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# A Review of the Supply of Liquid Propellants and Other Fluids in Support of the Space Shuttle Program

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## ABSTRACT

In this study, over twenty significant liquid propellants and other fluids were reviewed as to their supply in support of the Space Shuttle Program, primarily at the Kennedy Space Center.

The uniqueness of most of the products, either by their application or production characteristics, present a variety of supply issues to contend with. Each, however, is critical to the success of the Space Shuttle Program. It becomes necessary to formulate, and maintain, a logistic approach to assure a continued availability of each product.

For convenience, two categories were established. One, labeled "limited-availability," represents those products wherein they are single sourced, have production restrictions and/or there has been a history of supply problems. The other, labeled "universally-available," is characteristic of those having several sources and/or having little, if any, historical supply problems. This last category was not examined in depth.

Through concepts of establishing stockpile inventories, multiple supply contracts, or other arrangements the supply of liquid propellants and other fluids can be assured.

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## ACKNOWLEDGEMENTS

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Center Support Operations,
Kennedy Space Center, FL

## ABBREVIATIONS AND ACRONYMNS

| | |
|---|---|
| AFLC | Air Force Logistics Command |
| APCI | Air Products & Chemicals, Inc. |
| APU | Auxiliary Power Unit |
| ATCS | Active Thermal Control System |
| A-50 | A mixture containing 50% Hydrazine and 50% Unsymmetrical Dimethyl Hydrazine |
| BAir | Breathing air |
| Big Three | Big Three Industries, Inc. |
| BOC | Base Operations Contract(or) |
| CCAFS | Cape Canaveral Air Force Station |
| CCF-39 | Complex 39 Converter/Compressor Facility |
| CGA | Compressed Gas Association |
| CLS | Contingency Landing Site |
| cyls | compressed gas cylinders |
| DCAS | Defense Contract Administrative Services |
| DOD | (U.S.) Department of Defense |
| DOT | (U.S.) Department of Transportation |
| ECLSS | Environmental control and life support system |
| ECS | Environmental control system |
| EG&G | EG&G Florida, Inc. |
| ET | External tank |
| EVA | Extra Vehicular Activity |
| F | Fahrenheit |
| FCSS | Fuel cell servicing system |
| gal | gallon(s) |
| $GH_2$ | Gaseous Hydrogen |
| GHe | Gaseous Helium |
| $GN_2$ | Gaseous Nitrogen |
| $GO_2/GO_2A$ | Propellant-grade gaseous Oxygen |
| $GO_2F$ | High-purity gaseous Oxygen |
| gpm | Gallon(s) per minute |
| GSE | Ground support equipment |
| GT | (Compressed) gas trailer |
| HCl | Hydrochloric acid |
| HMF | Hypergolic Maintenance Facility |
| HPU | Hydraulic power unit |
| HSSF | Hypergol Stockpile Storage Facility |
| ICP | Inductively Coupled Plasma |
| IPA | Isopropyl Alcohol |
| JSC | Lyndon B. Johnson Space Center |
| KSC | John F. Kennedy Space Center |

## ABBREVIATIONS AND ACRONYMS
(Continued)

| | |
|---|---|
| LAir | Liquid air |
| LC-39(A)(B) | Launch Complex 39 (pad A or B) |
| LCD | Launch Countdown |
| LETF | Launch Equipment Test Facility |
| $LH_2$ | Liquid Hydrogen |
| $LO_2A$ | Propellant-grade liquid Oxygen |
| $LO_2F$ | High-purity liquid Oxygen |
| $LPGN_2$ | Low-pressure gaseous Nitrogen |
| LSOC | Lockheed Space Operations Company |
| LT | Liquid tanker |
| MBMR | Material Bench Maintenance & Repair |
| MSFC | Marshall Space Flight Center |
| MMH | Monomethylhydrazine |
| MON(-x) | Mixed Oxides of Nitrogen, x=1, 3, or 10% NO |
| $N_2H_4$ | Monopropellant-grade Hydrazine |
| $N_2O_4$ | Nitrogen Tetroxide |
| $NH_3$ | Ammonia, anhydrous |
| NaOH | Sodium Hydroxide |
| NaOH-25 | 25-Percent Sodium Hydroxide |
| NaOH-50 | 50-Percent Sodium Hydroxide |
| NASA | National Aeronautics and Space Administration |
| NO | Nitric Oxide |
| NOLA | New Orleans, LA |
| O&C | Operations and Checkout (Building) |
| OMS | Orbiter maneuvering system |
| OPF | Orbiter Processing Facility |
| PID | Procurement Information Document |
| ppm | Part(s) per million |
| PRSD | Power reactant supply and distribution (system) |
| psig | Pound(s) per square inch gage |
| R-21 | Refrigerant 21 |
| RCS | Reaction control system |
| RSV | Ready storage vessel |
| SA-ALC | San Antonio Air Logistics Center |
| SCAPE | Self contained atmospheric protective ensemble |
| scf | Standard cubic feet |
| scfm | Standard cubic feet per minute |
| SI-A | Propellants Consumables Management |
| SPC | Shuttle Processing Contract(or) |
| SRB | Solid Rocket Booster |
| SSC | Stennis Space Center |
| SSME | Space Shuttle main engine |
| STS | Space Transportation System |

## ABBREVIATIONS AND ACRONYMS
(Continued)

| | |
|---|---|
| TVC | Thrust Vector Control |
| USBI | United Space Boosters, Inc. |
| USEPA | U.S. Environmental Protection Agency |
| VAB | Vehicle Assembly Building |
| VJ | Vacuum-jacketed |
| WSSH | White Sands Space Harbor |
| WSTF | White Sands Test Facility |

# A REVIEW OF THE SUPPLY OF LIQUID PROPELLANTS AND OTHER FLUIDS IN SUPPORT OF THE SPACE SHUTTLE PROGRAM

## PURPOSE:

The purpose of this report is to address the supply of liquid propellants and other liquids and gases provided by and/or used by the John F. Kennedy Space Center (KSC) in support of the Space Shuttle Program.

## SCOPE:

This report identifies the variety of consumables (liquid propellants, other liquids, gases, and related fluids) provided by the Kennedy Space Center for use in servicing the Space Shuttle systems, related ground support equipment (GSE), and preparation of the Shuttle vehicle for launch at the Kennedy Space Center. Payload items are not included. The report addresses sources of supply, acquisition responsibilities, and a discussion of the issues and strategy of provisioning pertaining to the supply of each identified consumable.

## AUTHORITY:

This review was prepared at the request of the Directorate of Center Support Operations (NASA/SI), John F. Kennedy Space Center, Florida.

## INTRODUCTION:

To assure that launches of the Space Shuttle vehicles are performed as scheduled, an un-interruptable supply of the launch related propellants, liquids, and gases is required. A review of each of these consumables has been performed and is presented. At the end of the presentation of each limited-availability Space Transportation System (STS) fluid/propellant or "item", a detailed summary analysis and strategy for support during an interruption of the supply source is given. For each universally -available STS fluid/propellant or "item", a remarks summary statement is provided.

## SUMMARY:

This review reveals that some concerns exists regarding the supply of anhydrous Ammonia, liquid Hydrogen, and liquid Oxygen, grade F., required for Space Shuttle launches. The concern regarding Ammonia and liquid Oxygen, grade F, relates to the lack

of an alternate supplier, and the concern regarding liquid Hydrogen relates to the limited capability of supporting NASA's launch and engine testing requirements as scheduled, during loss or curtailment of the supplier's production capability.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### ANHYDROUS AMMONIA

| | |
|---|---|
| ITEM | ANHYDROUS AMMONIA ($NH_3$) |
| PROCUREMENT | KSC (EG&G) |
| CONTRACT | Purchase Request issue upon need. |
| RESP. KSC ORGS. | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered and used in CGA type 1K cylinders, 150-lb. nominal, 130-lb. each with full length eductor tube. OPF GSE racks are designed specifically to fit two each 150-lb. cylinders, in vertical position. Product is transferred from these cyls. into OPF High Bay GSE-654 cart of 50 gallons (252 lbs.) cap. for servicing the Orbiter. |
| SPECIFICATION | Federal Specification O-A-445B, with Amendment 1, modified by EG&G-PID-06 to 8 ppm oil, max., & with full length eductor tube. |
| USE | $NH_3$ is consumed in moderate quantities to remove heat from the Refrigerant 21 coolant loop of the Orbiter ATCS (Active Thermal Control System) upon re-entry at altitudes below 100,000 feet and after landing. |
| SUPPLIER | Matheson Gas Products, East Rutherford, NJ. |
| ISSUE | Inability of many suppliers to meet product specification. Since 1978 a number of contracts were canceled due to suppliers' inability to provide specification product. Matheson has been the only proven source. The problem appears to be related to cylinder preparation/cleanliness rather than product purity difficulties. Principal contaminants are water and oil. Ammonia is very hygroscopic and the oil source is refrigeration system compressors; both contaminants may be present from previous cylinder fillings if the cylinder is not cleaned. To provide the cited specification quality Ammonia, the supplier must be capable of preparing the cylinders, including cleaning, with the proper eductor tube configuration and also have sufficient selection of grade sources to meet the stringent purity requirement (99.98%). |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### ANHYDROUS AMMONIA

Relatively low-volume usage is not an incentive to suppliers to furnish product to specifications.

**AVAILABILITY**

Millions of tons of Ammonia are produced annually in the U.S., mostly for agricultural use. Most Ammonia is produced by modifications of the Haber-Bosch process. In modern plants, high temperature catalytic reactions between natural gas, air, and steam yield a mixture of Hydrogen, Nitrogen and oxides of Carbon. Oxide removal then follows the conversion. The remaining Hydrogen-Nitrogen mixture is compressed and passed over catalysts where Ammonia synthesis occurs at elevated temperatures. No grade specifications have been published as standard for the industry. However, generally accepted grade designations of commercially produced Ammonia are: Commercial (99.5%), Agricultural (99.7%), Refrigeration (99.95%), and Metallurgical (99.99%).

**CONSUMPTION**

On-board quantity is 97.6 lbs. in two 1.33 $ft^3$ tanks, which can last up to two missions under normal circumstances. There is about a 20% loss during Orbiter servicing. Ammonia boiler testing, when required, can increase consumption. During Orbiter servicing a cart-to-Orbiter flowmeter panel is used; a 6-month flowmeter calibration cycle necessitates cart dumping to vent to obtain off-line shop calibration.

**STORAGE**

Ten to twenty 150-lb. cyls. are stored under cover at the LC-39 Propellants North storage area.

**SUPPORTABLE MISSIONS**

A nominal two 150-lb. cyls. are furnished for each mission. Inventory to support a minimum of 5 missions is maintained.

**CURRENT SUPPORT**

Current practice is for sole source procurement from Matheson Gas on a batch basis to maintain the local inventory.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### ANHYDROUS AMMONIA

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- Interruption: Failure of Matheson Gas Products to provide product.
- Product requirement: Two 150-lb. cyls./mission will be the expected requirement.
- Support capability/duration: Ten 150-lb. cyls., minimum, will be maintained in inventory to provide the necessary support for 5 missions.
- Backfill options: None.
- Conclusions: KSC currently has no qualified alternative source of anhydrous $NH_3$ that can provide backfilling of inventory during supply interruption.
- KSC must develop alternative sources of $NH_3$ to provide for requirements during supply interruption.
- Action: KSC development of alternative sources of $NH_3$ is in process. KSC is also investigating the use of Government-controlled and maintained cylinders.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### FUEL CELL COOLING FLUID

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|---|---|
| ITEM | FUEL CELL COOLING FLUID ("COOLANT FC-40") |
| PROCUREMENT | KSC (LSOC) |
| RESP. KSC ORGS. | LSOC-421 867-5963 NASA/TV-FSD-12 867-0792 |
| CONTAINER | Procured in 1-gallon hard plastic lined cylindrical metal cans. Processed and transferred to 7.5-gal. (117.3 lbs.) canister for Orbiter loading. |
| SPECIFICATION | FLUORINERT FC-40 Brand Electronic Liquid. (Proprietary perfluorocarbon fluid formulated to 3M Company product specifications) |
| USE | FC-40 is used as a closed-loop fuel cell coolant to transfer waste heat from the Fuel Cells to to the Orbiter Coolant System. |
| SUPPLIER | Industrial Chemical Products Division<br>3M Company<br>3M Center<br>St. Paul, MN 55144-1000 |
| ISSUE | The 3M Company is the sole producer of FC-40. This 3M product satisfied the qualification testing and is thus specified as the necessary coolant fluid. |
| AVAILABILITY | STS usage is the only application for the perfluorocarbon liquid as a coolant fluid. The majority of commercial usage is for electronics testing. The 3M Company manufactures several similar perfluorocarbon liquids of varying molecular weight ranges and boiling points. There are three 3M Company plants located in the U.S. which are capable of producing FC-40 liquid: Decatur, AL; Cordova, IL; and Cottage Grove, MN. |
| CONSUMPTION | FC-40 liquid is required only in low volume, since it is used in a closed loop system. The system is serviced only on a contingency basis after the initial fill operations. When servicing is required, the product is recovered, filtered, and de-aerated prior to reuse. Processing is accomplished in the MBMR Lab in the VAB at KSC. The system is then topped off. Minor quantities are also used for |

component testing. Onboard quantities consists of 25 to 30 lbs. per Fuel Cell for a total of 75 to 90 lbs. per Orbiter. (4.8 to 5.8 gals.). Fuel Cells are received with the FC-40 already loaded. Maximum allowable leakage rate is 0.1 cu. in. (3.07 grams) per month per Fuel Cell.

| | |
|---|---|
| STORAGE | Orbiter loading is accomplished using special 7.5-gallon loading canisters which have been previously filled by transfer of liquid through filters from the 1-gallon units obtained from the manufacturer. Five canisters, with varying quantities of liquid, are maintained in the MBMR for Orbiter processing and loading. Replenishment is via LSOC stock, FSN 685-000-K82-3003. Fifteen gallons are maintained in LSOC inventory (Reorder quantities are procured for each gallon as it is withdrawn, i.e., a 15 Max/15 Min supply is maintained.) |
| SUPPORTABLE MISSIONS | A nominal mission can be estimated to use two gallons. Storage quantities are maintained to support 7 missions. |
| CURRENT SUPPORT | Current practice is for sole source procurement from the 3M Company to maintain inventory. |

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- Interruption: Failure of the primary plant to provide product.
- Product requirement: Two gallons/mission will be the expected requirement.
- Support capability/duration: Fifteen gallons, minimum, will be maintained in inventory to provide the product for 7 missions.
- Backfill options: Backfill of inventory will be accomplished by obtaining product from an alternate 3M plant.
- Conclusions: With multiple plant supply capability and LSOC stockage launch support is assured.
- Action: None.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### HYDROGEN

| | |
|---|---|
| ITEM | HYDROGEN |
| PROCUREMENT | KSC (SI) |
| CONTRACT | NAS8-31034, Through November 30, 1990 |
| RESP ORGS | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered in KSC-owned 13,000-gal. capacity liquid tankers, supplemented by Air Products and Chemicals, Inc. (APCI) owned 13,000-gal. capacity liquid tankers. NOTE: Seven KSC owned liquid tankers are GFE to APCI. |
| SPECIFICATION | Military Specification MIL-P-27201B |
| USE | $LH_2$ is required principally as the SSME propellant. $LH_2$ is also used to service the PRSD. $GH_2$ is required at the LC-39 Pads and OPF for fuel cell purging, and at the LETF for assorted hardware testing. |
| SUPPLIER | $LH_2$ is supplied by Air Products and Chemicals, Inc., Allentown, PA. from their plant in New Orleans, LA. $GH_2$ is produced at KSC by conversion of $LH_2$, using rechargers. |
| ISSUE | Relative to the production of other cryogenic products, there are limited production locations of $LH_2$ in the U.S. Most of the $LH_2$ production capability in the U.S. was underwritten by the Space Program. Commercial demand on the APCI New Orleans Commercial plant (Plant A) is now approaching 70 percent, with demand expected to continue to increase. During the final phase of construction, this plant could not be placed on-stream as a result of damage/flooding due to a hurricane. Consequently, the levee was raised from 8 feet to 18 feet. Product was shipped from a California plant (now dismantled) during this period to meet the small demands at the time.<br><br>It is noted that there are significant requirements for $LH_2$ in support of SSME testing at SSC. On occasion, prioritizing of deliveries and rescheduling of demands at various user sites has been required to accommodate production rate/storage inventory |

fluctuations. It is also significant that the major use of $LH_2$ at SSC does not routinely place demands on the commercial delivery system. This system consists of industry fleet trailers closely sized to meet current market loads, with some reserve margin. Supporting SSC totally with trailers could override this commercial reserve margin.

AVAILABILITY

Domestic sources of $LH_2$ are:

| | |
|---|---|
| Air Products, New Orleans, LA | 66 tons/day |
| Air Products, Sacramento, CA | 5 tons/day |
| Linde, Ashtabula, OH | 12 tons/day |
| Linde, Niagara Falls, NY | * 22 tons/day |
| Linde, Ontario, CA | 22 tons/day |

*In 1989, expected to increase to 33 tons/day

Canadian sources of $LH_2$ are:

| | |
|---|---|
| Air Products, Sarnia, Ontario | 22 tons/day |
| Liquid Air, Becancourt, Quebec | 11 tons/day |
| AirCo, Magog, Quebec | ** 15 tons/day |

** expected to go on line in June, 1990

The Sacramento, Niagara Falls, Sarnia, and Ashtabula plants are essentially sold out to commercial demand. The demand on the Canadian plants to support Canadian commitments and certain overseas shipments is unknown. The rise in U.S. commercial demand varies from 5 to 10 percent per year, one of the basic reasons for the Linde expansion. The Linde-Ontario plant (built in 1962) production was reduced for a time during the 1987 winter months due to feedstock curtailment.

The plant capacities stated above represent so-called nameplate ratings. To determine effective deliverable volumes on a calendar basis, industry uses a discounted value of about 85% of nameplate data. This accounts for outages due to plant normal and corrective maintenance/utility problems, and market load variability due to seasonal demand fluctuations.

CONSUMPTION

488,000 gallons (288,000 lbs.) per mission (1 attempt; ET + PRSD + Battery). Each additional launch attempt with a prior 24-hr. scrub and

| | |
|---|---|
| | drainback to the pad sphere consumes an additional 103,000 gallons (60,800 lbs.). Annual spheres losses equate to about 365,000 gallons (215,600 lbs.). Thus for 12 launches/year, the requirement is approximately 6,221,000 gallons (3,674,100 lbs.) + scrub quantities, if any. It is noted that consumption of $LH_2$ at other Government sites may exceed 20,000,000 gallons per year. |
| STORAGE | 830,000 gallons, nominal, storage capacity at each LC-39 pad. |
| SUPPORTABLE MISSIONS | With 750,000 gallons, pre-mission minimum, in the primary sphere and 10 liquid tankers scheduled to arrive on the day following the 1st Launch attempt, the launch attempt + one 24-hour scrub turnaround + one 72-hour scrub turnaround can be supported, without resorting to the secondary LC-39 pad sphere, before replenishment is required. |
| CURRENT SUPPORT | Provided by delivery of $LH_2$ tankers from APCI/NOLA per long term contract with APCI. The current contract expires November 30, 1990. Delivery capability is expected to increase in the second quarter, calendar year 1989 by utilization of four 34,400-gal. capacity railcars. These railcars provide sufficient on-site storage to replenish the quantity of product consumed in one Shuttle scrub turnaround. They also provide a convenient method of sphere-to-sphere $LH_2$ transfer between LC-39A and LC-39B pads. |

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- o <u>Interruption:</u> Failure of APCI/NOLA plant to provide product.

- o <u>Product requirement:</u> The expected requirements will be 488,000 gallons (288,000 lbs.)/mission + 103,000 gallons (61,000 lbs.) for each sphere drainback scrub, and annual spheres (heat) loss rate of 365,000 gallons (216,000 lbs.). The normal pre-launch inventory requirement is 750,000 gallons in the primary pad sphere. This is the minimum level required to provide

a 1st launch attempt and one 24-hour scrub turnaround. An additional scrub turnaround would require an additional 103,000 gallons of product delivery to prevent going below the minimum sphere level of 160,000 gallons.

Support at the Stennis Space Center normally runs at about 1,000,000 gallons per month.

- Support capability/duration: Depending upon timing of a supply interruption, KSC sphere inventory may or may not support a mission, and the APCI/NOLA inventory may or may not support a mission and engine testing simultaneously.

  It is noted that the transport of $LH_2$ by trailer for long distance hauling is potentially impacted due to the DOT imposed one-way travel time limit characteristic of the trailer age/condition. This circumstance is more prevalent in the older trailers, however, and can be mitigated by en route venting at appropriate contractor facilities, when available. A limiting factor at SSC is that the only trailer offloading capability is at the A-1 Test Stand and it is limited to only 2 stations.

- Backfill options: Throughout the current contract with APCI, a Government priority contract ending November 30, 1990, APCI would pre-empt some commercial customer deliveries and provide product from their Sarnia, Canada plant. APCI would utilize their "Industry Swap Agreement" with Union Carbide, Linde Division, to provide limited supplemental product for an interim period. This planning assumes the two 500,000-gal. storage spheres at NOLA are available for servicing the SSC barges and are available as an inventory buffer to supply other users when deliveries are not made directly from other production sites. The problem becomes one of how much of the commercial accounts will be curtailed and of the amount of product available from sources other than APCI. Even with the Government contract rating of DO, it is doubtful APCI could or would significantly impact existing commercial contract obligations, due to resulting commercial business repercussions. Also, the "Industry Swap Agreement" is not a binding agreement but exists as a convenience to provide assistance for short term situations. Product borrowed is accounted for and then typically replaced

in a short time-frame to maintain a no-debt balance. It is subject to a unilateral decision on the part of the provider.

- Conclusions: There is a very questionable capability to assure Hydrogen supply to support the launch requirements and engine testing program as currently scheduled, and within the operational parameters typically encountered. Launch support, being the most critical, could more than likely be sustained; however, engine testing would need to be limited, as well as other NASA center R&D work.

- Action: KSC is taking appropriate procurement actions to provide long range contracts to supply $LH_2$ beyond the current APCI contract term. It is expected that this procurement will satisfy the needs for primary and alternate LH2 supplies in the 1990's.

  KSC is taking action to have the current supplier develop a contingency supply plan to address near term supply interruptions.

  KSC is taking action to permit contingency utilization of product maintained in the secondary LC-39 pad sphere.

  SSC is taking action to allow the filling of barges onsite, using either railcars or trailers.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### HELIUM

| | |
|---|---|
| ITEM | HELIUM (GHe) |
| PROCUREMENT | KSC (SI) |
| RESP. KSC ORGS | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered in Railcar or Compressed Gas Trailer quantities |
| SPECIFICATION | Military Specification MIL-P-27407A, Grade A. |
| USE | Used for leak testing, inert purging, pressurization of GSE, and as an onboard Orbiter/ET pressurant. |
| SUPPLIER | U.S. Bureau of Mines, Amarillo, Texas. |
| ISSUE | Under the provisions of Public Law 86-777 (Helium Act), which resulted out of concern for wasteful losses of Helium contained in natural gas consumption, all Government agencies must obtain their Helium from the Bureau of Mines to support the conservation costs incurred in the 1960s whereby the Bureau of Mines purchased Crude Helium (an intermediate product extracted from Natural Gas and containing 50-80% Helium in $GN_2$) from private plants and stored it in the Cliffside gas field, a large dolomite underground storage area near Amarillo, Texas. In the 1970's, due to program changes, some private companies contracted with the Bureau of Mines to store their excess helium production in the Cliffside field.<br><br>The Bureau of Mines no longer extracts Helium from natural gas as was done for years using several Government-owned separation plants in Texas, Oklahoma, New Mexico, and Kansas. The only Government purification plant, located in Masterson, Texas, fills railcars and compressed gas trailers for delivery to user locations. This plant's source is the Crude Helium from the Cliffside gas field. |
| AVAILABILITY | The vast majority of Helium in the U.S. is provided by commercial sources who extract the product from Natural Gas Production. The Bureau of Mines' Cliffside field is estimated to have sufficient product to meet the demand |

for the next 100 years. The primary mode of GHe supply to KSC is by railcar. Due to a 40 year age limit on railcar usage, the existing railcar fleet is being phased out beginning in 1995. A shift to Helium deliveries by means of over-the-road compressed gas or liquid dewar trailers is occurring and will need to be in place by 2002 when the last railcars must be taken out of service.

There are several private Helium suppliers that have the capability to provide the quality and quantity of Helium needed. These suppliers are presently selling in the private market all the Helium they produce , with a great deal of this Helium being shipped overseas. To provide the quantities of gaseous Helium required, suppliers would need to reallocate Helium sales or obtain additional Crude Helium supplies. In addition, to be able to support high launch rates, additional compressor capacity would have to be added for an individual vendor to support KSC requirements. It is estimated that 6 months leadtime would be required for a vendor to add this additional capability.

| | |
|---|---|
| CONSUMPTION | 3,030,000 scf/mission, average. Each launch attempt/scrub turnaround consumes an additional 1,500,000 scf. 24,000,000 scf is required as the base annual usage. SSC uses about 22,000,000 scf on an annual basis. |
| STORAGE | An interconnected system of batteries at the VAB, LC-39A, and LC-39B, with a combined capacity of 7,400,000 scf. at 5,660 psig. (Railcars are positioned at the KSC CCF-39 siding prior to a launch). |
| CURRENT SUPPORT | All purchases are placed with the Bureau of Mines, Helium Division, Amarillo, Texas, per the Public Law 86-777 requirement. |
| SUPPORTABLE MISSIONS | The LC-39 GHe storage system could support one launch attempt without replenishment. Sufficient GHe to support three additional scrub turnaround launch attempts (21 railcars) is procured and delivered from the Bureau of Mines prior to the start of each launch countdown. |

LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

HELIUM

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- o Interruption Failure of Bureau of Mines capability to provide product.

- o Product Requirement: 3,030,000 scf/mission + 2,000,000 scf per month will be the expected requirement.

- o Support capability/duration: Existing GHe railcars on hand and enroute would be utilized, as required, until over the road compressed gas trailers can be received. Existing Bureau of Mines storage (over 11 million scf) could be utilized if available. All available railcars would be shipped to KSC and used as storage, and would be replenished by the trailers as Helium from other vendors becomes available.

- o Backfill options: The product will be obtained from some of the many commercial sources, as provided for by Part 602, Code of Federal Regulations which implements Public Law 86-777. There are seven major production plants with Grade A GHe and LHe capability in the United States; however, no individual plant would be able to support all of KSC's requirements. Most commercial source Helium is liquefied, and gaseous shipping facilities are limited.

  There are sufficient gaseous Helium compressed gas trailers to supply KSC's peak requirements. The Bureau of Mines has a fleet of 38 compressed gas trailers to deliver gaseous Helium to customers. Should a catastrophe occur at the Bureau's Helium production facility, gaseous Helium railcars at KSC could be retained, or those at the Bureau of Mines' Exell (Masterson, Texas) plant could be sent to KSC to provide emergency Helium storage as needed. The Bureau's compressed gas trailer fleet could then be used to expedite delivery of private gaseous Helium to KSC. Trailers would be offloaded into the railcars to maintain the onsite storage volume desired. If these trailers are insufficient to supply KSC's requirements, private carriers, such as Jack B. Kelley Company, could provide additional trailers on an emergency basis. None of the private GHe producers have the capability to fill GHe railcars.

- o Conclusions: In the event there is a catastrophe at the Bureau of Mines production facility, private industry could be utilized to support NASA

requirements. Railcars would be utilized at KSC for storage, while compressed gas trailers would deliver the product.

The Federal Helium Program, as conducted by the Bureau of Mines for the Secretary of the Department of the Interior under 50 U.S.C. 167, is designed to provide for the current and foreseeable future Helium requirements for essential Government activities. In the event of a catastrophe or problem with the Bureau's Helium production facility, the Bureau will contract with private industry to supply the Federal requirements for Helium and will continue to be responsible for supplying all of NASA's Helium requirements. Bureau of Mines contracting for all Government agencies using Helium would help to eliminate unnecessary competition for Helium and increased costs to the user agency and the Government. There is no formal agreement between the Bureau of Mines and the vendors for support in this type of emergency, but it is advantageous to the vendors to support the Bureau in this activity as the vendor would receive in return an equivalent amount of the Bureau's stored Helium reserves. The added incentive of increased domestic Helium sales is also beneficial to the vendors. In any scenario the Bureau of Mines would work to minimize the costs of Helium to the Government.

- Action: None.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### OXYGEN, GRADE F

| | |
|---|---|
| ITEM | OXYGEN, GRADE F |
| PROCUREMENT | KSC (EG&G) |
| RESP. KSC ORGS: | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered in three KSC-owned, dedicated Liquid Tankers, 4000-gal. capacity, with 2,730 to 3,150 gallons (14 $\pm$ 1 ton) per tanker delivery. |
| SPECIFICATION | Military Specification MIL-P-25508E, with Amendment 3, Grade F, modified by EG&G PID-07 to limit the Methane to 10 ppm vice 20 ppm. |
| USE | Liquid Oxygen, Grade F ($LO_2F$), commonly referred to as "high purity" oxygen is used primarily as a reactant with $LH_2$ in the Orbiter Power Reactant Supply Distribution System to provide Orbiter electrical power during flight. Gaseous Grade F Oxygen is produced from the liquid at KSC using a recharger to pressurize the pad Power Reactant Supply and Distribution System batteries. |
| SUPPLIER | Liquid Air Corporation<br>Industrial Gases Division<br>340 Interstate N350<br>Atlanta, GA 30339<br>(supplied from its plant in Savannah, GA.) |
| ISSUE | $LO_2F$ is commonly produced by an air separation process. Air separation plants are numerous in all states. The high-purity requirements of $LO_2F$, however, pose unique production and handling problems. Only modern design plants and/or plants located in areas not subject to air pollution problems can produce product to the required specification. Also, when product is shipped and stored, it is highly prone to go out of specification due to what is known as "Methane enrichment."<br><br>The Liquid Air Corporation Savannah plant is scheduled for conversion to a "gas-only" plant in October 1989. This company has been awarded the contract to supply $LO_2F$ for CY 89-91 and has indicated the product will be supplied from its Orlando, Florida plant, which may require modification to produce the quality needed. |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### OXYGEN, GRADE F

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|---|---|
| | Their Savannah plant is the only one in the United States with KSC-proven capability to produce $LO_2F$. |
| | An Air Products and Chemicals, Inc. plant in Decatur, Alabama, which has successfully produced $LO_2F$, can no longer do so. |
| AVAILABILITY | Other potential sources of $LO_2F$ are Union Carbide Corporation, Linde Division, from their plant in Camden, SC, and Air Products and Chemicals, Inc., from their plants in Glenmont, NY, and Santa Clara, CA. |
| CONSUMPTION | 14 tons $LO_2F$/mission for pad PRSD servicing. Multiple launch attempts may require pad battery reservicing (2.4 tons). About 2 tons of $LO_2F$ are required for base annual support. |
| STORAGE | Normally, upon delivery, $LO_2F$ is offloaded into a permanent 13,500-gal. (64.3 tons) capacity, zero-loss Dewar located at the CCF-39 Propellants North Operations area. The zero-loss Dewar vapor boil-off vent is cooled by $LN_2$, a lower boiling liquid, which is used sacrificially to recondense $LO_2F$ vapors to prevent boiloff losses and thus methane enrichment. |
| | During periods of zero-loss Dewar downtime, three KSC, 14-tons nominal load, liquid tankers are dedicated for delivery and onsite storage of $LO_2F$. Delivery of a <u>prime</u> tanker is made 7 days prior to the required support date with a backup shipment arriving 2 days prior to the required support date. A third tanker is delivered to the vendor's plant to provide for future deliveries. |
| SUPPORTABLE MISSIONS | With an operable zero-loss Dewar, ample product is available for three missions. During Dewar downtime, one mission will be supported with two tankerloads. Scrub turnarounds may require PRSD battery recharging, and without zero-loss Dewar availability, may require an additional tanker delivery. |
| CURRENT SUPPORT | Product is provided on a delivery order/lot basis when required from Liquid Air Corporation, Savannah, GA. |

LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

OXYGEN, GRADE F

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- Interruption: Failure of the supplier to provide product.
- Product requirement: 14.1 tons/mission for pad PRSD Dewar and battery servicing, plus 2.4 tons for battery re-servicing with extended scrubs, will be the expected requirement.
- Support capability/duration: 64.3 tons (13,500 gallons) will be maintained in the zero-loss Dewar, when operational, to provide product to support three missions. When the zero-loss Dewar is not operational an inventory beyond that required for an immediate launch cannot be maintained because of cryogenic boiloff and the Methane enrichment problem.
- Backfill options: None. To provide product during supply interruption, negotiation with an alternate supplier (APCI or Linde) would be required to furnish the emergency supply.
- Conclusions: KSC needs an alternative $LO_2F$ source of supply. KSC has been issuing 1-year subcontracts, on a calendar year basis, to provide product. For CY 89-91, a 1-year subcontract with two 1-year options was solicited and awarded.
- Action: EG&G will negotiate a call-type contract with an alternate supplier, and a tankerload will be ordered and tested to verify the alternate capability.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### NITROGEN, GASEOUS

| | |
|---|---|
| ITEM | NITROGEN, GASEOUS ($GN_2$) |
| PROCUREMENT | AFLC (SA-ALC) |
| RESP. KSC ORGS | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered by underground pipeline. |
| SPECIFICATION | Military Specification MIL-P-27401C, Grade B, Type I. |
| USE | $GN_2$ is used in large quantities for environmental purges, vehicle conditioning, and system pressurization. |
| SUPPLIER | Big Three Industries, Merritt Island, FL. |
| ISSUE | The Big Three plant/pipeline is the only source of $GN_2$ to LC-39. |
| AVAILABILITY | There are several nitrogen vendors in the area near KSC, but the capability of supplying 6,000+ psig $GN_2$ to the Complex 39 pipeline system is only present at the Merritt Island Big Three plant. In Central Florida, there are however several $LN_2$ vendors sufficiently capable of supplying $LN_2$ in launch quantities if storage and conversion equipment are available. |
| CONSUMPTION | LC-39 uses approximately 53 million scf of $GN_2$ per month with each launch requiring an additional 25 million scf. Each launch attempt can use up to 18 million scf of $GN_2$ within 24 hours if a scrub turnaround is experienced. The peak flow rate for STS launches is 16,000 scfm. Other pipeline users (CCAFS and HMF) average using a total of about 25 million scf per month. |
| STORAGE | The LC-39 high pressure storage system consists of fifty-four, 200 $ft^3$, storage vessels and associated piping for a total of 11,470 $ft^3$ (water volume). This volume is equal to 3.4 million scf. The Big Three and CCAFS underground pipeline has a water volume of 14,380 $ft^3$ and contains over 4.7 million scf of $GN_2$ at maximum pressures (Big Three pipeline at 6,500 psig and CCAFS pipeline at 6,000 psig). |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### NITROGEN, GASEOUS

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|---|---|
| CURRENT SUPPORT | The Big Three Merritt Island plant currently supplies $GN_2$ to KSC and CCAFS through a 32-mile long underground pipeline network. Daily support is provided by an air separation plant with a capacity of 3,500 scfm. Flow rates greater than the separation plant can provide are supported by a high-pressure liquid conversion system capable of providing up to 28,000 scfm. |
| SUPPORTABLE MISSIONS | There is insufficient $GN_2$ in storage to support a complete STS countdown without the Big Three $GN_2$ plant. |

### ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- Interruption: Failure of the Big Three plant to provide product.

- Product requirement: Approximately 69 million scf of $GN_2$ per month with an additional 25 million scf for each launch, and with a peak flowrate of 16,000 scfm at LC-39, concurrent with a 500 scfm for other users, during a launch will be the expected requirement.

- Support capability/duration: There would be only 2.8 million usable scf in inventory above the minimum pressure of 3,500 psig, and would be consumed within 24 hours at a nominal daily usage.

  Current contingency planning allows for the continuation of STS launch countdown for 6 hours plus an additional 4 hours for vehicle safing in the event the Big Three plant is lost during Shuttle cryogenic loading.

- Backfill Options: Two B.J. Titan rechargers have been procured for use in STS contingency support. Each of these rechargers is capable of providing up to 7,000 scfm each at 6,000 psig. There are also plans to construct a recharger pumping station at CCF-39 to accommodate the higher flow rates provided by the new rechargers. This pumping station will have connections for two rechargers with the capability of adding an additional connection if required. Activation of the new rechargers and pumping station would allow for the support of a complete STS countdown assuming no B.J. Titan recharger failures during countdown.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### NITROGEN, GASEOUS

There are three Big Three plant failures that could not be rectified in an expedient manner. Major failures of the pipeline compressor and air separation plant or the distillation column/cold box could be long lead-time items, but would only affect plant daily operations. Big Three would utilize the $LN_2$-to-$GN_2$ conversion system for daily support in the event the air separation was inoperable. The third failure, that of the $LN_2$ storage sphere, would severely impact support operations during launch. Big Three-supplied Nowsco rechargers could be utilized alone or in conjunction with the B.J. Titan rechargers to support launch requirements in the event that the $LN_2$ pumps were inoperable, but providing the large quantities of $LN_2$ required for cryogenic loading without a large storage reservoir would be difficult. Each launch attempt with scrub/turnaround activities has the potential of using over 200,000 gallons of $LN_2$ requiring a significant number of $LN_2$ tanker deliveries to be off-loaded during countdown.

- Conclusions: With the activation of the B.J. Titan rechargers and the ability of Big Three to bring in Nowsco rechargers, there is sufficient pumping capability to support both daily usage and launch flows. To ease $LN_2$ logistical problems and ensure sufficient capability is available alternate $LN_2$ storage would be required in the event of a catastrophic failure of the Big Three $LN_2$ storage tank.

- Action: None.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### HYDRAULIC FLUID, FIRE RESISTANT

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|---|---|
| ITEM | HYDRAULIC FLUID, FIRE RESISTANT |
| PROCUREMENT | JSC |
| RESP. KSC ORGS | LSOC-086 NASA/TL-FGP-5<br>867-5211 867-6458 |
| CONTAINER | 55-gallon drums |
| SPECIFICATION | Military Specification MIL-H-83282B conforming to Bray Oil Company formulation Micronic 882-NASA with a limit of 25-ppm maximum sulfur and 25-ppm maximum trichlorotrifluoroethane (Solvent 113). |
| USE | Used as the lubricating agent on the Orbiters' aerodynamic control surfaces, main engine, and landing gear, on the ET umbilical actuator, and on the SRB nozzle controls. |
| SUPPLIER | Bray Oil Company<br>16715 Von Karmen Avenue, Suite 230<br>Irving, CA 92714<br>(Subsidiary of Burmah-Castrol, Inc.) |
| ISSUE | Bray is the sole-source supplier per their Micronic 882-NASA formulation. Although other sources are probably available, BrayCo has performed the required qualification testing. Servicing of GSE and flight elements must be only from drums marked "Shuttle Use Only." |
| AVAILABILITY | JSC/GFE Orbiter Support Projects Control Office (VN3/BW3) is responsible for procurement of this special hydraulic fluid. It is normally purchased by batch order under individual contract on a one-time buy. Manufacturer delivery time is 3 to 4 months from date of order. Burmah-Castrol has other subsidiaries all over the U.S., including one in Florida that could develop the capability of producing the product, with additional qualification testing to meet NASA requirements. |
| CONSUMPTION | KSC usage has ranged from 10.8 drums per month in 1985 to 2.4 drums per month in the first half of 1988. |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### HYDRAULIC FLUID, FIRE RESISTANT

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| STORAGE | 1,200 drums were purchased on a one-time JSC buy in 1984 and 300 of these drums were received at KSC for storage on May 3, 1984. Inventory/storage is provided at KSC, VAFB, MSFC, WSTF, Rockwell/Downey, and Moog/New York. Immediate requirements can be filled by redistribution of user inventories via JSC direction. |
| SUPPORTABLE MISSIONS | If a minimum of 50 drums is maintained, about 14 missions will be supported. |
| CURRENT SUPPORT | The Hydraulic Fluid is supplied to all users as a "Government-furnished product" under JSC direction. Flight support quantities are issued by KSC LSOC Logistics (FSN-9150-00-K0-4237). Issue is controlled by an Item Manager who receives an automatic suspense when a request for issue is made. Issue is made only to authorized users. |

### ANALYSIS/STRATEGY FOR SUPPORT DURING NORMAL SUPPLY INTERRUPTION

- Interruption: Failure of the primary plant to provide product.
- Product requirement: 2.4 to 10.8 drums/month will be the expected requirement.
- Support capability/duration: A nominal 6-month supply, minimum, (about 50 drums) should be maintained in inventory to provide the necessary support.
- Backfill options: Backfill of inventory during supply interruption will be provided by obtaining product from an alternate Burmah-Castrol plant.
- Conclusions: With KSC flight support inventory at KSC, multiple plant supply capability, and the JSC inventory redistribution option, continuous launch support is assured.
- Action: EG&G will recommend that LSOC move the VAFB supply to KSC, and establish a KSC max/min quantity of 100/50 drums.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### HYDRAZINE

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|---|---|
| ITEM | HYDRAZINE ($N_2H_4$) |
| PROCUREMENT | AFLC (SA-ALC) |
| RESP. KSC ORGS. | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered to CCAFS stockpile in 55-gal. drums. |
| SPECIFICATION | Military Specification MIL-P-26536D. |
| USE | Hydrazine is the monopropellant fuel for the Orbiter HPU and APU, and for the TVC system (SRB HPU). |
| SUPPLIER | Olin Corporation, Lake Charles, LA. |
| ISSUE | Olin is the only domestic source of $N_2H_4$. |
| AVAILABILITY | SA-ALC has a multi-year production contract with Olin to produce $N_2H_4$. SA-ALC maintains drum inventory at the Olin plant in Lake Charles, at CCAFS, and at other user locations. Olin has storage for 1500 drums of various hydrazine products at the Lake Charles plant. The CCAFS area permits storage of 115 55-gallon drums. This area provides stockpile storage quantities as well as courtesy storage for users. SA-ALC also reviews inventory and forecasts 2.5 years requirements semiannually to assure a minimum 3-year stockpile. |
| CONSUMPTION | A nominal mission will require 150 gallons (1,260 lbs.). The breakdown is 117 gallons for the APU, 13 gallons for the HPU, and 20 gallons for the SRB HPU "hot firing." |
| STORAGE | The product is stored at the CCAFS Propellants South $N_2H_4$ Drum Storage Area. |
| SUPPORTABLE MISSIONS | SA-ALC maintains a stockpile to cover a forecasted three-year usage. The CCAFS established minimum stockpile will support 3 shuttle missions. The SA-ALC stockpile should extend launch support until mid-1992. Their supply forecast will be expected to change with launch schedule changes. |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### HYDRAZINE

CURRENT SUPPORT — The minimum controlled storage quantity at CCAFS for STS support is ten drums. When supply reaches this level, 20 $N_2H_4$ drums are either purchased from Air Force inventory or transferred to CCAFS from other stockpile sites. Distribution from storage is made either by drums or by loading KSC's 500-gal. liquid tanker from drums.

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- Interruption: Failure of the Olin Lake Charles plant to provide product.
- Product requirement: 150 gallons (1,260 lbs.) per mission will be the expected requirement.
- Support capability/duration: Ten 55-gal. drums, minimum, will be available in inventory to support 3 missions.
- Backfill options: Replenishment drums will be obtained from Olin's Lake Charles, LA. stockpile site.
- Conclusions: With Air Force stockpiles at CCAFS, Lake Charles, LA., and McIntosh, AL., continued launch support could be assured until such time as production capability is restored (estimated maximum of 2 years).
- Action: KSC has requested that SA-ALC provide, on a periodic basis, a time-oriented inventory analysis to determine storage and production run requirements.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### MONOMETHYLHYDRAZINE

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|---|---|
| ITEM | MONOMETHYLHYDRAZINE (MMH) |
| PROCUREMENT | AFLC (SA-ALC) |
| RESP. KSC ORGS | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivery to CCAFS (Propellants South) is accomplished by 6,000-gal. capacity, SA-ALC contracted liquid tankers (maximum load: 5,400 gallon). Distribution is accomplished with KSC-owned liquid tankers, one each: 3,000-gal., 5,000-gal., and (for fire training) 500-gal. capacity |
| SPECIFICATION | Military Specification MIL-P-27404B. |
| USE | MMH is used as the hypergol fuel for the Orbiter OMS and RCS. MMH is also used by the SRB's thrust vector control. Minor amounts are used for training exercises (fire fighting and spill/cleanup). |
| SUPPLIER | Olin Corporation, Lake Charles, LA. |
| ISSUE | Olin is the only domestic source of MMH. Although the hydrazine family is produced by $NH_3$ processes, MMH is unique due to reaction control difficulties when Methylamine is added. |
| AVAILABILITY | SA-ALC has a multi-year production contract to produce MMH with Olin to fulfill forecasted requirements and maintain a 3-year stockpile. Olin is under SA-ALC contract to store MMH in Government railcars at the Lake Charles site. SA-ALC has 22 Government railcars usable for MMH, A-50, or $N_2H_4$, and divides them appropriately to provide forecasted quantities. SA-ALC maintains stockpile, reviews inventory semiannually, and forecasts usage requirements. Olin has indicated it would take 3 years to totally rebuild the plant, providing Government funding is available. |
| CONSUMPTION | A nominal STS mission will require up to 1,470 gallons (10,800 lbs.) of MMH. The breakdown is 7,900 lbs. for the OMS, and 2,900 lbs. for the RCS. When and if additional orbital velocity is required during a mission, payload bay kits may be required. Each of up to three kits |

would require 4,500 lbs. STS training exercises require 500 gallons/year (3,700 lbs./year) and are supported with MMH received from OMS/RCS deservicing, system low-point and sample collection drains, etc. when available. KSC is the major user of MMH since VAFB is downmoded. Minor quantities are used by propulsion system components development sites.

STORAGE

LC-39 storage consists of up to 7,600 gallons in a Ready Storage Vessel at each of the two LC-39 pads. The Air Force controlled stockpile consists of storage at CCAFS (Propellants South) and Olin (Lake Charles, LA). Independent storage exists as well at NASA contractor components development sites. Olin storage is by railcars containing up to 6,700 gallons each. One to three storage tanks with up to 25,000 gallons of MMH in each are planned under HSSF for CCAFS.

SUPPORTABLE MISSIONS

SA-ALC maintains a 3-year stockpile to provide for forecasted usage. LC-39 Pad RSV quantity levels are usually maintained to provide a minimum total of 10,000 gallons between the two pads; thus a minimum of 6 missions could be supported with these RSV sources. Additional missions that could be supported are dependent upon the railcars inventory maintained by Olin and the resultant CCAFS HSSF storage tanks.

CURRENT SUPPORT

Orbiter MMH hyperload is accomplished from the 7,600 gallons in the LC-39 pad RSV. MMH is delivered to the LC-39 pad RSVs by a 3,000- or 5,000-gal. KSC-owned tanker after receipt and transfer of product from the SA-ALC-contracted tanker. With HSSF availability, SA-ALC tanker deliveries will be made directly to the HSSF, from which the KSC-owned tanker will be utilized for transfers to the LC-39 pad.

ANALYSIS/STRATEGY FOR SUPPORT DURING SUPPLY INTERRUPTION

- Interruption: Failure of the Olin production plant to provide MMH.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### MONOMETHYLHYDRAZINE

- Product requirement: An estimated 1,470 gallons (10,800 lbs.) per mission will be the expected requirement.

- Support capability/duration: RSV inventories will provide the necessary support for a minimum of 6 missions if the total volume of both pads is maintained at 10,000 gallons.

- Backfill options: The Air Force stockpile is maintained at CCAFS and Olin to provide for near-years requirements. Product from these sources will be used to provide pad product replenishment during supply interruption.

- Conclusions: With the two KSC RSV's minimally at 10,000 gallons, and the future HSSF storage of 25,000 to 75,000 gallons, a total of 35,000 to 85,000 gallons of storage could be available for support.

- Action: KSC has requested that SA-ALC provide, on a periodic basis, a time-oriented inventory analysis to determine storage and production run requirements.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### NITROGEN TETROXIDE

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|---|---|
| ITEM | NITROGEN TETROXIDE ($N_2O_4$) MON-3, LOW IRON |
| PROCUREMENT | AFLC (SA-ALC) |
| CONTRACT | NAS 3620 |
| RESP. KSC ORGS. | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Primary method of delivery to KSC is provided by two, KSC-owned, 3,000-gal. each, stainless steel tankers to assure that the low-Iron content required by the specification is maintained. Eleven SA-ALC-contracted carbon-steel tankers may also make deliveries of $N_2O_4$ which does not have an iron content limitation. Also, 110,000 lb. (9,100 gal.) SA-ALC-contracted carbon-steel railcars may be used. If the railcars or tankers are required as backup to the primary method, KSC molecular-sieve equipment may be used to filter out the Iron. |
| SPECIFICATION | NAS-3620, $N_2O_4$ MON-3 |
| USE | $N_2O_4$ MON-3 is used as a hypergol oxidizer in the OMS, APS, and RCS aboard the Orbiter. |
| SUPPLIER | Cedar Chemical Company, Vicksburg, MS |
| ISSUES | Cedar Chemical is the only active $N_2O_4$ producing site in the U.S. today. Hercules' California plant, a past producer of $N_2O_4$, is not active but responded to bid proposal.<br><br>While $N_2O_4$ normally can be stored indefinitely, unique storage and handling problems can develop. It has a tendency to absorb iron into solution (from carbon steel) and will go out of the NO specification if handled sufficiently, due to NO boiloff. MON-10, also supplied by Cedar Chemical, can be added to adjust the NO content. An iron-removal unit (molecular sieve), designed and procured at KSC to reduce the iron level, may be used if necessary.<br><br>$N_2O_4$ tanker transport is governed by DOT exemption DOT-E-3121. The DOT has modified their exemption requirements to require DOD to |

have an operational emergency response plan. The DOD has opted for escorting these shipments as the means for complying with this provision.

AVAILABILITY

SA-ALC contracts with Cedar Chemical to obtain a bulk quantity of product and to store $N_2O_4$ on the Company site. SA-ALC is developing a CCAFS storage site to stockpile $N_2O_4$ (Emergency Congressional funding obtained to allow 1989 completion of HSSF). After the HSSF expansion the total capacity will consist of four 22,000-gal. tanks with up to 239,100 lbs. in each, with the anticipated allocation as follows: one MON-3; and three MON-1. SA-ALC states that they maintain a MON-3 $N_2O_4$ stockpile inventory (cumulative at various sites) sufficient to cover users' requirements for a 2-year time-frame. MON-3 is also in storage at other Government facilities (such as WSTF) as well as at propulsion system components systems development sites (i.e., Aerojet General and Rocketdyne).

Cedar Chemical has equipment replacements on hand for "hard to purchase" items and indicated that a $N_2O_4$ plant could be rebuilt in 6 to 12 months. As an alternate production option, Cedar Chemical indicated that it has the technology available to modify their nitric acid plant to produce $N_2O_4$ within 4 months.

Hercules indicated that they can provide a one ton/day package plant at one's own selected site, based on a new concept which has been pilot-plant tested.

CONSUMPTION

A nominal STS loading requires 1,450 gallons (17,500 lbs.) of $N_2O_4$. When and if additional orbital velocity is required during a mission, payload bay kits may be required. Each of up to three kits would require 4,500 lbs. STS training exercises require 500 gallons/year (3,700 lbs./year), and are supported with $N_2O_4$ received from OMS/RCS deservicing, system low-point and sample collection drains,etc. when available. KSC is the only major user of MON-3; WSTF uses small test quantities.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### NITROGEN TETROXIDE

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|---|---|
| STORAGE | LC-39 storage consists of up to 7,600 gallons in a Ready Storage Vessel at each of the two LC-39 pads. Cedar Chemical provides storage at their plant of up to 9,000 gallons (108,700 lbs.). Additional storage capability at Cedar Chemical consists of three 28,000-gal., capacity, (25,000 gal. $N_2O_4$) carbon-steel tanks for MON-1 or MON-3 storage, in addition to three (9,100-gal. $N_2O_4$) carbon-steel railcars. |
| SUPPORTABLE MISSIONS | SA-ALC states that they maintain a stockpile to cover a forecasted 2-year usage. LC-39 Pad RSV quantity levels are usually maintained to provide a minimum total of 10,000 gallons between the two pads; thus a minimum of 6 missions could be supported with these sources. Additional missions that could be supported are dependent upon the dedicated inventory maintained by Cedar Chemical. |
| CURRENT SUPPORT | Orbiter $N_2O_4$ hyperload is accomplished from the 7,600 gallons in the LC-39 pad RSV. $N_2O_4$ is delivered to the pad by 3,000-gal. KSC tanker directly from the vendor until December 1990 when the DOT exemption will expire. With HSSF availability through December 1990, KSC tankers will continue to be used for delivery from Cedar Chemical directly to the HSSF or to the LC-39 pad RSVs, if ullage allows. After December 1990 and with HSSF availability, deliveries from HSSF to the LC-39 RSVs will be by KSC tanker; SA-ALC tankers (to be procured) will be used for deliveries from Cedar Chemical to the HSSF, or if the tankers permit, directly to the pad RSV when the RSV ullage will permit. |

### ANALYSIS/STRATEGY FOR SUPPLY DURING SUPPLY INTERRUPTION

- Interruption: Failure of Cedar Chemical production plant to provide product.
- Product requirement: An estimated 1,450 gallons (17,500 lbs.) of $N_2O_4$ per mission will be the expected requirement.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### NITROGEN TETROXIDE

- Support capability/duration: RSV inventories will provide the necessary support for a minimum of 6 missions if the total volume of both pads is maintained at 10,000 gallons.

- Backfill options: Product will be obtained from the Cedar Chemical 10,000-gal. (9,000 gallons of $N_2O_4$) dedicated storage tank to extend launch capability.

- Conclusions: With the 10,000 gallons of $N_2O_4$ in the two KSC RSV's, up to 9000 gallons of $N_2O_4$ in Cedar Chemical's storage tank, and anticipated 20,000 gallons of $N_2O_4$ in future HSSF storage, a total of up to 39,000 gallons of storage could be available for support.

- Action: KSC has requested that SA-ALC provide, on a periodic basis, a time-oriented inventory analysis to determine storage and production run requirements.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### SOLVENT 113

| | |
|---|---|
| ITEM | SOLVENT 113<br>(1,1,2-Trifluoro-1,2,2-trichloroethane) |
| PROCUREMENT | KSC (EG&G) |
| RESP. KSC ORGS | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Delivered in KSC-owned, 15,000-gal. railcar, NALX 190. |
| SPECIFICATION | MIL-C-81302D, Type II, amended by EG&G-PID-01. |
| USE | Solvent 113 is used as a final cleaning agent for numerous hardware components and softgoods where both water and alcohol are unsuitable. Solvent 113 is also used for contingency flushing and systems decontamination at the OPF, HMF, and pads. |
| SUPPLIER | Allied-Signal, Inc.<br>Morristown, NJ.<br>(from their Baton Rouge, LA plant) |
| ISSUE | As a result of mounting scientific evidence of stratospheric ozone layer damage, the United States EPA has recently ruled to limit the production of eight fully halogenated alkanes, including Solvent 113. Beginning July 1, 1989, the total U.S. production and import levels will be frozen at 1986 levels. These levels will be subsequently reduced to 50% within a decade. USEPA has stated that it would like to introduce legislation which would reduce consumption of the 8 halogenated alkanes 95% by 1998.<br><br>Currently, all substitute solvents and cleaners are either toxic or flammable. Where flammability is not an issue, Bioact DG-1 (manufactured by Petroferm Corporation) may be a suitable substitute at a cost 20% higher (per gallon) than solvent 113. |
| AVAILABILITY | Solvent 113 currently is also produced by duPont. |
| CONSUMPTION | KSC currently uses 160 - 240 tons/year of Solvent 113. On the average, EG&G Fluids Management supplies 170 tons per year of bulk |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### SOLVENT 113

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| | Solvent 113, BOC Materiel Supply (EGG-1010) supplies 15 drums (5 tons) per year, and SPC Supply (LSOC) supplies 70 drums (25 tons) per year. |
| STORAGE | KSC fixed storage consists of one 22,000-gal. tank. Solvent 113 is also stored in the KSC 15,000-gal. railcar, NLAX 190. |
| SUPPORTABLE MISSIONS | Inventory is maintained to provide support for minimum of about four missions, although consumption is not launch dependent. Quantities are also maintained for contingency flushing of OMS pods every fifth flight of an orbiter, a flight mission ground rule requirement. |
| CURRENT SUPPORT | A railcar delivery from Allied-Signal is made once every six months. Bulk solvent is transported to user locations by two 3,960-gal. liquid tankers, and two 5,000-gal. liquid tankers. Drum quantities are available from BOC Supply and SPC Supply. |

ANALYSIS/STRATEGY FOR SUPPLY DURING SUPPLY INTERRUPTION

- Interruption: Failure of the current supplier to provide the product (most likely due to back-order caused by EPA regulations).
- Product requirement: 30,500 gallons/year. (200 tons/year.) is the average annual requirement.
- Support capability/duration: 10,000 gallons, minimum, are maintained in bulk inventory to provide support for 4 months prior to re-order.
- Backfill options: Inventory replenishment will be contracted with an alternate supplier.
- Conclusions: With alternate supply sources, product availability is assured for continuous launch support.
- Action: None.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### REFRIGERANT 21

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| ITEM | REFRIGERANT 21 (dichlorofluoromethane) |
| PROCUREMENT | KSC (EG&G) |
| RESP. KSC ORGS | EG&G-630 867-4491 NASA/SI-A 867-4957 |
| CONTAINER | Procured in 1000-lb. gas cylinders, and, when required, distributed to offsite NASA Contractors in 150-lb. gas cylinders. |
| SPECIFICATION | Federal Specification BB-F-1421B (in accordance with STS program use specification JSC SE-S-0073) amended by EG&G-PID-09 to a boiling point of 48.1 $\pm$ 2 $^{o}$F. |
| USE | R-21 is the closed-loop heat transfer medium in the Orbiter main coolant system (ECLSS). R-21 is also required for testing of system components at manufacturing sites. |
| SUPPLIER | Most recent purchase was 20,000 lbs. in 1985 from Union Carbide, Danbury, CT. This purchase was the result of a special production run. |
| ISSUE | R-21 is the only known suitable refrigerant for the wide range of conditions experienced from Shuttle flight readiness through flight completion. The Shuttle's coolant system is the only known use for R-21. Hence, R-21 is rarely produced, and there is no domestic or foreign producer that regularly makes it. During the STS research and development phase and the first few launches, the source was duPont, West Germany. Union Carbide and Allied Chemical can also produce R-21. |
| AVAILABILITY | R-21 can be produced by changing the operating parameters of an R-22 production plant, however, due to low demand, special purchases on the order of 20,000 lbs. are required to justify the production and also to get a more reasonable price per lb. Since it is a toxic/hazardous material, requiring handling precautions during production (limiting personnel in the plant, etc.), the continued willingness of companies to produce R-21 may affect availability. |

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### REFRIGERANT 21

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| CONSUMPTION | The coolant system operates with 750 lbs. of R-21. However, the cooling system is a closed loop, and R-21 is required only to replace lost coolant, or for contingency refill. A base annual quantity of 4000 lbs./year is required by various offsite support organizations and laboratories for testing of Orbiter coolant system components. |
| STORAGE | An inventory of 1000-lb. cylinders and 150-lb. cylinders is maintained at LC-39 Propellants North. |
| SUPPORTABLE MISSIONS | Inventories are maintained to provide support requirements for a minimum of 2 years, and consumption is launch dependent only in a few instances (Orbiter cooling system top-off, payload quantities, and contingency refills). |
| CURRENT SUPPORT | EG&G provides R-21 via work order requests to authorized Shuttle users and their contractors. |

ANALYSIS/STRATEGY FOR SUPPLY DURING SUPPLY INTERRUPTION

- Interruption: Inability of one of the suppliers to provide the Refrigerant 21.
- Product requirement: The base annual requirement is 4000 lbs./year. Contingency Orbiter refill requirement is 750 lbs. Development and testing for OV-105 is anticipated to require two system fills.
- Support capability/duration: A minimum of 8,000 lbs., prior to re-order, is maintained in inventory and will provide support for 2 years.
- Backfill options: KSC will replenish inventory by purchasing product from an alternate supplier, either Union Carbide or Allied-Signal.
- Conclusions: Since product is expected to be available from at least 1 of 2 sources, continuous support for launches is assured. Since R-21 is a hazardous product, KSC should be aware of the above cited companies' willingness to produce it.

## LIMITED-AVAILABILITY STS REQUIRED FLUIDS/PROPELLANTS

### REFRIGERANT 21

- Action: When inventory is reduced to 8,000 lbs., EG&G will perform a market survey to determine product availability, followed by a procurement request to replenishment R-21 via subcontrct.

## UNIVERSALLY-AVAILABLE STS FLUIDS/PROPELLANTS

ITEM CITRIC ACID - 14 percent

REMARKS Citric Acid (14%) is used as a hypergolic fuel vapor scrubber solution at the pad and other support buildings. Drums of dry powdered citric acid are procured by KSC (EG&G) and stored at Central Supply. EG&G mixes the powder with water to a 38% solution for delivery to the user site; the user adjusts the concentration to 14% and adds antifoam agent for final use.

ITEM DEMINERALIZED WATER (DM Water)

REMARKS DM Water is used onboard the Orbiter in the water coolant loop, water boiler system, potable water system, the EVA liquid cooled garment and for many payloads. DM Water is produced at the KSC Water Plant, located at the CCF-39 area, from the KSC water supply obtained from the city of Cocoa, Florida. DM Water is also produced at user sites by portable deionizing units (PDU).

ITEM HALON-1301 (Bromotrifluoromethane)

REMARKS Halon-1301 is procured by KSC (EG&G). Halon-1301 is a liquefied gas used as a fire extinguishing agent in many KSC facilities and onboard the Orbiter. When placed in the fire extinguisher servicing cylinder, the pressure is boosted to the equivalent of 160 psig at 70 $^{o}$F with $GN_2$ to aid rapid dispersion during extinguisher activation. No Halon-1301 procurement concerns exist due to its widespread production and use. Halon-1301's production and use is widespread and there should be no procurement problems for the next 3 years. However, a recent Clean Air Act amendment has stipulated a production freeze at the 1986 annual quantity beginning in 1992. This freeze will likely cause a 10-15% shortage.

ITEM ISOPROPYL ALCOHOL (IPA)

REMARKS Drummed quantities of IPA are procured by KSC (EG&G) for general use. Bulk (2,000 to 5,000 gallons) quantities of IPA are procurable as a contingency flushing/drying agent should decontamination of STS hypergolic fuel distribution/storage systems be necessary. A 1-year subcontract is established for contingency procurement.

## UNIVERSALLY-AVAILABLE STS FLUIDS/PROPELLANTS

ITEM LIQUID ARGON (LAr)

REMARKS Liquid Argon, to specification MIL-A-18455B, is procured by KSC (EG&G). The principal use at KSC is to support analyses requiring ICP Spectrophotometers in the LC-39 Chemical Sampling and Analysis Laboratory, the O&C Building Microchemical Analysis Laboratory, and the CCAFS Biomedical Laboratory. Liquid Argon is available as a product of liquid air separation manufacturing.

ITEM HYDROCHLORIC ACID (HCl)

REMARKS HCl is procured by KSC (EG&G) and is used to regenerate the cation resin beds at the KSC CCF-39 demineralized water plant. HCl is a common product with several vendors located in the immediate area; therefore, no procurement concerns exist.

ITEM LIQUID NITROGEN ($LN_2$)

REMARKS $LN_2$ is converted to $GN_2$ through the use of mobile rechargers and stationary liquid vaporizers. Its uses include the manufacture of Liquid Air at KSC for SCAPE support, cryogenic testing of STS components and subsystems, a heat exchanger application to minimize $LO_2F$ boiloff, backup for the low-pressure ECS GN2 pipeline, and the requirements of institutional ground support facility operations. $LN_2$ is procured by SA-ALC and can be provided by a number of suppliers.

ITEM LIQUID OXYGEN ($LO_2A$)

REMARKS $LO_2A$ is used as a Space Shuttle main propellant to support SSME combustion and for manufacture of liquid air for SCAPE and otheer Breathing Air requirements. $LO_2A$ is procured by the SA-ALC and can be provided by a number of suppliers.

ITEM REFRIGERANT-114 (R-114) (Dichlorotetrafluoroethane)

REMARKS Refrigerant-114 is procured by KSC (LSOC) and is used in the Orbiter ground coolant loop and in Spacelab. Refrigerant-114 is readily available and no procurement concerns exist.

ITEM SODIUM HYDROXIDE-25 percent (NaOH-25)

REMARKS NaOH-25 is used as a hypergolic oxidizer vapor scrubber solution at the pad and other support buildings. NaOH-25 is procured by KSC (EG&G), with four known suppliers in the Florida area.

ITEM SODIUM HYDROXIDE-50 percent (NaOH-50)

REMARKS NaOH-50 is procured by KSC (EG&G) and used to regenerate the anion and mixed resin beds at the CCF-39 demineralized water plant. NaOH is readily available; therefore, no procurement concerns exist.

NASA National Aeronautics and Space Administration

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**16. Abstract**
In this study, over twenty significant liquid propellants and other fluids were reviewed as to their supply in support of the Space Shuttle Program (SSP), primarily at KSC. The uniqueness of most of the products, either by their application or production characteristics, present a variety of supply issues to contend with. Each, however, is critical to the success of the SSP. It becomes necessary to formulate, and maintain, a logistic approach to assure a continued availability of each product. For convenience, two categories were established. One, labeled "limited-availability", represents those products wherein they are single sourced, have production restrictions and/or there has been a history of supply problems. The other, labeled "universally-available", is characteristic of those having several sources and/or having little, if any, historical supply problems. This last category was not examined in depth. Through concepts of establishing stockpile inventories, multiple supply contracts, or other arrangements, the supply of liquid propellants and other fluids can be assured.

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