

Safety in Cryogenic Operations at RHIC *

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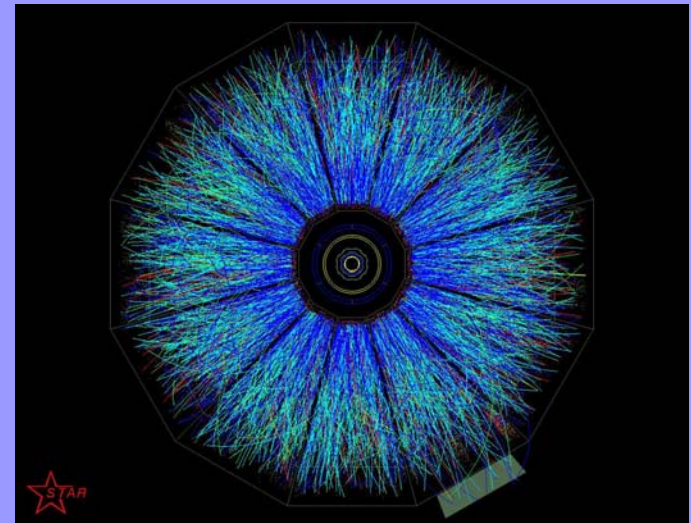
Collider-Accelerator Department

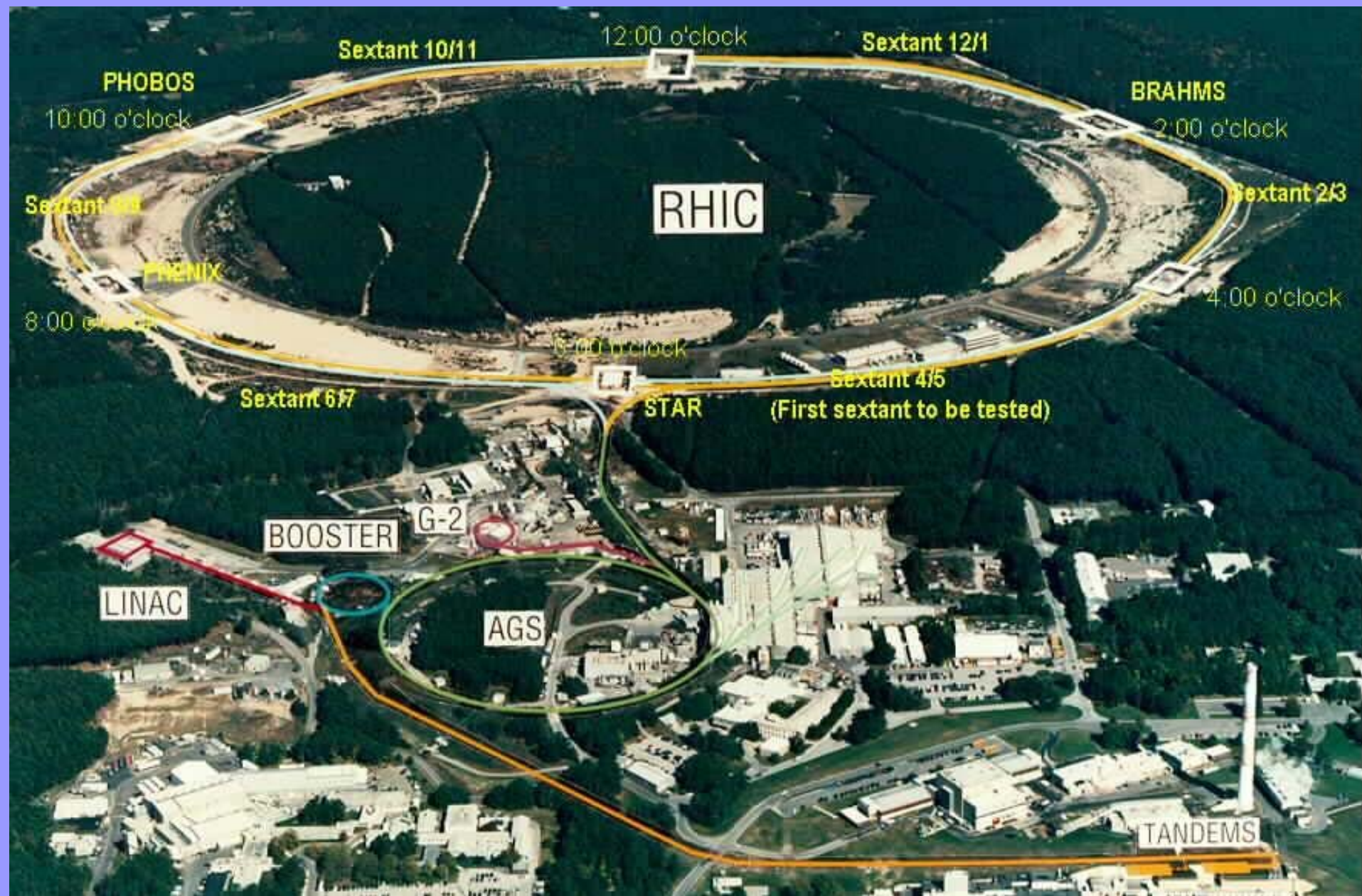
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RELATIVISTIC HEAVY ION COLLIDER

- Super Conducting Particle Accelerator commissioned in 1999
- Two 2.4 mile circumference magnet rings
- Over 1700 magnet assemblies
- Six beam intersecting regions for experimenters
- Part of the Booster – AGS – RHIC accelerator complex
- Used by a community of more than 1000 physicists from over 20 countries





RHIC Cryogenic System

- Main Refrigerator – 24.8 kW at 3.8K, 55kW at 55K
- Built and commissioned in the early 1980's as part of the ISABELLE accelerator
- Lay dormant until 1997 – restored for the RHIC First Sextant Test
- Modified to meet present RHIC requirements



- 6 Operating Rotoflow Turbine Expanders
 - 4 Warm 2 Cold
 - Redundant string available
- Howden Screw Compressors
 - 20 • 600 HP FS. Presently run 8
 - 5 • 2250 HP SS. Presently run 3
- Each ring is divided into 6 sextants by beam crossing regions
 - Cryo Valve Box located at each crossing region
 - Each sextant can be individually isolated for warm-up and magnet repair while maintaining the rest of the collider cold
- Liquid Nitrogen based collider pre-cooler/ 80K soak (maintenance) system
 - Independent of main refrigerator



OPERATIONS

- RHIC warms up during the summer
 - Power rates preclude year round running
- To date RHIC has been cooled down 6 times
 - Currently in run 6 – scheduled to warm up end of June
 - This year the plan is to maintain the collider at 80K during the shutdown – first time
- Physics runs average about 30-35 weeks
- Cool down to 80K with LN2 based precooler
 - 4 weeks typical cooldown time
- Operating He Inventory ~ 6 million scf
 - 2/3 is stored off site as liquid during shutdowns
- Currently operate with a 2 man rotating shift-24/7
 - One shift supervisor and one mechanical tech



General Safety Policies

- Work Planning
 - Procedures
 - Cryo Operations are procedure based
 - Procedures are written and reviewed within the cryo group initially, then reviewed by departmental safety personnel
 - OPM's are stored on C-AD web site and are easily accessible
 - Mandatory review every 3 years
 - Note: C-AD has a separate ESH Division for independent review that reports directly to the department chair
- Training
 - Annual training required on ODH, radiation, confined space, electrical safety, etc
 - Reminders emailed when training is due
 - Emails sent to supervisors when training has lapsed
 - Training records available on web
 - Training record is a part of performance reviews

Work Controls

BROOKHAVEN
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Work Permit # _____
Work Order # _____
Job# _____ Activity# _____

1. Work requester fills out this section. ☐ Standing Work Permit

Requester: _____ Date: _____ Ext: _____ Dept/Div/Group: _____
Other Contact person (if different from requester): _____ Ext: _____
Work Control Coordinator: _____ Start Date: _____ Est. End Date: _____
Brief Description of Work: _____
Building: _____ Room: _____ Equipment: _____ Service Provider: _____

2. WCC, Requester/Designer, Service Provider, and ES&H (as necessary) fill out this section or attach analysis

ES&H ANALYSIS

Radiation Concerns ☐ None ☐ Activation ☐ Airborne ☐ Contamination ☐ Radiation

☐ Other _____
☐ Special nuclear materials involved, notify Isotope Special Materials Group ☐ Radioactive materials involved, notify Laboratory Criticality Officer

Radiation Generating Devices: ☐ Radiography ☐ Moisture Density Gauges ☐ Soil Density Gauges ☐ X-ray Equipment

Safety Concerns ☐ None ☐ Ergonomics ☐ Transport of Hot/Rad Material ☐ Penetrating Fire Walls
☐ Adding/Removing Walls or Roofs ☐ Confined Space* ☐ Explosives ☐ Leaks* ☐ Pressurized Systems
☐ Asbestos* ☐ Corrosive ☐ Flammable ☐ Magnetic Field* ☐ Rigging/Critical Lift
☐ Beryllium* ☐ Cryogenic ☐ Fumes/Mist/Dust* ☐ Material Handling ☐ Toxic Materials*
☐ Biohazard* ☐ Electrical ☐ Heat/Cold Stress ☐ Noise* ☐ Vacuum
☐ Chemical* ☐ Elevated Work* ☐ Hydraulic ☐ Non-ionizing Radiation* ☐ Oxygen Deficiency* ☐ Other
☐ Excavation ☐ Lasers* ☐ Other

*Does this work require medical clearance or surveillance from the Occupational Medicine Clinic? ☐ Yes ☐ No

Environmental Concerns ☐ None ☐ Work Impacts Environmental Permit No. _____
☐ Airborne Discharges (radionuclides) ☐ Land Use Institutional Controls ☐ Soil Activation/contamination ☐ Waste-Mixed
☐ Chemical or Rad Material Storage or Use ☐ Liquid Discharges ☐ Waste-Clean ☐ Waste-Radioactive
☐ Caspools (LIC) ☐ Oil/PCB Management ☐ Waste-Hazardous ☐ Waste-Regulated Medical
☐ High water/power consumption ☐ Soil potential ☐ Waste-Industrial ☐ Underground Cuck/Piping
Waste disposition by: _____ ☐ Other _____

Pollution Prevention (P2)/Waste Minimization Opportunity: ☐ No ☐ Yes

FACILITY CONCERNS ☐ None ☐ Electrical Noise ☐ Potential to Cause a False Alarm ☐ Vibrations
☐ Access/Egress Limitations ☐ Impacts Facility Use Agreement ☐ Temperature Change ☐ Other
☐ Configuration Control ☐ Maintenance Work on Ventilation Systems ☐ Utility Interruptions

WORK CONTROLS

Work Practices ☐ None ☐ Exhaust Ventilation ☐ Lockout/Tagout ☐ Spill Containment ☐ Security (see Instruction Sheet)
☐ Back-up Person/Watch ☐ HP Coverage ☐ Posting/Warning Signs ☐ Time Limitation ☐ Other
☐ Baricades ☐ IH Survey ☐ Scaffolding requires inspection ☐ Warning Alarms (i.e. "high level")

Personal Protective Equipment ☐ None ☐ Ear Plugs ☐ Gloves ☐ Lab Coat ☐ Safety Glasses
☐ Coveralls ☐ Ear Muffs ☐ Goggles ☐ Respirator ☐ Safety Harness
☐ Disposable Clothing ☐ Face Shield ☐ Hard Hat ☐ Shoe Covers ☐ Safety Shoes ☐ Other

Permits Required (Permits must be valid when job is scheduled):
☐ None ☐ Cutting/Welding ☐ Impair Fire Protection Systems
☐ Concrete/Masonry Penetration ☐ Digging/Coax Drilling ☐ Rad Work Permit/RWP No. _____
☐ Confined Space Entry ☐ Electrical Working Hot ☐ Other _____

Dosimetry/Monitoring ☐ None ☐ Heat Stress Monitor ☐ Real Time Monitor ☐ TLD
☐ Air Effluent ☐ Noise Survey/Dosimeter ☐ Self-reading Pencil Dosimeter ☐ Waste Characterization
☐ Ground Water ☐ O₂/Combustible Gas ☐ Self-reading Digital Dosimeter ☐ Other
☐ Liquid Effluent ☐ Passive Vapor Monitor ☐ Sorbent Tube/Fiber Pump

Training Requirements (List specific training requirements)

Based on analysis above, the Walkdown Team determines the risk, complexity, and coordination steps below:

ES&H Risk Level: ☐ Low ☐ Moderate ☐ High
Complexity Level: ☐ Low ☐ Moderate ☐ High
Work Coordination: ☐ Low ☐ Moderate ☐ High

If using the permit when all hazard ratings are low, only the following need to sign: (Although allowed, there is no need to use back form)

WCC: _____ Date: _____
Service Provider: _____ Date: _____
Authorization to start: _____ Date: _____
(Departmental Sup/WCC/Designer)

- “Green Sheet”
 - Work control document
 - Associated with all work done in the department
 - Removing compressors for repair, work in a cold box...
 - Lists potential hazards associated with any job
 - Hazard level defines review level
 - Attach procedures, loto lists... any relevant documentation
 - Documents pre job briefings, post job walkthroughs, lessons learned
 - Reviewed, approved, and documented by ESH division

General Policies - Continued

- Confined Space
 - Confined space watch and fire watch – if welding
 - Log in and out with watch
 - Confined spaces clearly labeled
 - Constant monitoring of air quality inside cold box while occupied
 - Personal POM's required for entry
 - Constant air flow purge set up
 - Confined space training required
- Noise Monitoring
 - Technicians have worn noise monitors to determine average exposure level
 - Double hearing protection and working time limits imposed in compressor and refrigerator buildings



General Policies - Continued

- Shift Rounds (presently 2 man 24/7 shift coverage)
 - Single man rounds are acceptable
 - Regular communication with Cryo Control Room
 - Collider Accelerator Support (CAS- Two man 24/7 shift) available if necessary
 - “Floating” technician help.
 - Assists when a two man job is needed during overnight shifts
- Relief Valve Recertification
 - Take advantage of RHIC summer shutdowns to ASME recertify relief valves as part of preventative maintenance
 - Found some original Isabelle refrigerator relief valves needed rework
 - 5 year rotation implemented.
 - Will continue based on experience gained

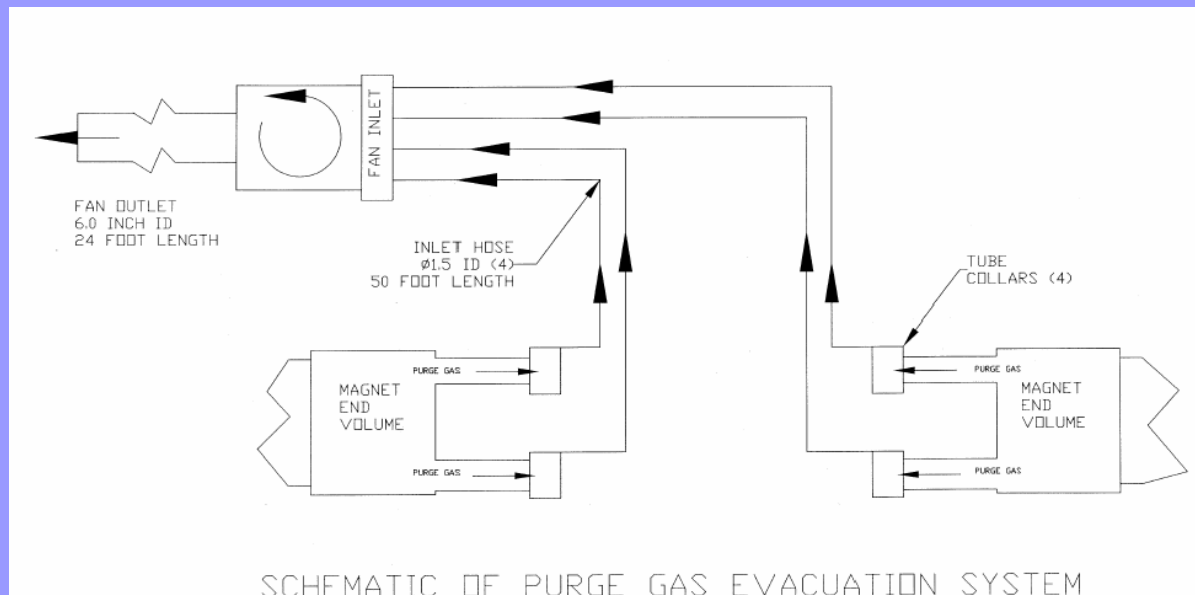
General Lock Out Tag Out

- Implemented at the beginning of every summer shutdown
- Isolates any potential sources of Helium from the system
 - Warm gas storage tanks
 - Helium Storage dewars
 - Main Compressors
 - Auxiliary Compressor
 - Gas makeup tanks
 - Liquid Nitrogen Dewar
 - Turbine buffer tanks
- Typically backed up by lock/out tag out local to job



Magnet Repair During Shutdown

- General Lock out/tag out in place, backed up by local LOTO at adjoining valve boxes
- N2 Purge maintained to minimize moisture propagation
- Area cordoned off – personal O2 monitors required
- Air quality checked every morning
- System setup to minimize N2 release into the tunnel



Single Sextant Warm Up

- On several occasions, a run has been stopped and a sextant warmed up to repair a magnet.
 - On one occasion three sextants were warmed up
- Performed under “Green Sheet” work controls with detailed procedures written and reviewed for every step
- Local Lock out/tag
 - Sextant to be warmed isolated at cryo valve box at either end
- Isolate and drop pressure in adjacent sextants
 - Pressure is monitored and alarmed in cryo control room
- Maintain helium purge while system is open to minimize water propagation
 - Personal Oxygen monitor required in areas where magnets is open
 - Tunnel Air quality local to open magnet checked every morning
- Ability to maintain the other ring at operating conditions
- Ability to maintain parts of ring being repaired at operating conditions but this is not necessarily done

Oxygen Deficiency Hazards

- 0,1,2.. Classification
 - ODH Class is based on the calculated probability of a fatality
 - Calculate
 - fatality factor determined from the lowest oxygen concentration based on worst case release rates
 - probability of event using equipment failure rates
 - fatality rate determined from first two
 - Determine ODH Class by the predicted fatality rate.
 - Ensure that ODH control measures are implemented

<u>Classification</u>	<u>Training/Access Requirements</u>	<u>Areas</u>
0	Collider Access Training	RHIC Tunnel Main Compressor Building Auxiliary Compressor Building
1	Specific ODH Training Respirator tests during physical Personal O2 Monitor 5 minute Air escape pack	RHIC Refrigerator Building

ODH -cont

- Cold Helium Spill Test (1999)
 - Released Cold Helium into the RHIC tunnel to verify effectiveness of ODH system
- Warm Nitrogen Release Test (2005)
 - Nitrogen is used to purge any magnet repair being made during a shutdown
 - The amount of purge N₂ introduced into the accelerator is controlled and monitored
 - A spill test was performed in the RHIC tunnel to confirm the adequacy of the ODH system in the presence of N₂ and to compare to theoretically predicted N₂ distribution
 - Matched theoretically predicted concentrations within reason

Cryogenic Safety Reviews

- Interdepartmental committee reviews all new cryogenic installations
- Reviewed for
 - Maximum design/Allowable working pressures and pressure vessel, piping and component ratings
 - Total quantity of cryogens;
 - Maximum release rates
 - Heat flux assumptions
 - Pressure relief capabilities;
- Quench protection (if necessary);
- If used in a ionizing radiation environment, calculations of gram quantities of explosive materials generated (such as ozone and oxides of nitrogen);
- Stress Analyses
- Adherence to applicable codes- ASME Boiler & Pressure Vessel, B31.3
- Materials used suitability for low temperatures
- Oxygen Deficiency hazard classification calculations
- Operating procedures/emergency procedures;
- Training requirements/personnel training status.

Lessons Learned

- 2002: Technician replacing solenoid was splashed with hot oil
 - Technician was intending to replace a faulty solenoid valve
 - Disassembled valve body instead of removing solenoid
 - This was on a pressurized oil line
 - Lesson learned – Establishing technician competence for the job is part of work planning

- 2004: Technician burned his hand on heater
 - Technician working in a cold box leaned on a hot calorimeter
 - Hand received first degree burn
 - Power switch to heater was turned off – it was assumed to be ok however circuit breaker was not locked out
 - Determined short in heater and faulty switch caused heater to be powered
 - Stop work issued on all valve box work until a complete review of all power and energy sources was completed and documented
 - Lesson learned – make no assumptions. LOTO must be complete

2006 Refrigerator Upgrades

- Rework this summer (RHIC Refrigerator Upgrade presentation by Dr. Sidi Yekhlef)
- This work will be completed on the refrigerator while the Collider is being maintained at 80K
 - Green sheet and work planning
 - Operations group planning and review
 - Review and approval by Cryogenic Engineering Group Supervisor (Dr. Sidi Yekhlef)
 - Two locked valves minimum between 80K ring and open refrigerator lines
 - Monitoring of valve leakage in the volume between locked out valves