# Discussion of Medical Suction for Exploration Medical Capability

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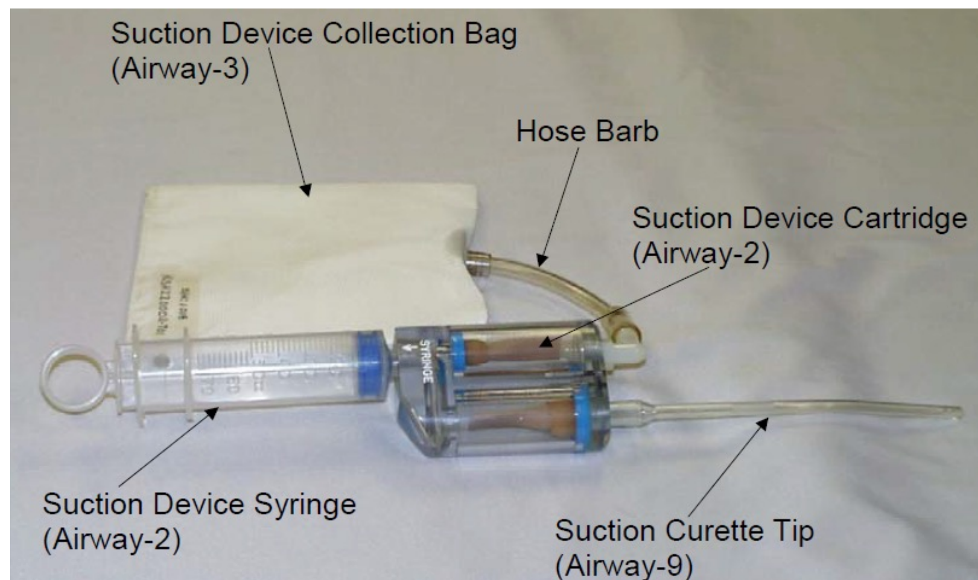
# Background

Exploration Medical Capability Gap 4.09

- Gap 4.09: “We do not have a system for medical suction and fluid containment that can operate properly in a reduced gravity environment.”

- Effort focuses on development of two medical suction and fluid containment systems that can operate in a reduced gravity environment.
  - System for airway management, surgical and dental procedures.
  - System for treatment of a pneumothorax

- To date, NASA has a device packed in Physician Equipment Pack.
  - Current Device has not been used.
  - Training has revealed that device could come apart during usage and is difficult to operate.
  - Current Device is not suitable to meet the wide range of requirements for medical suction



# Relevant Medical Conditions -Shall

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- Ventilator (and intubation) Support
  - Anaphylaxis
  - Choking/Obstructed Airway
  - Decompression Sickness
  - Medication Overdose/Adverse Reaction
  - Radiation Sickness
  - Seizure
  - Smoke Inhalation
  - Surgical Treatment
  - Toxic Exposure
- Dental Suction
  - Abscess
  - Avulsion/Tooth Loss
  - Caries
  - Crown Replacement
  - Exposed Pulp/Pulpitis
  - Filling Replacement
- Nasogastric Suction
  - Intra-abdominal Infection (diverticulitis, appendicitis, small bowel obstruction)
- Surgical Treatment

# Relevant Medical Conditions - Should

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- Medical Conditions to be treated if Mass, Power & Volume Constraints Permit:
  - Surgical Suction
    - Abdominal Injury
  - Nasogastric Suction
    - Abdominal Injury
  - Chest Tube Suction
    - Chest Injury/Pneumothorax
  - Ventilator support:
    - Stroke
    - Sudden Cardiac Arrest

# Suction Requirements

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- Airway Management, Oropharyngeal Suction, And Surgical Suction:
  - Vacuum Pressure: 500 mm Hg
  - Flow Rate: 30 l/min
  - Total Duration: 30 min
  - Exposure Intervals: 15 seconds ON, 60 second OFF
- Dental Suction
  - Vacuum Pressure: 400 mm Hg
- Nasogastric Suction
  - Vacuum Pressure: < 120 mm Hg
- For chest tube drainage
  - Vacuum Pressure: 10-20 cm $H_20$ (20-40 mm Hg)
  - Flow Rate: 20 l/min
  - Total Duration: 24 Hours
  - Heimlich Valve or Water Seal to prevent backflow.

# Typical Vacuum System

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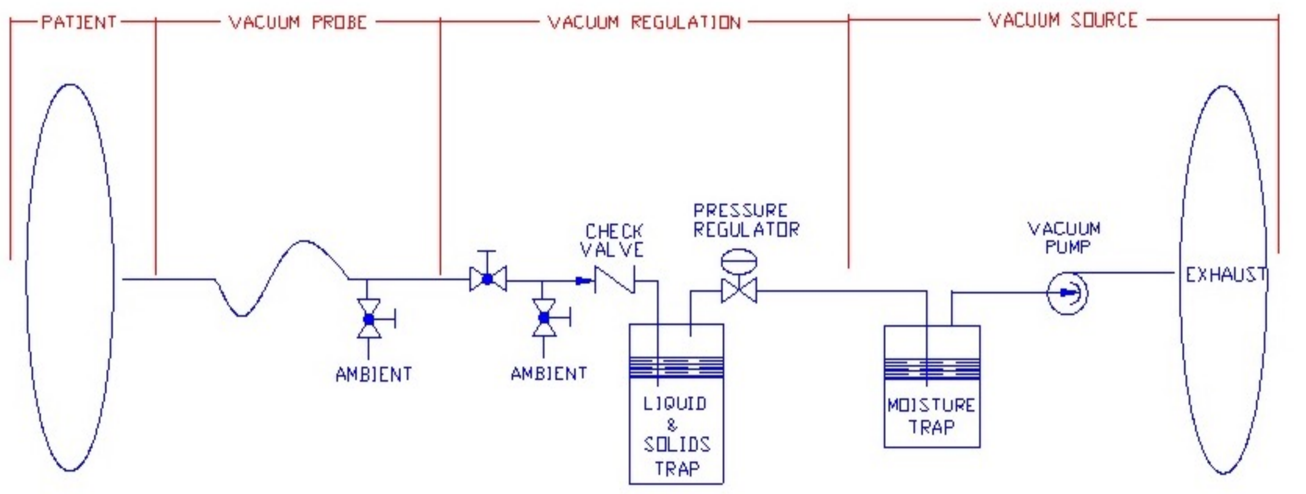


- Generic Layout:
  - Patient/Object to be evacuated
  - Probe
  - Vacuum Regulation
  - Trap(s)
  - Hose/Line
  - Pump
  - Exhaust
- Medical Systems Differences:
  - Collection Devices or Vacuum Probe
  - Patient imposes sterility requirements and backflow prevention

# Collection Probe

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- Dependent on type of medical suction being performed:
- Behavior may be loosely approximated by Hagen-Poiseuille Equation

$$\Delta P = \frac{8\eta L}{\pi D^2} Q$$

Where $\Delta P$ = *Vacuum Level*

$\eta$ = ***Viscosity or Fluids Resistance to Flow***

$L$ = *Tubing Length*

$Q$ = *Flow Rate*

$D$ = *Tubing Diameter*

Viscosity will increase significantly if biofluid contains blood, tissue, debris, or other solids!

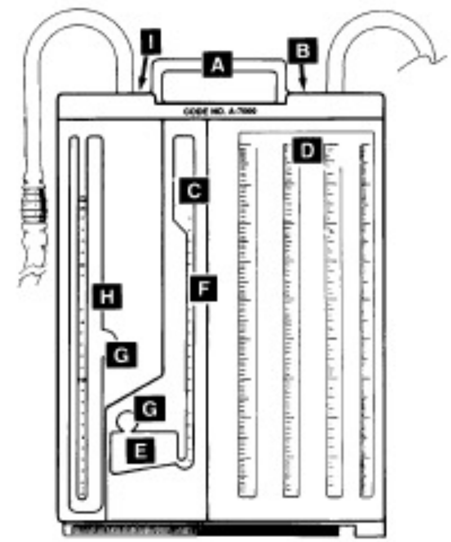
# Probe

- Oropharyngeal Suction - Yankauer suction tube
- Endotracheal Suction – Combitube - Double Lumen Device
- Nasogastric Suction -Salem-Sump Tube – Double Lumen Device
- Pneumothorax Suction –
  - Multiple eyelet catheter.
  - Check or one-way valve:
    - Heimlich if air only.
    - **Current Water seal devices are not useable in reduced gravity**

# Water Seals



- Used for Pneumothorax
- Provide Vacuum Regulation
- Prevent backflow
- “Dry” before use, but requires filling with sterile water prior to use.
  - Source of sterile water?
  - Fluid transfer and positioning in reduced gravity
- Air bubbles through water-filled tubes in multiple chambers.
  - Indicates flow
  - Prevents backflow contamination
  - Relies on gravity to keep fluid in tubes.




A Carrying Handle
B High Negativity Relief Valve
C High Negativity Float Valve and Relief Chamber
D Collection Chamber
E Patient Air Leak Meter (A-7000 only)
F Calibrated Water Seal
G Self-Sealing Diaphragm in Water Seal Chamber and Suction Control Chamber
H Suction Control Chamber
I Positive Pressure Relief Valve

# Centralized Vacuum Source

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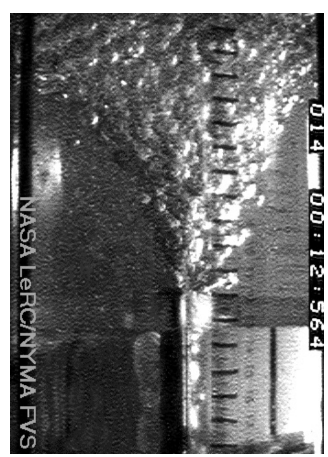
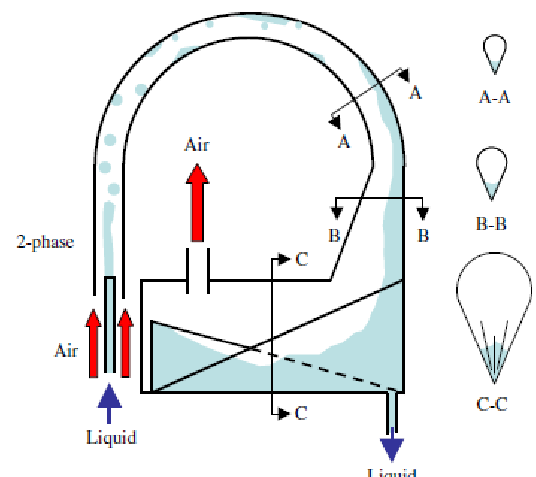
- Available sources:
  - ISS Housekeeping vacuum cleaner
  - For Aeromedical Evacuation on C-130, USAF uses Urinal Source.
    - Requires check valve to prevent backflow
    - ISS has sufficient air flow rate for similar design.
- Need to require separate storage and/or treatment for biofluid and human waste.  Avoid overboard venting/dumping
  - Contamination of sensitive surfaces: solar arrays, thermal radiators, antennas, etc.
  - Thrust associated with vented mass.

# Traps



- Terrestrial systems use traps that are primarily gravity driven.
  - As fluid is deposited into trap, air escapes out of the top because it is lighter than the fluid.
  - As an added measure of capturing the fluid, a porous insert is used to retain the biofluid especially as the liquid level rises in the trap.
- Other methods for retaining fluid and venting air in microgravity are necessary.
  - Cyclonic – flow is injected tangentially into a cylinder to centrifugally separate the gas and liquid
  - Capillary – surface tension and wetting phenomena are used to separate the gas and liquid.
  - UMPQUA



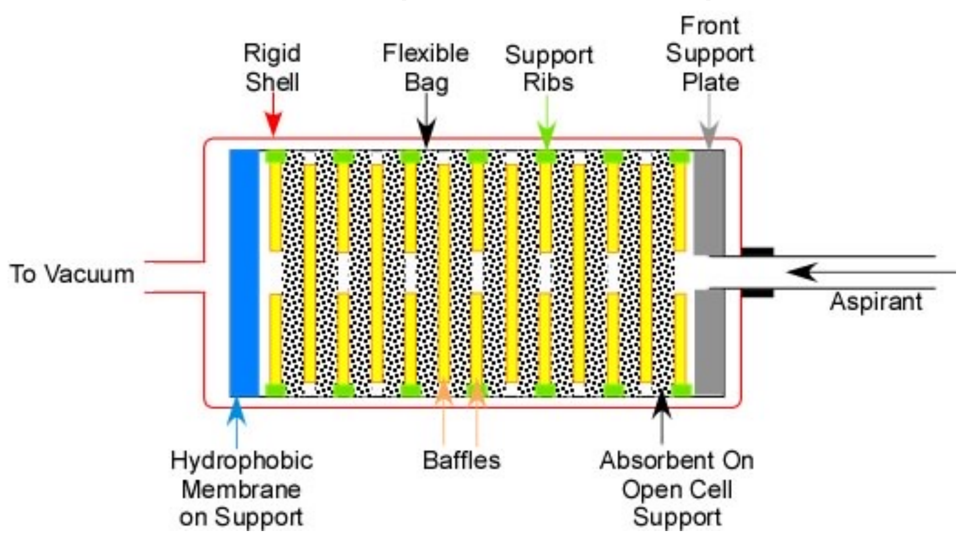



# UMPQUA Separator

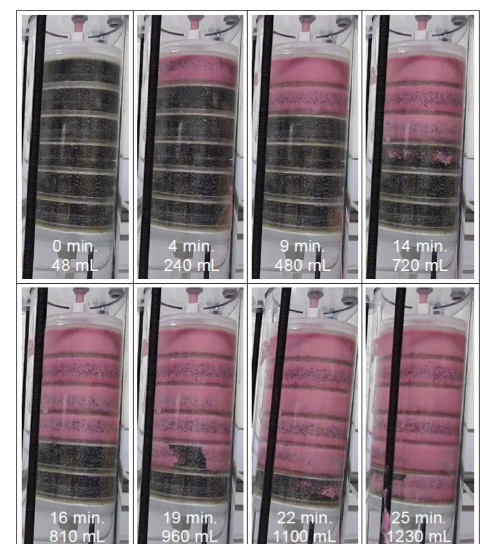


- UMPQUA Research Company developed and tested a collapsible device containing a highly absorbent material.
- Device successfully tested using biofluid simulants:
  - Saline solution
  - Yogurt
  - 50/50 mixture of bovine blood and normal saline solution
  - Cottage cheese

Biofluid Separator Concept




Yogurt Test Results



# Summary



- Many conditions require suction.
- Wide range of flow rate and vacuum pressure requirements.
- Vacuum source needs to be defined given impacts to spacecraft systems and capabilities.
- Critical technology is biofluid separation AND containment.
- UMPQUA has developed and successfully tested a prototype separator.