THE UNIVERSITY OF WISCONSIN

SPACE SCIENCE & ENGINEERING CENTER

MADISON, WI

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Title:	**RAM 2**
	Rapid Air Movement Drill 2
	Operations and Maintenance Manual, Configuration-1

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DOCUMENT APPROVERS

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(Maintain last 3 versions)

Version	ECN	Description of Changes	Date	Approval
1.0	N/A	Original document.	11/28/18	See above
2.0	1308	Added instruction to secure equipment to sled during transport. Removed references to ASIG and SLLD. Updated name to "Operations and Maintenance Manual"	2/4/19	C. Niendorf
3.0	1387	Updated the references section with the new wiring diagram part number.	11/12/20	C. Niendorf

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1.0 PURPOSE

The purpose of this document is to provide the operator with a working knowledge of the upgraded Rapid Air Movement (RAM2) drill. Including a description of the basic construction of the drill system as well as instructions for its assembly and operation.

2.0 SCOPE

This document applies to the RAM2 Drill Configuration-1. The RAM2 drill is the upgraded version of the original RAM drill. The upgrades reduced the borehole from the original 4" diameter to 3" diameter and changed from an air powered sonde motor to a more efficient electric sonde motor. Additionally, the original hose reel was replaced with a much smaller reel in the RAM2. In Configuration-1 of the RAM2 drill, compressed air is provided by two of the original 400cfm Ingersoll Rand compressors.

3.0 REFERENCES

3.1 8324-0010 RAM2 Safety Training
3.2 8324-0011 RAM2 Equipment Manuals
3.3 8324-0013 RAM2 Equipment List
3.4 8324-0014 RAM2 SDS Documents
3.5 8324-0721 RAM2 Wiring Diagram

4.0 DEFINITIONS

4.1 DOC – Depth of Cut
4.2 IDP – Ice Drilling Program
4.3 PSL – Physical Sciences Laboratory
4.4 QAS – Quality Assurance and Safety group
4.5 RAM2 – Rapid Air Movement Drill Upgrade
4.6 ROP – Rate of Penetration
4.7 SSEC – Space Science & Engineering Center

5.0 RESPONSIBILITIES

5.1 U.S. Ice Drilling Program (IDP) Engineering is responsible for the generation and maintenance of this document.

5.2 University of Wisconsin SSEC QAS is responsible for ensuring that this document is created, reviewed, approved, maintained and changed per applicable SSEC processes.

5.3 Project personnel are responsible for understanding this document.

6.0 RECORDS

6.1 None.

7.0 OPERATIONS AND MAINTENANCE

7.1 Safety Notes

⚠ Only IDP trained and approved drillers may operate the RAM2 drill system due to safety and operational risks. All drillers operating or assisting in operation of the RAM2 Drill System must read and understand the following:

- Ingersoll Rand Operating Maintenance and Parts Manual, see Equipment Manuals section 3.
- RAM2 Safety Training, see section 3.

The IDP Safety Plan, 8501-0008, provides an overview of the approach to safety on drill systems and field projects. The following highlight important safety notes for RAM2.

- RAM2Personal Protective Equipment
  - PPE – Workers shall wear appropriate hand, eye, and ear protection during all drill operations and setup.
- Mechanical Safety
  - Pinch Points - There are several areas on the drill where a finger, hand, arm, or clothing could be pinched; specifically, at all places where hose connections are made. Operators should identify all pinch points prior to operation and should be mindful of all such points during operation and setup.
  - Eye Protection - Operation of the RAM2 requires eye protection to be worn by operators at all times.
  - Burn Hazard - The exhaust and engines of both the RAM2 and the generator can become extremely hot. Avoid contact with either component. If service is required, allow time for the components to cool.
  - Combustibles - This system uses combustible glycol and fuels while also creating lots of heat. Take care to properly store all combustibles away from all major heat sources.
  - Hot Fluids - This system heats fluids above 100°C. Use appropriate PPE to prevent burns. Note that this heat will transfer from the fluid to a lot of the metal parts of the system. Take care to avoid burns from accidentally touching hot components.
  - Cold Hazard - Metal components and fluids may be extremely cold. Always wear appropriate gloves when handling.
  - Slippery Surfaces - The surrounding ice may become slippery when wet with melt water. Use caution whenever walking around the drill operations area.
  - Sharp Cutters - Special care should be taken with the cutters on this drill. They can be obscured by blowing ice and are moving much faster than those on a coring drill. Be sure everyone is well clear of the drill when cutters are rotating.

- Electrical Safety
  - Voltage – Extreme care shall be taken when assembling, disassembling, and servicing electrical equipment. Always disconnect power before servicing equipment.
  - Grounding – Because the drill sits upon a large thickness of ice, a common earth ground cannot be established. Workers shall ensure that all electrical equipment is bonded together to a common ground back to the generator.
- Chemical Safety
  - Use fluid resistant gloves and eye protection whenever handling ethanol, hot fluids, or fuel.
  - Use care and observe all safety warnings when handling chemicals.
- Environmental Safety
  - Cold – This drill will be deployed to extremely cold climates. Operators shall wear outerwear suitable to protect themselves from the cold, and should monitor their own and fellow workers' activities for exposure to cold.

7.2 System Overview

- Only IDP trained and approved drillers may operate the RAM2 drill system due to safety and operational risks.
- Detailed performance data for the rig is summarized in Appendix A1. See layout Fig. 1.
- Checklists highlighted below offer a step-by-step guide to normal drilling procedures. See equipment manuals referenced in section 3 for additional operating details.

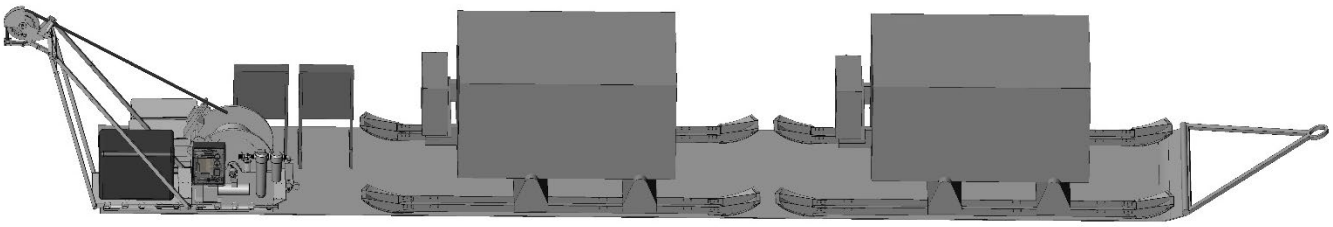

Fig. 1: RAM2 Configuration-1 shown on a 50'x 8' sled.

7.3 Pre-Ship Procedure

Compressor Maintenance

1) Inspect and repair covers.
2) Inspect and repair air treatment modules.
3) Complete maintenance per manufacturer's recommended maintenance schedule including:
   - Change engine oil, air filters, oil filters and fuel filters as necessary.
   - Change air-end oil, air filters, oil filters and separators as necessary.
   - Inspect and replace batteries, hoses, belts and cables as necessary.
4) Tag equipment with record of all maintenance.
5) Test run compressor for 5 minutes. Evaluate and address any warning lights.
6) Verify pressure set-points: compressor 200psi, safety relief valve 160psi, regulator 150psi. Fig. 3, 4, 5.
7) Compressor Service
   - ROLAND MACHINERY
     DEFOREST, WI. 53532
   - UNITED RENTALS
     MADISON, WI 53713

Generator Maintenance

1) Change oil, filters, and spark plugs if necessary.
2) Test for smooth operation jetted for test conditions, loaded and unloaded
3) Re-jet for altitude as necessary.
4) Replace spares as needed; see Equipment List.
5) Tag equipment with record of all maintenance.
6) Generator Service
   - ENGLEHART MOTOR SPORTS
     MADISON, WI. 53713
   - MIDDLETON POWER CENTER
     MIDDLETON, WI 53562

Hose Reel and Tower Maintenance

1) Assemble and test pendant, reel and display functionality.
2) Inspect and repair air treatment modules.
3) Inspect and repair tower and base as necessary.
4) Record all repairs.

Packing

1) Verify all parts are packed with the shipment. See Equipment List.
2) Run the engines dry.
3) Drain fuel holding tank and fuel lines.
4) Drain air separators and hoses.
5) Plug or cap all open fittings to prevent contamination.
6) Disconnect the engine module battery and tape terminals.
7) Tighten all fasteners.
8) Pack all equipment with appropriate padding.
9) Seal and label RFI with name and date.
10) Create packing lists and shipping labels.
11) Update shipping lists, as needed.
12) Send electronic copies of manuals to field operators.

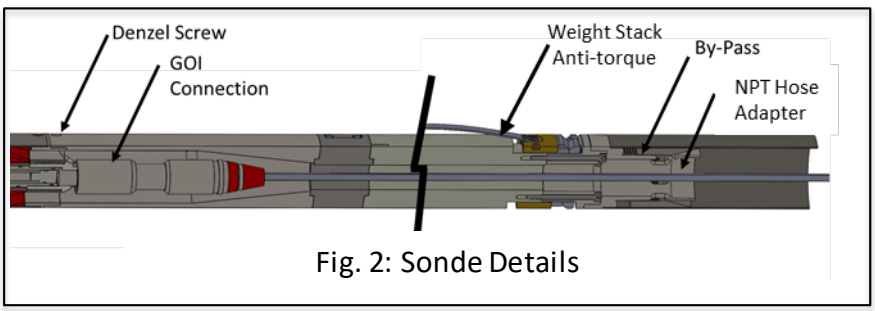

Fig. 2: Sonde Details

Fig. 3: Compressor Pressure Adjustment

Fig. 4: Regulator and Safety Relief Valve


Fig. 5: Air Treatment and Hose Reel.

7.4 Season Set-up Procedure

1) **Pre-heat compressors** with Herman Nelson and/or bullet heater. Heat for at minimum 3 hours if starting with a cold unit. It is critical that any frozen condensation in the air-end be warmed above freezing.
2) Set-up **tower, hose reel, and generator**. Secure to sled with straps and dunnage to assure equipment will not tip in transport.
3) Run power cords to **all heaters** on air treatment units.
4) Install and cable **display box, control box and pendant**.
5) Check for damaged or loose **fasteners, cables or connectors**.
6) Check fuel, oil-level and start **generator**.
7) **Check hose reel and display** are functioning normally.
8) **Prepare compressors**.
    - Check for any ice, debris, or packing materials including plywood near exhaust.
    - Install battery.
    - Install ether canister (#1 and #9 only).
    - Check engine oil, compressor oil, coolant. Top off AN8 tank.
    - Inspect cables, belts and hoses for damage.
9) **Test run compressors**.
    - Double check preheat is complete; use thermocouple as required.
    - Verify outlet valves are closed.
    - Turn compressor to "ON" position and check warning lights.
    - Depress and hold by-pass and start compressor (see fig. 7).
    - Wait 3-5minutes for air-end to warm.
    - Press-"Service Air"; pressure should ramp-up to 200psi.
    - Open outlet valve and check for proper air-flow.
    - Close valves and turn-off compressor.
10) **Assemble compressed air circuit** as shown at right. Fig. 6.
    - All interconnect hoses should be secured at each end with whip check cables.
    - All equipment should be secured to prevent tipping.
    - ~5' of cable is required beyond end of hose for sonde installation. This is marked with yellow on the cable and can be adjusted by paying-out and putting the hose under tension.
    - Sonde is assembled to the hose in multiple steps. First the NPT sonde adapter is screwed on to the hose fitting. This mates to the anti-torque section with "Denzel" screws. The air diverter screen slides up the hose out of the way for installation and is later secured with set-screws. The GOI connector is installed by removing adapter from lower sonde. The adapter and anti-torque/weight stack can then be re-assembled (Fig2).
    - *Pay special attention to the joint just above the motor section as the thin walled tube can potentially be distorted at the "Denzel" screws if improperly loaded.*
11) **Check sonde rotation and e-stop.**
    - *Limit sonde operation to <5sec to avoid potential for overheating without air flow.*
12) **Check hoses and connections** for damage and that each connection is tight over the entire circuit.
13) **Check regulator and safety relief valve** are heated and free of ice.
14) **Check for free flow of air**.
    - Open vent at three-way valve.
    - Start one compressor and supply a small amount of air initially.
    - Check pressure gauges for free flow of air.
    - Close vent and check for free flow of air through sonde.
    - Supply additional air until regulator reaches 150psi. It should require air from both compressors to reach 150psi.
    - Adjust regulator as necessary to limit output air to 150psi.
15) Check that the four **aftercoolers**, three **water separators** and **filter** are draining freely.

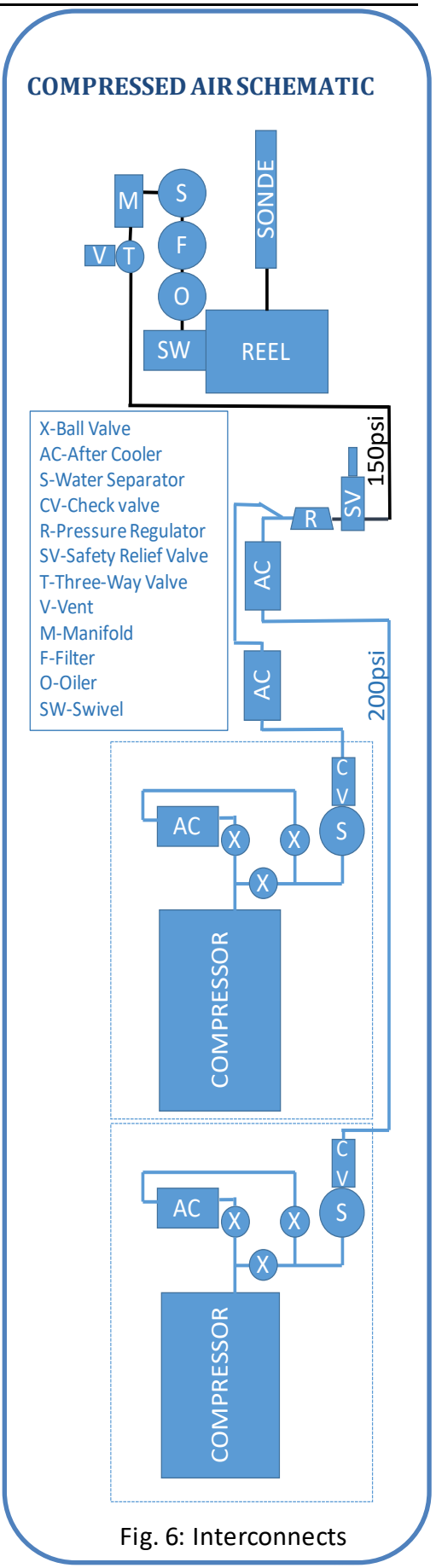

Fig. 6: Interconnects

7.5 Daily Start-up and Preventative Maintenance Procedure

1) **Pre-heat compressors** with Herman Nelson and/or bullet heater. It is critical that any frozen condensation in the air-end be warmed above freezing.
2) Check for damaged or loose **cargo straps, fasteners, cables or connectors**.
3) Check fuel, oil-level and start **generator**.
4) **Check hose reel and display** are functioning normally.
5) **Check for sonde rotation** (<5sec to avoid potential for overheating without air flow).
6) **Check hoses and connections** for damage and that each connection is tight over the entire circuit.
7) **Check regulator and safety relief valve** are heated and free of ice.
8) **Prepare compressors**.
    - Check for any ice, debris.
    - Install battery cables as necessary.
    - Check engine oil, compressor oil, coolant.
    - Top off AN8 tank.
    - Inspect cables, belts and hoses for damage.
9) **Start compressors**.
    - Double check preheat is complete; use thermocouple as required.
    - Verify outlet valves are closed.
    - Turn compressor to "ON" position and check warning lights.
    - Depress and hold by-pass and start compressor (Fig. 7).
    - Wait 3-5minutes for air-end to warm. Press "Service Air".
10) **Check for free-flow of air**.
    - Open vent at three-way valve.
    - Supply a small amount of air initially from one compressor.
    - Check pressure gauges for free-flow of air.
    - Close vent and check for free flow of air through sonde.
    - Supply additional air until regulator reaches 150psi. It should require air from both compressors to reach 150psi.
    - Adjust regulator as necessary to limit output air to 150psi.
11) Check that the four **aftercoolers**, three **water separators** and **filter** are draining freely.
12) Check **e-stop** is working properly.
13) Check connections and address any **air leaks**.

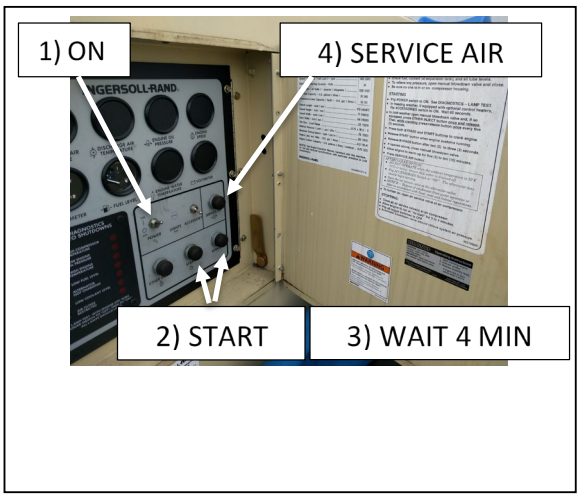

Fig. 7: Compressor Control Panels (left, units #1 and #9; right, unit #2)

7.6 Operation

1) Sonde Configuration:
   - Some air may leak from the sonde at the Denzel screws cleaning beneficial chips from the wall. This should be further evaluated and if problematic, tape can be added to the joint.
   - The by-pass at the top of the sonde can be adjusted and fixed with a very small set screw.
   - Large to extra-large cutters are expected to provide the best performance. Smaller cutters greatly limited hole depth in field testing.
   - The tables below shows shim combinations and sonde configuration most effective in Greenland testing.

Table 1: Shim thickness and resultant Depth of Cut. ROP's are calculated with the motor operation at 15,000rpm. The DOC is limited by motor power. The most practical options are highlighted in green.

Shim Combination	Shim Thickness [in]	Depth of Cut (DOC) [mm]	Rate of Penetration(ROP) w/ 8:1 [m/min]	Rate of Penetration (ROP) w/ 12:1 [m/min]
3x 0.010 + 1x 0.012	0.0420	0.0598	0.4983	0.3322
4x 0.010	0.0400	0.1106	0.9217	0.6144
3x 0.012	0.0360	0.2122	1.7683	1.1789
2x 0.012 + 1x 0.010	0.0340	0.2630	2.1917	1.4611
3x 0.010	0.0300	0.3646	3.0383	2.0256
2x 0.012	0.0240	0.5170	4.3083	2.8722

Table 2: Sonde configuration providing best performance in Greenland field testing.

Cutterhead	Cutter Diameter	Shims	Head Plugs	Choker	Reducer	Final Depth [m]	ROP [m/min]	By-pass	Notes
RAM1 Style	**3.18" (Large)**	**None**	**None**	**Least Closed**	**8:1**	**27.8**	**1.2**	**0.25"**	**8' plume**

2) Air Treatment:
   - Adjust separators and aftercooler drains so that water is exhausted at a rate that prevents clogging.
   - Two stages of water separation should eliminate the need for ethanol oiler. For reference, the original RAM drill used flow volume of ½ quart per 15 minutes.
3) Rate of Penetration:
   - Typical Rate: 1m/min to 5m/min.
   - Adjust ROP to maintain plume at least 4-8'.
   - All chips created must exhaust to avoid a stuck drill.
4) Stuck Drill Procedure:
   - Apply total tension up to 500lbs (design limit 600lbs, sonde ~140lbs; hose ~2lb/m).
   - Mark reference point on hose at surface.
   - Pour 1 quart of ethanol down outside of hose.
   - Wait 2 hours.
   - Repeat until drill is completely free.

7.7 End of Day Procedure

1) Drain separators and filter with compressed air flowing.
2) Power down equipment.
3) Cover compressors as required to minimize accumulation of blowing snow and to facilitate preheating.
4) Cover reel motor fan and aftercoolers.
5) Put away tools, cover and weatherize all other equipment.

7.8 End of Season Checklist

1) Drain separators and filter.
2) Drain and run dry generator and compressors as required for retrograde.
3) Disconnect battery cables and tape terminals.
4) Cover all open fittings.
5) Pack, cover, and weatherize equipment.

APPENDIX A1: SYSTEM SPECIFICATIONS

Type	Compressed Air Drill
Layout	Towable
Nominal Hole Diameter	7.6 cm (3 in)
Maximum Hole Depth	40 m to 100m, depending on configuration
Capabilities	Fast dry holes Transportable by Twin Otter or helicopter (in pieces) Transportable by Piston Bulley (assembled) Reel-driven hose payout.
Capacities	150 psi max system pressure 800 scfm at sea-level 230/ 120 VAC generator, 6500W nominal 50 gal AN8 fuel tank each compressor 6.2 gal gasoline tank generator
Electric Power Consumption	Approximately 5 kW
Crew Size	2
Auxiliary Equipment Required	See equipment list.
Weight Est. (dry)	14,000 lb
Target Hole Performance	
Hole Specs	7.6 cm (3 in) diameter x 100m @ sea level
System Configuration	2 x Ingersoll Rand Compressors
Drill Time	15 min
Cycle Time	30 min
Fuel	Project specific. Nominal 9 gal AN8 and 0.6 gal gasoline per hole.