NATIONAL ELECTROSTATICS CORP.

Instruction Manual No. 2AT051510 for
Operation and Service of

5SDH PELLETRON ACCELERATOR

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JBS

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ACCELERATOR SYSTEM
SAFETY INSTRUCTIONS

IMPORTANT SAFETY INFORMATION
READ CAREFULLY BEFORE USE OF EQUIPMENT
TRAINED TECHNICAL PERSONNEL REQUIRED

This system must only be operated and serviced by professional trained technical personnel who have been trained by NEC, read the instruction manuals and are familiar with the hazards associated with Accelerator Systems. Proper care and judgment must always be observed.

THERE ARE SERIOUS HAZARDS ASSOCIATED WITH TRANSPORTATION, ASSEMBLY, INSTALLATION, OPERATION, SERVICE AND DECOMMISSIONING OF THIS EQUIPMENT WHICH MUST BE CAREFULLY STUDIED BY ALL PERSONNEL INVOLVED WITH THIS ACCELERATOR SYSTEM.

Hazards may include (as applicable to each system)

- Heavy components requiring expert installation and/or decommissioning
- Dangerous electrical voltages
- Liquids under pressure
- Gases under pressure
- Heated highly reactive alkali metals
- Rotating and/or automatically actuated machinery
- Machinery noise
- Hot surfaces
- Possible ionizing radiation

Additional safety information is available in separate manuals covering component units. All personnel must also study these component manuals as applicable to the activities planned.

DOS AND DON'TS

DO:
- **CAREFULLY READ ALL INSTRUCTION MANUALS**
- **FOLLOW ALL INSTRUCTIONS AND WARNINGS EXACTLY**
- **STUDY SAFETY KEY AND LOCKOUT INSTRUCTIONS**
- **COMMUNICATE WITH OTHERS AT YOUR SITE**

DON'T:
- **OPERATE OR SERVICE EQUIPMENT WITHOUT INSTRUCTION**
- **FOLLOW ANY PROCEDURE NOT IN INSTRUCTIONS/TRAINING**
- **MODIFY EQUIPMENT OR BYPASS SAFETY MEASURES**
- **WORK ALONE**

TRANSPORTATION, ASSEMBLY, AND INSTALLATION

1. All equipment of substantial weight must be handled by personnel with proper experience moving heavy items, preferably professional riggers with the assistance of NEC staff.

2. Such personnel must use information provided by NEC concerning the weights of heavy items, their appropriate lifting, handling and proper mounting. Check packing lists, package markings and load/heavy items drawings.

3. All support frames must be properly assembled and securely fastened to a solid concrete floor according to documentation from NEC. Any modification that could affect safety should be reviewed with NEC.

4. All electrical equipment, cabling, grounding and safety barriers such as enclosures and safety cages must be assembled and installed according to documentation from NEC before energizing the system. Any modification that could affect safety should be reviewed with NEC.

5. All pressure equipment which will contain liquids or gases must be assembled and installed according to documentation from NEC before any system pressures are applied. Any modification that could affect safety should be reviewed with NEC.

OPERATION AND SERVICE

I. ELECTRICAL HAZARDS

SHOCK HAZARD WARNING
THIS SYSTEM USES AC MAINS POWER
SYSTEM UNITS CONTAINS DANGEROUS VOLTAGES
AND ENERGY

A. OPERATION:

1. Safety Cages:

Where applicable, systems components operating at dangerous voltages are surrounded by safety cages composed of sturdy fencing and use safety measures including automatic grounding bars actuated by the door(s), key locked doors, safety interlock key switches at the control console, an interlock door switch which shuts off the source of the high voltage, emergency stop switch(es) and a manual "shepherd's hook" used to ground the high voltage equipment during service.

a. Never operate high voltage parts of the equipment without the safety cage fully assembled and securely fastened to the floor. Grounding wires must be connected to all panels and attached to a system safety ground.

b. Never attempt to bypass or circumvent the automatic grounding bar or safety interlock switch(es).

c. Make sure that you are always aware of the location of the emergency stop switch(es) that may be needed in the event of an emergency.

When **Entry of the Safety Cages** is required, always use the following steps.

a. First ALWAYS SHUT OFF the high voltage power supply.

b. When provided, rotate the keyswitch and remove the key from the control console panel. This forces an additional shut down of the high voltage power supply. Keep this key with you during the entire service period or lock it away in a secure area.

NOTE: Any key duplicates must be kept in a secure area and not allowed near the system except to replace a damaged key. Cage door keys should be either permanently fastened to the keyswitch key or kept in a secure area. See the Safety Key Instructions at the end of this section of warnings.

In systems with multiple cages, there will be separate keyswitch assemblies and unique keys.

c. Unlock the cage door, leaving the key(s) in the door. Verify that the grounding drop bar has dropped onto the high voltage frame before entering the cage.

d. Use the grounded "shepherd's hook" to manually ground the high voltage area.

e. When all operations are complete, reverse the above steps including resetting the grounding drop bar and finally return the key to the keyswitch in the control console.

2. General:

a. Before connecting input AC power, ensure that all covers are in place and securely fastened. Ensure that the required building safety ground is connected to the system and sufficient cooling is supplied.

b. Proper grounding from the input AC power is required to reduce the risk of electric shock and to comply with safety agency and code requirements.

c. Use caution when connecting input AC power. Only apply the input voltage specified on the rating label.

d. Use caution when connecting any high voltage cables. Never handle any output cables when the high voltage source is operating.

e. After any unit is switched off, dangerous voltages may remain. While most voltages drain immediately, some may remain for a few minutes, such as the charge in a variable frequency drive. Always check the documentation to determine if a delay is needed.

Allow sufficient time for self-discharge before handling anything connected to an output. The component load must be taken into consideration when determining the time required. Always confirm that service is safe by manual grounding.

f. When user serviceable fuses are present, always replace fuses with the same type and volt/amp rating.

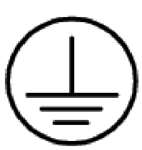
g. Never attempt to operate any unit in any manner not described in the instruction manual.

h. Never remove warning labels from any unit. Replace lost or damaged labels immediately. Contact NEC for replacement labels.

B. SERVICE:

The following safety labels apply to this system:

CAUTION - Risk of electrical shock



Protective Ground Conductor

1. Safety Cages:

When entering a safety cage, always follow the steps above under **Entry of the Safety Cages.**

2. General:

a. Service is best done by NEC trained technical personnel, either at the site during installation or by returning units to the NEC factory. Call NEC at 608-831-7600 for a Return Materials Authorization (RMA) number and ship unit(s) to 7540 Graber Road, Middleton, WI 53562.

b. If service is to be done at the user's site, this service may only be performed by trained and qualified personnel and must follow instructions from this manual, specific component unit manuals or from NEC technical personnel.

c. Consult NEC supplied assembly drawings, parts lists, circuit board drawings and schematic diagrams for service details.

II. PRESSURE HAZARDS

A. OPERATION

1. Before connecting service lines to pressurized units, ensure that all gas/liquid connectors, tubes and components are in place and securely fastened.

2. Use caution when connecting pressurized input/output lines. Only apply pressurized lines for the gas/liquid at the rating specified for each unit.

3. Ensure the correct gas/liquid is connected to the correct point on each unit.

4. When operating units under pressure, ensure all connectors, lines and components are leak tight.

5. Never attempt to operate any unit in any manner not described in the instruction manual.

B. SERVICE:

1. When pressurized inputs are turned off and/or a unit is shut off, dangerous pressures may remain in the equipment. Follow a proper pressure relief procedure from the manual before unfastening any pressurized component.

2. Service is best done by NEC trained technical personnel, either at the site during installation or by returning unit(s) to the NEC factory. Call NEC at 608-831-7600 for a Return Materials Authorization (RMA) number and ship unit(s) to 7540 Graber Road, Middleton, WI 53562.

3. If service of any unit is to be done at the user's site, this service may only be performed by trained and qualified personnel and must follow instructions from this manual or from NEC technical personnel.

4. Consult NEC supplied assembly drawings, parts lists and schematic diagrams for service details.

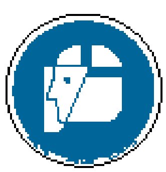
III. HEATED ALKALI METAL HAZARDS

Applicable units in this system must only be operated and serviced by qualified personnel who have read the instruction manual and are familiar with the hazards associated with the use of this equipment. Proper care and judgment must always be observed.

FIRE HAZARD !
KEEP BURNABLE
MATERIALS AWAY !

HOT SURFACES !
DO NOT TOUCH !

EXPLOSION HAZARD !
KEEP WATER AWAY FROM
ALKALI METAL RESERVOIR
AND AMPULES !



WEAR APPROVED FACE SHIELD WHEN
WORKING WITH ALKALI METALS !

WEAR APPROVED GLOVES WHEN
WORKING WITH ALKALI METALS !

WARNING: Applicable equipment contains an electrically heated reservoir of highly reactive alkali metal.

Care must be taken in operation to avoid contact with hot areas to prevent burns.

Alkali metals are extremely water reactive. In service procedures, instructions must be followed exactly to avoid burns from contact with alkali metals. Exposing significant quantities of alkali metals to water may cause an explosion.

A. OPERATION:

Under normal operating conditions, the alkali metals are completely contained inside the vacuum enclosure.

1. Never attempt to operate applicable units in any manner not described in the instruction manual.

2. Always follow heater values and temperatures specified in the manual.

3. Don't touch hot areas without heater shut off and ample time for cool down.

4. Always maintain applicable units under vacuum when no service procedures are being performed. Failure to maintain applicable units under vacuum may expose the alkali metal to the air. Exposure of the alkali metal to moisture in the air may result in rapid burning.

B. SERVICE:

Opening the vacuum enclosure allows exposure to highly water reactive alkali metals. Alkali metals will burn rapidly when in contact with water. Failure to follow the procedures in the instruction manual exactly could result in burns, fire and/or explosion. Service operations must only performed by properly trained and experienced technicians.

WARNING: - PERSONAL PROTECTIVE EQUIPMENT REQUIRED!
- END USER MUST SUPPLY PERSONAL PROTECTION EQUIPMENT IN ACCORDANCE WITH REGIONAL AND LOCAL LAWS

Approved Personal Protective Equipment including but not limited to face shield, gloves and apron must be worn. Requirements of each laboratory safety program and controlling agencies must be followed.

If alkali metal contacts skin or clothing, flush with copious amounts of water. If alkali metal contacts eyes, nose or mouth, flush with water and get immediate emergency medical care.

Alkali metals will burn rapidly when in contact with water. Failure to follow the procedures in the instruction manual exactly may result in fire and/or explosion.

Service operations must only performed by properly trained and experienced technicians.

1. Never remove warning labels from applicable units. Replace lost or damaged labels immediately. Contact NEC for replacement labels.

2. Allow adequate time applicable units to cool down after operation.

3. When opening vacuum enclosure, vent vacuum to Argon gas only. Do <u>NOT</u> use Nitrogen or other gases.

4. Maintain inert atmosphere flowing from applicable units while the vacuum enclosure is open. Follow detailed procedures in the manual <u>exactly</u>.

5. <u>Oven Removal:</u> As the oven is removed in the presence of an inert atmosphere, carefully seal it before removal from the inert atmosphere flow. Follow detailed procedures in the manual <u>exactly</u>.

6. <u>Oven Cleaning and Reloading:</u>

WARNING: Ion source ovens may contain a sufficient quantity of alkali metal that an explosion may result if exposed to water.

Many customers prefer to have this procedure done by NEC trained technical personnel, either at the site during installation or by returning unit(s) to the NEC factory. To return a used oven to NEC, call 608-831-7600 for a Return Materials Authorization (RMA) number, verify proper hazardous material packing procedures and ship unit(s) to 7540 Graber Road, Middleton, WI 53562 using the proper hazardous materials shipping methods.

If oven cleaning is to be done at the user's site, this service must be performed by trained and qualified personnel and must follow exactly the instructions from the instruction manual and/or from training by NEC technical personnel.

7. <u>Ion Source and Lens Cleaning:</u>

The ion source and lens parts may have small quantities of alkali metal on their interior surfaces. Washing with water may result in small reactions making sizzling or popping sounds; however, in small quantities, an explosion should not result.

a. Maintain sufficient ventilation during all cleaning operations.

b. Rinse the interior surfaces <u>ONLY</u> with water first, then with a solvent such as ethanol. Do <u>NOT</u> use solvents first.

WARNING: Always wash internal vacuum surfaces with water FIRST, never flammable liquids.

8. Oven Re-attachment: Be sure that an inert gas atmosphere is flowing from the ion source. Unseal the oven ONLY under the inert gas flow. Securely fasten the oven to the ion source with a new gasket.

9. Always use the NEC supplied instruction manual, assembly drawings and parts lists for service details of applicable units.

IV. ROTATING AND AUTOMATICALLY ACTUATED MACHINERY

Various components of NEC accelerator systems are operated either by electric motors or either electric or pneumatic actuators. Without fixed guards, operation of these components may result a pinching, crushing, shearing, entrapment or abrasion hazards. NEC provides these components with fixed guards which may take the form of a traditional guard or alternatively frameworks, cages, enclosures, component housings or even pressure vessels.

In cases where substantial power can be exerted by the motor or actuator, lockout switches or locking plug caps are provided to prevent operation during service when a guard may be removed. See the Safety Key Instructions at the end of this section of warnings.

Where access to equipment is not possible due to height, always use an approved step ladder to reach equipment.

Some equipment may have sharp edges. Follow warnings in the instruction manuals to avoid this hazard.

Some equipment may produce excessive noise levels. Follow the warnings in the instructions manuals and safety signs and labels. When noise levels exceed 85dB, approved ear protection is required.

Some systems are equipped with a moveable service platform. Follow warnings for safe operation, service and emergency procedures in the instruction manual.

A. OPERATION

Always operate equipment with all fixed guards securely fastened. Never bypass or modify the protection of a fixed guard. Wear approved ear protection if required in the instruction manual.

B. SERVICE

When it becomes necessary to remove a fixed guard for service, use the following procedures:

1. Turn off the lockout switch (where provided) and lock it in the off position. Retain the key to this lock. Ensure that you have the only or all keys to this lock during the service period until the guard is restored.

2. Follow facilities lockout/tagout instructions as required by regional and local regulations. All locked out switches must be tagged with the service person's name, date and time.

3. Where equipment is not provided with a lockout switch or locking plug cap, disconnect power and/or the pneumatic supply during the service period.

4. When the service is completed and the guard is securely replaced, lockouts may be activated and power and pneumatic supply restored.

V. HOT SURFACES

Some equipment provided in NEC accelerator systems may rise to temperatures where burns can result from contact. The following safety label should be found where such a hazard exists.

HOT SURFACE!
DON'T TOUCH!

A. OPERATION

During operation, do not make contact with equipment other than the normal controls of the system. Potentially hot surfaces will be marked with safety labels.

B. SERVICE

When service of potentially hot equipment is needed, remove power from the unit and allow sufficient time for cooling considering room temperature, conduction and convection, and the mass of the unit. Carefully test unit temperature before beginning service.

VI. IONIZING RADIATION

Some NEC accelerator systems are capable of producing ionizing radiation depending on operating conditions. This radiation is only possible when high energy sources such as high voltage decks and/or accelerator columns are energized. There are no radioactive isotopes used in NEC accelerator systems, therefore radiation is only possible when the system is energized. NEC provides a radiation survey map for normal machine operating conditions of its accelerator systems.

ALWAYS CONSULT CALIBRATIONS ENERGIES AND NUCLEAR REACTIONS TABLE AND OTHER WARNINGS IN THE INSTRUCTION MANUAL TO VERIFY POSSIBLE IONIZING RADIATION CONDITIONS.

It is the responsibility of the system user to monitor and control the sources of radiation associated with an accelerator system. Proper scientific training of personnel in the circumstances which could result in ionizing radiation is required. Appointing a Radiation Safety Officer and a list of Approved Operators is a required procedure to guarantee radiation safety.

Each accelerator system installation must follow all local, regional and national radiation protection regulations. Radiation detectors, alarms and rate meters, radiation dose badges and/or perimeter controls may be required depending on the specific requirements of the equipment and the installation. Consult local authorities for details.

DECOMMISSIONING

1. Removing heavy items must follow the methods and precautions found above under Transportation, Assembly and Installation warnings. If the equipment is simply being moved to another location, no disposal issues pertain.

2. Disposal of the system equipment presents no special issues for most items. Local regulations governing acceptable disposal practices will satisfy most concerns.

3. Where special requirements exists for the disposal of items containing heavy metals such as lead solder in PC Boards, see local regulations for guidance. If necessary, such items may be returned to NEC for proper disposal.

4. Certain chemicals and supplies such as solvents, oils and coolant may have special disposal requirements. See local regulations for guidance. If necessary, such supplies may be returned to NEC for proper disposal. Verify and follow all applicable hazardous material procedures required by air transport (IATA) or surface transport regulations before packaging, labeling and shipping hazmat materials such as Cesium, Rubdium, compressed gases, aerosols, paints, adhesives, and chemicals.

5. Alkali metals such as Cesium and Rubidium, if used, must be properly handled. Complete reaction by water will render these chemicals harmless if done according to the procedures explained under Heated Alkali Metals above. Subsequent disposal of the metal oxides must follow applicable local regulations.

6. Compressed gases, such as ion source gases or sulfur hexafluoride must be contained in approved vessels and handled following pressure warnings above. If necessary, such supplies may be returned to NEC for proper disposal. Verify and follow all applicable hazardous material regulations before packaging, labeling and shipping.

SAFETY KEY & LOCKOUT INSTRUCTIONS

General:
Some safety hazards in NEC Accelerator Systems are protected with locks and keys. This includes some High Voltage areas and Rotating Machinery. Proper handling of these locks and keys is essential for the protection measures to be effective.

Operators and service personnel must be aware of proper procedures for handling locks and keys used to protect against safety hazards. A key signout system or "lockout/tagout" system is required in many areas. NEC equipment facilitates such a system.

Safety Cages and Enclosures:
High Voltage areas where the danger is high are protected with a sturdy metal cage with a locked door. Depending on the severity of the danger, additional measures are implemented including a safety interlock circuit operated by the door, an automatic grounding bar operated by the door, a control console keyswitch which shuts off the high voltage and a manual "shepherd's hook" that is connected to the frame operating at high voltage during service.

Cage Keys must be kept in a secure location only accessible to qualified service personnel. Duplicate copies of keys must never be allowed out of the secure area.

Keyswitch Keys, when needed, must be inserted in the control console to operate the high voltage. The keyswitch does not allow removal of the key when it is in the ON position. When service inside the safety cage must take place, the applicable console keyswitch key must be removed from the console and stored in the secure area while the Cage Key is being used.

The BEST method is to permanently attach the Cage Key and Keyswitch Key to each other preventing opening the cage while the keyswitch is ON. This allows alternate use of the cage door and the high voltage but never both at the same time.

Tamperproof Hardware is used in some cases where a complex enclosure is rarely serviced. Always store special tools in a secure area.

Rotating Machinery:
Pelletron accelerators utilized a charging chain, rotating power shaft and other machinery for their operation. Operation of this machinery can result in hazardous conditions. Under normal operation, the Pelletron tank is closed and there is no exposure to these hazards. However, when service operations occur, the tank may be opened. The power circuits of these systems are provided with either a lockout switch assembly where individual switches may be padlocked in the OFF position or lockable plug caps which also may be padlocked.

Padlock keys must always be stored in a secure area. Duplicate copies of keys must never be allowed out of the secure area. A signout or "lockout/tagout" system is recommended for all service of Pelletron rotating machinery.

I. INTRODUCTION

The National Electrostatics Corporation Model 5SDH Pelletron is a 1.7 MV tandem electrostatic ion accelerator. This system is designed to accelerate light ions for materials science research using such techniques as Rutherford backscattering, PIXE, hydrogen profiling, implantation and nuclear physics experiments. However, it is also capable of producing low currents of heavy ions.

The accelerator consists of a high voltage insulating support structure, a charging system that produces the high voltage, and an evacuated acceleration tube through which the ion beam passes. It is a tandem type accelerator in that there are two stages of acceleration.

The principle of operation is quite simple. Negative ion beams produced in a negative ion source are preaccelerated to modest energies (20-30 keV) before being injected into the 5SDH. The beam enters what is referred to as the low energy (LE) end of the accelerator where the negative ions are attracted to the positively charged high voltage terminal and are thus accelerated. Once inside the terminal the negative ions enter a device known as the stripper where they are stripped of two or more electrons and converted into positive ions. As these positive ions exit the stripper and drift into the second stage of the accelerator, they are accelerated away from the high voltage terminal and thus accelerated once again. (Second stage is referred to as high energy (HE) end.) This dual acceleration gives the singly charged ions twice the energy they would acquire in a single stage accelerator having the same terminal voltage, and gives ions with a charge state of +n a final energy of (n+1) qV, where q is the electronic charge and V is the terminal voltage.

II. DESCRIPTION

The 5SDH includes many peripheral devices. These are described below.

TANK

The 5SDH is housed in a specially built steel pressure vessel that conforms to the ASME (American Society of Mechanical Engineers) pressure vessel code. It has a diameter of 30" (.76 m) and a length of 122" (3.1 m). The tank is made of two pieces: a long bell-shaped piece and an end plate on which the accelerator column is mounted. A steel cart with alignment screws supports the tank. The cart rolls on four wheels guided by steel tracks. The tank is rolled out of the beamline for servicing. Steel posts welded to the ends of the tracks provide precise, repeatable alignment. The end plate has a separate support (called the Head Trolley) with its own wheels, so that it can be rolled away from the bell section to access the column. A service stand with casters supports the LE end of the column if it is removed from the tank for servicing.

The tank contains the sulphur hexafluoride (SF_6) insulating gas required for high voltage operation. When the pressure vessel is opened for servicing, the SF_6 is reclaimed by the gas transfer system (see separate manual). Standard operating pressure is 80 psig. The tank is rated from 125 psig to full vacuum and is equipped with a pressure relief valve set for 120 psig that will open if the tank is over-pressurized. The vessel has many ports for various feedthroughs and controls. All the ports have been designed to prevent leakage of the SF_6 gas. O-rings should be kept clean and greased and sealing surfaces protected from dents and scratches.

COLUMN

The support column is a composite structure that provides mechanical support to the terminal and acceleration tube as well as electrical insulation and potential distribution between the terminal and ground. It is 14" (.36 m) in diameter and 100" (2.54 m) long. It comprises acrylic plates and specially formed aluminum rings. The acrylic plates provide mechanical support and electrical insulation for the column structure. They are held in position by four aluminum bulkheads. Each bulkhead has a set of four adjusting screws to align and secure the acceleration tube and stripper. **These have been adjusted in the factory. Don't touch!** Equipotential rings are attached to the acrylic plates at regular intervals between the bulkheads. They serve the dual purpose of stiffening the structure and grading the electrostatic field. Each ring is wired to an adjacent section of the accelerating tube to grade the potential from terminal to ground.

TERMINAL

A smooth cylindrical shell with rounded ends surrounds the terminal structure. The shell can be moved aside to access the internal elements. These include the gas stripper and the terminal end of the charging assembly. The shell is held in position by a screw which secures it to a post on one of the acrylic plates. For terminal servicing this screw is removed and the shell is moved to either end.

VACUUM SYSTEM

The accelerating tube, stripper and drift tubes (bellows weldments) comprise the vacuum system. These components are made from all metal and ceramic ultra high vacuum materials. NEC type metal vacuum seals and flanges are used. A ring (gasket) of soft aluminum wire compressed between two flat, polished surfaces makes the seal. A procedure for mounting and securing NEC gaskets is outlined in an appendix to this manual.

At the ends of the vacuum assembly are the LE and HE bellows weldments. Avoid over-stressing the bellows by bending severely or putting excessive tension or compression on them because leaks may result. These components are also equipped with o-rings which provide the high pressure seal to the tank. The one at the LE end is rotatable and has two o-rings, an inner and an outer. When the accelerator column is rolled into the tank, during final assembly, the outer o-ring should be well greased and fit into its groove so that it won't fall out or become pinched.

Ultrahigh vacuum turbo molecular pumps rated at 300 l/sec minimum should be positioned near each end of the Pelletron. Ionization gauges are used to monitor vacuum conditions at these locations and are very important for operation.

Always establish vacuum in the accelerator before filling the pressure vessel with SF_6 because a leak may be detected by a pressure rise in the vacuum as the tank is pressurized. Some information about the location of a leak can be gained by noting whether sudden changes in the vacuum occur at the HE or LE end of the accelerator. The stripper has a baffle at its LE end which prevents the stripper gas from streaming down the LE tube. This isolates the LE vacuum from the HE vacuum, to a large degree.

ACCELERATING TUBE

The accelerating tube provides an insulated high vacuum environment for the ion paths between the high voltage terminal and ground. An accelerating tube section is made of alternating metal and ceramic rings bonded together by a special process. Each tube section can support high voltage gradients and maintain vacuums below 10^{-8} Torr. Three tube sections make up the tube unit. Affixed onto the accelerating tubes at 1/2" (12 mm) intervals are annular stainless steel assemblies called "spark gaps." Across each spark gap is a 3 Gohm resistor. These resistors grade the potential between the terminal and ground. At full potential of 1.7 MV, the LE and HE resistor strings each pass about 8.6 μA of current. At the ground ends of the column the current through the last resistor is passed to a feedthru in the pressure vessel. The LE and HE column current is monitored at the control console and can be an important diagnostic tool.

Alumina ceramic used in the acceleration tube is hydroscopic. If the tank is opened under very humid conditions, the ceramic may absorb enough moisture from the air to form a conducting layer on its surface. Such a layer of moisture will increase the column current dramatically and may be sufficiently large to temporarily prevent the 5SDH from reaching full potential.

STRIPPING SYSTEM

The 5SDH terminal is provided with a beam stripping system that converts incident negative ions into positive ions. This is accomplished by passing the beam through a N_2 gas target that strips electrons from the ions. The gas stripper consists of a 3/16" (5 mm) diameter, 18-1/2" (470 mm) long tube or “canal” inside a 2" (50 mm) diameter pumping tube. A baffle with a 3/16" diameter aperture for the beam is mounted in the cup at the LE end of the stripper housing. This limits the stripping gas entering the LE tube. Gas is bled into the center of the stripper canal through an NEC Model No. VM-9 metering valve. (For more information about this valve refer to the VM-9 manual).

High pressure nitrogen gas is supplied to the metering valve from a 1000 cc sample cylinder located at the ground end of the tank. The gas flows to the high voltage terminal through 1/4" (6 mm) high density polyethylene tubing (400 psi rating). The sample cylinder, with a pressure rating of 1800 psig, is equipped with a regulator which should be adjusted to 150 psig. (Turn knob clockwise to increase, counterclockwise to decrease.) High pressure, pure N_2 gas **must** be maintained in this tube. If not this tube will **rupture**. The following procedure describes how to fill the tube:

1. Turn the regulator knob counterclockwise so that no gas can flow. (If the regulator output pressure does not read zero, loosen the gas line fitting to exhaust the gas. Then retighten the fitting.)

2. Open the metering valve to pump out the gas line. The pressure on the HE ion gauge will initially rise then fall as the gas line is evacuated.

3. Close the metering valve and turn up the regulator to pressurize the gas line with 150 psig N_2.

The metering valve is adjusted by means of an insulating control shaft. This shaft is driven by either a manual control knob or a motor drive unit (optional) located at the ground end of the tank. Turning clockwise closes the valve. Counterclockwise opens it. The user is advised to practice operating this valve with the accelerator off before attempting to do so while running. This is because the operating characteristics are different from what people are normally used to. The total travel of the valve is about 10-12 turns but the useful operating range is less than one full turn. From fully closed to about 5 turns is the "dead zone" where no gas flows. Then one encounters the useful operating range. Above this point the valve opens rapidly flooding the accelerating tubes with gas, causing them to glow discharge (terminal potential goes to zero). Further opening of the metering valve will quickly overwhelm the vacuum pumps.

When closing the valve resist the temptation to turn until you reach the stop. You will reach the dead zone within a turn or so from the operating point and the valve will be closed for all intents and purposes. This will make it all the easier to find the point where the valve begins to meter when operation is resumed. Also, it will extend the lifetime of the valve. If your machine is equipped with a motor drive unit for the metering valve then the preceding comments are particularly important. If you run the valve closed (or open) to the stop, damage will result in the drive assembly.

There is no provision for directly measuring the gas pressure in the stripper canal. In practice one observes the pressure on the HE ion gauge as the metering valve is opened. It is immediately obvious when gas begins to flow as the pressure rises rapidly from its base value of 10^{-8} Torr. Useful operating pressures in the stripper canal range from 1 to 10 mTorr which corresponds roughly to pressures read at the HE ion gauge from 10^{-6} to 10^{-5} Torr. The optimum value depends upon beam energy, charge state, and ion species. If you are uncertain what pressure to use simply set it to some intermediate value such as 8×10^{-6} Torr. Once the beam is guided to the target the current can be maximized by readjusting the metering valve.

<u>CHARGING SYSTEM</u>

Charging is accomplished by a pellet chain (from which the name "Pelletron" is derived). The chain is made of metallic cylinders joined by insulating links. This chain runs between the drive sheave at the ground end of the accelerator and the driven sheave in the high voltage terminal. The chain is rotated so that the top leg travels from ground to terminal. Correct chain tension is maintained by means of a counterweight system and is preset at the factory. Near each sheave are 6" long, U-shaped electrodes that envelop the chain. They are called either the "inductor" or "suppressor" (depending on function). At the ground end, the inductor is biased from 0 to -50 kV by the charging power supply. As the charging chain passes through the inductor, charge is **induced** on the pellets which carry it to the terminal. Inside the terminal the pellets come under the influence of the suppressor as they approach the terminal sheave. The purpose of the suppressor is to prevent the pellets from arcing to the sheave before contact is made. This extends sheave lifetime.

At both the ground end and inside the terminal, charging current passes through a carbon brush. At the ground end, wires connect the carbon brush to a feedthru on the tank end plate. This makes it possible for the operator to monitor charging current. At the terminal the brush is connected through a resistor to the terminal frame. The resistor biases the terminal sheave positive with respect to the terminal and thus provides the suppressor bias. (See charging system schematic.)

COOLING SYSTEM

A small, water-cooled heat exchanger is mounted above the drive charging system to cool the SF6 gas which is circulated by windage from the charging chain. A water flow rate of about 1 GPM (4 l/min) is sufficient to maintain the Pelletron operating temperature near ambient. Quick Connect® fittings are used to conveniently decouple the Pelletron from the water supply during servicing.

SHORTING RODS

When operating the 5SDH from 400 kV-700 kV it may be advantageous to short out a portion of the accelerating tube to provide optimal beam transmission. The shorting rod assembly consists of a nylon rods and stainless steel rods screwed together, and spring contacts on the distribution rings. The length of a rod is exactly equal to the distance between the equipotential rings which in turn correspond to units of the accelerating tube. As the rods are pushed in, they simultaneous short out successive units of the LE tube from the terminal toward ground and successive units of the HE tube from ground toward the terminal. To use the shorting rod, first screw in a number of rods corresponding to the number of units you wish to short. Then loosen the high pressure gas feedthru on the tank end flange through which the stainless rod passes. Push the rod in. As the rod is inserted, it will engage the spring contacts on the rings. Additional impedance will be felt at these points as the leader rod is pushed through. Once the rod is in the desired position retighten the feedthru fitting to prevent the pressure from pushing the rod back out. This fitting is intended for **hand tightening only**. Do not use a tool to tighten.

GENERATING VOLT METER

The generating volt meter (GVM) is a device used to measure the DC voltage on the 5SDH terminal. It consists of an electric motor that turns a rotating vane and four static sector plates. When voltage is applied to the Pelletron terminal, an A.C. voltage is induced on the stators by the electric field at the tank wall and the spinning, grounded rotor. This signal is amplified and rectified. Output is read on a digital display on the Voltage Controller. The GVM signal is used as feedback to regulate the terminal voltage. The GVM should be mounted so that it is centered in its porthole. It has been adjusted at the factory so that the rotating vane is flush with the inside surface of the accelerator tank.

To read the correct terminal potential the GVM must be calibrated. This is accomplished by: 1) determining the actual voltage by doing a nuclear reaction experiment and 2) adjusting the calibration potentiometer in the Voltage Controller (in manual mode) until the terminal voltage display indicates the correct value. (See the Voltage Controller manual for calibrator location). Note: The GVM is calibrated at the factory, but it is demounted for shipment. Reinstallation may change calibration slightly.

CAPACITOR PICKOFF

Just as the GVM is used to read the DC potential the capacitor pickoff (CPO) detects the AC component or “ripple”. The CPO is a circular plate mounted on the inside of the tank opposite the terminal and insulated from ground. Signals from the plate pass through a feedthru to an amplifier. The CPO amplifier is calibrated at the factory. 100VAC terminal ripple corresponds to 1VAC output. This signal it most commonly monitored by an oscilloscope. It is a useful diagnostic and tuning tool.

INJECTOR

Most 5SDH Pelletrons systems include a light ion injector equipped with an RF Charge Exchange ion source, but other sources are occasionally used. The injector provides beam preacceleration, focusing, steering, filtering and monitoring and well as serving as the LE pumping station. It includes all the power supplies and controls for the ion source and LE beamline components.

In operation the slowly diverging negative ion beam emerges from the source with about 5 keV energy. It drifts into the gap lens which accelerates the beam to about 20 keV and focuses it. The 20 keV negative ions and some fast neutrals then pass through the velocity selector where a magnetic field of about 800 gauss established by two permanent magnets, and a variable electric field established by 0 to 3 kV applied at right angles to the magnetic field across a pair of plates, selects a particular negative ion beam. Other negative ions which may have been produced along with the desired ions will be deflected and will not pass through the velocity selector aperture located beyond the magnetic and electric fields. The mass resolution of the velocity selector is about 5. Therefore, isotopes of hydrogen and helium can be individually selected and all heavier mass negative ions will be completely removed from the beam. The ion source and velocity selector are positioned at a small angle (3°) with respect to the accelerator axis. This small deflection angle prevents the energetic neutrals produced in the charge exchange cell from entering the accelerator. The negative ion beam will begin to slowly diverge again after passing through the velocity selector aperture. Two steering plates which can be biased 0-1.5 kV can change the beam direction slightly to optimize transmission of the beam through the accelerator. The still diverging negative ion beam then passes into a 0-30 kV Einzel lens. This lens imparts radial components of momentum to bring the beam to a focus in front of the acceleration tube. Proper adjustment of the lens is very important for producing the small beam size necessary at the accelerator gas stripper. A Faraday cup is provided after the velocity selector to allow measurement of ion beam intensity and to conveniently stop the beam from entering the accelerator.

AC POWER CENTER (ACPC)

This ACPC is the power center for the Pelletron. It contains a main breaker, several smaller circuit breakers for the individual components, a motor starter, and in some cases a 120 VAC transformer (if this power is not available on site). All electrical subsystems for the 5SDH are fed from the ACPC. The main power, 3-phase, electrical connection is made here to the main breaker. The ACPC is also the central grounding point for the 5SDH system. It is important that all accelerator components are grounded through the ACPC to avoid ground loops. Throwing the main breaker switch on the front of the ACPC interrupts power for the entire system.

The ACPC contains a motor starter activated by a relay through the Voltage Controller to start the charging chain. A pair of contacts is provided (on a barrier strip in the ACPC) in series with the charging chain relay circuit for the user to connect safety devices such as: radiation monitor setpoint switches or perimeter control door switches. Such switches should be of the normally open type so that if safety conditions are not satisfied the switch will open and thus automatically turn off the accelerator. Refer to the ACPC Schematic Diagram for information about the circuit connect points.

CONTROL CONSOLE

All the controls necessary for operating and monitoring the 5SDH Pelletron are mounted in a single console unit. It is constructed to allow mounting of 19-inch wide NEC electronic components and power supplies and has the EIA Standard mounting hole spacing. A door(s) at the rear of the console provide access to the rear panels of the electronic controllers where cable connections are made; therefore, the console should be installed with adequate clearance (21 inches) to open the door(s). A writing top is provided at table height in the front of the console so that the Pelletron can be controlled comfortably from a seated position. There is a lot of variation in console design depending on the beamline equipment purchased and whether the system is hard-wired or computer controlled. The control console draws its AC power through a conduit from the ACPC. It is also grounded in the ACPC at the same point as the Pelletron to avoid ground loops. Most controls operate on 120 VAC power, but some high wattage devices may use 220 VAC.

VOLTAGE/CHARGING CONTROLLER

The Voltage/Charging Controller (referred to as simply Voltage Controller in this manual) is an electronic device that controls all Pelletron functions except the stripper either directly or via computer. It can turn on the charging chain and charging power supply. It allows the user to control the charging voltage. It displays the terminal potential, charging current, column currents, and charging voltage. And it can regulate the terminal at any potential selected by the operator between 10 kV and 1.7 MV.

A switch allows the user to select one of two modes of operation: manual and auto. In **manual mode** the user can control the accelerator voltage by adjusting the charging voltage. More charging voltage results in more charging current and hence more potential on the accelerator high voltage terminal. Manual mode is used for setup and conditioning. In **auto mode** the Voltage Controller compares the GVM signal to the preset reference voltage and automatically controls the charging voltage to regulate the terminal potential. It can also automatically ramp the potential from zero up to the selected operating level.

A front panel light indicates the status of the interlocks (light "on" when interlocks satisfied). Interlock failure shuts down the charging system. Usually, the HE vacuum gauge and the stripper pressure switch are connected to this interlock.

METERING VALVE CONTROLLER/VACUUM STATUS READ

This device controls the Pelletron stripper. It displays the accelerator vacuum condition and allows the user to open/close the stripper metering valve. It also displays valve position. This device is only used on non-computerized systems.

INJECTOR CONTROLLER (Not used on computerized systems)

This device contains controls four injector beamline components: gap lens (also source bias), velocity selector (also X-axis steering), Y-axis Steerer, and Einzel lens. The Injector Controller contains an interlock that automatically shuts off the source bias voltage when the safety cage is removed.

FARADAY CUP CONTROLLER

This device allows the user to select and actuate any one of several Faraday cups. It also automatically connects the selected cup signal to an output jack that can be wired to an electrometer to measure the ion beam current. This device is only used on non-computerized systems.

III. **INSTALLATION** (*Installation is optionally performed by an NEC technician*.)

The 5SDH Pelletron is shipped as one unit almost completely assembled and filled with atmospheric air. Only a few items have been removed (to prevent damage). The beamlines and electronics are packed separately. When the shipment arrives check the crates for signs of damage. Notify NEC immediately.

POSITIONING EQUIPMENT

1) Draw a line on the floor along the accelerator beamline. A carpenters chalk line works well. The line can be made more permanent using a long straight edge and felt tip marker.

2) Move the 5SDH into position. Bolt the wheels to the bottom of the Tank Cart and bolt the casters to the caster struts on the Head Trolley. Place the tracks under the wheels. Position the tank directly over the beamline.

3) In the next step you are going to withdraw the accelerator column from the tank. An annular rubber bladder has been placed around the terminal and inflated with air to support and cushion the column during shipment. Before attempting to remove the column you must deflate the bladder by cutting the plastic inflating tube at the bottom tank flange.

4) Remove the tank tie down screws. Roll the tank into the service position. Screw the caster struts down until the casters touch the floor. Unbolt the tank endplate and roll the Pelletron column out half way. Place the service stand under the LE end of the column and adjust the support screw to take the weight. Continue withdrawing the column until it is clear of the tank.

5) Move the empty tank into the beamline position and bolt it to the stop posts. All other beamline stands should be positioned over the line and centered using plumb bobs. Alignment can now begin.

ALIGNMENT *(Most easily accomplished with two persons)*

1) Set up a theodolite or surveyor's telescope (transit with cross hair) directly over the Pelletron beamline beyond the switching magnet. Level the transit, set the height equal to the final beamline height, and rotate it to line up with the beamline. Once the transit is in place it must not be moved until the entire beamline is aligned. You may wish to put benchmarks on the wall and floor to recheck alignment at some future date.

2) Insert four bolts equally spaced through holes at the HE and LE ends of the tank. Wind string around them to form cross hair *on center*. Align the tank using the adjustment screws on the tank support. Alignment is now *approximate*.

3) Roll the tank out of the beamline and remove the string. Remove the LE bellows from the accelerating tube and using four bolts and string form cross hair on the accelerating tube entrance flange. Put the column back into the tank. Move the Pelletron into the beamline and secure it to the stops.

4) Look through the telescope. You should be able to focus on the cross hair on the LE acceleration tube viewing through the stripper. Adjust the LE tank positions screws to align the cross hair. (Hint: Back light cross hair with flashlight.)

5) Next focus on the stripper canal and adjust HE end of the tank to bring on axis. Go back to the LE end and repeat the adjustment until both the stripper and LE end are on aligned with the telescope.

6) Next align the injector with the Pelletron. The two injector components to be aligned are the velocity selector and Einzel lens (other components are self aligning). To align the velocity selector use the supplied acrylic alignment rod. This rod has cross hairs scribed on one end. Insert the rod through the velocity selector the same direction the beam travels. The small end of the rod will fit snugly in the velocity selector exit aperture. Shine a flashlight into the other end to illuminate the target. Align the velocity selector.

7) The Einzel lens alignment fixture is a cylinder of nylon with a small hole bored on center. Insert the fixture into the lens and align it. Remove the Einzel lens fixture and recheck the velocity selector. This may require several iterations until both the velocity selector and Einzel lens are aligned.

8) Mount the quadrupole lens. You can align it using a fixture which is very similar to the one for the Einzel lens. Insert it into one end of the quadrupole and align. Do same with other end. Repeat this process until both ends are simultaneously aligned.

9) Mount the switching magnet and remove the top of the yoke and top pole piece. To align the switching magnet use the steel pins provided. The height of the pins is exactly half the pole gap. The base of the pins are scribed on center. The bottom pole face of the magnet has scribe lines corresponding to the 0°, ± 15°, ± 30° beamlines. Place a pin at each end of the zero degree magnet line and line up the pin scribe lines with the line on the pole. Look through the telescope at the magnet pins. Adjust the position of the magnet until the pins are aligned and their points are at beamline height.

10) Once the magnet is aligned to the Pelletron the magnet pins may be placed on scribe lines corresponding to the target beamlines (+30°, +15°, -15°, -30°). Then you must move and realign the telescope with these pins. Next, align the target beamline components.

FINISH ASSEMBLY

1) Roll tank out of beamline. Remove column. Remove LE cross hair. Mount gasket and assemble LE bellows tightening screws in alternating pattern. Torque to 110 in-lbs. (See gasket mounting instructions in back of manual.)

2) Assemble the charging chain (Refer to illustration in back of manual). Check that the chain rotation is correct. The chain should rotate with the top leg going toward the terminal. If not, exchange any two of the three motor phases.

3) Install the control electronics and cables. Install all service facilities including: electrical power, cooling water, compressed air, etc.

4) Test the functioning of the stripper gas control rod.

5) With an ohmmeter test for continuity between the last HE resistor and the feedthrough on the end plate. Similarly, check for continuity from the drive pulley to its feedthru.

6) Dry fresh desiccant by baking at 200°C for one hour. Let cool. Place the gas dryer tray filled with desiccant at the bottom of the tank.

7) Refer to section on Tank Closing and follow procedure completely.

IV. ESTABLISHING VACUUM

Check for leaks with a helium leak detector before attempting to start the vacuum pumps. The vacuum pumps are manually operated and completely isolated from the control system. All controls are contained in the turbopump controller and the turbopump interlock. To start the evacuation process switch the turbopump interlock to "bypass" mode. Open the turbopump isolation valve. Engage the forepump(s). Watch the forepump vacuum on the vacuum gauge controller. The first time the system is pumped down confirm that there are no major leaks by pumping only with the forepump and observing that the vacuum reaches 10-20 mTorr within a few minutes. Then start the turbopumps. (On subsequent pumpdowns the turbopumps should be started at the same time as the forepump.) When the turbopumps are up to speed, turn on the ion gauge. The system will quickly pump down into the 10^{-6} Torr range. Finally, arm the turbopump interlock by flipping the bypass switch off. After a few days of pumping the vacuum should reach the 10^{-8} Torr range.

V. SF6 GAS TRANSFER

The Pelletron accelerator is insulated with SF_6 gas. Commercial grade SF_6 (99.99% purity) is quite good enough. Gas is transferred from the SF_6 storage unit to the pressure vessel. To transfer the SF_6 either into or out of the tank follow the directions given in the gas transfer system manual. Record the beamline vacuum pressure before transferring gas. Any changes indicate a vacuum leak. Use a halogen detector to check all seals for SF_6 leaks.

VI. PELLETRON CONDITIONING

CAUTION! During conditioning x-ray radiation can exceed 100 mR/hr at the Pelletron tank (unless the optional, lead, x-ray shield is purchased). It is the responsibility of the operator to provide safety shielding to protect laboratory personnel and to monitor radiation levels during conditioning.

Once the vacuum system is sealed and pumped out it is necessary to “condition” the accelerator up to voltage. Conditioning is the process whereby the accelerator is slowly brought up to its rated operating voltage of 1.7 Megavolts. If the accelerating tubes have been open to the atmosphere, they will absorb gas. When the tube is evacuated and voltage is applied the surfaces in the vacuum will desorb gas which becomes ionized. This causes micro-discharges to occur in the vacuum and initially limits voltage. Over a period of several hours the discharges cease and steady voltage can be maintained. The accelerator is now said to be conditioned. Once conditioning has been achieved, the voltage can be slowly raised to 1.7 MV with little or no conditioning. However, if vacuum is broken it will be necessary to recondition.

Conditioning can begin when the vacuum is below 1×10^{-6} Torr. First, set the Voltage Controller in the “manual” mode. Turn on the charging power supply and adjust to 2 kV. Start the charging chain motor. Slowly increase charging voltage. Watch the terminal voltage readout and vacuum gauges. Increase until *conditioning onset*. This can be recognized by vacuum activity, a reluctance by the terminal voltage to increase, and x-rays (only at high potentials); all signs of normal conditioning. After a little while this will go away and the potential will rise a few kV. At this point you should increase charging current slightly. The Pelletron potential will rise and again you will observe vacuum activity. Continue this process until the desired terminal voltage is reached. Occasionally, a major spark may occur accompanied by a loud cracking noise as the terminal discharges. Some sparking is normal during conditioning, but very frequent sparking disrupts conditioning. This can happen if the operator attempts to condition the accelerator too quickly. If repeated sparking occurs (more than 2 per minute) turn down the charging current and let the accelerator "idle" at some lower voltage for several minutes before proceeding with conditioning.

The length of time necessary to condition the accelerator depends on the vacuum conditions. If the accelerator vacuum is vented with dry N_2 and carefully sealed off during servicing, conditioning time will be short. Conversely, if the accelerating tubes are exposed to humid air for long periods of time conditioning will take many hours.

Generally, the accelerator will condition up to 1.7 MV in 1 - 3 hours. If the accelerator is to be operated at less than 1.7 MV initially it may be advantageous to do so. It will allow the vacuum to improve before full voltage operation is attempted. Running beam though the accelerator sometimes aids the conditioning process. If you are not sure that the GVM is correctly calibrated then you can use the column currents to calculate the actual voltage. Column current is proportional to terminal potential and equal to 8.6 μA at 1.7 MV.

VII. **PELLETRON OPERATION** (Running Beam)

CAUTION! High energy ion beams generate radiation. X-ray intensities of 10's or even 100's of mR/hr are common at the Pelletron tank (unless the optional, lead, x-ray shield is purchased). Also, the 5SDH is capable of generating ion beams with enough energy to yield neutrons from some target materials. It is the responsibility of the user to provide safety shielding to protect laboratory personnel and to monitor radiation levels during operation. NEC recommends that you place radiation detectors equipped with set point switches in appropriate locations and that you wire these switches to the user interlock terminal in the ACPC so that the Pelletron will automatically shut down when radiation levels exceed safety standards. (See ACPC description in Section II.)

Before running the beam through the accelerator do the following:

1) Turn on Pelletron cooling water and magnet cooling water.

2) Check the stripper gas line and confirm that there is at least 150 psig N_2 gas pressure. Confirm that the vacuum is good. (Note: Charging system is **interlocked** to both stripper gas pressure and HE vacuum through Voltage Controller.)

3) Adjust the stripper gas metering valve while watching the HE ion gauge readout until the desired pressure is attained. This pressure will be a function of voltage and ion species. The high energy vacuum may range anywhere from 10^{-6} to 10^{-5} Torr. Optimal values are those which maximize ion beam transmission. Keeping a log of pressure vs. energy for various ion species will be useful for proper stripper gas adjustment.

4) Turn Voltage Controller knob to desired setting (2 X desired voltage in MV)

5) Turn charging voltage knob to zero.

6) Switch Voltage Controller to “auto” mode.

7) Turn on the charging chain. Voltage Controller will automatically ramp to proper voltage.

Running ion beams through the accelerator requires steady ion source current, stable accelerator voltage, and proper adjustment of optical components. Operation of the ion source is explained in its manual. Successful operation of the accelerator is dependent upon the stability as well as the quantity of ion current.

8) Follow procedures in manual for ion source startup.

9) Set gap lens voltage at 17 kV and tune velocity selector to maximize the beam current on the injector Faraday cup. Adjust source gas.

10) Set Einzel lens voltage to 15 kV, Y-steerer to 0 kV. Switch the cup "out" so that the beam can enter the accelerator.

11) With switcher magnet off tune the Einzel lens and Y-steerer to optimize beam current on beam stop. Then energize the switching magnet. Adjust the magnetic field until the beam is positioned on target. Focus beam with quadrupole. Adjust stripper gas.

12) With the beam on target you can make slight adjustments of the injector parameters to maximize beam current.

TURNING OFF PELLETRON

1) Switch injector Faraday cup "in" to stop the beam.
2) Turn off charging chain.
3) Close stripper gas metering valve **one** turn.
4) Turn off gap lens and Einzel lens
5) Turn off quadrupole and switching magnet
6) Turn off cooling water
7) Follow procedures in manual for ion source shutdown.

VIII. PELLETRON SERVICING

The 5SDH has been designed to be a reliable, low-maintenance machine. There is no schedule for periodic tank opening and servicing. The philosophy is: "If it isn't broken then don't try to fix it." However, as with any machinery, occasionally the need may arise for you to open the accelerator to fix, adjust, or replace something. When a malfunction occurs that you don't understand, the best course of action is: 1) write down <u>all</u> operating parameters, 2) contact the factory. Doing so will almost assuredly save you time and trouble. If the problem can only be solved by opening up the accelerator then follow these procedures.

<u>TANK OPENING INSTRUCTIONS</u>

1) Transfer the SF_6 out of the tank and let the vacuum system up to dry nitrogen.

2) Make all necessary disconnections. Follow the checklist provided in this section of the manual.

3) Roll the accelerator out of the beamline.

4) Adjust the Head Trolley casters until they make firm contact with the floor.

5) Using a 1/4" hex wrench remove the eight cap screws which seal the LE bellows weldment to the tank.

6) Using 1-1/4" wrenches remove the bolts which secure the end plate to the tank.

7) Roll the column assembly out of the tank while having someone guide the bellows through the hole in the LE end of the tank to prevent it from catching on the edge.

8) Remove the desiccant tray and put it in a dry place. (Replace desiccant every other tank opening.)

9) Put the service stand under the low energy column and remove the column completely from the tank.

10) Cover the open ends of the vacuum system with aluminum foil.

TANK CLOSING INSTRUCTIONS

1) Remove dirt and debris from the column and tank.

2) Check to see that the o-rings on the LE bellows weldment and end plate are clean and greased and properly positioned.

3) Place low energy end of the column in the tank and remove the service stand.

4) Bake the desiccant and place the tray in the bottom of the tank at the HE end after it has cooled .

5) Roll the column into the tank until there is a 6" gap between the end plate and the tank. Have someone reach through the hole at the LE end of the tank and guide the bellows though while pushing the column in the rest of the way. (Note: LE bellows are easily damaged if flange is not aligned with LE support ring inside tank.) If the column is not well centered in the tank then roll the column back out and try again before attempting to complete the procedure.

6) Check to see that the holes in the LE bellows flange line up with the holes in the tank. If they are not rotate this flange until they are.

7) Bolt the end plate to the tank and secure the LE end with the eight 3/8"-16 cap screws.

8) Raise the Head Trolley casters until they are clear of the floor.

9) Mount gaskets on the beamline flanges.

10) Roll the accelerator back into the beamline. Make sure the bellows doesn’t catch on the beamline housings or gaskets

11) Assemble the split flanges on the ends of the accelerator. Try to keep the two halves of the flanges square to each other by tightening the screws adjacent to the split first. This will insure a leak tight seal.

12) Establish vacuum in the accelerator.

13) Transfer gas while watching for leaks in the vacuum system. (See Section IV.)

Check for SF_6 leaks using a halogen detector or similar device.

14) Reconnect the various cables. (Follow the checklist.)

TANK OPENING/CLOSING CHECKLIST

Disconnect/Connect the following cables:

_______ HE and LE vacuum connections

_______ LE column current

_______ HE column/charging current

_______ Generating volt meter

_______ Capacitor pickoff

_______ Charging power supply interface

_______ Chain motor power

_______ Metering valve power (optional)

_______ Cooling water lines

_______ Stripper pressure interlock

CHARGING SYSTEM TUNING AND MAINTENANCE

Note: You can perform tuning and maintenance procedures yourself IF: you have the right tools, reasonably good mechanical aptitude or experience, and you follow these instructions very carefully.

For peak efficiency of the Pelletron charging system, the individual components of the charging system must be accurately aligned and adjusted. Occasional replacement of worn parts may be necessary. Unstable or unusually low charging current indicates wear, improper adjustment or something worse. After very many 1000's of hours of operation the material in the charging chain sheaves will wear away. They may also wear unevenly due to misalignment. In this case it will be necessary to replace one or both sheaves. The sheaves can be rebuilt and reused. The plastic rim can be replaced and assembled together with the old aluminum sheave body. However, the groove in the rim must be machined **after** assembly to ensure concentricity with the hub. You may return the old sheaves to NEC for rebuilding or you can purchase blank rims to assemble and machine yourself.

When the tank is opened the following items should be checked:

a) Sheave rim wear (drive and terminal)

-Pitting shows spark erosion due to incorrect suppressor electrode voltage.

-Uneven wear side to side shows misalignment.

b) Chain

-Position with respect to column/bulkhead holes (centered ±1/8").

-Loosening of pins in the pellet wall.

-Drive screw heads and screws on master links in place.

c) Electrodes (inductor and suppressors)

-Commonly dirt accumulates on inside surfaces. Clean with alcohol.

Removal not necessary but eases cleaning.

d) Bearings (drive motor and terminal)

Check for smoothness. Replace if necessary. Do not grease!

e) Carbon brushes

-Check for alignment.

-Check for wear. Do not lubricate

SHEAVE REPLACEMENT

Caution! Steel contact bands on sheaves are sharp and can cut hands and fingers. Wear gloves when handling sheaves!

Whenever replacing sheaves or chains use service stand to relieve tension on the counterweight. Remove the chain by parting at a master link.

Drive End

1) Remove inductor.

2) Remove the carbon brush assembly. Slide contact plate to side.

3) Remove the four 1/4-20 SHCS that retain the sheave to the hub.

4) Carefully slide sheave assembly off the motor shaft.

5) Install ring insulator and then the new sheave. Make sure bolt holes are lined up. install insulators, washers and screws and tighten evenly.

6) Use a dial indicator to measure sheave run-out (maximum .010"). Some adjustment can be made by selective tightening of the mounting bolts.

7) Remount inductor on mount plate. Reinstall carbon contact assembly, chain and counterweights.

Terminal

1) Remove suppressors.

2) Remove four 1/4-20 SHCS on the hub and remove old sheave.

3) Install a new sheave on the hub, secure with 1/4-20 screws.

4) Reinstall suppressors and align.

Inductor and Suppressor Alignment

1) At the drive end, Insert the inductor alignment spacer, 2DD001240, between the inductor and the charging chain and adjust until it just fits.

2) Repeat above procedure for suppressors in terminal.

CHARGING SYSTEM CHECKS

The health and efficiency of the charging system can be surmised by operating at a reduced level in open air in the service position. The inductor will hold ~ 7 KV without breakdown (in reasonably dry air) and this is enough for some diagnostic testing. To do this first **ground the terminal** with a piece of wire. **Erect a temporary safety barrier around the Pelletron to protect people from the fast moving chain and high voltage electrodes**. Connect the charging power supply, charging current readback, and charging motor power cables to the appropriate connectors. Turn on the charging chain motor. Observe the chain. It should run smoothly and with just a little wobble. Slowly increase the charging power supply voltage to 7 KV. The charging current should be about 7 μA or more (depends on line frequency). If the current is unsteady and you can hear sparking between the inductor and the chain then the inductor is probably too close to the pellets. If the charging current is less than 7 μA the charging efficiency is not optimized and the inductor could be adjusted closer to the pellets. Suppressor spacing must be the same as the inductor.

IX. DO'S AND DON'TS

The Model 5SDH Pelletron is a very rugged and forgiving piece of machinery. Short of malicious abuse it is almost impossible to break it. There is one thing however, that will severely damage it and that you must be very careful to avoid. That is to allow forepump oil to backstream into the acceleration tubes. NEC acceleration tubes are constructed of all metal and ceramic materials and have a very low tolerance for organic compounds. Each turbopump is furnished with an interlock that automatically isolates the forepump from the Pelletron vacuum if a turbopump shuts down. This is to prevent backstreaming. Oil in the acceleration tubes will severely limit maximum voltage. If this happens the acceleration tubes must be removed from the column and returned to NEC for cleaning. This is a big, expensive, time-consuming job!

We encourage you to maintain a logbook of basic accelerator operating parameters, tank openings, maintenance performed, part replacement, etc. That way you will know if, and in what way, performance is deteriorating, and what factors may be the cause for malfunction. This will also help NEC to diagnose your problems (if necessary). Maintaining a logbook also provides some continuity in machine operation. Often, with personnel changes, valuable knowledge and information is lost and this inevitably leads to difficulties down the road. This can be prevented if operators are conscientious about keeping records.

If you have not already done so, read this <u>entire</u> manual. Though we have attempted to adhere to a topical outline, in the interest of brevity this has not been rigorously followed. So you may find, for instance, some information about operation in the description section.

X. TROUBLESHOOTING

Often, Pelletron problems don't pop up suddenly. Rather, an observant operator will notice a gradual slip in performance as something goes out of adjustment. Keeping operation records in a logbook will often help to identify problems before parts are broken and complete breakdown occurs. Here are some things to watch for.

Terminal voltage instability can be caused by lots of things including source and injector problems. If there is vacuum activity then the accelerating tubes may need conditioning. Charging system instability will result in terminal voltage instability. If the machine runs well in manual mode but not in auto mode the Voltage Controller is malfunctioning in some way. "Bugs" can cause instability. These are pieces of debris that charge up and fly around inside the tank under the influence of the electric field. You can see these through the LE viewport on the tank (your eyes must be darkness adjusted for 20 minutes to have enough sensitivity).

Terminal voltage limited is a condition in which the accelerator operates, but not at full voltage. This can be caused by lack of accelerator tube conditioning, poor vacuum, contaminated SF6 gas, moisture on the acceleration tubes (if tank was recently opened), or oil contamination inside the acceleration tubes (see Do's and Don'ts section above). It can also result from charging system malfunction. Yet another possibility is lost charge due to corona from the column. If column currents don't add up to charging current then you have lost charge.

Charging current instability indicates something is wrong with the charging system such as: a bad carbon brush, or sheave misalignment, inductor misalignment, improper chain tension, or something is loose. Charging system problems are sometimes accompanied by a change in sound.

Column current instability can indicate several different problems. If accompanied by vacuum activity, terminal voltage instability, and possibly x-rays, then there is discharge in the accelerating tubes and some conditioning is required. If there is no vacuum activity the problem is probably outside the tube, such as: a broken resistor or arcing between the charging chain and the HE accelerating tube and/or bulkhead caused by a malfunction of the chain tensioning system.

Poor beam transmission can result from improper beam tuning. If a gradual degradation is observed then the injector, the Pelletron, the magnet system, of target chamber may be going out of alignment. Floors can settle over time, especially new ones. After a very long time, there may be some sagging of the column plates. Poor transmission can also result from poor vacuum conditions.

XI. DOCUMENTATION

Note: In addition to the drawings in this manual each 5SDH Pelletron is furnished with a comprehensive documentation package that includes assembly drawings, parts lists, cable lists, and block diagrams. You will find it useful to refer to these documents when servicing the Pelletron. Also, there are some additional manuals furnished with the 5SDH that deal with specific accelerator components in greater depth and detail.

Chain Assembly	Drawing No. 2DS011950
Gasket Securement	Drawing No. 2GS062350
Aluminum Gasket Making	Drawing No. 2GD059810
Charging System Diagram	Drawing No. 2DS058510