ET24-V4-FOP-001
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National Aeronautics and
Space Administration

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

FACILITY OPERATING PROCEDURE
FOR
THERMAL VACUUM CHAMBER
V4

ENVIRONMENTAL TEST FACILITY BRANCH

STRUCTURAL AND ENVIRONMENTAL TEST DIVISION

TEST LABORATORY

ENGINEERING DIRECTORATE

CHECK THE MASTER LIST—
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

FACILITY OPERATION PROCEDURE
FOR
THERMAL VACUUM CHAMBER
V4

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1.0 GENERAL INFORMATION

1.1 PURPOSE

This document describes the procedures for the operation of Thermal Vacuum Chamber V4 located at the Environmental Test Facility (ETF) in MSFC Building 4619 Room 167B.

1.2 SCOPE

The procedures and practices outlined in this document are to be followed in the operation of Chamber V4. This document provides a record copy of Chamber V4 operations.

1.3 APPLICABLE DOCUMENTS

MPR 8715.1	Marshall Safety, Health, and Environmental (SHE) Program
MWI 8715.1	Electrical Safety Program
ET24-LOTO-SOP-001	Control of Hazardous Energy (Lockout/Tagout) Procedure for the Environmental Test Facility
ET24-UnattnOps-SOP-001	Unattended Operation of the Environmental Test Facility (soon to be superseded by)
ET24-ETF-OWI-001	Environmental Test Facility (ETF) Test Operations
ED26 (02-01)	Memorandum for Record, Safety Assessment for the ETF (soon to be re-issued as an ET24 memo, number unknown)

1.4 SAFETY

All test personnel working in this facility shall be familiar with the safety documents listed above and shall report any safety hazards, unsafe practices, safety incident or near misses to the ETF Branch Chief or the 4619 Building Manager Assistant. In the event of serious personnel injury, do not move the injured person unless necessary to prevent further serious injury.

All personnel working near cryogenics shall be diligent in preventing freeze burns caused by contact with cold surfaces or liquids. Protective clothing including eye protection and gloves shall be worn by all personnel involved in handling of cryogenics or when making repairs/modifications to cryogenic systems. Repairs/modifications to cryogenic systems shall be performed by certified cryogenic handlers. In the event of a cryogenics spill, line ruptures, or similar emergencies, personnel shall first ensure that there is no possibility of asphyxiation due to oxygen displacement. Use a portable oxygen monitor to verify that oxygen is adequate before entering the spill area.

The chamber can reach extreme temperatures both hot and cold. The test chamber and test article shall be given sufficient time to return to ambient temperature $\pm$ 10 degrees C ($\pm$ 18 degrees F) before removing the test article in order to minimize the extreme temperature hazard.

ET24 Safety Assessment, Memorandum of Record ED26 (02-01) (soon to be re-issued as an ET24 memo, number unknown) delineates the procedures, personal protective equipment (PPE) requirements and job hazard analysis (JHAs) for hazards associated with operation of this chamber. Operators shall follow this and other applicable procedures, implement the risk mitigation methods listed in the JHAs and use the required PPE to minimize risk from potential hazards during chamber operations.

1.5 EMERGENCY TELEPHONE NUMBERS

Dial **911** for all emergencies, including:

Medical	**911**
Fire	**911**
Ambulance	**911**
Security	**911**
Chemical Spills	**911**

Other numbers that can be used to obtain information about emergency, security, safety, and utilities are:

Medical Center	544-2390
Security	544-4357
Safety	544-0046
Utilities	544-3919
Other Assistance	544-4357 (4-HELP)

1.6 CHECKOUT TEST

A dummy test article shall be used for determining program set-points for the thermal controllers and safety devices prior to testing, especially for critical qualification tests. Use a dummy test article that provides an accurate thermal simulation of the actual test article.

1.7 HAZARDS LIST

- 208 and 120 volts AC electrical power.
- Extreme temperatures (hot and cold)
- Liquid nitrogen (LN_2)
- Extreme heat at the diffusion pumps
- Vacuum pump oil

********** WARNING**********

Failure to follow maintenance or operating procedures, techniques, restrictions, etc., exactly may result in severe personnel injury, loss of life or major equipment damage.

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1.7.1 Minimizing Electrical Shock Hazards

**********WARNING**********

Prior to performing maintenance on any equipment, lockout and tag the equipment in accordance with Lockout/Tagout Procedure MSOP-FA-ETF-413 (soon to be superseded by ET24-LOTO-SOP-001). Maintenance shall be performed by qualified technicians only.

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1.7.1.1 All electrical repairs and modifications shall be performed by electrical technicians to minimize the electrical shock hazard.

1.7.1.2 All bare electrical parts inside the chamber with a potential to ground of 50 volts or greater shall remain de-energized when the chamber is open. If this is infeasible, then safety related work practices shall be used to prevent electrical shock. The safety related work practices shall be documented in accordance with MWI 8715.1 and approved by a senior ETF electrical engineer. All work near energized bare electrical parts shall be performed by qualified persons.

1.7.1.3 Personnel shall not reach into a chamber with energized bare electrical parts where there is a lack of illumination or an obstruction of view. Personnel shall never blindly reach into an area that may contain energized bare electrical parts.

1.7.1.4 Personnel shall remove all conductive apparel before working near energized bare electrical parts, including jewelry, watches, key chains, metalized aprons, and metal head gear.

1.7.1.5 Personnel shall not perform housekeeping duties at close distances to energized bare electrical parts unless adequate safeguards are provided. Only non-conductive cleaning materials shall be used.

1.7.1.6 Personnel working near bare electrical parts energized at 50 volts or greater shall be provided protective equipment adequate to insulate the potential shock hazard. Personnel shall use insulating tools near energized bare electrical parts.

1.7.1.7 Safety signs or tags shall be used to warn personnel that an electrical shock hazard is present when there are bare electrical parts energized at 50 volts or greater.

1.7.1.8 Barricades shall be used in conjunction with signs or tags to limit personnel access.

1.7.1.9 Any de-energized electrical parts that are not locked-out, tagged-out, or unplugged shall be considered energized. Lock-out tag-out shall be in accordance with MSOP-FA-ETF-413 (soon to be superseded by ET24-LOTO-SOP-001). Any bare electrical part that is energized at less than 50 volts to ground need not be locked-out or tagged-out provided there is no risk of burns or arcing.

1.7.1.10 All live electrical parts located outside the chamber and energized at 50 volts or greater shall be guarded against accidental contact. Guarding methods include approved enclosures or permanent partitions or screens that restrict access by non-qualified personnel.

1.7.1.11 Personnel shall not handle, energize or de-energize, plug-in or unplug any electrical device when the device is wet, the employee is wet, or the floor is wet.

1.7.1.12 Locking type connectors shall be properly secured after connection.

1.7.1.13 After a circuit has been de-energized by the opening of a protective device, an ETF electrical technician shall inspect the circuit before the circuit is re-energized.

1.7.1.14 Over-current protective devices shall not be modified.

1.7.2 Minimizing Extreme Temperature Hazards

The test chamber and test article shall be given sufficient time to return to ambient temperature $\pm$10 degrees C ($\pm$18 degrees F) before removing the test article in order to minimize the extreme temperature hazard.

1.7.3 Minimizing LN_2 Hazards

Whenever LN_2 is being used, personnel shall be aware of the possibility of freeze burns by contact with cold surfaces or liquids. Protective clothing including eye protection and gloves shall be worn by all personnel involved in handling of cryogenics or when making repairs/modifications to cryogenic facilities. Personnel performing repairs/modifications to cryogenic systems shall be certified as cryogenic handlers. In the event of a cryogenics spill, line ruptures, or similar emergencies, personnel shall first ensure that there is no possibility of asphyxiation due to oxygen displacement. Use a portable oxygen monitor to verify the spill area is safe before entering.

1.7.4 Minimizing Extreme Heat Hazard at the Diffusion Pump

Stay clear of the diffusion pump to minimize the burn hazard. The diffusion pump can reach temperatures over 316^{o}C (600^{o}F).

1.7.5 Minimizing Vacuum Pump Oil Hazards

The vacuum pump oil can cause skin and eye irritation. Avoid skin and eye contact with the oil. Remove this oil from the skin using soap and water. Wear safety glasses and gloves while adding or changing oil. Remove oil from the eyes by flushing with water for 15 minutes. Avoid breathing vacuum oil mist.

There is a risk that the test article could be contaminated with diffusion pump oil. To minimize the risk of oil contamination, only allow trained personnel to operate the chamber. Also, ensure the cold trap between the diffusion pump and chamber is operational to reduce the contamination risk.

Any spilled oil is a slip hazard. Clean the floor of any spilled oil immediately. Use barricades to limit access in the area until the spill is cleaned.

1.8 RESPONSIBILITIES

ETF personnel shall be responsible for the operation of the V4 Thermal Vacuum Chamber. The designated operator of the chamber shall be responsible for the safe operation and conduct of the facility. This responsibility includes safety for personnel, the test article, and the facility. The name of the responsible operator shall be recorded in the chamber logbook.

Other task assignments and responsibilities at the ETF shall be in accordance with the Organizational Work Instruction ET24-ETF-OWI-001.

2.0 FACILITY DESCRIPTION

2.1 CHAMBER DESCRIPTION AND DIMENSIONS

Chamber V4 is a steel bell jar 23 inches in diameter and 30 inches tall, mating with a ring type base-plate 23 inches in diameter and 4 inches deep. There are 16, 2 3/4-inch feed-through plates available for use in the base-plate. NRC manufactured the system. Pressure is monitored by Granville-Phillips convectron and ionization gauges.

2.2 VACUUM PUMP DESCRIPTIONS

The vacuum pumping system consists of a model VHS-6 type 0184, NRC diffusion pump backed by a 15 CFM mechanical roughing pump. Oil migration into the bell jar is mitigated by a six inch LN_2 trap.

2.3 CONTROL SYSTEM

The control system consists of desktop computer running Windows NT operating system software and Intellution Dynamics *iFIX* control software for operating the chamber systems. A liquid level controller for LN_2 is used to control cooling of the cryo trap. The Intellution software is used to control the Dimension controller during thermal conditioning.

2.4 PERFORMANCE

Pumping speeds varies with test specimen, gas load, and internal chamber conditions. A clean-dry system performs approximately as follows:

- Atmosphere to 10^{-3} torr (1.0 E 5 to 0.13 Pascal) in about 30 minutes
- 10^{-3} torr to 10^{-6} torr (0.13 to 1.3 x10^{-4} Pascal) in about 60 minutes
- 10^{-3} torr to 10^{-7} torr (0.13 to 1.3 x10^{-5} Pascal) in about 2 ½ hours (cryo trap cooled to LN_2 temperature).

2.5 FAIL-SAFE FEATURES

The control system is designed so that an electrical power failure causes the entire pumping system to shutdown, closing all pneumatic valves and turning off the LN_2 controller to the cryo-trap. Likewise, loss of air to the two (2) pneumatic valves shall have the same results. The system is also protected from pressure surges in case of seal failure, or mechanical pump belt failure. The diffusion pump is thermally protected from overheating due to loss of cooling water or oil. The control power logic is designed to prevent operation of valves or pumps in the wrong mode. The thermal conditioning heating system is equipped with relays that interrupt power to the heaters if the temperature exceeds a preset limit. This limiting temperature is selected for each test. A manual restart of the heating system is required once the temperature limiting relays trip.

NOTE

Maintenance or operating procedures, techniques, restrictions, etc., requires emphasis for safe operation.

3.0 FACILITY OPERATION

Complete the As-run Buy-off Sheet when operating the chamber. This sheet is typically provided with the TPS. If none is provided, use a copy of Attachment A.

The operation of chamber V4 varies according to the temperature range, and specific requirements of the test. The procedure provides sufficient detail to operate the chamber in manual or steady state mode through one cycle. This procedure does not cover details for every feasible scenario such as for varying environments but it shall be followed as closely as reasonable. Any variation shall be noted in the chamber logbook. Use as many Buy-off sheets as needed if the test is required to re-start. Buy off sheets shall be numbered if more than one is used.

**********WARNING**********

Prior to performing maintenance on any equipment, lockout and tag the equipment in accordance with Lockout/Tagout Procedure MSOP-FA-ETF-413 (soon to superseded by ET24-LOTO-SOP-001). Maintenance shall be performed by qualified technicians only.

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3.1 FACILITY PREPARATION

3.1.1 Review the safety assessment, Memorandum of Record ED26 (02-01) (soon to be re-issued as anET24 memo, number unknown), to determine the JHAs and PPE that applies to operation of this chamber. Implement the risk mitigation methods listed in the JHAs and use the required PPE to minimize risk from potential hazards while operating this chamber.

3.1.2 Ensure that all connections to the chamber are compatible with proper operation of the chamber. Determine that the test is ready to start.

3.1.3 Verify that system supply air is regulated to 90 psig, and high purity (HP) air repress supplies are regulated at 2 to 5 psig.

3.1.4 Start the computer and run the control software.

3.1.5 Visually inspect the level and condition of the oil in the pumps. Add or change oil as needed. Oil shall be changed whenever it is darkened, contaminated, milky, or if the pump performance has degraded. Wear eye protection and gloves while adding or changing oil. Remove oil from the skin using soap and water. Remove oil from the eyes by flushing with water for 15 minutes. Avoid breathing vacuum oil mist.

Any spilled oil is a slip hazard. Clean the floor of any spilled oil immediately. Use barricades to limit access in the area until the spill is cleaned.

3.1.6 Calibration

3.1.6.1 Verify that all instrumentation to be used on this test have current calibration labels.

3.1.6.2 Verify that the calibrations do not expire before the expected test conclusion date.

3.1.7 Data Acquisition

Verify that the data acquisition system is recording data in accordance with customer's data requirements.

3.2 VACUUM SYSTEM OPERATION

3.2.1 Photograph the test article and test setup. Take as many photographs as necessary dependent on the complexity of the test setup. Copies of these photographs shall be given to the ETF Test Data Administrator before or immediately following the end of testing. This section shall be omitted if the customer requests no photographing of the test article.

3.2.2 Verify that system is closed and sealed.

3.2.3 Switch **ON** the mechanical pump. Allow time for the pump to warm.

3.2.4 The switch directly under the vacuum gauge controller shall be in the **DOWN** position if there is a Process Control Card in the vacuum gauge controller. If there is no Process Control Card installed, then this switch shall be in the **UP** position. If no Process Control card is installed then skip Steps 3.2.5, 3.2.12 and 3.2.15.

3.2.5 Select set point (**SP**) on the Process Control Card top toggle switch

3.2.6 **OPEN** the roughing valve.

3.2.7 Pump the chamber to the range of $8.0x10^{-2}$ to $5.0x10^{-2}$ torr (80 to 50 millitorr).

3.2.8 **CLOSE** the roughing valve and **OPEN** the foreline valve. Time delay opens the foreline valve in approximately 10 seconds. Evacuate the foreline and diffusion pump to $1.0x10^{-1}$ torr (100 millitorr).

3.2.9 Switch **ON** the LN_2 controller. Verify that the controller is in automatic mode. Allow the LN_2 trap to cool and begin cycling.

3.2.10 Switch **ON** the diffusion pump. Allow the diffusion pump approximately 30 minutes to come to temperature and full operation.

3.2.11 Verify that chamber pressure is $1.0x10^{-1}$ (100 millitorr) or lower. If chamber pressure is higher than 100 millitorr, pump the chamber by **CLOSING** the foreline valve and **OPENING** the roughing valve. Once the chamber pressure is $8.0x10^{-2}$ torr (80 millitorr) **CLOSE** the roughing valve and **OPEN** the foreline valve.

NOTE: If roughing to 80 millitorr exceeds 5 minutes, CLOSE the roughing valve and OPEN the foreline valve for 1 minute to "breathe" the diffusion pump.

3.2.12 Select the **ON** position on the ion gauge controller process control card.

3.2.13 Once the diffusion pump is at operating temperature of $600^{o}F$ or greater **OPEN** the high vacuum valve.

3.2.14 Switch **ON** the ion gauge.

3.2.15 Switch the Process Control Card back to **SP** once the chamber is at high vacuum. Adjust the vacuum gauge set point to about 10 times greater than the pressure it is maintaining. As the pressure improves the set point may be re-adjusted.

3.3 SYSTEM PARTIAL SHUTDOWN

3.3.1 Switch **OFF** the ion gauge controller.

3.3.2 **CLOSE** the high vacuum valve.

3.3.3 Allow the chamber and specimen to cool to ambient ±10 degrees C (±18 degrees F) if it was heated or warm to above the dew-point temperature if it was cooled.

3.3.4 The chamber may now be repressurized to ambient pressure.

3.4 SYSTEM HOT RESTART

3.4.1 The vacuum pumps and LN_2 controller are in operation with the high vacuum valve closed. Verify that bell jar is down and centered.

3.4.2 Verify the vacuum gauge controller with a Process Control card has the set point (SP) selected. Omit this step and 3.4.6 and 3.4.9 if there is no card.

3.4.3 **CLOSE** the foreline valve.

3.4.4 **OPEN** the roughing valve.

NOTE: If roughing to 80 millitorr exceeds 5 minutes, CLOSE the roughing valve and OPEN the foreline valve for 1 minute to "breathe" the diffusion pump.

3.4.5 At 80 millitorr **CLOSE** the roughing valve and **OPEN** the foreline valve and allow foreline pressure to fall below 80 millitorr.

3.4.6 Select the **ON** position on the Process Control card in the vacuum gauge controller.

3.4.7 **OPEN** the high vacuum valve.

3.4.8 Switch **ON** the ion gauge controller.

3.4.9 Select **SP** on the vacuum gauge controller's Process Control card. Adjust the vacuum gauge set point to about 10 times greater than the pressure it is maintaining. As the pressure improves, re-adjust the set point.

3.5 THERMAL CONDITIONING

Thermal conditioning can be accomplished using infrared lamps to heat or a cold plate to cool. Intellution Dynamics iFIX software is used for controlling thermal conditioning on the control computer screen.

3.5.1 Infrared Lamp Operation Using Dimension Controller

3.5.1.1 Verify the Dimension controller is switched **ON**.

3.5.1.2 **SET** the desired temperature on the computer screen.

3.5.1.3 Switch **ON** the V-4 limiter.

3.5.1.4 Set the limiter's hi limit to the upper temperature limit specified in the test preparation sheet (TPS). If no limit is specified in the TPS, set the upper limit to 10 degrees F above the required temperature. Hold down the up and down arrows together for three seconds. If the limiter does not display LIM, then press the up or down arrow until LIM is displayed. Press the green button twice. Use the up or down arrow to raise or lower the hi set temperature.

Then press the reset button or wait one minute for the limiter to automatically reset.

3.5.1.5 Verify the test article temperatures on the data system, and **ADJUST** the temperature set-point accordingly.

3.5.1.6 Once the test article reaches the set-temperature, set the limiter's low limit to the lower temperature limit specified in the TPS. If no limit is specified in the TPS set the low limit to 15 degrees F below the required temperature. Hold down the up and down arrows together for three seconds. If the limiter does not display LIM, then press the up or down arrow until LIM is displayed. Press the green button. Use the up or down arrow to raise or lower the set temperature. Press the green button again to check the upper limit. Then press the reset button or wait one minute for the limiter to automatically reset.

3.5.2 Cold Plate Operation

3.5.2.1 Verify the LN_2 supply valves to V4 are **OPEN**.

3.3.2.2 **SET** the desired temperature on the computer screen.

3.5.2.3 Verify test article temperatures on data system, and **ADJUST** the system temperature control accordingly.

3.6 VACUUM SYSTEM SHUTDOWN

3.6.1 Switch **OFF** the ion gauge.

3.6.2 **CLOSE** the high vacuum valve.

3.6.3 Verify all circuits in the chamber are switched off and de-energized, including IR lamp circuits and all of the customer's circuits. If it is infeasible to de-energize all circuits, comply with all requirements of Section 1.7.1 Minimizing Electrical Shock Hazards. If it is infeasible to de-energize all circuits on the test article, provide the customer with a copy of Section 1.7.1 Minimizing Electrical Shock Hazards.

3.6.4 Switch **OFF** the diffusion pump.

3.6.5 Set the limiter's low limit to about 15 degrees below the ambient, and then switch off the limiter.

3.6.6 Switch **OFF** the LN_2 controller and turn **ON** the LN_2 trap purge valve.

3.6.7 Allow approximately 45 minutes for the diffusion pump to cool and the LN_2 trap to warm to ambient temperature.

3.6.8 **CLOSE** the foreline valve.

3.6.9 Switch **OFF** the mechanical roughing pump.

3.6.10 Ensure that all temperatures are above the dew-point and at ambient $\pm$10 degrees C ($\pm$18 degrees F) before opening the chamber.

3.6.11 **OPEN** the chamber repress valve.

3.6.12 After the dome is lifted, and before other activities, an ETF electrical technician shall check for potential on all of the ETF's bare electrical parts energized at 50 volts or greater. The customer shall check for potential on the test article's bare electrical parts energized at 50 volts or greater.

3.7 UNATTENDED OPERATION

The thermal vacuum chamber is designed for continuous automatic operation. To preclude inadvertent automatic shutdown of the chamber or anomalies in the test environment and/or test data, complete the following steps before leaving the operating equipment unattended.

3.7.1 Verify that all facility expendable sources are available for the unattended period.

3.7.2 Complete applicable sections of the procedure ET24-UnattnOps-SOP-001, Unattended Operation of the Environmental Test Laboratory.

3.8 WEATHER EMERGENCY SHUTDOWN

If the chamber must be abandoned because of requirements to evacuate during a weather emergency, and if there is adequate time, perform the following steps. These steps are to prevent over cooling of the test article should a loss of electrical power occur while the chamber is abandoned. If no cooling is being performed, skip this section and proceed to a protected area.

3.8.1 **CLOSE** the LN_2 supply valve to the shroud or cold plate.

3.8.2 **OPEN** the V4 purge valve to the shroud or cold plate.

4.0 EMERGENCY SHUTDOWN

4.1 Switch **OFF** all V4 system thermal conditioning (heaters or cooling) and close all V4 valves on the control computer.

4.2 Switch **OFF** the pumps.

4.3 Vent the chamber and remove the test article only when there is no risk of injury to personnel and no risk of damage to the test specimen.

V4 Buy-off Sheet

Test Number _____ Customer Contact _____

Calling TPS or Work Instructions _____ Start Time & Date _____

Test Description_____ End Time & Date _____

Data Process Rate _____

Test Operator(s) (Print name and initial) _____ _____

3.1 FACILITY PREPARATION

3.1.1 _____

3.1.2 _____

3.1.3 _____

3.1.4 _____

3.1.5 _____

3.1.6.1 _____

3.1.6.2 _____

3.1.7 _____

3.2 VACUUM SYSTEM OPERATION

3.2.1 _____

3.2.2 _____

3.2.3 _____

3.2.4 _____

3.2.5 _____

3.2.6 _____

3.2.7 _____

3.2.8 _____

3.2.9 _____

3.2.10 _____

3.2.11 _____

3.2.12 _____

3.2.13 _____

3.2.14 _____

3.2.15 _____

3.3 SYSTEM PARTIAL SHUTDOWN

3.3.1_____

3.3.2 _____

3.3.3 _____

3.3.4 _____

3.4 SYSTEM HOT RESTART

3.4.1 _____

3.4.2 _____

3.4.3 _____

3.4.4 _____

3.4.5 _____

3.4.6 _____

3.4.7 _____

3.4.8 _____

3.4.9 _____

3.5 THERMAL CONDITIONING

3.5.1 Infrared Lamp Operation

3.5.1.1 _____

3.5.1.2 _____

3.5.1.3_____

3.5.1.4 _____

3.5.1.5 _____

3.5.1.6 _____

V4 Buy-off Sheet

3.5.2 Cold Plate Ops

3.5.2.1 _____

3.5.2.2 _____

3.5.2.3 _____

3.8. WEATHER EMERGENCY SHUTDOWN

3.8.1 _____

3.8.2 _____

3.6 VACUUM SYSTEM SHUTDOWN

3.6.1 _____ QA _____ NA if not applicable

3.6.2 _____

3.6.3 _____

3.6.4 _____

3.6.5 _____

3.6.6 _____

3.6.7 _____

3.6.8 _____

3.6.9 _____

3.6.10 _____

3.6.11 _____

3.6.12 _____

3.7. UNATTENDED OPERATION

3.7.1 _____

3.7.2 _____