Shawnee Industries, Inc.

A SUBSIDIARY OF **Thiokol** CHEMICAL CORP.

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CHEMICAL STEAM GENERATING SYSTEM

OPERATION AND MAINTENANCE
MANUAL

Prepared For

AEROJET GENERAL CORPORATION

Azusa, California

by

MASTER

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CHEMICAL STEAM GENERATOR
SYSTEM

designed and manufactured by

SHAWNEE INDUSTRIES, INC.
division of
THIOKOL CHEMICAL CORPORATION

for

AEROJET GENERAL CORPORATION

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1.0 INTRODUCTION

This manual presents the operating instructions and necessary background information to safely operate the Chemical Steam Generator provided by Thiokol Chemical Corporation for Aerojet General Corporation, REON Division.

This equipment is thoroughly engineered and fabricated of proven components, with maximum emphasis on reliability and safety. It is not possible, however, to replace the care and judgment exercised by a well trained operator, consequently, all personnel involved in the use of this equipment should be thoroughly familiar with this manual.

The equipment described herein was originally provided by Thiokol Chemical Corporation to Aerojet General Corporation under Purchase Order Number NP 000254.

2.0 SYSTEM HARDWARE DESCRIPTION GENERAL

The function of the Chemical Steam Generating System, illustrated in Figure 2.1 and Figure 2.2 is to produce steam on command from a high rate chemical process. The unit described in this manual is specifically designed to provide drive media for the operation of the exhaust system in the NERVA Rocket Engine Test Stand (ETS Number 1) located at the National Nuclear Rocket Test Facility, Jackass Flats, Nevada.

The required energy for Steam Production is released by the continuous combustion of propane with oxygen. The final steam output is increased in mass flow and temperature controlled by the direct injection of feedwater.

A detailed description of each major component is contained in the following sections.

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FIGURE 2.2
CHEMICAL STEAM GENERATING SYSTEM
(DRAWING NO. 1542)

FIGURE 2.2
 CHEMICAL STEAM GENERATING SYSTEM
 (DRAWING NO. 1542)
 PAGE 2 of 2

2.1 TOP ASSEMBLY

The chemical steam system consists of three steam generator sub-units, referred to as steam modules, in conjunction with a steam plenum output chamber and a common mounting base assembly. The three identical generator modules (Figure 2.3) are skid mounted on a common mounting base to form a top assembly. Each generator module includes a steam generator with control, safety, and sequence equipment that is capable of operating independently of the support of the other generator modules.

The base assembly consists of a support frame with equipment common to all modules. This equipment includes common control, inlet and distribution manifolds, gas regulators, and a steam collection and discharge duct.

The system is assembled by joining the generator modules and base assembly at their mating sides and connecting the mating manifold interfaces. The three major components of the chemical steam generating system are:

- (a) Steam Modules
- (b) Mounting Base and Plenum Assembly
- (c) Control System

These components are described in the following paragraphs.

The steam generator system is designed to produce a normal output of

THIS ILLUSTRATION TO BE PROVIDED

superheated steam in accordance with the following specifications:

(1) Total steam temperature	1300°F. $\pm$ 100°F.
(2) Minimum steam pressure	130 PSIA.
(3) Weight flow (nominal)	130 lbs/sec.

Each steam generator module, as shown in Figure 2.4, is capable of producing an output flow rate of 65 lbs/sec, consequently, the required 130 lbs/sec. output of chemical steam can be delivered by two of the generator modules. The third module is kept at standby (idle) and will automatically come to full output if required to maintain steam pressure.

The top assembly piping schematic is shown by Figure 2.5, and the top assembly control schematic is shown by Figure 2.6.

2.1.1 STEAM MODULE

The chemical steam module is an independent unit capable of being handled or operated by itself. All necessary equipment to support the operation of the steam module is rigidly attached to a mounting skid, and the equipment is tested and accepted as a major sub-assembly, thus prohibiting takedown of piping, etc., with attendant leakage problems.

The steam module consists of several major components as follows:

- (a) The combustion element.
- (b) The pneumatic control box.
- (c) The propellant valving.

FIGURE 2.4
GENERATOR MODULE
(DRAWING NO. 1649)

FIGURE 2.4
GENERATOR MODULE
(DRAWING NO. 1649)
PAGE 2 of 2

FIGURE 2.6
OVERALL ELECTRICAL CONTROL SYSTEM
BLOCK DIAGRAM
(DRAWING NO. 1541)

The steam module piping schematic is shown by Figure 2. 7.

2. 1. 1. 1 STEAM GENERATOR COMBUSTION ELEMENT - GENERAL

The steam generator combustion element is a pressure vessel to contain and control the combustion and mixing processes. Each will utilize 30 lbs/sec of propellants to produce gas at a temperature of 5125⁰F. (Steam output temperature is lowered to 1300⁰F. by a water injection system.) The fuel is burned at a mixture ratio of 3. 0 to 1. 0 (22. 5 pounds of liquid oxygen to 7. 5 pounds of liquid propane) in the main chamber and a mixture ratio of 2:6 in the igniter. The combustion element consists primarily of:

- (a) First-stage igniter,
- (b) Second-stage igniter,
- (c) Main-stage injector,
- (d) Combustion chamber, and
- (e) Water injection and cooling system.

These sub-assemblies are discussed individually in the following paragraphs.

2. 1. 1. 1. 1 FIRST-STAGE IGNITER

Ignition of the steam generator combustion process is accomplished by a two stage spark-initiated igniter (Figure 2. 8 and Figure 2. 9). The first stage igniter is operated on gaseous oxygen and liquid propane which are ignited by a continuous spark, provided by a 10, 000 volt transformer. The spark plug electrode is cooled by gaseous oxygen flowing across the spark gap

LEGEND

FIGURE 2.7
MODULE SCHEMATIC DIAGRAM
PIPING
(DRAWING NO. 1545)

THIS ILLUSTRATION TO BE PROVIDED

on the way to the flame front. The first-stage combustion chamber is cooled by external circulation of water through a concentric jacket. Gaseous oxygen, for first-stage ignition, departs from the main manifold as liquid oxygen. The liquid oxygen passes through a water heated tubular heat exchanger which converts the liquid oxygen to gas phase. This heat exchanger is part of the feedwater manifold and draws heat from the feedwater. Propane is supplied to the first-stage igniter in liquid state. It is not necessary to convert the propane to gaseous form, since adequate atomization takes place upon injection into the first-stage combustion chamber.

The rate of flow of propellants for first stage ignition is controlled by cavitating venturis in the liquid side of the system.

The first stage combustion chamber is cooled by external circulation of water through a concentric jacket.

Utilizing a gaseous oxidizer for the first-stage of ignition increases ignition reliability since only a small amount of propellant is dependent upon spark ignition and propellant accumulation is negligible. The use of a two stage ignition system eliminates dependence of liquid ignition on spark and yet makes available a high-energy second-stage flame for main ignition.

2.1.1.1.2 SECOND-STAGE IGNITER

The second-stage igniter (Figure 2.8) is concentric with the first-stage. It is ignited by the spear of flame produced by the first-stage and is operated

with liquid propellants (propane and oxygen) which are drawn from the main manifolds at a constant rate of flow that is controlled by cavitating venturis. The second-stage injector is of a vortex configuration, chosen because of its high inherent reliability.

The second stage injector has a flat face, water cooled by inlet water to the first stage combustion chamber.

Two tubes carry liquid oxygen through the water jacket and cause the two streams of liquid oxygen to impinge upon each other and upon the first stage flame. Propane is delivered to the combustion process by two similar tubes which cause the fuel to impinge upon the chamber wall in such a way as to swirl downstream. This fuel wash of the walls reduces the heat transfer to the walls, and increases igniter reliability. The combustion chamber for the second-stage igniter is also cooled by the external circulation of water through a double jacket, with a concentric inlet manifold. The second-stage igniter is designed for continuous duty and is independent of the spark and first-stage combustion after achieving ignition.

2.1.1.1.3 MAIN-STAGE INJECTOR

The main stage injector controls the mixing of approximately 97% of the propellants, and is essentially the heart of the steam generator (Figure 2.8). The injector is fabricated to receive the second-stage igniter on its center through a flanged throat to make the ignition process in-line, smooth and re-

liable. Liquid propellants are supplied to the main combustion chamber through the main-stage injector body. A triplet, spud-type injector mixes the propellants by causing the oxidizer to impinge on the fuel. (OX on OX on fuel). A triplet injector has been selected to provide maximum combustion efficiency, and also to eliminate axial momentum vectors resulting from variations of the supply pressure. Propellants are flow controlled by cavitating venturis to maintain steady state flow conditions under various down stream (chamber) conditions. The injector is primarily fabricated by use of drilled passages in a solid forging and safety bleeds are provided to protect the main injector from explosion due to intermixing of propellants in any area containing welds exposed to propellants. If a weld leak occurs, the bleeds will serve to conduct the propellants to atmosphere and prevent accidental pressurization of unlike propellant welds. The injector face is regeneratively cooled by fuel, and serves as a distribution manifold to supply the fuel to the spud type injectors. Film coolant holes maintain flow in all areas and reduce potential hotspots.

2.1.1.1.4 COMBUSTION CHAMBER

The combustion chamber contains the combustion process through completion and then provides mixing to reduce the gas temperature to design conditions (Figure 2.8). The configuration of the combustion chamber is such that a central opening is provided to receive the main-stage injector sub-

assembly. The propane and liquid oxygen injected into the combustion chamber burn with a flame temperature of 5125°F. and produce, as products of combustion, superheated steam and, in lesser quantities, oxides of carbon (CO and CO₂).

The main combustion chamber is cooled by external circulation of water through a double jacket, and all coolant is then discharged overboard or directly injected into the hot gas as feedwater. Superheat is controlled 1300°F by injection of a pre-set rate of flow of demineralized water, normally 35 lbs/sec. into the gas stream. This water, at a pressure in excess of combustion pressure, is utilized for coolant and then, at the discharge end of the chamber, mixed with the products of combustion, and discharged into the plenum.

The outlet temperature may be adjusted by varying the flow rate of the propellants. All flow rates are controlled by cavitating venturis. To change the rate of flow, the cavitating venturi must be substituted with a venturi calibrated for the required flow rate.

During idle conditions full water flow exists and part of the water is injected into the main combustion chamber by the low-flow film process, whereby a small quantity of water is admitted through film cooling holes to mix with the superheated ignition combustion products, and to cool the ignition flame to 1300°F or less (for mixing with the other steam outputs). Valving exists to discharge the remaining water overboard in the case of an extended idle period. The cooling system provides long-term "on-the-line" capability

without damage to the idling unit.

When full steam output is required the water is shuttled from "overboard" to "direct injection". Water flow rate in all cases is venturi-controlled to prevent change in flow due to changes in back pressure or passage size, and is automatically monitored for flow before the initiation of main combustion as well as during full system operation.

2.1.1.2 PNEUMATIC CONTROL BOX

The pneumatic control box (Figure 2.10) contains all necessary sequence and control valves for the generation of the larger air operated air valves in the skid. The box essentially provides an explosion proof housing for all components located within its bounds, and is the interface between electric and pneumatic signals.

Also contained in the box are various position points for other circuits, and the 10,000 volt ignition transformer.

The pneumatic equipment box is explosion proof to National Electrical Code, Class I, Group D Standard.

2.1.1.3 PROPELLANT VALVES

The valves utilized to control propellant flow in the chemical steam generator are all of the globe type, and pneumatically operated.

All valves have soft seats, and are made of materials compatible with both the propellants utilized and the anticipated radiation atmosphere.

Figure 2.10 PNEUMATIC CONTROL BOX

The operating pressure for the main valves is 150 PSIG, and all main valves are controlled by separate control valves. A position switch exists in all main valves, and all are either on or off with the exception of the water shuttle valve which is either "on board" or "overboard".

The valving on the igniter system is pneumatically controlled also, although several valves are operated from the same control valve for sequencing purposes. Again, all valves are of the non-throttling type and either shuttle or shut off the respective propellant service.

The choice of valves for this system has been based upon past experience with like systems, and all valves are commercial types proven in extensive service.

2.1.2 MOUNTING BASE

The mounting base assembly supports the three generator modules and provides all common services, (Figure 2.10). Attached to the mounting base assembly is the common equipment explosion proof box, which contains pressure-sensing switches for all common system functions, the control regulators and the inlet manifolds. These components are discussed in the following paragraphs.

2.1.2.1 STEAM PLENUM

The steam plenum is a water-cooled assembly which ducts the steam discharge of each of the three generator modules into the test stand exhaust

FIGURE 2.11
MOUNTING BASE ASSEMBLY
(DRAWING NO. 1648)

system. The plenum is water cooled, and has one inlet and manifold adjacent to each steam inlet to provide even distribution. Flow of water through the cooling jacket is venturi controlled, thus ensuring even flow to avoid the occurrence of hot spots.

Expansion of the plenum is free, and restraint is provided by gibs on a sliding surface.

2.1.2.2 CONTROL MODULE

The control module is an integral pressure reducing station, capable of reducing the required quantity of nitrogen for control purposes from any inlet pressure less than 1000 PSIG, (nominally 450 PSIG).

The control module is manually operated and contains a loading regulator, a high flow regulator, and all necessary gauges, relief valves, and checkout bleed valves.

2.1.2.3 COMMON EQUIPMENT BOX

The common equipment box contains several pressure switches which are associated with common operations to all steam modules.

These items are listed as follows:

- (a) Low Steam Pressure Switch - 1 unit.
- (b) Low Steam Pressure Switch - 2 units.
- (c) Lox Manifold Pressurized Switch.

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(d) Fuel Manifold Pressurized Switch.

(e) Water Manifold Pressurized Switch.

(f) High Control Manifold Pressurized Switch.

(g) Low Control Manifold Pressurized Switch.

The common equipment box is explosion proof to National Electrical Code, Class I, Group D. Standards, and contains provisions for a nitrogen purge.

2.1.2.4 MANIFOLD ASSEMBLIES

The mounting base assembly contains all common manifolds as integral units, and is complete with expansion capability. All manifolds contain full diameter flanged outlets at the opposite side from the inlets, to permit bleed of facility piping.

2.1.3 CONTROL SYSTEM

The control system for the chemical steam generating system controls the steam generating process, permits step variation by command, and automatically protects the system from damage due to malfunction. A control console, remotely located, is the sole operating point. All operations except "propellant fill" are automatic. Checkout of components is accomplished with simulated signals which operate all of the components in sequence. (It is not necessary to check out the components individually.) Accidental starting of the unit is prevented by de-energizing the propellant system. A power switch will prohibit all operation when such action is required. Note that a

power failure shutdown and a normal shutdown differ only in post shutdown indications (signals).

No damage is incurred by a full power failure shutdown.

2.1.3.1 CONTROL SYSTEM OPERATION

The control system has been set up to control generation of steam at either "igniter-idle" or "full-flow" conditions. Capability exists to operate any combination of units; normal operation comprises two of the three units to be "on-the-line" with the third unit on automatic standby and operating at igniter-idle.

The control system is set up to command each module to either generate steam at full flow or to operate at igniter-idle. The full capacity of steam is obtained when two modules are "on-the-line" and the third is at igniter-idle. In the event that a malfunction should require that one of the units be shut down, the standby unit can be automatically brought to full flow output in two seconds. This is achieved by the shuttling of cooling water from overboard to injection, and actuating the main propellant valves.

2.1.3.2 CONTROL SYSTEM COMPONENTS

The control system is built to National Electrical Code, Class I, Group D Standards which are maintained by installing approved components in explosion proof housings. The control system is also protected by the application of a continuous nitrogen purge. All electrical inter-connections on the skid

FIGURE 2. 12
MASTER SEQUENCE UNIT
SCHEMATIC DIAGRAM
(DRAWING NO. 1547)

FIGURE 2.12
MASTER SEQUENCE UNIT
SCHEMATIC DIAGRAM
(DRAWING NO. 1547)
PAGE 2 of 2

FIGURE 2.13
MODULE CONTROL SYSTEM
SCHEMATIC DIAGRAM
(DRAWING NO. 1546)

are conduit-enclosed. The relay racks (for both master and individual generator module functions) are not explosive proof components since they are designed for installation in a protected remote location.

The required AC and DC input power and all inter-connecting cables are provided by Aerojet General Corporation.

The overall control system block diagram is presented by Figure 2.6.

2.1.3.2.1 MASTER SEQUENCE UNIT

The master sequencing unit provides common control for all three generator modules and ensures that smooth overall system functioning is maintained. The electrical control schematic for the master sequence unit is shown by Figure 2.12.

2.1.3.2.2 GENERATOR MODULE SEQUENCE CIRCUITS

Operation of the individual generator modules is controlled by separate sequence circuits in each generator module. Control of these individual sequence circuits is coordinated by the master sequence unit. The electrical control schematic for an individual module is shown by Figure 2.13.

2.1.3.2.3 CONTROL CONSOLE *

The control console provides remote switches and display indicators for use in operating the chemical steam generating system. Refer to the Control Console Manufacturers Manual for control console details.

* This unit is not supplied by TCC.

2.1.3.3 STEAM GENERATION SEQUENCE

Before steam generation can begin, the control system must be armed as follows:

- (a) Set nitrogen high-pressure and low-pressure controls to 450 and 150 PSIG respectively.
- (b) Set control console main circuit breaker, master sequence breaker and the individual generator module power switches to "on".
- (c) Pressurize LOX, propane and water.
- (d) Depress "Propellant-bleed switch".

(A detailed explanation of the above operations is provided in Appendix VI.)

Depressing the "start" switch (armed by preceding operations) begins the automatic idle sequence. Each step presents a signal to indicate accomplishment. Automatic safety switches guard against malfunction at all times, and provide a locked-in signal which records the reason for malfunction until the reset switch is manually reset. The sequence proceeds automatically as follows:

2.1.3.3.1 READY LIGHT "ON"

- (a) System pressurized and bled.
- (b) Low speed instrumentation on (by others).

2.1.3.3.2 "START" (Switch Depressed).

- (a) Water valve opens.

- (b) Water shuttle goes to overboard position.
- (c) Display board reads, "cooling flow OK" (overboard).
- (d) Main purge valve opens.
- (e) Bleed valve re-opens.
- (f) Water flow detected.
- (g) Water flow switch signals igniter-fire.

2.1.3.3.3 T = 0 SECONDS

- (a) Nitrogen purge checked.
- (b) Spark on.
- (c) First stage purge off.
- (d) Propellant on first stage.
- (e) First stage igniter fires (pressure switch signal to second stage igniter).

2.1.3.3.4 T + 2 SECONDS (Typical)

- (a) Second stage purge off.
- (b) Second stage propellant valves open.
- (c) Bleed valves close.
- (d) Second stage igniter fires (pressure switch signal to full steam).
- (e) Display board reads, "steam idle".
- (f) Ignition detected.
- (g) Full steam switch armed.

2.1.3.3.5 T - 4 SECONDS (TYPICAL)

"Full Steam" (switch depressed). *

- (a) Water valve shuttles to "on-board"
- (b) Water flow detected ("on-board").
- (c) Signal to main valves.
- (d) Main LOX purge off.
- (e) Main LOX valve opens.
- (f) Main fuel valve opens and main fuel purge "off".
(One second after "main valve" signal.)
- (g) Display board reads, "Full Steam Output".

2.1.3.3.6 T - 6 SECONDS (TYPICAL)

- (a) Full pressure.
- (b) Gauge indicates steam pressure and temperature.

2.1.3.3.7 T - 8 SECONDS (TYPICAL)

(Three (3) seconds from main LOX valve signal.)

- (a) Timer arms low-pressure steam cut-off and high-pressure steam temperature cut-off.

2.1.3.3.8 T - 11 SECONDS (TYPICAL)

(Six (6) seconds from main LOX valve signal.)

- (a) Timer dis-arms all individual cut-off circuits.

* Selector switch selects units to go to full steam output. Alternate unit is on "idle" and will not proceed past "idle" until signalled by pressure failure.

- (b) Timer arms low-pressure steam circuit for two units (to supply additional steam if required), and combination cut-off for low water flow and high steam temperature.

2.1.3.3.9 "STOP" (Any time after start).

Display board reads "purge", and auxiliary display board reads "manual shut-down".

- (a) All valves revert to normal position.
- (b) Purge valves on for 20 seconds (pneumatic delay on closing).

2.1.3.3.10 "VENT" (Any time after stop).

- (a) All systems vent, safety valves close, lines drain (control by others).
- (b) Low speed instrumentation "OFF".*
"RESET" (Any time after stop).

- (a) All interlocks clear.

2.1.3.4 CONTROL SYSTEM SAFETIES

Automatic safety devices monitor the equipment operation until full-flow of steam is achieved. The system will shut-down immediately if a questionable situation arises. A timer is provided to de-energize all safety devices after a safe period at full-flow. Automatic shut-down will occur only when

*This instrumentation not supplied by TCC.

both conditions of high temperature and no water-flow occur simultaneously.

The safety circuits which are provided may be divided into two categories, as follows:

2.1.3.4.1 PRE-START SAFETIES

The steam generator control system contains several safety circuits to prevent start of the system if all conditions are not correct at the time of start. These circuits are as follows:

- (a) Lox manifold pressure OK (pressure switch).
- (b) Fuel manifold pressure OK (pressure switch).
- (c) Water manifold pressure OK (pressure switch).
- (d) High control nitrogen manifold pressure OK (pressure switch).
- (e) Low control nitrogen manifold pressure OK (pressure switch).
- (f) Fuel manifold bleed OK (pressure switch).
- (g) Oxygen manifold bleed OK (pressure switch).

2.1.3.4.2 POST START SAFETIES

The control system contains several safeties to shut down the steam generator, or to call for the spare generator in the event of a malfunction after start. Notice that all operations in the sequence are triggered by the successful completion of the last operation, and are thus inherently safe. These circuits are armed or dis-armed at several points in the sequence, as follows:

- (a) Low Purge Failure - Pressure switch detection system on main

purge system armed for cut-off with main water OK pressure switch pickup.

Active until main LOX valve signal plus 6 seconds.

(b) Low Water Flow - Delta pressure switch detection system armed for cut-off any time after water flow detected.

Active until main LOX valve signal plus 6 seconds.

(c) First Stage Ignition - Delta pressure switch detection system armed for cut-off any time after signal for first stage combustion. Cut-off within 3 seconds if not actuated.

(d) Second Stage Ignition - Delta pressure switch detection system armed for cut-off any time after signal for second stage combustion. Cut-off within 3 seconds if not actuated.

Active only for interval from second stage signal to second stage ignition.

(e) Water Overboard - Delta pressure switch detection system to provide cut-off any time after "on-board" water flow detected, and consequently lost.

Active from "full steam" signal until 6 seconds after main LOX valve signal.

(f) Low Steam Pressure - Gauge pressure switch to detect low steam pressure after signal to full steam.

Active 3 seconds after main LOX valve signal until 6 seconds after main LOX valve signal.

(g) High Steam Temperature - Thermal snap switch to detect over temperature.

Active from 3 seconds after main LOX valve signal until 6 seconds after main LOX valve signal.

(h) High Steam Temperature plus Low Water Flow - Emergency signal to indicate certain destruction of the module.

Active from 6 seconds after main LOX valve signal until shutdown.

(i) Low Steam Pressure (Two Units) - Gauge pressure switch detection system to call for additional steam module if steam pressure low.

Active 6 seconds after main LOX valve signal until shutdown.

3.0 OUTPUT CAPACITY - GENERAL

The output of the steam generator for the system is variable in several parameters. Basically, the parameters which are of interest from an engineering standpoint are:

- (a) Weight flow rate.
- (b) Temperature.
- (c) Composition.
- (d) Pressure.

The individual generator may vary slightly at rated conditions, however, several conditions vary during operation at "off design" points. These "off design" conditions are discussed individually in the following paragraphs, while the normal design point conditions are listed in Figure 3.1.

3.1 WEIGHT FLOW-RATE

The total weight flow-rate is a total of the main water flow and the total quantity of propellants burned at any time (including igniter flow). Notice that a number of combinations are possible in the total system, dependent upon "idle" conditions, etc. The rated flow-rate for the complete system is 130 lb/sec. minimum, (195 lb/sec. maximum), however, the reader is referred to Acceptance Test Records (Appendix VIII) for actual flow rates under given conditions.

For given propellant processes, weight flow-rate will remain constant

IGNITION	Lox Flow (lb/sec)	Lox Temp.	Propane Fuel Flow (lb/sec)	Propane Fuel Temp.	Coolant Water Flow (lb/sec)	Coolant Water Temp. °F	Chamber Pressure (ea. unit) (PSIG)	Chamber Pressure (2. unit) (PSIG)
1st Stage	.0332	170°R	.0102	60°F	1.0	70°F	163	163
2nd Stage	.6	170°R	.22	60°F	2.6	70°F	155	155
Main Stage	21.6	170°R	8.0	60°F	4.0	70°F	65	130

STEAM OUTPUT		
	NORMAL	EMERGENCY
Weight Flow Total (lbs/sec)	132 (min.)	195 (min.)
Temperature (degrees F.)	1300 + - 100	1300 + - 100
Pressure (PSIA)	130 (min.)	130 (min.)

COMPONENT OUTPUT
NORMAL DESIGN CONDITIONS

Figure 3.1

due to venturi control conditions, provided that additional units are not brought on the line.

Weight flow rate is independent of steam pressure provided the latter is less than 120 PSIG. (If steam pressure is greater than 120 PSIG, weight flow may decrease slightly, and temperature may further increase or decrease.)

3.2 TEMPERATURE OUTPUT

The steam output temperature of the steam generator is primarily a function of the quantity of water added to the combustion products, and very slightly a function of mixture ratio. Since it is considered unlikely that the unit will shift mixture ratio enough to vary the output temperature appreciably the discussion will be limited hereafter for variation in water flow-rate.

Two possibilities exist for variation of the coolant flow-rate, namely:

(a) Reduction in total flow by pressure decrease or by venturi change, and

(b) Bleed of coolant by removing a part of the coolant in the bypass-injection loop. (A blind flange is provided for this possibility at a later date.) Should it be required to raise the steam temperature above design conditions, it is recommended that valving be added to the "bleed port" since this method of adjusting output temperature does not reduce the cooling capability of the combustion chamber.

Notice that the steam temperature of a generator at idle is approxi-

mately 1300°F. at a back pressure of 130 PSIA, but will be much lower under "no steam pressure" conditions since film coolant flow is dependent on differential across the chamber wall, and the jacket pressure is approximately constant.

3.3 STEAM COMPOSITION

The composition of the steam produced by the system, and consequently its molecular weight and specific test ratio, is dependent upon overall mixture ratio and water percent added.

Essentially, addition of coolant tends to reduce the molecular weight and increase the specific heat ratio. This is shown in Figure 3.2 for the chemical composition of the combustion products. The reader is referred to Appendix VII and actual calculations for further information.

3.4 STEAM PRESSURE

The pressure at which the steam is delivered (below 130 PSIA) is directly proportional to back-pressure, since the flow rate is constant. Increases or decreases may be made, within limits, by adjustment of the back-pressure system (or orifice).

D-44
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FIGURE 3.2
IBM COMPOSITION

4.0 SUPPLY REQUIREMENT

The operation of the steam generator requires the delivery of all propellants in a smooth and continuous manner for satisfactory operation. The rated requirements are as listed in Figure 4.1.

4.1 TEMPERATURE CORRECTION

Control of the propellant temperature for the rated point is a difficult and unnecessary situation, although flow must be controlled within fairly narrow limits for consistent performance. A correction factor to compensate for the effect of propellant temperature on weight flow (at the venturi) is included as Figure 4.1. Examination of this figure will reveal correction factors utilized for propane and oxygen only, since the temperature on the others is negligible.

Propellant	Quantity Module*		Quantity System**		Static Pressure	Dynamic Pressure	Temp.	Max. Particle Size
	Idle lb/sec.	Full lb/sec.	Idle lb/sec.	Full lb/sec.	PSIG	PSIG	°F.	Microns
Liquid Oxygen Mil. Spec. P-25508	.6	23.1	1.8	46.8	450	400	-290	100
Liquid Propane, TCC Spec. 0014	.22	7.72	.66	15.66	450	400	60	100
Demineralized Water	35	35	105	105	230	190	70	100
Gaseous Nitrogen, Fed. Spec. BB-N-411	SCFM	SCFM	SCFM	SCFM	PSIG	PSIG	°F	Microns
Purge	150	0	450	150	450	450	70	100

* 65 lb/sec. total steam output.

** 132 lb/sec. total steam output, 1 unit at idle.

FIGURE 4.1
RATED DELIVERY CONDITIONS

FIGURE 41 (a)

FIGURE 41 (b)

5.0 INSTRUMENTATION

The instrumentation used during operation of the steam generation system is for preparation and record purposes only. No actual measurements are required during the operation, since all functions and safeties are automatic.

Thiokol Chemical Corporation has provided mechanical and electrical taps for the convenience of Aerojet General Corporation in monitoring the performance of the system, in locations as described below.

5.1 ELECTRICAL TAPS

The electrical schematics included in this manual as Figures 2.12 and 2.13 , locate these taps at their respective connections and it is envisioned that Aerojet General Corporation will interrupt these signals as they pass through Aerojet General Corporation terminal strips.

It is recommended that any signals which are part of an operating sequence be isolated from the recording circuit by a blocking rectifier.

5.2 FLUID TAPS

The fluid taps provided by Thiokol Chemical Corporation are illustrated by Figure 5.1.

FIGURE 5.1
LOCATION OF MECHANICAL INSTRUMENTATION
TAP POINTS
(DRAWING NO. 1596)

6.0 CHECK-OFF LIST

The operation of any complex system is best accomplished by the use of a check-off list, generally prepared for use at a particular run. This type of worksheet acts as a guide in the preparation of the machine for use, reduces the possibility of error, and is useful in instigating safe procedures. A typical check-off list is included herein to serve as a basis for development of a final list suitable to the overall steam system.

This chapter also includes a sample copy of the steam generator Log Sheet, provided with each generator to permit orderly life records on all serialized parts.

6.1 CHECK-OFF LIST

LOX- PROPANE STEAM GENERATOR OPERATION

Propellants: LO_2 - C_3H_8 , H_2O

Description of Full Safety Gear

1. Rubber Suit
2. Face Shield
3. Rubber Gloves
4. Rubber Boots

Operator _____
Date _____
Location _____
Run No. _____

- NOTE: (1) Wash down all spilled propane with excess water.
- (2) Do not, under any circumstances, use oil or hydrocarbon on any part in the oxygen system. (Including bolts, fittings, etc.)
- (3) Never leave propellant lines, etc. open to contamination. Always cap, plug, or polyethylene shield.
- (4) Do not use fire or open flame in vicinity of steam generator.

A. GENERAL

1. All personnel entering propellant areas must have complete safety gear on at the following times:
 - (a) At such times when propellant lines are being disconnected.
 - (b) Whenever fuel valves are being removed.
 - (c) When filling the propellant tank.

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- (d) When a dangerous condition may be evident.
- 2. Warning lights ON (visual check).
- 3. Determine if propellant tanks require filling.
- 4. Check N₂ cascade pressure, 1600 PSI MIN.
- 5. Check DC voltage (26 volts min.).
- 6. Check master sequence circuit breaker "ON" (green light).
- 7. Check instrumentation, propellant and nitrogen lines.
- 8. Insure all bolts and fittings are properly torqued.
- 9. Check personnel safety showers.
- 10. Determine from operating engineer intention and duration of run.
- 11. REMOVE fire safety key (control console).

B. PRE-RUN

- 1. Nitrogen Cascade
 - (a) Bank hand shut-off valves OPEN.
 - (b) Main shut-off valve OPEN.
 - (c) Set purge regulator (450 PSIG), by adjusting hand loader.
 - (d) Set low control pressure (set 150 PSIG).
 - (e) OPEN hand bleed to check set pressure, (RECLOSE).
- 2. Generator Water System
 - (a) Check H₂O tank level (fill if necessary).
 - (b) Hand safety OPEN.
 - (c) Fill valve CLOSED.

(d) Manometer valve CLOSED, Manometer drain OPEN.

3. Oxygen System

(a) Check tank level, fill if required.

(b) Check hand vent valves CLOSED.

(c) Fill valves CLOSED.

4. C₃H₈ System

(a) Check tank level, (OPEN manometer valve top and bottom, read level, fill if necessary, CLOSE manometer valve top and bottom, OPEN manometer, drain, CLOSE, flush spillage).

C. RUN PHASE

1. Steam generator system operator report to panel. Check communications with engine panel operator.
2. Secure area, warning lights "ON".
3. Inspect panel. All switches de-energized.
4. Insert safety key, power "ON".
5. Control pressure OK, light "ON".
6. Put mode selector switch to "AUTO".
7. CLOSE tank valve vent.
8. OPEN tank safety valve.
9. Set tank pressures to 400 PSIG. (Performed from Aerojet General Corporation console by standard procedures.)
10. "Propellant OK" lights go "ON".

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11. Selector switch set to select units to operate.
12. Operate bleed switch (Lox and fuel bleed signals returned, ready light "ON").
13. Insure rocket engine is ready for test.
14. Depress "START" button, on command.
15. Rocket engine fired.

D. SHUTDOWN

1. Depress shutdown switch (generator will stop, purge will come on for 15 seconds).
2. CLOSE tank safety valves.
3. Vent tanks.
4. Run down purge and low control regulators.
5. Secure DC power.

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6.2 SAMPLE LOG SHEET

CHEMICAL STEAM GENERATOR MODULE

CHEMICAL STEAM GENERATOR MODULE

1.0 STEAM MODULE SERIAL NO. _____
 Previous Operating Time _____ Sec.
 Time This Operation _____ Sec.
 Total Time _____ Sec.
 (Life-40,000 Sec.)

2.0 IGNITER SERIAL NO. _____
 Previous Operating Time _____ Sec.
 Time This Operation _____ Sec.
 Total Time _____ Sec.
 (Life-40,000 Sec.)

3.0 INJECTOR SERIAL NO. _____
 Previous Operating Time _____ Sec.
 Time This Operation _____ Sec.
 Total Time _____ Sec.
 (Life-40,000 Sec.)

4.0 CHAMBER SERIAL NO. _____
 Previous Operating Time _____ Sec.
 Time This Operation _____ Sec.
 Total Time _____ Sec.
 (Life-40,000 Sec.)

5.0 SPARK PLUG SERIAL NO. _____
 Previous Operating Time _____ Sec.
 Time This Operation _____ Sec.
 Total Time _____ Sec.
 (Life-15,000 Sec.)

TEST NO. _____
Date _____
Location _____
Temperature _____ °F
Engineer _____
Operator _____
Inspector _____
Purpose _____

6.0 OPERATION DATA	SECONDS OF OPERATION		
	Units	Igniter	Module
Total Flow-Rate	lbs/sec.		
Output Temperature	°F.		
Output Pressure	PSIG		

7.0 MALFUNCTIONS OR COMMENTS _____

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APPENDIX I

PROPANE HANDLING

APPENDIX I

PROPANE HANDLING

(SYNONYM: DIMETHYLMETHANE)

A. PHYSICAL PROPERTIES

Molecular Weight	44.10
Vapor pressure @ 70°F	109.6 PSIG
Specific volume, 70°F, 1 atm.	8.674 cu. ft./lb.
Boiling point @ 1 atm.	-43.82°F
Freezing point @ 1 atm.	-305.88°F
Specific gravity, Gas (Air = 1)	1.562
Density of gas @ 32°F	0.1261 lb/cu. ft.
Density of liquid @ B. P.	0.585 lb/cu. ft.
Critical temperature	206.2°F
Critical pressure	617.4 PSIA (42 atm.)
Critical density	0.220 g/C. C.
Flammable limits in air	2.2 - 9.5% (by volume)
Auto ignition temperature	874°F
Flash point	-156°F
Explosive range	2.3 - 7.3% (by volume)

B. THERMODYNAMIC PROPERTIES

TEMPERATURE	VAPOR PRESSURE PSIA	SPECIFIC VOLUME LIQUID CU. FT./LB.
-80°F	5.65	0.0265
-70°F	7.48	.0268
-60°F	9.78	.02703
-50°F	12.60	.02733
-40°F	16.00	.02763
-30°F	20.18	.02794
-20°F	25.05	.02826
-10°F	30.95	.02859
0	37.81	.02893
10°F	45.85	.02930
20°F	55.00	.02970
30°F	65.70	.03011
40°F	77.80	.03055
50°F	91.50	.03101
60°F	106.9	.03150
70°F	124.3	.03209
80°F	143.6	.03269
90°F	165.0	.03329
100°F	188.7	.03390

TEMPERATURE	VAPOR PRESSURE PSIA	SPECIFIC VOLUME LIQUID CU. FT./LB.
100°F	188.7	.03390
110°F	214.8	.03452
120°F	243.4	.03532
130°F	274.5	.03612
140°F	308.4	.03702
150°F	345.4	.03817
160°F	385.0	.03962
170°F	426.0	.04132
180°F	473.2	.04367
190°F	523.4	.04712
200°F	575.0	.0521

C. VISCOSITY AND DENSITY OF LIQUID PROPANE

TEMPERATURE	DENSITY (g/C. C.)	VISCOSITY (CENTIPOISE)
-100°F	0.618	0.301
-80°F	0.606	0.262
-60°F	0.593	0.231
-40°F	0.580	0.205
-20°F	0.567	0.183
0	0.553	0.163
20°F	0.539	0.147
40°F	0.525	0.133

TEMPERATURE	DENSITY (g/C. C.)	VISCOSITY (CENTIPOISE)
60°F	0.509	0.121
80°F	0.492	(0.110) *
100°F	0.474	(0.100) *

D. DESCRIPTION

Propane is a colorless flammable gas at atmospheric pressure and normal temperatures. It has a characteristic natural gas odor and is soluble in ether, alcohol, and slightly soluble in water. Propane is one of the group of liquefied petroleum gases, and it is normally shipped in low pressure cylinders as a liquefied gas under its own vapor pressure of approximately 110 PSIG at 70°F.

E. TOXICITY

Propane is considered a simple asphyxiant, and in higher concentrations has an anesthetic action. It is not considered to be a toxic gas. There are apparently no ill effects from fumes remaining for several hours in an atmosphere containing concentrations as high as 3 - 5% propane, or from repeated exposures.

F. MATERIALS OF CONSTRUCTION

Since propane is a non-corrosive gas any common or commercially available metal may be used. However, piping systems or vessels to contain propane should be designed to have a working pressure as specified by

* Extrapolated Values

competent engineers using a safety factor conforming to the ASME code for pressure piping.

G. LEAK DETECTION

All fittings and joints should be painted with soap solution to detect leaks, which will be indicated by bubble formation. NEVER USE A FLAME TO DETECT LEAKS.

H. CLASSIFICATION

Propane is classified by the Interstate Commerce Commission as a flammable compressed gas. "RED GAS LABEL" is required.

I. PRECAUTIONS IN HANDLING AND STORAGE

The hazards due to the handling of propane stem mainly from its extreme flammability. Store and use propane in well ventilated areas away from heat and all ignition sources such as flames and sparks. NEVER use flames to detect flammable gas leaks, use soap water solution. Do not use propane around sparking motors or other non-explosion-proof equipment. Do not store reserve stocks of propane with containers of oxygen, chlorine, or other highly oxidizing or flammable materials. Ground all lines and equipment use with propane. Never tamper with safety devices in valves or cylinders.

J. FILLING DENSITIES

The "filling density" is defined as the percent ratio of weight of the gas

in a container to the weight of water the container will hold at 60°F. All containers shall be filled according to the following filling densities:

SPECIFIC GRAVITY AT 60°F	ABOVE GROUND CONTAINER, 0-1200 U. S. GALS. TOTAL WATER CAPACITY
. 473 - . 480	38%
. 481 - . 488	39%
. 489 - . 495	40%
. 496 - . 503	41%
. 504 - . 510	42%
. 511 - . 519	43%
. 520 - . 527	44%
. 528 - . 536	45%
. 537 - . 544	46%
. 545 - . 552	47%
. 553 - . 560	48%
. 561 - . 568	49%
. 569 - . 576	50%
. 577 - . 584	51%
. 585 - . 592	52%
. 593 - . 600	53%
. 601 - . 608	54%
. 609 - . 617	55%
. 618 - . 626	56%
. 627 - . 634	57%

K. MAXIMUM LIQUID VOLUME - PERCENT

The maximum liquid volume in percent of total container capacity shown below may be used in lieu of the preceding table to determine maximum quantity that may be placed in containers up to 1200 gallons total water capacity.

Liquid	Above Ground Containers Liquid Temp. assumed to be 40°F
Propane (approx. Sp. gr. 0.51)	80%
Mistures (approx. Sp. gr. 0.55)	83%
Butane (approx. Sp. gr. 0.58)	86%

L. TRANSFER OF LIQUIDS

1. At least one attendant shall remain close to the transfer connection from the time the connections are first made until they are finally disconnected, during the transfer of the product.
2. Containers shall be filled or used only upon authorization of the owner.

M. TRANSPORT TRUCK UNLOADING POINTS AND OPERATIONS

1. Unloading area shall be relatively level.
2. A man shall be in attendance at all times while the tank truck is being unloaded.
3. The pipe line or container to which the unloading hoses are connected shall be equipped with a back flow check valve to prevent discharge

of the LP gas from the receiving container and line in case of line hose and/or fittings rupture.

N. FIRE FIGHTING

When there is fire under way where liquefied petroleum gas equipment is installed and the equipment is exposed to excessive heat, it should be remembered first of all that pressure in an LP-Gas container varies directly with the temperature of the contained product. Therefore, it is logical and desirable to keep the container as cool as possible in order to prevent or minimize any discharge of gas through the relief valve due to excessive pressure build-up. This can be done by applying a stream of water to the container. If it is possible and practicable, it is wise to disconnect the containers (small containers and cylinders), remove them from the fire zone and place them at a safe distance in an upright position. It is important to keep containers in an upright position in order to prevent the discharge of liquid through the relief valve.

If a fire is adjacent to a liquefied petroleum gas container, but no LP-Gas is escaping, efforts should be made to keep the container cool, thus diminishing the possibility of a build-up in pressure great enough to open the safety relief device. If a fire occurs at a large installation such as a bulk plant or an industrial installation, efforts should be directed toward cooling the storage tank by the application of streams of water. If possible, any fire around the container which is heating the contents of the tank should be extinguished.

When the source of heat is removed, the pressure within the container will diminish and the relief valve will close. If the gas is escaping at the safety relief valve stacks, it should be ignited if doing so creates no further hazard. Such a torch will be safe as it will diminish and go out when the tank pressure is reduced below the set pressure of the relief valve.

It should be remembered that when fighting LP-Gas fires it is generally advisable to permit any escaping gas to burn itself out. The fire can be controlled within limits. However, if the fire is extinguished without stopping the leakage, the gas may accumulate and under certain conditions, if reignited, cause an explosion.

Should the upper portion of the container valves be in a protecting device or hood which is located, the lock can be broken by a hammer or axe and the container valve then shut off with the hand wheel or with an adjustable wrench. If the container is to be removed after the valve is closed, the flexible connections can be disconnected or, if necessary, cut with an axe.

If the container relief valve has opened and the gas is discharging through the relief valve and is burning, play a stream of water on the container to cool the liquid and reduce the pressure therein. This will cause the relief valve to close. If the container is equipped with a fusible plug which has opened, it is safest to let the escaping gas continue to burn until the contents are exhausted, for the escaping gas, if not burned, might create an added hazard. If a gas line is broken and the escaping gas ignited, one of the first consid-

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erations should be to stop the flow of gas. Generally, this can be done by closing the valves at the storage container if no other means are provided. After the flow of gas is stopped, an extinguisher such as dry powder chemical should be used to extinguish the fire. It is important to remember that the fire should be controlled and not extinguished, unless the gas leakage can be stopped.

These same principles should be followed in event of a fire involving LP-Gas tank truck or tank car.

O. EXPLOSION HAZARD

Highly dangerous explosive when exposed to heat or flame. (Does not heat spontaneously.)

Shock can shatter the compressed gas container with explosive force. Can react vigorously with oxidizing materials, causing fire or explosion.

P. REFERENCES

1. Dangerous Properties of Industrial Materials - SAX.
2. Matheson Gas Data Book - The Matheson Co., Inc.
3. National Fire Codes, Vol. I - National Fire Protection Association.

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APPENDIX II

SHAWNEE INDUSTRIES, INC.
SPECIFICATION NO. 0014

PROPANE PROCUREMENT

[illegible]

SHAWNEE INDUSTRIES INC.
A SUBSIDIARY OF
THOROGOOD CHEMICAL CORPORATION
ROCKAWAY, NEW JERSEY

SECURITY CLASSIFICATION

SPECIFICATION 0014

CLASS I

PG. 2 OF 2

LET.

SPEC. 0014

TITLE

PROPANE, DETAILED SPECIFICATION FOR PROCUREMENT OF

1.0 SCOPE

This specification is provided to define the chemical properties of liquid propane to be used as a fuel in chemical steam generators.

2.0 REQUIREMENTS

This paragraph will set forth the chemical requirements for the subject liquid propane.

2.1 CHEMICAL COMPOSITION

Propane, as described by this specification, shall be 95% minus 0 plus 5% propane (C_3H_8). The remaining 5% may consist of the following contaminants:

2.1.1	Propylene (C_3H_6), permissible percentage	0 to 5%
	Butane	0 to 3%
	Ethane	0 to 3%
	Ethylene	0 to 3%
	Isobutane	0 to 1%

The maximum concentration of sulphur, olefins, and moisture shall be less than .1%.

2.1.2 The vapor pressure of the mixture shall be 109.6 psig ± 2 psi when measured at 70°F.

2.1.3 Particle Contamination. The maximum particle size which shall exist in the propane as delivered shall be 100 micron or smaller.

3.0 QUALITY ASSURANCE PROVISIONS

To insure that the propellant meets the above specification a certification will be required from the supplier and the customers quality control personnel will make spot checks of the propellant as requested by engineering.

4.0 ANALYSIS OF THE DELIVERED PRODUCT

The vendor shall provide a certified chemical analysis statement of compliance with this specification with each propellant batch delivered.

SECURITY CLASSIFICATION

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APPENDIX III

OXYGEN HANDLING

APPENDIX III

OXYGEN HANDLING

A. PHYSICAL PROPERTIES

Formula	O ₂
Molecular Weight	32.0
Freezing Point	-363°F
Boiling Point	-297°F
Critical Temperature	-181.8°F
Critical Pressure	49.7 atm. , 7304 PSIA
Auto Ign. Temp.	None
Specific Gravity	1.144 g/CM ³ @ -297°F
Density	71.27 lbs/cu. ft. - 9.54 lbs/gal. @ -297°F.
Vapor Pressure	0 PSIG @ -297°F, 716 PSIG @ -181.8°F
Color	Slightly Bluish
Odor	Odorless
State	Liquid at reduced temperature
Flammable limits	Not flammable
Shock sensitivity	Not shock sensitive
Extreme cold	Has no affect on O ₂

B. TOXICITY

Oxygen is non-toxic and does not form toxic decomposition products. Spillage is troublesome only because the low temperature of the liquid can cause serious "burns" on contact with skin or eyes.

C. FIRST AID

1. Remove any contaminated clothing immediately.
2. Flush contaminated skin with water, and then treat as for an ordinary burn.
3. For eye contamination; flush with water for approximately fifteen minutes. Then wash eye with 3% boric acid solution.
4. For other than very minor exposures, get medical attention after first aid has been rendered.

D. FIRE FIGHTING

Liquid Oxygen is not flammable, but very actively supports combustion of all flammable materials.

Oxygen in contact with many materials may present an explosive hazard due to the impact sensitivity increase when mixed with and frozen by liquid oxygen. The following general procedures are applicable to all fires involving oxygen.

1. Remove everyone not actively engaged in fighting the fire.
2. If at all possible, shut off the flow of liquid or gaseous oxygen.

3. Use large quantities of water, preferably in the form of spray to cool adjacent exposures and to cool any burning material below the ignition point.
4. Chemical foam, dry chemical powder, and carbon dioxide extinguisher may also be used on fires involving oxygen.
5. If electrical equipment is involved in the fire, use carbon dioxide or dry chemical powder. DO NOT USE WATER.

E. PROTECTIVE EQUIPMENT

1. Loose fitting gloves of asbestos or leather, (asbestos preferred) when handling anything that is, or may recently have been, in contact with liquid oxygen.
2. Goggles and protective clothing of the apron type, or rubber coat and pants shall be used when handling liquid oxygen.
3. Safety shower and eye bath are required near storage and handling areas as a rapid method of decontaminating personnel with gross contamination.

F. HANDLING PRECAUTIONS

1. Liquid oxygen must be stored in tanks of approved materials and construction. These tanks may be either stationary or mobile.
2. Storage transfer and test areas must be kept neat and free of combustible material, and must be inspected frequently.

3. Never allow liquid oxygen to spill or leak on asphalt, concrete, or porous materials such as paper, transite or earth. An explosion hazard exists when these materials are frozen with liquid oxygen, and subjected to shock.

Where any possibility of these conditions exist, drip trays will be provided and used.

4. Liquid oxygen creates an explosion hazard when contaminated with oil, grease, or other organic materials and subjected to shock or ignition.
5. Cap all transfer lines when not in use to prevent entry of contaminating materials.
6. Storage tanks shall be equipped with an adequate vent line and a pressure relief valve. Vent shall discharge to the outdoor atmosphere.
7. Do not trap liquid oxygen between closed hand valves or in closed hand valves or in closed systems.

G. CLEANING AND DECONTAMINATION

1. All materials and equipment used in liquid oxygen service shall be clean, free of dirt, grease, oxidation and moisture. Valves shall be completely disassembled, including packing glands, and cleaned before use.

2. Cleaning prior to use, will be done in accordance with Shawnee Industries, Inc. Specification Number 0007 - "Cleaning, Packaging and Inspection of Oxygen Systems", included in this manual as Appendix XI. Cleaning and preserving other components shall be accomplished in accordance with Shawnee Industries, Inc., Specification Number 0006 "General Parts and Assembly Cleaning Procedure" which is included in this manual as Appendix XII.

H. STORAGE CONDITIONS

1. An adequate supply of water for fire fighting shall be immediately available. Personnel safety showers shall be located in the various work and storage areas.
2. Storage containers shall be insulated, vacuum-jacketed tanks with insulation of a non-combustible material such as Santo cel or glass wool, properly cleaned to remove all grease and dirt. The insulated area between the inner and outer shell shall be equipped with either a rupture disk or a pressure relief device, so that pressure cannot build up and rupture the vessel.

The storage tank itself shall be of a welded construction and shall be equipped with an adequate vent line and a pressure relief valve. These vents shall discharge to the outdoor atmosphere.
3. Large quantities of liquid oxygen should be stored outdoors, the storage site should conform to the recommendations of National

Fire Prevention Association Pamphlet Number 566 "Bulk Oxygen Systems At Consumer Sites". Small amounts in cylinders or containers may be stored inside buildings, provided the storage facility is of non-combustible materials and is well ventilated.

4. All wiring and electrical equipment shall be in rigid metal conduit and shall be vapor and explosion - proof.
5. Storage and use areas must be kept scrupulously clean at all times, free of grease, oil, organic matter, moisture accumulation in vent lines, and waste. These areas must be inspected frequently to insure the above conditions:
6. Liquid oxygen storage areas should be located as far as practicable from combustible exposures, personnel occupancies, and sources of ignition.
7. Storage life of liquid oxygen will depend strictly on the quality and effectiveness of the insulation surrounding the container. Since there is no perfect insulation, storage life may be termed "short" in comparison to non-cryogenic propellants.
8. Disposal - if it becomes necessary to dispose of liquid oxygen, dispose of it outdoors in well ventilated areas, free of contaminating materials and away from all sources of ignition.

Shawnee Industries, Inc.

A SUBSIDIARY OF **Thiokol** CHEMICAL CORP.

APPENDIX IV

SPECIFICATION NO. MIL-P-25508

OXYGEN PROCUREMENT

MIL-P-25508D
16 March 1962
Superseding
MIL-P-25508C (USAF)
7 November 1960

MILITARY SPECIFICATION

PROPELLANT, OXYGEN

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers two types of oxygen propellant and processing of cylinders.

1.2 Classification. Oxygen propellant shall be of the following types, as specified (see 6.2):

Type I - Gaseous
Type II - Liquid

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-V-2	Valves, Gas Cylinder (Compressed or Liquefied Gases)
MIL-T-5542	Thread Compound, Antiseize and Sealing, Oxygen Systems
MIL-S-27626	Sampler, Liquid Oxygen TTU-131/E

STANDARDS

Military

MIL-STD-129	Marking for Shipment and Storage
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(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

U. S. Pharmacopoeial Convention Publication

(Copies of the U.S.P. publication may be obtained from the Mack Publishing Company, Easton, Pennsylvania.)

National Bureau of Standards

Research Paper

No. 1865 - Measurement of Water in Gases by Electrical Conduction in a Film of Hygroscopic Material and the Use of Pressure Changes in Calibration.

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington 25, D. C.)

Interstate Commerce Commission

49 CFR 71-78 - Interstate Commerce Commission Rules and Regulations for the Transportation of Explosives and Other Dangerous Articles.

(The Interstate Commerce Commission regulations are now a part of the Code of Federal Regulations (1949 Edition - Revised 1950) available from the Superintendent of Documents, Government Printing Office Washington 25, D. C. Orders for the above publication should cite "49 CFR 71-78 (Rev. 1950)".)

3. REQUIREMENTS

3.1 Material

3.1.1 Purity. Type I shall contain not less than 99.5 percent oxygen by volume when tested in accordance with 4.5.1.1. Type II shall contain not less than 99.5 percent oxygen by volume when gasified and tested in accordance with 4.5.1.1.

3.1.2 Impurities. The types of oxygen propellant shall be free from all contaminants of combustible nature to the maximum practicable. Type II shall also be free from low solubility constituents to the maximum practicable. Limitations on specific impurities are as follows:

3.1.2.1 Total hydrocarbons. The total hydrocarbon content of Type I or Type II, when gasified, shall not exceed 25 parts per million by weight as carbon (66.7 parts per million by volume as methane) when tested in accordance with 4.5.1.2.1.

3.1.2.2 Acetylene. The acetylene content of Type II shall not exceed 0.5 parts per million by weight (0.62 parts per million by volume) when tested in accordance with 4.5.1.2.2.

3.1.2.3 Moisture. Type I and Type II, when gasified, shall not contain more than 26.3 parts per million by volume of water vapor at 70°F (21.1°C) and 760 millimeters (mm) of mercury pressure (-63.5°F frost point) when tested in accordance with 4.5.1.2.3.

3.1.2.4 Particulate. The particulate (see 6.3.1) content of Type II shall not exceed 1.0 mg/liter when tested in accordance with 4.5.1.2.4.

3.2 Filling Pressure. Cylinders containing Type I oxygen propellant shall be filled to 1800, 2015, or 2200 psi nominal gage pressure as specified by the procuring activity (see 6.2). When tested as specified in 4.5.2.1, the cylinder pressure shall not differ more than plus or minus 25 psi from the applicable pressure value shown in table I. Table I shall be used to insure that the net content of each cylinder corresponds to the specified nominal pressure at 70°F (21.1°C).

3.3 Leakage. Cylinders containing Type I oxygen propellant and valves shall not leak when tested in accordance with 4.5.2.2.

3.4 Cylinder processing. Processing of cylinders for refill with Type I oxygen propellant shall be in accordance with 3.4.1. Rejected filled cylinders shall be processed in accordance with 3.4.3. Cylinders shall be processed in accordance with the flow diagram shown in figure 1.

3.4.1 Cylinder inspection. Cylinders for refill shall be inspected as specified in 3.4.1.1 through 3.4.1.7. After filling, each cylinder shall be subjected to the tests specified in 4.5.2.

3.4.1.1 Hydrostatic test date. Each cylinder shall be dated when hydrostatic tested. If the last date of testing was less than 5 years prior to the intended filling date, the cylinder shall be inspected in accordance with 3.4.1.2.

3.4.1.2 Prefilling pressure. Each cylinder shall be checked for internal pressure in accordance with 4.5.2.1. A cylinder for refill with less than 5 psig pressure or insufficient internal pressure to

TABLE I.—Table of temperatures and gage pressures (p.s.i.g.)

Temp. °F.	Filling pressures at 70°F.			Temp. °F.	Filling pressures at 70°F.		
	1800	2015	2200		1800	2015	2200
-50	1239.5	1369.8	1479.1	50	1707.7	1908.9	2081.6
-48	1248.9	1380.7	1491.2	52	1716.9	1919.8	2093.4
-46	1258.3	1391.6	1503.4	54	1726.1	1930.0	2105.2
-44	1267.8	1402.5	1515.6	56	1735.4	1940.8	2117.0
-42	1277.3	1413.5	1527.9	58	1744.6	1951.1	2128.9
-40	1286.8	1424.5	1540.2	60	1753.9	1961.7	2140.8
-38	1296.2	1435.3	1552.4	62	1763.1	1972.3	2152.6
-36	1305.6	1446.1	1564.6	64	1772.3	1982.9	2164.4
-34	1315.1	1457.0	1576.8	66	1781.5	1993.6	2176.2
-32	1324.6	1467.9	1589.1	68	1790.7	2004.3	2188.1
-30	1334.1	1478.8	1601.3	70	1800.0	2015.0	2200.0
-28	1343.5	1489.6	1613.3	72	1809.2	2025.5	2211.9
-26	1352.9	1500.4	1625.3	74	1818.4	2036.0	2223.8
-24	1362.3	1511.3	1637.3	76	1827.6	2046.8	2235.7
-22	1371.7	1522.2	1649.4	78	1836.8	2057.0	2247.6
-20	1381.1	1533.0	1661.5	80	1846.1	2067.6	2259.6
-18	1390.5	1543.8	1673.7	82	1855.3	2078.2	2271.5
-16	1399.9	1554.5	1685.9	84	1864.4	2088.9	2283.3
-14	1409.3	1565.2	1698.1	86	1873.6	2099.6	2295.0
-12	1418.7	1576.0	1710.4	88	1882.9	2110.4	2306.8
-10	1428.1	1586.8	1722.6	90	1892.1	2121.1	2318.3
-8	1437.4	1597.6	1734.8	92	1901.3	2131.6	2330.1
-6	1446.8	1608.4	1746.8	94	1910.4	2142.1	2341.9
-4	1456.2	1619.3	1758.6	96	1919.6	2152.7	2353.7
-2	1465.6	1630.2	1770.7	98	1928.8	2163.2	2365.6
0	1475.0	1641.1	1782.8	100	1938.0	2173.8	2377.5
2	1484.3	1651.9	1794.8	102	1947.1	2184.3	2389.3
4	1493.6	1662.6	1806.8	104	1956.3	2194.8	2401.1
6	1503.0	1673.3	1818.8	106	1965.4	2205.3	2412.9
8	1512.4	1684.1	1830.9	108	1974.6	2215.8	2424.7
10	1521.8	1694.9	1842.9	110	1983.8	2226.3	2436.4
12	1531.1	1705.6	1854.8	112	1992.9	2236.8	2448.1
14	1540.4	1716.3	1866.6	114	2002.0	2247.3	2459.8
16	1549.7	1727.0	1878.4	116	2011.2	2257.8	2471.4
18	1559.1	1737.8	1890.3	118	2020.3	2268.3	2483.1
20	1568.4	1748.6	1902.2	120	2029.5	2278.8	2494.8
22	1577.7	1759.3	1914.2	122	2038.6	2289.3	2506.6
24	1587.0	1769.8	1926.1	124	2047.7	2299.8	2518.4
26	1596.3	1780.5	1938.2	126	2056.8	2310.4	2530.2
28	1605.6	1791.2	1950.2	128	2066.0	2320.9	2542.0
30	1614.9	1801.9	1962.3	130	2075.1	2331.4	2553.8
32	1624.2	1812.6	1974.3	132	2084.2	2341.9	2565.5
34	1633.5	1823.3	1986.3	134	2093.3	2352.4	2577.1
36	1642.8	1834.0	1998.3	136	2102.4	2362.9	2588.8
38	1652.1	1844.8	2010.4	138	2111.5	2373.4	2600.4
40	1661.4	1855.5	2022.4	140	2120.6	2383.9	2612.1
42	1670.7	1866.3	2034.3	142	2129.7	2394.4	2623.7
44	1679.9	1876.9	2046.1	144	2138.8	2404.9	2635.3
46	1689.3	1887.5	2057.9	146	2147.9	2415.5	2647.0
48	1698.6	1898.3	2069.7	148	2157.0	2426.0	2658.6
				150	2166.1	2436.6	2670.3

cause an audible hissing sound when the valve is cracked shall be processed in accordance with 3.4.1.7. Cylinders having sufficient internal pressure may be inverted and the remainder of the internal pressure used to force out any separated water through the cylinder valve. The cylinder shall be processed in accordance with 3.4.1.7 if water is detected.

3.4.1.3 Marking. Each cylinder shall be inspected for proper marking in accordance with 5.2. Cylinders for refill found to be improperly or unsuitably marked shall be remarked. Marking may be performed either before or after filling.

3.4.1.4 Cylinder evacuation. Before filling, each cylinder shall be inspected for evacuation to approximately 100 millimeters of mercury pressure and maintained in that condition until refilled.

3.4.1.5 Cylinder valve. During inspection, when a valve is found to be damaged, inoperative, or otherwise unsatisfactory, a new cylinder valve conforming to Specification MIL-V-2 shall be installed except where minor adjustments will put the valve in satisfactory operation. Valves shall be tightened into the cylinder to a torque of 250 - 275 foot-pounds.

3.4.1.5.1 Thread compound. When valves are installed, or removed and reinstalled, a small amount of thread compound in accordance with Specification MIL-T-5542 shall be applied only to the male threads, except for the first two threads. Caution shall be used to prevent the contact of thread compound with the bursting disk.

3.4.1.6 Hydrostatic. Cylinders that have not been hydrostatically tested within 5 years prior to the intended filling date shall be tested by the contractor in accordance with detailed procedures specified by the contractor and included in the contract or order (see 6.2). If the contract or order does not specify hydrostatic testing, the cylinder shall be considered unsatisfactory for filling and shall be processed in accordance with 3.4.2.

3.4.1.7 Drying methods. Cylinders shall be dried by either the hot gas purging method specified in 3.4.1.7.1 or the evacuation method specified in 3.4.1.7.2.

3.4.1.7.1 Hot gas purging. The cylinder shall be dried by removing the cylinder valve; inserting a tube extending approximately to the bottom of the cylinder; and passing clean, hot, dry, oil-free nitrogen or air through the tube. At the end of the drying process, the cylinder valve shall immediately be reinstalled and inspected in accordance with 3.4.1.5, and closed.

LEGEND:

Cylinders inspected within 5 yrs. _____

Cylinders outdated or defective

Cylinders rejected - - - - -

3.4.1.7.2 Evacuation. The cylinder shall be dried by attaching a vacuum pump to the cylinder valve outlet, opening the valve, and heating the cylinder in an oven or hot-water bath to approximately 180°F (82.2°C) while evacuating the cylinder to approximately 100 mm of mercury pressure.

3.4.2 Unsatisfactory cylinder. A cylinder considered unsatisfactory for filling or refilling shall be processed in accordance with 3.4.2.1 and returned to the Government or contractor as specified by the contract or order (see 6.2).

3.4.2.1 Rejection tag. A tag bearing the reason for rejection shall be firmly wired to the cylinder cap. The information shall be legible, and the tag and markings shall be impervious to climatic conditions.

3.4.3 Rejected filled cylinders. Filled cylinders rejected as a result of a test failure shall be processed in accordance with the following corresponding processing requirements:

Test Failure	Processing Requirement
(a) Purity (4.5.1.1)	3.4.3.1
(b) Total hydrocarbons (4.5.1.2.1)	3.4.3.1
(c) Moisture (4.5.1.2.3)	3.4.3.1
(d) Filling pressure (4.5.2.1)	3.4.3.2
(e) Leakage (4.5.2.2)	3.4.3.3

3.4.3.1 Purity or impurity. Cylinders rejected for purity or impurity content shall be discharged to zero psig pressure and processed in accordance with 3.4.1,4 before refilling.

3.4.3.2 Filling pressure. A cylinder having more than the maximum allowable filling pressure shall be discharged to within the acceptable range as specified in 3.2 and subjected to the required test. A cylinder having less than the specified minimum filling pressure shall be charged to within the acceptable pressure range and retested as a freshly filled cylinder and shall not be selected as a test sample.

3.4.3.3 Leakage. If leakage occurs through the valve or at the junction between the valve and the cylinder, the cylinder shall be

discharged to zero psig pressure and the valve reinstalled, repaired, or replaced in accordance with 3.4.1.5. The cylinder shall then be evacuated in accordance with 3.4.1.4 before refilling. Leakage through the cylinder wall shall be cause for rejection and the cylinder shall be discharged to zero psig pressure and processed in accordance with 3.4.2.

3.5 Filter. A filter with a 10-micron nominal and 40 absolute rating shall be installed between the manufacturer's plant system and the container to be filled for delivery.

4. QUALITY ASSURANCE PROVISIONS

4.1 The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Points of inspection (see 6.2).

4.1.1.1 Cylinders. Unless otherwise specified, acceptance tests of Type I oxygen propellant cylinders shall be conducted at the site of filling.

4.1.1.2 Containers. When Type II oxygen propellant containers are filled from manufacturer's plant system or other storage facilities for delivery to destination by any mode of transportation, acceptance tests shall be conducted on the container contents prior to leaving the site of filling.

4.2 Classification of tests. The inspection and testing of the oxygen propellant shall be classified as acceptance tests.

4.3 Acceptance tests. Acceptance tests shall consist of:

(a) Individual tests 4.3.1

(b) Sampling tests 4.3.2

4.3.1 Individual tests. Each cylinder of Type I oxygen propellant shall be subjected to the following test:

Leakage test 4.5.2.2

4.3.2 Sampling tests. The oxygen propellant shall be selected in accordance with 4.3.2.1.1 and, Type I and Type II cylinder-filled and Type II container-filled propellant shall be subject to the following tests and as described under 4.5.1 except Type I propellant shall be excluded from the test specified in 4.5.1.2.2 and 4.5.1.2.4.

- (a) Purity 4.5.1.1
- (b) Total hydrocarbons 4.5.1.2.1
- (c) Acetylene 4.5.1.2.2
- (d) Moisture 4.5.1.2.3
- (e) Particulate 4.5.1.2.4

4.3.2.1 Sampling plan.

4.3.2.1.1 Lot.

4.3.2.1.1.1 Type I cylinder-filled. When Type I oxygen propellant cylinders are filled, each set of cylinders charged on the same manifold at the same time shall constitute a lot. The number of samples per lot shall conform to table II. Each cylinder selected for testing shall have approximately 1 cubic foot of gas withdrawn before sampling for all tests.

Table II

Test Samples

Lot Size	Number of Samples
1 to 10	1
11 to 40	2
41 to 70	3
71 and up	4

4.3.2.1.1.2 Type II cylinder-filled. When gaseous oxygen is compressed into cylinders from the vaporization of liquid oxygen, the following sampling procedure shall apply:

4.3.2.1.1.2.1 Procedure. Each day, after initial filling or any additional filling of the liquid storage system, samples from the first set of cylinders charged on the manifold shall be selected in accordance with table II. Between the initial or any additional filling, one sample cylinder shall be taken at random for test from each lot of 20 filled cylinders. Each cylinder selected for testing shall have approximately 1 cubic foot of gas withdrawn before sampling for all tests.

4.3.2.1.1.3 Type II container-filled. When Type II oxygen propellant containers are filled, each container shall constitute a lot. Three samples shall be drawn from each lot. The samples are required for acceptance tests and shall be taken at the lowest outlet of the container.

4.4 Test Conditions

4.4.1 Temperatures. Temperatures shall be measured using thermocouples or thermometers. Thermocouples shall be connected to an accurately calibrated potentiometer. Laboratory thermometers having scale divisions of one-half degree Fahrenheit shall be used.

4.4.2 Pressure. Pressures shall be measured with Bourdon tube or equal gages having scale divisions of 5 psi.

4.4.3 Sampler. A sampler in accordance with Specification MIL-S-27626 shall be used for sampling Type II oxygen propellant.

4.4.4 Container samples. One sample, taken with the sampler in accordance with the following procedure shall be used for tests in accordance with 4.5.1.1, 4.5.1.2.1, and 4.5.1.2.3. The other samples, taken in a suitable vessel of sufficient size or as specified herein, shall be used for tests in accordance with 4.5.1.2.2 and 4.5.1.2.4.

4.4.4.1 Procedure. One sample shall be obtained by drawing a sample of liquid from the container into the sampler and allowing the liquid to completely vaporize and come to approximately room temperature. The sampler shall then be connected to the test equipment. Sufficient gaseous oxygen shall be permitted to flow to displace any air present in the line before connection to the test equipment.

4.5 Test methods

4.5.1 Propellant

4.5.1.1 Purity. Samples shall be tested for purity in accordance with the following nitrometer method or equivalent Orsat method.

4.5.1.1.1 Procedure. The test for purity shall be conducted by placing a sufficient quantity of mercury in a 100 ml calibrated nitrometer, provided with a two-way stopcock, a two-way outlet, and properly connected with a balancing tube. Connect one of the outlet tubes of the nitrometer with a gas pipette of suitable capacity. Place in the pipette a coil of copper wire that extends to the uppermost portion of the bulb, and add approximately 125 ml of ammonium chloride-ammonium hydroxide solution prepared in accordance with 4.5.1.1.2. Draw the solution (free from air bubbles) through the capillary and stopcock openings in the nitrometer by reducing the pressure in the nitrometer tube and opening the stopcock connection to the gas pipette. Close the stopcock. Having completely filled the nitrometer; the other stopcock opening; and the other intake tube with mercury, draw exactly 100 ml of oxygen into the nitrometer by reducing the pressure in the tube. Close the stopcock. Increase the pressure on the oxygen in the nitrometer tube, and open the stopcock connection to the gas pipette. Force the entire volume of gas into the pipette. Close the stopcock and rock the pipette gently, providing frequent contact of the liquid gas and the copper spiral. At the end of 15 minutes, most of the gas will have been absorbed by the liquid. At this time, to facilitate absorption of the last portion of the oxygen, draw some of the liquid into the nitrometer tube, and force the residual gas back upon the surface of the liquid in the gas pipette. Again, rock the pipette until no further diminution in the volume of gas occurs. Draw the residual gas, if any, into the nitrometer tube and measure its volume. The volume of gas remaining undissolved shall not exceed 0.5 ml. If desired, the ammonium chloride-ammonium hydroxide solution may be used for leveling purposes.

4.5.1.1.2 Preparation of ammonium chloride-ammonium hydroxide. The test for purity (according to USP Publication) requires the use of freshly-prepared ammonium chloride-ammonium hydroxide solution (made by mixing 950 ml of water and 950 ml of concentrated ammonia hydroxide (27 percent), and saturating with 565 - 570 grams of ammonium chloride). This solution shall be aged by making 5 or 6 runs before taking test data for purity.

4.5.1.2 Impurities. Samples shall be tested for impurities in accordance with the following methods except as exempted in 4.3.2.

4.5.1.2.1 Total hydrocarbons. Type I cylinder-filled propellant samples or samplers for Type II container-filled propellant shall be

connected to the inlet of a total hydrocarbon analyzer meeting the requirements of 4.5.1.2.1.1. Sufficient gaseous oxygen shall be permitted to flow to obtain a stabilized reading.

4.5.1.2.1.1 Total hydrocarbon analyzer. The total hydrocarbon analyzer shall operate on some method such that all hydrocarbons in the sample stream shall be reduced to a common reference. The common reference shall be quantitatively analyzed and indicated in parts per million by weight as carbon or in parts per million by volume as methane equivalent, or in any other indication that can readily be converted to these units. The analyzer shall have an accuracy of plus or minus 0.5 parts per million at and below the limits specified herein.

4.5.1.2.2 Acetylene. The acetylene content of Type II container-filled propellant samples shall be determined by an acetylene detection apparatus operating on the Ilosvay solution method. The method shall have an accuracy of 0.2 parts per million by weight of acetylene.

4.5.1.2.2.1 Procedure. The sample line of the container shall be purged before taking sample. Pre-cool a 1-liter dewar flask with Type II container-filled propellant from the sample line for 1 minute. Discard the contents of the dewar flask and refill. Add 0.5 ml of silica gel to a clean, dry, test tube precalibrated and marked at the 14 ml level. Fill a 180 ml beaker with the sample from the dewar flask. Using test tube clamps, place the calibrated test tube in the beaker and pre-cool for 1 minute. When boiling subsides, fill the test tube with the sample from the dewar flask to the 14 ml mark. Remove the test tube from the beaker, place in a rack and allow the sample to completely evaporate without agitation. After evaporation, immediately pour 3 ml of copper-ammonia solution into the test tube. Hold the test tube in the hand until the ice melts. Tilt and gently swirl the test tube to insure that all of the silica gel contacts the copper-ammonia solution. Add 12 drops of hydroxylamine hydrochloride solution to the test tube and gently swirl. Allow 15 minutes for the color to develop. Visually compare the silica gel color with color standards prepared in accordance with 4.5.1.2.2.2.

4.5.1.2.2.2 Color standards. The color standards shall be prepared as follows:

- (a) 1.0 parts per million: add 2.0 ml of concentrated hydrochloric acid to 150 ml of distilled water in a beaker and stir. Weigh 10.00 grams of cobaltous chloride-hexahydrate, 2.00 grams of cupric sulfate-pentahydrate and 0.30 grams of ferric chloride-hexahydrate, and add to the acid solution in the

beaker. Stir until dissolved and quantitatively transfer to a 200 ml volumetric flask. Dilute to the mark with distilled water and shake thoroughly. Add 15 ml of this solution to a 150 mm by 20 mm pyrex test tube and seal.

- (b) 0.25 parts per million: add 2.0 ml of concentrated hydrochloric acid to 150 ml of distilled water in a beaker and stir. Weigh 1.90 grams of cobaltous chloride-hexahydrate, 1.30 grams of cupric sulfate-pentahydrate and 0.20 grams of ferric chloride-hexahydrate, and add to the acid solution in the beaker. Stir until dissolved and quantitatively transfer to a 200 ml volumetric flask. Dilute to the mark with distilled water and shake thoroughly. Add 15 ml of this solution to a 150 mm by 20 mm pyrex test tube and seal.
- (c) 0.50 parts per million: Transfer 7.50 ml each of the 1.0 and 0.25 parts per million color standards to a 150 mm by 20 mm pyrex test tube and seal.

· 4.5.1.2.2.3 Reagents and equipment. The following reagents and equipment shall apply as test conditions of 4.5.1.2.2.

- (a) Reagents:
 - (1) Soluble starch: reagent grade.
 - (2) Cupric sulfate - pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$): reagent grade.
 - (3) Cobaltous chloride - hexahydrate ($\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$): reagent grade.
 - (4) Ferric chloride-hexahydrate ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$): reagent grade.
 - (5) Ammonium hydroxide (NH_4OH): specific gravity at $60^\circ/60^\circ\text{F}$ = 0.900, assay 28.4 percent NH_3 - reagent grade.
 - (6) Hydrochloric acid (HCl): specific gravity at $60^\circ/60^\circ\text{F}$ = 1.191, assay 37.7 percent HCl - reagent grade.

- (7) Hydroxylamine hydrochloride: reagent grade.
- (8) Silica gel: purified activated 14 - 20 mesh.
- (b) Equipment:
 - (1) Flask: dewar, 1-liter capacity.
 - (2) Tubes: pyrex test, 150 mm x 20 mm, 6 required.
 - (3) Rack: test tube.
 - (4) Clamp: test tube.
 - (5) Beaker: electrolytic, 180 ml capacity.
 - (6) Bottle: dropper, 4 oz capacity.
 - (7) Bottle: reagent, narrow-mouth, 32 oz capacity.
 - (8) Cylinder: graduated, 5 ml capacity.
 - (9) Flask: volumetric, 1-liter capacity.
 - (10) Flasks: volumetric, 200 ml capacity, 2 required.

· 4.5.1.2.2.3.1 Preparation of copper-ammonia. The copper-ammonia solution shall be prepared in accordance with the following procedure. Add 1 gram of soluble starch to 10 ml of distilled water and stir to form a thin paste. Pour the paste into 200 ml of boiling distilled water. Stir the mixture to dissolve the starch and allow to cool. In a 1-liter volumetric flask containing approximately 500 ml of distilled water, dissolve 5 grams of copper sulfate. Add 50 ml of ammonium hydroxide to the copper sulfate solution. Pour the previously prepared starch solution to the copper-ammonia solution and dilute to the mark with distilled water. Store the test solution in a 32 oz reagent bottle.

· 4.5.1.2.2.3.2 Preparation of hydroxylamine hydrochloride. The hydroxylamine hydrochloride solution shall be prepared by dissolving 36 grams of hydroxylamine hydrochloride in 100 ml of distilled water. Store the test solution in a 4 oz dropper bottle.

· 4.5.1.2.3 Moisture. Type I cylinder-filled propellant or sampler containing Type II container-filled propellant shall be tested for moisture content in accordance with one of the following methods. The accelerated gravimetric method of 4.5.1.2.3.1 shall be the standard reference method.

- (a) Accelerated gravimetric method (4.5.1.2.3.1).
- (b) Electrical conductivity method in accordance with N.B.S. Research Paper No. 1865.
- (c) Frost point method.
- (d) Electrolytic method.
- (e) Low temperature volumetric freeze-out method.

· 4.5.1.2.3.1 Accelerated gravimetric method. Moisture content shall be determined by measuring the increase in weight of phosphorus pentoxide (P_2O_5) when using the following procedure:

4.5.1.2.3.1.1 Procedure. Invert the cylinder or sampler to be tested and place it in a rack. Connect the cylinder or sampler to the test apparatus by a length of bent, seamless, corrosion-resistant steel tubing and a high pressure union with needle valve and glass to metal joint. A mercury safety valve shall be connected between the low pressure outlet of the needle valve and the first absorber. The steel tubing shall be installed to pass through 2 water baths at ambient temperature. The apparatus shall consist of 3 U-tube absorbers in series, each 4 inches high and one-half inch in diameter, containing phosphorous pentoxide on glass wool and connected through a water saturator to a calibrated wet test meter of one-twentieth of a cubic foot size equipped with a 1-liter dial. The needle valve connecting the cylinder or sampler to the absorber shall be flushed with oxygen from the cylinder so that only discharged gas will pass through the absorbers. Before installation; the absorbers shall be brought to constant weight in a stream of dry oxygen, before they are weighed, so they will be filled with oxygen at all times. Before each weighing of the absorbers, they shall be opened momentarily to the air, closed, and cleaned. One hundred liters of gaseous oxygen shall be discharged through the apparatus at a rate not to exceed 0.4 liter per minute. The gas volume corresponding to the gain in weight shall be calculated to standard conditions of 760 millimeters of mercury and 70°F (21.1°C). The moisture content shall be computed in terms of milligrams per liter at standard conditions.

· 4.5.1.2.4 Particulate. A Type II container-filled sample shall be tested for contamination in accordance with the following method.

· 4.5.1.2.4.1 Dewar cleaning. Clean a 5-liter dewar flask by rinsing 3 times with 200 ml of filtered petroleum ether or freon TF, or equal; dry the flask with filtered gaseous nitrogen; close the flask with a slotted, degreased, aluminum foil-covered stopper.

4.5.1.2.4.2 Sample. Remove the stopper from the cleaned dewar flask and collect approximately 1-liter of the sample, swirl content and discard. Collect a 5-liter Type II sample. Immediately close the flask with the stopper.

4.5.1.2.4.3 Procedure

4.5.1.2.4.3.1 Filter disc tare. Using forceps, place one 1.2 micron Millipore or equivalent membrane filter disc and back-up pad in an open identified petri dish. Place the dish in a vacuum oven at 158°F (70°C) for 30 minutes. Remove the dish and place in a desiccator containing dustless calcium sulfate for 30 minutes. Using forceps,, remove the filter disc (without the back-up pad) from the desiccator and place on a balance. Allow a 2-minute interval permitting the filter disc to come to constant weight. Record the weight to the nearest 0.1 mg. Using forceps, remove the filter disc from the balance and replace in the covered petri dish.

4.5.1.2.4.3.2 Filtration. Connect a heavy-wall 2-liter pyrex filter flask to a water aspirator with a heavy-wall rubber hose and place in a hot water bath 4 inches deep. Place the stainless steel base of the filter assembly on the top of the pyrex flask. Connect ground wire to top of filter funnel. Using forceps, remove the filter disc and back-up pad from the petri dish and place them on the stainless steel base. Immediately lower the filter funnel onto the base; place a degreased aluminum foil cover on top of the filter funnel. The locking ring should be loose to prevent tearing of the membrane filter. Turn-on the water aspirator. Remove the aluminum foil cover and pour 3 or 4 drops of the Type II sample from the dewar flask into the filter funnel to precool and prevent shattering of the filter disc. Pour the remaining contents of the dewar flask into the filter funnel but not directly on the filter disc. Between pourings cover the filter funnel with the aluminum foil cover. Disconnect the funnel and discontinue water aspiration. Using forceps, transfer the filter disc to the open petri dish and place in a vacuum oven at 158°F (70°C) for 30 minutes. Remove the dish and place in the desiccator for 30 minutes. Using forceps, remove the filter disc from the desiccator and place on a balance. Allow a 2-minute interval to permit the filter disc to come to constant weight. Record the weight to the nearest 0.1 mg. A particulate content of the sample shall not exceed 1.0 mg/liter.

4.5.1.2.4.3.3 Test equipment. The test equipment or its equivalent shall consist of the following:

- (a) Flask: dewar, 5-liter capacity, round configuration, 2-inch opening with slotted cork.

- (b) Holder: filter, stainless steel; complete with stainless steel base, rubber stopper, integral locking ring and 650 ml stainless steel funnel.
- (c) Disc: filter, membrane, 1.20 microns, 47 mm diameter with grid.
- (d) Foil: aluminum
- (e) Aspirator: water
- (f) Desiccator: containing calcium sulfate.
- (g) Dish: petri, plastic.
- (h) Forceps: unserrated tips.
- (i) Balance: analytical, 0.1 mg sensitivity.
- (j) Flask: filter, pyrex, heavy-wall, 2-liter, with side arm.
- (k) Over vacuum.

4.5.2 Cylinder

4.5.2.1 Filling pressure. Samples shall be tested for proper filling pressure by attaching a Bourdon tube or equal gage to the valve outlet and by attaching either a thermocouple or thermometer to the cylinder wall. If a thermometer is used, tape or putty shall be applied to the bulb to protect it from alien temperatures. Putty shall not be applied between the bulb and the cylinder wall. The cylinder shall be stabilized to approximately room temperature. The cylinder valve shall be opened and the internal pressure observed on the gage. If the internal pressure differs from the applicable pressure value shown in table I, by more than 25 psi, the sample cylinder and all other cylinders filled from the same manifold at the same time shall be rejected.

4.5.2.2 Leakage. Each cylinder shall be tested for leakage by brushing a soap solution over the surfaces of the cylinder and valve, except for the valve outlet. Each cylinder shall be tested for leakage through the closed valve outlet by connecting a tube to a container of liquid. Any evidence of leaking shall be cause for rejection. No liquid shall be brought into contact with the valve outlet.

4.6 Preparation for delivery inspection. The preservation, packaging, packing and marking for shipment and storage of oxygen propellant shall be inspected to determine compliance with the requirements of section 5 of this specification.

4.7 Rejection and retest. When one or more Type I and Type II oxygen propellant cylinder-filled samples from a lot fail to meet the tests specified in 4.3.2, acceptance of all cylinders in this lot will be withheld until the extent and cause of failure are determined. When a Type II container-filled sample fails to meet the tests specified in 4.3.2, remaining containers shall not be filled until the extent and cause of failure are determined. If the cause of failure in either case cannot be located, or cannot be corrected in sufficient time to avoid delays in completion of the contract or order, the procuring activity shall be notified immediately and the rejected filled cylinders or containers shall be emptied. If the cause of failure is expeditiously located and corrected, rejected Type I oxygen propellant cylinders shall be reprocessed in accordance with 3.4.3. Rejected Type II oxygen propellant containers shall be purged with oxygen or nitrogen gas.

5. PREPARATION FOR DELIVERY

5.1 Packaging and packing. All filled cylinders, whether Government-owned or contractor furnished, shall be packaged and packed in accordance with Interstate Commerce Commission Regulations.

5.2 Marking. All cylinders shall be marked in accordance with ICC Regulation 49 CFR 71-78 and MIL-STD-129. A tag shall be firmly wired to the cylinder valve or to the liquid oxygen transporter in a conspicuous location. The tag and markings shall be impervious to climatic conditions and shall contain the following information:

Propellant, Oxygen
Specification MIL-P-25508D
Type _____
Federal Stock No. 9135-_____
Quantity _____
Contract or Order No. _____
Name of Manufacturer _____
Name of Contractor (if different from manufacturer)

6. NOTES

6.1 Intended use. The propellant covered by this specification is intended for use as an oxidizer (Type II), and for purging and pressurization of propellant systems (Type I), of rocket engines.

6.2 Ordering data. Procurement documents should specify the following:

- (a) Title, number, and date of specification.
- (b) Type of oxygen propellant required. (see 1.2).
- (c) Nominal filling pressure required for Type I oxygen Propellant cylinders. (see 3.2)
- (d) Detailed procedure for hydrostatic testing of Type I cylinders where necessary unless the contractor is not to be responsible for this testing. (see 3.4.1.6)
- (e) Instructions for disposition of Type I oxygen propellant cylinders found unsatisfactory for filling. (see 3.4.2)
- (f) Whether Type I oxygen propellant cylinders will be furnished by the contractor without cost to the Government for return when empty, whether the Government will furnish the cylinders for filling, or whether cylinders will be furnished by the contractor and remain the property of the Government. (see 3.4.2)
- (g) Points of Inspection. (see 4.1.1)
- (h) The applicable transportation description, carload and truckload minimum weights, to be specified are as follows:
 - Type I
 - Carload weight - 30,000 lbs
 - Truckload Weight - 30,000 lbs
 - Type II
 - Carload weight - 60,000 lbs
 - Truckload weight - 30,000 lbs
- (i) The basis for procurement of oxygen propellant should be either the cubic foot or gallon based upon normal atmospheric conditions. Type II propellant procurement may be either by the pound or short ton. The following conversion factors for Type II oxygen may be used:

Cubic Feet of Gaseous Oxygen at 70°F (21.1°C)
 Unit = and 760 mm Hg
 115.2 (for gallon)
 12.08 (for pound)

- (j) Method of shipment, type and capacity of containers required.
- (k) The interval of inspection at contractor-operated government facilities.
- (m) That two copies of the test report, signed by the Contractor's representative listing values obtained on all tests (quantitative values where method provides) shall accompany each shipment delivered to the consignee.

6.3 Definition

6.3.1 Particulate. The undissolved solids retained on a 1.2 micron filter paper.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

Custodians:

Army - Ord
Air Force - AFSC
Navy - Wep

Preparing activity:
Air Force - AFSC

Shawnee Industries, Inc.

A SUBSIDIARY OF **Thiokol** CHEMICAL CORP

APPENDIX V

SPECIFICATION NO. FED. BB-N-411

NITROGEN PROCUREMENT

FEDERAL SPECIFICATION

NITROGEN

This specification was approved by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal agencies.

1. SCOPE AND CLASSIFICATION

1.1 Scope.—This specification covers those types, classes, and grades of commercially available gaseous and liquid nitrogen which are suitable for Federal Government requirements.

1.2 Classification.—The nitrogen shall be of the following types, classes, and grades, as specified:

Type I.—Gaseous

Class 1.—Oil-free

Grade A.—99.95 percent pure, low moisture content

Grade B.—99.50 percent pure, low moisture content

Grade C.—99.50 percent pure, moisture content not specified

Class 2.—Oil-tolerant

Grade A.—99.50 percent pure, low moisture content

Grade B.—99.50 percent pure, moisture content not specified

Type II.—Liquid

Class 1.—Oil-free

Grade A.—99.95 percent pure, low moisture content

Grade B.—99.50 percent pure, low moisture content

Grade C.—99.50 percent pure, moisture content not specified

Class 2.—Oil-tolerant

Grade A.—99.50 percent pure, low moisture content

Grade B.—99.50 percent pure, moisture content not specified

2. APPLICABLE SPECIFICATIONS AND OTHER PUBLICATIONS

2.1 Specifications.—There are no other specifications applicable to this specification except those referenced in section 7 by individual departments.

(Activities outside the Federal Government may obtain copies of Federal Specifications and Standards as outlined under General Information in the Index of Federal Specifications and Standards and at the prices indicated in the Index. The Index, which includes cumulative monthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

(Single copies of this specification and other product specifications required by activities outside the Federal Government for bidding purposes are available without charge at the General Services Administration Regional Offices in Boston, New York, Atlanta, Chicago, Kansas City, Mo., Dallas, Denver, San Francisco, Los Angeles, Seattle, and Washington, D. C.

(Federal Government activities may obtain copies of Federal Specifications and Standards and the Index of Federal Specifications and Standards from established distribution points in their agencies.)

2.2 Other publications.—The following publications, of the issues in effect on date of invitation for bids, form a part of this specification:

U. S. Pharmacopoeial Convention Publication:
Pharmacopoeia of the United States.

(Copies of the Pharmacopoeia of the United States may be obtained from the Mack Publishing Company, Easton, Pa.)

Code of Federal Regulations:

49 CFR 71-78—Interstate Commerce Commission Rules and Regulations for the Transportation of Explosives and Other Dangerous Articles.

(Copies of the Code of Federal Regulations may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.. Application for copies should cite "49 CFR 71-78, Revised 1950.")

3. REQUIREMENTS

3.1 Materials.—Nitrogen of both types shall be supplied in classes and grades which shall conform to table I.

TABLE I.—*Composition*

Classes and grades	Percent by volume		Moisture content (see 4.3.1)
	Nitrogen or inert gas (see 4.3.2)	Active contaminants (see 4.3.2)	
	<i>Minimum</i>	<i>Maximum</i>	<i>Maximum</i>
Class 1:			
Grade A ..	99.95	0.05	0.02 mg. per liter ¹
Grade B ..	99.50	0.5	0.02 mg. per liter ¹
Grade C ..	99.50	0.5	to pass test
Class 2:			
Grade A ..	99.50	0.5	0.02 mg. per liter ¹
Grade B ..	99.50	0.5	to pass test

¹ The moisture content as specified in table I represents an average of 0.06 mg. per liter and a dew (frost) point of minus 70° F. for the entire contents of the cylinder.

3.2 Oil-free nitrogen.—Nitrogen shall be considered oil-free if the gas is compressed with a water-lubricated compressor or if the gas is produced from a liquid which is oil-free.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Lot.—A lot shall not exceed the number of cylinders charged on a manifold at one time.

4.2 Sampling.—Inspection and test samples shall be taken at random from each lot of cylinders dried and filled with nitrogen by the manufacturer. The number of samples taken shall be as specified in table II for the lot size or fraction thereof.

TABLE II.—*Sampling*

Lot size	Number of samples
1-10	1
11-40	2
41-70	3
70 and up	4

4.3 Tests.—All samples shall be tested in accordance with the procedures specified herein. Chemicals conforming to the Pharmacopoeia of the United States and distilled water shall be used throughout the tests. Gaseous nitrogen shall be discharged from the sample cylinder to decrease its pressure approximately 10 pounds per square inch gage (p.s.i.g.) before sampling for tests. A sample of liquid nitrogen shall be withdrawn from each flask and the sample completely evaporated. Tests shall be conducted on the evaporated sample.

4.3.1 Moisture content.

4.3.1.1 Type I and II, class 1, grade A and B, and class 2, grade A.—The moisture content shall be determined by means of the accelerated gravimetric method. The electrical conductivity method, the dew (frost) point method, or other methods that have been approved by the Government may be used in lieu of the accelerated gravimetric method. However, the accelerated gravimetric method shall be the standard.

4.3.1.1.1 Accelerated gravimetric method.—The moisture content shall be determined by measurement of increase in weight of phosphorous pentoxide (P_2O_5) when subjected to a flow of a measured volume of nitrogen in accordance with the following procedure:

The cylinder to be tested shall be inverted in a suitable rack. The cylinder shall be connected to the test apparatus by means of a length of bent, seamless, corrosion-resisting steel tubing, and a high pressure union with needle valve and a glass to metal joint (no rubber connections shall be used; a sleeve joint secured with thermoplastic is acceptable). The apparatus shall consist of 3 U-tube absorbers in series, each 4 inches high and $\frac{1}{2}$ inch in diameter, containing phosphorous pentoxide on glass wool and connected through a water-saturator to a calibrated wet test meter of $\frac{1}{20}$ cubic foot size equipped with a one-liter dial.

A mercury safety valve shall be connected between the low pressure outlet of the needle valve and the first absorber. The steel tubing shall be so fabricated that it will first pass through a water bath at room temperature and then into a second bath also at room temperature. The

needle valve connecting the cylinder to the absorber shall be flushed with nitrogen so that only gas discharged from the cylinder will pass through the absorber. The absorbers shall be brought to constant weight in a stream of dry nitrogen before they are weighed so they will be at all times filled with nitrogen. Before each weighing of the absorbers they shall be opened momentarily to the air, closed, and cleaned. One hundred liters of gaseous nitrogen shall be discharged through the apparatus at a rate not to exceed 0.4 liter per minute.

The gas volume corresponding to the gain in weight shall be calculated to 760 millimeters of mercury and 70°F. The moisture content shall be computed in terms of milligrams per liter.

4.3.1.2 Type I only, class 1, grade C, and class 2, grade B.—Nitrogen shall be tested for moisture content by supporting a cylinder which has been inverted at room temperature for 5 minutes. The gas shall then be allowed to leak out very slowly into a suitable dry 25-ml. graduated glass container for one minute. Collection of 5 or more millimeters of water shall be cause for rejection.

4.3.2 Purity.—The purity of the material shall be determined by means of the Haldane or Sheppard gas analyzing apparatus or approved equal equipped with one absorption pipette. A solution of alkaline pyrogallol (10 to 15 percent pyrogallol in 40-percent potassium hydroxide) shall be placed in the pipette. The absorbent solution shall be saturated with the gas being tested immediately prior to the determinations. Exactly 100 ml. of the material being tested shall be measured into the measuring burette. The sample shall be slowly bubbled back and forth through the absorption pipette until there is no further reduction in volume and the residual gas then returned to the measuring burette. The loss in volume shall be recorded as active contaminants and the residual gas as nitrogen.

4.3.3 Valve leakage test.—All cylinders after filling shall be tested for leakage by applying soap solution to the valve outlet, inlet threads, safety nut, stem, and gland, and the cylinder examined for evidence of leakage. Special attention should be given to valves of new cylinders

and refill cylinders returning with a residual pressure of less than 5 p.s.i.g.

4.3.4 Capacity (see 6.3).—To determine if cylinders have been filled to full rated capacity specified by contract or order, the pressure in the cylinders shall be checked in accordance with table III. A variance of plus 16 p.s.i. or minus 10 p.s.i. is permissible.

4.4 Rejection and retest.—Rejected containers of nitrogen shall not be resubmitted for approval without furnishing the Government inspector full particulars concerning previous rejection and corrective action taken.

TABLE III.—*Dependence of settled cylinder pressure on temperature for the following standard conditions: 1800 p.s.i.g. at 70° F., 2015 p.s.i.g. at 70° F., 2200 p.s.i.g. at 70° F., and 3500 p.s.i.g. at 70° F.*

Temperature	Filling pressure			
	1800 p.s.i.g.	2015 p.s.i.g.	2200 p.s.i.g.	3500 p.s.i.g.
°F.	p.s.i.g.	p.s.i.g.	p.s.i.g.	p.s.i.g.
-70	1177.5	1303.0	1408.6	2200.0
-60	1222.5	1355.0	1466.3	2292.5
-50	1267.8	1406.5	1524.0	2385.4
-48	1276.6	1416.6	1535.2	2404.1
-46	1285.5	1426.8	1546.5	2422.8
-44	1294.4	1437.0	1557.8	2441.5
-42	1303.3	1447.2	1569.2	2460.2
-40	1312.2	1457.4	1580.6	2478.8
-38	1321.2	1467.7	1592.0	2497.2
-36	1330.1	1478.0	1603.5	2515.6
-34	1339.1	1488.3	1615.1	2534.0
-32	1348.2	1498.7	1626.6	2552.4
-30	1357.2	1509.0	1638.2	2570.8
-28	1366.1	1519.2	1649.3	2589.4
-26	1374.9	1529.3	1660.5	2608.0
-24	1383.7	1539.4	1671.8	2626.6
-22	1392.6	1549.5	1683.1	2645.2
-20	1401.5	1559.6	1694.4	2664.0
-18	1410.4	1569.8	1705.7	2682.6
-16	1419.4	1580.1	1717.1	2711.2
-14	1428.4	1590.3	1728.5	2729.8
-12	1437.4	1600.5	1739.9	2748.4
-10	1446.3	1610.7	1751.3	2757.1
-8	1455.2	1620.8	1762.6	2775.8
-6	1464.1	1630.9	1773.8	2794.5
-4	1473.0	1641.0	1785.0	2813.2
-2	1481.9	1651.1	1796.2	2831.9
0	1490.8	1661.2	1807.5	2850.8
2	1499.7	1671.3	1818.8	2869.3

TABLE III.—Dependence of settled cylinder pressure on temperature for the following standard conditions: 1800 p.s.i.g. at 70° F., 2015 p.s.i.g. at 70° F., 2200 p.s.i.g. at 70° F., and 3500 p.s.i.g. at 70° F.—
Continued

Temperature °F.	Filling pressure			
	1800 p.s.i.g.	2015 p.s.i.g.	2200 p.s.i.g.	3500 p.s.i.g.
4	1508.6	1681.5	1830.1	2887.8
6	1517.6	1691.7	1841.5	2906.3
8	1526.6	1701.9	1852.9	2924.8
10	1535.5	1712.1	1864.2	2943.3
12	1544.3	1722.2	1875.4	2961.8
14	1553.1	1732.2	1886.6	2980.3
16	1561.9	1742.3	1897.7	2998.8
18	1570.7	1752.5	1908.9	3017.3
20	1579.5	1762.6	1920.1	3035.8
22	1588.4	1772.8	1931.4	3054.5
24	1597.2	1783.0	1942.6	3073.2
26	1606.1	1793.2	1953.9	3091.9
28	1615.0	1803.4	1965.2	3110.6
30	1623.9	1813.6	1976.4	3129.3
32	1632.7	1823.7	1987.6	3147.9
34	1641.5	1833.7	1998.7	3166.5
36	1650.3	1843.7	2009.8	3185.1
38	1659.1	1853.7	2020.9	3203.7
40	1667.9	1863.8	2032.0	3222.3
42	1676.8	1873.8	2043.2	3241.0
44	1685.7	1883.9	2054.4	3259.7
46	1694.6	1894.0	2065.6	3278.4
48	1703.5	1904.1	2076.9	3297.1
50	1712.3	1914.2	2088.1	3315.8
52	1721.1	1924.3	2099.2	3334.2
54	1729.8	1934.3	2110.3	3352.6
56	1738.5	1944.3	2121.4	3371.0
58	1747.3	1954.3	2132.6	3389.4
60	1756.0	1964.4	2143.8	3407.9
62	1764.8	1974.5	2155.0	3426.3
64	1773.6	1984.6	2166.2	3444.7
66	1782.4	1994.7	2177.4	3463.1
68	1791.2	2004.8	2188.7	3481.5
70	1800.0	2015.0	2200.0	3500.0
72	1808.7	2024.8	2211.1	3518.5
74	1817.5	2034.8	2222.2	3537.0
76	1826.3	2044.8	2233.3	3555.5
78	1835.1	2054.8	2244.4	3574.0
80	1843.9	2064.8	2255.5	3592.7
82	1852.7	2074.8	2266.7	3601.4
84	1861.5	2084.8	2277.9	3620.1
86	1870.3	2094.8	2289.1	3638.8
88	1879.1	2104.8	2300.3	3657.5
90	1887.9	2114.8	2311.4	3686.4
92	1896.6	2124.7	2322.4	3704.7
94	1905.3	2134.6	2333.3	3723.0

TABLE III.—Dependence of settled cylinder pressure on temperature for the following standard conditions: 1800 p.s.i.g. at 70° F., 2015 p.s.i.g. at 70° F., 2200 p.s.i.g. at 70° F., and 3500 p.s.i.g. at 70° F.—
Continued

Temperature °F.	Filling pressure			
	1800 p.s.i.g.	2015 p.s.i.g.	2200 p.s.i.g.	3500 p.s.i.g.
96	1913.9	2144.5	2344.1	3741.3
98	1922.6	2154.4	2355.0	3759.6
100	1931.2	2164.3	2365.9	3777.6
102	1939.9	2174.2	2376.8	3795.7
104	1948.6	2184.1	2387.8	3813.8
106	1957.3	2194.0	2398.7	3831.9
108	1966.0	2204.0	2409.7	3850.0
110	1974.7	2213.9	2420.7	3868.2
112	1983.5	2223.8	2431.7	3886.7
114	1992.2	2233.7	2442.8	3905.2
116	2001.0	2243.6	2453.9	3923.7
118	2009.8	2253.5	2465.0	3942.2
120	2018.7	2263.4	2476.1	3960.9
122	2027.5	2273.4	2487.2	3978.6
124	2036.3	2283.4	2498.4	3996.3
126	2045.2	2293.3	2509.6	4014.0
128	2054.1	2303.3	2520.8	4031.7
130	2062.9	2313.2	2532.0	4049.2
132	2071.6	2323.0	2543.1	4066.6
134	2080.2	2332.7	2554.2	4084.0
136	2088.8	2342.4	2565.4	4101.4
138	2097.4	2352.1	2576.6	4118.8
140	2106.1	2361.8	2587.8	4136.4
142	2114.8	2371.6	2599.0	4154.0
144	2123.4	2381.3	2610.2	4171.6
146	2132.1	2391.1	2621.5	4189.2
148	2140.8	2400.9	2632.8	4206.8
150	2149.5	2410.7	2644.0	4224.2

5. PREPARATION FOR DELIVERY

5.1 Packaging.—Type I nitrogen shall be furnished in cylinders conforming to the requirements of Specifications 3A and 3AA of the Interstate Commerce Commission Regulations stipulated in the Code of Federal Regulations 49 CFR 71-78, adequate for the service pressure required. Type II nitrogen shall be shipped in accordance with commercial practice.

5.2 Packing.—The cylinders shall be shipped in compliance with the requirements of the Interstate Commerce Commission Regulations for Transportation of Explosives and Other Dangerous Articles.

5.3 Marking.—When specified, each cylinder shall be marked with a complete description of the contents as defined by the contract or order under which the shipment is made; the type, class, and grade of nitrogen; date of filling; the name of the contractor; and the number of the contract or order. This information shall be marked on a suitable waterproof shipping tag firmly attached to the cylinder valve. Each cylinder shall have a decal attached to it with the following instructions:

IMPORTANT
DO NOT LEAVE VALVE OPEN
DO NOT REDUCE GAGE PRESSURE OF
CYLINDER TO LESS THAN 10 P.S.I.G.

6. NOTES

6.1 Intended use.—The nitrogen covered by this specification is intended for use in pressurizing fuel tanks, winterizing and superpressurizing carbon dioxide cylinders, calibration of instruments, or any other application where nitrogen is needed. Class 1 nitrogen must be used where there is a possibility of oxygen also being used, i. e., purging of oxygen lines.

6.2 Ordering data.—Procurement documents should specify the title, number, and date of this specification. Purchasers should exercise any desired options offered herein and should specify the type, class, and grade of nitrogen. The type and size of container and valve for the container should be suitable for the material and amount to be supplied. (See 1.2, 5.1, 5.3, 6.2.1, 6.3, 6.5 and 7.)

6.2.1 Purchasers should also specify in the invitation for bids whether the cylinders shall be furnished by the contractor without cost to the Government, for return when empty; whether the Government will furnish cylinders for charging; or whether the cylinders will be furnished by the contractor and remain the property of the Government.

6.3 The basis of purchase should be the cubic foot, based upon normal atmospheric conditions. Gaseous nitrogen is commercially available in cylinders with rated capacities of 100, 184, 200, and 330 cubic feet. Normally nitrogen cylinders

will be filled to the following standard conditions: 1800 p.s.i.g., 2015 p.s.i.g., 2200 p.s.i.g., or 3500 p.s.i.g. at 70° F.

6.4 Federal specifications do not include all types, classes, grades, sizes, etc., of the commodities indicated by the titles of the specifications, or which are commercially available, but are intended to cover the types, etc. which are suitable for Federal Government requirements.

6.5 Transportation description.

6.5.1 *Transportation description applicable to this item is:*

Type I

Gases, nitrogen, other than liquid (indicate how packed):

Carload minimum weights—30,000 and 40,000 pounds

Gases, nitrogen:

Truckload minimum weight — 30,000 pounds

Type II

Gases, nitrogen, liquid:

Carload minimum weight — 60,000 pounds

Gases, nitrogen:

Truckload minimum weight — 30,000 pounds

Minimum weights shown apply when material is transported at classification ratings. They will vary when material moves on commodity rates. When in doubt consult General Services Administration Regional Traffic Manager.

6.6 Cross reference.—The following is a cross reference of items under the basic specifications in the "a" revision.

Fed. Spec. BB-N-411 Fed. Spec. BB-N-411a

Type I, grade A	Type I, class 1, grade A
Type I, grade B	Type I, class 1, grade B
Type II	Type I, class 2, grade B

Patent notice.—When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have

formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

7. DEPARTMENTAL REQUIREMENTS

7.1 The following departmental standards of the issues in effect on date of invitation for bids, and special requirements, form a part of this specification for purchases made under this specification by the respective departments:

7.2 Army, Navy, and Air Force.

7.2.1 Applicable standards.

Military Standards:

MIL-STD-101—Color Code for Compressed Gas Cylinders and Pipelines.

MIL-STD-129—Marking for Shipment and Storage.

(Copies of standards required by the contractor in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

7.2.2 Filling pressures.

7.2.2.1 Cylinders filled to 2200 p.s.i.g.—Cylinders conforming to Specification ICC-3A2015 or otherwise qualified shall be filled to the equivalent of 2200 p.s.i.g. at 70° F., in accordance with table III.

7.2.2.2 Cylinders filled to 3500 p.s.i.g.—When specified, 330 cubic feet of water-pumped type I, class 1, grade B nitrogen shall be supplied in ICC 3AA3500 cylinders charged to a pressure of 3500 p.s.i.g. when corrected to 70°F. in accordance with table III. A government supplied valve shall be installed on the cylinder.

7.2.3 Marking.—In addition to any special marking required, marking for shipment and storage shall be in accordance with Military Standard MIL-STD-129. The cylinders shall be color coded in accordance with Military Standard MIL-STD-101.

MILITARY INTEREST:

Army—C E O M

Navy—Sh A Or MC

Air Force.

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APPENDIX VI
DETAILED OPERATION
OF
CONTROL SYSTEM

APPENDIX VI

DETAILED OPERATION OF THE CONTROL SYSTEM

1.0 GENERAL FUNCTIONS OF CONTROL SYSTEM

The entire operation of the steam system is controlled by the sequence circuits. Each generator module has its own sequence and safety equipment. The master sequence unit controls operation of more than one unit at any time. Tank pressurizing and facility-control functions are accomplished by operations from the Aerojet General Corporation control panel.

After all readiness operations have been completed and automatically checked by the master sequence unit, the system is ready for "bleed". The bleed function removes all gases from the individual steam module propellant manifolds. Bleed valves close automatically when liquid reaches them.

After completion of the bleed sequence, the system is ready for "start" (ready light "on"). If the start sequence is not initiated within one minute, it will be necessary to repeat the bleed sequence while a condition of igniter idle maintains a continuous LOX bleed. The system will re-bleed after start of water flow, and will continue to bleed until second-stage propellant valves open.

Automatic safety devices monitor the equipment operation until full-flow of steam is achieved. The system will shut down immediately if a questionable situation arises. A timer is provided to de-energize all safety devices after

a safe period at full-flow. Automatic shut-down will occur only when both conditions of high temperature and no water-flow occur simultaneously.

2.0 DETAILED FUNCTIONS OF CONTROL SYSTEM

The control system functions are described schematically in Figures 8 and 9. A step-by-step operating procedure and a detailed discussion of the theory of operation of the control system is provided in the following paragraphs:

NOTE: Components with a number series of 1 to 100 are located in each of the three generator module control boxes. The components associated with the 101 to 200 series are located in the master sequence unit. The components numbered 200 and up are located in the common equipment control box.

(a) Step 1: Turn on main 28-volt DC power supply.

Engage the main steam generator circuit breaker (C3-1). After the circuit breaker has been closed, power is transmitted to the indicator light (DS1) indicating power availability to the control system.

(b) Step 2: Close the "power on" switch.

Closing the "power on" switch actuates relay R-120, which delivers 28-volt power to all three generators simultaneously. Indicator light (DS2) is illuminated by this operation and indicates power is "on" to all busses in the steam generator system.

(c) Step 3:

(1) Set 450 PSI "high control" nitrogen supply.

- (2) Set "low control" nitrogen supply at its predetermined point
(150 PSIG).

Satisfactory completion of these two functions will cause the low-control and the high-control pressure switches to close, energizing relay R101.

Relay R101 (terminals 2 and 4) delivers power from the master sequence buss to illuminate the control pressure "OK" indicator. The operator has now pressurized the LOX tank, the propane tank, and the water system to approximate specification values, and relays R102, R103 and R104 are energized. These relays, working in series with R101, provide a preparation complete ladder which, upon completion, energizes the relays R105 and R106.

Relay R105 (terminals 2 and 4) completes the circuit between steam generator module No. 1 and the control console in preparation for receipt of a start switch power signal. Relays R105 (terminals 5 and 7) and R106 (2 and 4) perform parallel functions for steam generator modules No. 2 and 3.

NOTE: The following discussion will be concerned with one generator module only, since all are identical.

- (d) Step 4: Depress "propellant bleed" switch for each of the three
steam generator modules.

The "propellant bleed" signal passes through the normally closed contacts of R5 (terminals 6 and 7) and is delivered through the blocking rectifiers CR1

these will be interlocked on the same switch.

(e) Step 5: Depress "start" switch.

Depression of the "start" switch arms the circuit to energize the start relay, R4, which, through terminals 2 and 4, locks in to the cut-off buss. Energizing relay R4 cannot be accomplished when the system is in cut-off, since the ground circuit is broken by terminals 2 and 3 of relay R22.

Actuation of relay R4 simultaneously draws power from the main 28-volt buss through its terminals 5 and 7 to the main water-propellant valve and the main purge valve, both of which are normally closed. This signal is also transmitted through the normally closed terminals 6 and 7 of relay R12 energizing the water shuttle valve. This shuttle valve is de-energized when water is injected at full flow consequently the valve must be energized to discharge water overboard during the "idle" phase.

After water flow is established, differential pressure is sensed by the differential pressure switch which delivers power from the cut-off buss to energize relays R5, R6 and TDR2, all of which lock in to the cut-off buss through terminals 2 and 4 of relay R5. At this time, a signal is also transmitted to the "low purge" pressure switch which, if not actuated prior to this time, will result in "low purge" cut-off.

"Low purge" pressure cut-off energizes relay R11 which locks in through a set of its own terminals (2 and 4), to the re-set buss. This draws power from the re-set buss, through its own contacts (terminals 5 and 7), and

and CR2 to energize relays R2 and R1 respectively. These relays are each locked in through a set of their own contacts (R1, terminals 2 and 4; and R2, terminals 2 and 4) which draw power from the "LOX bleed" and the "fuel bleed" pressure switches, respectively.

The bleed valves are simultaneously actuated by relays (R1, terminals 5 and 7, and R2, terminals 5 and 7), thereby causing bleed flow. The related pressure switches, which in turn draw power from the cut-off buss will hold relays R1 and R2 energized until the propellants force all gasses through the propellant bleed orifices at which time the pressure switches are momentarily actuated.

Momentary actuation of the pressure switches causes drop-out of the relays R1 and R2 while simultaneously actuating relays TDR1 and R3. Drop-out of relays R1 and R2 result in cessation of bleed operations. At this time, signals of "LOX bleed complete" and "fuel bleed complete" are transmitted to the control console and a power signal is delivered to the operator's "start" switch.

The system is now completely armed and any combination of steam generators may be operated from this point. An additional operation is necessary to select the number of units which will be placed on stand-by and involves placement of a selector switch on the control console.

It is assumed that the control console also has provisions to select the generators which will be put on "prime service" or "idle service" and that

through the normally closed terminals 6 and 7 of relay TDR6, to energize relays R22 and R25 (cut-off relays). This, in turn, drops all power from the cut-off buss by opening the R25 normally closed terminals (6 and 7) and (2 and 3), which are in parallel.

Dropping power from the cut-off buss releases all relay locks which have previously been established and results in a safe "shutdown" of the system permitting all components to return to normal position.

Relays R22 and R25, if energized, are locked to the re-set buss by relay R22 (terminals 5 and 7), and remain in this condition until a "re-set" signal is provided. The "re-set" must be accomplished by depressing a switch on the control console which will actuate relay R23. Actuation of R23 de-energizes the re-set buss (terminals 2 and 3, and 6 and 7).

The cessation of power to the re-set buss will result in dropping the locks on the cut-off system (R22, terminals 5 and 7) and will also result in dropping locks in any malfunction circuit which has been previously signaled.

However, if the low-purge pressure switch has been actuated prior to the pickup of relays R5, R6 and TDR2, the system will continue in operation by transmitting power from the positive buss through the normally-open terminals 5 and 7 of relay R6 to energize the "first stage" ignition propellant valve and pick-up R201. Relay R201, in turn, draws 110 volt power through its contacts 2 and 4, and 5 and 7 to the high-voltage transformer and from there to the spark plug.

The spark plug continues to fire until such time as the system reverts to shut-down. Relay R5 also blocks the capability of the operator to further "bleed" the system by opening its normally closed contacts (terminals 6 and 7), which are in series with the propellant bleeding circuit, and simultaneously closing its normally open contacts, terminals 5 and 7. This in turn draws power from the normally closed contacts of R10, terminals 2 and 3, to begin bleeding of both systems. The systems will continue to bleed until second-stage propellant valves are signaled to be opened.

A "water flow OK" signal is transmitted from the second-stage ignition pressure switch through the contacts of R6, terminals 2 and 4, to the control console. This signal is carried to both of these circuits to be used in such a way that the "water flow OK" signal will turn on after water flow is satisfactory, and will turn off after the system goes to steam idle.

The combustion process will be initiated in the first stage combustion chamber. The presence of combustion will be determined by a differential pressure switch (first-stage ignition) which will in turn, upon actuation, energize relays R10, R7 and TDR3 which lock in to the cut-off buss through relay R7 (terminals 5 and 7).

If the first-stage ignition pressure switch does not actuate before the time on TDR2 expires, a signal will be provided from the cut-off buss through the normally closed points of the differential pressure switch through the terminals 2 and 4 of TDR2 which are now (after time expires) closed and energize

relay R9. Relay R9 will lock in through a set of its own terminals 2 and 4 and will transmit a "no first-stage ignition" cut-off signal to the control console. Relay R9 will simultaneously transmit a signal from the re-set buss through its terminals 5 and 7 and through TDR6 (terminals 6 and 7), thereby energizing the cut-off in an identical manner to that previously described for the low-purge cut-off.

If the first stage ignition operates satisfactorily, a signal will be transmitted with the pick-up of relay R10 through its own terminals 2 and 4 to operate the second-stage propellant and purge valves. Delivery of this signal to the second-stage purge valve will also drop the previously supplied signal to R10 (terminals 2 and 3) which has been providing a continuous bleed on the fuel and oxidizer system since the pick-up of R5 (water flow OK). This bleed is provided to ensure that any gasification of oxygen in the manifold has been removed, and will not adversely affect start transients. If the second-stage combustion is satisfactorily achieved before the expiration of TDR3, relay R15 will be energized by actuation of the second-stage ignition differential pressure switch and will lock in through a set of its own contacts (terminals 2 and 4).

If the second-stage does not operate satisfactorily prior to the expiration of TDR3, the closing of terminals 5 and 7 of relay 15 transmits power from the 28-volt buss through the normally closed contacts 6 and 7 of TDR4, and indicates "steam idle" on the control console. This same signal is intended to

be used as a power signal for the full steam command circuit, thus preventing accidental mis-sequencing. The system stops at this point until such time as the "full steam" command is given.

(f) Step 6: Depress "full steam" switch.

The "full steam" command may be delivered to any of the three units provided that unit has been brought to a "Steam Idle" condition.

Depression of the "full steam" signal energizes relay R12 which locks in to the cut-off buss through its own contacts, terminals 2 and 4. Simultaneously with the operation of R12, its normally closed contacts (terminals 6 and 7) open and de-energize the water overboard valve, permitting it to return to its position, i. e. , water-on-board. The presence of water-on-board is sensed by the water by-pass differential pressure switch which draws power from the cut-off buss to energize relay R17 and R18. These relays lock in to the cut-off buss through the normally open contact (terminals 2 and 4) of relay R18.

Relay R17 transmits power through its normally-open contacts (terminals 2 and 4) to operate the "main LOX propellant" valve and the "main LOX purge" valve. This results in "main LOX flow" under rated conditions and cessation of "main LOX purge".

A similar signal is delivered with the same set of contacts to energize TDR4 which, after its time interval expires, closes terminals 2 and 4 to energize the "main fuel propellant" valve and the "main fuel purge" valve (cessation

of purge). At the same time, TDR4 (terminals 6 and 7) interrupts the "steam idle" signal and provides, through terminals 5 and 7, a "full steam" signal. After energizing, TDR5 waits until its time interval elapses and then actuates its own contacts (terminals 2 and 4) to arm the "low steam pressure" cut-off and the "high steam temperature" cut-off. At any time after the expiration of TDR5, but before the expiration of TDR6, any cut-off circuit can independently cause shut-down in a manner similar to that described for the "low-purge" cut-off. After expiration of TDR6, however, its normally closed contacts, terminals 6 and 7 in the cut-off circuit open and prohibit the receipt of a cut-off signal to the cut-off relays from any circuit, except a manual cut-off (R21) or a compound condition of high steam temperature (R24) and low water flow (R13, terminals 2 and 4). This combined signal by-passes entirely the cut-off signal chain and is delivered directly to the cut-off relay coils R22 and R25 which lock in and perform in the previously described manner.

After the expiration of time on relay TDR6, a signal is transmitted through terminals 2 and 4 from the cut-off buss of the particular generator module in question to arm the "low steam pressure for two units" circuit. This signal will be transmitted through the blocking rectifier CR101 and, should the "low steam pressure switch for two units" be in a de-activated position, through relay R107 (terminals 2 and 4), R108 (terminals 2 and 4), or R109 (terminals 2 and 4) (depending on which unit has previously been idling) to raise the steam pressure.

If, after the expiration of time on TDR5, the steam pressure in the plenum is not sufficiently high to operate the "low steam pressure switch for one unit", the signal from TDR5 (points 2 and 4) will be delivered through blocking rectifiers CR104, CR105, or CR106 to the low steam pressure switch which in turn will return the signal through CR107, CR108, or CR109 to all units relay R20. Relay R20 will consequently lock in through its own points (2 and 4) to the reset buss and, simultaneously, deliver a "low pressure steam cut-off" signal to the control console.

The operation of any primary valve is monitored by position switches which indicate both "open" and "closed" positions. These position switches have not been included in this discussion since they are not an active part of the control circuit and are used for reference or troubleshooting purposes only.

It should be noted that the operating system is set up in such a way that no electrical circuits are used in the shut-down of the equipment and that a power failure at any point throughout the operation will not result in a hazardous condition.

The only system which will be in operation after a shut-down is the purge network. All purge valves that are associated with a particular propellant system are normally open and are provided with purge gas from the main purge valve. This valve has been designed in such a way as to make its closing entirely independent of any electrical system, thereby performing in a normal shut-down position.

It is apparent, therefore, that a power failure cut-off differs from normal only in that no reason for cut-off is recorded (since no power is available for this purpose).

A re-start may be accomplished at any time after cut-off and re-set.

3.0 SAFETY INTERLOCKS

Safety interlocks are provided which monitor operation of the steam generating system at all critical areas and cause the system to shut down if a questionable situation arises. The following is a listing of the safety interlocks and the system functions that are monitored:

1. No start if:
 - (a) All propellant lines are not charged (pressure switches).
 - (b) Control pressure not at set valve (pressure switches).
 - (c) Propellant lines have not been bled (LOX within 60 seconds, propane since "power on") (pressure switches).
2. No first-stage ignition if:
 - (a) Water flow not present (differential pressure switch).
 - (b) Nitrogen purge not present (gauge pressure switch).
3. No second-stage ignition if:
 - (a) First-stage ignition circuit does not actuate (pressure switch and timer).
 - (b) Water-flow not present (differential pressure switch).

- (c) Nitrogen purge not present (gauge pressure switch).
- 4. No main flow if:
 - (a) Second-stage ignition circuit does not actuate (pressure switch and timer).
 - (b) Cooling water not flowing into gas stream (differential pressure switch).
- 5. Shut-down if:
 - (a) Chamber pressure not up to pre-set level in two seconds (timer and pressure switch activated after two seconds).
 - (b) Chamber pressure decreases (pressure switch, active until safety elimination timer expires) main flow plus five seconds.
 - (c) Water-flow failure (active until safety elimination timer expires) main flow plus five seconds.
 - (d) Steam temperature (temperature switch) (active until safety elimination timer expires) main flow plus five seconds.
 - (e) Steam temperature plus water-flow failure simultaneously (active two seconds after main flow).
 - (f) Manual signal for shut-down (always active).
- 6. Auxiliary unit to full-flow if:
 - (a) Steam pressure drops below pre-set value (pressure switch plus timer at five seconds past full steam) and provided that an auxiliary unit has been placed on stand-by by the control console

selector switch.

NOTE: Lockouts may be provided for each malfunction circuit where override is desired to avoid loss of steam flow.

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APPENDIX VII

IBM COMPOSITION

Shawnee Industries, Inc.

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PROPELLANT PERFORMANCE

REPORT NO. 1

(Pc: 125 PSIG)

DATE: 11/4/63

FILE: C3H8

SAS NO.

INGREDIENTS INFORMATION

PROJ. NO. 8593-20-1000

NAME OR SYMBOL	EMPIRICAL FORMULA	FEED T DEG. K	DENS. G/CC	MOL. WT. G/MOLE	DELTA H/F KCAL/MOLE
C3H8	(Liquid Propane) (L)	298.15	0.508	44.097	-28.643
LOX	(Liquid Oxygen) (L)	90.00	1.140	32.000	-3.081

A		B	C
COMPOSITION WEIGHTS GRAMS:			
O/F (Oxidizer-Fuel Ratio)	2.000	1.000	0.500
C3H8 (Liquid Propane)	33.333	50.000	66.667
LOX (Liquid Oxygen)	66.667	50.000	33.333

ELEMENTS IN PROPELLANT, GRAM ATOMS			
C	2.26771	3.40160	4.53548
H	6.04722	9.07092	12.09460
O	4.16669	3.12500	2.08331

THERMAL DATA PERFORMANCE PARAMETERS:			
(CP) C EQUIL.	17.04	26.92	53.74
GAMMA BAR	1.157	1.125	1.097
ENTROPY	3.245	3.399	3.131
CF, VAC	1.918	2.019	2.200
AE/AT	1.777	1.762	1.747
CF, IDEAL	0.246	0.243	0.241
RHO/BULK	0.806	0.703	0.623
C*	5894.1	4382.2	3647.9
ISP, IDEAL	45.03	33.16	27.36
ISP. RHO/B	36.28	23.30	47.04
ISP. SPACE	351.37	275.05	249.42
EQUILIBRIUM	SHIFTING	SHIFTING	SHIFTING

	CHAMBER	EXHAUST	CHAMBER	EXHAUST	CHAMBER	EXHAUST
PRES., PSIA	140.00	130.00	140.00	130.00	140.00	130.00
PRES., ATM	9.526	8.846	9.526	8.846	9.526	8.846
TEMP. K	2992.1	2262.1	1291.4	1280.7	1098.3	1083.1
TEMP. F	4926.1	4872.1	1864.8	1845.6	1582.8	1490.0
MOLE WT.	18.555	18.574	13.777	13.811	15.401	15.422

PRODUCT COMPOSITIONS					
CH4		0.17838	0.17992	0.82753	0.82476
C O	1.96662	1.96462	2.83551	2.81246	1.09015
H C O	0.00035	0.00032			
CO2	0.30074	0.30277	0.06597	0.07275	0.18310
H	0.13653	0.12995			
O H	0.05079	0.04736			
H2	1.38817	1.39125	4.02107	4.00840	3.76524
O2	0.00138	0.00125			
O	0.00307	0.00279			
H2O	1.54161	1.54355	0.15755	0.16703	0.62697
C-S			0.32165	0.33633	2.43466

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PROPELLANT PERFORMANCE

REPORT NO. 2

(Pc: 125 PSIG)

DATE: 11/4/63

FILE: C3H8

SAS NO.

INGREDIENTS INFORMATION

PROJ. NO. 8593-20-1000

NAME OR SYMBOL	EMPIRICAL FORMULA	FEED T DEG. K	DENS. G/CC	MOL. WT. G/MOLE	DELTA H/F KCAL/MOLE
C3H8	(Liquid Propane) (L)	298.15	0.508	44.097	-28.643
LOX	(Liquid Oxygen) (L)	90.00	1.140	32.000	-3.081

A		B	C
COMPOSITION WEIGHTS GRAMS:			
O/F (Oxidizer-Fuel Ratio)	3.600	3.300	3.000
C3H8 (Liquid Propane)	21.739	23.255	25.000
LOX (Liquid Oxygen)	78.261	76.745	75.000

ELEMENTS IN PROPELLANT, GRAM ATOMS			
C	1.47895	1.58208	1.70080
H	3.94386	4.21888	4.53546
O	4.89131	4.79657	4.68750

THERMAL DATA PERFORMANCE PARAMETERS:			
(CP) C EQUIL.	53.28	52.10	48.96
GAMMA BAR	1.080	1.081	1.084
ENTROPY	2.810	2.875	2.946
CF, VAC	1.524	1.523	1.522
AE/AT	2.469	2.466	2.457
CF, IDEAL	1.272	1.272	1.271
RHO/BULK	0.897	0.884	0.869
C*	5613.8	5703.8	5797.9
ISP, IDEAL	221.90	225.42	229.05
ISP, RHO/B	199.07	199.27	199.12
ISP, SPACE	265.90	270.02	274.25
EQUILIBRIUM	SHIFTING	SHIFTING	SHIFTING

	CHAMBER	EXHAUST	CHAMBER	EXHAUST	CHAMBER	EXHAUST
PRES., PSIA	140.00	14.70	140.00	14.70	140.00	14.70
PRES., ATM	9.526	1.000	9.526	1.000	9.526	1.000
TEMP. K	3364.0	2846.6	3373.1	2848.2	3369.1	2826.7
TEMP. F	5595.6	4664.1	5611.8	4667.0	5604.7	4628.3
MOLE WT.	23.731	25.217	23.037	24.479	22.253	23.616

PRODUCT COMPOSITIONS						
C O	0.19055	0.15117	0.21630	0.18103	0.24574	0.21748
CO2	0.16040	0.22178	0.14813	0.20623	0.13271	0.18418
H	0.03231	0.01985	0.03678	0.02280	0.04119	0.02461
O H	0.09201	0.05898	0.08608	0.05289	0.07587	0.04167
H2	0.05333	0.04102	0.06642	0.05375	0.08496	0.07335
O2	0.08602	0.07255	0.06004	0.04444	0.03658	0.02079
O	0.03289	0.01782	0.02814	0.01409	0.02177	0.00887
H2O	0.35246	0.41684	0.35808	0.42477	0.36114	0.42906

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APPENDIX VIII

ACCEPTANCE TEST RECORDS

THIS ILLUSTRATION TO BE PROVIDED

Shawnee Industries, Inc.

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APPENDIX IX

APPLICABLE DRAWINGS
AND
SPECIFICATIONS

APPLICABLE DRAWINGS
AND
SPECIFICATIONS

A. REFERENCE DRAWINGS

Drawing Number	Title	Quantity Used
1542	Steam Generator Skid and Plenum Base Assy.	1
1648	Plenum Base Assy.	1
1170	Plenum Assy. Steam	1
1694-2	Plate, Baffle	3
1694-3	Plate, Baffle	3
1694-4	Plate, Baffle	1
1694-5	Plate, Baffle	4
1694-6	Plate, Baffle	2
1694-7	Plate, Baffle	2
1694-8	Plate, Baffle	5
1688	Plate, Baffle	2
1690	Plate, Baffle	2
1689	Plate, Baffle	4
1693-1	Plate, Baffle	1
1693-2	Plate, Baffle	1
1692	Plate, Baffle	4
1691	Plate, Baffle	2
1559-3	Torus Expansion, Combustion Chamber	5
1563-1	Gasket	5
1563-2	Gasket	3
1696	Base, Plenum and Skid	1
1686	Frame-Skid Mounting Box	1
1680	Cavitating Venturi Assy. 2"	3
1530-3	Venturi, Cav. 2"	1
1679	Venturi, Holder 2"	1
1531	Ventur, Retainer 2"	1
1634	Plenum Water Inlet Line	3
1635	Propane Main Supply Line, Steam Generator	1
1636	Water Inlet Supply Line	1
1637	Main, Water Outlet	1
1638	Line, Lox Main Supply	1
1639	Line, Plenum Water Feed	1
1642	Line, GN ² Main Purge	1
1670	Slide-Plenum	4
1671	Gib, Plenum Slide	4

Drawing Number	Title	Quantity Used
1673	Plate-Plenum Base	2
1672	Shim-Plenum Base	2
1785	Box-Common equip. , Explosion Proof	1
1644	Plate, Mounting	1
1645	Upright	1
1647	Box, Explosion Proof	1
1646	Spacer Explosion Proof Box	6
1580	Switch, Gauge Pressure	6
1573-1	Coupling, Explosion Proof Box	8
1640	Switch, Pressure Gauge	1
1589	Module Control, N ₂	1
1518	Regulator, Powreactor	1
1517	Regulator	1
1520	Valve, Relief	1
1519	Valve, Hand	1
1516	Valve-Check	1
1521	Gauge, Pressure	1
1590	Modular Enclosure N ₂ Cont. Module	1
1348	Nameplate	
1660-1	Support, Water Inlet Pipe	1
1658-1	Support, Propane Pipe	1
1659-1	Support, Water Outlet Pipe	1
1674	Slide-Plenum Elbow	2
1675	Gib, Plenum Elbow	2
1677	Plate-Plenum Elbow	1
1676	Shim-Plenum Elbow	1
1658-3	Propane Pipe Support	1
1658-2	Support-Propane Pipe	1
1659-3	Support-Water Out. Pipe	1
1659-2	Support-Water Out. Pipe	1
1660-3	Support-Water Inlet Pipe	1
1660-2	Support-Water Inlet Pipe	1
1563-5	Gasket- Plenum Water Inlet	9
1348	Nameplate	1
1347	Nameplate	1
1698	Tubing & Fitting	

Drawing Number	Title	Quantity Used
1649	Module Assembly, Steam Generator	3
1683	Skid, Steam Generator	1
1569	Assembly, Explosion Proof Box	1
1502	Valve, Three-Way	4
1580	Switch Gauge Pressure	1
1508	Switch-Pressure	1
1512	Switch-Differential Pressure	4
1527	Valve-Three Way	2
1570	Box, Explosion Proof	1
1646	Spacer, Explosion Proof Box	9
1571	Plate, Mounting, Explosion Proof Box	1
1572	Mounting Plate, Long Pressure Switch	1
1573-1	Coupling, Explosion Proof Box	12
1573-2	Coupling, Explosion Proof Box	12
1573-3	Coupling, Explosion Proof Box	6
1665	Ferrule	1
1574	Manifold, Exhaust	1
1576-1	Spacer	1
1576-2	Spacer	1
1577-1	Spacer	2
1592	Vertical Manifold (sm.) right	1
1593	Manifold, Pressure	1
1594	Mtg. Plate Short, Pressure Switch	4
1595	Mtg. Plate Transformer	1
1599	Spacer, Small	15
1684	Vertical Manifold (sm.) Left	1
1600	Manifold Vertical, Large	1
1581	Solenoid, four way	5
1666	Stud	2
1667	Spacer, Manifold, Clip	6
1685	Stud #10-32	2
1563-3	Gasket	1
1656	Transformer	1
1587	Switch, Pressure	1
1682	Clamp Generator	2
1538-2	Filter-Screen, Propane	1
1538-1	Filter-Screen, Lox	1
1678	Support Flange	1
1533-2	Venturi Retainer 3"	1

Drawing Number	Title	Quantity Used
1536	Venturi Holder 3"	1
1535	Venturi Retainer 3"	1
1534-2	Venturi Cavitating 3"	1
1602	Steam Generator Assembly	1
1565	Igniter Top Assembly	1
1564	Igniter Assembly	1
1618	Tube Assembly	1
1619	Tube Assembly	1
1567	Plate	1
1566	Igniter Assembly, 1st and 2nd Stage	1
1609	Tubing Assembly	1
1610	Tubing Assembly	1
1611	Tubing Assembly	1
1612	Tube	1
1614	Tube	1
1615	Tube	2
1616	Tubing Assembly	1
1617	Tubing Assembly	1
1620	Tube	1
1568	Plate	1
1500	Valve Assembly	3
1501	Valve Assembly	5
1504	Valve Check	6
1514	Spark Plug	1
1515	Cable, High Voltage	1
1526-1	Valve Check, Special	1
1505	Check Valve	1
1613	Tubing Valve	1
1582-3	Filter Screen	2
1583-4	Holder - Filter	2
1528-3	Venturi - Lox	1
1507-3	Union, 1/2 Bulk Head Modified	2
1507-7	Union, 1/2 Bulk Head Modified	2
1507-1	Union, 1/2 Bulk Head Modified	1
1506-3	Union, 1/4 Bulk Head Modified	2
1506-1	Union, 1/4 Bulk Head Modified	1
1506-7	Union, 1/4 Bulk Head Modified	2
1525-2	Check Valve (Lox)	1

Drawing Number	Title	Quantity Used
1505	Check Valve	1
1613	Tubing Assembly	
1543	Injector, Steam Gen. , Lox Propane	1
1544	Manifold Assembly	1
1553	Injector Body	1
1561	Spud Assembly	
1550	Combustion Chamber	1
1551	Flange, Top	1
1552	Flange, Bottom	1
1555	Helix, Starter	1
1556	Helix, Long	1
1557	Helix, Short	2
1558	Tube, Drain	4
1559-1	Torus, Expansion	6
1559-2	Torus, Expansion	2
1560	Ring, Orifice	2
1695	Nameplate Bracket	1
1347	Plate, Identification	1
1348	Plate, Identification	1
1604	Hose and Flange Assembly	1
1627-2	Gasket	1
1627-1	Gasket	1
1554-1	Bolt, Orifice	5
1603-2	Bolt, Orifice	25
1578	Washer, Orifice	30
1563-2	Gasket	5
1563-1	Gasket	1
1633	Water Interface Conn.	1
1669	Propane Interface Conn.	1
1668	Water Outlet Interface Conn.	1
1632	Lox Interface Conn. Line	1
1631	Water Outlet Line	1
1563-4	Gasket	1
1630	Lox Inlet	1
1681	Clamp Gen. Base	2

Drawing Number	Title	Quantity Used
1629	Water Inlet and Heat Exchanger	1
1529-1	Cavitating Venturi	1
1530-1	Venturi, Cavitating	1
1532	Venturi, Holder	1
1531	Venturi Retainer	1
1628	Propane Inlet	1
1529-2	Venturi-Propane	1
1530-2	Ventur, Cavitating	1
1532	Venturi Holder	1
1531	Venturi Retainer	1
1533-1	Venturi Water In.	1
1534-1	Venturi, Cavitating 3"	1
1535	Retainer, Venturi 3"	1
1536	Venturi Holder 3" Pipe	1
1699	Tubing and Fittings	as req'd.
1506-8	Union Bulkhead	1
1588-3	Orifice	1
1505	Valve Check	4
1507-8	Union-Bulkhead	1
1579	Thermal Switch	1
1562	Well Temperature Switch	1
1513	Valve, 3-Way Water	1
1526	Valve, 2-Way Water	1
1510	Valve, 2-Way Propane	1
1509	Valve, 2-Way Lox	1
1537	Valve, 2-Way Purge	1
1563-5	Gasket 2"	12
1563-7	Gasket 3"	5
1563-6	Gasket-Lox	2
1650	Spacer	6
1563-5	Gasket	6
1563-7	Gasket	6
1549	Master Sequence Unit	1

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APPENDIX IX (cont.)

Drawing Number	Title	Quantity Used
1348	Plate, Identification	1
1657	Handle, Chassis	2
1651	Circuit Breaker	1
1654	Silicon Rectifiers	9
1655	Rectifier Socket (mounting)	9
1548-1	Control Relay Unit	1
1348	Identification Plate	1
1657	Handle, Chassis	2
1653	Relay, Time Delay	5
1652	Relay, Time Delay	1
1654	Silicon Rectifier	2
1655	Mounting-Rectifier	2
1548-2	Relay Control Unit	1
1348	Identification Plate	1
1657	Handle, Chassis	2
1653	Relay, Time Delay	5
1652	Relay, Time Delay	1
1654	Silicon Rectifier	2
1655	Mounting - Rectifier	2
1548-3	Relay Control Unit	1
1348	Identification Plate	1
1657	Handle Chassis	2
1653	Relay, Time Delay	5
1652	Relay, Time Delay	1
1654	Silicon Rectifier	2
1655	Mounting Rectifier	2

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APPENDIX X

NITROGEN HANDLING

APPENDIX X
NITROGEN HANDLING

A. PHYSICAL PROPERTIES

Formula	N ₂
Molecular Weight	28.016
Freezing Point	-346.0°F.
Boiling Point	-320.3°F.
Auto Ignition Temperature	None
Density	50.46 lbs/cu. ft. @ -320.3°F.
Color	Colorless
Odor	None
State	Gaseous above -320.3°F
Flammable limits	Not flammable
Shock Sensitivity	Not shock sensitive
Extreme Cold	Has no affect on N ₂

B. TOXICITY

Nitrogen is non-toxic and does not form toxic decomposition products. Spillage is troublesome only because the low temperature of the liquid can cause serious "burns" on contact with skin or eyes.

C. FIRST AID

1. If a person seems to become dizzy or loses consciousness while work-

- ing with nitrogen, take him to a well ventilated area immediately. If breathing has stopped, apply artificial respiration. Use oxygen inhalator if available. Summon a physician.
2. For eye contamination, flush with water immediately and get patient to physician for treatment.
 3. If liquid nitrogen is splashed onto unprotected skin, flush contaminated area of body with large quantities of unheated water and then apply cold compresses and treat as ordinary burn.
 4. For other than minor exposures, if skin blistering occurs, get medical aid after first aid has been rendered.

D. FIRE FIGHTING

Nitrogen gas is non-flammable and does not support combustion. Consequently, nitrogen presents no fire hazard.

E. SAFETY PRECAUTIONS

MAINTAIN GOOD VENTILATION

Nitrogen may be used or stored safely only in a well ventilated area. When nitrogen gas escapes as liquid nitrogen evaporates in an unventilated place, the nitrogen displaces oxygen from the air and the percentage of oxygen remaining may become dangerously low. When the oxygen content in the air is sufficiently low, a man can become unconscious without sensing any warning symptoms such as dizziness. If a man remains in this atmosphere

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(cont.)

long enough, death can result. The oxygen content of the air should never be allowed to fall below 16 percent.

F. REFERENCES

1. Linde Company - Division of Union Carbide Corp.
2. Bloomer Research Bulletin No. 18, Institute of Gas Tech., October 1952.
3. General Review of Gases, Trans. ASME, October 1954.
4. National Bureau of Standards, Circular No. 564.
5. RMD Chemistry and Materials Department.

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APPENDIX XI

SHAWNEE INDUSTRIES, INC.
SPECIFICATION NO. 0007

CLEANING, PACKAGING AND
INSPECTION OF

OXYGEN SYSTEM

SPEC. 0007

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TITLE

CLEANING, PACKAGING AND INSPECTION OF OXYGEN SYSTEMS

PURPOSE

To prepare a specification covering the degreasing, packaging and handling procedure for parts to be used in oxygen systems of test equipment.

LET.	REL. NO.	DATE	PAR.	CHANGE	CHK.	APP.
	A	12/10/63	IIId	Specified maximum contaminants		
		"	IIId	Specified maximum contaminants		
		"	IVe	Added Step 5		
		"	V	Added "Cleanliness of environment"		
		"	VIIa	Added "Parts shall pass original inspection tests".		
		"	VIIb	Added "This shall be determined inspections".		
		"	VIII	Added "No markings on internal surfaces".		
				Walter	APPR	201
				246	CEK	
				12-1-63	12/1/63	12-1-63

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TITLE

CLEANING, PACKAGING AND INSPECTION OF OXYGEN SYSTEMS

I. PURPOSE:

To prepare a specification covering the degreasing, packaging and handling procedure for parts to be used in oxygen systems of test equipment.

II. GENERAL REQUIREMENTS:

Before cleaning, all components should be disassembled into individual parts as far as possible. For example "O"-rings should be removed, threaded connections broken, etc.

Vapor (solvent) degreasing, Section IVa, shall be used only with welded assemblies or unit metal parts.

Detergent cleaning, Section IVb, shall be used with all plastic components or metal parts containing unremovable plastic inserts. Detergent cleaning may be used with all-metal units where it is demonstrated that the Inspection requirements IX are met.

Solvent (Immersion) Degreasing, Section IVc, or Solvent Cleaning Section IVd, or Emulsion Cleaning, Section IVe, may be used on all metal (only) parts where it is demonstrated that the Inspection requirements are met.

Solvent (Immersion) Degreasing, Section IVc, or Solvent Cleaning, Section IVd, may be used for plastics where it is demonstrated to the TCC Quality Control Department and the Procuring Service that the cleaners are compatible (cause no deterioration of physical or chemical properties) with plastic parts.

Pickling and electrolytic cleaning may be used for stainless steel, corrosion resistant steel and aluminum to remove corrosion products, machining chips, weld and heat treat scale acquired during fabrication. Pickling or anodic cleaning may not be used without prior written permission of TCC when martensitic corrosion-resistant materials (440C, 17-7PH, 17-4PH etc.) whose hardness exceeds RC32 or as-welded unstabilized steel (302, 304 etc.) are used.

Ultrasonic cleaning with a compatible solvent may be used wherever possible.

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III. MATERIALS:

The following chemicals are used:

- (a) Trichlorethylene, stabilized per MIL-T-7003 or Vythene E.
- (b) Alcohol (MIL-A-6091) or Solox.
- (c) Demineralized Water. (Solid contaminants 20 mg/liter max.). (Particle size - 105 microns max.)
- (d) Dry Nitrogen (MIL-N-6011) or filtered, dry air. (Dew points 150°F approximately. Particle size - 105 microns max.)
- (e) "Dreft", "Vel", "Oakite 61A", or Fidelity #612, Versene "Regular" Powder.
- (f) Emulsion Cleaners. (Teclene)
- (g) Concentrated nitric acid and hydrofluoric acid.
- (h) Diversay Everite
- (i) Tectsol 989 (Section IVd only).

IV. CLEANING:

a) Vapor (Solvent) Degreasing

1. Large parts shall be hung in the vapors of a vapor degreaser operated at 180°F, until condensation on the part ceases. On small parts which come to temperature rapidly, it is necessary to withdraw parts; cool to room temperature; then repeat (as required) degreasing until clean.
2. Parts shall be removed, cavities drained and the trichlorethylene or equivalent (IIIc) allowed to evaporate completely.
3. All parts shall be placed in a vented forced-air oven maintained between 170 and 180°F to dry.

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b) Detergent Cleaning

Plastics or parts containing plastics, shall be cleaned by this procedure unless otherwise specified. Metal parts may be cleaned by this procedure when Section II, (General Requirements) are met.

- (1) Parts shall be immersed and agitated in a mild detergent solution maintained at 130 to 140F for 15 to 20 minutes.
- (2) After removal from the detergent solution, the parts shall be drained and immediately immersed in a bath of distilled water at room temperature, and rinsed thoroughly for at least one minute.
- (3) Parts shall be blown dry with clean dry nitrogen or filtered, dry air.
- (4) Components shall be dried in an oven maintained at a temperature of 150F until completely dry. (optional)

c) Solvent (Immersion) Degreasing

Solvent (immersion) cleaning shall be used in accordance with the requirements of Section II of this specification. Solvent cleaning equipment must be capable of continuously filtering the solvent.

- (1) Parts shall be immersed and agitated in trichloroethylene or equivalent (IIIA) at room temperature.
- (2) Parts shall be removed, cavities drained and the trichloroethylene or equivalent allowed to evaporate completely.
- (3) Parts shall be immersed in a bath of alcohol (MIL-A-6091) at room temperature and agitated for not less than thirty seconds. Care shall be taken that all surfaces of the part are rinsed well in the alcohol.

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- (4) After draining the parts of alcohol, but before they are dry, they shall be immersed in a bath of distilled water at room temperature and rinsed thoroughly for at least one minute.
- (5) Parts shall be blown dry with clean, dry nitrogen or filtered, dry air. Water marks indicate that the distilled water is contaminated.
- (6) Test in accordance with Section IX.
- (7) Components shall be dried in an oven maintained at a temperature of 150F until completely dry. (optional)

d) Solvent Cleaning

Solvent cleaning shall be used in accordance with the requirements of Section II of this specification. Solvent cleaning is primarily intended for use where vapor degreasing equipment or solvent immersion equipment is not feasible due to size of part.

- (1) Part shall be thoroughly immersed or flushed with Tectsol 989 at room temperature.
- (2) Cavities shall be drained and a sample (not less than 200cc) of the last drained Tectsol shall be tested for compliance with Section IX4. Care shall be taken that the solvent is thoroughly evaporated. Perform a Wipe Test per Section IX1a wherever possible.
- (3) Parts shall be blown dry with clean dry, filtered nitrogen or filtered dry air. The nitrogen or air shall not contain particles in excess of 50 microns in size.

e) Emulsion Cleaning

Emulsion cleaning may be used when the requirements of Section II are met.

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- (1) Emulsion cleaners used with or without added water.
- (2) Distilled water rinse.
- (3) Dry nitrogen, or filtered, dry air blown thoroughly over this part.
- (4) Dry components in an oven maintained at 150F. (optional)
- (5)

f) Flushing:

Where the internal configuration of the part does not permit examination to determine the presence of foreign matter (i.e. flakes, chips, heat treat scale, corrosion products, residue etc.) the passages shall be flushed at sufficient pressure with distilled water, or dry nitrogen or dry air, to remove above foreign matter. If after flushing, there is still indication of entrained foreign matter, parts shall be cleaned using materials (Section III) or Section IVg and h) if acceptable, and compatible with the components per Section II. This flushing procedure shall ordinarily be applied as a primary step before cleaning.

g) Aluminum Tubing

The following procedure shall be used on all unanodized aluminum tubing, prior to cleaning, where flushing (Section IVf) indicates entrapped foreign matter or corrosion products.

- (1) Pickle the tubing stock in a water solution of 20 percent nitric acid and 3 percent hydrofluoric acid for 15 seconds. The solution shall be heated to 120F to 140F for this pickling operation.
- (2) Rinse the tube stock in tap water.
- (3) Clean the tube stock in a water solution of 20 percent nitric acid for 10 seconds.

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- (4) Rinse the tube stock in tap water and, using clean, oil free nitrogen, blow the tube stock dry.
- (5) Inspect the tube stock and reject it if its inside and outside surfaces do not have a mat finish of uniform texture. Any white coating on the tube stock after it was pickled and cleaned indicates that the tube stock is excessively weathered, and that it shall not be used for form a tube assembly. However, if a black coating is on the tube stock, repeat cleaning step (3) and rinsing step (4) and reinspect the tube.
- (6) Flare one end of the tube stock and clean the part as specified in Section IVc before forming the tube to drawing requirements, or fitting the tube to an assembly.
- (7) After final forming and flaring of the tube assembly, but prior to any installation, clean the assembly as specified in Section IVc except that besides degreasing the part, also flow Trichloroethylene through it.

h) **Stainless Steel Tubing**

The following procedure shall be used on all stainless tubing prior to cleaning, where flushing per Section IVf indicates entrapped matter or corrosion products.

- (1) Flare one end of the tube stock and clean the part as specified in procedure IV.
- (2) After final forming and flaring of the tube assembly, but prior to any installation, do the following:
 - (2.1) Pickle the tube assembly in a water solution of 20 percent nitric acid and 3 percent hydrofluoric acid for 5 minutes. The solution shall be heated to 120F to 140F for this pickling operation.
 - (2.2) Rinse the tube stock in distilled water.

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(2.3) Dry components in an oven maintained at 150°F.

V. **ASSEMBLY:**

All parts shall be assembled as completely as possible immediately after drying. Hands of the individual doing the assembling should be thoroughly washed with soap and hot water and maintained clean during the assembly operation. Wherever possible, operators must wear clean, white, line-free gloves. Care shall be taken to insure cleanliness of the environment.

VI. **PACKAGING:**

The unit parts, sub-assemblies, or assemblies, shall be packaged or sealed immediately after the operations of Section IV have been completed to eliminate any possibility of contamination of the cleaned parts. The packaging shall fit loosely around the part or assembly to prevent any cutting of the package by projections on the packaged item. After the part or assembly is packaged or sealed in accordance with one of the following methods, it shall be identified with a green identification label or tag securely attached to the package or part. This tag shall contain the following information:

Part or Assembly - Number and Title

WARNING: This part has been cleaned, and is ready for use in oxygen systems. DO NOT open package until ready for installation.

(a) Small parts or sub-assemblies having openings which cannot be conveniently covered with a plug or seal.

(1) Parts shall be enclosed in a clean, oil-free envelope, and sealed in such a way as to exclude contaminants. Envelope material may be:

- (a) Aluminum Foil Wrap (Alcoa, Reynolds, Kaiser, etc.)
- (b) Plastene 6004 (Banat Products, Inc., Tomah, Wis.)
- (c) Koroseal (B.F. Goodrich Co.)
- (d) Polyethylene (Crystal X Co., Lenni Mills, Pa.)
- (e) Saran - (Dow Chemical Co.)
- (f) Nox Rust Clear Pak (Daubert Chemical Co.)
- (g) Metalam (Dobekmann Co.)

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- (2) All other openings in the subject parts shall be sealed in such a manner as to exclude contaminants. Seals for these openings shall be of one of the materials listed under VI a (1), and shall be secured over the opening with masking tape or a similar adhesive product.

VII. TRANSFER OF PARTS:

- (a) When transferring parts between one oxygen system and another, it will not be necessary to repeat the cleaning procedure if the parts have been maintained in an uncontaminated condition during the period of transfer by the use of such plugging, sealing and labelling procedures as may be required by the part configuration and the delay anticipated, prior to reinstallation. Before reuse, parts shall pass all original inspection tests.
- (b) It will be the responsibility of the person reinstalling such a part or sub-assembly to determine the adequacy of the storage procedures, and to return for cleaning, any parts which have been contaminated. This shall be determined as inspection.

VIII. QUALITY:

- (a) No residue, contaminant, marking filler or finish other than that specified on the drawing will be permitted on parts treated in accordance with this specification. No markings shall be permitted on the internal surfaces.

NOTE: All permissible markings shall be compatible with the cleaners used in this specification as well as with liquid or gaseous oxygen (not detonable or pyrophoric). Where doubt exists, consult TCC Materials Department.

IX. INSPECTION REQUIREMENTS:

All parts cleaned and assembled or packaged in accordance with this specification must be capable of meeting the following inspection requirements when requested by the TCC Quality Control Department or its authorized designee or the Procuring Service. These inspection requirements are in addition to all

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drawing or specification requirements. In case of conflict, the drawing requirements shall be met.

(1) Water Break Test

The items or test specimens (if permitted) shall be rinsed in running distilled water and the surface examined for discontinuity of the water film. If the water film is discontinuous, parts may be subject to rejection. After the test, parts shall be dried and baked in accordance with this specification.

- (1-a) Where the results of the water break test are disputed, the following referee test may be used. Wipe the surface with a clean lint-free cloth, or clean filter paper. Presence of stain may subject the part to rejection.

(2) Freedom from Alkalis and Strong Acids

The surface of the parts to be tested shall be wet with a few drops of distilled water. Indication of alkali or acid with litmus paper reaction may subject the part to rejection. Parts subjected to this test shall be blown dry and baked per this specification.

(3) Freedom from Foreign Particles

All surfaces shall be free of particles as determined by examination with a 5X magnification lens. Where particles are found, the part may be subject to rejection.

(4) Solvent Extraction

The sample in accordance with Section IVd, when analyzed, shall not contain more than 50 parts per million of dissolved or suspended impurities with a maximum particle size of 175 microns, unless otherwise specified by the applicable drawing.

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APPENDIX XII

SHAWNEE INDUSTRIES, INC.
SPECIFICATION NO. 0006

GENERAL PARTS AND ASSEMBLY

CLEANING PROCEDURE

SPEC. 0006

SPECIFICATION 0006

CLASS I

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LFT. B

TITLE

GENERAL PART AND ASSEMBLY CLEANING PROCEDURE

PURPOSE

To specify a method of cleaning parts for general usage, which will in addition to adequately cleansing, minimize corrosion of the parts.

LET.	REL. No.	DATE	PAR.	CHANGE	CHK.	APP.
A	6-576	11/5/63	C-2-b	Delete Alcohol Rinse Page 3	K	11/5
B		11/21/63	C-1	Changed to read "in detail individually"	K	11/21
		"	C-2-b	ADDED work "loose" before "chips"	K	11/21
		"	C-4	DELETED	K	11/21

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TITLE

GENERAL PART AND ASSEMBLY CLEANING PROCEDURE**A. PURPOSE.**

- A-1 To specify a method of cleaning parts for general usage, which will in addition to adequately cleansing, minimize corrosion of the parts.

B. EQUIPMENT AND MATERIAL.

- B-1 AN-T-37 Trichloroethylene or Vithane "E" Stabilized Degreasing.
- B-2 Nitrogen or air blast pressure and a suitable method of baking parts at 200F.
- B-3 "Dreft", "Vel", "Oakite 61A" or "Fidelity 812".

C. PROCEDURE.

- C-1 Always clean parts in detail, individually if possible since cleaning assemblies will not allow thorough cleaning of all surfaces.
- C-1.1 Unless otherwise specified, clean all plastics, rubber, or parts containing plastics by the following procedure:
- a. Parts shall be immersed and agitated in a mild Dreft (or equivalent) solution maintained at 130 to 140F for 3 to 5 minutes.
 - b. After removal from the Dreft solution, the parts shall be drained and immediately immersed in a bath of tap water at room temperature, and rinsed thoroughly for at least one minute.
 - c. Dry the parts, either with clean dry air or by baking them at 150F. (optional)
- C-2 Clean other detail parts generally as follows:
- a. Degrease in AN-T-37 Stabilized trichloroethylene or Vithane "E" preferably at a temperature of

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180°F, otherwise soak at room temperature until all grease and dirt is removed.

- b. Flush all internal flow passages by flowing continuously filtered trichloroethylene through them. Flow the solvent at a velocity which is high enough to remove all loose chips, flakes, scale, slag and other foreign matter from the passages.
- c. After rinsing the part, bake it at 160°F until it is dried. (optional)

C-3 Clean parts which must be hydrostatic or water flow tested in an assembly as follows:

- a. Degrease in AN-T-37 Stabilized trichloroethylene or Vithane "E" preferably at a temperature of 180°F, otherwise soak at room temperature until all grease and dirt is removed.
- b. Assemble parts as required.
- c. Hydrostatic test or flow test as required.
- d. Dry assembly thoroughly either by air blast or by baking at 200°F maximum.

C-5 Aluminum Tubing: The following procedure shall be used on all aluminum tubing stock which will be formed, fitted and flared into a tube assembly.

- a. Rinse the tube stock in tap water and using clean, oil free nitrogen blow the tube stock dry.

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GENERAL PART AND ASSEMBLY CLEANING PROCEDURE

- b. After final forming and flaring of the tube assembly, but prior to any installation, clean the part as specified in procedure C-2.

C-6 Stainless Steel Tubing: The following procedure shall be used on all stainless steel tubing stock which will be formed, fitted and flared into a tube assembly.

- a. After final forming and flaring of the tube assembly, but prior to any installation:

1. Rinse the tube stock in tap water.
2. Clean the assembly as specified in procedure C-2.

D.

PACKAGING

D-1 Each unit part, sub-assembly or assembly shall be individually packaged (except as noted in paragraph D-2 (1) below) and sealed immediately after the operations of Section C have been completed. This will eliminate any possibility of contaminating the cleaned parts. The packaging shall fit loosely around the part or assembly to prevent any cutting of the package by projections on the packaged items.

D-2 Small parts or sub-assemblies having openings which cannot be conveniently covered with a plug or seal.

- (1) Each part shall be individually enclosed in a clean, oil-free envelope and sealed in such a manner as to exclude contaminants. A single envelope may be used for more than one part of the same part number if all of the parts within the envelope are to be used immediately upon opening the envelope. (For example, it may be less expensive to package a set of identical parts for a single assembly.) This option must be specifically authorized by TCC process sheets or purchase orders. A single envelope may also

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be used if sealing is accomplished in such a manner that removal of one or more parts will not break the seal that protects the parts remaining in the envelope. Envelope material may be:

- (a) Aluminum Foil Wrap (Alcoa, Reynolds, Kaiser, etc.)
- (b) Plastene 6004 (Banat Products, Inc., Tomah, Wis.)
- (c) Koroseal (B.F. Goodrich, Co.)
- (d) Polyethylene (Crystal X Co., Lenni Mills, Pa.)
- (e) Saran (Dow Chemical Co.)

- (2) After a part or assembly is sealed in one of the above envelopes, and is intended for shipment or interplant handling, it should be packaged additionally in accordance with good commercial practice.

D-3 Parts having openings which can be conveniently covered with a seal, cap or plug. (a)

- (1) All threaded openings in the subject parts shall be closed with a plug or cap of the proper size. The plugs and caps used shall have been previously cleaned, and shall have been maintained free of contaminants prior to installation.
- (2) All other openings in the subject parts shall be sealed in such a manner as to exclude contaminants. Seals for these openings shall be of one of the materials listed under D-2 (1) and shall be secured over the opening with masking tape or a similar adhesive product.
 - (a) Caplugs closures are recommended.
Caplugs Div., Protective Closures Co., Inc.
Buffalo, N. Y.

E. QUALITY

E-1 No residue, contaminant, marking, filler or finish other than that specified on the drawing will be permitted on parts

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treated in accordance with this specification.

NOTE: All permissible markings shall be compatible with the cleaners used in this specification. Where doubt exists, consult TCC Materials Department.

F. INSPECTION REQUIREMENTS

All parts cleaned and assembled or packaged in accordance with this specification must be capable of meeting the following inspection requirement when requested by the TCC Inspection Department or its authorized designee or the Procuring Service. This inspection requirement is in addition to all drawing or specification requirements. In case of conflict, the drawing requirements shall be met.

F-1 Freedom from Foreign Particles

All surfaces shall be free of particles as determined by examination with a 5 x magnification lens. Where particles are found, the part may be subject to rejection.

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