locations.

In the unlikely event of a SRM accidental ignition either at the plantsite or during transportation to Kennedy Space Center, Florida, a temporary localized degradation of air quality would result. Possible effects on man, flora and fauna are discussed in Sections 4.7 and 4.8.

4.3 Noise

Noise will be generated as a result of processing operations and by test firings of the Space Shuttle Solid Rocket Motor (SRM). Effects on man, fauna and buildings resulting from noise are discussed in Sections 4.7 and 4.8.

4.3.1 SRM Processing

Most of the processing activities that will be conducted at Thiokol/Wasatch are light industrial processes which do not generate excessive noise levels. Examples of such processes are cleaning; painting; propellant mixing, casting and curing; inspection; etc. A few manufacturing processes may result in the generation of significant noise levels, for example, the removal of insulation from rocket motor cases during refurbishment. However, this and other noisy operations are conducted in special facilities and the noise is largely confined within the specific facility.

None of the processing activities will produce noise that will be audible to the public. This is assured by the conduct of the processes within buildings and the remoteness of the buildings from any point of public access. Noise is well recognized as an occupational hazard and exposure of workers to noise is controlled by OSHA. Thiokol/Wasatch meets all occupational standards for noise exposure through control of the noise at its source, isolation of the noise source from workmen, and where these are not possible, by individual protective devices.

4.3.2 SRM Static Test Firings

Test firings of the Space Shuttle Solid Rocket Motor (SRM) will produce noise. In normal test firings, the major source of noise is the result of fluctuating pressures accompanying the mixing of the ambient atmosphere with the hot, high velocity rocket exhaust. Abnormal firings might result in a pressure rupture of the motor case.

4.3.2.1 Normal Static Test Firings

Predictions of the noise levels generated by SRM static test firings have been made using the methods of Reference 42 (see Appendix K). Figure 31 shows the calculated noise levels in octave bands as well as the overall sound pressure level. The acoustic energy is concentrated in the lower frequencies, and it may be noted that the higher frequencies are more rapidly attenuated by passage through the atmosphere than are the low frequencies.

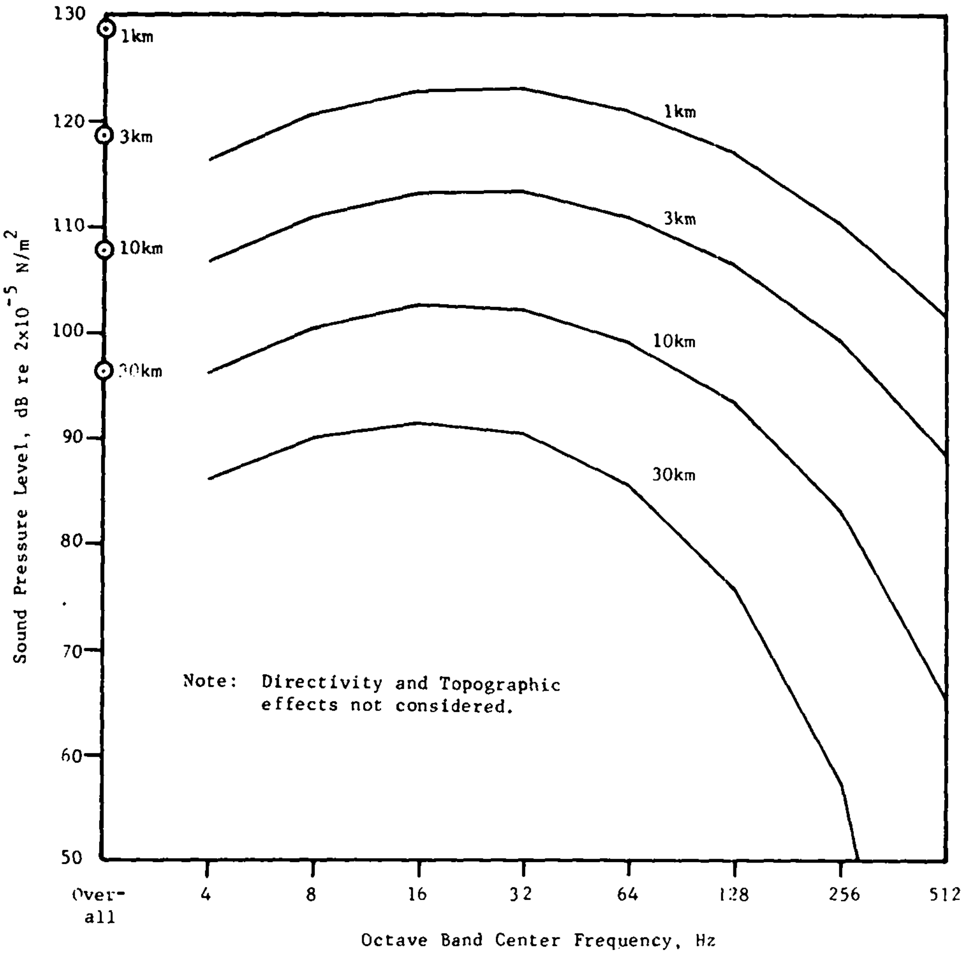


FIGURE 31. PREDICTED OVERALL AND OCTAVE BAND SOUND PRESSURE LEVELS AT VARIOUS DISTANCES FROM THE SPACE SHUTTLE SRM TEST SITE

Because the human ear is not equally sensitive to all sound frequencies, the overall sound pressure level does not accurately reflect the sound intensity as perceived by an observer. To account for this characteristic of human hearing, sound pressure levels can be expressed in the "A" weighted scale, in which the sound levels at various frequencies are weighted in accordance with the normal sensitivity of the human ear.

Figure 32 shows the trend of both the overall sound pressure level and the "A" weighted sound pressure levels with distance from the test site. The "A" weighted levels are 20 dB or more below the unweighted levels and decrease more rapidly with distance.

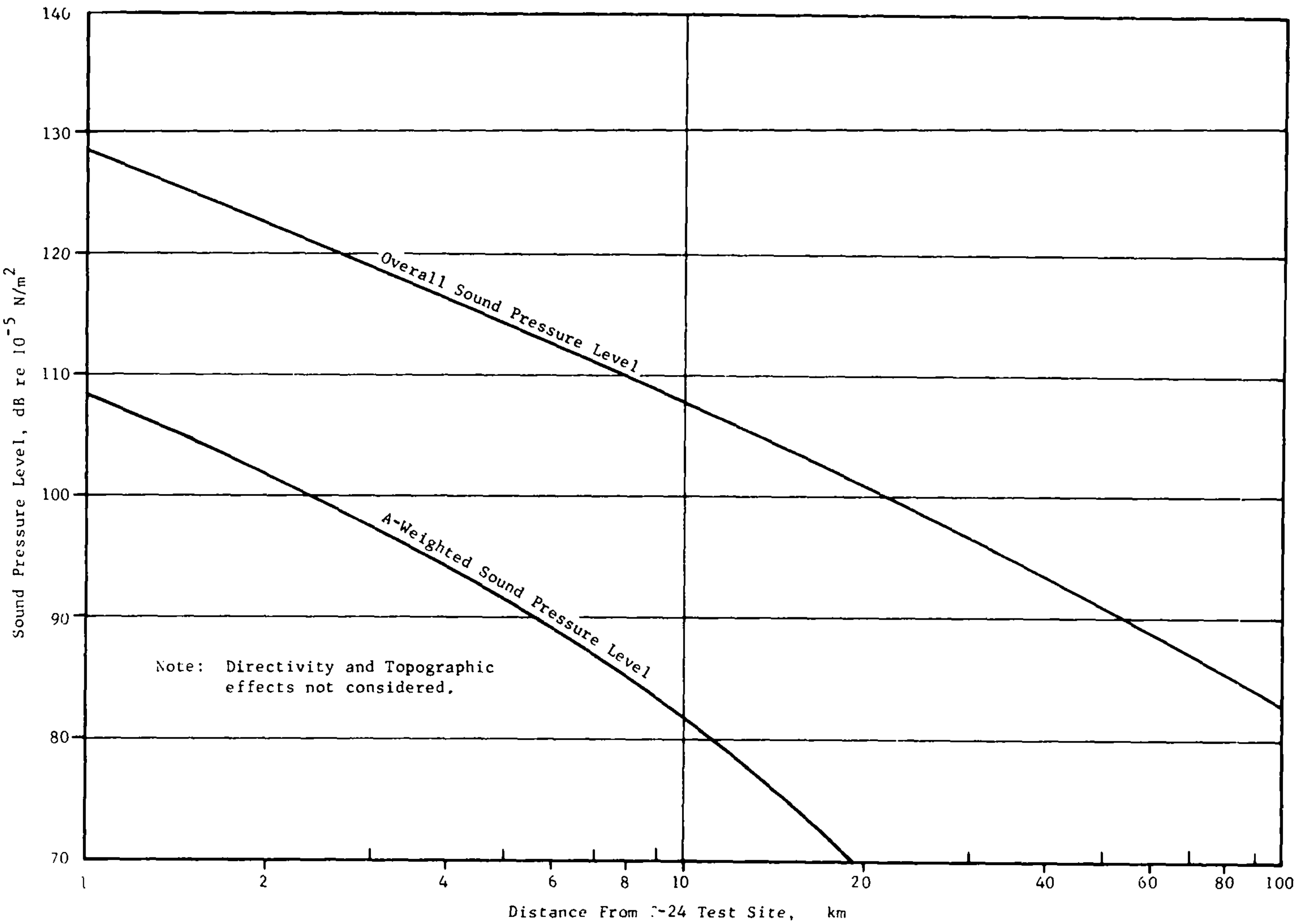


FIGURE 32. OVERALL AND WEIGHTED SOUND PRESSURE LEVELS RESULTING FROM STATIC TEST FIRINGS OF THE SPACE SHUTTLE SRM

Figures 31 and 32 do not consider that the rocket motor is a directive sound source. The directivity pattern is such that a minimum of sound energy is radiated along the axis of the exhaust jet, and a maximum of sound energy is radiated at an angle of about 60 degrees from the axis in the direction of the jet. Figures 33 and 34 show the predicted sound pressure contours for the SRM test firings for the overall and "A" weighted sound pressures including directivity effects.

The ridge between the test site and the ranches and communities to the east and north shields these areas from the test site and reduces the sound pressure levels below those indicated by the sound pressure contours

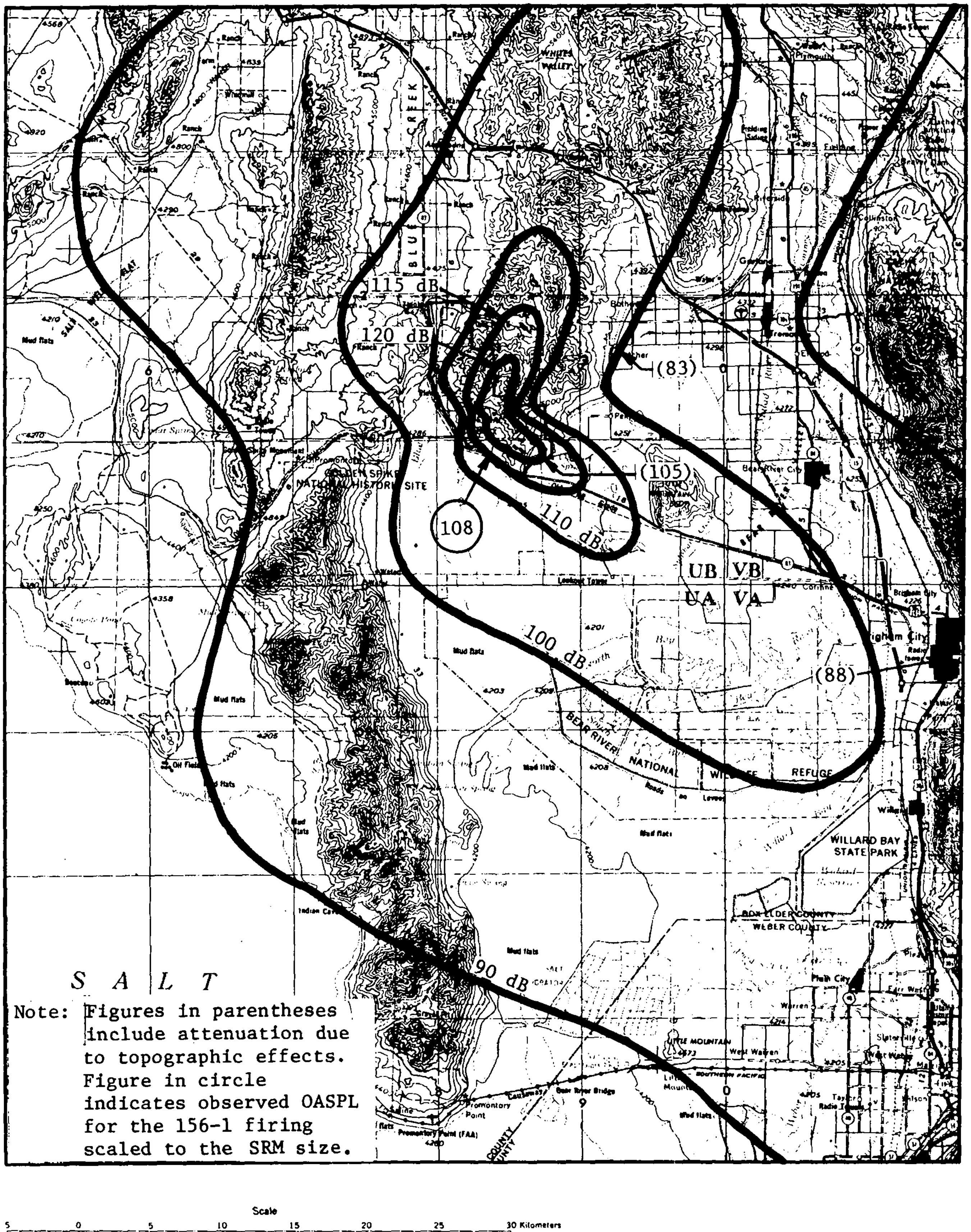


FIGURE 33. PREDICTED OVERALL SOUND PRESSURE CONTOURS FOR THE SPACE SHUTTLE SRM STATIC TEST FIRINGS

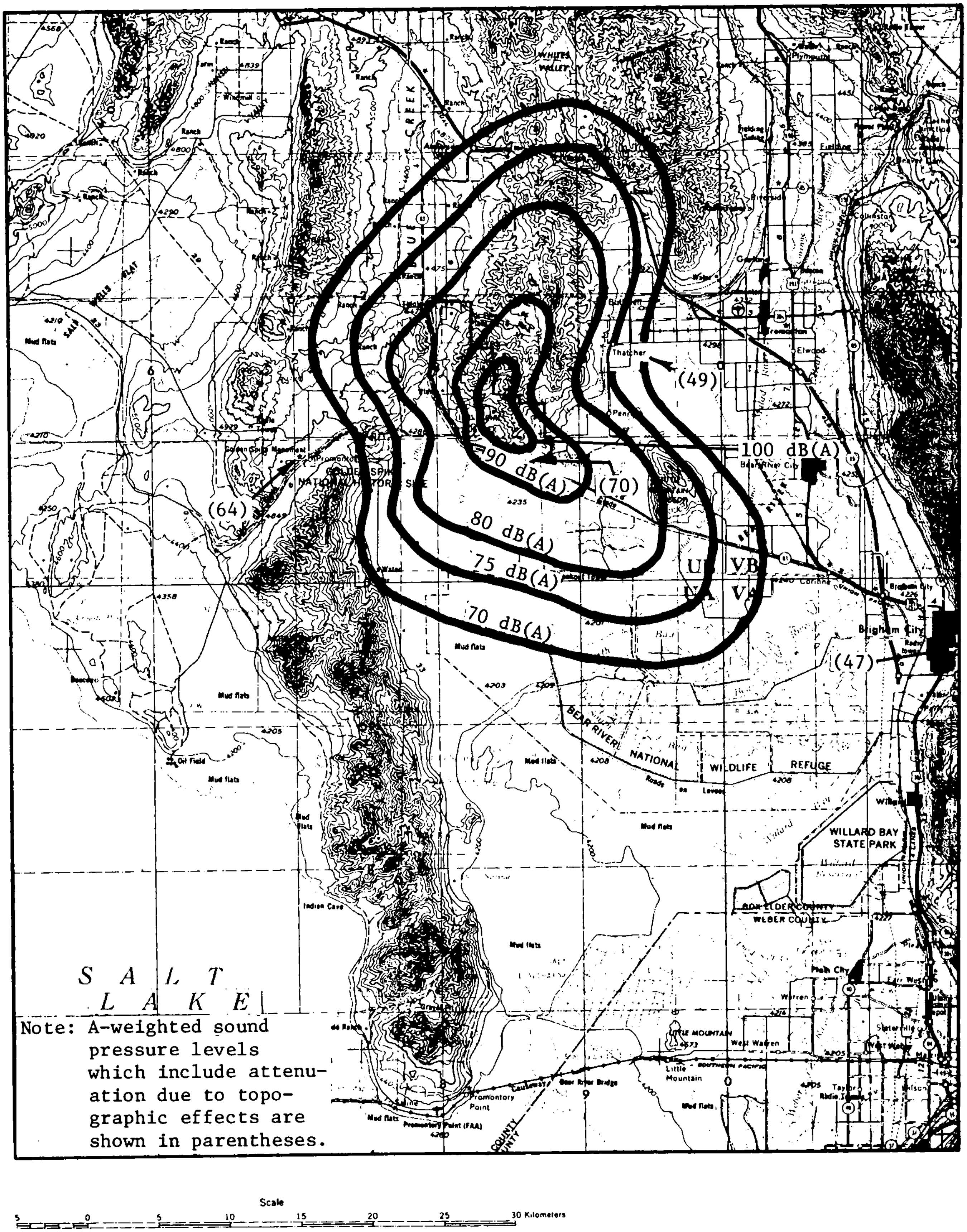


FIGURE 34. PREDICTED "A" WEIGHTED SOUND PRESSURE CONTOURS FOR THE SPACE SHUTTLE SRM STATIC TEST FIRINGS

shown in Figures 33 and 34. Attenuations due to this topographic effect have been calculated for Connor Springs, Thatcher and Brigham City. The resultant sound pressure levels are shown in Figures 33 and 34 in parentheses.

A test firing of a 156-inch diameter SRM (the 156-1) was made at the T-24 test site in 1964. The average sound pressure level was measured as 104 dB at an observation post near SR 83 (43). Scaled to the thrust level of the SRM, this corresponds to 108 dB. This may be compared to the predicted value for the SRM of 116 dB, suggesting that the predicted value may be somewhat high. Similarly, an analysis of the noise levels observed at a number of other solid rocket motor test firings suggests (see Appendix K) that the levels predicted here may be conservative by about 8 dB.

The firing of the 156-1 motor was observed by an individual at the Bear River Migratory Bird Refuge, about 22 km (14 mi) from the test site (44). He reported that the sound was a rumbling noise, similar to a train in the distance, and believed that the noise would have been unnoticed by an observer not anticipating the firing. The predicted "A" weighted sound pressure level at the refuge for the 156-1 firing, using the same prediction method as used for the SRM, is 67 dB(A). If the value is decreased by the 8 dB of observed additional attenuation discussed above, the resulting sound level would be 59 dB(A). Such an "A" weighted sound pressure level seems consistent with the observations of the witness.

In conclusion, large areas will be subjected to modest levels of predominantly low frequency noise. Some perceivers, who happen to be close by, may be annoyed, however, no population centers should be affected. Sections 4.7 and 4.8 further discuss possible effects of noise on man, fauna and buildings.

4.3.2.2 Abnormal Test Firings

The only abnormal event during a test firing that would cause noise different from that of a normal test firing would be a pressure rupture of the motor case. Two primary causes of a motor case pressure rupture can be distinguished: (1) an increase in motor pressure above the structural limit of the case (due to increased propellant burning surface caused by grain cracks, improper propellant burning rate, or inhibitor failure), and (2) degradation of or flaws in the case, including the insulation, seals, adhesives, and case materials.

If the case rupture were to occur near the end of the test firing, when the maximum volume of pressurized gases was contained in the case, the isentropic expansion energy of the gases would be 7.1 x 10^9 joules (6.7 x 10^6 Btu), or the equivalent of about 1500 kg (3300 lb) of TNT. This is the maximum conceivable energy release for a case rupture.

Figure 35 shows the blast wave overpressure that would be created by a pressure rupture of the motor case near the end of the test firing. The blast wave would be perceived as a brief noise pulse that would probably be audible at considerable distances. Shown in Figure 35 are two criteria for evaluating the potential effects of blast waves, glass breakage and ear drum rupture. The nearest inhabitable area, the blockhouse (T-22), is 550 meters (1800 ft) from the test site (T-24), where only minor overpressures would be experienced.

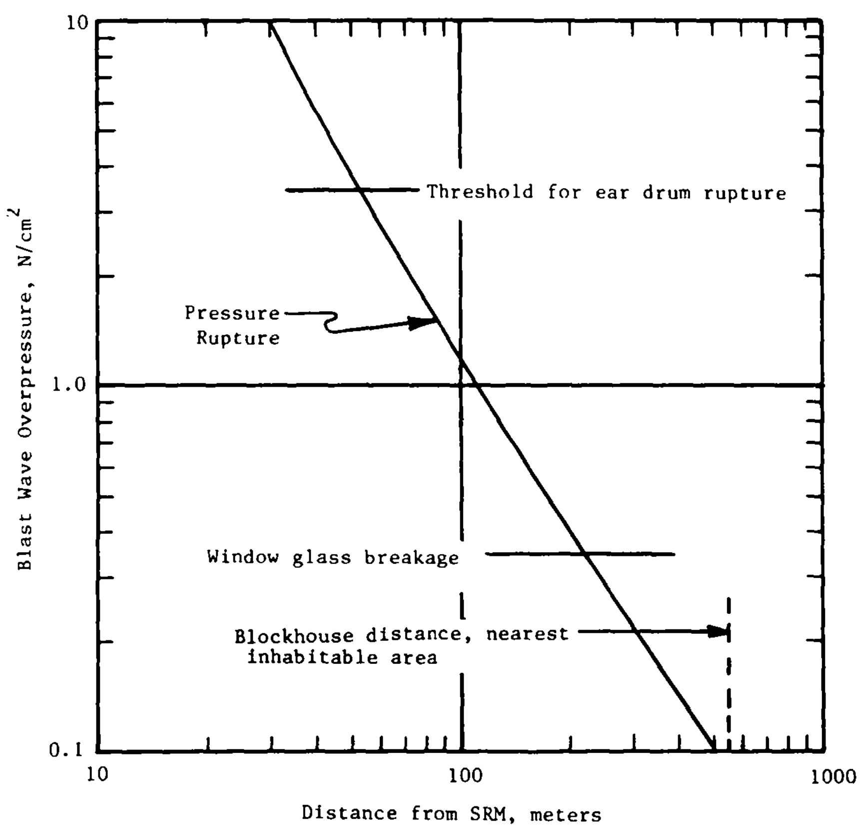


FIGURE 35. CALCULATED BLAST WAVE OVERPRESSURE RESULTING FROM A PRESSURE RUPTURE OF THE SPACE SHUTTLE SOLID ROCKET MOTOR

4.4 Water Quality

Only a few facets of the Space Shuttle SRM DDT&E Program could conceivably contribute to changes in water quality in any direct way, and suitable measures will be taken to minimize any threat to water quality. Impacts upon flora and fauna resulting from possible degradation in water quality are discussed in Section 4.8.

4.4.1 SRM Processing

Activities which could conceivably contribute to changes in water quality are: disposal of waste propellant; SRM case refurbishment (washout); and normal processing and employee support activities.

4.4.1.1 Disposal of Waste Propellant

Waste SRM propellant will be taken to the disposal area (M-136, (see Figure 21) and burned. Approximately 70,000 kg (150,000 lb) of propellant is expected to be disposed of in this way during the Space Shuttle SRM DDT&E Program. Residual materials remaining after burning consist primarily of aluminum slag (Al_2O_3). The approximate amount of material remaining at the surface of the burn area as a result of all anticipated SRM DDT&E burning activities is estimated at 190 kg (400 lb). It is not expected that these materials would be transportaed to Blue Springs Creek and/or into the groundwater table. Larger quantities of propellant residuals in conjunction with the Minuteman Program have occurred during the past 6 years (see Figure 22), and have not affected water quality in Blue Springs Creek or in springs and wells on and in the vicinity of the plantsite (see Tables 1 and 2). Therefore no effect upon Blue Springs Creek or the groundwater table is expected from open burning of waste propellant.

4.4.1.2 SRM Case Refurbishment (Washout)

During SRM case refurbishment (see Appendix F), water will be used to remove charred insulation from fired SRM segments. After the insulation has been removed and the "washout" operation is complete, waste water will be deposited in a percolation/evaporation catch basin and pass down an arroyo next to the M-115 Washout Facility. This flow is never expected to reach any surface waters or springs. Sludge, removed from the waste water prior to waste water disposal in the catch basin, will be disposed in the sanitary landfill. The sludge will consist of inert charred insulation and liner material. No changes in water quality in surface water or ground water are expected, as none were observed during case washing activities in the Minuteman Case Refurbishment Program, in which raw propellant, insulation, and liner material were removed in significant quantities (see Tables 1 and 2).

4.4.1.3 Normal SRM Processing and Employee Support Activities

Changes in water quality could also conceivably occur due to other SRM DDT&E processing and support activities at the Thiokol/Wasatch plantsite. Waterborne wastes resulting from industrial processes are discharged into underground catch basins which feed into clay tile fields to permit evaporation and percolation. Sanitary wastes are discharged into septic tanks, the effluent of which is also discharged into tile fields in isolated areas. Any sludge accumulation affecting efficient septic tank operation is removed and deposited in remotely located drying beds. These operations are in compliance with stipulations laid down by the Utah State Board of Health. Sanitary engineers periodically evaluate the facilities for adequacy and safety of operation in the interest of public health.

Since all of these operations are virtually identical to those which were conducted during previous and other ongoing programs, no environmental effects, caused by the SRM DDT&E Program, would be expected, as no effects have been observed in the past.

4.5 Solid Wastes

Disposal of waste solid materials at Thiokol/Wasatch is an on-site activity. A sanitary landfill is located east of Blue Springs Creek in the northwestern corner of the plantsite. A typical day's disposal in the landfill is indicated in Table 19. Waste materials, which are collected for salvage or recovery, are also listed. Quantities similar to those would be anticipated for the duration of the SRM DDT&E Program. These figures represent totals for all programs at Thiokol/Wasatch, of which the subject program will represent approximately one-fifth. Also, the cleaning of SRM cases during refurbishment operations will generate small amounts of inert solid waste which will also be buried in the Thiokol/Wasatch landfill.

TABLE 19. SOLID WASTE DISPOSAL AT THIOKOL/WASATCH

Total Plant - All Programs		
Solid Wastes to Burial		
Paper		3,600 kg/day
Wood		1,100 kg/day
Rags		230 kg/day
Garbage (wet)		50 kg/day
Metal Scrap (turnings, non-salvageable)		540 kg/day
Metal Scrap to Salvage	Iron	200,000 kg/yr
	Aluminum	9,000 kg/yr
Waste Motor Oil for Reclamation		7,600 ℓ/yr
Contaminated Solvent Wastes to Burn Pits		19,000 ℓ/yr
Sewage Sludge to Drying Beds (80% H_2O)		230,000 ℓ/yr

4.6 Pesticides

The use of pesticides is an ongoing activity at Thiokol/Wasatch. No additional usage is anticipated to be required in conjunction with the Space Shuttle SRM DDT&E Program. Present uses will be continued. Table 20 presents the yearly usage of herbicides and insecticides within the facility boundaries. The use of these quantities is not anticipated to present an environmental impact in the area.

TABLE 20. ANNUAL PESTICIDE UTILIZATION AT THIOKOL/WASATCH

Herbicide	~300 kg Athracene powder
Insecticide	~200 ℓ Westicide (for control of household pests within buildings)
	~20 ℓ Malathion (for control of mosquitos in wet areas)

4.7 Effect Upon Humans

Possible effects on the health and safety of Thiokol employees or the public might arise from the previously described activities associated with the Space Shuttle Solid Rocket Motor DDT&E Program. These possible adverse effects are associated with the SRM processing, open burning of waste propellant, static test firings, and transportation of the finished solid rocket motor segments. Releases of toxic or noxious materials to the atmosphere and the generation of noise are the routes through which adverse effects might occur.

4.7.1 SRM Processing

The Space Shuttle SRM processing activities release small amounts of solvents to the atmosphere and generate modest noise levels (see Sections 4.2.2 and 4.3.1). Because of the small quantities involved and the remoteness of the processing facility, no hazard is presented to the public by these emissions. Under unfavorable circumstances, the emissions might create an occupational hazard to the workers directly involved in specific operations. However, these possible occupational hazards are recognized and are typical of many processing operations. Hence, methods of control (ventilation, isolation and, where necessary, individual protective equipment) are known and are applied by Thiokol. Exposure of workers to occupational hazards is controlled by OSHA, among other agencies. Thiokol meets all applicable workplace regulations. Hence, no effects are anticipated.

4.7.1.1 Open Burning of Waste SRM Propellant

Open burning of hazardous waste propellant is permitted by the State of Utah (see Section 4.2.3.1) at the Thiokol/Wasatch plantsite. Table 21 gives the predicted peak ground level concentrations and dosages for worst case open burning (largest predicted quantity of waste propellant and poorest meteorological conditions) of HCl, Cl_2, and Al_2O_3.

Concentrations and dosages of all species are below the criteria shown in Table 24 (see Section 4.7.2.2 for discussion of criteria); hence, no public health or safety problem will result from open burning of waste propellant.

TABLE 21. PREDICTED PEAK GROUND LEVEL CONCENTRATIONS AND DOSAGES OF POTENTIALLY HAZARDOUS SUBSTANCES RESULTING FROM OPEN BURNING OF WASTE SRM PROPELLANT

Peak Concentration			Maximum Integrated Dose		
HCl, ppm	Cl_2, ppm	Al_2O_3, mg/m^3	HCl, ppm·min	Cl_2, ppm·min	Al_2O_3, mg/m^3·min
2.3	0.25	5.0	2.6	0.3	5.7

4.7.1.2 Accidental Ignition of a SRM Segment at the Plantsite

Accidental ignition and burning of a SRM segment at the Thiokol/Wasatch plantsite would result in the release of HCl, Cl_2 and Al_2O_3, as detailed in Section 4.2.3.3. Table 22 presents the predicted peak ground level concentrations and dosages of these species for the most unfavorable meteorological condition investigated.

When compared with the criteria listed in Table 24, only Al_2O_3 concentration is seen to exceed the criteria for emergency or accidental exposures. The peak dosage of Al_2O_3, however, is only 6 percent of the criterion. Concentrations above the criteria are not expected at distances greater than 3 km (2 mi). Thus, under most circumstances, exposure to Al_2O_3 concentrations above the criterion would be restricted to the Thiokol/Wasatch property.

The high concentration of Al_2O_3 is fleeting; the predicted average concentration during a 10 minute period is only 2.2 mg/m^3. In view of the small areas over which the criterion is exceeded and the fleeting exposure, no health or safety effects are expected due to an accidental ignition at the plantsite.

TABLE 22. PREDICTED PEAK GROUND LEVEL CONCENTRATIONS AND DOSAGES OF POTENTIALLY HAZARDOUS SUBSTANCES RESULTING FROM IGNITION AND BURNING OF A SRM CENTER SEGMENT

Peak Concentration			Maximum Integrated Dose		
HCl, ppm	Cl_2, ppm	Al_2O_3, mg/m^3	HCl, ppm·min	Cl_2, ppm·min	Al_2O_3, mg/m^3·min
14	1.6	31	34	3.8	75

4.7.2 SRM Static Test Firings

Test firings of the Space Shuttle SRM will release large quantities of HCl and Al_2O_3 to the atmosphere and generate locally intense noise levels. Abnormal test firings may result in pressure ruptures as well as the release of HCl and Al_2O_3.

4.7.2.1 Noise From SRM Static Test Firings

The noise generated by test firings is locally intense, of predominantly low frequencies, of short duration (2 minutes) and will occur infrequently (seven times over a period of 18 months). The minimum time between two firings will be approximately 45 days, but more typically will be two months.

Figures 33 and 34 of Section 4.3.2 show the predicted sound pressure contours, without allowance for topographic effects. As indicated in Section 4.3.2, these predictions are probably conservative (high) by about 8 dB. Also, the topography of the region provides significant noise attenuation to the north and east of the test site. Figures 33 and 34 also show the calculated noise levels at Connor Springs, Thatcher, and Brigham City, which include the attenuation due to the topography.

In terms of audible response, the effect of this noise on humans is best measured by the "A" weighted sound pressure levels [dB(A)]. Figure 34 shows that the maximum noise level to which the public might be exposed to is 95 dB(A) on State Route 83. Kryter[45] has indicated that, for a 2-minute exposure, the threshold sound level to induce hearing loss is about 118 db(A). Hence, no hearing injury to the public will occur.

At frequencies of 16 Hz and less, the EPA has indicated that exposure to sound pressure levels below 130 dB should not result in significant health effects, and that the threshold level for unpleasant sensations is about 120 dB.[46] The overall sound pressure level shown in Figure 33 at State Route 83, about 116 dB, is about 4 dB higher than the sound pressure level at frequencies below 16 Hz. Hence, the exposure of the public to infrasound will not result in any health effect and will be below the level where unpleasant sensations are induced.

Although no specific safety issue has been identified in connection with the 95 dB(A) noise level predicted to occur on SR 83, as a precautionary measure traffic will be stopped on SR 83 during the first few test firings. Depending on the outcome of observations made at these early firings, this practice may be continued or discontinued for subsequent firings.

Traffic on State Route 83, other than Thiokol employee traffic, consists mostly of visitors to the Golden Spike Monument. An average of 13,000 vehicles visit this Monument during the May-October season. During the four-hour period when a test firing might be made, about 35 vehicles pass the Thiokol plant. If traffic were not stopped, the probability of a vehicle being on State Route 83 at the time of a motor firing is about 0.4 during the 5-month season, considering that Golden Spike visitors will be making round trips. If traffic is stopped for 15 minutes, about 3 or 4 vehicles would be affected.

The EPA has suggested a measure for environmental noise designated L_{eq}, which is the average "A" weighted sound pressure level over a 24 hour period.[46]

Assuming that the background noise makes a negligible contribution to L_{eq}, the L_{eq}'s for the SRM may be obtained by subtracting 29 dB(A) from the "A" weighted contours of Figure 34. The EPA has suggested criteria of $L_{eq} \leq 70$ dB to protect against hearing loss and $L_{eq} \leq 55$ dB to avoid annoyance in quiet areas.

From Figure 34, it can be seen that the area subjected to $L_{eq} > 70$ dB is effectively confined to the Thiokol/Wasatch facility and thus poses no hazard to the public. (The region to the north of the test site within the 100 dB(A) contour and outside the facility boundary is partially shielded by the local topography, so that sound levels there will be less than indicated by the contours.)

L_{eq}'s in excess of the 55-dB criterion for annoyance will extend over a substantial area, but this area, which corresponds to an 84 dB(A) contour, includes few residences. No community will be exposed to an L_{eq} as high as 55 dB as a result of the SRM DDT&E Program. Consequently, on the basis of the L_{eq} criteria, no adverse effects are anticipated.

Although no direct noise-related health effects will result from the Space Shuttle SRM tests, Figure 33 shows that large areas will be subjected to predicted overall sound pressures of 100 dB or more, predominantly composed of low frequencies. Low-frequency sound of this intensity may cause vibrations of windows or building panels, rattling of dishes, and other similar effects. Public response to such effects is not easily predictable. If prolonged or frequent, these effects would be expected to cause annoyance and complaints. When of short duration and infrequent, and when associated with an advanced technical undertaking, such effects may cause interest and excitement in the perceiving person. The accepted presence of the Thiokol/Wasatch plant (see Section 2.3.7) and its contributions to the economic and social life of the area (see Sections 2.3 and 2.4) suggest that the affected public will be tolerant of the minor and infrequent disturbances caused by the SRM firings.

Abnormal behavior of the SRM during test firings will in most cases not result in any dramatic change in the noise produced. An exception would be a failure that results in a pressure rupture of the motor and generation of a blast wave (see Section 4.3.2.2). Figure 35 shows the blast wave overpressure that would result from such a pressure rupture.

The threshold blast wave pressure to cause ear drum rupture is about 3.45 N/cm^2 (5 psi), and a pressure of 10.3 to 13.8 N/cm^2 (15 to 20 psi) will cause ear drum rupture in 50 percent of the population.[42] From Figure 35, such pressures will occur only at distances less than 55 m (180 ft). Glass breakage in windows will occur at an overpressure of about 0.345 N/cm^2 (0.5 psi).[42] This pressure occurs only at distances less than 220 m (720 ft). Because these direct effects would occur only very near the test site, well within the controlled area of the facility, no health or safety hazard will be caused to the public by possible pressure ruptures during the test firings.

4.7.2.2 Combustion Products from SRM Static Test Firings

The potentially harmful substances emitted during the SRM test firings are HCl, Al_2O_3, nitrogen oxides (NO_x), and Cl_2. No official criteria for infrequent, short-term public exposure to these materials exist. In the case of HCl, the Advisory Center on Toxicology has recommended such criteria both for predicted exposures and for accidental exposures.[47,48] These recommendations are:

Duration of Exposure, minutes	STPL[a], ppm		PEL[c], ppm	
	TWA[b]	Peak[d]	TWA[b]	Peak[d]
10	4	8	7	14
30	2	4	3	6
60	2	4	3	6

(a) Short-term public limit (STPL).

(b) Time-weighted average (TWA).

(c) Public emergency limit (PEL).

(d) Not to be exceeded.

For exposure to Al_2O_3, a particulate, some guidance can be obtained from the ambient air quality standards.[49] These standards are based on 24-hour averages, and are:

	Air Quality Standard (24-Hour Average Concentration),[49] mg/m^3	Equivalent Dose	
		1-Hour, $mg/m^3 \cdot min$	24-Hour, $mg/m^3 \cdot min$
Primary air quality standard	0.260	15.6	374
Secondary air quality standard	0.150	9.0	216
Warning	0.625	37.5	900
Emergency	0.875	52.5	1260

These standards give no guidance as to the peak concentrations that may be acceptable. However, criteria have been suggested for emergency exposure of controlled populations, which include a value of 50 mg/m^3 for periods not exceeding 10 minutes.[50] For HCl, the equivalent criterion is 30 ppm.[50] By applying the same safety factor for short-term public exposure as exists for HCl, the resultant TWA STPL for Al_2O_3 would be

$$\frac{4}{30} \times 50 = 7 \text{ mg/m}^3 \text{ for 10 minutes,}$$

and the TWA PEL would be

$$\frac{7}{30} \times 50 = 12 \text{ mg/m}^3 \text{ for 10 minutes.}$$

Allowing an excursion factor of 2 for the instantaneous peak concentration in parallel with the suggested criteria for HCl, the resultant peak allowable concentrations would be 14 and 24 mg/m^3. It may be noted that the threshold limit value (TLV)[51] for "nuisance particulates" (which includes Al_2O_3) is 10 mg/m^3 for industrial workplace exposure, which corresponds to a maximum dosage of 4800 $mg/m^3 \cdot min$ for an 8 hr workday.

The Advisory Center on Toxicology has also suggested STPL's and PEL's for nitrogen oxides.[52] These are:

Duration of Exposure, minutes	STPL, ppm		PEL, ppm	
	TWA	Peak	TWA	Peak[a]
10	1	1	5	--
30	1	1	3	--
60	1	1	2	--

(a) Not stated. Assumed to be 5 ppm in parallel with the STPL's.

The Advisory Center on Toxicology's suggested short-term public exposure criteria for chlorine are:[53]

Duration Exposure, minutes	STPL, ppm		PEL, ppm	
	TWA	Peak	TWA	Peak
10	1.0	3	3	3
30	0.5	1	2	2
60	0.5	1	2	2

The TLV (industrial workplace exposure) for chlorine is 1 ppm.

Table 23 lists the peak ground level concentrations and integrated dosages for HCl, Cl_2, NO_x (NO_2 + NO expressed as NO_2), and Al_2O_3 resulting from test firings of the SRM for values of the Clearing Index (CI) greater and less than 500 (see Section 4.2.3). Table 24 presents the criteria for public exposure as developed above.

Based on the predicted concentrations and dosages, no public health or safety problem will result from normal or abnormal test firings, regardless of the Clearing Index at the time of the test.

TABLE 23. PREDICTED PEAK GROUND LEVEL CONCENTRATIONS AND DOSAGES OF POLLUTANTS RESULTING FROM SRM TEST FIRINGS

	Peak Concentrations				Maximum Integrated Dose			
	HCl, ppm	Cl_2 ppm	NO_x, ppm	Al_2O_3, mg/m^3	HCl, ppm·min	Cl_2, ppm·min	NO_x, ppm·min	Al_2O_3 mg/m^3·min
Normal firing CI > 500	1.7	0.1	0.15	3.5	3.6	0.2	0.3	8.0
Normal firing CI < 500	0.54	0.03	0.05	1.3	2.8	0.17	0.2	6.5
Abnormal firing CI ≥ 500	5.0	0.56	--	11.	8.6	0.72	--	19.
Abnormal firing CI < 500	4.1	0.46	--	9.0	6.5	0.95	--	14.

TABLE 24. CRITERIA FOR PUBLIC EXPOSURE TO POLLUTANTS IN THE SRM COMBUSTION PRODUCTS

	Normal Operations, 10 Minute Exposure		Emergency (Accidents), 10 Minute Exposure	
Substance	Peak Concentration	Integrated Dose	Peak Concentration	Integrated Dose
HCl	8 ppm	40 ppm·minutes	14 ppm	70 ppm·minutes
Cl_2	3 ppm	10 ppm·minutes	3 ppm	30 ppm·minutes
NO_x	1 ppm	10 ppm·minutes	5 ppm	30 ppm·minutes
Al_2O_3	14 mg/m^3[(a)]	374 mg/m^3·minutes[(b)]	24 mg/m^3[(a)]	1260 mg/m^3·minutes[(b)]

(a) Based on short-term criterion for controlled populations (50 mg/m^3)[(50)] and criterion for short-term exposure of controlled population to HCl (30 ppm)[(50)] and the STPL and PEL for HCl (4 and 7 ppm).[(47)]

(b) Based on air quality standards.[(49)]

4.7.3 Transportation of SRM Segments

Basic features concerning transportation of the SRM segments are described in Section 1.2.5. Transportation of SRM segments off Thiokol/Wasatch property will be accomplished via flatbed trailer truck and railroad. To transport SRM segments to the T-24 static test firing facility, SRM segments will be loaded on flat bed trailers at the R&D Area, and transported to the test area along State Route 83 (SR 83). The road bed of SR 83 was specially constructed to support heavy loads. The road bed can adequately support the heaviest segment and its specially designed transporter. In terms of potential adverse effects from transportation accidents, the most significant part of the trip is the railway transportation, which covers a distance of about 4000 km (2500 mi).

4.7.3.1 Railway Accident Statistics

In 1973, U.S. railroads had a total of 9375 accidents* to trains causing damage to railway property of $149,360,000, an average of $15,932 per accident.[54] In addition, a total of 3,496 grade crossing incidents causing $5,950,000 damage to railroad property were reported, or average damage of $1700 per incident. The low average damage per incident for the grade crossing incidents suggests that they may be ignored as potential causes of major train damage.

In 1973, 853×10^6 train kilometers (530×10^6 train miles) were accumulated by trains in the U.S. Hence, the train accident rate is about 1.1×10^{-5} per km (1.8×10^{-5} per mi), and the expected probability of an accident during the rail transport of segments on a single train would be 0.043 per trip. In view of the small average property damage per accident, most of the accidents will be trivial in terms of causing an ignition of the Space Shuttle SRM segment (the only event leading to a possible environmental effect). By far the majority of these accidents would not involve the cars carrying the SRM segments.

*Only incidents resulting in damage to railroad property of $750 or more are reported in the statistics.

Accident statistics for 1969 permit breakdown of the accident rates by railway car accidents (rather than train accidents) per car kilometer (rather than train kilometer).[55] The rate was 5×10^{-7} non-grade crossing car accidents per car kilometer (8×10^{-7} per car mile). Further, 91 percent of these accidents were serious collisions or derailments causing major shipment damage. It is unlikely that all of these accidents were sufficiently serious to cause ignition of a SRM segment, but for a single shipment of 4 segments, the probability of a segment being involved in such an accident would be 0.007.

The 1969 statistics indicate that fire was involved in 1.5 percent of the major railway car accidents. It is not clear that this percentage is applicable to the SRM segment cars, but at face value, this would indicate that the probability of a major accident to a segment with fire would be 0.00011.

Ignition of the segment might also occur as a result of an accident leading to ignition and burning of other freight in the same train. Flammable liquified gases (e.g., propane) or flammable liquids (e.g., gasoline and petroleum based solvents) probably represent the most extreme fire hazard.

4.7.3.2 Vandalism and Malicious Mischief

Vandalism, malicious mischief, sabotage by arson, high explosives, or rifle fire could cause the SRM segment to ignite. Set or accidental fires or impact by a high velocity rifle bullet might ignite the propellant.[56] Sabotage with high explosives may cause rapid deflagration of the segment and a low equivalent explosive yield, about 1.4 percent[57], or the equivalent of 1900 kg (4200 lb) of TNT. This would cause a blast wave overpressure of about 0.34 N/cm^2 (0.5 psi) at a distance of 235 m (770 ft). This is a factor of 10 below the level which would produce physiological damage (ruptured ear drums).

4.7.3.3 Experience in Rail Transport of Large Solid Rocket Motors

Large solid propellant rocket motors are commonly shipped by rail, and no instance of ignition in transit has occurred. 4568 shipments of Minuteman motors have been made, totaling 7.2×10^6 km (4.5×10^6 mi) without an accident of any kind. Approximately 75 120-inch diameter motors have been shipped as a part of the Titan III program, totaling about 225,000 km (140,000 mi), with only one minor incident, a scrape mark on the shipping container.

4.7.3.4 Rail Shipment of Other Hazardous Materials

Many hazardous materials are commonly shipped by rail, for example, chlorine, ammonia, propane, etc. These materials may be shipped in tank cars containing from 27,000 to 82,000 kg (60,000 to 180,000 lb) of material. For chlorine, whose release in an accident would be considerably worse than ignition of an SRM segment (being cold, the chlorine cloud would tend to hug the ground and disperse slowly), approximately 2.5×10^9 kg (5.5×10^9 lb) was shipped in 1973, accumulating 18×10^6 car kilometers (11×10^6 car miles).[58] Also, about 7.3×10^8 kg (1.6×10^9 lb) of large military ammunition (over 30 mm) was shipped in 1973, accumulating 2.2×10^7 car kilometers (1.4×10^7 car miles).[58] One "serious accident" and one "serious incident" involving rail transportation of explosives (including civil and military) were recorded in 1973. A total of 412 reports of rail transport incidents involving hazardous materials were filed in 1973.[59]

As rail freight, the SRM segments are large and heavy, but by no means are such shipments unknown to the railroad industry. Single items as large as 225,000 kg (500,000 lb) and 55 m (180 ft) long have been shipped by rail in commercial operations.[60] No unusual safety problems are anticipated to result simply from the size or mass of the SRM segments.

4.7.3.5 Consequences of a SRM Transportation Accident

The most likely adverse outcome of a severe transportation accident is the ignition and burning of a SRM segment. Sabotage or severe accidents involving high explosives or munitions carried in adjacent rail cars could result in either ignition or rapid deflagration of a segment.

Rapid deflagration would result in the creation of a blast wave equivalent to the detonation of 1900 kg (4200 lb) of TNT. Such a blast wave would fall below the thresholds for structural damage of massive multistory buildings at a distance of 22 m (72 ft), total structural damage of light-frame construction at a distance of 56 m (184 ft), ear drum rupture at a distance of 60 m (190 ft), and the window glass breakage at a distance of 235 m (770 ft). Should the rapid deflagration of an SRM segment result from explosion of high explosives or munitions carried in a nearby rail car, calculations indicate that the contribution of the SRM segment to the resulting blast wave would be minor. The probability of accidents which would cause a rapid deflagration of an SRM segment is extremely low.

Table 22 (Section 4.7.1.2) presents the predicted peak ground level concentrations and dosages that would result from ignition and burning of a center segment under unfavorable meteorological conditions (see Section 4.2.3.3). Comparing the values in Table 22 with the criteria in Table 24, it is seen that all concentrations and dosages are within the criteria, except the peak concentration of Al_2O_3, which exceeds the suggested criterion by a factor of 1.3. However, the dosage of Al_2O_3 is only 6 percent of the criterion. During the short period corresponding to the predicted peak concentration, some interference with vision may occur, which could impede traffic on nearby roads downwind of the accident.

The probability of occurrence of the unfavorable meteorological conditions causing the high Al_2O_3 concentrations is estimated as about 0.09. Combined with the average probability of a transportation accident (0.007 per trip), the upper bound probability of an accident under unfavorable meteorological conditions is 6×10^{-4}. As not every accident will result in ignition of a segment, the true probability of occurrence of a worst case situation is likely to be substantially lower than this upper bound.

The significance to health and safety of the high peak concentration of Al_2O_3 is not clear, particularly since this peak concentration is fleeting (the average concentration during a 10-minute period is only 2.2 mg/m^3). Further, the method of making the prediction assumes that all aluminum in the propellant becomes and remains airborne Al_2O_3. Actually, under the low intensity burning conditions which would be associated with the accidental ignition of a SRM segment, not all of the aluminum would be burned, and some of the unburned aluminum and Al_2O_3 would remain on the ground as a slag. Also, experience in normal rocket firings has indicated that much of the mass of Al_2O_3 is present as large particles which rapidly settle out of the cloud. In view of the small elevation of the predicted peak concentration above the criterion, the very short duration of concentrations exceeding the criterion, and the conservative nature of the prediction, little or no impact on health or safety is expected.

4.8 Effects Upon Flora and Fauna

Possible effects upon flora and fauna might arise from the previously described activities associated with the Space Shuttle Solid Rocket Motor (SRM) DDT&E Program. These possible effects are associated with SRM processing, open burning of waste propellant, static test firings and transportation of finished SRM segments. Releases of toxic or noxious materials to the atmosphere and the generation of heat and noise are the routes through which adverse effects might occur.

4.8.1 SRM Processing

Preceding discussions in Section 4.0 have reviewed the activities associated with the processing of the Space Shuttle SRMs. Releases to the environment will be controlled to minimize their effects. These planned releases to the air and water, as well as solid wastes, will be similar to previous processing activities at the plantsite. The SRM DDT&E Program will represent approximately 20 percent of the processing activities at Thiokol/Wasatch.

Inasmuch as the releases and/or physical activities and alterations are minimal, impacts to the biota, both terrestrial and aquatic, can be expected to be small. There will be no additional alteration of terrestrial habitat resulting from the SRM processing activities and, therefore, no effect to terrestrial biota. There should not be any significant effects on springs and surface waters as a result of the SRM processing. Consequently, no appreciable changes are expected to occur in the flora and fauna of the aquatic ecosystems therein.

4.8.1.1 Open Burning of Waste SRM Propellant

Routine open burnings of waste propellant is an ongoing operation at Thiokol/Wasatch (Section 4.2.3.1). A review of the predicted levels of air pollutant releases, which will result from Space Shuttle SRM-related open burning, does not indicate levels which would affect the terrestrial biota of the immediate area. Prior commitment of the burn pit site to similar waste burning activities minimizes the potential for any new or unforeseen impacts occurring as a result of the activity.

Available data suggest that water quality in Blue Springs Creek is not measurably affected by nearby open burning which have been associated with the Minuteman program (Tables 1 and 2, and Reference 61). Given the similarity between the Minuteman program and the SRM DDT&E Program, this pattern would be expected to continue. Since no changes in water quality or flow are anticipated as a result of open burning associated with the SRM DDT&E Program, no effects on the flora and fauna of the aquatic ecosystems therein are expected to occur.

4.8.2 SRM Static Test Firing

Static test firings of the SRM will be accompanied by release of toxic gases into the air and by loud noises. The potential impact to the biota depends predominantly on the distance from the test.

4.8.2.1 Terrestrial Ecosystems

The horizontal firing position of the SRM during the static test results in the lateral expulsion of hot exhaust material. A cloud is formed and the buoyancy and terrain effects contribute to an upward turn of the cloud. In the ground area downstream of the rocket motor and prior to the upturn of the exhaust cloud, excessive temperatures, fire, and toxic gases will eliminate any terrestrial organisms, either plant or animal. This area represents approximately 0.01 km^2 (2.5 acres). The prior use of the T-24 facility for horizontal test firings of large solid rocket motors, such as the 156-inch boosters, significantly reduces the initial negative impact of the SRM tests, in that the area has previously been exposed to these conditions (see Figure 36). Some recovery of vegetation and enroachment by animal populations will have occurred in the 8 years since the last major horizontal test at this site. However, the area has not returned to its natural condition and still retains its "denuded" character (Figure 36). The initial test in the SRM DDT&E series will reverse any recovery which has begun.

Information available on the toxicity of the primary toxic exhaust products of the Space Shuttle SRM--HCl, Al_2O_3, NO_x, and other chlorine containing byproducts--is limited and in some cases conflicting.

FIGURE 36. A JANUARY 1976 PHOTOGRAPH OF THE AREA WHICH WOULD BE EXPOSED DURING A SPACE SHUTTLE SRM STATIC TEST AT T-24

Lerman, et al.[62], have recently done a study on the toxicity of HCl to cultivated plant species and Cicerone, et al.[63], have reviewed the literature on effects of HCl on plants and animals. Summary results of their studies are presented in Tables 25, 26, and 27. The reader is referred to the original papers for specific references, if required. Section 4.2.3.2 summarizes the levels of HCl which would be anticipated downwind of the test firing under various normal and abnormal test conditions. It can be noted that the highest ground level concentrations and dosages predicted to occur in the improbable worst case of an abnormal test firing are below the levels and doses at which any effects are observed in plants or animals. Thus, the release of HCl to the atmosphere by a test firing of a SRM under the conditions described would not be expected to result in any measurable effect to terrestrial, including avian (birds), biota in the area (see Section 4.8.2.3).

Large amounts of alumina (Al_2O_3) are released into the atmosphere within the plume during a normal test firing of a SRM. Peak instantaneous concentrations of alumina are projected to be 3.5 mg/m^3, with doses of the order of 8 $(mg/m^3)\cdot min$. To date, no visible effects to plants by even extremely high concentrations of alumina have been demonstrated.[62] The magnitude of injury from HCl exposure is increased by simultaneous exposure to Al_2O_3, but the addition of alumina does not lower the HCl effects threshold.[62] The potential for observable impacts to animals from exposure to Al_2O_3 is poorly understood. The projected concentrations and doses of exposure to animals in the vicinity of the SRM test firings do not approach the levels which may result in symptoms to animals.[62,63]

Levels of NO_x projected to occur in the vicinity of the static test firings of the SRM are not expected to result in measurable effects or visible symptoms to flora and fauna in the area. Experimental evidence available on the phytotoxicity of NO_x indicates that the levels projected for the SRM will not result in visible symptoms. Extremely low (0.5 ppm) concentrations may affect plants grown under continuous exposure. However, these low concentrations do not precipitate the effects under short exposure periods.[64] Sensitive plant species may be injured by 2-hour exposures to 6 ppm.[64] These extended exposure levels will not occur as a result of SRM static test firings. Available experimental evidence dealing with animal exposure to

TABLE 25. INJURY SYMPTOMS OF EIGHT PLANT SPECIES EXPOSED TO HCl GAS AT CONCENTRATIONS RANGING FROM 1-25 PPM FOR 20 MINUTES

Plant	HCl Concentration* (Dosage) 15-25 ppm (300-500 ppm min)	7-14 ppm (140-280 ppm.min)	1-6 ppm (20-120 ppm min)
Aster	Temporary Wilting, extensive interveinal bronzing on lower leaf surface, necrosis of young tissue.	Interveinal bronzing on lower surface, trace of necrosis.	Trace of necrotic spots on young leaves.
Calendula	Temporary wilting, lower surface bronzing, discoloration necrosis. The younger the leaf, the more distal the damage.	Bronzing of lower leaf surface, interveinal necrosis, marginal discoloration.	Traces of lower surface bronzing.
Centaurea	Extensive necrosis, rolling, speckling, temporary wilting, discoloration.	Discoloration along the leaf margins, rolling.	
Cosmos	Extensive necrosis, extensive rolling, flower discoloration, tipburn of sepals.	Tipburn, tip rolling.	Tipburn
Marigold, Dwarf	Severe necrosis of almost all leaves, rolling.	Discoloration, necrosis of mid-aged leaves, some rolling.	Traces of necrosis or discoloration.
Marigold, Sen. Dirksen	Severe necrosis, extensive rolling, tipburn of sepals on flowers.	Interveinal discoloration of mid-aged leaves, some rolling.	Traces of necrosis or discoloration.
Nasturtium	Interveinal bleached lesions, on younger leaves in addition, marginal bleaching and rolling.	Discoloration, necrotic speckling, rolling.	Traces of discoloration.
Zinnia	Bronzing on basal leaf portions, extensive necrosis and rolling on rest of leaf. Occasional petal necrotic spots.	Speckling, interveinal bronzing.	Trace of lower surface bronzing.

* Note: Plants were evaluated 24 hours after exposure.

Source: Reference 62

TABLE 26. SUMMARY OF REPORTED TOXIC EFFECTS OF HYDROGEN CHLORIDE EXPOSURE TO PLANTS

Species	Concentration (ppm)	Exposure Time	Effects or Comments
Plants	10-50		No leaf damage
Plants	100-1,000		Leaf damage
Sugar beets	10	Few hr.	Threshold for marking
Viburnum seedlings	5-20	24 hr.	Leaves rolled at the edges, withered, shrunk, faded, and necrotic
Beech	1,000	1 hr.	Local lesions produced
Oak	1,000	1 hr.	Local lesions produced
Maple	2,000		Marginal leaf scorch
Birch	2,000		Marginal leaf scorch
Pear	2,000		Marginal leaf scorch
Viburnum seedlings	5-20	48 hr.	Plants died
Larch	5-20	48 hr.	Plants died
Fir	1,000	1 hr.	Local lesions formed
Spruce	2,000	1 hr/day for 80 days	No apparent injury
Tomato plants	5	2 hr.	Developed interveinal bronzing followed by necrosis within 72 hours after exposure
Liriodendron tulipifera	3	4 hr.	Threshold for visible injury
Ainus glutinosa	6	4 hr.	Threshold for visible injury
Prunus serotina	6	4 hr.	Threshold for visible injury
Acer saccharum	7	4 hr.	Threshold for visible injury
Acer platanoides	7	4 hr.	Threshold for visible injury
Quercus rubrum	13	4 hr.	No visible injury
Pinus strobus	8	4 hr.	Threshold for visible injury
Pseudotsuga mantissii	10	4 hr.	Threshold for visible injury
Abies balsamea	10	4 hr.	Threshold for visible damage
Pinus abies	19	4 hr.	Threshold for visible damage
Pinus nigra	18	4 hr.	No visible damage
Thuja occidentalis	43	4 hr.	No visible damage
Spruce seedlings	<50	20 min.	Plants died

Source: Reference 63

TABLE 27. SUMMARY OF REPORTED EFFECTS OF INHALATION OF HYDROGEN CHLORIDE ON ANIMALS

Species	Concentration (ppm)	Exposure Time	Effects or Comments
Rabbits	4,300	30 min.	Fatal in some cases, due to larnygeal spasm, laryngeal edema, or rapidly developing pulmonary edema
Guinea pigs	4,300	30 min.	Fatal in some cases, due to laryngeal spasm, laryngeal edema, or rapidly developing pulmonary edema
Cats	3,400	90 min.	Death after 2 to 6 days
Rabbits	3,400	90 min.	Death after 2 to 6 days
Guinea pigs	3,400	90 min.	Death after 2 to 6 days
Cats	1,350	90 min.	Severe irritation, dyspnea, and clouding of the cornea
Rabbits	1,350	90 min.	Severe irritation, dyspnea, and clouding of the cornea
Guinea pigs	1,350	90 min.	Severe irritation, dyspnea, and clouding of the cornea
Rabbits	670	2 hr.	Fatal in some cases
Guinea pigs	670	2 hr.	Fatal in some cases
Rabbits	300	6 hr.	Corrosion of the cornea and upper respiratory irritation
Guinea pigs	300	6 hr.	Corrosion of the cornea and upper respiratory irritation
Rabbits	100-140	6 hr.	Only slight corrosion of the cornea and upper respiratory irritation
Guinea pigs	100-140	6 hr.	Only slight corrosion of the cornea and upper respiratory irritation
Rabbits	100	6 hr/day for 50 days	Slight unrest and irritation of the eyes and nose
Guinea pigs	100	6 hr/day for 50 days	Slight unrest and irritation of the eyes and nose
Pigeons	100	6 hr/day for 50 days	Slight unrest and irritation of the eyes and nose
Monkey	33	6 hr/day 5 days week for 4 weeks	No immediate toxic effects and no pathological changes
Rabbit	33	6 hr/day 5 days/week for 4 weeks	No immediate toxic effects and no pathological changes
Guinea pig	33	6 hr/day 5 days/week for 4 weeks	No immediate toxic effects and no pathological changes
Rabbits	60	5 min.	Cessation of ciliary activity without recovery
Rabbits	30	10 min.	Cessation of ciliary activity without recovery

Source: Reference 63

NO_x is limited to test experience with laboratory animals used as human analogs.[52] These organisms have symptomatologies and sensitivities similar to those of humans. Therefore, because the levels of NO_x produced by the SRM test firing will meet human exposure standards, toxic effects to animal populations would not be anticipated.

Peak chlorine levels projected to result during static test firings of the SRM range from 0.1 ppm for normal firings to 0.56 ppm for the highly improbable abnormal test condition. Duration of these peak levels is very brief (a few minutes). Literature concerning toxic effects to plants from exposure to Cl_2 reports measurable effects from concentrations similar to those expected at SRM static test firings, but only after exposures of much longer duration--2 to 4 hours.[64] These lengthy exposures would not occur with the Space Shuttle SRM tests. While the literature is not definitive, it appears highly unlikely that measurable effects to vegetation would occur even in areas of peak concentrations of Cl_2 as a result of SRM static testing. Chlorine is described as "a primary irritant of the entire respiratory tract" of animals.[53] However, levels projected to occur during the SRM DDT&E Program are at or below threshold odor detection levels. Therefore, there is no reason to expect any measurable, temporary, or permanent effect to exposed animals.

Section 4.3.2 discusses the noise levels which will be anticipated to occur during the 2-minute static test firings. A review of the effects of noise on animals[65] indicates that, while some animals may be startled by these noise levels, most quickly return to normal activities. Noise levels in the immediate vicinity of T-24 (test site) could be high enough to result in permanent or temporary hearing loss to those animals present. Holders of grazing permits will be notified prior to a test in order that they may relocate any cattle that are in the immediate test area. It is likely that the increased amount of human activity and machinery operation in the immediate vicinity of T-24 prior to a test would cause most larger mammals and raptorial birds, if any, to leave the area. It should be recalled at this point that brief, loud sounds from jet aircraft and rocket motor test programs are not uncommon in this region and thus will not be a unique experience to the animals of the area.

4.8.2.2 Aquatic Ecosystems

Test firings will produce exhaust clouds which, under normal circumstances, will rise and disperse. In the unlikely event that precipitation scavenging of HCl from the exhaust cloud were to occur (see Section 4.2.3.2.3), the possibility that this would affect surface water quality at isolated locations in the region is unlikely. Potential effects to surface water quality, even if they did occur, would be exceedingly minor, given the paucity of surface water resources in the area, and the buffering capacity of the surface waters in the area due to alkalinity. For example, the bicarbonate alkalinity of the northern basin of the Great Salt Lake ranges from 480 to 520 ppm[5], and the total alkalinity of Blue Springs water which feeds Blue Springs Creek has been observed as 265 ppm[66]. Most of this is probably also attributable to the bicarbonate ion, as the pH of Blue Springs water is nearly neutral. Likewise, the pH of the northern basin of the Great Salt Lake is near but slightly greater than neutral (7.4 to 7.7).[5] Calculations suggests that up to 40 ppm HCl could be added to surface waters in the event of worst case precipitation scavenging. Even if such an event were to occur, this loading would be substantially less than the bicarbonate buffering capacity of surface waters in the area. Consequently, no appreciable downward pH shifts would be expected to occur. Table 28 summarizes some of the effects of pH changes on aquatic organisms.[67] Assuming the pH of Blue Springs Creek, springs in the area, and the Great Salt Lake are slightly above neutrality, any slight pH shifts which could conceivably occur would be much less than the pH effects ranges described in Table 28. Thus, no changes in aquatic flora or fauna would be expected, even in the unlikely event of precipitation scavenging of HCl from the exhaust clouds of SRM test firings.

TABLE 28. A SUMMARY OF EFFECTS OF pH ON FRESHWATER FISH AND OTHER AQUATIC ORGANISMS

pH	Known Effects
11.5-12.0	Some caddis flies (Trichoptera) survive but emergence reduced.
11.0-11.5	Rapidly lethal to all species of fish.
10.5-11.0	Rapidly lethal to salmonids. The upper limit is lethal to carp (Cyprinus carpio), goldfish (Carassius auratus), and pike. Lethal to some stoneflies (Plecoptera) and dragonflies (Odonata). Caddis fly emergence reduced.
10.0-10.5	Withstood by salmonids for short periods but eventually lethal. Exceeds tolerance of bluegills (Lepomis macrochirus) and probably goldfish. Some typical stoneflies and mayflies (Ephemera) survive with reduced emergence.
9.5-10.0	Lethal to salmonids over a prolonged period of time and no viable fishery for coldwater species. Reduces populations of warmwater fish and may be harmful to development stages. Causes reduced emergence of some stoneflies.
9.0-9.5	Likely to be harmful to salmonids and perch (Perca) if present for a considerable length of time and no viable fishery for coldwater species. Reduced populations of warmwater fish. Carp avoid these levels.
8.5-9.0	Approaches tolerance limit of some salmonids, whitefish (Coregonus), catfish (lctaluridae), and perch. Avoided by goldfish. No apparent effects on invertebrates.
8.0-8.5	Motility of carp sperm reduced. Partial mortality of burbot (Lota lota) eggs.
7.0-8.0	Full fish production. No known harmful effects on adult or immature fish, but 7.0 is near low limit for Gammarus reproduction and perhaps for some other crustaceans.
6.5-7.0	Not lethal to fish unless heavy metals or cyanides that are more toxic at low pH are present. Generally full fish production, but for fathead minnow (Pimephales promelas), frequency of spawning and number of eggs are somewhat reduced. Invertebrates except crustaceans relatively normal, including common occurrence of mollusks. Microorganisms, algae, and higher plants essentially normal.
6.0-6.5	Unlikely to be toxic to fish unless free carbon dioxide is present in excess of 100 ppm. Good aquatic populations with varied species can exist with some exceptions. Reproduction of Gammarus and Daphnia prevented, perhaps other crustaceans. Aquatic plants and microorganisms relatively normal except fungi frequent.
5.5-6.0	Eastern brook trout (Salvelinus fontinalis) survive at over pH 5.5. Rainbow trout (Salmo gairdneri) do not occur. In natural situations, small populations of relatively few species of fish can be found. Growth rate of carp reduced. Spawning of fathead minnow significantly reduced. Mollusks rare.
5.0-5.5	Very restricted fish populations but not lethal to any fish species unless CO_2 is high (over 25 ppm), or water contains iron salts. May be lethal to eggs and larvae of sensitive fish species. Prevents spawning of fathead minnow. Benthic invertegrates moderately diverse, with certain black flies (Simuliidae), mayflied (Ephemerella), stoneflies, and midges (Chironomidae) present in numbers. Lethal to other invertebrates such as the mayfly. Bacterial species diversity decreased; yeasts and sulfur and iron bacteria (Thiobacillus-Ferrobacillus) common. Algae reasonable diverse and higher plants will grow.
4.5-5.0	No viable fishery can be maintained. Likely to be lethal to eggs and fry of salmonids. A salmonid population could not reproduce. Harmful, but not necessarily lethal to carp. Adult brown trout (Salmo trutta) can survive in peat waters. Benthic fauna restricted, mayflies reduced. Lethal to several typical stoneflies. Inhibits emergence of certain caddis fly, stonefly, and midge larvae. Diatoms are dominant algae.
4.0-4.5	Fish populations limited; only a few species survive. Perch, some coarse fish, and pike can acclimate to this pH, but only pike reproduce. Lethal to fathead minnow. Some caddis flies and dragonflies found in such habitats; certain midges dominant. Flora restricted.
3.5-4.0	Lethal to salmonids and bluegills. Limit of tolerance of pumkinseed (Lepomis gibbosus), perch, pike, and some coarse fish. All flora and fauna severely restricted in number of species. Cattail (Typha sp.) is only common higher plant.
3.0-3.5	Unlikely that any fish can survive for more than a few hours. A few kinds of invertebrates such as certain midges and alderflies, and a few species of algae may be found at this pH range and lower.

SOURCE; **Reference 67**

4.8.2.3 Rare and Endangered Species

Peregrine falcons, the endangered species listed in Table 6 (Section 2.2.5.6), are likely to include the Thiokol/Wasatch plantsite within their territorial travels during their tenure in the area of the Bear River Migratory Bird Refuge. Status-undetermined species may rarely venture over the area. No raptor nests are known to occur on the Thiokol/Wasatch plantsite.

As a result of experience gained through previous rocket motor static testing and USAF supersonic aircraft passage over the area (sonic boom), no additional measurable negative effects would be expected to occur from the SRM DDT&E Program. The wildlife refuge at Kennedy Space Center, Florida is abundant in bird life, reptiles and mammals. This refuge experiences, on a routine basis, rocket noise and rocket effluent releases due to launch activities. A recent census conducted by the National Wildlife Service indicates that this refuge is highly productive and is expanding in population.[68]

4.8.2.4 Special Consideration to The Bear River Migratory Bird Refuge

Because of the importance of The Bear River Migratory Bird Refuge to migratory waterfowl and raptorial species of the area, a review of conditions which a Space Shuttle SRM static test firing will impose on it is in order.

Noise levels of between 80 dB(A) and 55 dB(A), depending upon the distance from the test site, T-24, are predicted at the refuge (see Figure 34). Section 4.3.2.1 indicates that these levels may be conservative (high) by about 8 dB(A). Noise even at the conservative levels may temporarily disturb some birds, but it is unlikely that the majority will respond. Temporary disturbances normally do not have a negative influence on birds. The major exception occurs during the nesting season, when prolonged exposure of eggs or hatchlings to the sun, cold, or predators due to absence of the parents may result in loss of young. This effect has not been documented at Bear River during previous rocket motor test firings nor as a result of sonic booms or other effects from aircraft passage. Such an effect would not be anticipated to result from a SRM test firing.

Peak HCl levels of less than 2 ppm and doses of 4 ppm·minutes would be anticipated at ground level, should winds carry the cloud over the Refuge (see wind rose - Figure 15). The highest ground level HCl concentrations predicted over the Refuge, for a SRM static test firing during one of the worst of the 23 meteorological cases, are depicted in Figure 28. Peak Al_2O_3 levels of less than 4 mg/m^3, peak NO_x levels of less than 0.2 ppm and peak Cl_2 levels of about 0.1 ppm at ground level are also predicted. These levels are not expected to have any effect upon the floral and faunal resources of the Refuge or surrounding marshes.

HCl concentrations as high as 10 ppm are expected to exist within the exhaust cloud at high altitude (2 to 4 km). Should any migratory waterfowl fly through the exhaust cloud, no effect is anticipated. The probability of waterfowl or other bird contact with the rising cloud is considered to be remote. A number of factors contribute to this prediction. Test firings will occur at midday - a low flight activity time for waterfowl. Noise and the turbulent rising nature of the cloud will not attract birds, though it cannot be ruled out that individuals might pass through the cloud. Levels of pollutants and temperatures drop rapidly (~1 to 2 minutes) to a point that any bird passing through the cloud would probably not be affected. Thus, it is considered unlikely that bird passage through the test cloud would result in substantial negative effects to any individual bird, and no effect can be anticipated to the species present in the region.

4.8.3 Accidental Ignition of Segments During Transport

In the highly unlikely event of the accidental ignition of segments of a SRM, the immediate environment, including resident flora and fauna will be subjected to conditions as described in Sections 4.2.3.3, 4.7.1.2, and 4.7.3.5. The levels of noise and air pollutants are not predicted to be great enough to result in any measurable effects beyond the immediate area. Location of the segment and the weather conditions at the time of ignition do, however, control the specific impacts to the specific ecosystems affected. A worst case accident may cause localized destruction by fire or toxicants; however, the occurrence of such an event is highly unlikely.

4.9 Culture

4.9.1 Demographic

The demography of the region around Thiokol/Wasatch as described in Section 2.3.1 will remain unchanged by the conduct of the Space Shuttle SRM DDT&E Program. Continuity of labor force is expected to result from the activities of the Space Shuttle SRM DDT&E Program, as other programs are phased out. Additionally, local support requirements will remain similar to existing levels during the course of the program.

4.9.2 Social

Social services and social amenities in the region surrounding Thiokol will be unaffected by the conduct of the SRM DDT&E Program. Continuity of employment levels coupled with continuity of labor force will prevent any major emigration or immigration of people. Throughout the period when SRM DDT&E activities peak, the important role which Thiokol plays in the social services and amenities of the region will remain similar to its present role. The social role of Thiokol and its employees as described in Section 2.3.2 will be continued, including charitable contributions, sponsorship of local activities, and educational support.

4.9.3 Historical

Conduct of the Space Shuttle SRM will not result in any impact to the historical resources of Box Elder County, in particular, Corinne Methodist Episcopal Church and Golden Spike National Historic Sites. No new facility construction, beyond modification of existing facilities, is anticipated either primarily on the Thiokol plantsite or secondarily as a result of local service needs. Thiokol participation in historical programs such as the "Pioneer Days" will be maintained.

4.9.4 Recreational

Recreational activities will not be affected either positively or negatively by the conduct of the Space Shuttle SRM DDT&E Program. Static test firings should in no way interfere with active recreation activities in the area outside of plantsite boundaries including, but not limited to, skiing, hunting, and fishing. Recreational and educational utilization of The Golden Spike National Monument will not be affected by conduct of the program, including static test firings. Individuals in the immediate area may hear and feel vibrations from the infrequent static test firings but should feel no discomfort. Further information concerning the effect of noise on man is presented in Section 4.7.

4.9.5 Archeological/Paleontological

Archeological and paleontological resources exist within Box Elder County, Utah, with several archeological sites located on or in the vicinity of the Thiokol/Wasatch plantsite (see Section 2.3). Conduct of the SRM DDT&E Program will not affect any known archeological or paleontological materials. All facilities and testing areas proposed for the SRM DDT&E Program are currently used for activities which are similar to existing programs.

Thiokol/Wasatch has demonstrated its interest in stewardship of these resources by support of thorough on-site study by the University of Utah. Several small petroglyphs, recovered by the University of Utah's archeological study team, are displayed near the entrance to the R&D Area.

It is concluded that the activities of the SRM DDT&E Program will not effect existing archeological and paleontological resources.

4.9.6 Aesthetics

As described in Section 2.3.7 and elsewhere, the static test firing of a Space Shuttle Solid Rocket Motor will produce noise, vibration, and a visible white or grayish cloud which will quickly rise above the test site. This static test firing condition, scheduled to occur seven times during the 18-month period or an average of once every 3 months, will be a temporary influence on the aesthetics of the area.

Noise contours for a static test firing are presented in Figure 34. The duration of the test firing is 2 minutes. In general, a dB(A) level of 60 to 65 can be compared to normal conversational tones and a level of 100 to 110 dB(A) to a jet aircraft at takeoff, heard from a position near the end of the runway. Individuals in the area will be exposed to these levels and various levels between, depending upon their position relative to the test facility. Beyond the contours at lower sound levels (Figure 34), the noise may be lost within ambient noise levels and either not heard or be indistinguishable.

Visibility within the northern Great Salt Lake region is generally very good. Inasmuch as static test firings will be undertaken on days of high visibility, the plume or cloud rising above the test will be highly visible over great distances. Individuals within the zone where the noise of the test is distinct will in all likelihood look to the sky to determine the source of the sound and observe the rising plume. Because the cloud formed by the test is ordinarily similar in color to natural clouds in the sky, an observer noticing the cloud once it has stabilized, and the sound levels returned to normal, will probably think it is simply an unusual cloud formation.

While the noise levels may be higher, the cloud size may be larger, the region and its inhabitants have experienced similar incidents many times in the past. Numerous static test firings of solid rocket motors of considerable size have been made at Thiokol in the past. Additionally, supersonic aircraft passage over the area with coincident sonic booms is not uncommon due to the proximity of Hill AFB and several nearby weapons testing or bombing ranges.

The static test firings are short-lived events which will occur seven times during the program. Some people in the immediate vicinity may become annoyed by the noise levels during the 2-minute test period; others, seeing the rising cloud above the test area may realize quickly what is happening and think nothing of it or become interested in what they are witnessing.

Other activities of the Space Shuttle SRM DDT&E Program including the minor facility alterations and day-to-day processing and test activities should not affect the opinions of visitors or local residents regarding the aesthetics of the area.

4.10 Economics

Conduct of the Space Shuttle SRM DDT&E Program will have no direct effect on farming activities of the surrounding area. All land needed for the SRM DDT&E Program is presently, or has been, dedicated to similar industrial activity. Grazing rights on facility lands will be maintained. Continuity of employment levels will minimize any effect to farm families. Section 8.0 presents information relative to industrial employment, and local and non-local venders.

5.0 POSSIBLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

The environmental effects of the Solid Rocket Motor (SRM) Design, Development, Test, and Evaluation (DDT&E) Program have been discussed in detail in Section 4.0, both as to effects upon the physical environment and the implications to humans and to affected flora and fauna. Table 29 is a summary, in tabular form, of these effects for each of the factors considered. It is evident that no significant effects are expected to result from any of the Space Shuttle SRM DDT&E activities under normal circumstances. The possible effects of certain types of accidents involving the SRM or of its individual segments may be of marginal significance, but restricted chiefly to air quality and noise, and the corresponding effects upon humans and upon flora and fauna. These specific effects of air quality and noise, and a minor impact on land use, are summarized in the following Sections 5.1, 5.2, and 5.3, respectively.

In summary, although the possible effects of certain types of accidents may be of marginal significance to the human environment and to plants and animals in the vicinity, the combinations of events leading to such situations are believed to be very rare; no examples have occurred. The consequences appear to be less than would be associated with similar accidents involving many hazardous materials (e.g., high explosives, toxic and flammable gases) manufactured and transported in larger quantities throughout the United States.

5.1 Air Quality Effects

Normal or abnormal test firings will result in the release of air pollutants, HCl, Al_2O_3, NO_x, and Cl_2, which will cause a temporary, localized, small degradation of air quality in the area downwind of the test site. This will not occur more frequently than about once every two months, for a total of 7 tests. This fleeting change in air quality is not expected to have any significant adverse effects on the flora, fauna, or human population. Test firings will be made in accordance with the regulations of the Utah Air Conservation Committee, Department of Social Services, Division of Health.

TABLE 29. SUMMARY OF POTENTIAL ENVIRONMENTAL EFFECTS OF SPACE SHUTTLE SOLID ROCKET MOTOR DDT&E PROGRAM

Impact Area	Processing	Test Firings: Normal	Test Firings: Abnormal	Normal Transportation	Accident, Onsite or in Transportation (Segment Ignition)
Air Quality	Temporary localized small degradation due to waste propellant burning. No change from preexisting conditions	Temporary, localized small degradation	Temporary, localized small degradation	No significant effect	Under unfavorable conditions will cause temporary localized degradation
Noise	No environmental effect	Large area subjected to modest levels of predominantly low frequency noise: possible annoyance to some. No population center affected.	Possible case rupture (loud noise) could result in annoyance or startle of perceivers	No significant effect	Possible (unlikely) rapid deflagration (loud noise)
Water Quality	No appreciable change due to the SRM Program	No effect	No effect	No effect	No anticipated effect
Solid Waste	Cleaning cases for reuse will generate small quantities of solid waste. No measurable change due to SRM Program in other wastes	No effect	No significant effect. Debris resulting from case rupture would be added to solid waste for salvage or burial	No effect	Debris from accident would become solid waste for salvage or disposal
Pesticides	No change in current minor usage	Not used	Not used	No change in current usage by transportation organization (railroads)	Not involved
Human	No effect, meets all health and safety regulations	No effect	No effect	No effect	Worst case accident may cause temporary localized particulate concentrations in excess of suggested guideline: effects probably not significant. Fire or blast waves could cause damage to nearby area
Flora and Fauna	No significant effect	No effect except for small area at test site already degraded by tests in past programs	No effect except for small area at test site alreadv degraded by tests in past programs	No effect	Worst case accident may cause localized destruction by fire or toxicants
Culture	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged
Economics	SRM DDT&E Program will help maintain local economy at current levels. Insignificant effects nationwide; however, specific vendors will see positive effects	(Part of overall program economics)	No effect anticipated	(Part of overall program economics)	No significant effect anticipated; however, would require manufacture of replacement segments

Accidental ignition of a SRM segment during processing activities or in transport would also result in a temporary, localized degradation in air quality. Under unfavorable conditions, the peak concentration of Al_2O_3 is predicted to exceed, fleetingly, the tentative criterion, although the predicted dosage is only 6 percent of the tentative criterion. Destruction of the flora and non-mobile fauna in the immediate vicinity of the burning segment would be expected as a result of the fire, but impacts to human health and safety are not expected.

Burning of waste propellant will generate the same air pollutants as do test firings and accidental ignition and burning of a SRM segment. Waste propellant is burned as prescribed by the Utah Air Conservation Committee. No adverse effects on the flora, fauna, or human population are expected, and none have been observed to result from the more intensive activities of the past.

5.2 Noise Effects

Static test firings, either normal or abnormal, will subject a large area to moderate sound levels of predominately low frequencies, for periods of about 2 minutes. Some people may be annoyed by the noise, but the population exposed is very small. The noise may also temporarily disturb birds at the Bear River Migratory Bird Refuge.

5.3 Land Use Effects

The SRM DDT&E Program will require that improvements be made to railroad property at Corinne. Since the land involved is already railroad property, there will be no significant change in usage.

6.0 ALTERNATIVES TO THE PROPOSED ACTION

The Space Shuttle Program has been developed by a continuing analysis of the technological, economic, environmental, and other pertinent factors. The Solid Rocket Motor/Booster concept was selected only after consideration of a number of alternatives; these considerations are covered in The Environmental Impact Statement for the Space Shuttle Program.(1) Alternatives within the Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) Program, are discussed in the following paragraphs.

6.1 No Action

The "No Action" alternative is equivalent to the abandonment of the current Space Shuttle concept. The concept of using Solid Rocket Boosters (SRB's) was judged as optimal through a systematic evaluation of various concepts, including liquid fueled boosters. Since the SRM is an integral and necessary part of the Space Shuttle Solid Rocket Booster, the "no action" alternative would preclude the ultimate benefits anticipated from the Space Shuttle (see Section 7.0).

6.2 Modification to the Proposed Action

Modifications to the proposed action have been considered. Possible alternatives that have been evaluated relate to: (1) solid propellant choice, (2) other methods of waste propellant disposal, (3) static test firings, (4) the use of an HCl washout scrubber device, and (5) transportation method and route. These are discussed below in the following paragraphs.

6.2.1 Solid Propellant Choice

The PBAN/AP/Al solid propellant chosen for the SRM has an extensive background of development and safe, reliable use in large solid rocket motors. From an environmental viewpoint, it has the disadvantages of having HCl and Al_2O_3 in its combustion products. Propellants are known or could be developed that contain no chlorine and no aluminum, and hence would emit neither HCl or Al_2O_3.

By replacing the ammonium perchlorate (AP) with ammonium nitrate (AN) or cyclotetramethylene tetranitramine (HMX), a chlorine-free propellant can be obtained. AN-based propellants are generally low in performance (low Isp); as a consequence, the SRM's would have to be much larger, containing much more propellant, than when the chosen propellant is used. With such a low performance propellant, the entire concept of the Space Shuttle would be of marginal feasibility. Also, the increased quantity of propellant would result in the emission of larger quantities of other potential air pollutants.

Propellants based upon a high content of HMX, where HMX replaces AP, have performance equal to or greater than those based on AP; unfortunately, such propellants become Class 7 (detonating) and are much more expensive than AP-based propellants. The use of a Class 7 propellant in the SRM is not considered feasible because of the potential impact on reliability, safety, and cost. Mixtures of AN and HMX conceivably could safely replace the AP with acceptable performance but such propellants have not progressed beyond the laboratory study phase.

Elimination of aluminum (Al) from the propellant results in a low performance (low Isp) propellant. As in the case of replacing AP with AN, the solid rocket motors would need to be larger than with the chosen propellant. The feasibility of the entire Space Shuttle concept would be questionable if such Al-free propellant were used.

Because the chosen PBAN/AP/Al propellant is not expected to cause any severe or prolonged environmental problems, and because the possible alternative solid propellants all have significant disadvantages, all of the alternative solid propellants have been rejected in favor of the PBAN/AP/Al propellant.

6.2.2 Other Methods of Waste Propellant Disposal

Various methods have been and are being investigated as alternatives to the standard open-burning method of disposing of waste propellant. These methods include reclamation or recovery of the propellant or one or more of its ingredients, confined burning or incineration, and alternative (nonpropellant) uses.

Recovery methods investigated typically involve leaching the AP from the waste propellant with water in a grinder or shredder.[69,70] Some aluminum may be recovered from the solids, or the aluminum and binder disposed of by burial or burning as a nonhazardous material. Preliminary cost estimates indicate that the recovery process may be economically feasible. Further development is required, as only laboratory or small pilot-scale facilities have been operated.

A number of methods of controlled, confined burning of waste propellants and explosives have been investigated.(69) As applied to the SRM propellant, the combustion process would be followed by a water scrubber to collect the Al_2O_3 particles and absorb the HCl. The HCl would then be neutralized, probably with lime, forming calcium chloride. Ultimate disposal of the calcium chloride without pollution of the water or soil is an unsolved problem. Capital and operating costs (the enclosed incinerators all consume fuel) and the problem of disposing of the collected HCl, have inhibited the acceptance of enclosed incinerators, but investigations by a number of organizations are continuing.

Alternative uses of waste propellant as a fire starter (for the Forest Service) and as an ingredient of slurry blasting agents (explosives) have been studied.(70) These applications appear technically feasible, but detailed processes and markets have not been developed.

Thiokol/Wasatch Division follows (and contributes to) the development of these alternative methods of disposing of waste propellants. One or another of these alternatives may be adopted if sufficiently developed. Meanwhile, all evidence indicates that the open burning method has not had an adverse effect on the environment.

6.2.3 SRM Static Test Firing

Static test firings are the final verification of the successful design and process of the SRM, and are required to demonstrate that the required performance parameters and reliability have been achieved.

Because static test firings of large rocket motors are expensive operations, the number of such firings is always set at the minimum necessary to demonstrate achievement of the program objectives. Thus, a reduction in the number of static test firings is not considered to be a viable alternative. Further, the anticipated environmental effects of the test firings are so small that little benefit to the environment would result from a reduction.

As explained in Section 4.2.3, the specific day and time chosen for the test firings will be subjected to a number of constraints intended to minimize any adverse effects of the firing. The planned schedule, approximately two months between firings, is based on other program aspects, but the two-month interval is more than enough to allow adverse effects to dissipate, with the exception of the impact to the flora in the immediate test area caused by direct impingement of the exhaust gases. Alternative schedules might also be considered to reduce possible annoyance to persons using State Route 83 to visit the Golden Spike National Monument. Major test rescheduling would interfere unfavorably with the planned scheduling of the total DDT&E Program, and provide little benefit.

The test firings will be conducted with the SRM in a horizontal position. An alternative would be to conduct the static test firings in a vertical position. The major effect of such a change would be to reduce the damage to the flora in the area where the exhaust from a horizontal firing impinges on the ground (an area of about 0.01 km^2). As discussed in Section 4.8.2.1, this small area has previously been impacted by horizontal test firings of large solid rocket motors and this previous use reduces the immediate impact of the SRM tests. A change to a vertical orientation would also result in a change in the sound level contours to a more circular shape.

The T-24 test facility is configured for horizontal test firings, and no alternative test facility capable of firing the SRM in a vertical position exists at the Wasatch site. Modification of T-24 to accommodate vertical tests, or construction of a new large vertical test facility, would be expensive and would not result in a significant reduction in adverse environmental effects, which in any event will be small.

6.2.4 HCl Washout Scrubber Device

Potential adverse environmental effects associated with the HCl present in the rocket exhaust gases might be reduced by use of a system for neutralizing the HCl. Such a system is currently being analyzed by NASA/Langley Research Center for use during launches of the Space Shuttle from the Kennedy Space Center (KSC), Florida. The current concept (see Reference 71) is to spray a sodium carbonate solution into the exhaust from the flame trench at the launch pad for a period of about 10 seconds. After that period, the Space Shuttle will be in flight and the exhaust gases will no longer be passing through the flame trench. Because the exhaust gases are released continuously from a fixed motor during a static test, the neutralization system would be required to operate during the entire burn, about 2 minutes.

The proposed neutralization scheme is not a proven technique, and it is uncertain how effective it would be in neutralizing the HCl. Use of the system would result in salt (NaCl) and unreacted sodium carbonate being deposited from the exhaust cloud. Also, the cooling effect of the evaporating water would suppress the afterburning of the exhaust, and reduce the cloud rise; thus, increasing the Al_2O_3 and CO ground level concentrations. NASA/Langley Research Center plans to continue to assess the possible adverse effects of neutralization techniques and weigh the advantages and disadvantages of neutralizing the HCl in the exhaust cloud.

Because the potential environmental effects of the test firings on air quality and the potential secondary effects (see 4.7 and 4.8) are small, and because the effects of a neutralization system may not be entirely favorable to the environment, no neutralization system is planned for the T-24 test facility.

6.2.5 Transportation Method and Route

The SRM segments will be shipped from the Wasatch facility to KSC by rail, with truck transport between the Thiokol plant and the rail head at Corinne (see Section 1.2.5). Alternative methods of shipment investigated were truck, air, rail directly to KSC, or one of these means to a West Coast port, then by sea via the Panama Canal to KSC. These alternatives have been rejected based upon: complex routing problems, aircraft capability, schedules and prohibitive costs.

None of the alternatives appear to offer a lower environmental impact than does rail transportation. At best, alternative shipment methods might hopefully reduce the possibility of an accident leading to segment ignition, but it is not clear that any of the alternatives will, in fact, accomplish this. If necessary, the possibility of a serious accident during rail transport can be reduced by special train handling (including limited speeds) and equipment and route inspection.

The specific routing for rail shipment was chosen to accommodate the clearance requirements of the large diameter segments and the relatively high mass transported by a single car. As no specific disadvantages are known to apply to the chosen route that would not apply equally to some alternative route, there is little incentive to search for alternative routes.

7.0 THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The Space Shuttle Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) activities are a vital part of the Space Shuttle Program. Current plans call for the Space Shuttle, the first reusable manned space vehicle, to replace the current fleet of expendable launch vehicles in the early 1980's. The SRM DDT&E Program, to be conducted in Utah by the Thiokol Corporation for NASA Marshall Space Flight Center, will be performed in a manner which will provide maximum levels of safety, reliability and economy.

In preceding sections, it has been demonstrated that the undesirable potential short-term effects resulting from the processing and testing activities of the SRM DDT&E Program are minor, infrequent, transient, and nonpersistent. The SRM DDT&E Program will not have any long-term adverse environmental effects. The desirable long-term effect of the program is that employment levels and economic support in the Brigham City area can be maintained, as other programs being conducted, which have also served national needs, are phased out.

In the past, the space program has helped people to better understand, utilize, predict, protect, and control his life-sustaining environment. In the future, the Space Shuttle vehicle is expected to help expand the use of space for the betterment of all people. Users of the Space Shuttle will include: communication networks, research foundations, universities, observatories, federal departments and agencies, state agencies, county and city planners, public utilities, farm cooperatives, the medical profession, the fishing industry, the manufacturing industry, the transportation industry, water conservation planners and foreign countries.

Payloads launched by the Space Shuttle will provide practical data that will affect both the daily lives and the long-term future of people. A few areas and associated long-term benefits are described below:

<u>Agriculture</u> - Sensor systems in space can help solve world food problems. The sensors can identify crops, tell the vigor and probable yield of those crops, and determine plant diseases or insect infestation. This information will help agriculture specialists predict total food available on a worldwide basis.

Communications - Communications satellites have made intercontinental television possible and are reducing the costs of transoceanic and transcontinental telephone service. Communications costs are expected to continue to decrease and the applications of satellites to communications needs are expected to expand as the Shuttle becomes operational.

Environment - Future environmental monitoring satellites, planned to be launched with the Space Shuttle, will be able to: transmit vital weather and disaster warning information to the ground, survey land use, and monitor air and water quality. Satellites will also be able to aid in determining to what extent substances released into the atmosphere are affecting the ozone layer.

Resources - Photographs of the Earth taken from spacecraft launched by the Space Shuttle can help identify petroleum, mineral, and forest resources. The location of new petroleum, geothermal, and mineral deposits is expected to ease energy and materials shortages predicted in the future. Forest resources can be planned, controlled and conserved by the discovery of forest fires, by detection of various diseases and pests, by providing accurate inventories of timberland, and by identification of soil conditions.

Scientific Studies - Spacelab, a completely equipped manned scientific laboratory designed and built by the European Space Agency, will be transported into orbit by the Space Shuttle so that man may perform scientific research in an zero-gravity environment. A considerable number of discoveries are anticipated in the areas of: materials processing, pharmaceuticals, physics, chemistry, astronomy and medicine, just to name a few. The ongoing scientific programs in planetary exploration, solar physics, etc., will continue and be supported by the Space Shuttle.

In view of the importance of the Space Shuttle Solid Rocket Motor DDT&E Program to the Space Shuttle Program, the projected benefits/uses of space, in conjunction with the launching of the Space Shuttle vehicle, are also dependent upon the success of the SRM DDT&E Program.

8.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The performance of the Space Shuttle Solid Rocket Motor (SRM) Design, Development, Test and Evaluation (DDT&E) Program at the Wasatch Division of the Thiokol Corporation requires the commitment of manpower, materials, energy, water, and certain lands and facilities. These commitments are not different from those necessary for many other research and industrial operations, and are similar to the activities that have been carried out at the Thiokol/Wasatch plantsite for the past 18 years.

8.1 Employment

The Space Shuttle SRM DDT&E Program will require the commitment of Thiokol/Wasatch, local vendor, and non-local manpower. These commitments are discussed below.

8.1.1 Industrial Employment

Conduct of the Space Shuttle SRM DDT&E Program at the Thiokol/Wasatch Division will result in maintenance of near static employment levels. As current programs are phased out, the Space Shuttle work will provide continuity of employment for many individuals. A manpower need of approximately 500, including direct and indirect support, is anticipated during the subject program (see Figure 37). This represents approximately one-fifth of the total employment at Thiokol/Wasatch.

Inasmuch as Thiokol represents the largest employer in the area, the continuity of employment for these predominantly skilled and professional workers contributes to the economic stability of the area.

8.1.2 Local Vendors

Any effects which local suppliers may perceive from the SRM DDT&E Program at Thiokol will be minimal. While some minor shifts in local contracting may occur as a result of shifts in needs, such as the modification of facilities, the overall level of goods and services requirements remains fairly level with current needs throughout the SRM DDT&E Program.

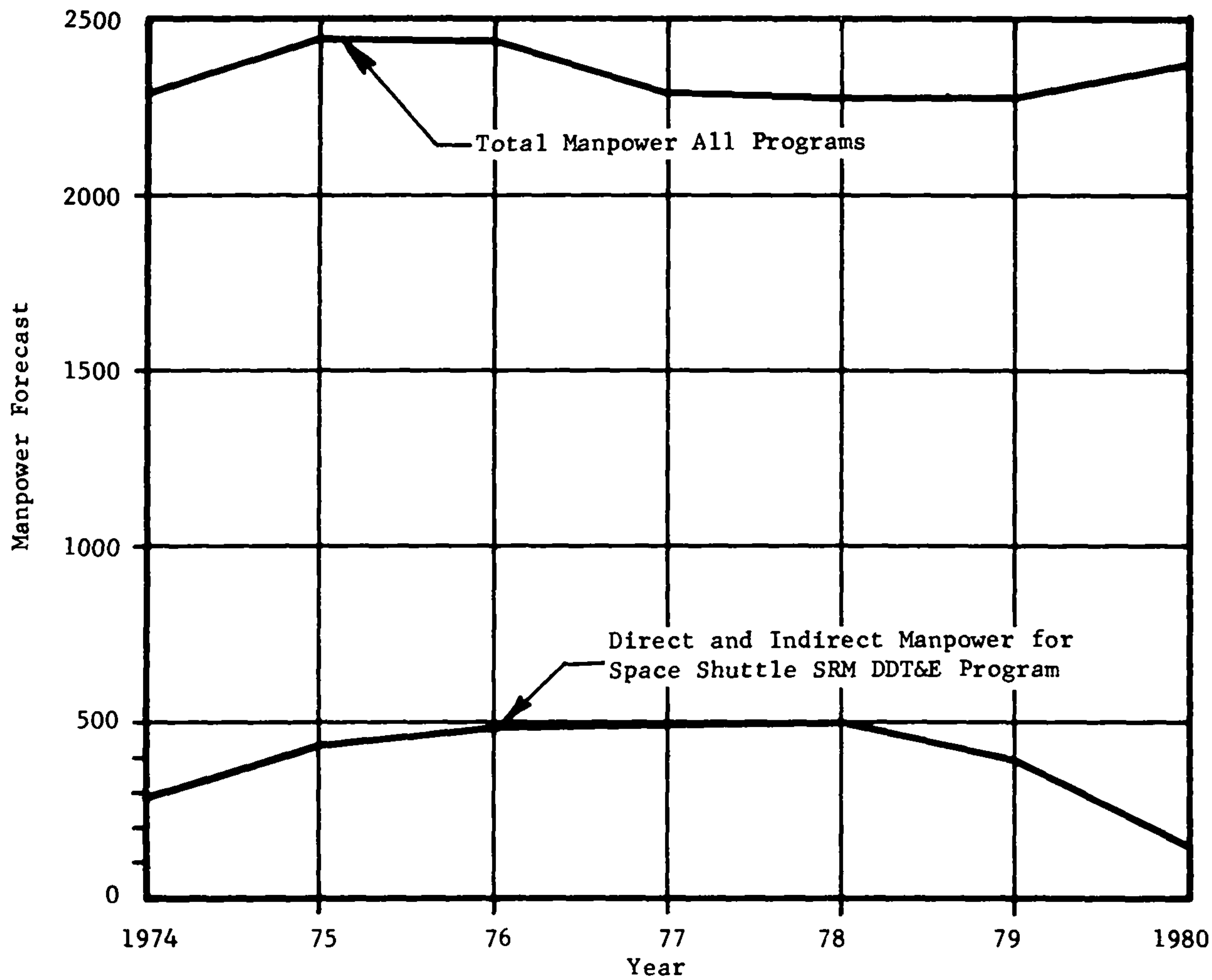


FIGURE 37. THIOKOL/WASATCH MANPOWER FORECAST

8.1.3 Non-Local Vendors

Non-local vendors to the SRM DDT&E Program will supply most of the large hardware items, propellant ingredients, and some preparatory services. The area adjacent to the vendor's facilities will accrue the impacts, both positive and negative, of the production of these items. These non-local vendors are from all parts of the United States and have or will be chosen by competitive procurement practice.

Approximately 40 to 60 percent of the Space Shuttle SRM DDT&E Program dollars will be transferred by contract to vendors (Figure 38). Most of these vendors will be non-local, though there are exceptions. For example, the first subcontract announced in this program was to United Precision Machine and Engineering Company of Salt Lake City. This is a small company which supplies subscale nozzle components.

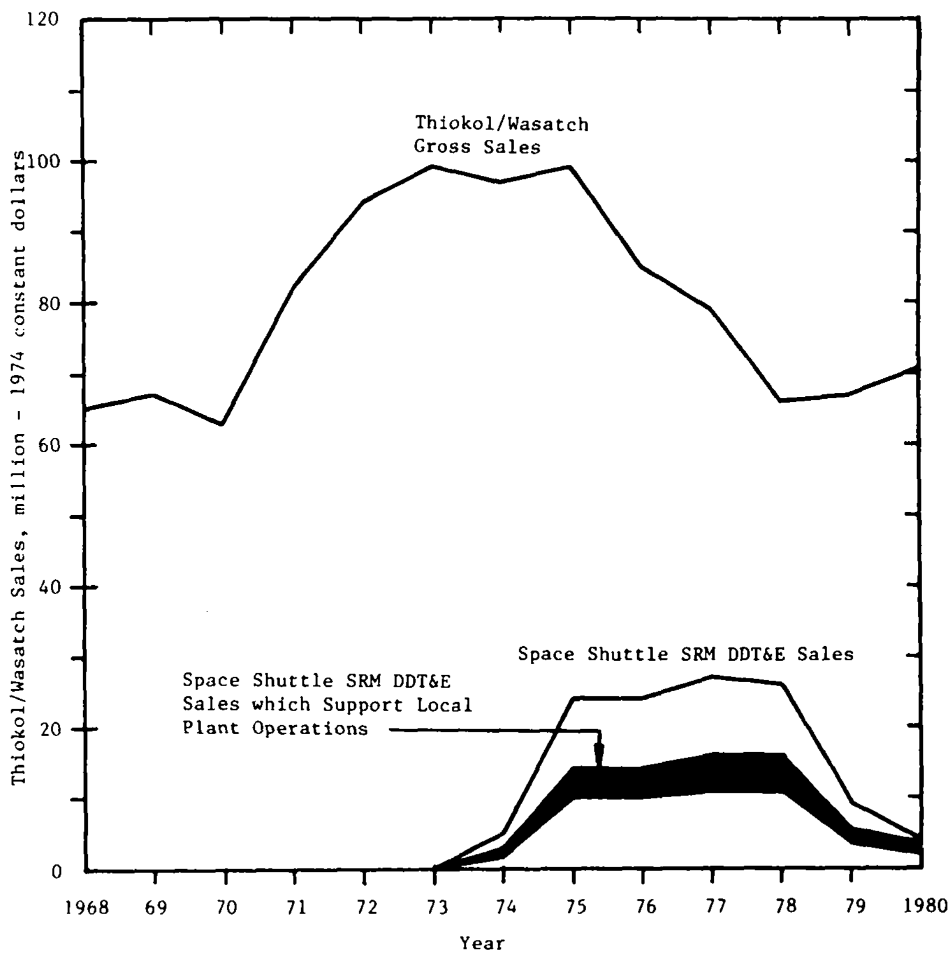


FIGURE 38. COMPARISON OF SPACE SHUTTLE SRM DDT&E SALES TO THIOKOL/WASATCH TOTAL SALES

Examples of major subcontractors include: Rohr Industries of Chula Vista, California, which will fabricate and test motor case segments for the SRM; Ladish Company of Cudahy, Wisconsin, which will provide the rough machined forgings for the case segments; Cal-Doran Metallurgical Services of Los Angeles, California, which will heat treat the segments; Kaiser Aerospace and Electronics of San Leandro, California, which will fabricate the nozzle metal parts; American Synthetic of Louisville, Kentucky, which will provide the propellant binder (PBAN); and Kerr-McGee and Pacific Engineering, Henderson, Nevada, which will provide the propellant oxidizer (AP).

Section 8.2.1 reviews the materials requirements for the SRM DDT&E Program. In summary, demands upon the industries in producing case hardware and propellant ingredients are within current unused production capacity of the industries. In cases where a considerable proportion of unused capacity is required, the impact should be noticeable and may be positive, while in most industries the demand will be met with little, if any, measurable effect.

8.2 Materials and Energy

Activities associated with the Space Shuttle SRM DDT&E Program will utilize and consume various quantities of materials and energy. This section attempts to quantify those items which are known to be a major part of the program.

8.2.1 Materials Requirements

Major materials anticipated to be used in the Space Shuttle SRM DDT&E Program are listed in Table 30. The four categories which are considered most significant are: (A) SRM propellant ingredients, (B) Thiokol plant SRM fuel requirement, (C) Thiokol/Wasatch plant electrical requirement, and (D) materials (mostly steel) for the SRM cases.

The amount of propellant which has been processed since 1970 and the amount which is projected through 1980 at the Thiokol/Wasatch facility is represented in Figure 39. The amount of propellant required for the Space Shuttle SRM DDT&E Program represents a significant increase over that required during the previous 6 years, but it is approximately 30 percent of the peak experienced during 1965 Stage I Minuteman production (11×10^6 kg/year).

The Thiokol/Wasatch plant fuel and electrical energy (coal) requirements for the Space Shuttle SRM DDT&E Program are compared with plant totals in Figure 40. The average amounts of electricity, residual fuel oil, gasoline, and distillate fuel oil required for SRM DDT&E are estimated to be less than 20 percent of the total requirement for all programs carried out at Thiokol/Wasatch during the late 1970's. The Space Shuttle SRM DDT&E Program is not expected to significantly increase total fuel or electrical energy requirements at the Thiokol/Wasatch plant site.

TABLE 30. SUMMARY OF MATERIALS REQUIRED FOR SPACE SHUTTLE SRM DDT&E PROGRAM

A. SRM Propellant Ingredients
- Ammonium Perchlorate
- Aluminum Powder
- PBAN Binder
- Epoxy Curing Agent
- Iron Oxide

B. Thiokol Plant Fuel for SRM-DDT&E
- Residual - #4 and #5
- Distillate - #2
- Gasoline

C. Thiokol Plant Electricity for SRM-DDT&E
- Coal

D. SRM Case Materials
- Steel - Case and Components
- Aluminum
- Paint/Primer
- Chemlok - Primer/Adhesive
- Inhibitor
- Insulation
  - Rubber
  - Silica
  - Asbestos
  - Zinc Oxide
  - Sulfur
- Liner
  - Asbestos
  - CTPB Binder
  - MAPO
  - Epoxy Resin
  - Castor Oil
  - Iron Octoate

E. SRM Nozzle Materials
- Rubber/Adhesives/Sealants
- Silica Cloth Phenolic
- Glass Cloth Phenolic
- Steel
- Aluminum

F. Ignition System
- Steel
- Aluminum
- Chemlok - Primer/Adhesive
- Insulation
- Propellant
- Safe and Arm Device

G. Rail Transportation of Loaded/Unloaded Case Segments
- Diesel Fuel

H. Facility Modifications
- Equipment
- Concrete
- Building Materials

I. Various Chemicals
- Trichloroethane (1,1,1)
- Toluene
- Methylethyl Ketone
- Xylene
- Carbon Dioxide
- Methyl Cellosolve

J. Miscellaneous Supplies and Equipment

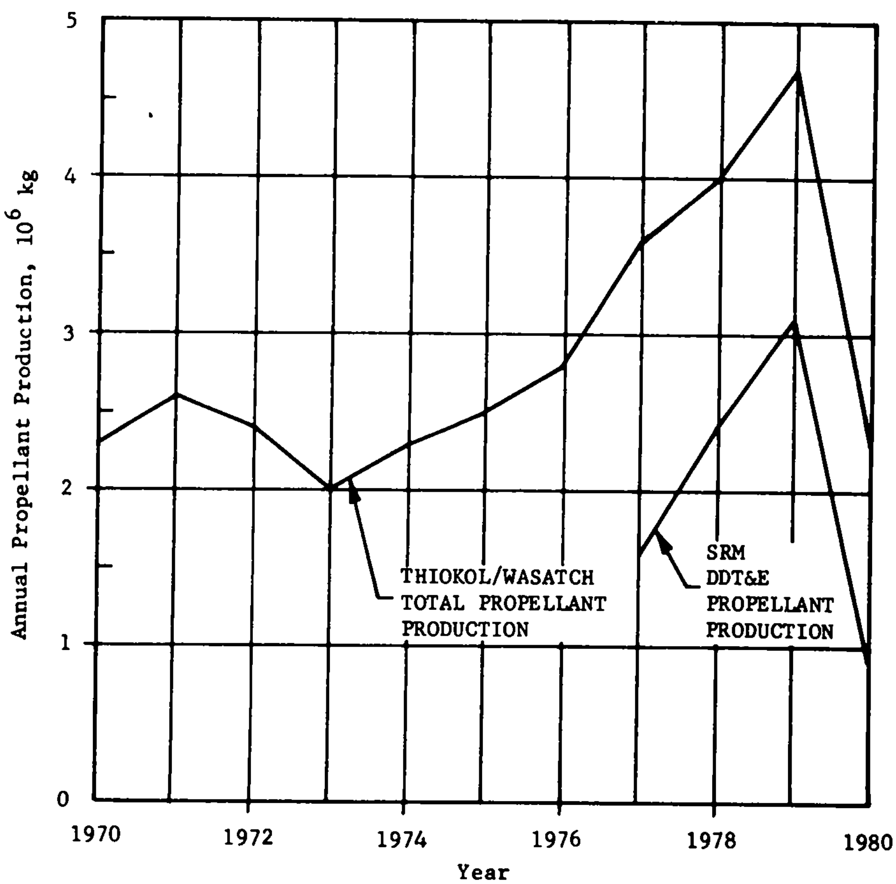
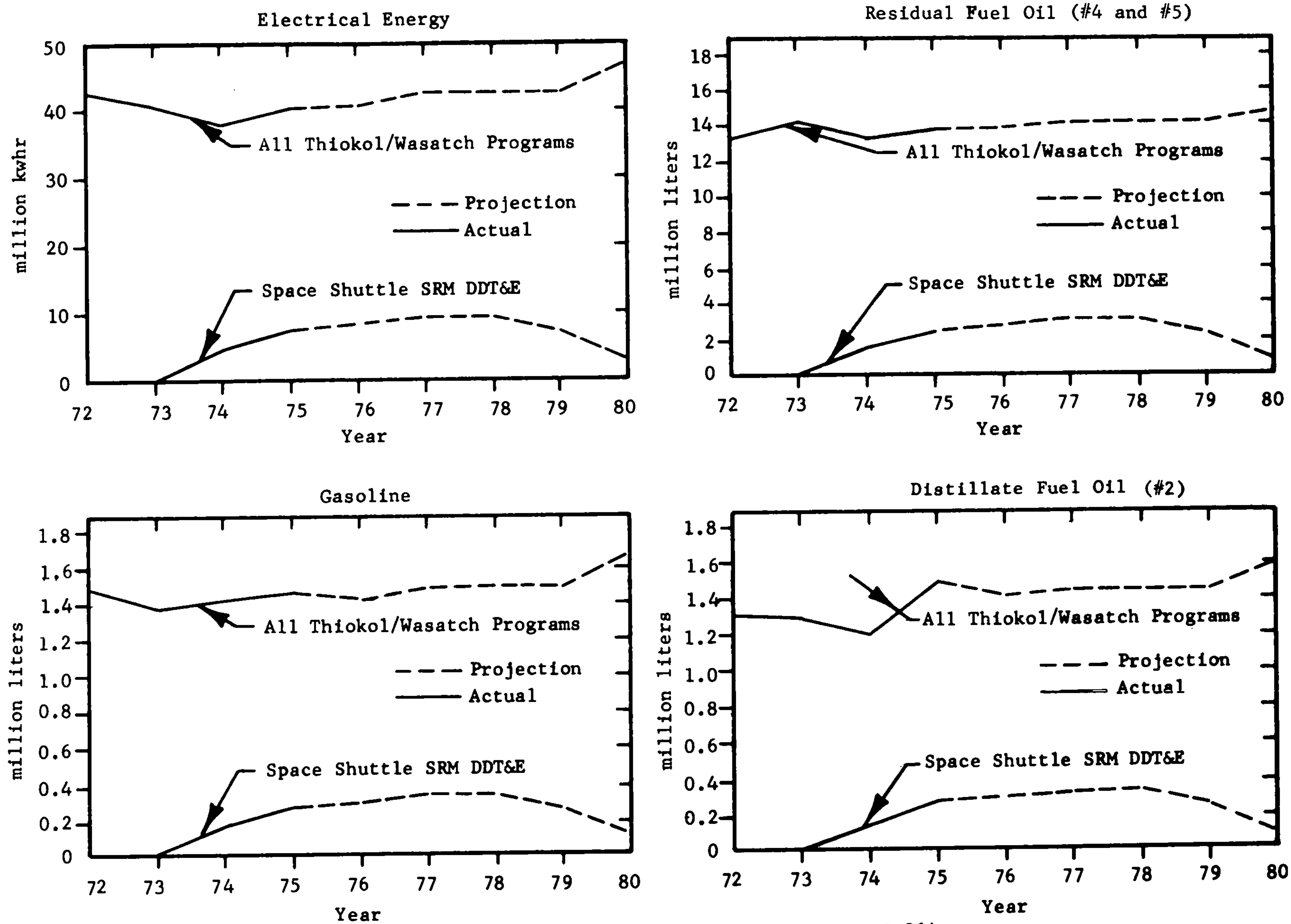


FIGURE 39. COMPARISON OF PROJECTED ANNUAL SPACE SHUTTLE SRM DDT&E PROPELLANT PRODUCTION QUANTITIES TO THIOKOL/WASATCH TOTAL, 1970-1980



Conversion Factor: gallons = liters x 0.264

FIGURE 40. ACTUAL AND PROJECTED FUEL AND ELECTRICAL ENERGY REQUIREMENTS FOR SPACE SHUTTLE SRM DDT&E VERSUS THOSE FOR ALL THIOKOL/WASATCH PROGRAMS

Although no data are available on the total amount of steel required for Thiokol's programs of previous years, no significant increase is expected for the years when SRM DDT&E activity occurs. NASA, in its efforts to reduce the cost of space transportation, has designed the SRM to be reusable. Because the Space Shuttle SRM case has been designed to be processed and flown at least 20 times, a considerable amount of raw materials (mostly steel) is conserved. The fifteen cases that will be manufactured for SRM DDT&E will continue to be used beyond the six Shuttle development flights.

The peak annual requirements for major materials categories (A through D) have been estimated and are shown in Table 31, where they are compared to annual U.S. production rates. The SRM DDT&E requirements for propellant ingredients (Category A) appear to show the greatest impact upon the current U.S. production when compared to other categories. Uses of these materials for purposes other than solid rocket propellant are trivial.

The SRM solid propellant binder, polybutadiene acrylic acid acrylonitrile (PBAN), is currently produced by American Synthetic of Louisville, Kentucky. American Synthetic is currently producing 0.4×10^6 kg (0.9×10^6 lb) of PBAN per year and has a capacity of 2.7×10^6 kg (6×10^6 lb) per year.[72] The estimated annual SRM DDT&E PBAN requirement is 0.6×10^6 kg (1.3×10^6 lb) per year. American Synthetic should welcome this new business and be able to easily handle the required quantities without providing any increase in the current capacity.

Ammonium perchlorate (AP) is the oxidizer ingredient in the SRM propellant and is currently produced only (in large amounts) by Kerr McGee Chemical Corporation and Pacific Engineering and Products Company of Nevada, both located in Henderson, Nevada. Thiokol/Wasatch will be procurring AP from both suppliers. Currently, neither of the manufacturers is producing AP at full capacity. It has been estimated that in 1975 total production was about one-third of the total 21×10^6 kg (46×10^6 lb) per year capacity.[73] The SRM AP requirement is estimated at 3.3×10^6 kg (7.3×10^6 lb) per year, well within the total capacity of the Nevada plants.

ALCOA, ALCAN, and Reynolds are typical producers of aluminum powder for solid rocket propellants. The peak yearly aluminum powder requirement for SRM DDT&E is estimated at 0.75×10^6 kg (1.65×10^6 lb). In 1974, approximately 73×10^6 kg (160×10^6 lb) aluminum powder, flake, and paste, was produced.[74] The aluminum powder requirement for the SRM DDT&E is therefore judged to have an insignificant impact upon the total production.

TABLE 31. IMPACT OF SRM DDT&E PROGRAM ON SUPPLIERS OF VARIOUS CONSUMABLE MATERIALS

Major Consumable Material	Supplier	Annual U.S. Production (year)	SRM DDT&E Peak Annual Requirement	SRM DDT&E Requirement Divided by Total U.S. Production
SRM Propellant Ingredients				
PBAN Binder	American Synthetic	0.4×10^6 kg(1975)[a][72]	0.6×10^6 kg	1.50
Ammonium Perchlorate (AP)	Kerr McGee and Pacific Engineering	7×10^6 kg(1975)[b]	3.3×10^6 kg	0.47
Aluminum Powder/Flake/Paste	Many	73×10^6 kg(1974)[74]	0.75×10^6 kg	0.01
SRM Case Material				
Steel	Many	132×10^9 kg(1974)[75]	0.3×10^6 kg	2×10^{-6}
SRM Plant Energy				
Residual Fuel Oil	Many	42×10^9 ℓ(1969)[76]	3.1×10^6 ℓ	7×10^{-5}
Electricity	Many	2×10^{12} kwhr(1973)[77]	10×10^6 kwhr	5×10^{-6}
Distillate Fuel Oil	Many	135×10^9 ℓ(1969)[76]	0.32×10^6 ℓ	2×10^{-6}
Gasoline	Many	330×10^9 ℓ(1969)[76]	0.33×10^6 ℓ	1×10^{-6}

Notes: (a) Current PBAN annual capacity is estimated at 2.7×10^6 kg.[72]
(b) Current AP annual capacity is estimated at 21×10^6 kg.[73]

The steel alloy, D6AC, used for the SRM case will be provided to the Ladish Company in Cudahy, Wisconsin, which will begin the case manufacturing operation. The yearly requirement of steel anticipated for the SRM DDT&E Program, mostly steel in the SRM case, is estimated at 0.3×10^6 kg (0.7×10^6 lb). Table 31 indicates that this requirement is approximately 2×10^{-6} of the 1974 steel production in the United States.[75] No measurable impact is anticipated.

Impacts of fuel and electricity requirements for SRM DDT&E (see Table 31) are insignificant. Current electrical power capacity provided to Thiokol/Wasatch is adequate for conducting all envisioned programs, including SRM DDT&E.

In summary, it is anticipated that there will be a noticeable impact upon the suppliers of PBAN and AP. However, the required production will not require the expansion of the current capacity.

8.2.2 Energy Requirements

The energy requirements for the six-year Space Shuttle SRM DDT&E Program are separated into local and non-local contributions. Local energy requirements are those including the electricity, fuel oil, and gasoline required to support SRM DDT&E Thiokol/Wasatch plantsite processing and test activities (see Figure 40). Non-local energy requirements are grouped into four categories: (1) production of raw materials for SRM propellant; (2) manufacturing of subcontracted SRM components (not including raw materials); (3) production of raw materials for SRM hardware; and (4) transportation of the Space Shuttle SRM case segments. Energy for secondary effects such as work force transportation and energy consumed at employees' homes are not included, as these would occur, to a large degree, independently of the proposed action.

Table 32 summarizes the estimated local and non-local energy requirements for the Shuttle SRM DDT&E Program. The most demanding requirements are for local energy and for the production of raw materials used in the SRM propellant. The total energy requirement for the Space Shuttle SRM DDT&E Program is estimated at 3.3×10^{12} kJ (3.1×10^{12} Btu). The projected peak annual energy consumption for the SRM program has been estimated at 1.1×10^{12} kJ (1.04×10^{12} Btu). Table 33 compares the annual energy requirements for the SRM Program and its contributions to the energy requirements of various other activities.

TABLE 32. ESTIMATED SPACE SHUTTLE SRM DDT&E ENERGY REQUIREMENT

Category	Total Quantity of Material, etc.	Conversion Factor[78] (Material → Energy)	Energy Consumed
Local (Thiokol Plantsite)			
Electricity	49×10^6 kwhr	9,600 kJ/kwhr	470×10^9 kJ
Residual Fuel Oil	16×10^6 liters	41,000 kJ/liter	656×10^9 kJ
Distillate Fuel Oil	1.7×10^6 liters	39,000 kJ/liter	66×10^9 kJ
Gasoline	1.7×10^6 liters	35,000 kJ/liter	60×10^9 kJ
Subtotal			1252×10^9 kJ
Non-Local			
SRM Propellant Ingredients[a]			
Ammonium Perchlorate	6.7×10^6 kg	97,600 kJ/kg	654×10^9 kJ
Aluminum Powder	1.5×10^6 kg	323,000 kJ/kg	484×10^9 kJ
PBAN Binder	1.2×10^6 kg	84,400 kJ/kg	101×10^9 kJ
Other	0.2×10^6 kg	50,000 kJ/kg	10×10^9 kJ
Subtotal			1249×10^9 kJ
Manufacturing of Subcontracted Components	---	---	750×10^9 kJ [78]
Raw Materials for SRM Hardware[b]			
Steel	0.8×10^6 kg	58,000 kJ/kg	46×10^9 kJ
Aluminum	0.01×10^6 kg	323,000 kJ/kg	3×10^9 kJ
Other	0.2×10^6 kg	50,000 kJ/kg	10×10^9 kJ
Subtotal			59×10^9 kJ
Rail Transportation of SRM			
Diesel	0.21×10^6 liters	39,000 kJ/liter	8×10^9 kJ
TOTAL SRM DDT&E ENERGY			3318×10^9 kJ

Notes: (a) Includes waste propellant.
(b) Based on: 15 cases manufactured and 19 SRMs processed for test or flight.

Thiokol/Wasatch has implemented an extensive energy conservation program, and has demonstrated considerable success. Other industries which will support this action have also implemented energy conservation programs.

No measurable overall energy impact is expected from the Space Shuttle SRM DDT&E Program. However, the energy requirements for SRM propellant ingredient suppliers (Kerr McGee, Pacific Engineering, and American Synthetic) could increase significantly.

TABLE 33. ENERGY REQUIREMENT COMPARISONS

Category	Annual Energy Consumption $\times 10^{12}$ kJ
Space Shuttle SRM DDT&E Program (peak year estimate)	
Local (Thiokol Plantsite-SRM Processing)	0.24
Non-Local	
SRM Propellant Ingredients	0.60
Manufacturing of Subcontracted Components	0.20
Raw Materials for SRM Hardware	0.02
Rail Transportation	0.01
TOTAL	1.07
Other Activities	
1971 Astrodome Electrical Energy (79)	0.6
Manufacture of 10,000 Automobiles (80)	1.3
10,000 Midwest Homes (78)	3.7
People Traveling to Rodeos (81)	10.0
Utah Power and Light Company (22)	93
Total in the U.S.A.	~80,000

8.3 Water Use

Figure 13 depicts projected water use at the Thiokol/Wasatch plantsite. As mentioned in Section 2.2.3.3, current and projected water use is well within the capacities of present and planned well fields. The enaction of the Space Shuttle SRM DDT&E Program at Thiokol/Wasatch will result in virtually no change in water use, for several present programs will be phased out as the SRM Program activities increase.

In 1975, 88 percent of ~900 x 10^6 liters (240 x 10^6 gal) of water used was consumed in processing areas; 7 percent was consumed in the test areas; 4 percent was system losses, and 1 percent was consumed by local ranchers. Therefore, the Space Shuttle SRM DDT&E processing activities are anticipated to consume most of the water used in the SRM DDT&E Program. Water consumed as a result of SRM testing activities should be a small part of the total requirement. The principal water use associated with the Space Shuttle SRM DDT&E Program will be: SRM case refurbishment activities; bleed-water from the water supply system to thwart stagnation; sanitary wastewater; steam production for process heat; and cooling water.

Available data (see Table 2) suggest that water withdrawals from the plant's groundwater resources have not affected the yield, capacity, or quality of wells and springs. Since no appreciable changes in water use is anticipated in connection with the SRM Program, this pattern is expected to continue in the present wells and in the springs which have been monitored on and near the plantsite.

Present wells supply ~ 2,250 liters (600 gal)/min to the plant's water supply system. The development of the well field north of the plantsite, near Howell, will supplement the existing supply with an additional 1050 liters (280 gal)/min. The estimated capacity of the planned well field is well above anticipated withdrawals (see Figure 13). Hence, saltwater intrusion into the freshwater aquifer is expected to be inconsequential.

The Space Shuttle SRM DDT&E activities are anticipated to result in the consumption of ~ 1000 x 10^6 liters (260 x 10^6 gal) of water over a 6-year period, less than 20 percent of the total water projected to be consumed at the plant for that same period. The rate of withdrawal necessary to accommodate the SRM DDT&E Program will amount to less than 380 liters (100 gal)/min during peak program activities. This rate of withdrawal is approximately 17 percent of the capacity of the current water supply system and will be about 12 percent of the capacity of the system when the well field near Howell is incorporated into the system.

In summary, water use in connection with the Space Shuttle SRM DDT&E Program is not expected to have any significant effect on groundwater yields or quality for Thiokol or other users in the vicinity of the plantsite. No appreciable change in total water usage at the Thiokol/Wasatch plantsite is anticipated as a result of the Space Shuttle SRM DDT&E Program.

8.4 Land and Facility Use

No new lands or major facilities will be committed for use in the SRM DDT&E Program, as those intended to be used have already been committed for the processing and testing of solid rocket motors.

None of the activities performed in connection with the processing and testing activities of the SRM DDT&E Program at the Thiokol/Wasatch plant-site will result in any significant disruption of the local environment or in the curtailment of future beneficial use of the land areas involved. No significant commitment of local natural resources is involved, and there will be no impact on cultural resources in the area.

9.0 COMMENTS RECEIVED AND NASA RESPONSES

Comments on the Draft Environmental Statement for the Space Shuttle SRM DDT&E Program (released September 24, 1976) were requested from DoA, Department of the Air Force, DoC, DoD, DoI, DoT, CEQ, ERDA, EPA, OMB, and appropriate state and local agencies (see Summary). Comments were received (in the form of 13 letters) from DoA (2), Department of the Air Force, DoI, ERDA, EPA, and the States of Georgia (2), Mississippi (2), Nebraska, and Wyoming (2). Comments requiring NASA responses were from DoA, DoI, ERDA, and the State of Nebraska.

Copies of all comments received on the Draft Environmental Statement for the Space Shuttle SRM DDT&E Program and NASA responses are presented below:

Comments Received on the Draft Environmental Statement for the Space Shuttle SRM DDT&E Program

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Washington, D. C. 20250

NOV 1 1976

Mr. Duward L. Crow
Associate Deputy Administrator
Office of the Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

We have reviewed the draft environmental statement for the Space Shuttle Solid Rocket Motor DDT&E Program at Thiokol/Wasatch Division, Promontory, Utah, that was transmitted to the Department of Agriculture by a copy of your September 24, 1976, letter to Honorable Russell W. Peterson, Chairman of the Council on Environmental Quality. We concur in the statement that there has been a good safety record with this program in the past. However, we feel that the possibility of a train accident with an explosion of associated freight in an adjacent car causing deflagration of the transported motor segments should be considered. This is especially true where the railroad tracks are in close proximity to densely populated urban areas. The resultant blast wave described on page 107 could level a city block area.

The statement would be strengthened if the above was included in the worst case accident with human impact in Table 29. Although the probability for this type of accident is very low, it is not impossible.

Thank you for the opportunity to review and comment on this document.

Sincerely,

Acting

William M. Johnson
Deputy Administrator
for Technical Services

U.S. Department of Agriculture, Soil Conservation Service, Washington, D. C.

Comment: The DoA, Soil Conservation Service, suggested that an accident involving the explosion of other freight carried by the train causing rapid deflagration of a Space Shuttle SRM segment be considered. DoA suggested that such an accident could cause severe and extensive physical damage if it occurred in densely populated urban areas.

Response: It is certainly within the realm of possibility that an explosion of associated freight on a train transporting SRM segments could occur. It is also conceivable that this explosion could ignite an SRM segment. However, the probability of such an occurrence is extremely low.

Based on a review of DoT Hazardous Material Regulations, Title 49, Code of Federal Regulations, placarded rail cars containing Class A explosives, liquid petroleum gas, gasoline, etc., cannot be placed adjacent to placarded rail cars containing Class B hazardous materials, such as an SRM segment. Under a worse case condition the two dissimilar hazardous materials could be no closer than 15.2 m (50 ft), the distance of one rail car. Further, rail cars authorized to carry hazardous materials can, at a maximum, carry approximately 45,000 kg (100,000 lb) of Class A explosives, considering proper equipment, packing, packaging, containers, etc. Assuming that the 45,000 kg (100,000 lb) of Class A explosives did detonate, the surface pressure seen by the SRM external protective cover would be about 760 N/cm^2 (1100 psi). This blast wave pressure would not induce an SRM rapid deflagration and, at most, it would cause the SRM to ignite and burn at a slow rate. Even if a rapid deflagration were to occur, the contribution of the SRM propellant to the main Class A hazardous material explosion would be negligible.

Explosions of Class A hazardous materials are usually associated with the creation and radial dispersal of fragments. Penetration of the SRM protective cover by a fragment and subsequent impact on the propellant grain could conceivably ignite the propellant. However, this condition would, at most, cause a rapid deflagration.

With respect to damage caused by a rapid deflagration of an SRM segment, Table 34 provides blast wave damage data for a SRM segment as extrapolated from Reference 88. Table 34 data assume an explosive yield of 1900 kg (4,200 lb) of TNT (SRM segment equivalent) and no intervening structure. In built-up areas, the damage zones would be significantly reduced by absorption of blast wave energy by intervening structures. Table 34 indicates, for example, that if a rapid deflagration were to occur, total structural damage to adjacent residential/commercial buildings (light frame construction) would be limited to a maximum distance of approximately 56 meters (184 ft). If an explosion of a rail car containing 45,000 kg (100,000 lb) of Class A explosives were to somehow initiate a SRM rapid deflagration, the initial rail car explosion would cause structural damage over an area nine times larger than the damage that would be caused by only a SRM rapid deflagration alone. The addition of the blast energy available from the SRM segment to that of the rail car would only increase the damage area by 3 percent.

TABLE 34. THRESHOLD RADII FOR VARIOUS TYPES OF BLAST WAVE DAMAGE CAUSED BY 1900 KG OF TNT*

Structure	Blast Wave Distance for Indicated Damage Class, meters: Total Destruction	Major Repair Required
Light Frame Construction	56	105
Brick Apartment House	41	75
Reinforced Concrete Multistory Building	31	60
Massive Multistory Building	22	50

*Based on Reference 88.

It can be concluded that the probability of a rapid deflagration of an SRM segment during rail transportation is very unlikely, and if such an event did occur, damage as indicated by Table 34 would be possible. However, if the deflagration were caused by a large amount of explosive material in an adjacent rail car, the contribution due to the SRM would be negligible.

Information relating to structural damage caused by rapid deflagration of an SRM segment during rail transportation has been added to the text (Section 4.7.3.5, page 107). Additionally, the possibility of human injury as the result of such an event has been reflected in Table 29. Sections 4.3.2.2, 4.7.2.1, 4.7.3.2, and 4.7.3.5 have been revised to include blast wave data from Reference 42. These differ only slightly from data quoted in the Draft Environmental Statement.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
4012 Federal Building, Salt Lake City, Utah 84138

October 5, 1976

Mr. Duward L. Crow
Associate Deputy Administrator
Office of the Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Mr. Crow:

We received a copy of the Draft Environmental Statement for the Space Shuttle Solid Rocket Motor DDT&E Program at Thiokol/Wasatch Division, Promontory, Utah that was transmitted by your September 24, 1976 letter to Honorable Russell N. Peterson, Chairman of the Council on Environmental Quality. We have reviewed the document and find that it adequately addresses the existing conditions, the proposed action and the project impacts as they relate to agriculture.

We appreciate the opportunity to review this document and have no specific comments.

Sincerely,

George D. McMillan
State Conservationist

U.S. Department of Agriculture, Soil Conservation Service, Salt Lake City, Utah

Response: No response is required.

DEPARTMENT OF THE AIR FORCE
WASHINGTON, D.C. 20330

OFFICE OF THE ASSISTANT SECRETARY

8 NOV 1976

Dear Sir:

The Air Force has reviewed the Draft Environmental Impact Statement for the Space Shuttle Solid Rocket Motor DDT&E Program at Thiokol/Wasatch Division, Promontory, Utah. We have no comments for modification of the document.

Sincerely,

BILLY E. WELCH, Ph.D.
Special Assistant for
Environmental Quality

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics & Space Administration
Washington, D.C. 20546

<u>Department of the Air Force, Office of the Assistant Secretary,
Washington, D. C.</u>

<u>Response</u>: No response is required.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER-76/981

NOV 1 7 1976

Dear Mr. Crow:

This is in response to your request of September 24, 1976, for the Department of the Interior's review and comments on a draft environmental statement for the Space Shuttle Solid Rocket Motor Design, Development, Test and Evaluation Program at Promontory, Utah.

Section 2.2.4 - Meteorology
The discussion on meteorology in the final statement should also include the existing air quality at the site.

Section 2.2.5.1 - Upland Habitats
The common name for "Atriplex sp." is shadscale, not sagebrush. This should be corrected in Table 3 also.

Section 2.2.5.6 - Rare and Endangered Species
There are several errors in Table 6. The Bald Eagle is not currently listed in the Federal Register as endangered. The scientific name shown for the Bald Eagle is, in fact, that of the Southern Bald Eagle which does not occur north of the 40th parallel. The Prairie Falcon is not currently listed as endangered in the Federal Register. Listing of the Snowy Plover, Long-Billed Curlew and Burrowing Owl as "status undetermined" is of little value. The only Sandhill Crane endangered within North America is the Mississippi Sandhill Crane and, as its name implies, it is found only in the State of Mississippi.

Section 2.3.3 - Historical
Golden Spike National Historic Site, a unit of the National Park System, is in the immediate vicinity of the plant site. Test firings will impose high levels of noise on the site and will have an adverse impact on visitors and staff. This impact should be fully addressed in the final statement.

Consultation with the Superintendent, Golden Spike National Historic Site, Post Office Box 394, Brigham City, Utah 84302, should be undertaken to develop a program to minimize this adverse impact. The results of this consultation should be reported in the final statement.

Section 4.2.2.2 - Emissions Resulting from Energy Utilization
Any precautions taken to guard against groundwater contamination from spills at the storage facilities for fuel oils and gasoline should be discussed in the final statement.

Section 4.4.1.1 - Disposal of Waste Propellant
We note the development of a new well field and the mention that no effect on water levels is expected; however, the final statement should include data on water-level trends in the well fields in order to make appraisal of hydrologic impacts possible.

Section 6.2.2 - Other Methods of Waste Propellant Disposal
Leaching the ammonium perchlorate with water in a grinder or shredder is discussed. Any potential for impacts of this process on ground water should be fully assessed in the final statement.

We hope these comments will be helpful to you.

Sincerely yours,

Stanley D. Doremus

Deputy Assistant Secretary of the Interior

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D. C. 20546

U.S. Department of the Interior (DoI), Office of the Secretary, Washington, D. C.

Comment: DoI suggested that the discussion on the baseline meteorology (Section 2.2.4, page 28) in the Final Environmental Statement include information on the existing air quality at the site.

Response: No baseline air quality data exist for the plantsite area. The area surrounding the plantsite is rural and contains no other industry; air quality in the plantsite area is currently considered excellent. A qualitative description of air quality in the plantsite area is presented in Section 4.2, starting on page 53 (Air Quality), where previous activities such as automobile and other vehicle emissions, emissions from energy utilization, open burning of waste propellant, and static test firings of various past programs are discussed. No changes have been made to the text as a result of this comment.

Comment: DoI suggests that the common name for *Atriplex* sp. is shadscale, not sagebrush as shown in Table 3, page 33.

Response: It is recognized that plants with the scientific name *Atriplex* sp. are generally known as shadscale and those with the name *Artemisia* sp. as sagebrush. However, in the Salt Lake area the common names are sagebrush for *Atriplex* and big sagebrush for *Artemisia*. In deference to this, the Draft Statement was prepared using the local common names; the more generally used common names were also shown for the benefit of non-local readers (Table 3, page 33). No change has been made to the text as a result of this comment.

Comment: DoI indicated that several errors exist in the rare and endangered species list shown in Table 6, page 40.

Response: Table 6, entitled "Rare and Endangered Species Using the Bear River Migratory Bird Refuge", has been updated to reflect the current Department of Interior, Fish and Wildlife Service Endangered and Threatened Wildlife and Plants List of Species published in The Federal Register, October 27, 1976.[89] This material replaces data from USDI publication "Seasonal Abundance of Birds on the Bear River

Refuge" (July, 1972), which additionally provided information on the abundance of these species at the Refuge. Information now shown in Table 6, page 40, has been confirmed by an official at the Bear River Migratory Bear Refuge.(90) Section 4.8.2.3, page 119, has been revised to reflect the changes made in Table 6.

Comment: DoI states that the SRM static test firings would impose high levels of noise on the Golden Spike National Historic Site and that this would have an adverse impact on the visitors and staff. DoI suggests that the Golden Spike National Historic Site Superintendent be contacted regarding this problem. They also suggest that a program be undertaken to minimize the adverse impact.

Response: The calculated sound level at the Golden Spike Monument resulting from the Space Shuttle SRM static test firing is 64-dB(A). Attenuation caused by topographic effects is negligible, since the line connecting the test site and the monument aligns with a pass in the Promontory Mountains. It is likely that the higher ground to either side of the relatively narrow pass would cause some attenuation, but no method exists to predict the value. The 64-dB(A) value has been added to the maps that show A-weighted sound pressure levels (Figure 34 on page 91 and Figure K-6 on page K-8). This sound pressure level is comparable to background noise levels generally acceptable for office-type environments. Also, it is noted that this sound pressure level environment is predominantly lower frequencies and, therefore, this should not interfer with normal speech communications.

Section 4.3.2.1, starting on page 87, indicates that this prediction is conservative in view of the observed sound pressure levels resulting from the 156-1 static test firing (see page 92). The predicted sound pressure level at the Golden Spike Monument, resulting from a SRM static test firing, would be similar to that predicted at the Bear River Migratory Bird Refuge for the 156-1 test firing. As described in the text (page 92), an individual at the Refuge reported that the sound level resulting from the 156-1 static test firing was such that it might well have been unnoticed by an observer not anticipating the event. The predicted sound pressure level of 64-dB(A) at the Golden Spike Monument is not in itself regarded as high and likely to adversely impact visitors.

Additionally, the probable conservative nature of the prediction and the likely, but uncalculatable, topographic attenuation suggests that the actual sound level will be significantly below the predicted value.

On January 6, 1977, Mr. George Church, Superintendent of The Golden Spike National Historic Site, was contacted to clarify the acoustic levels that are expected as a result of the SRM static test firings at the Thiokol/Wasatch Plantsite. The resulting conversation confirmed that he had reviewed the Draft Environmental Statement for the Space Shuttle SRM DDT&E Program, and that he did understand that low-frequency, low-amplitude acoustic levels are predicted for the historic site during SRM static test firings. He also expressed minor concern relative to the acoustic impact on his staff or visitors. However, since the National Park Service does reenact the driving of the Golden Spike for the public four times daily during the summer months, it was requested that they be notified of the SRM static test firing schedule. This will enable the National Park Service to inform those present of the origin of any noticed noise or exhaust cloud. Therefore, prior to each Space Shuttle SRM static test firing, the Superintendent of the Golden Spike Historic Site will be notified of the planned firing time.

Comment: DoI indicated that the potential for fuel oil and gasoline spills at storage facilities and their potential effect on groundwater should be discussed in the Final Environmental Statement.

Response: Section 4.4 (starting on page 94) discusses water quality impacts of the proposed activity. No new construction of storage facilities or significant additional quantities of fuel oil or gasoline are expected to be required as a result of the Space Shuttle SRM DDT&E Program. However, protection exists to prevent any contamination to the groundwater as a result of a spill at fuel storage facilities. Dikes, which would hold the entire tank capacity, and the fact that the groundwater table is anywhere from 100 to 120 m (350 to 400 ft) below the surface, provide adequate protection. Recently, a study of fuel storage facilities indicated that all facilities were properly located and diked.[91] No changes have been made in the text as a result of this comment.

Comment: DoI commented that the development of a new well field (Howell Well) could cause an effect on water levels and that the Final Statement should include data on water-level trends so that the potential hydrologic impacts can be appraised.

Response: Static water levels have been constantly measured for all wells since ~1959. Production wells are checked on a weekly basis and salt wells are checked on a monthly basis. The Howell Well, expected to be put into production in the 1977-1978 time period, is located over 32 km (20 mi) away from existing Thiokol wells and is part of a different hydrologic region. Thiokol currently practices strict management procedures to insure that salt water is kept out of all fresh water wells in the area. Proper hydrostatic levels are maintained throughout all seasons of the year. Based upon experience and past historical records, Thiokol will not allow pumping from wells, if certain criteria have been exceeded. For example, specific drawdown levels are given for all wells, and if these are exceeded, pumping stops immediately. If pumping were to occur over a 48-hour period, then 12 hours is allowed for the well to replenish. Criteria are now being defined to manage the water production from Howell Well. Every effort will be taken to insure that conservation criteria are applied to Thiokol's operation of this well. Proper management will prevent any effect upon the water quality (salt water intrusion) and any adverse effect on water levels in the area. No changes have been made in the text as a result of this comment.

Comment: The DoI comment infers that planned waste propellant disposal activities will involve a water leaching process which would remove ammonium perchlorate (AP) from the waste propellant and, as a consequence, cause potential adverse impacts to groundwater.

Response: This method of waste propellant disposal is not planned for this program. It is listed as an alternative to the proposed action (Section 6.2.2., page 129). As indicated on page 129, if this method were used, the AP would be recovered from the water for reuse, thus eliminating problems involving potential groundwater contamination in the area. No changes have been made in the text as a result of this comment.

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

NOV 2 2 1976

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

This is in response to your transmittal dated September 24, 1976, requesting review and comments on the draft environmental statement for the Space Shuttle Solid Rocket Motor Design, Development, Test and Evaluation Program at Thiokol/Wasatch Division, Promontory, Utah.

We have reviewed the statement and have determined that the proposed action will not conflict with current or known future Energy Research and Development Administration programs. However, the following comments are offered for your consideration in the preparation of the final statement.

NASA states that if the chance of rain exists, the SRM test will be postponed. We suggest that NASA quantify this (e.g., 0 chance, 5%, 10%, etc.) in the final statement. "Snowout" should also be discussed because it is more likely to occur than rainout during the winter months. Both rainout and snowout should be in terms of probability andtime before, during, or after firings.

Since NASA does not plan to use a sodium bicarbonate scrubber/neutralizer at Thiokol/Wasatch, will it be used at Cape Canaveral?

Thank you for the opportunity to review and comment on this draft statement.

Sincerely,

W. H. Pennington, Director
Office of NEPA Coordination

cc: CEQ (5)

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

U.S. Energy Research and Development Administration (ERDA), Office of NEPA Coordination, Washington, D. C.

Comment: ERDA suggested that NASA clarify the conditions under which an SRM static test firing would be postponed due to the likelihood of local precipitation (Section 4.2.3.2.3, page 83). ERDA also indicated that, in addition to precipitation scavenging during rain storms ("rain-out"), "snowout" also be considered, since precipitation is likely to be in the form of snow during the winter months.

Response: The text has been modified to clarify test firing conditions under which the firing would be postponed due to the likelihood of local precipitation, including both rain and snow. The text now states (page 83) that if rain or snow is forecast within two hours after the SRM test firing, the test will be postponed. Ongoing NASA studies indicate that a two-hour time period is normally more than adequate to assure that the exhaust cloud and, in particular, the HCl, has dispersed to the point where no adverse effects of precipitation scavenging ("rainout" or "snowout") would occur.

Comment: ERDA also questioned the status of NASA's plans for using an HCl neutralization system at the Space Shuttle launch site, Kennedy Space Center (KSC), Florida.

Response: Current plans do not include the use of such a neutralization system at KSC. NASA is continuing to analyze the environmental advantages and disadvantages of such a system.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION VIII
1860 LINCOLN STREET
DENVER, COLORADO 80203

OCT 26 1976

Ref: 8W-EE
D-NAS-J99001-UT

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space
Administration
Washington, D.C. 20546

Dear Mr. Crow:

The Environmental Protection Agency has reviewed the draft environmental impact statement for the space shuttle SRM DDT&E program, and we feel that the impact statement has adequately addressed the expected environmental impacts. EPA recommends that your agency continue to seek improved methods to minimize the environmental impacts that will occur.

These comments have been given an LO-1 designation. Thank you for providing EPA the opportunity to review this draft impact statement.

Sincerely yours,

John A. Green
Regional Administrator

U.S. Environmental Protection Agency, Region VIII, Denver, Colorado

Response: No response is required.

Office of Planning and Budget

Executive Department

James T. McIntyre, Jr.
Director

GEORGIA STATE CLEARINGHOUSE MEMORANDUM

TO: Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D.C. 20546

FROM: Charles H. Badger, Administrator
Georgia State Clearinghouse
Office of Planning and Budget

DATE: November 10, 1976

SUBJECT: RESULTS OF STATE-LEVEL REVIEW

Applicant: National Aeronautics and Space Administration

Project: Draft EIS--Space Shuttle

State Clearinghouse Control Number: 76-10-07-01

The State-level review of the above-referenced document has been completed. As a result of the environmental review process, the activity this document was prepared for has been found to be consistent with those State social, economic, physical goals, policies, plans, and programs with which the State is concerned.

The following State agencies have been offered the opportunity to review and comment on this project:

Department of Natural Resources
Office of Planning and Budget, Executive Department

cc: Ray Siewert, DNR

Department of Natural Resources, Office of Planning and Budget, Executive Department, Atlanta, Georgia

Response: No response is required.

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space
Administration
Washington, D.C. 20546

FROM: STATE CLEARINGHOUSE
OFFICE OF PLANNING AND BUDGET
INTERGOVERNMENTAL RELATIONS DIVISION
270 WASHINGTON STREET, S.W.
ATLANTA, GEORGIA 30334

DATE: October 7, 1976

SUBJECT: RECEIPT NEGATIVE DECLARATION/ENVIRONMENTAL ASSESSMENT OR DRAFT/FINAL ENVIRONMENTAL IMPACT STATEMENT

APPLICANT: National Aeronautics and Space Administration

PROJECT: Space Shuttle - Draft EIS

STATE CLEARINGHOUSE CONTROL NUMBER: 76-10-07-01

OFFICE OF PLANNING AND BUDGET CONTACT: C. Badger/S. Williams

The environmental information for the above project was received by the State Clearinghouse on October 7, 1976.

The State-level review on this project has been initiated and every effort is being made to insure prompt action. The document will be carefully evaluated relative to its consistency with State economic, social, physical goals, policies, plans, objectives and programs. You may expect to be informed by the State Clearinghouse of the results of the initial review by November 7, 1976.

In future correspondance regarding this document, please include the State Clearinghouse Control Number shown above. If you have any questions concerning this project, please call us at (404) 656-3855 or (404) 656-3829.

FORM SC-EIS-1
July 1975

<u>State Clearinghouse, Office of Planning and Budget, Intergovernmental Relations Division, Atlanta, Georgia</u>

<u>Response:</u> No response is required.

STATE OF MISSISSIPPI

OFFICE OF THE GOVERNOR

Cliff Finch
GOVERNOR

Glenn A. Smith
COORDINATOR OF FEDERAL-STATE PROGRAMS

STATE CLEARINGHOUSE FOR FEDERAL PROGRAMS

TO: Duward L. Crow, Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D. C. 20546

State Clearinghouse Number
76100801

Date: October 12, 1976

DRAFT ENVIRONMENTAL IMPACT STATEMENT: Space Shuttle Solid Rocket Motor Design, Development, Test and Evaluation (DDT&E) Program at Thiokol/Wasatch Division, Promontory, Utah.

(XXX) 1. The State Clearinghouse has received a copy of the Draft EIS as noted above.

(XXX) 2. After proper notification, no State agency has expressed an interest in conferring with the applicant(s) or commenting on the proposed project.

( ) 3. The proposed project is: ( ) consistent ( ) inconsistent with an applicable State plan for Mississippi.

(XXX) 4. Although there is no applicable State plan for Mississippi, the proposed project appears to be: (XXX) consistent ( ) inconsistent with present State goals and policies.

COMMENTS: This notice constitutes Final STATE CLEARINGHOUSE REVIEW AND COMMENTS. The requirements of U. S. Office of Management and Budget Circular No. A-95 have been met at the State Level.

Edward A. May, Jr.
Clearinghouse Director

<u>State of Mississippi, Office of the Governor, State Clearinghouse for Federal Programs, Jackson, Mississippi</u>

<u>Response</u>: No response is required.

STATE OF MISSISSIPPI
DEPARTMENT OF ARCHIVES AND HISTORY
P. O. BOX 571
JACKSON, MISSISSIPPI 39205

October 28, 1976

Mr. Edward A. May, Jr.
Clearinghouse Director
1503 Walter Sillers Building
500 High Street
Jackson, Miss. 39201

Re: Clearinghouse #76100801, Space Shuttle Solid Rocket Motor Design, Promontory, Utah.

Dear Mr. May:

We have reviewed the above mentioned project, and have determined that no properties listed on, or eligible for listing on, the National Register of Historic Places are present. Our Mississippi survey records indicate that no known historical or archaeological sites will be affected. We are pleased, therefore, to give our concurrence on this project. There remains a remote possibility that unrecorded archaeological sites may be encountered. Should this occur we would appreciate your contacting this Department immediately.

Thank you for notifying us of this project. We hope you will call on us if we can be of further assistance.

Sincerely,

ELBERT R. HILLIARD
State Historic Preservation Officer

By: Paul Newsom
Environmental Coordinator

PN/rw

cc: Duward L. Crow, Associate Deputy Administrator
National Aeronautics and Space Administration

State of Mississippi, Department of Archives and History, Jackson, Mississippi

Response: No response is required.

STATE OF NEBRASKA

OFFICE OF PLANNING AND PROGRAMMING

BOX 94601 · STATE CAPITOL · LINCOLN, NEBRASKA · 68509 · (402) 471-2414

Governor J. James Exon
State Planning Officer

W. Don Nelson
Director

October 26, 1976

Mr. Duward L. Crow, Associate Deputy
Administrator
Office of the Administrator
National Aeronautics and Space Administration
Washington, D. C. 20546

Mr. George B. Hardy, Manager
SRB Project Office
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama 35812

Gentlemen:

Under the provisions of OMB Circular A-95, Part I, this agency has completed a state level review of the draft Environmental Impact Statement for the Space Shuttle Solid Rocket Motor Design, Development, Test and Evaluation Program.

The proposed project does not appear to be in conflict with any state level comprehensive plans and does not represent a duplication in the expenditure of state or federal funds. I would suggest that prior to the transportation of the SRB's, that the Nebraska Department of Roads be contacted to insure adequate bridge clearances during movement. Should the proposed action be modified, this office requests the opportunity to review the modified plan.

This completes the state clearinghouse review.

Sincerely,

Warren G. White
Natural Resources Coordinator

WGW:np
cc: Thomas Doyle

State of Nebraska, Office of Planning and Programming, Lincoln, Nebraska

Comment: The State of Nebraska suggested that prior to the transportation of the SRM segments, the Nebraska Department of Roads be contacted to insure adequate bridge clearances during movement, and also if the proposed action is modified, they wish to be notified.

Response: The Nebraska Department of Roads will be notified prior to SRM segment shipment during the SRM DDT&E Program. In 1972, a comprehensive study of railroad clearances along the route from Utah to Florida (see Figure 9, page 17) was conducted.[92] From the results of the study, it can be concluded that the current SRM design can be shipped via rail with adequate clearances and without special handling. A copy of this study[92] is being sent to The Nebraska Department of Roads. If there is modification to the proposed transportation action, The Nebraska Department of Roads will be contacted.

WYOMING
EXECUTIVE DEPARTMENT
CHEYENNE

ED HERSCHLER
GOVERNOR

November 3, 1976

Office of the Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Sirs:

In compliance with the National Environmental Policy Act of 1969, Office of Management and Budget Circular A-95 (revised) and the Wyoming State Review Procedure, the State of Wyoming has no comment on the draft Environmental Impact Statement for the Space Shuttle Solid Rocket Motor Design, Development, Test and Evaluation (DDT&E) Program at Thiokol/Wasatch Division, Promontory, Utah.

Thank you for providing an opportunity to review the draft statement. We appreciate your effort in keeping us informed.

Yours sincerely,

Ed Herschler

EH/dhr

<u>Wyoming Executive Department, Office of the Governor, Cheyenne, Wyoming</u>

<u>Response</u>: No response is required.

WYOMING
EXECUTIVE DEPARTMENT
CHEYENNE

ED HERSCHLER
GOVERNOR

October 14, 1976

Office of the Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Sirs:

The State Planning Coordinator's Office, serving as the State Clearinghouse, is in receipt of the draft Environmental Impact Statement for the Space Shuttle Solid Rocket Motor, Design, Development, Test and Evaluation (DDT&E) Program at Thiokol/Wasatch Division, Promontory, Utah.

We appreciate your effort in keeping us informed, and find the major activities of the Program have very insignificant environmental affect on the State of Wyoming.

Thank you for providing an opportunity to review the draft statement. We are looking forward to the success of the program.

Sincerely yours,

David D. Freudenthal
State Planning Coordinator

DDF:dhc

Wyoming Executive Department, State Planning Coordinator, Cheyenne, Wyoming

Response: No response is required.

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

(1) Anon., "Environmental Statement for the Space Shuttle Program", Final Statement, NASA, July, 1972.

(2) Anon., "Wasatch Division Maintenance Manual", Thiokol/Wasatch Division, Brigham City, Utah.

(3) Anon., "Thiokol Corporation, Wasatch Division Safety Regulation Number 43; Construction, Modification, and Renovation of Facilities, Utilities and Equipment". Thiokol/Wasatch Division, Brigham City, Utah, April 1973.

(4) Anon., "Division Procedure 2180-34-5200.23; Facility Specifications Drawings, Safety Review and Approval Of", Thiokol/Wasatch Division Brigham City, Utah.

(5) Stokes, W. L., The Great Salt Lake, A Guidebook to the Geology of Utah, Number 20, Utah Geological Survey, 1966.

(6) Chadwick, R. S., et al., "Soil Survey of Box Elder County, Utah/Eastern Part", Soil Conservation Service, USDA and Fish and Wildlife Service and Bureau of Land Management, USDI, June, 1975.

(7) Workmann, Gar, Ecology Center, Utah State University, Logan, Utah, personal communication, March 2, 1976.

(8) Anon., "Meteorological Program Plan-TU-363 Motor Test", Thiokol Corporation, Wasatch Division, 1967.

(9) Anon., "Mammals of the Bear River Migratory Bird Refuge", RL-322, GPO 893-242, Fish and Wildlife Service, USDI, December, 1966.

(10) Burt, W. H., and Grossenheider, R. P., A Field Guide to the Mammals, The Riverside Press, Cambridge, Massachusetts, 1952.

(11) Anon., "Common Plants of the Bear River Migratory Bird Refuge, Fish and Wildlife Service, USDI.

(12) Anon., "Plants of the Bear River Migratory Bird Refuge Herbarium", Bear River Migratory Bird Refuge, Brigham City, Utah, Fish and Wildlife Service, USDI, Brigham City, Utah, March, 1972.

(13) Anon., "Bear River Migratory Bird Refuge", RL-2-R-3, GPO 944-747, Fish and Wildlife Service, USDI, 1966.

(14) Allen, Leerue and Velasquez, Vern, Bear River Migratory Bird Refuge, Brigham City, Utah, personal communication, December, 1975.

(15) Gaufin, Arden, Department of Biology, University of Utah, Salt Lake City, Utah, personal communication, March 3, 1976.

(16) Stephens, D. W., and Gillespie, D. M., "Community Structure and Ecosystem Analysis of the Great Salt Lake", IN : The Great Salt Lake and Utah's Water Resources, Proceedings - First Annual Conference of Utah Section of the American Water Resources Association, Water Research Laboratory, Utah State University, Logan, Utah, 1972.

(17) Behle, W. H., The Bird Life of Great Salt Lake, University of Utah Press, Salt Lake City, Utah, 1958.

(18) Anon., "Seasonal Abundance of Birds on the Bear River Refuge", Fish and Wildlife Service, USDI, July, 1972.

(19) Madsen, D. B., and Berry, M. S., "Box Elder County (Archeology)", - Manuscript prepared for Utah State Department of Development Sciences, Division of State History, Salt Lake City, Utah, June, 1974.

(20) Madsen, J., Department of Geology and Geosciences, University of Utah, Salt Lake City, Utah, a personal communication, April 20, 1976.

(21) Anon., "Compilation of Air Pollutant Emission Factors, AP-42, Environmental Protection Agency, 2nd Edition, April, 1973.

(22) Russon, Milt, Utah Power and Light Company, Salt Lake City, Utah, a personal communication, February 27, 1976.

(23) Winn, G. S., Utah Air Conservation Committee, a letter to Mr. J. E. Mason, Thiokol/Wasatch, Brigham City, Utah, issuing an exemption from Utah Air Conservation Regulations for Open Burning (Section 2.1), February 19, 1976.

(24) Winn, G. S., Utah Air Conservation Committee, a letter to Mr. John Higginson, Thiokol/Wasatch Division, Brigham City, Utah, indicating that the Space Shuttle SRM test firings, if conducted under suitable weather conditions, would not violate Utah's Air Quality Regulations, June 10, 1973.

(25) Anon., "Air Conservation Regulations", State of Utah Department of Social Services, Division of Health, Utah Air Conservation Committee, Salt Lake City, Utah, July 9, 1975.

(26) Anon., "Clearing Index Statistics", Utah State Division of Health, Bureau of Environmental Health, Air Quality Section", Salt Lake City, July 18, 1973.

(27) Dumbauld, R. K., and Bjorklund, J. R., "NASA/MSFC Multilayer Diffusion Models and Computer Programs - Version 5", prepared by H. E. Cramer Company, Inc., for NASA/MSFC, NASA CR-2631, December, 1975.

(28) Stephens, J. B., NASA/MSFC, and Pellett, G. L., and Gregory, G. L., NASA/LaRC, personal communications, 1976.

(29) Anon., "Meteorological Program Plan - TU-363 Motor Test", Safety Department, Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah, 1967.

(30) Chapman, W. T., Meteorologist in Charge, Salt Lake City Weather Station, Salt Lake City, Utah, a personal communication, March 12, 1976.

(31) Cramer, H. E., Bjorklund, J.R., Dumbauld, R. K., et al., "Development of Dosage Models and Concepts", DTC-TR-72-609-I prepared by GCA Corporation for U.S. Army Dugway Proving Ground, Dugway, Utah, February, 1972.

(32) Chapman, W. T. Meteorologist in Charge, Salt Lake City Weather Station, Salt Lake City, Utah, personal communications, March 9, 22, 23, 1976.

(33) Rice, E. E., Battelle's Columbus Laboratories, a letter to Mr. R. C. Laney, Thiokol Chemical Corporation, Brigham City, Utah, providing meteorological sounding data, BCL-SEA-IL-76-14, May 27, 1976.

(34) McIntosh, M. J., et al., "Solid Rocket Propellant Waste Disposal/Ingredient Recovery Study", MER-1374, Thiokol/Wasatch Division, July 28, 1975.

(35) Winn, G. S., Utah Air Conservation Committee, a letter to Mr. J. E. Madsen, Thiokol Chemical Corporation, Brigham City, Utah, describing the conditions of the 1975 Variance on open burning, January 24, 1975.

(36) Wanlass, K. J., "SRM Accidental Ignition During Transportation", 2814-76-M042, Thiokol/Wasatch Division, March 10, 1976.

(37) Wanlass, K. J., and Webb, K., "SRM Nozzle Exhaust Equilibrium Composition for Nozzle Exit Plane Conditions (Expansion Ratio 7.16)", TWR-10975, Thiokol/Wasatch Division, December 16, 1975.

(38) Gomberg, R. I., and Stewart, R. B., "A Simulation of the After-burning Process Occurring Within Solid Rocket Motor Plumes in the Troposphere", Preliminary Draft, NASA/Langley Research Center, 1976.

(39) Pellett, G. L., NASA/Langley Research Center, a personal communication, March 31, 1976.

(40) Pellett, G. L., "Washout of HCl and Application to Solid Rocket Exhaust Clouds" NASA/Langley Research Center, Hampton, Virginia, prepared for Precipitation Scavenging Symposium sponsored by USAEC and Illinois State Water Survey, 1974.

(41) Knutson, E. O., and Fenton, D. L., "Atmospheric Scavenging of Hydrochloric Acid", NASA CR-2598, prepared by IIT Research Institute, Chicago, Illinois, for NASA/Marshall Space Flight Center, August, 1975.

(42) Anon., "General Safety Engineering Design Criteria", Vol. I, JANNAF Propulsion Committee, JANNAF Hazards Working Group, CPIA Publication 194, Chemical Propulsion Information Agency, October, 1971.

(43) Rice, E. E., Battelle's Columbus Laboratories, a letter to Mr. R. C. Laney, Thiokol Chemical Corporation, Brigham City, Utah, presenting a noise analysis of the 156-1 test firing data, BCL-SEA-IL-76-15, May 27, 1976.

(44) Laney, R. C., Thiokol/Wasatch Division, Brigham City, Utah, a personal communication, March, 1976.

(45) Kryter, K. D., <u>The Effects Of Noise on Man</u>, Academic Press, New York, 1970.

(46) Anon., "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety", U.S. EPA, Report No. 550/9-74-004, March, 1974.

(47) Anon., "Guide for Short-Term Exposure to the Public to Air Pollutants: II Guide for Hydrogen Chloride", Advisory Center on Toxicology, National Academy of Sciences-National Research Council, August, 1971.

(48) Wands, R. C., Director, Advisory Center on Toxicology, National Research Council, a letter to Dr. J. B. Stephens, NASA/MSFC, giving the permissible excursion factor for HCl, April 8, 1975.

(49) Anon., Federal Register, October 23, 1971, Vol. 36, No. 206, p. 20513.

(50) Smyth, H. F., Jr., "Military and Space Short-Term Inhalation Standards", Archives Environmental Health, Volume 12, pp 488-490, April, 1966.

(51) Anon., "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment With Intended Changes for 1975", American Conference of Governmental Industrial Hygienists, 1975.

(52) Anon., "Guides for Short-Term Exposures of the Public to Air Pollutants. I. Guide for Oxides of Nitrogen", The Committee on Toxicology, National Academy of Sciences-National Research Council, April, 1971.

(53) Anon., "Guides for Short-Term Exposures of the Public to Air Pollutants. VIII. Guide for Chlorine", National Academy of Sciences-National Research Council, The Committee on Toxicology, March, 1973.

(54) Hoess, J. A., et al., "Definition and Characterization of the Safety Problem in the Railroad Industry", Report to the American Association of Railroads, Battelle's Columbus Laboratories, November, 1975.

(55) Engle, J. E., "SRM Rail Transport", memorandum to L. G. Koch, Thiokol/ Wasatch Division, March 16, 1976.

(56) Morey, L. E., Hercules, Inc., private communication to A. E. Weller, Battelle's Columbus Laboratories, April 20, 1973.

(57) Dinsdale, V. T., "TNT Equivalency of SRM Propellant", memorandum to R. C. Laney, Thiokol/Wasatch Division, December 5, 1975.

(58) Anon., "Carload Waybill Statistics, 1973", U.S. Department of Transportation, June, 1975.

(59) Anon., "Fourth Annual Report of the Secretary of Transportation on Hazardous Materials Control, Calendar Year 1973", U.S. Department of Transportation (no document number or publication date).

(60) Mr. McCloud, Association of American Railroads, personal communication, May, 1976.

(61) Anon., "Water Pollution Control Program Water Analysis", Thiokol/ Wasatch Division, Brigham City, Utah.

(62) Lerman, S., Cooper, R., Scherfig, J., and Greenhouse, G., "Environmental Quality Research First Annual Report", AMRL-TR-74-82 GPO 1975-657-020/523, University of California, Irvine, California, 1975.

(63) Cicerone, R. J., Stedman, D. H., Stolarski, R. S., Dingle, A. N., and Cellarius, R. A., "Assessment of Possible Environmental Effects of Space Shuttle Operations", NASA CR-129003, University of Michigan, Ann Arbor, Michigan, 1973.

(64) Jacobson, J. S., and Hill, A. C. (Ed.), "Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas", Prepared under the auspices of Air Pollution Control Association and National Air Pollution Control Administration, Pittsburgh, Pennsylvania, 1970.

(65) Anon., "Effects of Noise on Wildlife and Other Animals", NTIS PB-206 720, Memphis State University, 1971.

(66) Allen, A. D., Thiokol/Wasatch Division, a personal communication, March, 1976.

(67) Rooney, R. C. (Ed.), "Water Quality Criteria 1972. A report of the Committee on Water Quality Criteria", Environmental Studies Board, National Academy of Sciences, Washington, D.C., USGPO 5501-00520, 1974.

(68) Anon., Draft Amendment Number 1 to the NASA/KSC Institutional Environmental Impact Statement, NASA/KSC, Florida, October 2, 1972.

(69) Saarder, D. S., and Jensen, A. V. (Editors), "Environmental Impact Considerations for Disposal of Propellants and Ingredients", CPIA Publication 269, September, 1975.

(70) McIntosh, M. J., et al., "Solid Rocket Propellant Waste Disposal/ Ingredient Recovery Study", Final Report, Thiokol/Wasatch Division, MER-1374, July 28, 1975.

(71) VanderArend, P. C., Stoy, S. T., and Krahyecz, T. E., "Feasibility Study of Launch Vehicle Ground Cloud Neutralization", CR-draft report, Cryogenic Consultants, Inc., Allentown, Pa., March 1976.

(72) Goreham, Art, American Synthetic Rubber Corporation, Louisville, Kentucky, a personal communication, August 18, 1975.

(73) Rice, E. E., "Telephone Conversations Regarding Ammonium Perchlorate Costs and Energy Requirements", BMI-NLVP-TC-75-26, Battelle's Columbus Laboratories, August 19, 1975.

(74) Anon., Metal Statistics 1975, American Metal Market, Fairchild Publications, Inc., New York, 1975.

(75) Anon., Annual Statistical Report, American Iron and Steel Institute, Washington, D.C., 1974.

(76) Anon., Petroleum Facts and Figures, American Petroleum Institute, Washington, D.C., 1971.

(77) Anon., Statistical Yearbook of the Electric Utility Industries for 1973, No. 41, Publication Number 74-34, Edison Electric Institute, New York, November, 1974.

(78) Rice, E. E., Battelle's Columbus Laboratories, Columbus, Ohio, a personal communication, March, 1976.

(79) Anon., "Energy and the Environment - Electrical Power", Council on Environmental Quality, August, 1973.

(80) Berry, R. S., and Fels, M. F., "The Production and Consumption of Automobiles; an Energy Analysis of the Manufacture, Discard and Reuse of the Automobile and Its Component Materials", A Report to the Illinois Institute of Environmental Quality, Department of Chemistry, University of Chicago, July, 1972.

(81) Shuldinger, H., "Recreation Roundup - Gas for Recreation", Popular Science, April, 1974.

(82) Turner, D. B., "Workbook of Atmospheric Diffusion Estimates", Public Health Service Publication No. 999-AP-26, 1967.

(83) Gregory, G. L., Wornom, D. E., Bendura, R. J., Wagner, H. S., "Hydrogen Chloride Measurements From Titan III Launches at the Air Force Eastern Test Range, Florida, 1973 through 1975", NASA TM X-72832, NASA/Langley Research Center, Hampton, Virginia, March, 1976.

(84) Anon., "Mass Properties Monthly Status Report No. 17 for Space Shuttle Solid Rocket Motor Project", DR No. 3-2, Thiokol/Wasatch Division, Brigham City, Utah, February 1, 1976.

(85) Harris, C. M., "Absorption of Sound in Air Versus Humidity and Temperature", J. Acoustical Soc. Am., 40, 148-149 (1966).

(86) Kurze, U., and Beranek, L. L., "Sound Propagation Outdoors", Chapter 7 of Noise and Vibration Control (Ed., L. L. Beranek), McGraw-Hill, 1971.

(87) Rudnick, I., "Propagation of Sound in the Open Air", Chapter 3, Handbook of Noise Control (Ed., C. M. Harris), McGraw-Hill, 1957.

(88) Glasstone, Samuel, The Effects of Nuclear Weapons, U.S. Atomic Energy Comission, June 1957.

(89) Anon., Federal Register, October 27, 1976, Vol. 41, No. 208, page 47180.

(90) Rodney, Krey, Bear River Migratory Bird Refuge, Brigham City, Utah, Personal Communication, December 15, 1976.

(91) Judd, B. G., "Spill Prevention Control and Countermeasure Plan", Thiokol/Wasatch, October 15, 1974.

(92) Rasmussen, R. M., "Space Shuttle Solid Rocket Motor Overland Transportation and Handling Demonstration", Thiokol/Wasatch Division, TRW-6644, December 27, 1972.

APPENDIX B

ABBREVIATIONS

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ABBREVIATIONS

AP	-	Ammonium perchlorate
Al	-	Aluminum
B.P.	-	Before present
CI	-	Clearing Index
dB	-	decibel
dB(A)	-	decibel, "A" weighted scale
DDT&E	-	Design, development, test and evaluation
ECA	-	Epoxy curing agent
EPA	-	Environmental Protection Agency
ET	-	Space Shuttle External Tank
Hz	-	Hertz (cycles per second)
Isp	-	Specific impulse (thrust/flow rate)
kJ	-	Kilojoules
KSC	-	Kennedy Space Center (NASA)
MSFC	-	Marshall Space Flight Center (NASA)
MST	-	Mountain Standard Time
NASA	-	National Aeronautics and Space Administration
NEPA	-	National Environmental Policy Act
OASPL	-	Overall sound pressure level
OSHA	-	Occupational Safety and Health Act or Administration
PBAN	-	Polybutadiene acrylic acid acrylonitrile
PEL	-	Public Exposure Limit
ppm	-	Parts per million, by volume
QC	-	Quality Control

R&D	-	Research and Development
S&A	-	Safe and Arm
SPL	-	Sound Pressure Level
SR83	-	State Route 83
SRM	-	Solid Rocket Motor
SRB	-	Solid Rocket Booster
SSSRM	-	Space Shuttle Solid Rocket Motor
STPL	-	Short Term Public Limit
STS	-	Space Transportation System
T-24	-	SRM test site - Test facility number 24
TLV	-	Threshold limit value
TNT	-	Trinitrotoluene
TVC	-	Thrust vector control
TWA	-	Time weighted average
UPLC	-	Utah Power and Light Company
VAB	-	Vehicle Assembly Building
WTR	-	Western Test Range

APPENDIX C

METRIC/ENGLISH CONVERSION FACTORS

APPENDIX C

METRIC/ENGLISH CONVERSION FACTORS

To Convert	Into	Multiply By
atmospheres	pounds per square inch (psi)	14.70
centimeters (cm)	inches (in)	0.3937
	feet (ft)	3.281×10^{-2}
	yards (yd)	1.094×10^{-2}
cubic meters(m^3)	cubic feet(ft^3)	35.32
hectare	acres	2.471
	square feet (ft^2)	1.076×10^5
	square kilometers (km^2)	0.010
kilocalories/kg (kcal/kg)	Btu/pound (Btu/lb)	1.80
kilogram (kg)	pound (lb)	2.205
kilojoules (kJ)	Btu	0.948
	kilowatt hours (kwhr)	2.778×10^{-4}
kilometers (km)	feet (ft)	3,281
	miles (mi)	0.6214
kilowatts (kw)	Btu per hr	3,413
	horsepower (boiler)	0.1020
liters (l)	gallons (gal)	0.2642
	cubic feet (ft^3)	0.03531
meters (m)	inches (in)	39.37
	feet (ft)	3.281
	yards (yd)	1.094

To Convert	Into	Multiply By
metric ton	pounds (lb)	2205
	ton	1.102
millibar (mb)	pounds per square inch (psi)	1.451×10^{-2}
	atmospheres	9.869×10^{-4}
milligrams (mg)	pounds	2.205×10^{-6}
Newton (N)	pound (lb_f)	0.2248
Newton/cm^2	pounds per square inch (psi)	1.4504

to convert ^oC to ^oF use:

$$F = \frac{9}{5} C + 32$$

APPENDIX D

SPACE SHUTTLE SRM DESIGN CHARACTERISTICS

APPENDIX D

SPACE SHUTTLE SRM DESIGN CHARACTERISTICS

The Space Shuttle Solid Rocket Motor consists of a weld-free segmented case, a PBAN composite propellant, a propellant liner, a propellant/case insulation, a casting and face inhibitor, a nozzle, and an ignition system. The design characteristics of these components/systems are discussed below.

Case

The segmented SRM case is roll formed from D6AC steel. The case is weld free and consists of 11 segments (Figure D-1). Nominal case OD is 3.71 m. The five unique case segments required to assemble a complete SRM case are shown below:

CASE SEGMENT	MASS	QUANTITY REQUIRED
FORWARD	1,642 KG	1
CYLINDRICAL	5,159 KG	6
ATTACH	3,086 KG	1
STIFFENER	4,021 KG	2
AFT	2,184 KG	1
	ASSEMBLED CASE MASS 46,515 KG	

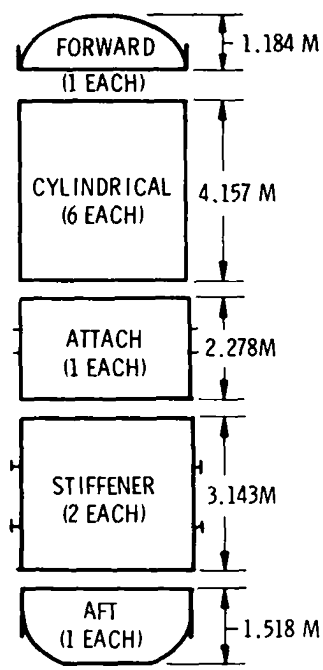


FIGURE D-1. SRM CASE SEGMENT CONFIGURATION

The configuration and number of case segments were selected so that welds could be eliminated and existing proven roll forming, heat treating, and machining capabilities could be employed. The six cylindrical segments, attach segment, and two stiffener segments are roll formed from ring rolled forgings. The ribs on the attach segment (for attachment of the SRB/ET attach ring) and on the stiffener segments (for attachment of stiffening rings required to resist water impact loads) are integrally formed during case roll forming and machining operations. The forward and aft segments are forged between closed dies to produce weld-free closures with the necessary SRB/SRM attach provisions obtained by subsequent machining operations.

Case segments and casting segments are joined using clevis type joints (Figure D-2). This joint concept has been used successfully on previous large motor programs. It was employed successfully on both 120-inch and 156-inch diameter cases, and successful operational flights have been achieved with the Titan III SRM using this joint concept. Individual case segments are joined together into four casting segments as illustrated in Figure D-2. All segmented joints incorporate redundant O-rings to assure a positive seal and to provide for leak checking during SRM assembly. This feature permits leak testing as the individual casting segments are stacked and joined at the launch site, obviates the requirement for leak testing after complete motor assembly, and precludes the possibility of having to destack the SRM. Similar redundant and testable dual seals have been incorporated in the nozzle and igniter to case joints. One hundred eighty 1-inch diameter pins are required to mate each segmented joint. Pins will be fabricated from MP35N, an alloy whose major constituents are cobalt, nickel, and chromium. This material was selected for its high strength, ductility, and resistance to salt water corrosion.

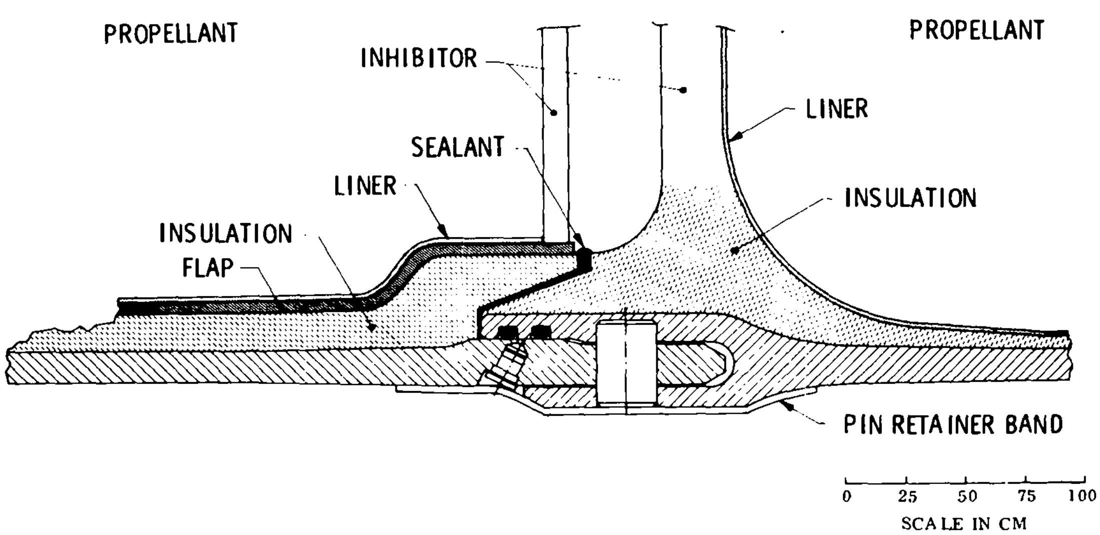


FIGURE D-2. SRM SEGMENT JOINT CONFIGURATION

The SRM case application differs from that associated with previous rocket motors because of the requirement for reuse. Each case is designed to be capable of a total of 20 uses; therefore, in addition to the normal strength criterion, fracture mechanics and environmental effects were carefully considered in the design and integrated with nondestructive test and proof test techniques. A protective coating (a two-part epoxy polyimide) will be employed to protect external case surfaces from sea water attack. Internal insulation and liner will protect the interior of the case.

Propellant/Liner/Insulation/Inhibitor

The propellant selected for the SRM is a polybutadiene acrylic acid acrylonitrile terpolymer (PBAN)/ammonium perchlorate (AP)/aluminum formulation. A small amount of catalyst is employed to achieve the desired burning rate. The selection of a PBAN propellant for the SRM was based primarily on the extensive industry experience with this family of propellants. More than 90 million kilograms of PBAN propellant have been processed by the industry. Major operational systems using this propellant at present are Stage I Minuteman, Stage I Poseidon, and the Titan III 120-inch diameter SRMs.

The specific formulation selected for the SRM is shown in Table D-1. The simplicity of the formulation, which contains only four major ingredients, assures reproducible propellant ballistic and mechanical properties. Ballistic properties of the selected propellant have been thoroughly demonstrated. The projected propellant vacuum specific impulse of 2570 m/sec is based upon conservative projections from previous large motor programs. Excellent aging

TABLE D-1. SRM PROPELLANT FORMULATION

Constituent	Function	Mass Percent
Ammonium Perchlorate	Oxidizer	69.6
Aluminum	Fuel	16.0
Iron Oxide	Combustion Accelerator	0.4
PBAN Polymer and Epoxy Curing Agent (ECA)	Binder/Fuel	14.0

characteristics have been demonstrated in long-term storage of carton samples and in motor aging programs. Motors employing this basic propellant have been successfully tested after being stored for over 10 years. The hazards classification of the propellant is well established as Class II.

SRM insulation, liner and inhibitor selection was based upon demonstrated compatibility with the selected PBAN propellant. The insulation and full web inhibitors are fabricated from asbestos/silica filled nitrile butadiene rubber (NBR). The chamber insulation system and full web propellant grain inhibitors, plus propellant stress relief flaps, are designed as integral units to facilitate fabrication. Segment aft face partial web inhibitors will be cast in place and will employ the same filled carboxy terminated polybutadiene polymer material used for the liner. A safety factor of two was used in the insulation design to provide design conservatism for the manrated SRM.

A thin coat of liner is applied to the insulation internal surfaces to bond the propellant to the insulation. The selected liner is identical to that currently employed in the Stage I Poseidon motor. This liner is a modification of the liner employed in the Stage I Minuteman motor. Identical insulation, liner, and inhibitor patterns selected for each cylindrical segment provide cylindrical segment interchangeability.

Nozzle

The SRM nozzle is a conventional movable, submerged, convergent-divergent design. The nozzle employs a flexible bearing to achieve the required thrust vector deflection. The flexible bearing provides the necessary omniaxial deflection capability of ±8 degrees. The nozzle design (Figure D-3) provides high performance at minimum weight and cost.

The flexible bearing assembly consists of alternate laminae of elastomeric and metallic shims bonded integrally to, and between, the forward and aft attachment end rings. Ten D6AC metallic shims and 11 natural rubber elastomeric pads comprise the core of the flexible bearing. The forward and aft end rings of the bearing are connected to the movable and fixed portions of the nozzle.

Selection of materials for the SRM nozzle was based upon their state-of-the-art status and successful application in previous large motors. Carbon cloth phenolic material is used in the nose, throat and forward exit cone

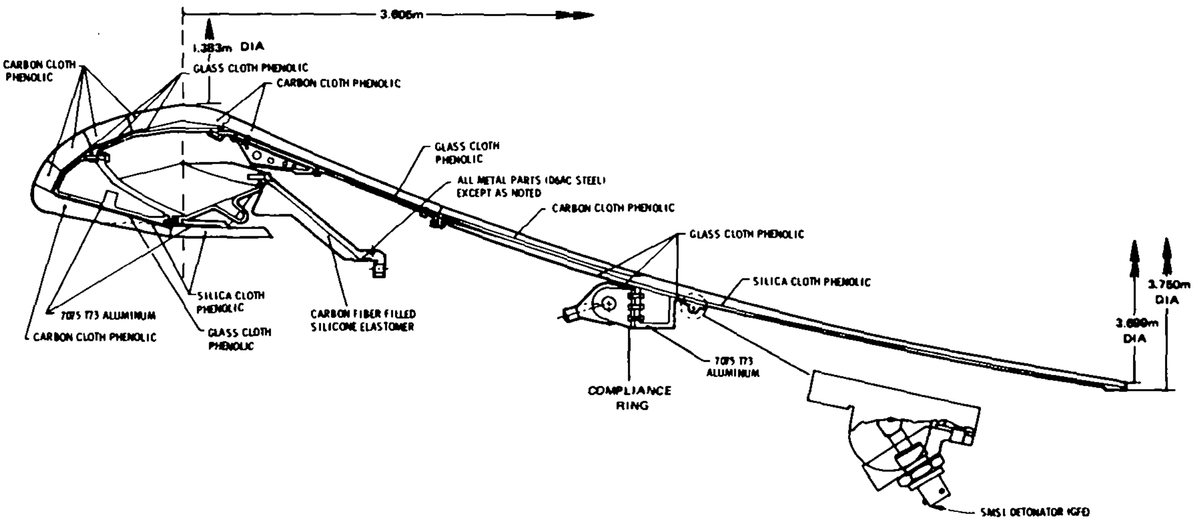


FIGURE D-3. SPACE SHUTTLE SRM NOZZLE DESIGN

sections where the exhaust gas environment is severe. Silica cloth phenolic is used in the aft exit cone area; glass cloth phenolic is used throughout the nozzle as an insulation and as a structural material in the aft exit cone. Nozzle metallic structural components are fabricated from D6AC, with the exception of the nozzle nose support structure and compliance ring, which are 7075-T73 aluminum.

An optimum contoured exit cone is employed to obtain maximum performance efficiency. A snubbing device, positioned on the exit cone steel structure, permits vectoring of the nozzle without interference, but bottoms out on the bearing aft end ring at water impact. This prevents forward motion of the nozzle and reduces the chance of damage to the flexible bearing and motor aft closure.

The exit cone extension is shipped as a separate item and is mated to the nozzle following aft segment/SRB aft skirt assembly. A linear shaped charge is mounted on the exit cone aft of the nozzle compliance ring. This charge severs the exit cone at this location following SRB burnout and separation. This is done to minimize loads on the SRB during water impact.

Ignition System

SRM ignition will be achieved with a pyrogen type ignition system, which will provide safe, positive and reproducible motor ignition. It consists basically of a small rocket motor employed to ignite the large SRM. This ignition system has been adopted as an industry standard, and currently is employed in practically all major operational SRMs. Motor ignition will occur nominally within 300 msec. The pyrogen igniter will produce a controlled and relatively gradual rate of rise of SRM pressure and minimize ignition thrust imbalance between the motors during the ignition phase.

APPENDIX E

SPACE SHUTTLE SRM DDT&E PROCESSING FACILITIES AT THIOKOL/WASATCH

APPENDIX E

SPACE SHUTTLE SRM DDT&E PROCESSING FACILITIES AT THIOKOL/WASATCH

The Thiokol/Wasatch facilities required for the Shuttle SRM DDT&E Program are divided into five major categories. These facility categories follow the processing plan for the SRM: (1) case, (2) propellant, (3) motor, (4) nozzle, and (5) igniter. Figures E-1 and E-2 indicate the locations of various SRM DDT&E processing facilities.

Case Processing Facilities

Case preparation operations are to be consolidated in the R&D plant complex which includes facilities M-8, M-10, M-52, and M-111 (see Figure E-1). The complex was designed for case preparation and provides more than adequate capacity for SRM production during the DDT&E Program.

All cases will be received and stored on a pad north of M-111. Preparation of new cases will start in M-52 with cleaning, then they will be moved to M-111 for: assembly into casting segments, painting, insulating, and lining. Insulation washout of fired SRM segments will be done in M-115, utilizing a unique system designed for removing propellant from Minuteman motors. The M-115 system is automated and remotely controlled. Little modification to this facility is required. Cases will then move to M-10 in the inert complex for disassembly, to M-52 for cleaning and magnetic particle inspection, back to M-10 for hydrotest and dimensional inspection, to M-52 for cleaning, and then to M-111 for painting, insulating, and lining.

The existing 27-metric ton bridge crane and hydrotest pit in M-10, the grit blast chamber, 18- and 27-metric ton cranes in M-52, the painting and lining pits in M-111 and supporting services such as the liner and mixing room and insulation preparation area in M-52 are currently suitable for SRM processing.

Propellant Processing Facilities

Propellant processing will be performed in the R&D Area adjacent to the casting area. The only exception is oxidizer grinding in AF Plant 78

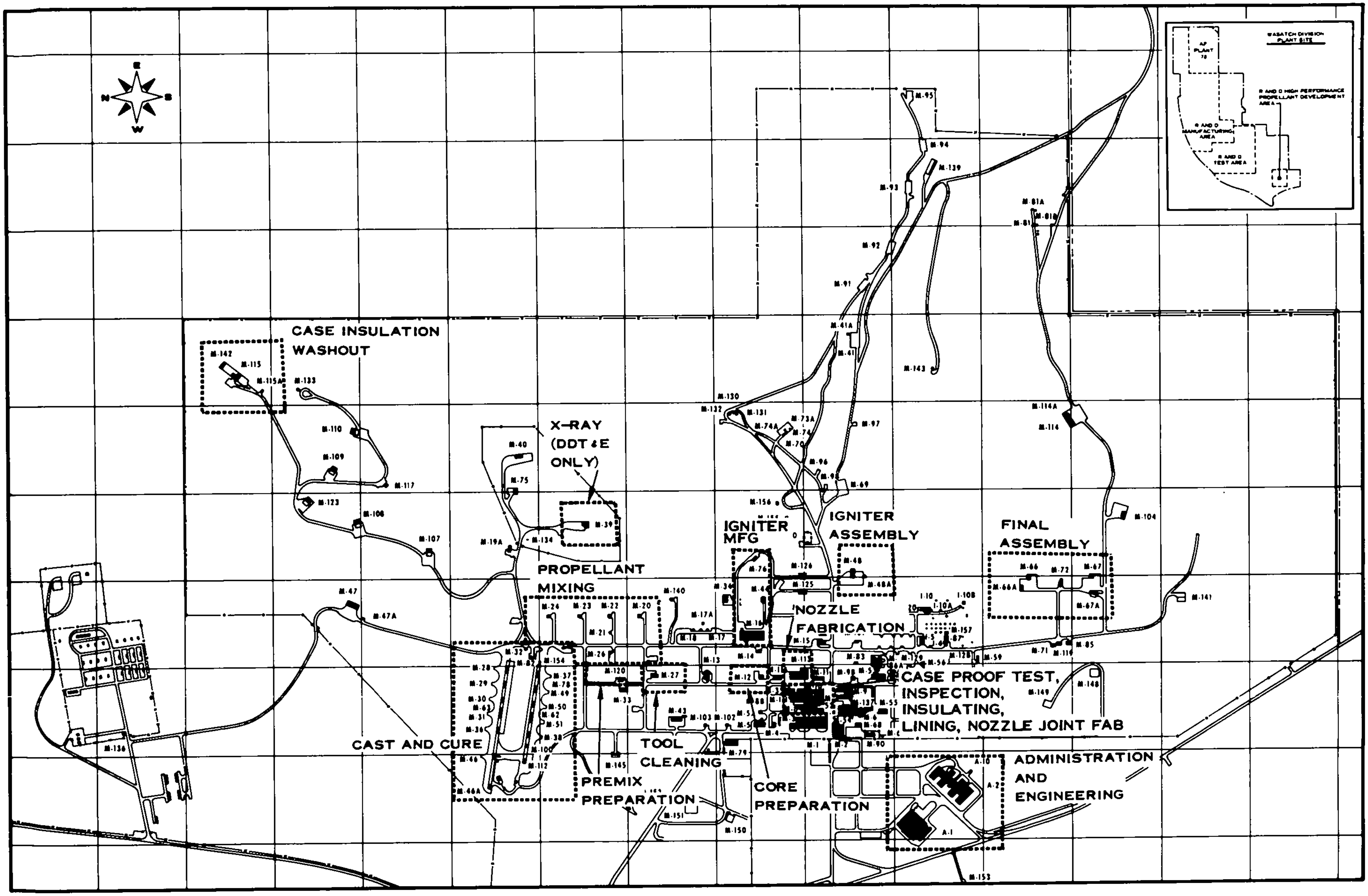


FIGURE E-1. THIOKOL/WASATCH R&D AREA

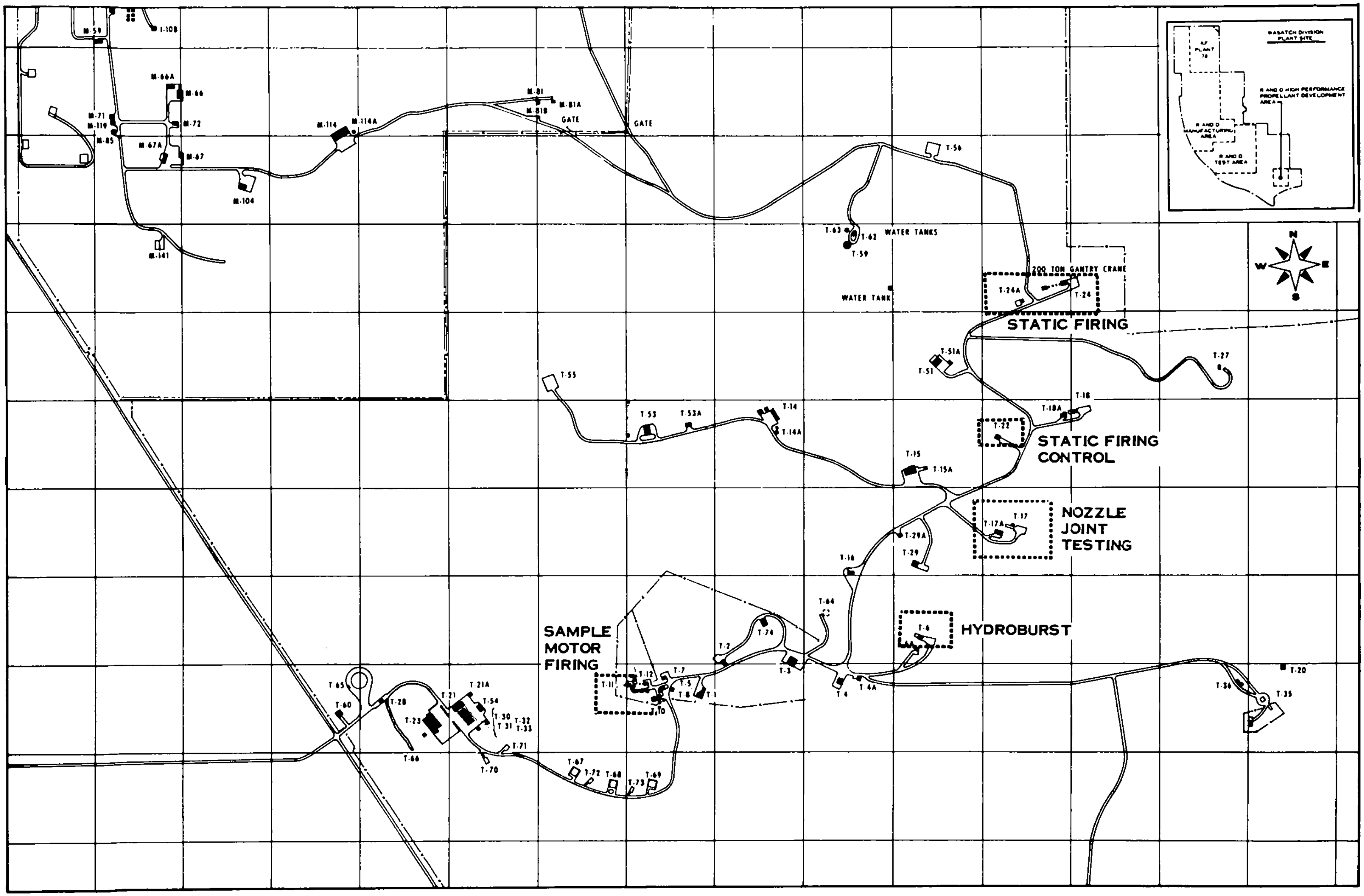


FIGURE E-2. THIOKOL/WASATCH TEST AREA

Building M-606. All major facilities are available and were previously designed to support high rate production of large solid rocket motors. M-606 was selected because a mill and feeder system are available and because later phaseout of Minuteman and Poseidon Programs will free production capacity to support future SRM production.

The same logic applies to Premix Building M-120 and the R&D Mixer Buildings M-20, M-22, and M-24. In each case, redundancy provides duplicate capacity for the Shuttle SRM DDT&E Program and available space and equipment for high rate production. M-120 requires equipment rearrangement for the DDT&E Program and additional equipment for future production at higher rates. The mixer buildings, with minor equipment modifications, will support the anticipated SRM production rates.

Motor Processing Facilities

Motor processing includes casting, curing, X-ray, and assembly, all to be done in the R&D Plant Area. Casting and curing are accomplished at the large pit oven complex. X-ray, planned for DDT&E only, is performed in M-39 which will be modified to accommodate the SRM transporter. The assembly building M-67 will house the weight and center-of-gravity machine and requires modification of the door and apron. Final segment assembly will include nozzle, raceway, and igniter installation.

The available cast/cure complex includes 12 large pit ovens, two casting houses, two storage buildings, two 45-metric ton and one 180-metric ton gantry cranes, and remote control center M-32. Modifications for the DDT&E Program include provision of two pit houses to permit maximum utilization of the existing casting houses, acquisition of a 180-metric ton gantry crane for the north row of pits, modification of the north row casting house and rehabilitation of two pit ovens.

After final assembly, the segments will be delivered to the static firing bay T-24 or will be shipped to the launch site. Motor testing at T-24 requires reinforcement of the thrust block, test bay extension, extension of mobile weather cover and 180-metric ton gantry crane tracks, and addition of the instrumentation and camera equipment.

Nozzle Processing Facilities

All nozzle fabrication and refurbishment effort will be performed in three existing buildings. These buildings are all in the same complex. The main nozzle fabrication and assembly building will be M-113. A 2.74-meter hydroclave, a 3.05-meter vertical boring mill (VBM), and a 4.27-meter vertical boring mill (VBM) will be installed in this building. The VBMs will be equipped with tape wrapping attachments. All of the nozzle tape wrap, hydroclave, machining, bonding, and assembling processes will be performed in Building M-113.

The autoclave will be located in Building M-111, which is directly across the street from M-113. Seven insulation liners will be cured in this building for each nozzle.

The large press for the bearing boot mold assembly operations will be located in a new enclosure within Building M-52. All of the bearing fabrication processes, boot layup and cure, and fixed housing insulation casting operations will be performed in Building M-52. Nozzle reclamation and refurbishment will be performed in Building M-116, just north of M-113.

The flex bearing acceptance testing will be performed in T-17. Some refurbishment will be required on this building to prepare it to receive the flex bearing test fixture. Radiographic inspection of the nozzle components will be performed in Building M-39 using an existing 15-Mev LINAC.

Igniter Processing Facilities

The igniter processing facilities are available and require no modification or additions. The size of the SRM igniter favors processing in the existing R&D Area tactical motor complex, which has little planned utilization.

Case preparation will be performed in M-16. Grit blasting, cleaning, insulating, and lining facilities are available.

The R&D Area vertical mixers, used for main motor mixing, will also be used for igniter mixes, one mix providing propellant for five igniters.

Casting will be done in one of two M-76 bays. Six curing pits are also available. Finishing and assembly will be accomplished in M-16. If other work increases in M-16, M-48 (in the same complex) is available and has no planned use. X-ray will be done in M-590 using an existing, 1,000-curie cobalt 60 source.

Initiators will be prepared and assembled in M-590 and cast in M-605. The safe and arm (S&A) initiator assembly will be purchased. Boron-potassium nitrate pellets for the S&A initiator will be pressed in Building I-10 (R&D Area).

Oxidizer will be ground at Plant 78 in Building M-606. Premix will be prepared at Building M-120 in the R&D Area, and the mixing operation will be performed in the R&D mixing complex.

Summary of Facilities Modifications

Associated effort pertinent to the processing, static test firing, and delivery of Space Shuttle Solid Rocket Motors, during the DDT&E Program, will be the modification of some existing facilities. Significant effort was made by the Thiokol Corporation in the early facilities planning exercises to keep modifications and new construction at a minimum. A summary description of the facilities modifications is presented in Table E-1.

TABLE E-1. SUMMARY OF FACILITY MODIFICATIONS

Bldg.	Function	Description of Modifications
M-10	Hydrotest and inspect recycled SRM cases	Relocate the current Minuteman hydrotest system. Add a new SRM hydrotest system and rotary table for case inspection.
M-12	Clean and wax casting cores	Relocate equipment. Enlarge paint booth and building turnaround apron.
M-27	Clean casting fixtures and mix bowls	Add new high pressure water cleaning system, table, bowl dumper and hoist.
M-39	Radiographic inspection	Building modifications. Add 13 to 18-Mev linear accelerator.
M-52	Case degrease, grit blast, Magnaflux, insulation preparation and flex bearing fabrication	Consolidate insulation preparation station. Relocate paint booth. Add insulation storage area, Magnaflux machines, vapor degreaser, vacuum cleaner for grit blast, and press.
M-111	Paint, insulate and line case	Building additions. Add 27-metric ton bridge crane, autoclave, exhaust system, painting station, high pressure air compressor, and 10 concrete storage pads.
M-113	Nozzle fabrication	Add 3.06-m and 4.27-m VBM, hydroclave, dust collector exhaust system, and tape wrapper attachments.
M-115	Wash insulation from fired SRM cases	Deepen washout system pit. Add larger door and hoist. Alter splash shield and associated tooling.
M-116	Nozzle refurbishment	Add oven and minor equipment.
M-606	Oxidizer grind and blend	Alter grinding system. Add tote bins and storage shed.
T-24	Static fire SRMs	Add larger thrust blocks, protection building and instrumentation, and concrete turnaround.

APPENDIX F

SPACE SHUTTLE SRM DDT&E MANUFACTURING PROCESSES

APPENDIX F

SPACE SHUTTLE SRM DDT&E MANUFACTURING PROCESSES

Space Shuttle SRM DDT&E Manufacturing Processes are described in the following paragraphs. Figure F-1 outlines the manufacturing processes. Refer to Appendixes D & E for SRM design characteristics and Thiokol processing facility information.

Case Processing

The case manufacturing effort will be conducted by several contractors located throughout the country. The Ladish Company, Cudahy, Wisconsin, will perform forging operations; Cal Doran, Los Angeles, California, will heat treat forged cases; and Rohr, Chula Vista, California, will perform the final machining, drilling, and testing activities. Figure F-2 presents a step-by-step description of the overall case manufacturing process. The finished case segments will be transported vertically to the Thiokol/Wasatch plantsite by rail.

A commercial low-bed trailer will be used for segment transport from the railhead at Corinne to the plantsite. Upon receipt at the Thiokol/Wasatch plantsite, the case segments will be inspected, unloaded, positioned vertically in the storage area (north of M-111) and protected from the elements.

When scheduled to start into process, the case segment will be placed on a low-bed transporter and transported vertically to the inert parts preparation complex. All internal and external surfaces of each case segment will be cleaned with trichloroethane in a vapor degreaser (M-52). After solvent cleaning, the segment will be positioned on an air cushion pallet and moved to the assembly station (M-111) for assembly into casting segments. Verification of mated segment joint seals will then be accomplished by pressure checking techniques.

The casting segment will then be positioned vertically in the painting pit (M-111) on a rotating table. The exterior of the casting segment will then be painted via remote control with a primer coat of Rust-Oleum 9373. After about one hour a top coat of epoxy paint, Rust-Oleum 9392, will be

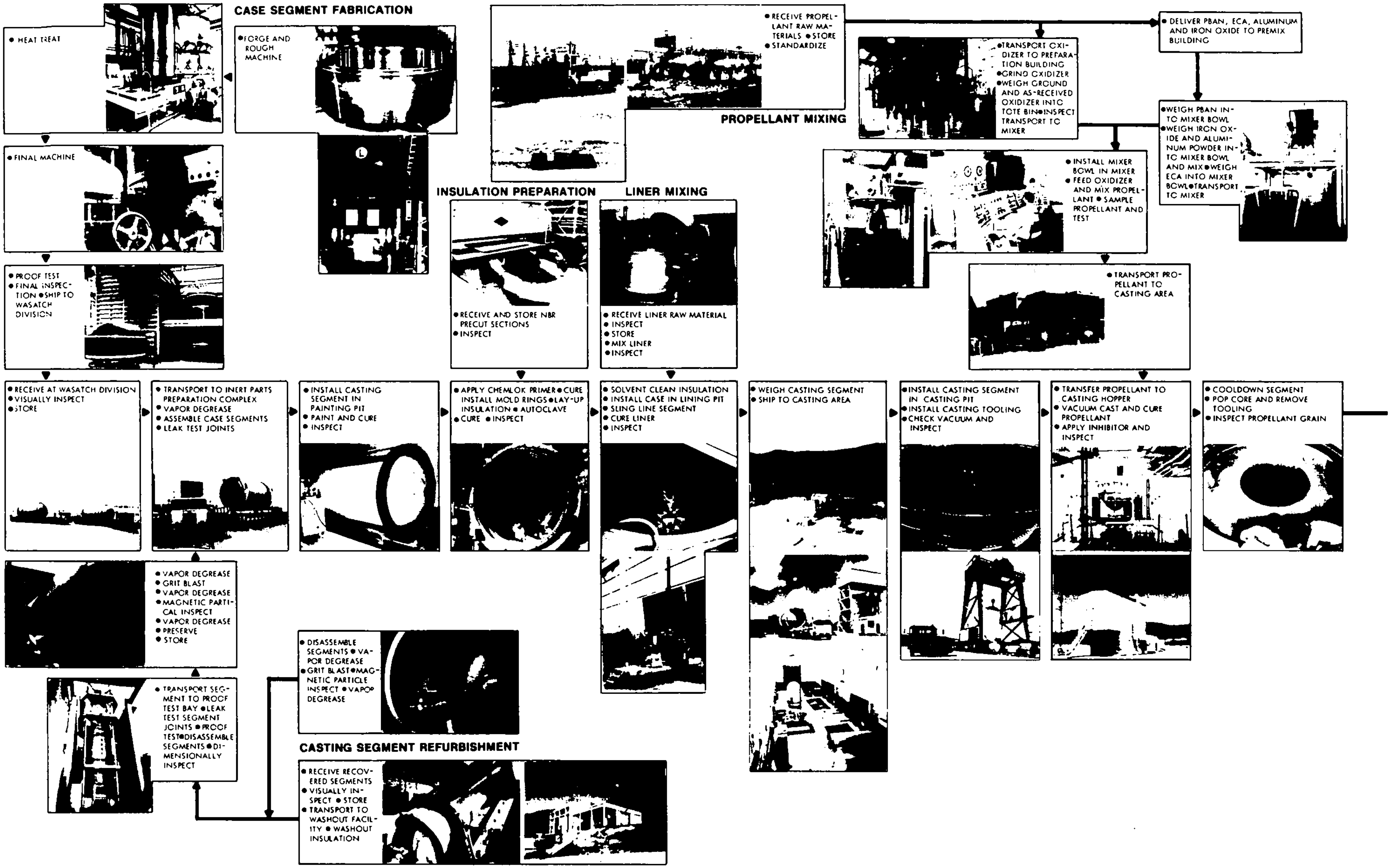


FIGURE F-1. SRM MANUFACTURING FLOW CHART (Sheet 1 of 2)

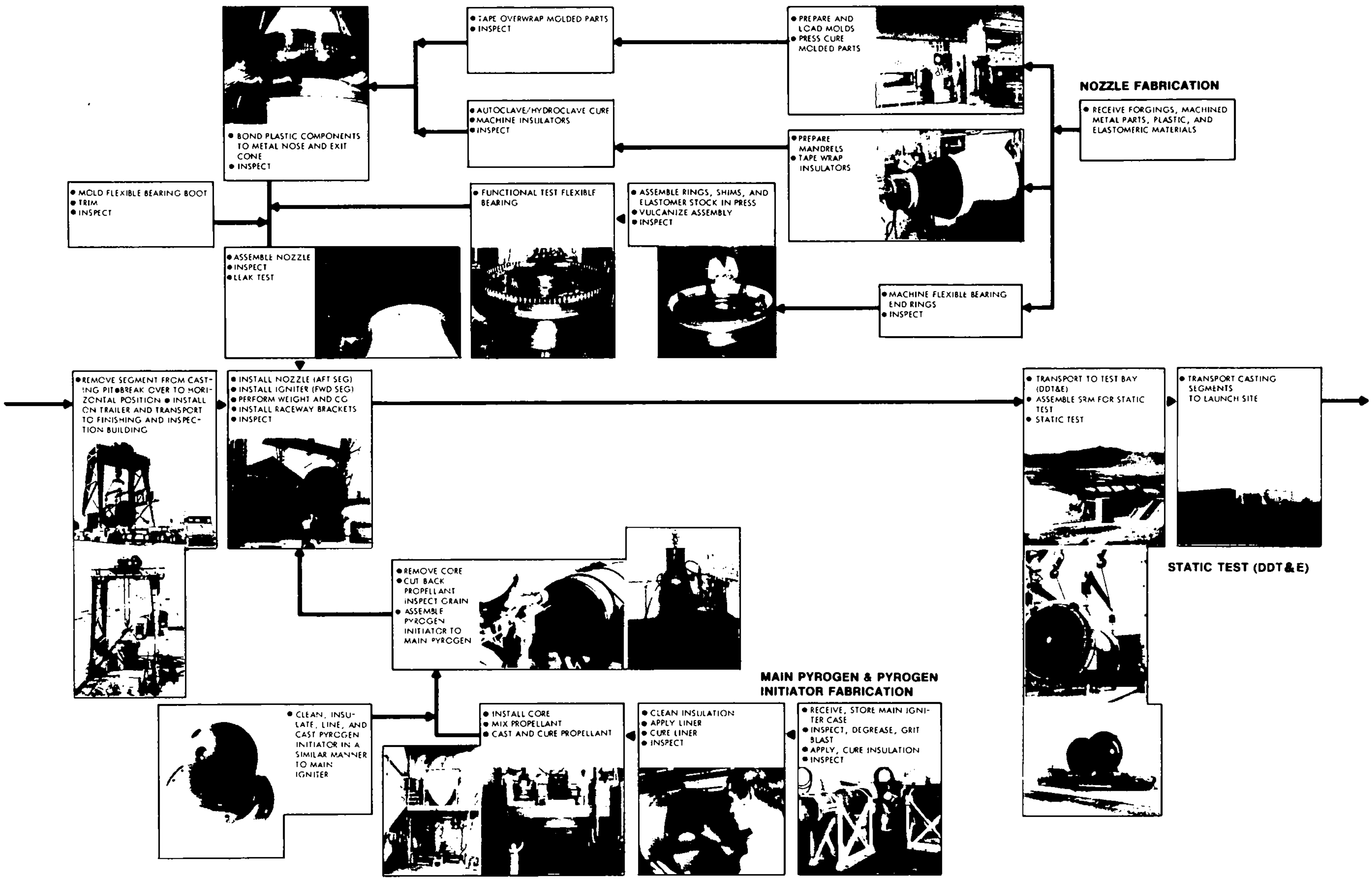


FIGURE F-1. SRM MANUFACTURING FLOW CHART (Sheet 2 of 2)

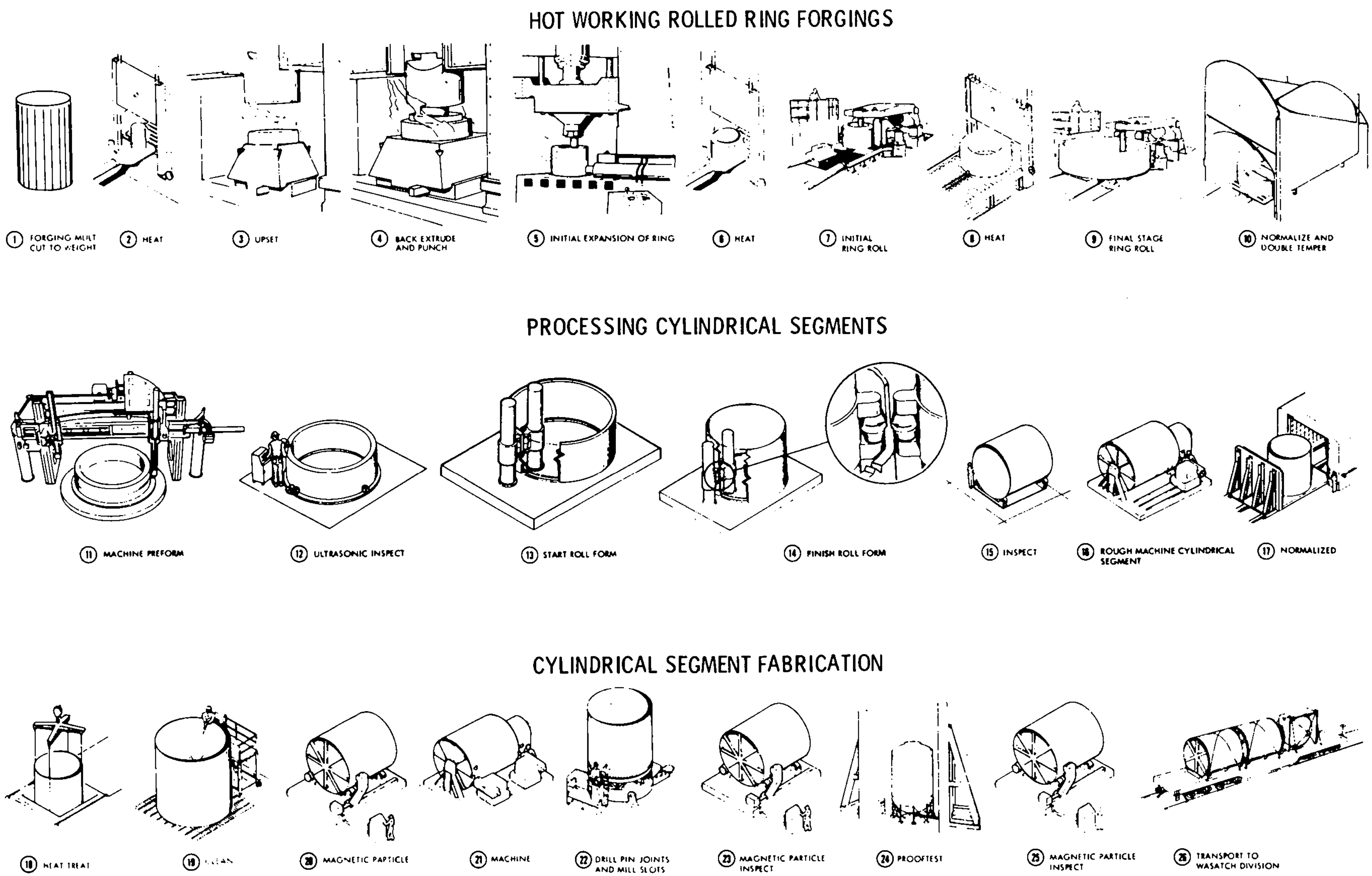


FIGURE F-2. SRM CASE MANUFACTURING STEPS applied. The epoxy paint will be cured for a minimum of three hours at 77° C, using the pit heating system.

At this point in the preparation process, the casting segment is ready for internal application of Chemlok primer in preparation for insulating.

Case Refurbishment

Recovered SRM casting segments will be received from the Wasatch Division test area or the launch site. The SRM will have been disassembled into the four casting segment configurations. Upon receipt, the solid rocket motor segments will be placed on a dolly designed to interface with the existing high-pressure washout equipment (M-115). The segment and dolly will be transported to this facility for washout operations.

The M-115 facility utilizes high-pressure water to remove inert insulation from rocket motor cases. A 15,000-liter tank supplies water to the high-pressure pump which delivers a cutting pressure of ~4000 N/cm^2. The nozzle will be positioned off-center inside the segment to enable close position to the segment wall. The casting segment will then be rotated to accomplish the washout operation. The inert solids will be separated from the water into collection hoppers for ultimate transfer to the waste disposal area.

After washout, the casting segments will be transported to the inert parts complex for: disassembly, vapor degreasing, grit blasting with zirconium silicate, magnetic particle inspection, and storage.

Insulation

The installation of the rubber insulation in the SRM casting segments will use both a manual and semimechanized layup technique, followed by in-place autoclave vulcanization.

The insulation will be a silica and asbestos filled acrylonitrile butadiene rubber (NBR). The insulation formulation is shown in Table F-1 below.

TABLE F-1. SRM INSULATION FORMULATION

Constituent	Mass Percent
Chemigum N-7 (NBR)	56.31
Silica (HI SIL 233)	11.28
Magnesium Silicate (Asbestos)	28.18
Zinc Oxide	2.82
Sulfur	1.13
Methyl Tuads (Tetramethyl Thiuram)	0.28

The NBR will be purchased in rolls, each roll being packaged in a separate carton and stored at a maximum of 27° C. Uncured NBR extrusions will also be procured for use in the layup where irregular-shaped pieces can be used. This application will normally be in the thicker insulation area of the segment joint.

Prior to the layup of the internal NBR insulation, a Chemlok adhesive is applied to the internal surfaces of the casting segment. After Chemlok application, segments will be removed from the spray booth and positioned on a process dolly for transfer into the insulating bay.

After the proper number and orientation of insulation pieces have been prepared to meet the insulation profile in the forward clevis joint and inhibitor, the aft and center segments will be repositioned on the process dolly and moved into the horizontal insulating work station. At this point, the insulating process for all three casting segment configurations, aft, center, and forward, will take place.

The insulation in the cylindrical section of the segments will be applied to the segment wall directly from the roll, using a mechanical feed system. This tool feeds the insulation onto the cylinder wall and also rolls the insulation into place.

A bleeder cloth and vacuum bag film will be positioned over the top of the insulation. The edges and ends of the vacuum bag are sealed using noncuring vacuum putty, and a series of vacuum lines are attached from a manifold to the vacuum bag. The air is evacuated from between the bag and insulation, and the arrangement is checked for leaks, which are sealed as required with vacuum putty.

Vulcanization will be accomplished in a horizontal autoclave which will be sized for the SRM casting segments and will have a pressure range of 0 to 170 N/cm^2 (17 atmospheres) and a maximum temperature of 200° C. The autoclave will be pressurized using CO_2 gas.

After removal from the autoclave, the vacuum bag material will be removed from the segment, and the insulation surface will be solvent cleaned with trichloroethane. At this point, segments are ready to proceed into the liner application process.

Liner

The liner formulation is identical to that used on the Stage I Poseidon motor, and it is very similar to the liner used in Stage I Minuteman and Genie motors. The processing techniques for this liner have been thoroughly developed. The liner formulation is shown in Table F-2.

TABLE F-2. TYPICAL SRM LINER FORMULATION

Constituent	Function	Approximate Mass Percent
Carboxyl Terminated Polybutadiene Polymer (HC Polymer)	Binder	83.42
Tris 1-(2 Methyl)Aziridinyl Phosphine Oxide (MAPO)	Curing Agent	2.18
Epoxy Resin, Trifunctional (ERL-0510)	Curing Agent	1.35
Hydrogenated Castor Oil (Thixcin E)	Thixotropic Agent	1.75
Iron Octoate	Cure Accelerator	1.00
Magnesium Silicate (Asbestos)	Insulation Filler	10.30

The liner ingredients are stored in closed containers and are temperature controlled. When mixes of liner are required for production use, the ingredients are drawn from accepted raw material lots and measured in compliance with a formulation sheet or batch card.

Liner application will be accomplished in three of four existing deep pits in the inert parts preparation complex. Each of these pits was specifically designed for application and high temperature cure of Thiokol liner formulations. A workstand will be positioned in each pit to support the casting segment during the liner application and cure operations.

The cylindrical portion of the segment will be lined using the sling lining technique. The liner material is viscous, tenacious, and difficult to spray. However, successful development of the specialized equipment and procedures of the sling lining technique facilitate a straightforward, high quality application. With this qualified technique, the liner material is pumped down the sling liner boom into a hollow, rotating disk and physically impelled by centrifugal force onto the insulation, producing intimate surface contact and wetting action. The sling liner device is programmed to traverse the case length automatically in several passes to apply the required quantity of liner. This multiple-pass application assures uniform distribution of the liner.

The dome section design of the aft segment will also allow it to be sling lined. The traverse speed and liner material feed rate will be varied in the aft dome section to achieve the specified liner thickness.

After application, the liner surface will be visually inspected for complete coverage and uniformity, and oven cured. Upon completion of liner cure, the segments will be weighed, the end covers will be installed on the segment to protect the liner surface from contamination, and the segments will then be shipped to the propellant casting pits.

SRM Propellant

Propellant mixing, casting and curing facilities are available to support production of Shuttle SRMs. All processes are state of the art and have been demonstrated in the production of more than 90 million kg of the selected propellant formulation.

To minimize thrust imbalance between two SRMs during launch of the Shuttle vehicle, two motor segments will be cast simultaneously using two or more propellant mixers. Blending will be achieved by alternately casting mixes from each mixer into each segment.

Oxidizer Preparation. Oxidizer (ammonium perchlorate) preparation for Shuttle SRM propellant will employ the same facilities and processes that are used for Minuteman and Poseidon propellants (M-606).

Oxidizer is stored in 2,040-kg weatherproof Econ-O-Bins on existing outdoor, lightning protected, all-weather paved pads. These containers are loaded by the AP vendor, and no material transfer is required until the bin is unloaded into processing equipment.

Oxidizer preparation consists of grinding a portion of the AP, then weighing predetermined quantities of the ground and as-received unground AP into a special transport container designed for in-house handling of AP. This container (a tote bin) is sealed and taken to the propellant mixer building and serves to feed the AP directly into the mixer. Approximately one-third of the AP must be ground to achieve ballistic and rheological property control; the other two-thirds is used as received.

Premix Preparation. Premixing propellant ingredients, excluding the oxidizer, is common practice in propellant processing. It allows use of much less expensive equipment to conduct the nonhazardous portion of the ingredient mixing, reserving the higher cost propellant mixer for that portion of the ingredient mixing cycle that truly needs it.

All propellant ingredients, other than oxidizer, are weighed and charged to the propellant mix bowl in the premix operation. This consists of the polybutadiene acrylic acid acrylonitrile (PBAN) polymer and epoxy curing agent (ECA) liquids, and aluminum and iron oxide powders. The purpose of the premix operation is to accurately charge the mixer bowl with these ingredients in a manner that is safe, and which remains safe when the bowl is installed on the propellant mixer and the oxidizer added.

The PBAN and ECA will be delivered in tankers from the vendors directly to the tank farm. The four larger polymer tanks will store a total of 220,000 kg of PBAN polymer. The four epoxy curing agent tanks will store 48,000 kg.

Aluminum powder is received in 2,500-kg Econ-O-Bins and stored on existing all-weather pads. In-plant transportation of aluminum powder Econ-O-Bins will be on existing flatbed trucks.

Iron oxide powder is used in very small quantities. It will be procured in 23-kg cans and stored in the raw materials warehouse. It will be transported to the premix building (M-120) by the pallet load for a working inventory and to minimize handling.

During premix, the first material added to the mixer bowl is the PBAN polymer. The second material added will be aluminum powder. With the required amount of aluminum powder and polymer in the mixer bowl, the iron oxide powder will be weighed and then added to the mix. After a brief stirring period, the ECA is added to the bowl. The ECA is not stirred into the mix in order to retard the cure reaction until the bowl is at the propellant mixer. The bowl cover is then installed and sealed, and the bowl is ready for transport to the mixer building.

Propellant Mixing. Three available 2270-liter vertical change-bowl mixers will be used to support the Shuttle SRM DDT&E Program.

Each mixing facility includes hoisting capability for handling mixer bowls on and off the bowl transport trailers, an oxidizer tote bin handling, dumping, screening and feeding system, and remote controls and monitoring instrumentation.

The prepared oxidizer tote bins will be transported to the mixer building on a flatbed truck. Premix, prepared as described earlier, will be transported in a mixer bowl on a trailer and pulled by a tug vehicle. The tote bin and mix bowl will be moved to the mixer building at the beginning of the cycle. An empty tote bin will be removed from the dump station and placed on the truck. The full tote bin will be picked up from the truck and placed on the dumper. The empty bin is then returned to the oxidizer preparation building for recharging with ammonium perchlorate.

During the change of tote bins, a bowl trailer is positioned at the mixer and a full bowl of finished propellant is placed on the empty trailer. The bowl containing the premix is then taken off another bowl trailer and placed on the rails that lead to the mixer. The bowl is moved on the rails to its position under the mixer housing and blades.

The operators performing these mixer operations will have the control key to the control panel with them, so that no equipment can operate until they return to the control room. After returning the key to the control room operator, the operator will remotely raise the bowl into position on the mixer and start the mixer. At appropriate times in the cycle, the oxidizer feed system will be started. At the end of the mix cycle, the bowl will be remotely lowered from the blades.

Propellant adhering to the mixer blades will be wiped off the blades manually to prevent propellant from dripping onto the floor when the bowl is removed. At this point, operations personnel will remove a small amount of propellant from the mix bowl for laboratory testing. After the transport cover is installed on the bowl, the bowl is rolled out of the facility and transported to the casting area.

Propellant Casting. The SRM segment casting will be accomplished in a 12-pit casting complex (Figure F-1) which consists of two rows of six pits. Each row is serviced by a 45-metric ton gantry crane with a 180-metric ton gantry crane existing on one row. Another 180-metric ton gantry crane will be required for the other row.

As part of the casting complex, there are two casting houses (Figure F-1) which move from pit to pit during segment installation, casting, and tool removal operations. Some modifications will be required to one of the casting houses to accommodate SRM casting. A new mobile pit house will have a retractable roof for installing and removing very large items, such as the segment itself, the vacuum bell and dome, cores, and centering rings.

The casting pit operations include: tooling and segment assembly, propellant casting, propellant cure, tooling disassembly, and segment removal.

The insulated and lined casting segment will be lifted off the transport trailer and lowered into the pit and onto the casting stand. The prepared assembled core will then be lowed into position, followed by the lowering of the vacuum bell. The vacuum bell dome is then lowered onto the bell. After passing leak tests, the casting arrangement is then ready for positioning of the casting house. The house is positioned over the pit, and associated casting equipment is installed using the existing casting house bridge crane.

Propellant in the mix bowl is received at the casting house on a trailer, as described earlier. The bowl is lifted off the trailer and into the building by the casting house bridge crane. The bowl is then positioned over an empty casting hopper and the propellant is poured out of the mix bowl into the hopper. Only after Quality Control (QC) has accepted the mix, is the propellant allowed to flow into the motor. The mix bowl is removed from the dump stand, lowered onto the bowl trailer, and returned to the premix area. Successive mixes are dumped into the three hoppers in rotation.

Casting is accomplished by opening the valves between a hopper and a bell dome. The vacuum in the bell draws the propellant into the segment. On exposure of the propellant to the vacuum, trapped air bubbles are released, insuring a void-free propellant grain.

When the propellant level is correct and vacuum released, tooling disassembling begins. The hoppers and associated assemblies are removed first and sent to the cleanup building. The vacuum bell dome is removed, and the wet propellant level manually adjusted to the design dimension and trowelled smooth. The dimensions and surface quality are then verified by inspectors. Finally, the vacuum bell will be hoisted out of the pit, leaving the cast segment in place. The pit covers are closed and the propellant is cured (see motor finishing section of this appendix).

Nozzle Processing

All nozzle processing efforts will be performed in five existing buildings (M-10, M-52, M-111, M-113, and M-116). These buildings are all in the same complex on two adjacent blocks.

The nozzle ablative liners will be tape wrapped, hydroclave or autoclave cured, and machined in Building M-113. Buildings M-52 and M-10 will be used to perform the following functions:

- Metal parts inspection, chemical cleaning, vapor degreasing, grit blasting, and painting
- Flex bearing fabrication and molding
- Vacuum casting of fixed housing insulation
- Layup and molding of boot
- Nozzle metal parts refurbishment.

The nozzle bonding and final assembly operations will be performed in Building M-116.

The SRM nozzle processing effort is divided into three general categories: metal structural components, ablative liner/insulating parts, and the flexible bearing. Thiokol will subcontract the fabrication of all metal components.

The D6AC alloy will be prepared using the same methods employed for the Stage I Minuteman and the Titan SRM cases. The process is initiated with melting in an electric furnace where an electrode ingot is made to the specified composition range. The electrode ingot is then remelted by the consumable electrode method under vacuum into an ingot for reprocessing into finished components.

The fabrication process will begin with a billet cut to the proper weight. The billet will be upset and pierced in a press, rendering the initial shape, and then roll formed to an intermediate size for inspection and conditioning before final ring rolling. The forgings will be heat treated to provide the required metallurgical specifications and machined to final dimensions. Final inspection consists of ultrasonic and magnetic particle inspection. After final inspection, the fixed housing will be pressure tested. The components will then be protected with oil and shipped to Thiokol for subsequent processing.

The 7075-T73 alloy billets will be forge/roll formed to the rough forging dimensions. Ultrasonic inspection will be performed prior to heat treating. Following heat treating, the parts will be machined to final dimensions. The aluminum parts will then be shipped to Thiokol for subsequent processing.

The ablative and insulative liner materials will be procured from established suppliers used on prior production programs. The process flow for the carbon cloth tape begins with rayon cloth material as the precursor. The rayon is heated in an oven, thus turning the rayon to carbon cloth. The carbon cloth is then impregnated with a carbon filled phenolic resin, which results in the final product as received at Thiokol. The raw material is inspected visually for workmanship and chemically by testing for volatile content, resin solids, carbon filler content, and resin flow. The carbon cloth tape will be stored at 4°C maximum until required for processing.

The glass and silica cloth phenolic materials start out as woven cloth which is impregnated with the same resin as the carbon cloth, except that a silica filler is used in place of the carbon filler. The same inspection is performed on all three materials.

The carbon fiber filled silicone rubber insulation material used to protect the fixed housing and cowl housing will be procured as a silicone resin base and a curing agent. The material will be inspected for viscosity, working life, and constituents.

The adhesive and sealants will be procured, inspected, and properly stored until required.

The natural rubber compound used to form the elastomer pads between the steel shims in the flex bearing will be procured in accordance with existing Thiokol specifications and from established suppliers.

Nozzle Refurbishment

The nozzle metal parts and the flex bearing will be refurbished to reduce overall nozzle cost. The initial disassembly, cleanup, and passivation of the salt water condition will be performed at the launch recovery site during the SRM post-flight disassembly operations. The final refurbishment will be performed at the Thiokol/Wasatch Division.

The nozzle will be removed from the aft segment and placed vertically with the nose down and disassembled to the point that all bolted joints are separated. All of the assemblies will be flushed with fresh water until all visible contaminants are removed. The nozzle assemblies will be dried with forced air and all bare metal surfaces coated with oil, and returned to Thiokol/Wasatch for further processing.

The nozzle refurbishment effort is divided into five basic processes:

(1) Remove ablative liners and adhesives from the D6AC steel components and reinspect

(2) Remove ablative liners and adhesives from the aluminum components and reinspect

(3) Proof pressure test the fixed housing, remove, reinspect and replace charred insulation

(4) Clean the flex bearing, conduct acceptance pressure test, and reinspect

(5) Remove the elastomer and primer from the flex bearing metal parts and reinspect.

After the metal parts have been refurbished and reinspected, they will be preserved and identified (to record the number of times refurbished) and sent to storage for reuse the same as a new component.

Ignition System

The SRM ignition system is composed of four basic parts: an igniter, an initiator, an igniter adapter, and a safety and arming (S&A) device. After processing of these components, final assembly will occur at M-16.

Igniter Processing. The processing of the igniter chamber is essentially identical to that employed for the SRM segments except for considerations associated with component size. The chamber will be received at the case preparation area, grit blasted and degreased. The chamber will be transferred to the lining area, where a coat of primer and adhesive will be applied to the chamber and allowed to air dry.

NBR insulation will be applied to the chamber interior and exterior. A vacuum bag will be installed on the internal and external insulation and the chamber will be positioned in an autoclave and cured.

After the insulation is cured, the liner will be applied. The premachined phenolic liner insert will then be bonded into place and cured. The chamber will then be transferred to the casting site (M-76).

Lined chambers will be assembled and preheated prior to propellant casting. The igniter propellant formulation is shown in Table F-3. Propellant mixes will be processed in the same way as described for SRM propellant mixing.

TABLE F-3. IGNITER PROPELLANT FORMULATION

Constituent	Function	Mass Percent
Ammonium Perchlorate	Oxidizer	77.0
Aluminum Powder	Fuel	2.0
Iron Oxide	Combustion Accelerator	3.0
PBAN Polymer and Epoxy Curing Agent	Binder/Fuel	18.0

After casting, igniter chambers will be transferred to the core seating area. The core will be positioned in the chamber and connected to the core seat plunger rod. The plunger rod is hydraulically controlled to slowly plunge the core into the propellant until seated. This is a remote operation, with the operator located outside the bay. After the core seating operation, the chamber will be placed in an oven to cure. After a cooldown period, the core will be remotely removed from the chamber. A pneumatically driven cutback machine will be operated from a remote station outside the bay and a rotary blade will cut back the propellant grain until the desired dimension is reached.

Initiator Processing. New initiator chambers will be received, abraded, and solvent cleaned. The same liner that was used for the igniter chamber will be used for the initiator. Similar procedures will be used. The initiator will be cast employing the same propellant mixes as used for the igniter.

Igniter Adapter Processing. The igniter adapter is a forged and machined purchased part, which receives magnetic particle and dimensional inspection prior to acceptance. Refurbished parts will be subjected to the same acceptance testing. Silica filled NBR insulation will be bonded to the outer surface of the adapter.

Safe and Arm Device Processing. The safe and arm (S&A) device is a purchased unit and is received without the boron-potassium nitrate pellets installed. A foam cushion will be installed into the booster barrier and it will be loaded with boron-potassium nitrate pellets and a barrier plate installed.

Motor Finishing

Motor finishing operations for the forward and center segments will begin after propellant casting and at the point where the trowelable inhibitor is to be applied on the segment propellant surfaces. Finishing operations for the aft segment will begin at the core removal operation.

Midway through propellant cure, an inhibitor will be applied to the propellant surface of the forward and center segments. The inhibitor will then cure simultaneously with the completion of propellant cure.

Following propellant cure of the forward, center, and aft segments, the core tooling will be lifted from the motor segments with the gantry crane and lowered onto a handling trailer for transport to the cleanup building. The segment will be lifted free of the pit and transferred laterally along the gantry rails to the breakover fixture, which rotates the segments from vertical to horizontal or from horizontal to vertical.

The bed of the transporter/dolly is detachable from the tow tractor coupling and will be attached to the breakover fixture, so that when the segment is installed into the breakover fixture, it will be positioned on the transporter/dolly bed. The transporter/dolly will carry the SRM segment to the X-ray inspection building, M-39. The tractor will position the transporter/dolly within the building. A film holding fixture will be installed to allow complete inspection of the propellant grain.

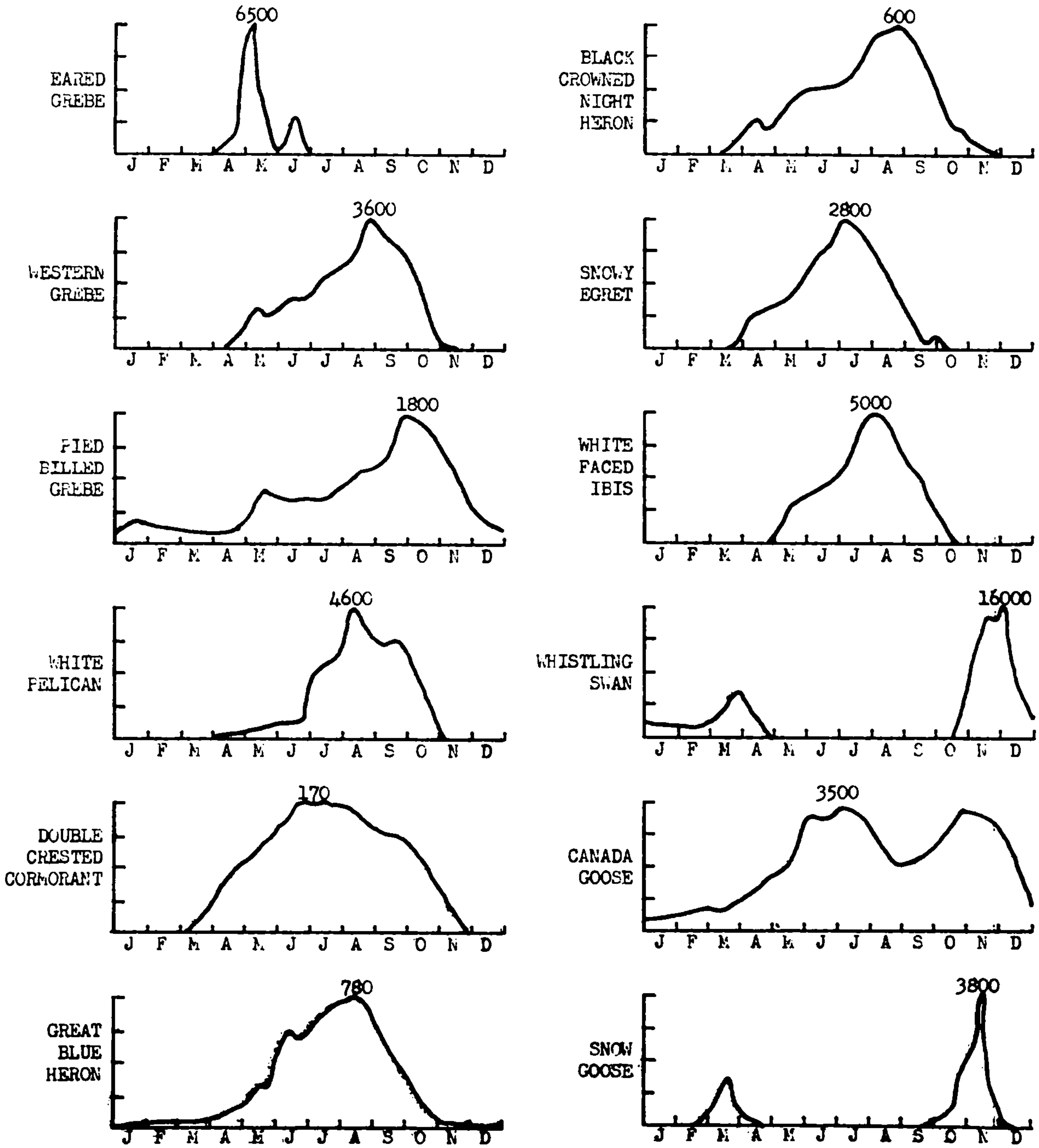
After X-ray inspection, the segment will then be moved to the motor finishing building (M-67). Forward segments will have the igniter assembly installed. The operational flight instruments will be installed and the SRM segment weight and center of gravity will be determined. Instrumentation peculiar to static test motors will be installed and checked out at the static test bay (T-24).

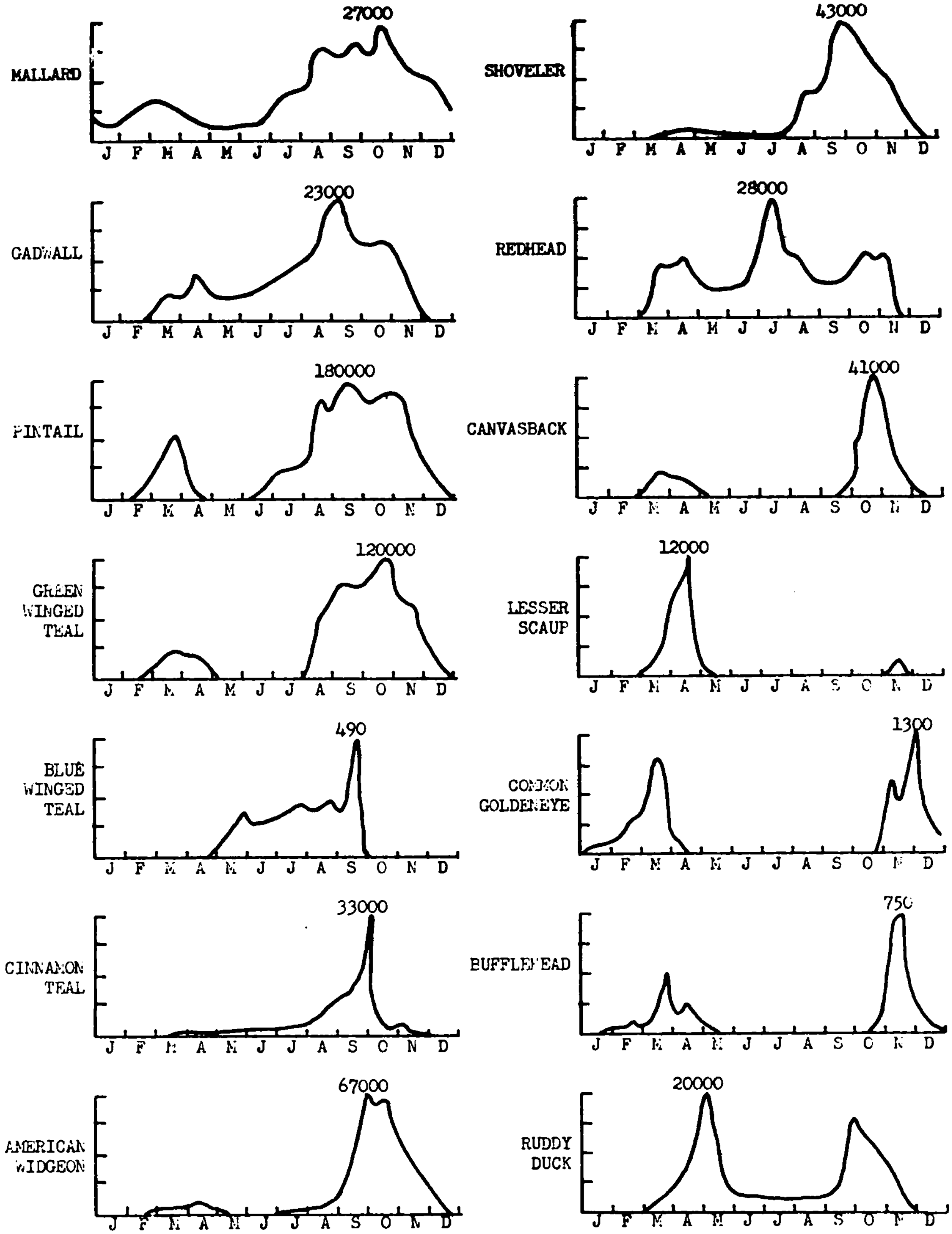
The nozzle subassembly, less the exit cone extension, will be installed on aft SRM segments. After the proper inspections and tests, nozzle alignment will be performed.

APPENDIX G

AVERAGE MONTHLY ABUNDANCE BY SPECIES OF BIRDS
ON THE BEAR RIVER REFUGE

AVERAGE MONTHLY ABUNDANCE BY SPECIES OF BIRDS
ON THE BEAR RIVER REFUGE
(SOURCE: Reference 18)

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SHOVELER
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GADWALL
23000
REDHEAD
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PINTAIL
180000
CANVASBACK
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120000
LESSER SCAUP
12000
BLUE WINGED TEAL
490
COMMON GOLDENEYE
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BUFFLEHEAD
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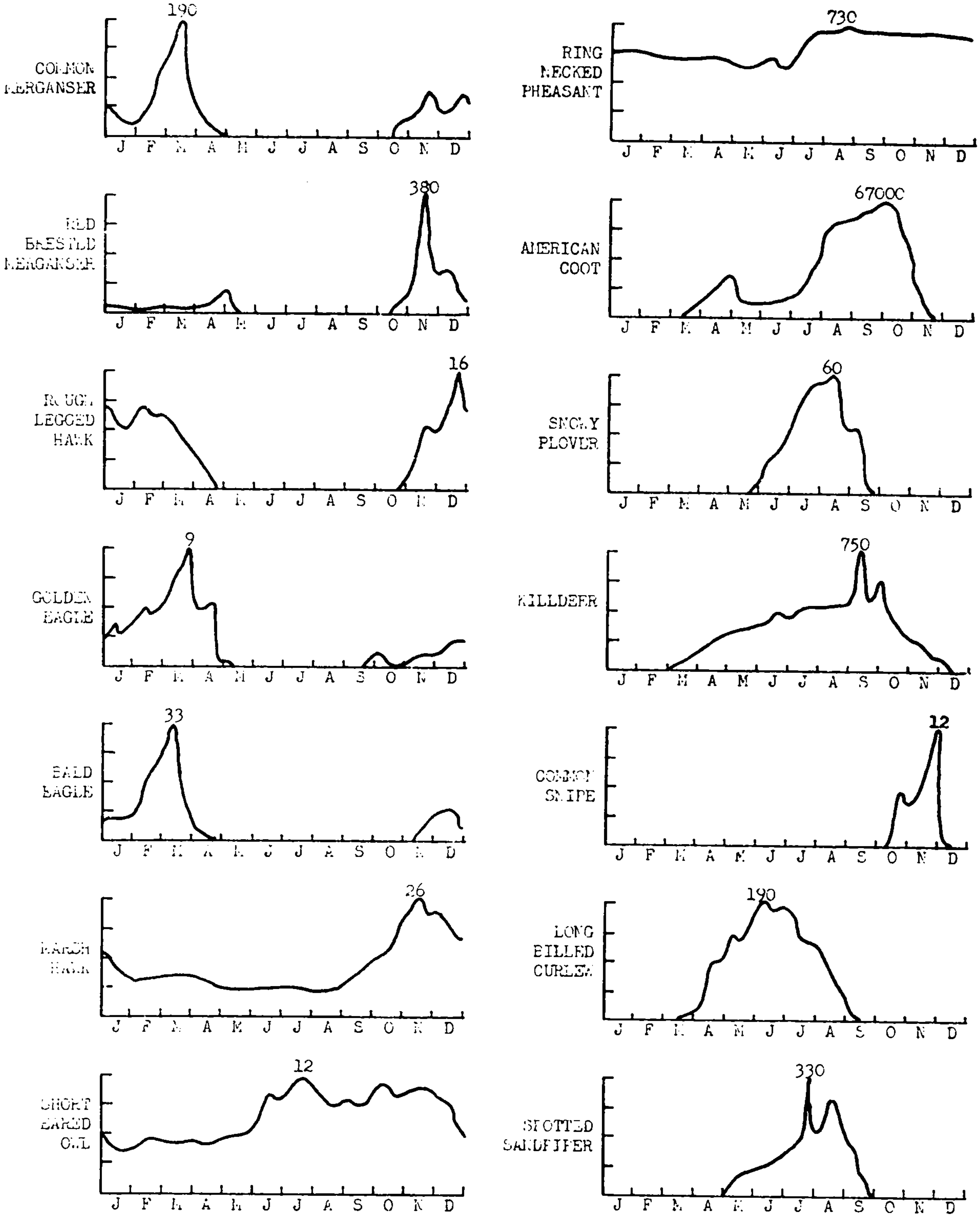
AMERICAN WIDGEON
67000
RUDDY DUCK
20000
J F M A M J J A S O N D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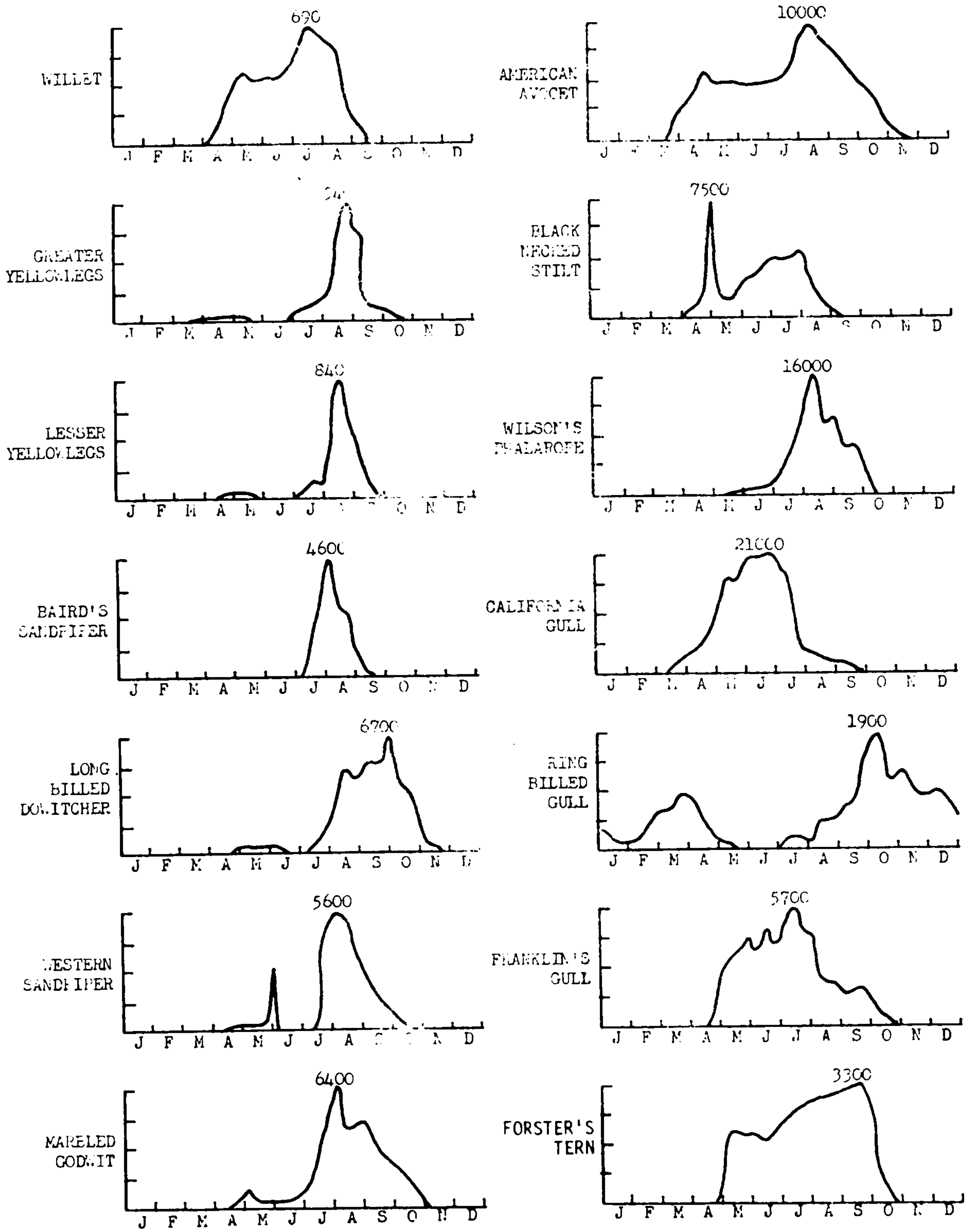
RING NECKED PHEASANT
730
RED BREASTED MERGANSER
380
AMERICAN COOT
67000
ROUGH LEGGED HAWK
16
SNOWY PLOVER
60
GOLDEN EAGLE
9
KILLDEER
750
BALD EAGLE
33
COMMON SNIPE
12
MARSH HAWK
26
LONG BILLED CURLEW
190
SHORT EARED OWL
12
SPOTTED SANDPIPER
330
J F M A M J J A S O N D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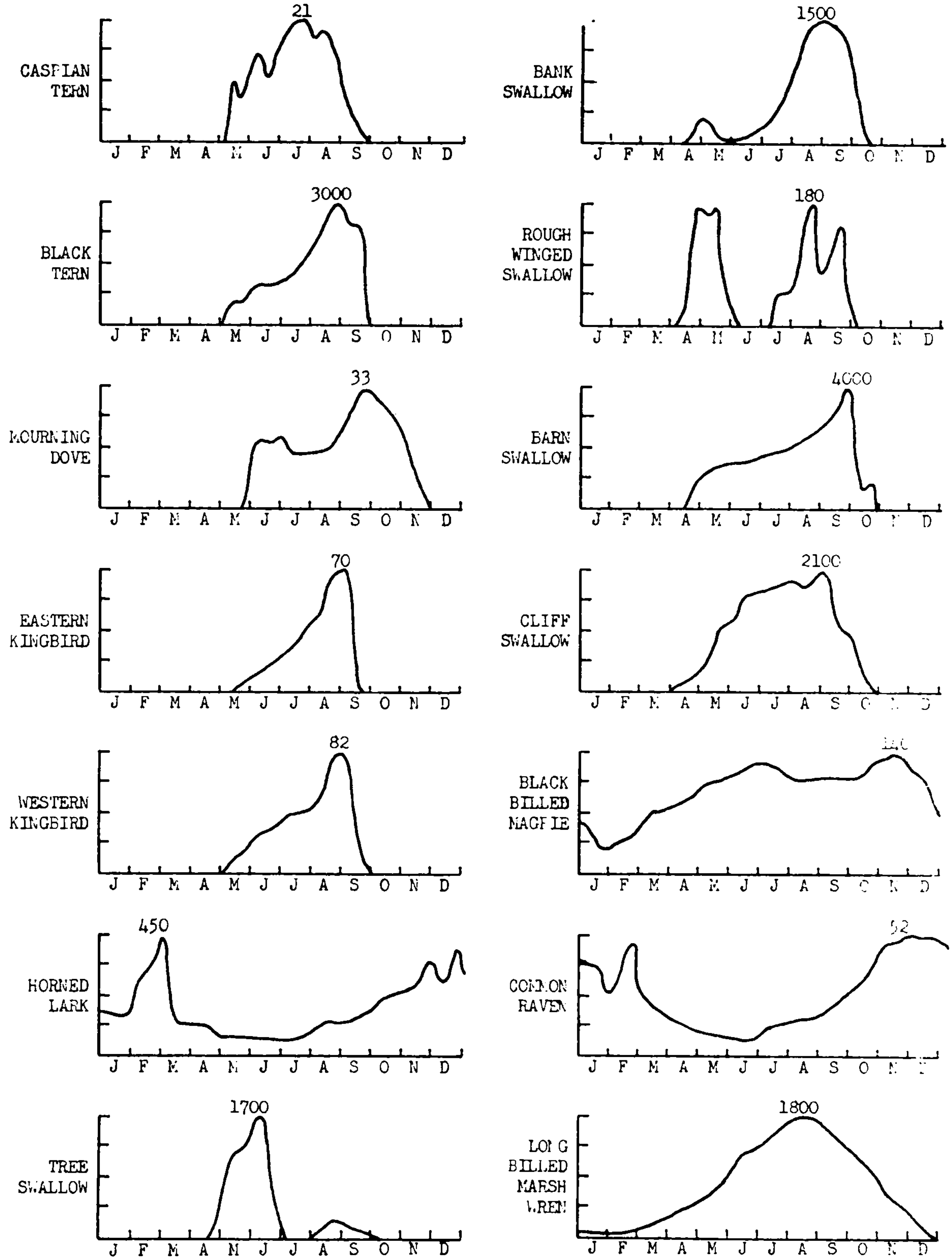
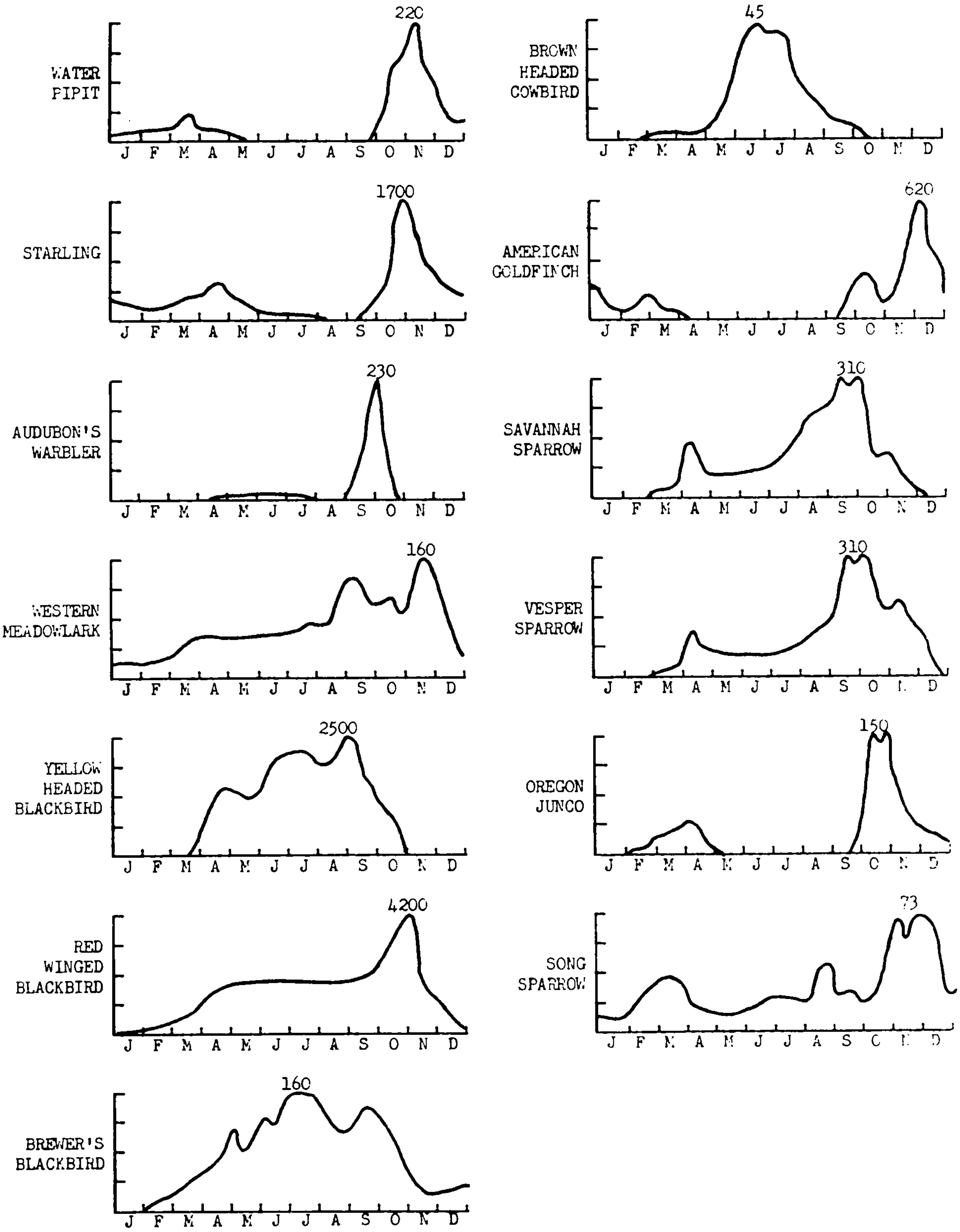
AMERICAN AVOCET
10000
GREATER YELLOWLEGS
BLACK NECKED STILT
7500
LESSER YELLOWLEGS
840
WILSON'S PHALAROPE
16000
BAIRD'S SANDPIPER
4600
CALIFORNIA GULL
21000
LONG BILLED DOWITCHER
6700
RING BILLED GULL
1900
WESTERN SANDPIPER
5600
FRANKLIN'S GULL
5700
MARBLED GODWIT
6400
FORSTER'S TERN
3300
J F M A M J J A S O N D



CASPIAN TERN
21
BANK SWALLOW
1500
BLACK TERN
3000
ROUGH WINGED SWALLOW
180
MOURNING DOVE
33
BARN SWALLOW
4000
EASTERN KINGBIRD
70
CLIFF SWALLOW
2100
WESTERN KINGBIRD
82
BLACK BILLED MAGPIE
HORNED LARK
450
COMMON RAVEN
TREE SWALLOW
1700
LONG BILLED MARSH WREN
1800
J F M A M J J A S O N D


WATER PIPIT
220
BROWN HEADED COWBIRD
45
STARLING
1700
AMERICAN GOLDFINCH
620
AUDUBON'S WARBLER
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SAVANNAH SPARROW
310
WESTERN MEADOWLARK
160
VESPER SPARROW
310
YELLOW HEADED BLACKBIRD
2500
OREGON JUNCO
150
RED WINGED BLACKBIRD
4200
SONG SPARROW
73
BREWER'S BLACKBIRD
160
J F M A M J J A S O N D

APPENDIX H

REGISTERED ARCHEOLOGICAL SITES IN THE VICINITY OF THE THIOKOL/WASATCH PLANTSITE

APPENDIX H

REGISTERED ARCHEOLOGICAL SITES IN THE VICINITY OF THE THIOKOL/WASATCH PLANTSITE

(SOURCE: Reference 19)

Site No: 42Bo12
Map Reference: None
Location: Sec. 6, T10N, R4W, "15 miles north of Corinne on hillside overlooking B Ranch"
Investigation Status: Surveyed
Type Site: Open; petroglyph
Cultural Affiliation: Unknown

Site No: 42Bo13
Map Reference: None
Location: "Sec. 8, T10N, R5w"
Investigation Status: Surveyed
Type Site: Rockshelter; projectile points and pottery; undetermined cultural depth
Cultural Affiliation: Great Salt Lake Fremont/Numic

Site No: 42Bo16
Map Reference: None
Location: Sec. 19, T11N, R5W
Investigation Status: Surveyed
Type Site: Cave; projectile points, pottery, ground stone in cave
Cultural Affiliation: Great Salt Lake Fremont/Numic

Site No. 42Bo17
Map Reference: None
Location: "Sec. 3, T10N, R5W, "one mile north of Highway 83 which runs from Corinne to Promontory, about 20 miles from Corinne"
Investigation Status: Surveyed
Type Site: Cave; pottery and chipped stone
Cultural Affiliation: Great Salt Lake Fremont/Numic

Site No: 42Bo24
Map Reference: None
Location: Sec. 28, T10N, R3W, "5 miles NW of Corinne on paved highway and about 2 miles East of paved road on the hillside. On Provo Terrace about 2 miles east of Corinne highway--looks SW to the lake over a vast area of cultivated land"
Investigation Status: Surveyed
Type Site: Cave; rockshelter
Cultural Affiliation: Great Salt Lake Fremont/Numic

Site No: 42Bo25
Map Reference: None
Location: Sec. 28, T10N, R3W, "Provo Terrace about 1 mile from site 42B024 on the Provo Terrace to the NW. Looks out to the SW to the lake"
Investigation Status: Surveyed
Type Site: Rockshelter; potsherd; grinding stone fragment; chips
Cultural Affiliation: Possibly Fremont and/or Numic

Site No: 42Bo26
Map Reference: None
Location: Sec. 28, T10N, R3W, "5 miles from Corinne about 3 miles east of road near the Bonneville Terrace about 1000 feet up the hill. Above the Bonneville Terrace looking SW to the lake, overlooking a large area of cultivated land west of Corinne"
Investigation Status: Surveyed
Cultural Affiliation: Possibly Fremont and/or Numic

Site No: 42Bo126
Map Reference: Bear River City Quad, Utah
Location: Sec. 30, T10N, R3W, "On Little Mountain 1/4 mi. northwest of Promontory Road and 1/2 mile west of Stinking Springs ca. 900 ft. up hillside"
Investigation Status: Surveyed
Type Site: Rockshelter/cave; chips, bone, charcoal, glazed pottery
Cultural Affiliation: Probably Great Salt Lake Fremont

Site No: 42Bo127
Map Reference: Public Shooting Grounds Quad, Utah
Location: Sec. 14, T10N, R4W, "Western side of Little Mountain approximately 1 mile north of Promontory Road and 1/3 mile from road along west Little Mtn."
Investigation Status: Surveyed
Type Site: Rockshelter; scattered, scanty remains of chips (obsidian) in talus in front of shelter
Cultural Affiliation: Unknown

Site No. 42Bo128
Map Reference: Public Shooting Grounds Quad, Utah
Location: Sec. 11, T10N, R4W, "West side of Little Mountain ca. 3 miles north of Promontory Road and 1/4 mile from improved dirt road running along west side of Little Mountain"
Investigation Status: Surveyed
Type Site: Rockshelter/Cave; potsherds, rock with scratching on it, chips of obsidian, burned bone, numerous small mammal bones
Cultural Affiliation: Possibly Great Salt Lake Fremont

Site No: 42Bo129
Map Reference: Brigham City Quad, Utah
Location: Sec. 6, T10N, R4W, "On E. side of Blue Springs Hills, ca. 3/4 mi. from extreme southeast tip and ca. 250 ft. up the hillside"
Investigation Status: Surveyed
Type Site: Cave; pictograph; cave 50 ft. long (N-S) and 8-10 ft. deep. Obsidian chips.
Cultural Affiliation: Unknown

Site No.: 42Bo130
Map Reference: Brigham City Quad, Utah
Location: Sec. 1, T10N, R5W, "1.0 mi. from the extreme SE tip of Blue Spring Hills ca. 300 ft. up hillside from dirt road"
Investigation Status: Surveyed
Type Site: Cave; 10 ft. wide, 15 ft. deep, 8 ft. high; obsidian scraper, chips, burned rocks on surface of deposits
Cultural Affiliation: Unknown

Site No: 42Bo131
Map Reference: Tremonton Quad, Utah
Location: Sec. 6, T11N, R3W, "E side of Salt Springs ca. 3 mi. W of Tremonton on road to Thatcher, 150-200 ft. N of road"
Investigation Status: Surveyed
Type Site: Open, one scraper, chipping detritus
Cultural Affiliation: Unknown

Site No: 42Bo132
Map Reference: Tremonton Quad, Utah
Location: Sec. 7, T11N, R3W, "ca. 1/3 mi. So of Tremonton-Thatcher highway on E bank of Salt Creek on ridge of high ground 150 ft. from creek"
Investigation Status: Surveyed
Type Site: Open; mano fragments, chipping detritus scattered on plowed ridge top
Cultural Affiliation: Unknown

Site No: 42Bo133
Map Reference: None
Location: "due west from Salt Springs ca. 50 yds."
Investigation Status: Surveyed
Type Site: Petroglyph
Cultural Affiliation: Possibly historic Numic/possibly others

Site No: 42Bo134
Map Reference: Tremonton Quad, Utah
Location: Sec. 6, T11N, R3W, "On W side of Salt Creek and Spring in a garden plot N of red brick house on road to Thatcher"
Investigation Status: Surveyed
Type Site: Open; points and chipping detritus
Cultural Affiliation: Unknown

Site No: 42Bo135
Map Reference: Thatcher Mtn. Quad, Utah
Location: Sec. 2, T10N, R4W, "On west side of Little Mtn. at north end located 200 ft. to north and 250 ft. up from gravel pit 1/4 mi. from dirt road"
Investigation Status: Surveyed
Type Site: Rockshelter; possible mano fragment, chips, bone
Cultural Affiliation: Unknown

Site No: 42Bo136
Map Reference: Public Shooting Grounds Quad, Utah
Location: Sec. 11, T10N, R4W, "Ca. 2-1/4 miles north of promontory road and 1/4 mile west of dirt road running along west side of Little Mtn. It lies next to a "spring"
Investigation Status: Surveyed
Type Site: Rockshelter; potsherds, numerous chips (obsidian), charred bone
Cultural Affiliation: Possibly Fremont (Great Salt Lake)

Site No: 42Bo137
Map Reference: Public Shooting Grounds Quad, Utah
Location: Sec. 11, T10N, R4W, "On north side of most western proturberance of Little Mtn. ca. 1/3 mile from dirt road (west of) ca. 150' above lower ground"
Investigation Status: Surveyed
Type Site: Cave; obsidian chips; bone
Cultural Affiliation: Unknown

Site No: 42Bo138
Map Reference: Tremonton Quad, Utah
Location: Sec. 19, T11N, R3W, "Site lies on high ground on the west side of the Salt Creek. It is about 100 yds. north of where the Salt Creek refuge fence crosses the creek and ca. 100' east of fence"
Investigation Status: Surveyed
Type Site: Open; potsherds, point (of white color and crooked), obsidian chips, point, shell and mano fragment.
Cultural Affiliation: Fremont/Numic

Site No: 42Bo139
Map Reference: Tremonton Quad, Utah
Location: Sec. 19, T11N?, T3W, "On the west bank of Salt Creek 3/4 of a mile north of where Refuge Road crosses creek. 100 yds. east of road and 50 yds. west of creek"
Investigation Status: Surveyed
Type Site: Open; obsidian chips, quartz broken point, mano fragments
Cultural Affiliation: Unknown

Site No: 42Bo140
Map Reference: Tremonton Quad, Utah
Location: Sec. 19, T11N, R3W, "ca. 1 mile from where Waterfowl Refuge Road crosses Salt Creek on west side of creek in flats"
Investigation Status: Surveyed
Type Site: Open; obsidian and quartz chips
Cultural Affiliation: Unknown

Site No: 42Bo141
Map Reference: Whistler Canal Quad, Utah
Location: Sec. 3, T8N, R3W, "On the SW side of Whistler's Bend a road runs S. to the flats. After leaving high (4210') ground and just before flats is site"
Investigation Status: Surveyed
Type Site: Open; scattered rocks (some burnt), quartzite, obsidian chips
Cultural Affiliation: Unknown

Site No: 42Bo142
Map Reference: Whistler Canal Quad, Utah
Location: Sec. 3, T8N, R3W, "Site lies along road that runs south from bird refuge road and begins at SW corner at Whistlers Bend"
Investigation Status: Surveyed
Type Site: Open; 1 sherd, daub, chips
Cultural Affiliation: Fremont?

Site No: 42Bo143
Map Reference: Thatcher Mt. Quad, Utah
Location: Sec. 34, T11N, R4W, "Site lies east of Jesse Knoll between there and the waterfowl area"
Investigation Status: Surveyed
Type Site: Open; obsidian chips, broken point, possible metate fragment
Cultural Affiliation: Unknown

Site No: 42Bo144
Map Reference: Tremonton Quad, Utah
Location: Sec. 6, T11N, R3W, "Site lies on high ground at extreme south tip of point lookout. About 1/4 mile north of salt springs"
Type Site: Petroglyph
Investigation Status: Surveyed
Cultural Affiliation: Unknown

Site No: 42Bo147
Map Reference: Bear River City Quad, Utah
Location: Sec. 19, T10N, R3W, "1 mi. east of Promontory Road on Little Mt. ca. 5 mi. west of Corinne"
Investigation Status: Surveyed
Type Site: Rockshelter: quartzite and obsidian chips
Cultural Affiliation: Unknown

Site No: 42Bo148
Map Reference: Bear River City Quad, Utah
Location: Sec. 11, T9N, R3W, "Going west from Corinne on Cemetary Road. Take first paved road to left. Continue south at bend, hit dirt road south into end"
Investigation Status: Surveyed
Type Site: Open; obsidian chips, charcoal; mano and numerous arrowheads reported

Site No: 42Bo149
Map Reference: Brigham City Quad, Utah
Location: Sec. ?, T12N, R5W, "ca. 1 mi. N and slightly E of Howell Ward-house in low range of hills. Visible from main road"
Investigation Status: Surveyed
Type Site: Rockshelter; scrap bone (burned and unburned)
Cultural Affiliation: Unknown

Site No: 42Bo151
Map Reference: Brigham City Quad, Utah
Location: Sec. ?, T10N, R4w, "On a flank of the Blue Spring Hills, ca. 1-1/2 mile north of Utah 83. About 50 ft. above and west of side road"
Investigation Status: Surveyed
Type Site: Rockshelter, bark fiber, stone chips, mano, scrap bone
Cultural Affiliation: Unknown

APPENDIX I

CLEARING INDEX DEFINITION

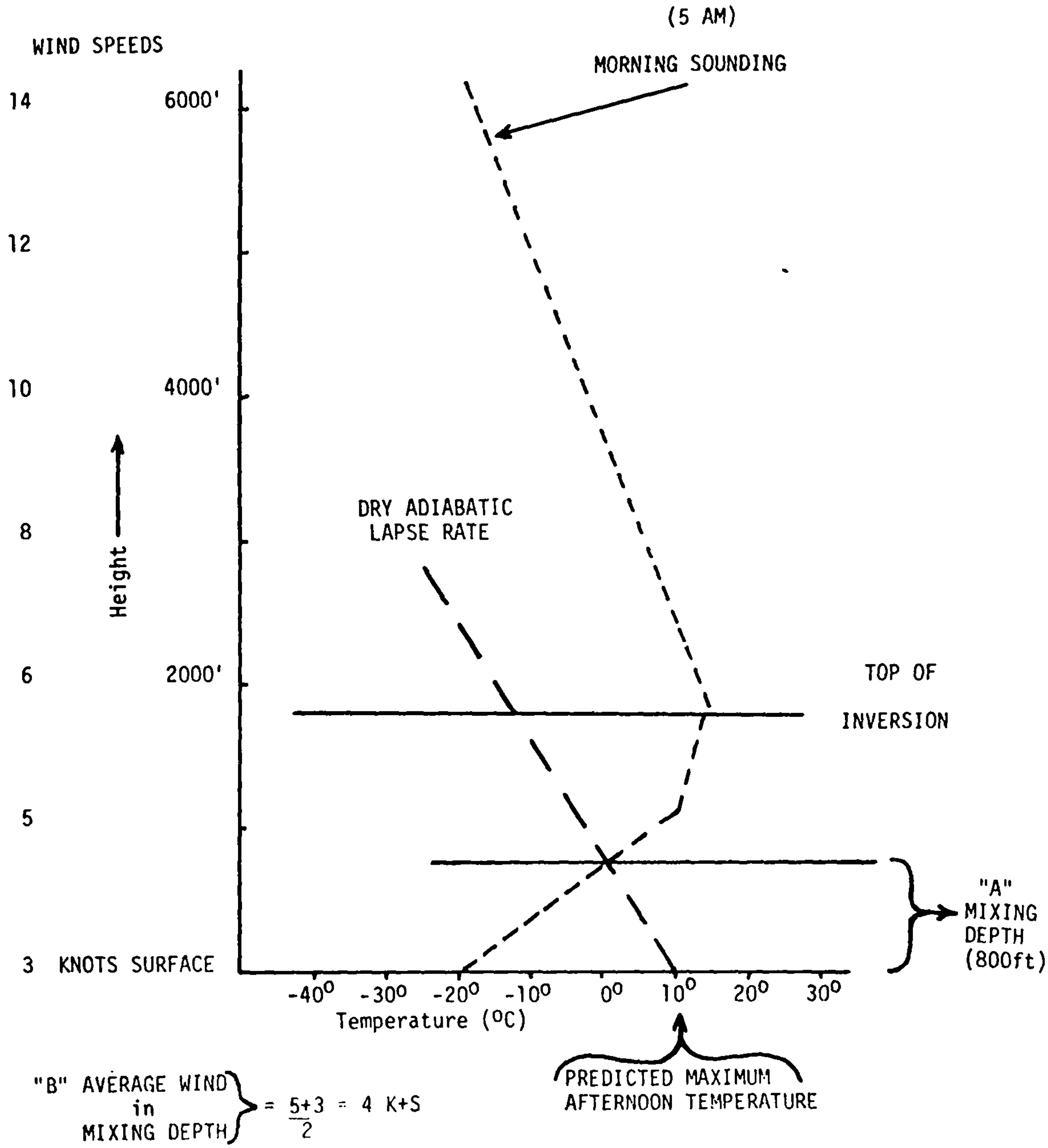
APPENDIX I

CLEARING INDEX DEFINITION[25]

The State of Utah uses a "Clearing Index" (CI) as a determining factor in granting permission for certain classes of open burning. The clearing index is directly related to atmospheric stability, indicating periods of ambient pollutant increase. The critical value has been found to be 500; lower values indicate atmospheric stagnation.

Under stable meteorological conditions (including temperature inversions), normal dispersion of pollutants emitted to the atmosphere is markedly diminished. In the Wasatch Front (Provo to Ogden), inversions occur almost daily. In the period March through October, stable atmospheric conditions build only during evening and night; during the daytime, surface heating normally causes the air to become unstable, thus dispersing pollutants through a deep layer of the atmosphere and, consequently, decreasing any pollution concentrations to insignificant levels. In the period November through February, cold air drainage from the mountains into the valleys sometimes causes deep temperature inversions to exist for periods up to three weeks without interruption. During such conditions, visibility decreases because of the formation of fog aggravated by increased particulate concentration.

An example of the method of calculation of the clearing index is diagrammatically shown in Figure I-1. The clearing index (CI) is defined as 1/100th of the product of the surface mixing depth (ft) times the average wind speed (kt) within that mixing depth. The surface mixing depth is calculated as the height above the surface where the dry adiabatic lapse rate for the predicted maximum afternoon temperature first intercepts the 5 a.m. Salt Lake temperature profile (sounding data).



$$\text{CLEARING INDEX} = \frac{\text{"A" x "B"}}{100} = \frac{800 \times 4}{100} = \underline{32}$$

FIGURE I-1. CLEARING INDEX DEFINITION [25]

APPENDIX J

ATMOSPHERIC DIFFUSION MODEL

APPENDIX J

ATMOSPHERIC DIFFUSION MODEL

If a small quantity of a gas is released in the atmosphere, its subsequent motion and dispersion is shown by observation to be described by a process resembling molecular diffusion, but with an effective diffusion coefficient that is from a few to many orders of magnitude larger than the molecular diffusion coefficient. This effective diffusion coefficient, often called the eddy diffusivity or turbulent diffusivity, results from the non-uniform, non-steady motion of the atmosphere, and depends basically on the degree of turbulence.

In principle, quite complex diffusion problems can be solved. The problem of predicting the dispersion of a pollutant released into the atmosphere thus becomes primarily that of determining the proper diffusion coefficient. Generally, this problem has been handled by defining broad classes of meteorological conditions, for example, "stable", "neutral", and "unstable", and establishing empirical measures of the turbulent diffusion coefficient for each condition.[82] However, if suitable meteorological measurements are available, it is possible to relate these empirical measures to more detailed features of the atmosphere. Over a period of years, the NASA/MSFC Multilayer Diffusion Program[27] has been developed to predict atmospheric dispersion of rocket effluents. The model is thermodynamically dependent and uses vertical profiles of wind velocity and variations in the wind azimuth and elevation angles to define measures of the turbulent diffusivity.

A second problem, particularly important for predicting the atmospheric dispersion of gases from static test firings and other hot releases, is defining the source; that is, the initial distribution of the gases resulting from the buoyancy of the hot exhaust gases. Observation shows that the exhaust gases form a cloud elevated above the surface. A combination of theoretical analysis and empirical observations has been used to create a mathematical model of the cloud, and thus provide a source description for subsequent atmospheric dispersion analyses.[27] However, one aspect of the source model may be subject to question and possible future revision. This is the distribution of the exhaust gases within the cloud. For the analysis used in this environmental assessment, the gases were assumed to have a Gaussian distribution. A uniform concentration within the cloud suggests itself as a plausible alternative to the Gaussian distribution, and exhaust cloud measurements made following Titan launches indicate that this type of distribution exists.[83] This situation is thought to arise as a result of the intense turbulent motion of the cloud, derived from the kinetic energy of the rocket exhaust, and the radial inflow of air at the base of the cloud as its buoyancy causes it to lift from the ground. Comparisons of the predicted downwind ground level concentrations of exhaust gases using these two distributions have shown that the use of the Gaussian distribution is conservative: that is, it results in higher predicted concentrations than does the uniform distribution.

In addition to the meteorological parameters mentioned previously, which are the principal factors determining the turbulent diffusivity of the atmosphere, the depth of the surface mixing layer or the presence of an inversion layer can profoundly affect the predicted ground level concentrations of rocket exhaust gases. A low lying inversion or shallow surface mixing layer is accompanied by a very stable atmospheric layer in which the diffusivity is very small. As a result, an inversion or the top of the surface mixing layer acts effectively as a barrier to diffusion; pollutants located below the inversion height are effectively trapped between the inversion and the ground, while pollutants located above cannot penetrate and, thus, theoretically contribute nothing to the ground level concentrations. Consequently, there is an interaction between the inversion height or height of the surface mixing layer and the height of the source cloud in determining the downwind ground level concentrations of exhaust gases.

The diffusion model used for this environmental assessment is Model 3 of the NASA/MSFC Multilayer Diffusion Program - Version 5.[27] Model 3 was chosen because of its extensive use at NASA/KSC in predicting downwind concentrations of HCl and other constituents resulting from the launches of Titan and Delta space vehicles, and its relatively good agreement with measurements. The reader is referred to Reference 27 for details concerning Model 3. The model employs data such as the temperature, pressure, relative humidity, and wind speed profiles, and the heat release rate (flow rate x specific heat content) to establish the cloud rise.

The combustion characteristics of the SRM propellant and meteorological conditions at the time of the release of exhaust constituents into the atmosphere are required as input to the MSFC preprocessor program[27] to calculate the cloud rise and the initial source strength distribution of pollutants in the troposphere. Five types of releases were considered for analysis in this environmental assessment of the Space Shuttle SRM DDT&E Program: (1) open burning of waste SRM propellant; (2) normal static test firing; (3) abnormal static test firing; (4) accidental forward segment ignition; and (5) accidental center segment ignition (see Section 4.2.3).

Propellant consumption, heat content, and exhaust species data, employed to calculate dispersion data presented in Section 4.2.3 for the five types of releases, are shown in Table J-1. Heat content data were based upon Reference 27. Heat content values would be higher by almost a factor of two if complete afterburning were to take place. The use of the lower heat content values results in lower cloud rise, hence higher, more conservative downwind ground level pollutant concentrations. Other data in Table J-1 are based upon References 27, 36 and 84.

TABLE J-1. DIFFUSION MODEL INPUT

	Type of SRM Propellant Combustion				
				Accidental Segment Ignition	
Property	Open Burning	Normal Test Firing	Abnormal Test Firing	Forward	Center
Propellant Expenditure Rate (kg/sec)	26.5	4,132	1,680	194.2	137.6
Total Burn Time (sec)	120	122	300	700	900
Propellant Heat Content* (kcal/kg)	1,000	1,500	1,000	1,000	1,000
Total Propellant Expended (kg)	3,175	504,050	504,050	135,900	123,800
Mass Fractions of Exhaust Species at Point of Release*					
Al_2O_3	.285	.304	.285	.285	.285
HCl	.180	.207	.180	.180	.180
CO	.250	.280	.250	.250	.250

* NOTE: Data do not include afterburning effects.

Data Sources: References 27, 36 and 84.

The combustion of SRM propellant in all of the five types of releases considered in this environmental assessment, results in the formation of a cloud of hot exhaust products which subsequently rises and entrains ambient air until an equilibrium with ambient conditions is reached. Previous cloud rise calculations for normal rocket launches, on-pad single SRM burns, and catastrophic failures have employed one of two cloud rise models, the "instantaneous" or "continuous" source cloud rise model. The reader is referred to Reference 27 for a detailed description of these cloud rise formulae. The continuous model has been used for on-pad single SRM burns and catastrophic failures. This model is more conservative than the instantaneous model, in that it predicts a lower cloud rise than the instantaneous model. These considerations, plus the fact that all of the releases considered here are of longer duration (considered "quasi-instantaneous") than those which employ the instantaneous model (e.g., Titan and Space Shuttle normal launches), have dictated the use of the continuous source cloud rise model for calculations.

The minimum, average, and maximum values for cloud rise, calculated for the five types of releases during the 23 meteorological conditions, are shown in Table J-2.

TABLE J-2. CLOUD RISE DATA

	Type of SRM Propellant Combustion				
				Accidental Segment Ignition	
Category	Open Burning	Normal Test Firing	Abnormal Test Firing	Forward	Center
CI < 500 (13 cases)					
Minimum	262	1353	802	457	419
Average	565	2126	1592	950	882
Maximum	976	2906	2379	1627	1617
CI ≥ 500 (10 cases)					
Minimum	392	1676	1102	556	497
Average	633	2710	2049	1196	1066
Maximum	978	4317	2881	1948	1750

NOTE: Cloud rise values represent the distance, in meters, of the cloud center above the surface.

Surface mixing layer depths used for diffusion calculation using Model 3 were chosen from levels identified in Reference 33, such that the mixing depths for calculations were just greater than those estimated by Salt Lake City Weather Station (see Table 13). The choice of deeper mixing depths results in slightly higher ground level effluent predictions, thus providing additional conservatism. Figure J-1 depicts the modeled configuration of the exhaust cloud at the time of stabilization for a normal SRM static test firing, if it were to have occurred on 28 January 1974 at the Thiokol/Wasatch plantsite. The dotted area in Figure J-1 represents the dimensions of the stabilized cloud that will disperse within the surface mixing layer. The cloud defined within the surface mixing layer is used in the dispersion calculations.

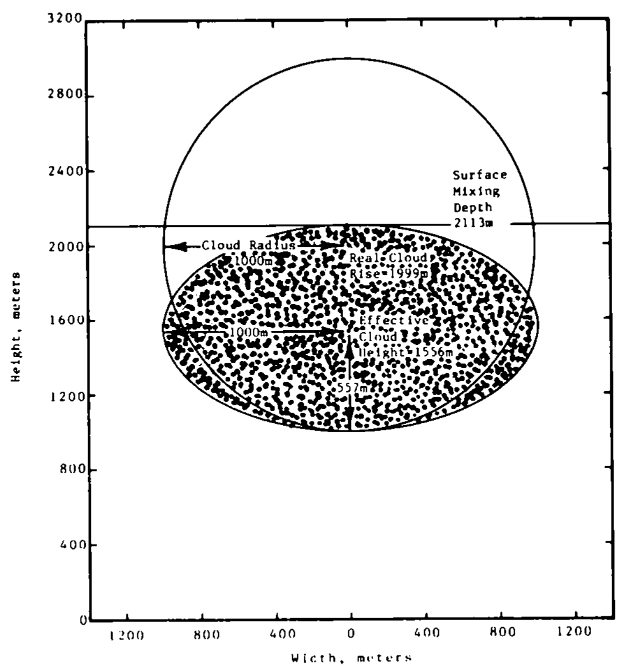


FIGURE J-1. CONFIGURATION OF STABILIZED CLOUD OF EXHAUST PRODUCTS FOR A SIMULATED NORMAL TEST FIRING OF THE SPACE SHUTTLE SRM IF IT WERE TO HAVE OCCURRED ON 28 JANUARY 1974

Examples of the Model 3 calculations for the maximum instantaneous peak concentration, the ten-minute average concentration and peak dosage for HCl as a function of distance at ground level for a normal SRM static test firing, if it were to have occurred on 28 January 1974, are shown in Figure J-2. Concentration and dosage data for all five types of releases are presented in Section 4.2.3.

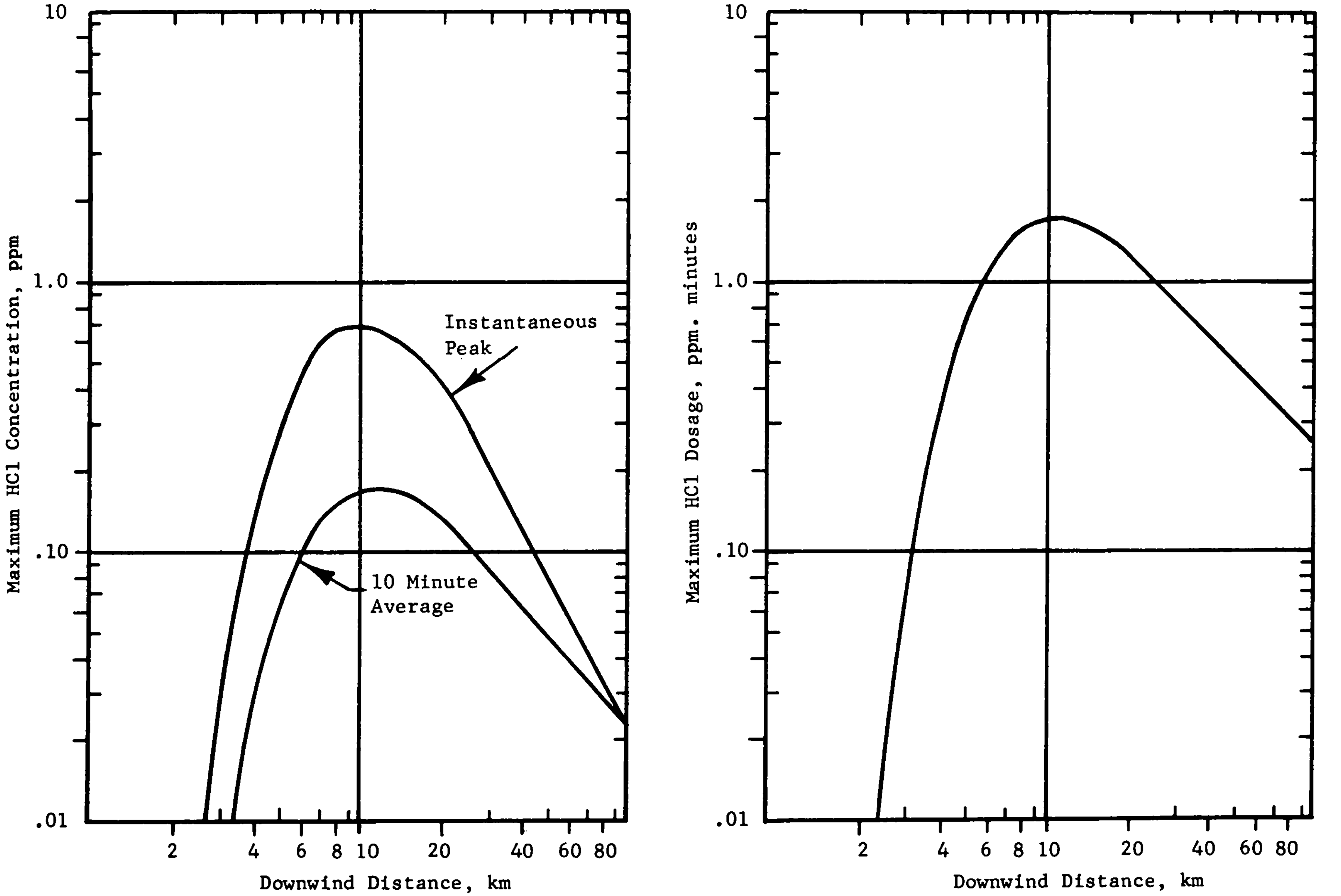


FIGURE J-2. PREDICTED MAXIMUM INSTANTANEOUS AND TEN-MINUTE AVERAGE HCl CONCENTRATIONS AND MAXIMUM HCl DOSAGES AT GROUND LEVEL FOR A SPACE SHUTTLE SRM STATIC TEST FIRING AT THIOKOL/WASATCH, IF IT WERE TO HAVE OCCURRED ON 28 JANUARY 1974

APPENDIX K

SOUND LEVEL PREDICTIONS FOR THE SPACE SHUTTLE SOLID ROCKET MOTOR TEST FIRINGS

APPENDIX K

SOUND LEVEL PREDICTIONS FOR THE SPACE SHUTTLE SOLID ROCKET MOTOR TEST FIRINGS

The mechanical power in the jet of a rocket engine is

$$W = 1/2\ TV,$$

where T is the rocket thrust in Newtons, V is the jet velocity in m/sec and W is the mechanical power in watts. For the Space Shuttle Solid Rocket Motor (SRM) where T is 11.6×10^6 N and V is 2570 m/sec, the mechanical power is 14,900 megawatts. Observations of many rocket motor firings have shown that between 1/4 and 1/2 percent of the mechanical energy in the jet is converted to acoustic energy.

The spectrum, or distribution of energy with frequency, of the noise generated by a rocket motor depends on the size of the rocket motor, in particular, the nozzle exit diameter, and the jet velocity. In general, large rocket motors generate high levels of low frequency sound. Also, high frequency sound is attenuated more rapidly by the atmosphere than is low frequency sound. As a result, at large distances from the rocket motor, much of the acoustic energy will be below the lowest frequency perceived by the ear, about 20 Hz. With the higher frequencies severely attenuated, the noise is heard as a rumbling sound.

Predicted Sound Pressure Levels

A method of predicting the noise levels due to a rocket firing, based on acoustic theory and many observations of large rocket motor firings is given in Reference 42. The equation is

$$OBSPL = 10 \log A(f) - 20 \log R - EA + DF + 10 \log f_0 - 9.5$$

where

OBSPL is octave band sound pressure level (dB)

A(f) is the spectral power distribution, watts/Hz

R is the distance from the rocket motor

EA is the atmospheric and other attenuations

DF is the directivity factor of the rocket motor sound source
f_o is the center frequency of the octave band
(lb-ft-sec are consistent units for the above equation).

The spectral power distribution, A(f), is dependent on the Strouhal number, f_oD/V, where D is the rocket nozzle exit diameter, and the total acoustic power radiated. The relationship between A(f) and the Strouhal number is plotted in Reference 42.

The values used for the attenuation of the sound by absorption in the atmosphere are those given by Reference 85, calculated for the temperature and humidity characteristic of the Thiokol/Wasatch test site. Figure K-1 shows the attenuation as a function of frequency. The combinations of temperature and humidity existing at the test site are such that a single curve can be used throughout the year for firings at approximately mid-day. In addition to the atmospheric attenuation given by Figure K-1, a further attenuation is observed which is ascribed to atmospheric inhomogeneities and ground

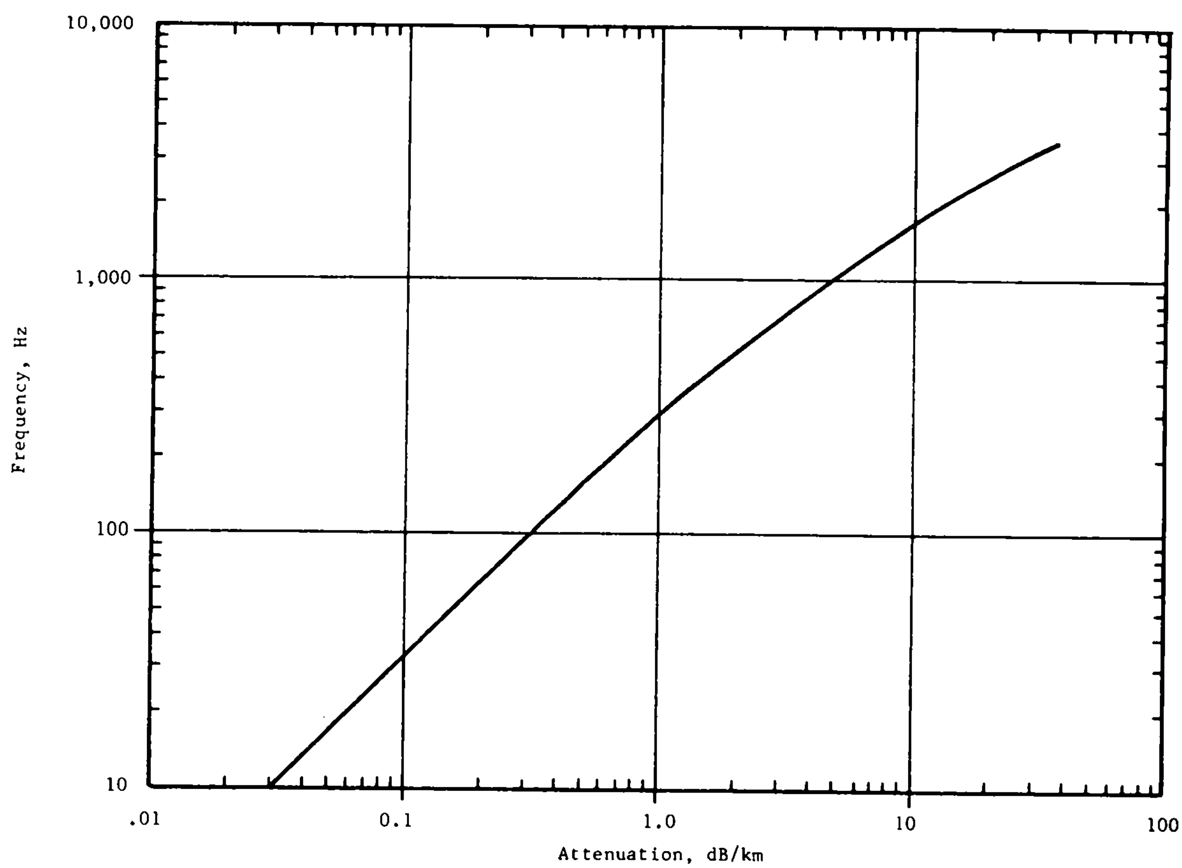


FIGURE K-1. ATMOSPHERIC ATTENUATION OF SOUND FOR THE THIOKOL/WASATCH TEST SITE effects.(86) This attenuation is highly nonlinear with respect to distance but can be approximated by a constant attenuation of 13 dB between about 400 and 1200 Hz, provided the distance is at least 1 km. Below 400 Hz, the attenuation decreases linearly with frequency. Above 1400 Hz, an additional attenuation of 11 dB/[(km)·(kHz above 1400 Hz)] occurs.

Figure K-2 shows the calculated noise levels at various distances from the test site in octave band levels as well as the overall sound pressure level for an assumed acoustic efficiency of 1/2 percent. For this figure, the directivity of the rocket motor sound source discussed below, was not included.

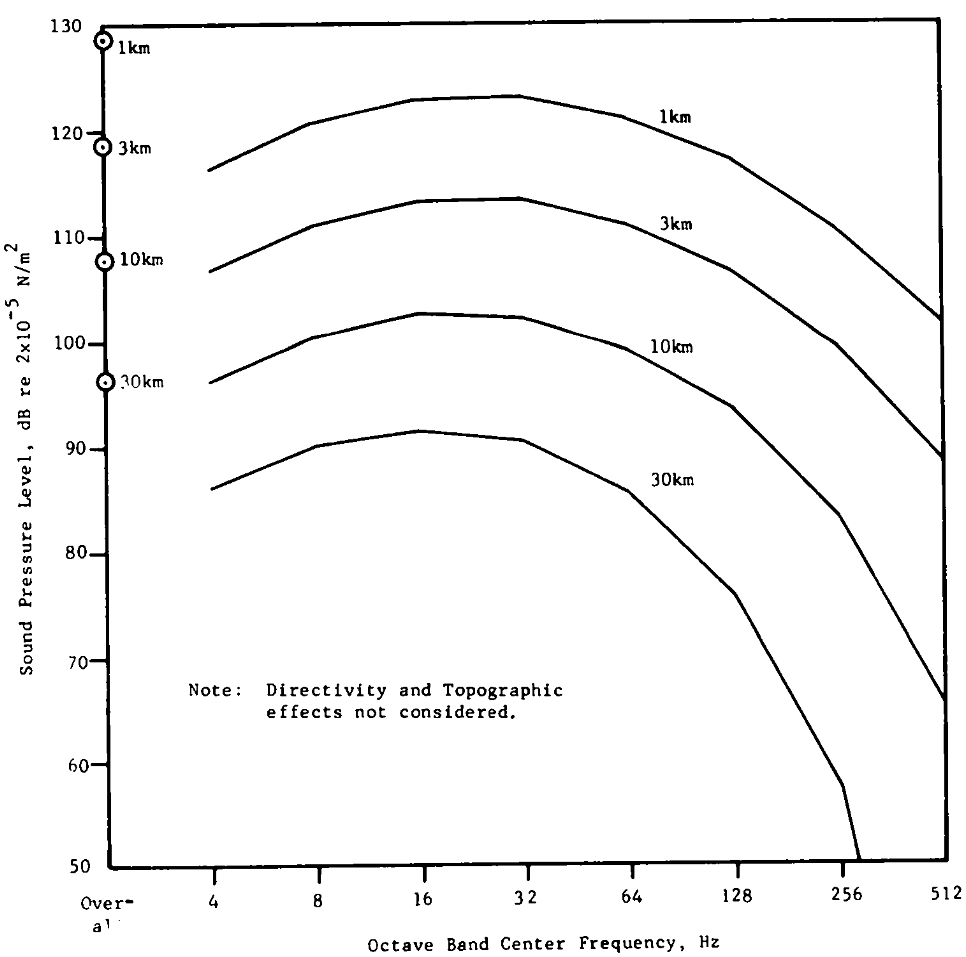


FIGURE K-2. PREDICTED OVERALL AND OCTAVE BAND SOUND PRESSURE LEVELS AT VARIOUS DISTANCES FROM THE SPACE SHUTTLE SRM TEST SITE

"A" Weighted Sound Pressure Levels

The human ear is not equally sensitive to all sound frequencies. Rather, it is most sensitive to frequencies in the range of 1000-6000 Hz, and decreases in sensitivity at both lower and higher frequencies. To account for this characteristic, sound pressure levels are frequently given in the "A" weighted scale, where the sound levels at various frequencies are weighted in accordance with the normal sensitivity of the human ear.

Figure K-3 presents the predicted sound pressure levels resulting from a SRM test as a function of distance both as the overall sound pressure

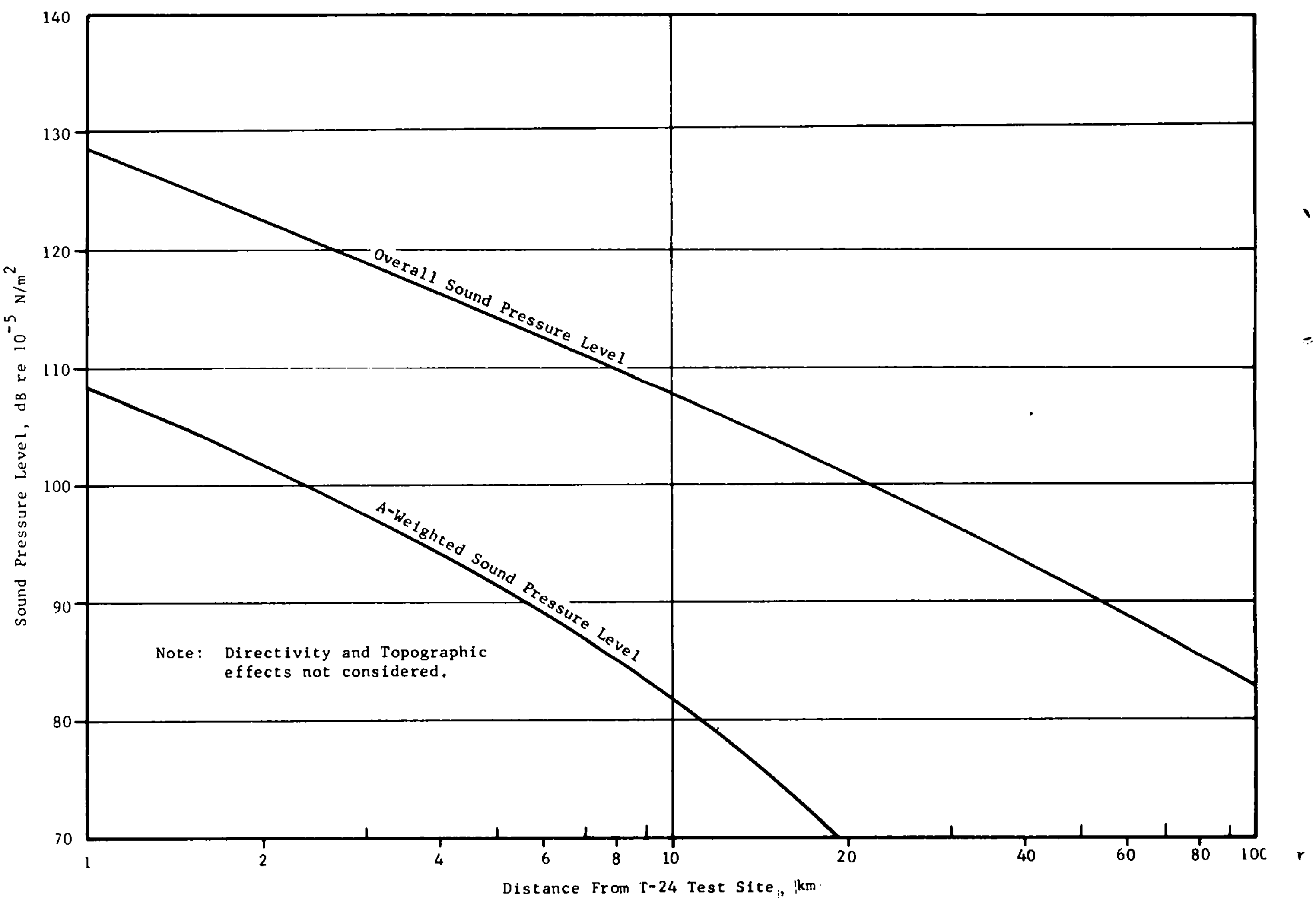


FIGURE K-3. OVERALL AND WEIGHTED SOUND PRESSURE LEVELS RESULTING FROM TEST FIRINGS OF THE SPACE SHUTTLE SRM level (unweighted) and as the "A" weighted sound pressure level. It may be noted that the "A" weighted levels are more than 20 dB below the unweighted levels and that the difference increases with distance. This is a result of the greater attenuation with distance of the higher frequency sounds.

Directivity Effects

Rocket motors are directive sound sources. The directivity pattern is shaped such that the maximum sound energy is radiated at an angle of about 60 degrees from the axis of the jet in the direction of the jet. The sound energy radiated on the motor centerline is a minimum. The overall result is to give the lines of constant sound pressure level a somewhat butterfly shape.

Measurements of the directivity patterns of a number of large rocket motors have been made and summarized in Reference 42. Figure K-4

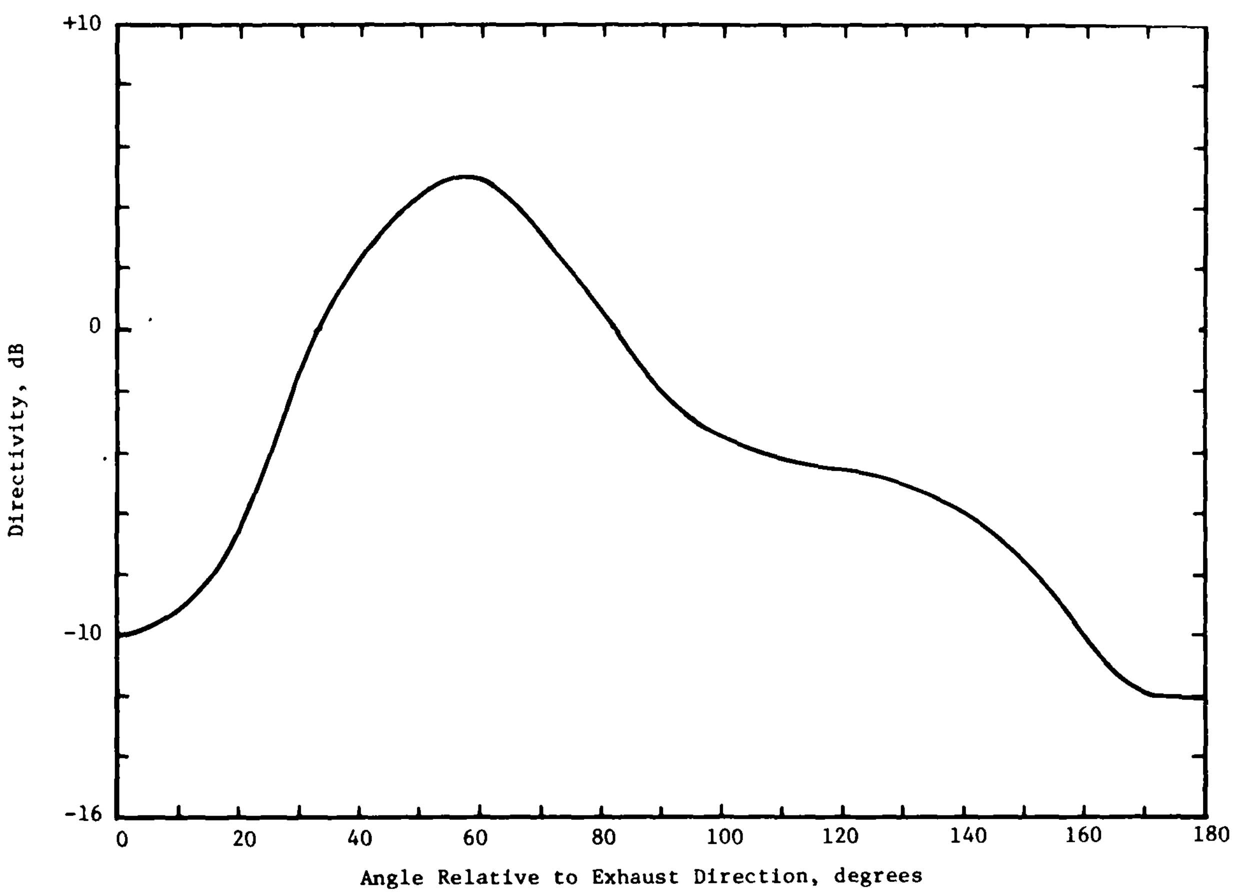


FIGURE K-4. DIRECTIVITY CHARACTERISTICS OF ROCKET NOISE shows the directivity as a function of the angle measured from the exhaust jet axis.

Figure K-5 shows the contours of constant overall sound pressure level plotted on a map of the test site and vicinity. In Figure K-6, the contours for the "A" weighted sound level are plotted.

Topographic Effects

The contours of constant overall and "A" weighted sound pressure levels in Figures K-5 and K-6 ignore the effect of topography, specifically the shielding effect of high ridges between the source and observer. Reference 84 presents an empirical equation for calculating the attenuation caused by a barrier between the source and observer. This equation is $13 + 10 \log \frac{2(A+B-D)}{\lambda}$ up to 24 dB, where A+B is the shortest path between the source and observer, D is the straight line distance, and λ is the wave length.

Because a high ridge exists between the test site and ranches and communities to the east and north, noise levels in those areas will be reduced significantly below those shown in Figure K-5 and K-6. Calculated attenuations for Thatcher, Brigham City, and Connor Springs are:

	Attenuation, dB		
Frequency	Thatcher	Brigham City	Connor Springs
8	13	7	10.5
16	16	10	13.6
32	19	13	16.6
64	22	16	19.6
128	24	19	22.6
256	24	22	24
≥512	24	24	24

Applying these attenuations to the predicted sound levels, the OASPL and "A" weighted sound pressure levels will be 83 dB and 49 dB(A) in Thatcher, 88 dB and 47 dB(A) in Brigham City, and 105 dB and 70 dB(A) at Connor Springs.

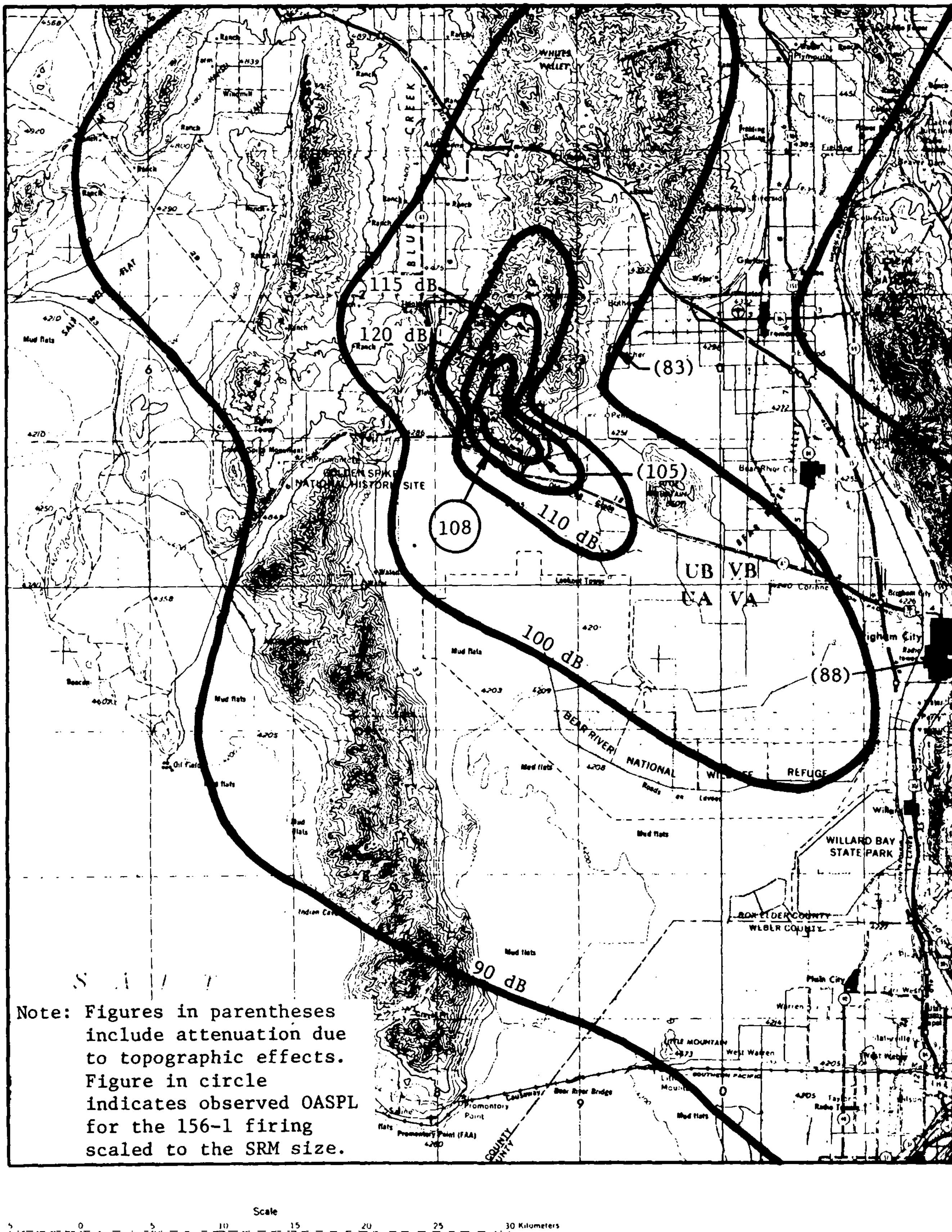


FIGURE K-5. PREDICTED OVERALL SOUND PRESSURE CONTOURS FOR THE SPACE SHUTTLE SRM STATIC TEST FIRINGS

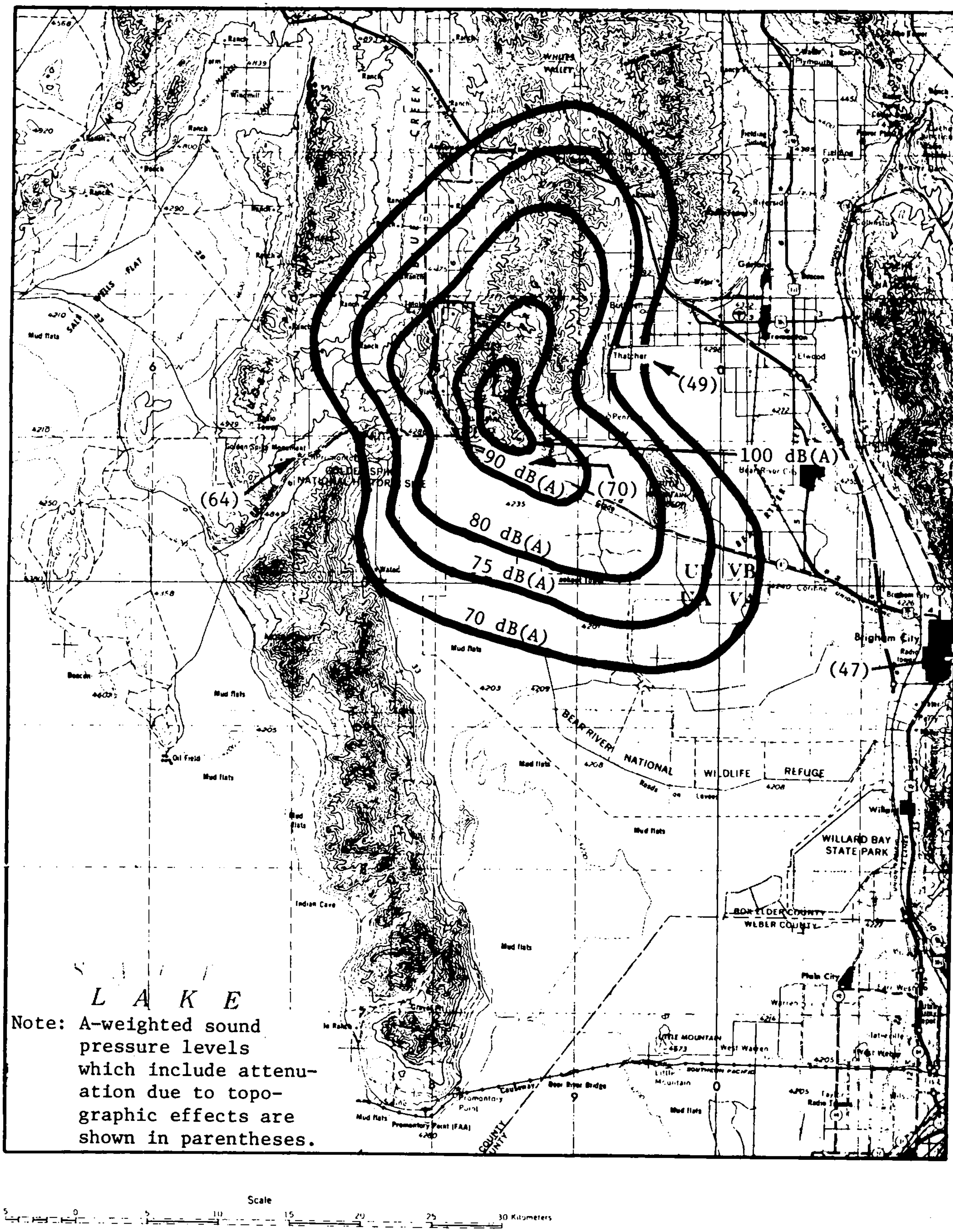


FIGURE K-6. PREDICTED "A" WEIGHTED SOUND PRESSURE CONTOURS FOR THE SPACE SHUTTLE SRM STATIC TEST FIRINGS

Comparison of Predicted and Observed Sound Pressure Levels

Acoustic measurements have been made at the test firings of a number of solid rocket motors. Those which appear most comparable to the SSSRM are listed in Table K-1. (Detailed acoustic levels for the 156-1 firing are given in Reference 43). Because the test motors differ in size and because the observations were made at different distances and angles, all observations were scaled to the size of the SRM at a uniform distance of 3 km with no directivity. The scaling was done by using the same methods and parameters as were used in predicting the sound pressure levels for the Space Shuttle SRM.

The average scaled overall sound pressure level (OASPL) for all test motors is 111 dB. The high scaled OASPL's for the 156-3 may be related to the short distance at which the observations were made.

For the same conditions as used in preparing Table K-1, the predicted OASPL for test firings of the SRM is 119 dB, 8 dB higher than the average OASPL observed for the motors fired at the Thiokol/Wasatch site when scaled to the SRM size.

An attenuation of from 10 to 20 dB above that attributed to all known causes has been observed in sound propagation over a 2-km path in rough terrain.[87] Because this attenuation is not well understood, it is not ordinarily used in making predictions of noise levels. It is possible that the 8 dB difference between the predicted OASPL for the SRM and the scaled observed OASPL's represents an attenuation due to the rough terrain at the test site and that the predicted OASPL's are, in fact, too high by about 8 dB.

TABLE K-1. OBSERVED AND SCALED SOUND PRESSURE LEVELS AT STATIC TEST FIRINGS OF LARGE SOLID PROPELLANT ROCKET MOTORS

	Acoustic Observations				Scaling Factors				
Motor Designation	Test Site (Firing Orientation)	OASPL, db	Distance, m	Angle from Motor Center-line, °	Motor Size Scale Factor, dB	Distance Scale Factor, dB	Atmospheric Attenuation Factor, dB	Directivity Factor, dB	Scaled OASPL,* dB
156-1	Thiokol/Wasatch (Horizontal)	104	2715	104°	+ 3.6	- 0.9	0.0	+3.9	111
TU-122	Thiokol/Wasatch (Horizontal)	97	3050	Approx max directivity	+15.3	+ 0.1	0.0	-5.1	107
		97	2355	101°	+15.3	- 1.7	0.0	+3.6	114
156-2C-1	Brunswick, Ga (Vertical)	105	3317	~90°	- 1.9	+ 0.9	0.0	+2.0	105
		102	7473	~90°	- 1.9	+ 7.9	+0.5	+2.0	111
156-3	Beaumont, Ca (Vertical)	137	209	~90°	+ 6.0	-23.1	-2.1	+2.0	120
		141	105	~90°	+ 6.0	-29.1	-2.1	+2.0	118
AGC-100FW-1	Not stated (Horizontal)	97	3050	60°	+11.2	+ 0.1	0.0	-5.0	103

*Note: Observed levels scaled to the Space Shuttle Solid Rocket Motor at a distance of 3 km with no directivity.