VAPOR RECOVERY MAINTENANCE UNIT
(VRMU)

ORMAT Task 7530- PUNA

Operational Manual for Vapor Recovery Maintenance Unit

Cat. No. 0.795.94.001.0

REV.	DATE	DESCRIPTION	PREPARED BY	APPROVED
0	13/6/2012	VRMU system	A Smolansky/ J. Ben-Ari	O. Rotem
1	03/03/2013	VRMU system	A Smolansky/ M.Kanowitz	O. Rotem
2	10/11/2024	Puna Mod.	Ian C	Emmanuel. H
3	05/12/2024	VRMU system	Yonatan V	Yonatan V

DISCLAIMER

GENERAL

If you received this file in error please notify the said author immediately. (email@provider.com)
The confidential nature of and/or privilege in the file enclosed is not waived or lost as a result of a mistake or error in this file.
The said author accepts no liability whatsoever, whether it was caused by:
1. Accessing or other related actions to this file.
2. Any links, and/or materials provided/attached to this file.
The said author assumes that all users understand risks involved within this file and/or its attached materials.
All other brands, logos and products are trademarks or registered trademarks of their respective companies.

NOTICE TO USER

ORMAT retains legal title to and ownership of this [publication] and its contents, and remains entitled to freely use, modify, license or otherwise dispose of the same in its discretion. All brands, logos and names contained herein are trademarks or registered trademarks of ORMAT.
This publication and the contents thereof constitute ORMAT proprietary / confidential information. Duplication, use, translation into any language or computer language, disclosure, transfer or distribution without the prior written consent of an authorized representative of ORMAT is strictly forbidden."

This [publication] is intended solely for personnel who attended appropriate training by ORMAT with respect to ORMAT'S [system] (including operation, servicing and troubleshooting). This [publication] is solely for illustration purposes and not to substitute the application of any contract(s) between [ORMAT] and recipient or the use of safe and good practices, which recipient and its contractors are responsible to ensure. The contents of this [publication] are not intended as recommendations and/or definition of scope. There are no warranties of any nature with respect to the accuracy or reliability of any information contained in this [publication]. [ORMAT] accepts no liability for the contents of this [publication] or for the consequences of any actions taken on the basis of the same. The use of or reliance on this [publication] is at the sole risk of recipient and/or its contractors. ORMAT is not responsible for such use or reliance and shall be held harmless from any damages, costs and expenses resulting from the same.

The descriptions, specifications, design and procedures contained in this [publication] were effective at the time of release. ORMAT reserves the right to modify any of the above at any time without notice and without incurring obligations.
Changes are periodically made to the information herein; these changes will be incorporated in new editions of the publication. ORMAT Ltd. may make improvements and/or changes in the products described in this publication at any time.

TRADEMARKS

All other trademarks are the property of their respective holders and are hereby acknowledged.
This manual should not be construed as any representation or warranty with respect to the items named herein.

NOTICE

The descriptions, specifications, design and procedures contained in this manual were effective at the time of publication of this manual. ORMAT Ltd. reserves the right to modify any of the above at any time without notice and without incurring obligations. This manual offers information regarding the system, as provided by ORMAT Ltd. We recommend that only persons who have attended appropriate training for the ORMAT System (including Operation, Servicing and Troubleshooting) be allowed to use it.

NOTES

TABLE OF CONTENTS

TABLE OF FIGURES

1. INTRODUCTION

Scope of Manual

This manual is for the operation and maintenance of the Vapor Recovery Unit (VRMU). The manual presents the control loops for the VRMU and all relevant Sequence of Operations and valves setup at the different steps of action. The manual deals with safety issues, system description and theory of operation, troubleshooting and maintenance procedures for correct VRMU handling.

THE VRMU UNIT HAS BEEN DESIGNED AND TESTED FOR OPERATION IN ADVERSE CONDITIONS AND HAZARDOUS AREAS.

TO ENSURE PERSONNEL SAFETY AND AVOID EQIUPMENT DAMAGE, ADHERE TO PRECAUTIONS AND INSTRUCTIONS AT ALL TIMES.

THE PLANT MANAGER MUST ENSURE THAT VRMU OPERATORS ARE FAMILIAR WITH, AND CARRY OUT THE SAFETY PRECAUTIONS.

IF ANY OF THE INFORMATION IN THIS MANUAL IS LACKING, INCONSISTENT OR UNCLEAR PLEASE CONTACT ORMAT FOR CLARIFICATION AND INSTRUCTIONS.

2. ABBREVIATIONS

ABBREVIATION	NAME
BOP	BALANCE OF PLANT
CSC	CENTRAL STATION CONTROLLER
CV	CONTROL VALVE
FC	FAIL CLOSE
FO	FAIL OPEN
HMI	HUMAN MACHINE INTERFACE
HSV	HEAT SOURCE VALVE
ITLU	INTEGRATED TWO LEVEL UNIT
MCC	MOTOR CONTROL CENTER
MF	MOTIVE FLUID
NCG	NON CONDENSABLE GAS
OEC	ORMAT ENERGY CONVERTOR
PID	PROPORTIONAL INTEGRAL DERIVATIVE CONTROL
P&ID'S	PIPING AND INSTRUMENTATION DIAGRAMS
PLC	PROGRAMMABLE LOGIC CONTROLLER
ROC	RATE OF CHANGE
SP	SET POINT X
VFD	VARIABLE FREQUENCY DRIVE
X	X = VRMU SET POINT
XC	CONTROL LOOP

3. SAFETY

3.1. GENERAL

The aim of this chapter is to identify the main dangers and safety issues when establishing and running the power plant or any other equipment associated with it. Proper attention to the details below promotes worker safety and prevents injury.

> This document is in addition to the safety material supplied by ORMAT SYSTEMS LTD.
>
> Countries where Ormat facilities are located may have local safety regulations regarding the operation and handling of equipment and substances located on Ormat sites. National regulations are to be applied in conjunction with safety parameters listed in this document

This procedure covers the main and typical safety issues of all ORMAT sites. On arrival at a worksite ask the responsible authority for the details of all the general and specific safety issues as well as prevention procedures followed at that site. The plant manager must ensure that each person entering the power plant is familiar and adheres to the safety precautions and acts accordingly.

Ensure that all personal (of different languages) understand the safety instructions and issues involved.

NOTE:

- Specific plant equipment safety labels will appear in the appropriate locations throughout the plant.
- Further information regarding storage and preservation safety instructions is included in the vendor's equipment manuals.
- Strictly follow safety regulations with:
  - General plant work procedures.
  - Temperature/pressure dangers.
  - Electrical dangers.
  - Hazardous substances.
  - Equipment Operational safety.
  - Environmental safety.

Basic safety procedures:

- Prevent electrical and mechanical sparks.

- Unless known otherwise assume all liquid and solid waste generated on the site is hazardous and must be collected/contained and put into approved disposal containers.
- Using relevant substance identification methods, ensure the area (especially closed areas) is clear of dangerous vapors before access.
- Do not come into contact or inhale dangerous substances.
- Prevent uncontrolled release of dangerous substances.
- Ensure proper grounding/earthing of Cyclopentane tanks during filling.
- Do not enter areas where there is work or part moving in progress.
- Familiarize yourself with your environment know the location of fire alarms, extinguishers, first aid stations, eye wash stations etc.

Minimum personal protection gear:

- Hard hat.
- Protective glasses.
- Gloves.
- Safety boots.
- Safety harness.
- Long sleeve protective clothing.
- Ear protection.
- Protective gloves according to work activity.

3.2. WARNING TYPES

WARNING	**AN OPERATING PROCEDURE THAT COULD RESULT IN PERSONAL INJURY OR LOSS OF LIFE IF NOT FOLLOWED CORRECTLY.**
CAUTION	**AN OPERATING PROCEDURE WHICH COULD RESULT IN DAMAGE OR DESTRUCTION TO EQUIPMENT IF NOT FOLLOWED CORRECTLY.**

3.3. PLANT SAFETY REGULATIONS

- Use proper tools and equipment.
- Do not compromise. If in doubt, ask qualified personnel.
- Only qualified personnel familiar with the construction, operation and the hazards of the equipment should install, adjust, operate and/or service relevant units.
- Required safety precautions should be taken to avoid personal injury when working with high pressure systems and equipment.
- To avoid risk of personnel injury, ensure correct operational pressures in all sections of the plant.
- Use approved cleaning solvents and ensure adequate ventilation when cleaning equipment,
- Be aware of high temperature regions in the working area to reduce the personnel injury.
- Wear personal protection gear which includes helmet, eye goggles, long sleeve overalls (preferably of fire retarding material), gloves and safety boots.

3.4. TEMPERATURE/PRESSURE DANGERS

3.4.1. DANGER SOURCES

A typical worksite contains liquids and gasses that can be at high pressures and temperatures. These materials can cause burns or high pressure injuries. The temperature and pressure danger sources are:

- Water, geothermic boilers, thermal oil, high pressure/temperature gasses.
- Cyclopentane at high pressure/temperature.
- Methane (natural gas) at high pressure.
- Hot exhaust gases from turbines and other components.
- Compressed air.
- Welding fumes.
- High pressure nitrogen.
- CO_2 and H_2S gases.

3.4.2. PREVENTIONS

- Avoid contact with hot, non insulated surfaces.
- Prevent uncontrolled release of hot or high pressure substances.
- Ensure the system is not under pressure before opening taps, flanges, valves or plugs.
- Avoid exhaust gas injury by avoiding areas close to exhaust ports, automatic drainage ports, etc.

3.5. ELECTRICAL DANGERS

3.5.1. DANGER SOURCES

A typical worksite contains a wide range of heavy and light electrical equipment. There is a danger of electrocution as the equipment can be supplied with power from various sources that all need to be under supervision.

3.5.2. PREVENTIONS

- Take protective measurements before dealing with active electrical equipment. This includes releasing breaker switches, locking them in OPEN and posting the relevant notification.
- Consider the use of electrical bypasses for extra protection.
- Prevent mechanical, static and electrical sparks in areas where there may be flammable gases.
- Be alert when using electrical equipment. Avoid contact with the un-insulated electrical equipment metal parts.
- Avoid defective ground connections on portable electrical equipment and always ground stationary equipment.
- All portable devices should be tested frequently to ensure a solid electrical circuit exists from the metal frame, through the grounding conductor, the electric cord and to the grounding contact in the attachment plug.
- Do not use portable electric equipment with frayed, burned, damaged cords. Report the damaged equipment to authorized personnel.

- De-energize electrical machinery that needs to be serviced. Also tag the relevant circuit as "out of service".
- Ensure that adequate, functioning and correct fire fighting equipment is present at all times.
- When cleaning equipment, use approved cleaning solvents with adequate compartment ventilation.
- Be careful not to short-circuit terminals and wires.

3.6. HAZARDOUS SUBSTANCES

Check the MSDS safety manual for hazardous substances. This information is supplied with the equipment operating material.

Unless otherwise known assume all liquid and solid waste generated on the site to be hazardous, needing to be collected/contained and put into approved disposal containers.

3.6.1. CYCLOPENTANE

Cyclopentane is a colorless liquefied gas stored and used as a working fluid in the power plant under high pressure and temperature in a large majority of the piping. The gas has a characteristic odor. It is heavier than air and will accumulate in low lying areas. It has a flash point of -35 F. Cyclopentane is extremely flammable and can easily explode. Cyclopentane is non-toxic but will act as an asphyxiate. Other physical hazards are cold burns and other skin damage due to cold caused by gas expansion and hazards of high temperature and pressure. Main dangers include:

- Leaks.
- Flammability.
- Injury on contact, on eye contact, on swallowing, on inhalation.
- Heat, sparks and flames.

3.6.2. HYDROGEN SULPHIDE (H_2S)

H_2S appears as a gas accompanying geothermic turbine activity or it is discharged from various petrochemical processes. H_2S has a pungent odor. As it is heavier than air it may accumulate in low non-ventilated locations resulting in suffocation. The main dangers include:

- High toxicity.

3.6.3. BRINE AND STEAM

Can contain heavy metals and H_2S.

High temperatures

Injury on contact, on eye contact, on swallowing, on inhalation.

3.6.4. LUBE OIL

This oil contains a petroleum-based mineral oil and is used between the feed pump double mechanical seal to prevent n-Pentane escape. Not expected to be harmful if swallowed or inhaled.

The main dangers include:

- May cause respiratory irritation or other pulmonary effects following prolonged or repeated inhalation of oil mist at airborne levels above the recommended mineral oil mist exposure limit.
- Symptoms of respiratory irritation may include coughing and difficult breathing.

3.6.5. WELDING FUMES, OILS, FLAMMABLES, CLEANING AGENTS, SOLVENTS AND PAINTS

Main dangers include:

- Leaks.
- Flammability.
- Toxicity.
- Injury on contact, on eye contact, on swallowing, on inhalation.

3.7. EQUIPMENT OPERATIONAL SAFETY

Refer General on Page 9.

3.7.1. ROTATING EQUIPMENT

Do not activate this equipment without protection on exposed relevant parts. i.e. pumps, engines or pistons.

3.7.2. LIFTING AND MOVING EQUIPMENT

Ensure correct operation of all manual and other lifting and transportation equipment used on the worksite. Follow all manufacturer safety procedures.

3.7.3. WORK AT HEIGHT

Work at height is permitted only with the proper lifting and climbing equipment (harness) to prevent accidents. Do not enter areas where there is work or part moving in progress.

3.7.4. ENTRANCE INTO CONFINED SPACES OR EXCAVATIONS

Before entering these areas (equipment rooms, pump rooms, wells etc) ensure there is no toxic gas accumulation.

Before lowering into wells or excavations ensure there is no danger of collapse and that escape routes exist.

3.8. ENVIRONMENTAL SAFETY

Worksites may be in areas with extreme of specific local conditions and limitations. The following precautions should be followed:

- Be careful of collapse due to excessive rainfall and mud.
- Use protective clothing (special attention to head and hands) to preserve body heat in cold areas.

3.9. PERSONAL SAFETY

- Vaccinations or medications relevant to worksite or host country regulations
- Avoid bites, stings from local domestic and wild animals. If bitten or stung refer to local medical treatment center.
- Do not enter swamp or forested area with required preparation and permission
- Prevent dehydration on hot areas by regular fluid intake.
- Ensure safe work procedures including rescue if required in various local conditions i.e. darkness, snow storm etc.
- Use protective clothing (special attention to head and hands) to preserve body heat in cold areas.
- Prepare "Plan B" work procedures for use if needed.
- Take rest periods to stay alert and minimize the effects of general exhaustion.

3.10. REMINDERS

- Personal protective clothes, earplugs, gloves, boots, eyeglasses.
- Flammable substances:
  - Cyclopentane.
  - Methane – natural gas.
  - Welding gases.
  - Lubricants, oils, paints, dilution compounds.
- Toxic substances:
  - H2S
- Gases and liquids from equipment at high temperatures.
- Gases and liquids at high pressure.
- Electrocution prevention.
- Suffocation in non ventilated areas.
- Injury from revolving parts.
- Danger of falling.
- Injury from work and transport equipment.
- Injury from collapse of tunnels and wells.
- Dangers from personal exhaustion in unfamiliar work environments.
- Dangers of extreme environmental factors.

3.11. PLANT COMPONENTS

The measures below apply to pressure vessels, heat exchangers, pumps, expansion tanks piping. Read the instructions below and apply those relevant to your particular plant component.

- Lifting devices including eyebolts, lugs, clips or other devices are placed by ORMAT SYSTEMS LTD. On plant components, these lifting devices are for lifting the empty components only to which they are attached and not assembled components unless explicitly specified otherwise.
- Ensure that the component's design limits shown on the specification sheet and nameplate(s) are observed and vessel design conditions and operating limits are not exceeded.
- All operating and maintenance personnel should be aware of specific limitations including pressures and temperatures, flow rates, start-up/shut-down procedures and cleaning procedures.
- Do not remove channel covers, shell covers, floating head covers, bonnets or connecting piping until all pressure has been released. For heat exchangers ensure both shell and tube sides are completely drained. Exceptions are permissible when design permits independent pressure testing of shell or tube sides of heat exchangers.
- Plugged tubes and double tube sheets may remain pressurized after shell and tube sides (of heat exchangers) are depressurized unless vented.

WARNING

Vessels can circulate toxic fluids which are lethal or flammable and dangerous to humans. These fluids can cause problems if bolted or threaded joints are not maintained in leak-tight operating or no-flow ambient conditions.

Proper precautions, such as effective draining and purging, must be taken in handling and decontamination when any vessels are opened for any reason.

Exercise caution in loosening tube plugs or opening of vents to avoid sudden release of pressure or harmful materials.

When heat exchangers are cleaned, be aware of circulating fluids, fouling materials, and the cleaning agent to be used. Use care when handling these components. Use eye protection, respirators or other appropriate protective devices.

3.12. GENERAL SAFETY FOR TURBINES

- Follow all personal safety rules.
- Follow manufacturer safety recommendations for lifting heavy machinery.
- Lift turbines using the attached eyebolts, lugs, clips or other devices are installed by ORMAT SYSTEMS LTD. on the turbine.
- Do not use flammable substances within 5 m of turbine unless relevant sampling has been carried out and flammable material level is within permissible levels.
- Ensure that the MF purged with Nitrogen from the OEC before dismantling the turbine components.
- Ensure all relevant electrical components for the required turbine procedure have been shutdown and locked according to recommended procedure.
- Do not place anything in the rotating part of the equipment to be serviced.
- Do not service machinery without clearing all materials and covers from rotating parts and tagging the turbine area out of service.
- Reduce contact with high temperature areas of the turbine to reduce risk personnel injury.

3.13. GENERAL SAFETY FOR GENERATORS

- Only qualified personnel should install, adjust, operate and/or service this unit.
- Shutdown generator starting circuit before repairs or changes. Dangerous voltages and accidental contact can be fatal.
- Disconnect space heaters power by opening the motor power circuit breaker before removing end covers on the generator.
- Regulator sensing circuit must never be opened while power is applied to the regulator input power terminals.
- Voltage regulator dc output terminals (F+ and F-) are not opened during operation.
- Keep work area clear of objects and personnel.
- Never apply a lifting force to structural points other than those provided for that purpose.
- Megger or high potential test equipment must not be used when testing the voltage regulator.
- Remove any flammable protective covering material from the generator before heaters are activated.
- Do not apply heat too rapidly when drying winding.

3.14. GENERAL SAFETY FOR MOTORS

- Only qualified personnel should install, adjust, operate and/or service this unit. Read understand this manual in its entirely before proceeding. Failure to observe this precaution could result in severe bodily injury or loss of life
- Do not service machinery BEFORE shutdown and tagging the circuit as out of service.
- Shutdown generator starting circuit before repairs or changes. Dangerous voltages and accidental contact can be fatal.
- Clean equipment with approved cleaning solvents.
- Ensure that the work area is adequately ventilated.

3.15. GENERAL SAFETY FOR VALVES AND PUMPS

- Only qualified personnel should install, adjust, operate and/or service this unit.
- Do not service machinery BEFORE shutdown and tagging the circuit as out of service.
- Before starting preservation work, ensure that the unit is pneumatically and electrically disconnected.
- Clean equipment with approved cleaning solvents.

3.16. GENERAL SAFETY FOR COMPRESSORS

- Read and understand all safety signs on the air compressor and in the air compressor manual.
- Before air compressor maintenance or preservation work, open a drain valve to release all pressure from the compressor system.
- Minimize contact with high temperature working area to avoid personnel injury.
- Do not place any objects in the vicinity of the compressor rotating parts.
- Take care when purging compressed air.
- Shut down unit on order to not create oil tank pressure.
- Isolate the unit, drain and clean.

4. THE VAPOR RECOVERY MAINTENANCE UNIT (VRMU)

The VRMU skid is located at each power plant providing the plant with the ability to clear and recover all MF vapors from the OEC prior to performing maintenance.

The VAPOR RECOVERY UNIT FOR MAINTENANCE (VRMU) is specially built for evacuating motive fluid gasses from the ORMAT ENERGY CONVERTER (OEC) and its piping before purging the OEC to the atmosphere during plant maintenance. This is to reduce MF emission levels to levels below the permitted environmental limits.

The basic unit components and main valves locations are displayed below. Refer to Figure 4-1 on page 19 and Figure 4-2 on page20.
The unit handles work in hazardous areas categorized as follows:

American classification - Class I, Division 2 Group D, T3

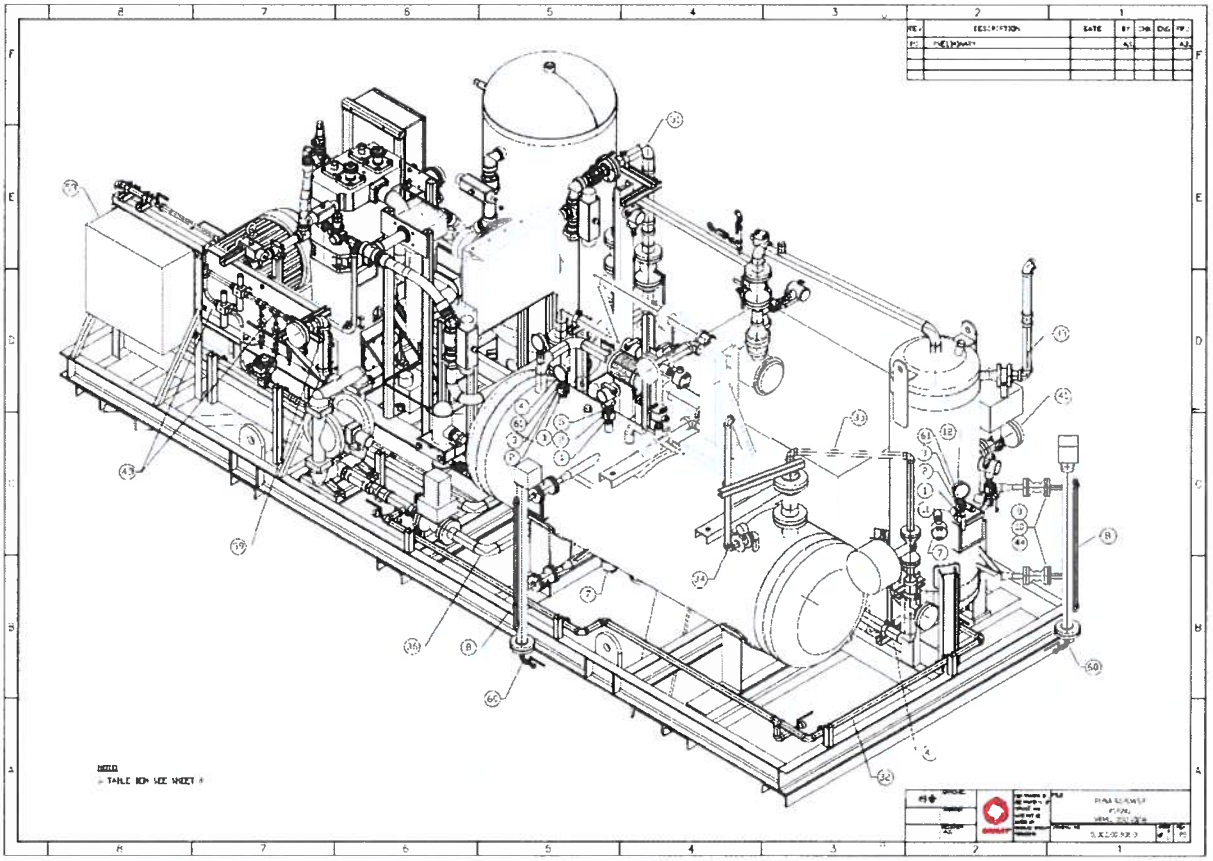


Figure 4-1: VRMU – Front View

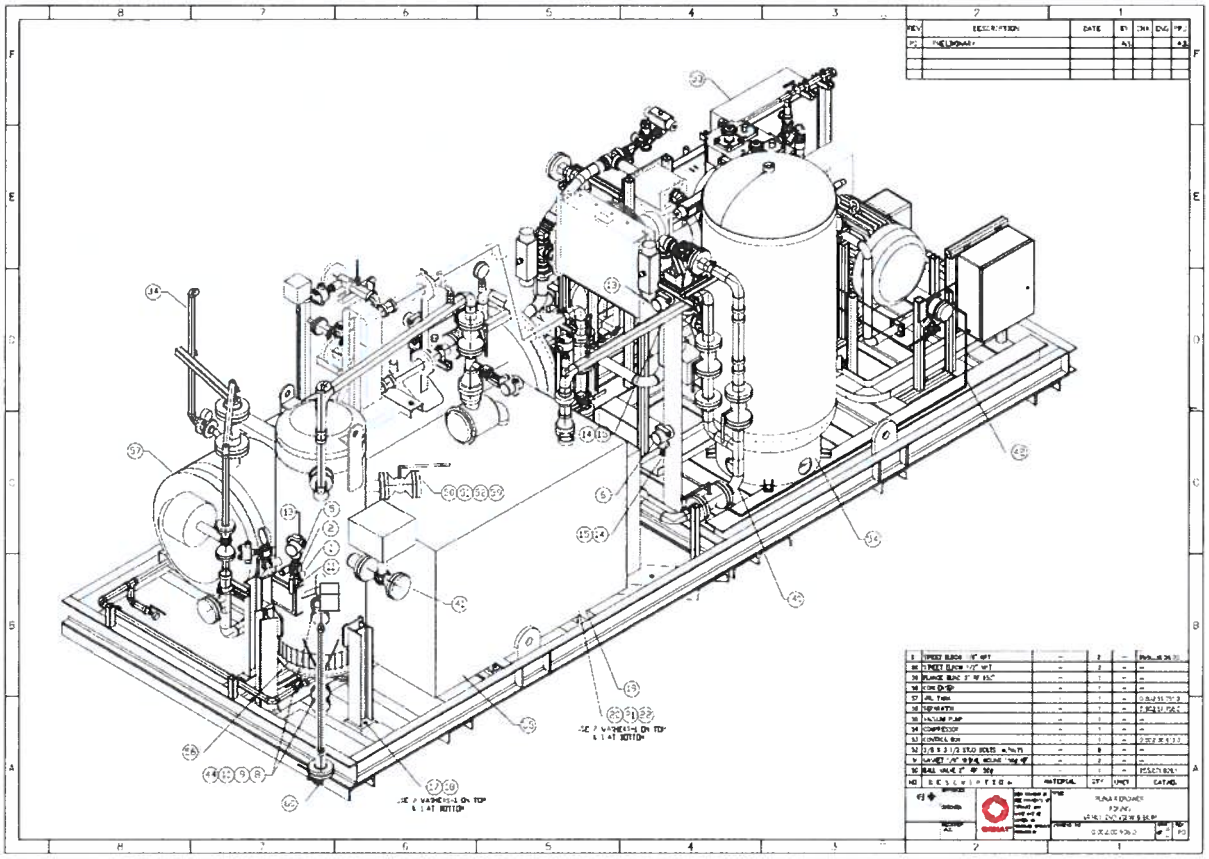


Figure 4-2 VRMU – Rear View

4.1. PROCESS DESCRIPTION

The VRMU utilizes air cooled condensation detailed in four major steps (Operating Instructions on page 30) for environmentally hazardous MF recovery.

The main evacuation step is Step-2 NORMAL EVACUATION OF THE OEC on page 35 where the VRMU vacuum pump extracts MF vapors from the OEC and pumps them to the compressor. The compressor increases pressure to MF vapors condensation pressure level and the vapor flow continues to the condenser. Here the vapors are liquefied and further sub-cooled before temporary storage in the condensate tank.

During operation, compressor outlet pressure (in the VRMU) may rise above the required condensation pressure when NCG is also extracted from the OEC. A pressure control valve located on the condensate tank releases this over pressure (refer Figure 4-1 page19). When this valve opens, MF and NCG vapors are released together to a predefined safe location.

4.1.1. TECHNICAL SPECIFICATIONS

Description	Info
Hazardous area specifications	American classification – Class 1, Division 2 Group D, T3
Flow capacity	60 SCFM
Recovery efficiency	>98% of the Hydrocarbon
Unrecovered hydrocarbon vent	Captured with active carbon filter
Max. ambient operating temperature	122˚F
Min. ambient operating temperature	35 ˚F
Max. Air supply pressure	125 psia
Electrical supply	60 HZ, 3 phase, 480 volts
Evacuated MF type	Cyclopentane
Estimated NCG content at feed	10%/0%/50% volume (design/min/max)
Max, Vacuum pump inlet temperature	100˚F
Max. operating vacuum	29.5 "Hq.
Designed condensing pressure	87 psia
Designed condensing temperature	224˚F (designed with90% Cyclopentane)
MF vapors condenser outlet temperature	50˚F (designed with 90% Cyclopentane)
MF Liquid Accumulator volume	35.3 cubic feet (1 m^3) Operational – 31.8 cubic feet (0.9 m^3)
Pressure set points	Final vacuum set point: 2 psia (initial setting) System inlet pressure valve set point: 4 psia (initial setting) Vacuum pump outlet burst disk pressure: 15 psig MF liquid accumulator pressure valve set point: 87 psia MF knock out drum burst disk pressure: 15 psig MF Liquid Accumulator burst disk pressure: 145 psig

4.2. EXTERNAL DETAILS

Description	Info
VRMU general dimensions	Width- 7' 6.5" (2300 mm) Length 19' .05" (5806 mm) Height 7' 10" (2390 mm)
Total dry weight	~15,5000 lb (7 tons)

4.3. ON-SITE UNIT REQUIREMENTS

It is recommended that the VRMU is placed on and secured to a pre-prepared concrete apron. The local authorized engineer is responsible for calculating the thickness and weight bearing capacity of the concrete apron based on the VRMU dimensions, weight and local climatic factors. The VRMU skid has six holes for anchor lugs. These lugs secure the VRMU to the concrete apron at the predefined locations as shown in the figure below.

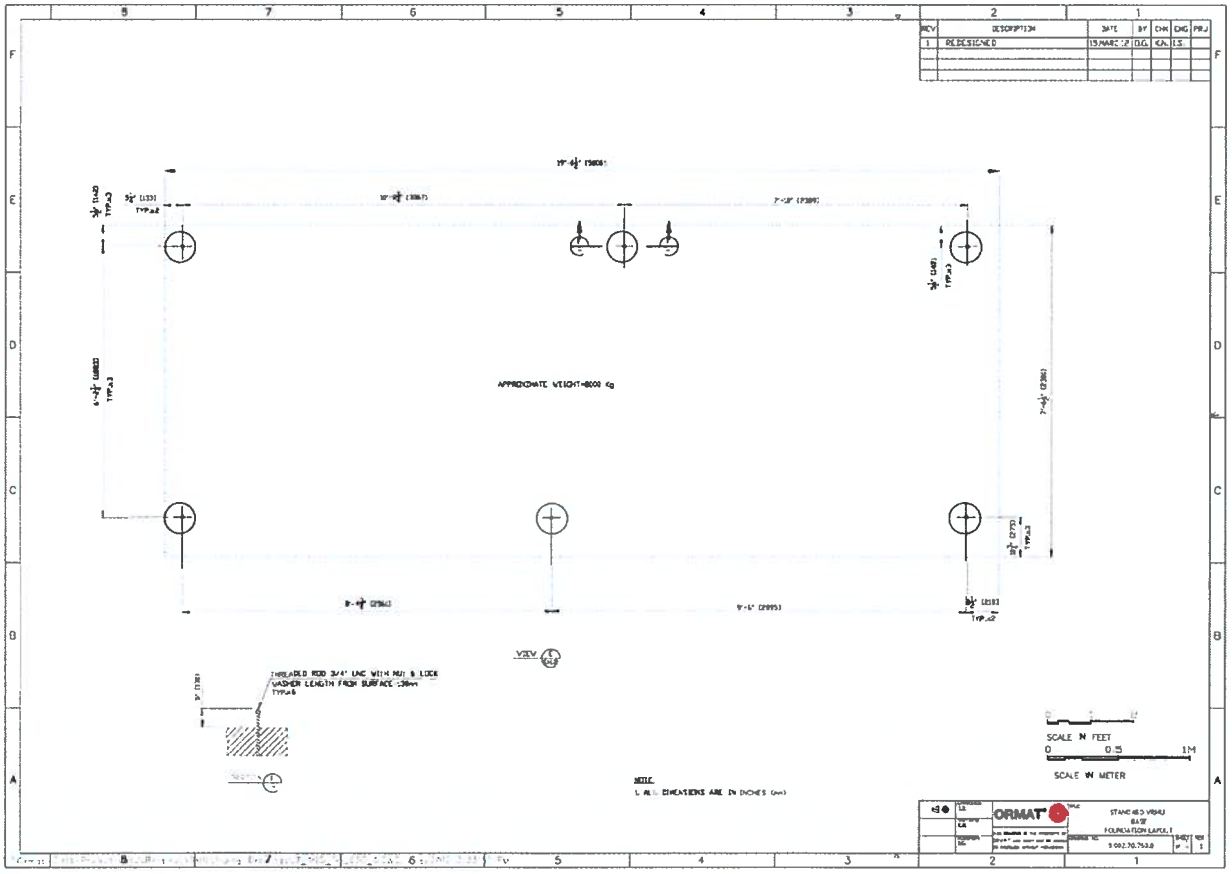


Figure 4-3: VRMU Foundation Layout

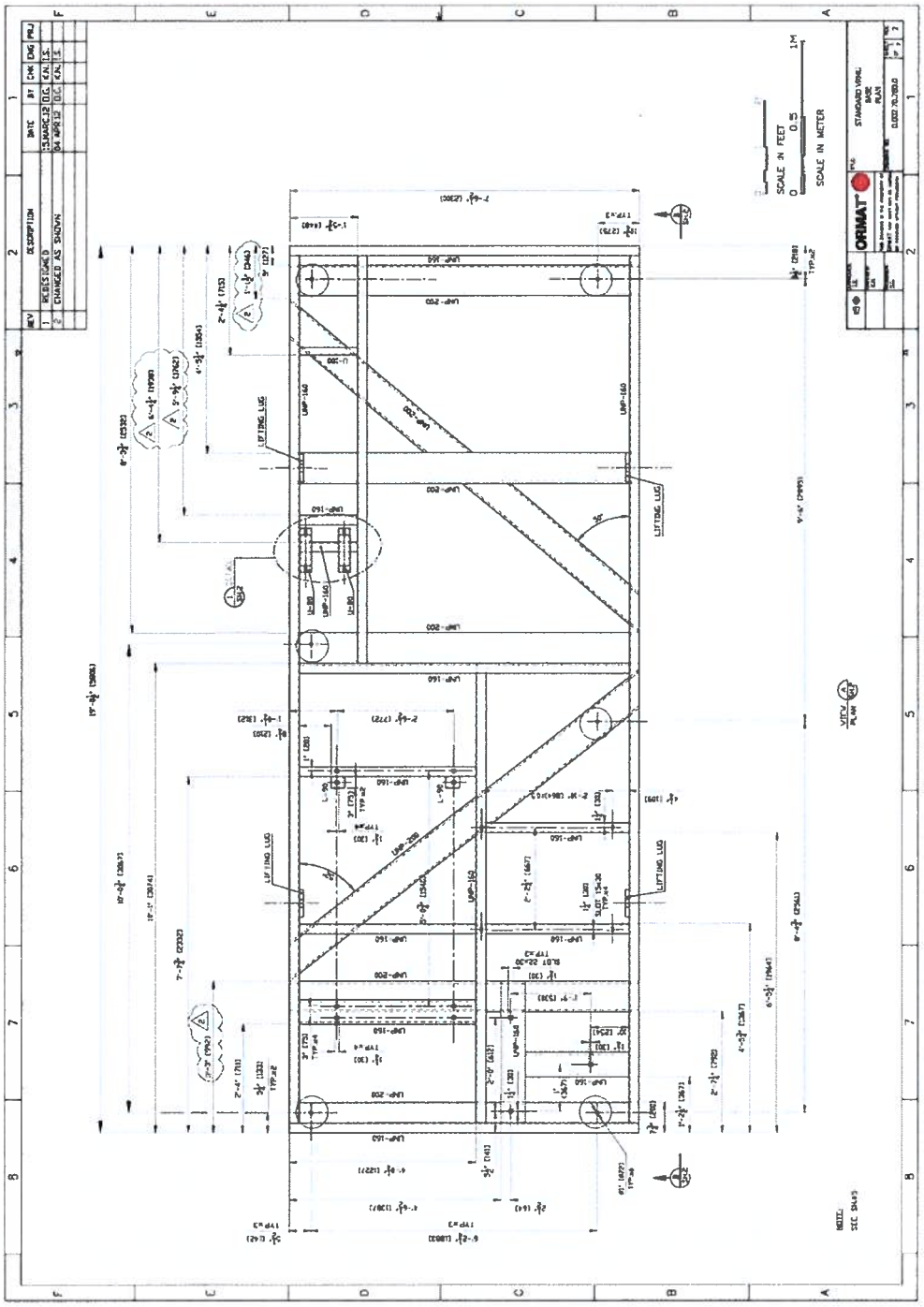


Figure 4-4: VRMU Base Plan

4.4. VRMU SUBSYSTEMS

The VRMU is composed of the following main parts:

DESCRIPTION	REF.	COMMENT
15 HP vacuum pump motor	M-6801	SINGLE UNIT
Vacuum pump	P-6801	
50 HP compressor motor	M-6802	SINGLE UNIT
Compressor	C-6802	
Buffer Tank	V-6805	
Fan motor	M-6804	
MF Pre-Cooler	HE-6804	
1 HP fan motor	M-6803	SINGLE UNIT
MF vapors condenser	HE-6803	
MF knock out drums	V-6801A/B	
Pneumatic drainage pump	P-6803	
MF liquid accumulator	V-6802	

4.5. SUBSYSTEM DESRIPTIONS

- ### 15 HP vacuum pump motor / vacuum pump

  The vacuum pump is located downstream from the MF knock out drum and is a 15 HP air-cooled single positive displacement lubricated rotary screw vacuum unit driven by a totally enclosed fan-cooled motor. The pump produces a vacuum to extract the MF from the OEC.

- ### 50 HP compressor motor / compressor

  The compressor is located downstream from the vacuum pump and is a 50 HP oil-free, air-cooled gas compressor. The compressor raises the pressure at the inlet to the condenser.

- ### 1 HP fan motor / MF vapors condenser

  The MF vapors condenser is a tube and fin air-cooled heat exchanger. Vapors entering the condenser from the compressor (at condensing pressure) undergo condensation and are further sub-cooled to below MF saturation temperature.

- ### MF knock out drums

  The VRMU vacuum pump extracts MF vapors. Under specific environmental conditions, vapors may condense in the piping. The knock out drums ensures that no liquid enters the vacuum pump (P-6801).

- ### Pneumatic drainage pump

  The pump drains MF from the liquid accumulator and the Knockout drum (V-6802) to the plant storage tank. This is a diaphragm pump powered by compressed air. The pump is used to transfer liquids within the system as required.

- ### MF liquid accumulator

  MF is accumulated in this tank for future handling. From this tank the MF liquid is pumped to the OEC storage tank.

- ### Piping (MF/NCG/AIR)

  Piping is designed with flanged connections for optimal sealing and easy dismantling. All valves and instruments are built to handle Cyclopentane

- ### Electrical control panel and vacuum pressure supply

  The VRMU control center is at the electrical control panel and is certified for work in areas classified as non hazardous.

  The Control panel shall be installed at a distance from the VRMU Skid in order to comply with non-hazardous standards. Control panel sealing shall be in accordance with NEMA 4.

5. CONTROL PHILOSOPHY

An OEC contains MF for the standard heat exchange operations (organic Rankine cycle) which may have to be drained (evacuated) for maintenance purposes. After the MF is drained from the OEC (using documented drainage procedures), a small amount of not drained trapped liquid and additional MF vapors may remain in the OEC. As environmental regulations limit direct venting of MF into the atmosphere the standalone VRMU is connected to the OEC to purge any MF residing remains.

Extracted MF is condensed, cooled and stored as a liquid in the VRMU MF liquid accumulator tank (Figure 4-1 page19) for future return to the OEC.

When the VRMU is powered up, step-2 Evacuation on page 35 is activated causing flow through the slowly opening inlet valve (NV-6811). The vacuum pump flow continues from the knock out drums towards the compressor where the pressure rises to 87 psia. From the compressor the flow continues to the condenser where it is cooled and condensed. The liquid MF is stored in the accumulator.

NCG present in the mixture accumulates in the condenser collector and in the MF liquid accumulator resulting in increased condensing pressure. A pressure control valve at the top of the liquid accumulator controls over pressure by directing MF vapors and NCG to a dedicated safe location vent.

OEC nitrogen purging is carried out using step-3 (see page 37) which starts up the vacuum pump but bypasses the compressor and condenser and is vented via the active carbon filters.

6. PRE-OPERATION PROCEDURES

Note

The following procedures shall be carried out by skilled and trained personal only.

Drain all motive fluid from the OEC prior to VRMU skid connection.

The following steps are manually controlled by hand valves and from the HMI screen. Refer Figure 4-2 on page 19 and Figure 7-1.

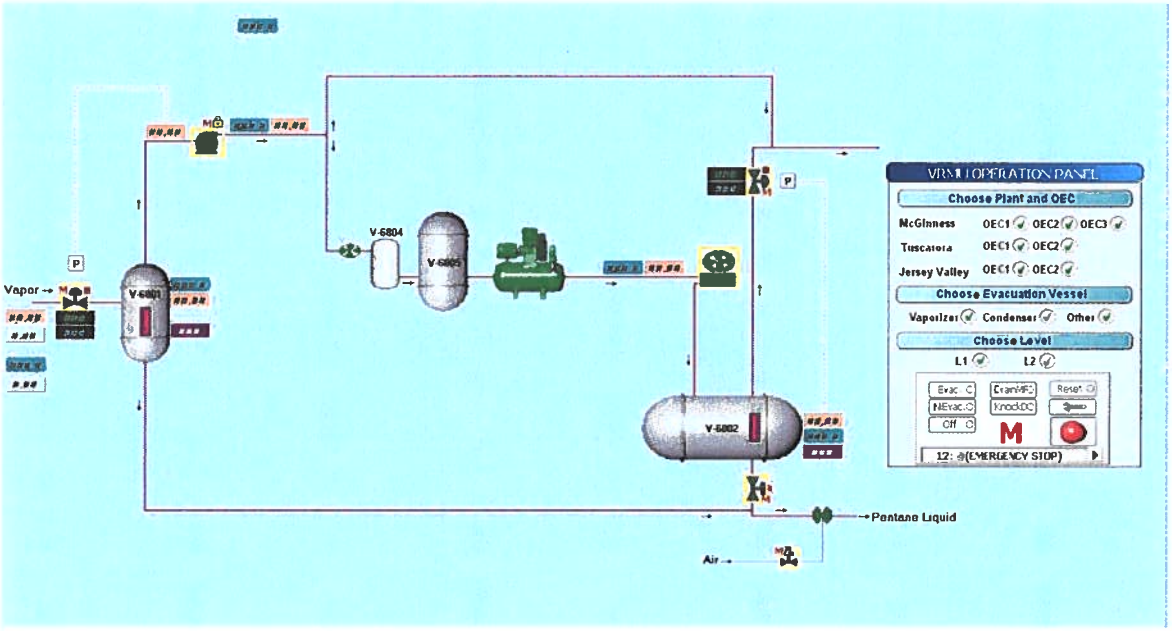


Figure 7-1 HMI Screen

The following checklist ensures correct compressor and vacuum pump preparation and operation:

On initial operation and following any pipe disconnection perform a pressure and vacuum leak test to endure the unit is properly sealed. Repair any leaks as required and repeat the tests until the unit is sealed and safe for vapor handling.

Carry out a visual check to verify VRMU integrity and safety.

Verify that there are no foreign objects around the areas with rotating parts.

Verify the integrity of the rupture disks (PSE-6801, PSE-6802).

Verify VRMU power supply.

Check oil levels in vacuum pump and compressor and fill as required. In case of excessive oil consumption refer to vendor manuals.

Using the manual mode on the HMI, set the valve status as listed below and run the vacuum pump by clicking on the HMI screen ON button.

NV-6811 Closed

PV-6801 Open (0)

HV-6821 Open

HV-6820 Open

HV-6823 Open

HV-6819 Closed

Verify system integrity by checking that the operating temperature is below 100˚F (37˚C).

Observe return line sight glass and maintenance indicators. Refer to vendor manuals for unresolved issues.

When vacuum pump reaches pressure of 29"Hg, shut down the pump by clicking the HMI screen OFF button to de-activate. Refer Figure 8-1 (see page 31) & Table 8-1.

Set all valves to standby mode. Refer Figure 8-1 on page 31.

The VRMU system has now been checked and is ready for operation

7. OPERATING INSTRUCTIONS

7.1. VRMU OPERATIONAL PROCEDURE STEPS

NOTE:

- **The following steps are manually controlled using the HMI.**
- **The following procedures are carried out by skilled and trained personal only.**
- **Drain all motive fluid from the OEC and the evacuation header prior to VRMU skid connection.**

7.2. VRMU CONTROL SYSTEM

The VRMU operation status is graphically displayed on the HMI (Human Machine Interface).

The control sequence is divided into "Steps". The operator needs to provide only the START or the STOP signals. The control system will guide the VRMU from step to step, moving through the start-up sequence to the "Evacuation" step. To stop the VRMU, the operator transmits a STOP signal to the VRMU, wherewith the control system automatically brings the VRMU to "Full Stop" ("Standby mode" step 1).

The Operational Steps are below:

1. Standby mode - Basic VRMU storage, non activity mode. (off)
2. Evacuation – Normal evacuation of the OEC. (After liquid drainage)
3. Nitrogen Evacuation – Evacuation of the OEC after nitrogen fill up in order to break vacuum.
4. Standby mode after evacuation.
5. Draining MF liquid accumulator.
6. Spare.
7. MF knock out drum drain.
8. Standby mode after drainage.

7.3. MOVING FROM ONE VRMU STEP TO ANOTHER

There are permissive or conditions which need to be met for the VRMU sequence to move from one step to another. The below table indicated the basic conditions needed to move from step to step.

1 to 2	Operation mode selector changes from "Standby" to "Evacuation" (start step 2).
1 to 3	Operation mode selector changes from "Standby" to "Nitrogen Evacuation" (start step 3).
2,3 to 4	When OEC pressure reaches final vacuum set point P0 and operator select the stop button.
2 to 5	When accumulator level exceeds high set point L1.
2,3 to 7	When knock out drum level exceeds high set point L2.
1,4 to 5	Operation mode selector clicks on the HMI screen Step 5.
1,4 to 7	Operation mode selector clicks on the HMI screen Step 7.
5 to 8	When accumulator reaches its low level L3.
7 to 8	When knock out drum reaches its low level L4.
8 to 1	When operation mode selector confirm drainage is complete.
8 to 2	When OEC pressure is not at the final vacuum set point P0.
8 to 3	When OEC pressure is not at the final vacuum set point P0.

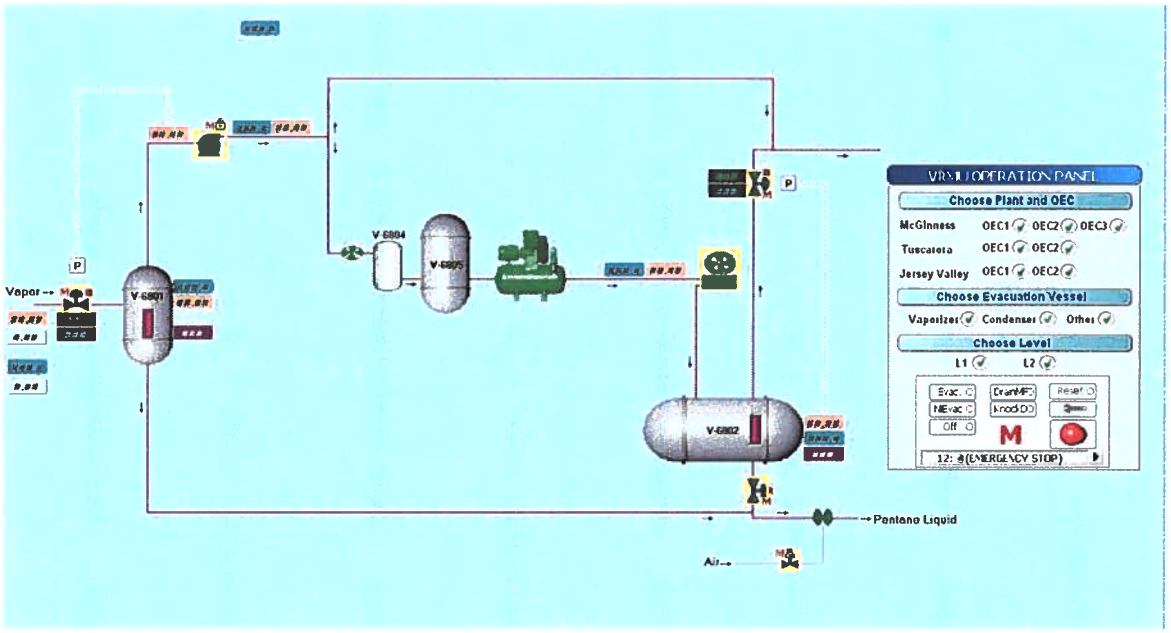


Figure 8-1 HMI screen

7.4. NOMENCLATURE – VRMU CONTROL TABLES

The below table provides a description of the control tables that are utilized to describe the function of the analog control loops presented here within.

Controller Tag No.		Describes the Control Tag Number as Represented on the P&ID's
Input Tag No.		Process inputs for the control loop
Output Tag No.		Process Control Valve, Pump, VFD, etc that the loop is controlling.
Mode		Describes the method the control loop performs (On/OFF, PID, Reverse PID, Cascade PID)
General Description		Describes the general operation of the control loop
Overrides / Interlocks		Overrides describe the conditions in which the control loop will be over ridden. Examples of overrides include but are not limited to manual operator control or operating conditions that require a deviation from normal automated control sequences or philosophy. Interlocks are conditions which prevent a control loop from operating outside of a predefined range. This can include mechanical and electrical protections from both analog and discrete control signals. Interlocks and Overrides do not appear on the P&ID's.
Fail Position		Describes the fail position of the Control Device if the control loop fails
Special Feature		Describes Special Features of the control loop
Process Step		**1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |	
Output Tag Number	**Mode**	Mode of control loop based off process step according to the VRMU sequence steps.
	Set Point	Normal Set Points for the Controller
	Override Interlocks	Overrides / Interlocks in each control step

7.4.1. ANALOG CONTROL LOOPS

The feedback control system comprises the following closed-loop circuits:

VRMU Control loops:
a. Skid inlet pressure control loop (XC-6801)
b. Accumulator pressure control loop (XC-6802)

7.5. VRMU CONTROL SYSTEM

7.5.1. XC-6801 SKID INLET PRESSURE CONTROL

The purpose of control loop XC-6800 is to control the motive fluid pressure at the skid inlet. The parameter (pressure) is controlled by a PID loop. Control valve (PV-6801) regulates the inlet gas flow and affects skid inlet pressure. The valve will throttle in order to maintain a regulated set point pressure at skid inlet.

The skid inlet pressure set point for the control valve will be P1.

Controller Tag No.		XC-6800								
Input Tag No.		PT-6809								
Output Tag No.		PV-6801								
PLC | Mode		VRMU | Open/Closed/PID								
General Description		**PV-6801:** If SP < Current Value (PT-6809) Close Control Valve If SP > Current Value (PT-6809) Open Control Valve								
Override / Interlocks		If Vacuum pump P-6801 run indication is "0" the valve will be disabled (close) If V-6801 high pressure failure detected (PT-6804A/B) the valve will close. (P2) If V-6801 high level failure detected (LT-6806A/B) the valve will close. (L2) PV-6801 - Valve mismatch[1] will trip the unit and close the valve.								
Fail Position		PV-6801 - Fail Closed								
Special Features		Valve will start operating only after PT-6804 reaches P4 set point.								
Process Step		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
PV-6801	**Mode**	0	PID		0					
	Set Point	N/A	P1		N/A					
	Override & Interlock		0							

1A mismatch is declared if the deviation between the opening signal and the position is more than a preset value (typically 5%) for a preset time delay (typically 3 seconds).

7.5.2. XC-6802 ACCUMULATOR PRESSURE CONTROL

The purpose of control loop XC-6801 is to control the motive fluid pressure at the accumulator V-6802. The parameter (pressure) is controlled by a PID loop. Control valve (PV-6834) regulates the outlet gas flow and affects tanks pressure. Due to NCG present the tank pressure may raise above the condensing pressure, if that is the case the valve will open to reduce the pressure.

The accumulator pressure set point for the control valve will be the designed condensing pressure (P3).

Controller Tag No.		XC-6802								
Input Tag No.		PT-6821								
Output Tag No.		PV-6834								
PLC | Mode		VRMU | Open/Closed/PID								
General Description		**PV-6834:** If SP < Current Value (PT-6821) Open Control Valve If SP > Current Value (PT-6821) Close Control Valve								
Override / Interlocks		PV-6834 - Valve mismatch will trip the unit and close the valve.								
Fail Position		PV-6834 - Fail Closed								
Special Features										
Process Step		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
PV-6834	**Mode**	0	PID		PID	PID	PID	PID	PID	
	Set Point	N/A	P3		P3	P3	P3	P3	P3	
	Override & Interlock									

7.6. VRMU CONTROL LOOP SET POINTS

Warning
Set points and software should not be changed without Ormat Approval

- All set points are subject to change based on start-up and commissioning. A revised set point table will be issued at that point.

The table below represents the severity of the warnings and failures listed in Section 4.2. This table is only related to VRMU control loops that are operating based on the VRMU Step sequence.

Severity	Alarm	From Step:	To Step
0	Emergency Alarm	All Steps	1
1	Trip Alarm	2, 3	4
		5, 7	8
2	Critical Alarm	2, 3	4
		5, 7	8
3	Warning	N/A	N/A

Description	Controller	Sensor	Set point Name	Set Point
Final vacuum set point	N/A	OEC evacuated Vessel PT	PO	1 Psia **
Skid inlet pressure set point	XC-6800	PT-6809	P1	10 Psia **
Knock out drum pressure set point for opening PV-6801	N/A	PT-6804	P4	3 Psia
Accumulator pressure set point	XC-6802	PT-6821	P3	87 Psia
Accumulator level set point	XC-6803	LGT-6825	L1	80%**
Knock out drum level set point	XC-6801	LGT-6806	L2	95%**

** Set points and time delays values should be dynamically changeable through the HMI

7.7. STEP-1 STANBY MODE (OFF)

This is the basic VRMU storage, non activity mode. This mode is the point of origin for VRMU operations.

In this mode all valve positions are as shown in table 8-1 (also attached to VRMU junction box).

7.8. STEP-2 EVACUATION

This is the OEC evacuation. The system is in standby mode.

1. Ensure OEC is connected to the skid inlet flange verify all hand valves are aligned as shown on the P&ID and according to table 8-1 ST2.
2. Check all lubrication fluids and equipment are according to OEM instructions.

3. Energize power circuit to skid.
4. Energize compressed air source to the skid.
5. Press the start button on the HMI screen and select step 2 (see page 35). This starts the evacuation sequence:
   a. Condenser fan activated, after 5 second time delay.
   b. Compressor motor activated, after 5 second time delay.
   c. Vacuum pump activated.

   ** Each item of equipment will start only after receiving an enable signal from the equipment that started before.
6. Allow skid to run until full vacuum is observed at the knock out drum V-6801A/B according to PT-6804A/B reading (P4).
7. VRMU inlet valve PV-6801 opens slowly. This will start evacuation of the piping leading to the process equipment. Wait until all piping is evacuated according to PT-6810 reading (P4).
8. Slowly open manual isolation valve at process vessel. This begins the evacuation of vapors from the process equipment.
9. The OEC evacuation is complete when OEC pressure reaches its set point (PO). This is indicated on the HMI. The unit will continue running until the operator presses the STOP button.
10. The VRMU proceeds to step 4 (see page 38) during the sequence:
    a. PV-6801 closes.
    b. Vacuum pump motor, compressor motor and fan motor are de-activated.
    c. Open HV-6823.

7.9. STEP-3 NITROGEN EVACUATION

This step is used for OEC evacuation when it is full with nitrogen. The system is in standby mode.

1. Ensure OEC is connected to the skid inlet flange. Verify that all valves are aligned as shown on the P&ID and according to table 8-1 ST3.
2. Check all lubrication fluids and equipment according to OEM instructions.
3. Energize power circuit to the skid.
4. Energize compressed air source to the skid.
5. Press the start button on the HMI screen and select step 3 (see page 37). This starts the evacuation sequence: vacuum pump activated.
6. Allow skid to run until full vacuum is observed at the knock out drum V-6801 according to PT-6804 reading (P4).
7. VRMU inlet valve PV-6801 opens slowly. This will start the evacuation of the piping leading to the process equipment. Wait until all piping is evacuated according to PT-6804 reading (P4).
8. Slowly open manual isolation valve at process vessel. This begins the evacuation of vapors from the process equipment.
9. The OEC evacuation is complete when OEC pressure reaches its set point (PO). This is indicated on the HMI. The unit will continue running until the operator presses the STOP button.
10. The VRMU proceeds to step 4 (see page 38) during the sequence:
    a. PV-6801 closes.
    b. Vacuum pump motor is de-activated.

7.10. STEP-4 STANDBY MODE AFTER EVACUATION

The system is inactive and is waiting for user prompt for further steps. After a 5 minute time delay where no action was taken the system will move to step 1 (see page 35).

7.11. STEP-5 DRAINING MF LIQUID ACCUMULATOR

1. On the HMI screen click on step 5 (see page 38) and click start. The step can also start automatically from step 2 (see page 35).
2. The following sequence occurs:
   a. Valve NV-6809 opens.
   b. Diaphragm pump air inlet valve NV-6810 opens.
3. The MF liquid accumulator drains until operator confirms that the tank is empty. This is denoted by LGT-6825 low level warning. The following sequence occurs when accumulator reaches its final level set point (L3) and a low level warning is activated:
   a. Valve NV-6809 closes.
   b. Diaphragm pump air inlet valve NV-6810 closes.
   c. Confirm to proceed to step 8 (see page 38).

7.12. STEP-7 MF KNOCK OUT DRUM DRAIN

The system is in standby mode.

1. Open HV-6817.
2. On the HMI screen click on step 7 (see page 38) and click start.
3. Diaphragm pump air inlet valve NV-6810 opens.
4. The MF knock out drum drains until you confirm that the tank is empty. This is denoted by LGT-6806 low level warning (L4).
5. The following sequence occurs:
   a. Diaphragm pump air inlet valve NV-6810 closes.
   b. Close and lock HV-6817.
   c. Confirm to proceed to step 8 (see page 38).

7.13. STEP-8 STANDBY MODE AFTER DRAINAGE

The system is inactive and is waiting for user prompt for further steps. After a 30 second time delay if OEC pressure does not reach its final vacuum set point PO, the unit will move back to step 2 (see page 35).

After a 5 minute time delay if no action was taken the system will move to step 1 OFF (see page 35).

Table 8-1: VRMU Control

ITEM #	TAG	NAME	VRMU STATUS/MODES							
			ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8
1	PV-6801	VRMU INLET CONTROL VALVE	0 (NC)	0→1	0→1	0	0	N/A	0	0
2	HV-6821	P-6801 INLET VALVE	1 (NO)	1	1	1	1	N/A	1	1
3	HV-6820	P-6801 OUTLET VALVE	1 (NO)	1	1	1	1	N/A	1	1
4	HV-6823	C-6802 BYPASS VALVE	1 (NC)	0	1	1	1	N/A	1	1
5	HV-6819	C-6802 INLET VALVE	1 (NO)	1	0	1	1	N/A	1	1
6	HV-6818	C-6802 OUTLET VALVE	1 (NO)	1	1	1	1	N/A	1	1
7	HV-6834	HE-6803 NCG RELEASE VALVE	1 (NO)	1	1	1	1	N/A	1	1
8	NV-6809	V-6802 DRAIN VALVE	0 (NC)	0	0	0	1	N/A	0	0
9	NV-6810	P-6803 AIR INLET VALVE	0 (NC)	0	01	0	1	N/A	1	0
10	PV-6834	V-6802 PRESSURE CONTROL VALVE	0 (NC)	0→1	0→1	0→1	0→1	N/A	0→1	0→1
11	HV-6817	V-6801 DRAIN VALVE	0 (NC)	0	0	0	0	N/A	1	0
12	M-6801	VACUUM PUMP MOTOR	0	1	1	0	0	N/A	0	0
13	M-6802	COMPRESSOR MOTOR	0	1	0	0	0	N/A	0	0
14	M-6803	FAN MOTOR	0	1	0	0	0	N/A	0	0

7.14. OEC NITROGEN PURGING

In the previous steps the VRMU achieves the required OEC vacuum set point. Proceed with this action only after concluding all the previous steps. At this stage the OEC is under vacuum pressure.

To purge the OEC with Nitrogen (if required) carry out the following steps:

1. Connect a drain/vent from evacuated vessel at the OEC to a nitrogen container.
2. Open the above drain/vent and using nitrogen fill the OEC until it reaches atmospheric pressure (~ 15 Psia).
3. Close the drain/vent.
4. On the HMI screen click on Step 3 (see page 37) and click Start.
5. The vacuum pump (P-6801) evacuates the OEC MF and the nitrogen mixture.
6. If no other action is required the system will revert to Step 1 Standby Mode (see page 35).

8. MAINTENANCE PROCEDURES

The VRMU consists of vacuum and pneumatic pumps, knock out drums, tanks, condensers, valves and connecting pipes. All these components require maintenance to ensure integrity of the system. The main maintenance points are listed below. Refer to the detailed maintenance for each component as required.

8.1. VACUUM PUMP

1. MAINTENANCE AFTER INITIAL 50 HOURS OF OPERATION

   After the initial 50 hours of operation, a few maintenance requirements are needed to rid the system of any foreign materials. Perform the following maintenance operations to prevent unnecessary problems:

   a. Clean the return line strainer.
   b. Clean the return line orifice if so equipped.

2. MAINTENANCE EVERY 4000 HOURS

   After 4000 hours of operation, it will be necessary to perform the following:

   a. Clean the return line strainer.
   b. Lubricate the Silicon Control linkage.
   c. Drain the sump and change the vacuum pump fluid.

3. FLUID FILTER MAINTENANCE

   Replace the fluid filter element under any of the following conditions, whichever occurs first:

   a. Every 1000 hours.
   b. Every six (6) months.
   c. Every fluid change.

8.2. COMPRESSOR MOTOR

The following table contains a maintenance /inspection schedule for the compressor with relatively clean inlet conditions (no acidic components, filters to 0.1 micron) and 75°F ambient temperature running 8 hours per day. Time frames may need to be shortened in harsher environments.

The gas packings need only periodic inspection once the compressor has been broken in. As the packings are the heart of the leakage control system, it is imperative that they not be allowed to deteriorate beyond reasonable limits. Once the lifetime of the packings is known in an application, they can be replaced prior to failure.

Inspection/Action	Daily	Weekly	Monthly	6 Months	Yearly
Visually check the compressor	X				
Check oil pressure	X				
Check discharge pressure	X				
Drain the condensate from piping system, drain legs and air receiver	X				
Check for oil in distance piece		X			
Check the crankcase oil pressure		X			
Check for leaks in the piping system		X			
Manually operate all safety valves			X		
Clean cylinder, intercooler and after cooler cooling surfaces			X		
Check "V" belt tension			X		
Replace intake filter element				X	
Change oil and oil filter*				X	
Inspect valves, replace gaskets on reassembly				X	
Inspect un-loader diaphragms/pistons				X	
Inspect all control switches				X	
Inspect motor starter contacts					X
Lubricate motor bearings in accordance with manufacturer's recommendations**					X
Replace rings, valves, packings, oil scrapers					X

* Oil and filter should be changed every 2000 hours or 6 months, whichever occurs first. Units without an oil filter should be changed every 1000 hours or 6 months whichever occurs first.

** Humid climates and certain operation conditions can cause moisture to be drawn into the motor. The motor should be run on a clear day without the V-belts for at least an hour. During this time the motor should heat up enough to vaporize the moisture within the motor.

8.3. PNEUMATIC PUMP

This pump has minimum maintenance. Pay attention to the following:

1. AIR SUPPLY

   Air supply pressure cannot exceed 125 psi (8.6 bar).

2. AIR VALVE LUBRICATION

   The air distribution valve and the pilot valve are designed to operate WITHOUT lubrication. This is the preferred mode of operation. Proper lubrication requires the use of an air line lubricator (available from Warren Rupp) set to deliver one drop of SAE 10 non-detergent oil for every 20 SCFM (9.4 liters/sec.) of air the pump consumes at the point of operation.

3. AIRLINE MOISTURE

   Water in the compressed air supply can create problems such as icing or freezing of the exhaust air, causing the pump to cycle erratically or stop operating. Reduce the water in the air supply.

4. AIR INLET AND PRIMING

   To start the pump, open the air valve approximately 1/2" to 3/4" turn. After the pump primes, the air valve can be opened to increase air flow as desired. If opening the valve increases cycling rate, but does not increase the rate of flow, cavitation has occurred. The valve should be closed slightly to obtain the most efficient air flow to pump flow ratio.

5. MAINTENANCE BETWEEN USES

   When the pump is used for materials that tend to settle out or solidify when not in motion, the pump should be flushed after each use to prevent damage.

   In freezing temperatures the pump must be completely drained between uses in all cases.

8.4. VRMU VENTING BEFORE MOVING THE UNIT

NOTE: Use eye protection when carrying out the following procedure.
The VRMU may be moved between locations only after any hazardous remnants of MF have been purged from the VRMU with clean air. To purge proceed as follows:

1. VRMU is in standby mode (Step-1 STANDBY MODE on page 35), verify PV-6801 is closed.
2. Disconnect inlet valve flange PV-6801.
3. Carry out STEP-2 EVACUATION (see page 35) and STEP-3 NITROGEN EVACUATION (see page 37). Run for one hour and shut down the unit. This allows the VRMU to take in air via PV-6801 and purge it through PV-6834 to the dedicate3d safe location vent.
4. To release or break the pressure in the MF liquid accumulator (V-6802) carry out the following step manually from the HMI:

   CAUTION: Stay away from VRMU MF discharge flange.

5. Manually open valve NV-6809. This releases the pressure in the MF liquid accumulator (V-6802).
6. After releasing the MF liquid accumulator pressure open the 1" NPT venting plug on top of the tank (V-6802), open the accumulator drain valve (NV-6809) and activate the drainage diaphragm pump by opening air inlet valve (NV-6810).
7. Verify air inlet pressure regulator (PCV-6810) to 9 psi (6 barg).
8. Allow the pump to purge the piping for five minutes. Shut off the diaphragm pump .by closing NV-6810.
9. Set all valves to standby mode. Refer Step-1 STANDBY MODE on page 35.

9. TROUBLESHOOTING

9.1. WARNINGS AND ALARMS

REFERENCE P&ID DRAWING NO.

7.013.00.068.0

The VRMU issues the following alarms and warnings:

Table 10-1 Alarms and Warnings

Tag No.	Description	Set Point	Trip Warning Information	Note	Severity	Action
PT-6804	Knock out drum high pressure	10 Psia	Warning			
PT-6804	Knock out drum high pressure	23 Psia	Trip	P2		
LT-6806	Knock out drum high level	98%	Trip			ST 7
LT-6806	Knock out drum high level	90%	Warning			ST7
LT-6806	Knock out drum low level	5%	Warning	L4 Step 7 only		ST2, ST3
TE-6812	Vacuum pump high discharge temperature	180˚F	Warning			Shut down Unit Cool down
PT-6814	Vacuum pump high discharge pressure	22.2 Psia	Warning			
PT-6816	Compressor high discharge pressure	100 Psia	Warning			
TE-6818	Compressor high discharge temperature	300˚F	Warning			
PT-6821	Accumulator high pressure	100 Psia	Warning			ST1
PT-6821	Accumulator high pressure	130 Psia	Trip			ST1
LGT-6825	Accumulator high level	85%	Trip	Step 2 only		ST5
LGT-6825	Accumulator high level	70%	Warning	Step 2 only		ST5
LGT-6825	Accumulator low level	5%	Warning	L3		ST1, ST2

				Step 5 only		

Note: Trouble shooting and Parts replacement procedures – see Vendor's documentation.

10. PRESERVATION PROCEDURES

10.1. INTRODUCTION

Non-operational equipment is exposed to harsh physical conditions including moisture, corrosion, dirt etc. that can result in equipment damage and deterioration.

The following chapter deals with procedures taken if the power plant or its sub-systems are non-operational (or in storage) for short or long periods of time. This document contains storage and preservation instructions for all items requiring attention.

NOTE: ORMAT SYSTEMS LTD. advises the following storage and preservation procedures. The final professional choice of method lies with the authorized plant personnel after consulting the equipment manuals, evaluating all prescribed and documented methods as well as taking local environmental factors into account.

NOTE: All components stored outdoors should be placed at least 4 inches above ground level.

10.2. SAFETY

WARNING: Follow all operating procedures correctly to avoid personal injury, loss of life and possible equipment damage. Read and refresh safety measures in *Error! Reference source not found.*.

NOTE: Carefully follow storage and preservation work safety instructions. Vendor procedures take preference over documented procedures below. Perform all procedures according to prescribed safety regulations.

10.3. PRESERVATION MATERIALS AND SPECIAL EQUIPMENT

Preservation materials for this procedure are detailed in following table.

Description	Vendor Info./Usage
Vapor Corrosion Inhibitor (VCI) Storage Grease – Corrosion Preventive Emitter Capsule Cortec VC2-1, VC6-2 (Ormat Code #956.160.153.1)	Any approved supplier
VCI Paper bags	Any approvedsupplier
Desiccant bags	Any approved supplier

Required preservation equipment is detailed in following table.

Description	Usage
Strap wrench	Turbine-generator shaft rotation.
Vacuum cleaner	Power and control cabinet internal cleaning.
Megger, 1000 VDC	Insulation resistance testing.
Grease gun	Greasing the bearings and other surfaces.
Low pressure air source kit	Power and control cabinet internal cleaning.
Oil pressure calibration kit	Oil pump relief valve pressure calibration.
Penknife	Packing seal replacement.
Personal protection gear	For personal safety.

10.4. EQUIPMENT STORAGE AND PRESERVATION PROCEDURES

The recommended storage and preservation procedures for the VRMU include the following:

DESCRIPTION	Reference
Motors preservation instructions	MOTOR PRESERVATION INSTRUCTIONS
Valves and pumps preservation instructions	VALVES AND PUMPS PRESERVATION
Electric cables preservation instructions	ELECTRIC CABLES PRESERVATION
Electrical boards, junction boxes, breakers preservation	ELECTRICAL BOARDS, JUNCTION BOXES,
Piping sections preservation instructions	PIPING SECTIONS PRESERVATION
Pipe supports preservation instructions	PIPE SUPPORTS PRESERVATION INSTRUCTIONS

NOTE: During preservation, the following items require lubrication:

- ***Motors***
- ***Pumps***

10.4.1. MOTOR PRESERVATION INSTRUCTIONS

Refer **Error! Reference source not found.**.

NOTE: Do not tight-seal the plastic sheet to avoid internal condensation.

Short term preservation

The recommended preservation procedure for motors not active for a period less than three months is as follows:

1. Attach desiccants or other humidity control methods (VCI capsules) around the motor to minimize condensation. Refer Preservation materials and special equipment
2. Coat all external machined surfaces with a corrosion prevention material, e.g. Exxon Rust Ban #392.
3. Control cabinet and LTC control cabinet heaters must be activated to prevent condensation.
4. Wrap the motors with a plastic sheet.

Long term preservation

The recommended preservation procedure for motors not active exceeding three months is as follows:

NOTE: Do not tight-seal the plastic sheet to avoid internal condensation.

1. Perform all above short term storage requirements for motors preservation. It is preferable that long term motor storage is indoors. Continue as described below.
2. Remove the grease drain plug, (opposite the grease fitting) on the bottom of each end bracket.
3. Apply grease to the fan motors according to the vendor's manual.
4. Rotate TO and MF motor shafts ten revolutions manually every month.
5. Rotate the fan motor shaft at least fifteen manual revolutions every three months after greasing to distribute bearing grease.
6. Seal the motor in an airtight vapor barrier bag with desiccant bags inside. Refer "Preservation materials", page 398.
7. Measure and record the electrical resistance on fan motors winding insulation every three months (as in vendor's manual), and before start up. Measure and record the electrical resistance of TO pumps motors & MF pumps motors only before start up.
8. Log and save the motor data for before start up.
9. Change MF motors bearing oil before start up.

10.4.2. VALVES AND PUMPS PRESERVATION INSTRUCTIONS

Refer **Error! Reference source not found.**.

Perform the following valve and air line preservation procedure:

1. Close the air supply valves leading from the compressor building to the VRMU components. Do not close the air supply.
2. Bleed all water traps on air supply lines.
3. Energize heat tracing before startup.

Control valves

1. Disconnect air supply.
2. Close air vent opening.
3. Clean all surfaces of rust and dirt.

4. Apply storage grease to the valve face ends.
5. Remove nozzle vent covers.
6. Check and exercise the valves once a month.
7. Cover vents nozzles.
8. Attach VCI capsules to each valve.
9. Wrap valves with a plastic sheet.

Manually operated valves

Perform the monthly valve and pump preservation procedure as follows:

1. Clean all surfaces of rust and dirt.
2. Fully open and close the valve manually several times. Ensure free valve rotation.
3. Oil and grease moving part.
4. Place VCI emitter in valve.
5. Wrap valve with plastic sheet.

Pumps

1. Verify storage grease is applied to the motor shaft end, coupling, spacer and all machined surfaces.
2. Attach VCI capsules to the inner surface.
3. Seal the pump ports with plywood covers.
4. Rotate shaft monthly.

Pump motor

1. Verify that storage grease is applied to motor shafts.
2. Connect a power supply to motor space heaters.
3. Rotate the shaft once a month:

WARNING: Ensure adequate ventilation to avoid stator overheating

10.4.3. ELECTRIC CABLES PRESERVATION INSTRUCTIONS

Seal the cable ends with plastic sheets.

10.4.4. ELECTRICAL BOARDS, JUNCTION BOXES, BREAKERS PRESERVATION INSTRUCTIONS

The recommended preservation procedure for electrical boards and breakers is:

1. Keep electrical boards and breakers dry and clean at all times.
2. Disconnect power to the electrical boards, junction boxes and breakers.
3. Vacuum and clean all the electrical boards, junction boxes and breakers every three months (with appropriate detergents). Refer Preservation materials and special equipment.
4. Attach VCI capsules to electrical boards, junction boxes and breakers.
5. Activate space heaters if required.
6. Wrap electrical boards, junction boxes and breakers in plastic sheets.

10.4.5. PIPING SECTIONS PRESERVATION INSTRUCTIONS

1. Grease the flange sealing surfaces with storage grease.
2. Plug each piping section with plywood. Attach a VCI capsule to the inner surface of each pipe section both sides.
3. Cover the piping sections with canvas.

10.4.6. PIPE SUPPORTS PRESERVATION INSTRUCTIONS

Cover pipe supports with canvas.

10.4.7. ON ENDING PRESERVATION PERIOD

As on-site preservation decisions may have been applied in addition to, or in place of ORMAT SYSTEMS LTD. recommendations, a specific set of procedures for preservation termination cannot be detailed. However, the following guidelines are recommended.

1. Remove all protective covers, layers, tagouts, VCI emitters from equipment.
2. Clean equipment.
3. Deactivate heater if required for reactivation process.
4. Replace equipment in operational location and configuration (following all engineering and safety regulations) if it was moved for preservation.
5. If specific oils and lubricants were used for preservation, then and remove these substances and replace with recommended operational oils and lubricants.
6. Ensure all major moving parts path not obstructed.
7. Carefully release all air pressures in preserved systems according to relevant safety procedures.
8. Read through and understand all relevant safety regulations and vendor manuals before activating any power plant equipment.
9. Repressurize systems as required for normal startup and operation.
10. Reactivate systems according to documented procedures, avoid sudden temperature and pressure increases in re-activation.

11. TECHNICAL DIAGRAMS

Figure 11-1 VRMU P&ID

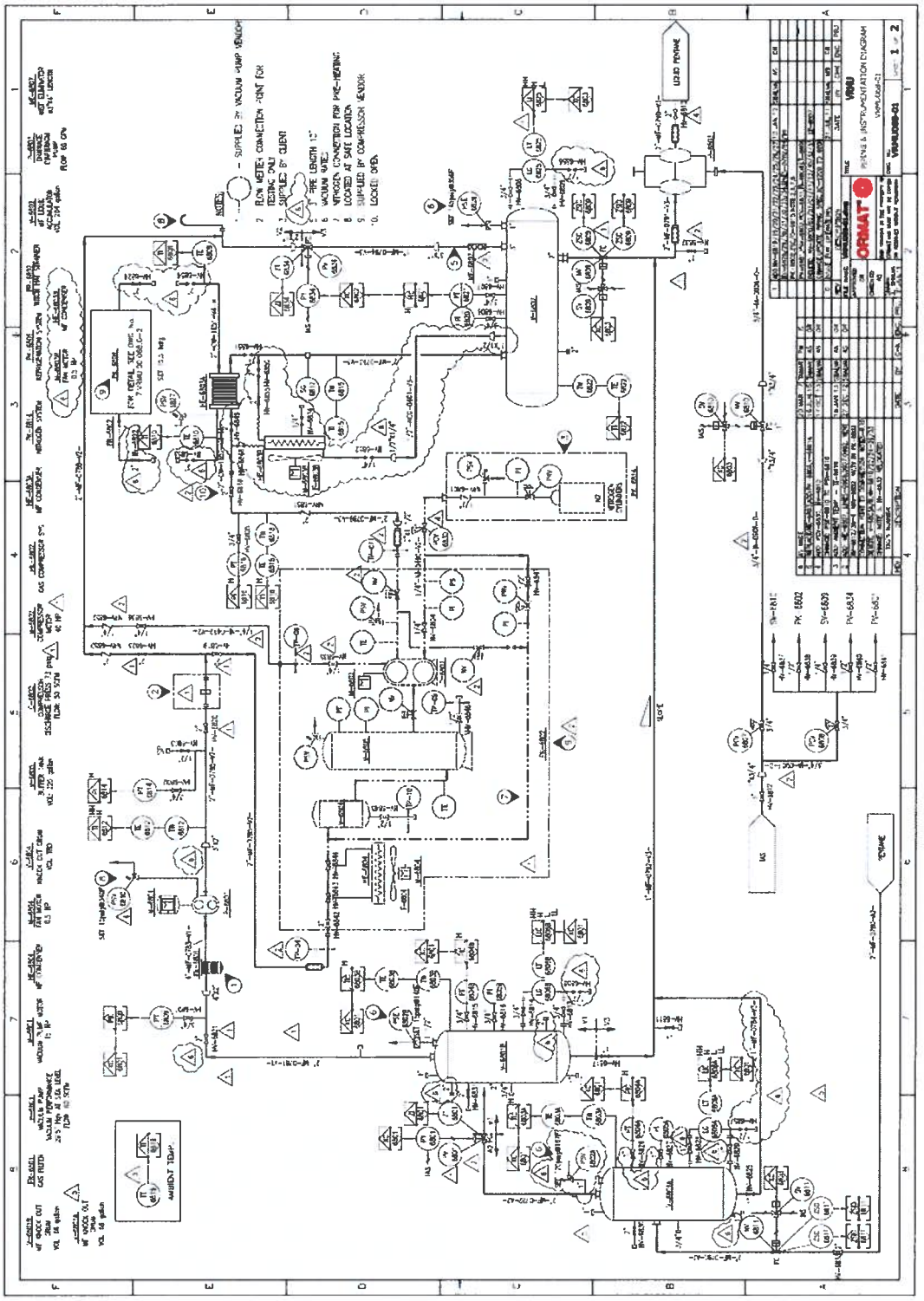


Figure 11-2 Power supply distribution - 2

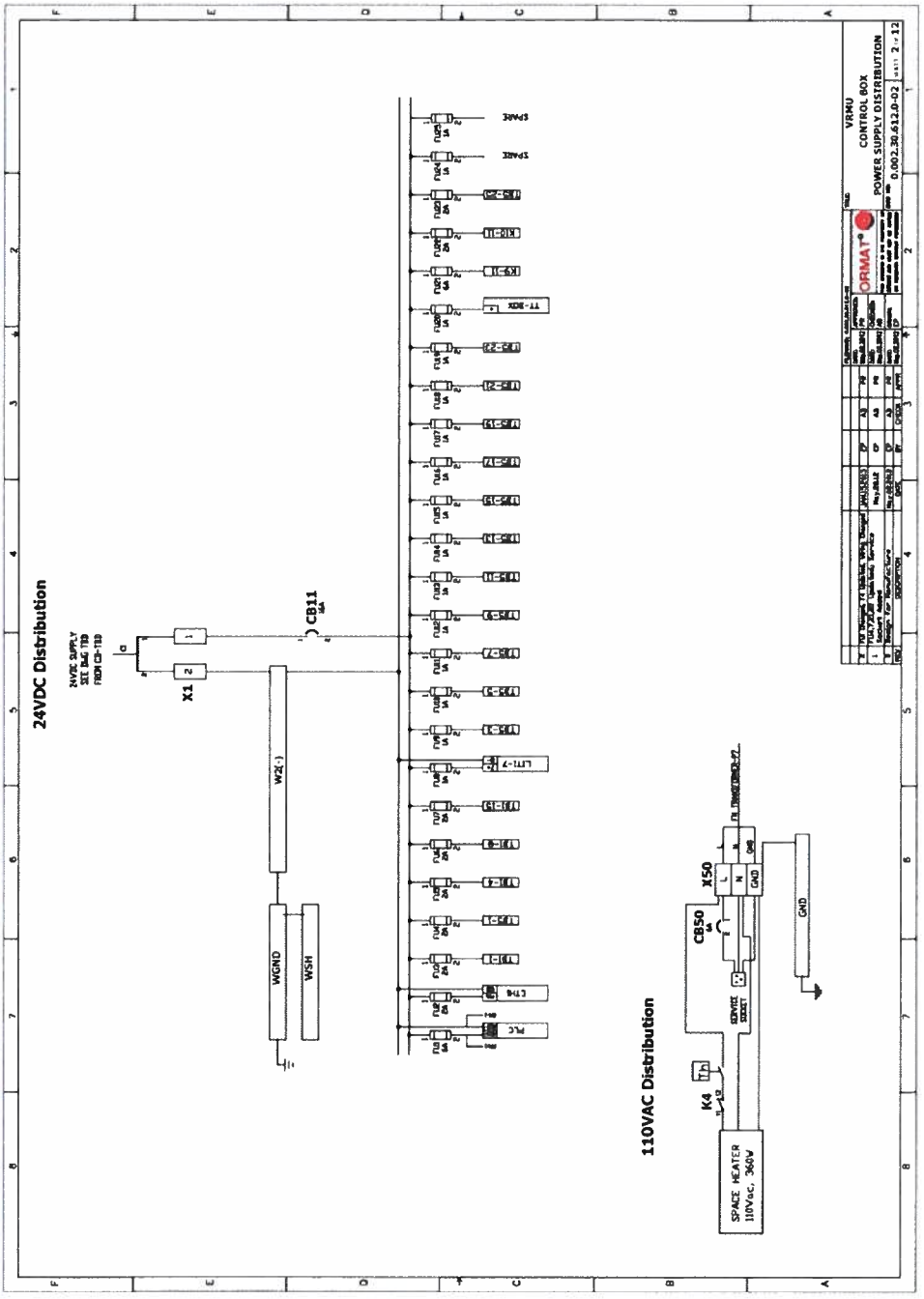


Figure 11-3 Power supply distribution -3

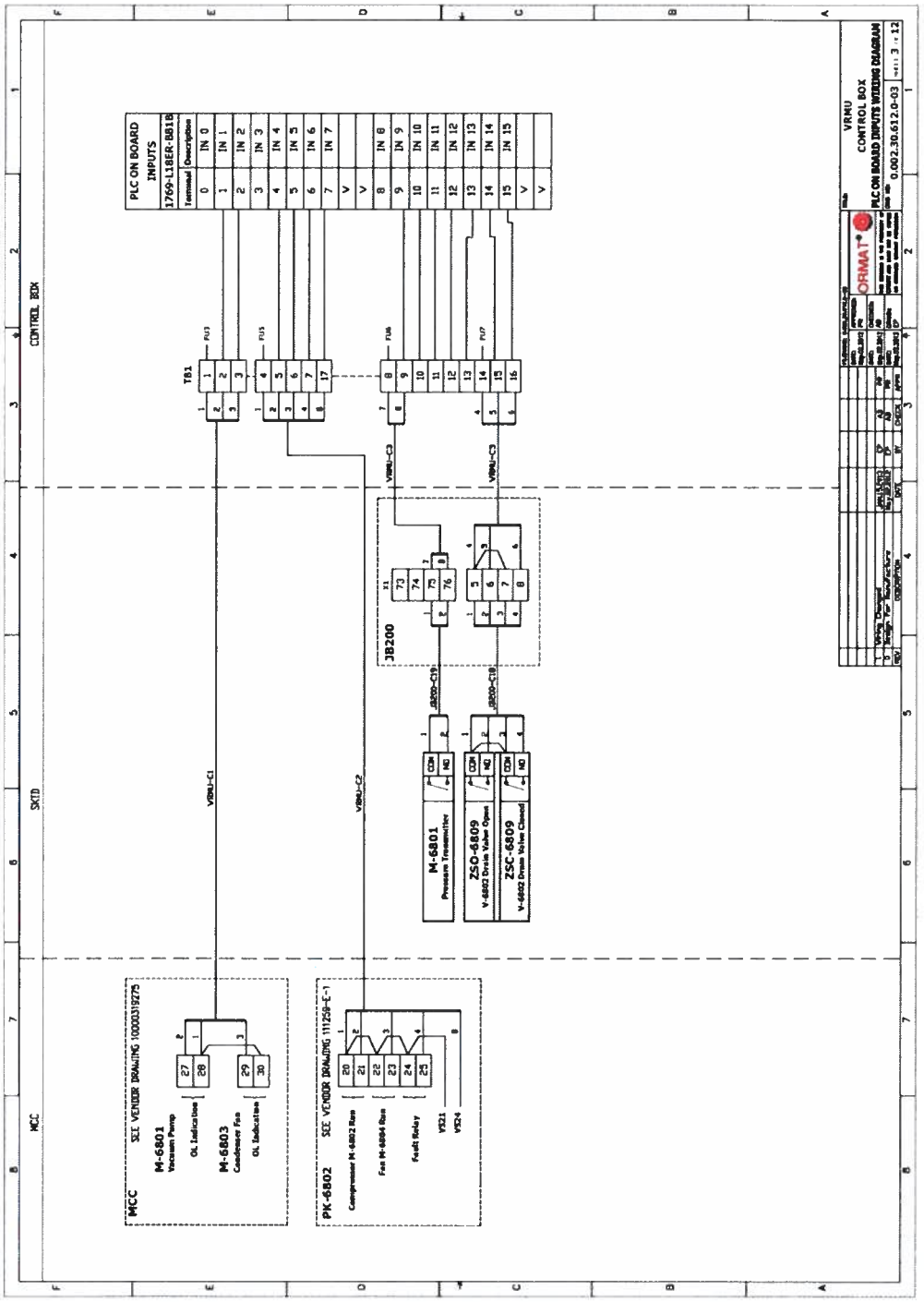


Figure 11-4 Power supply distribution – 4

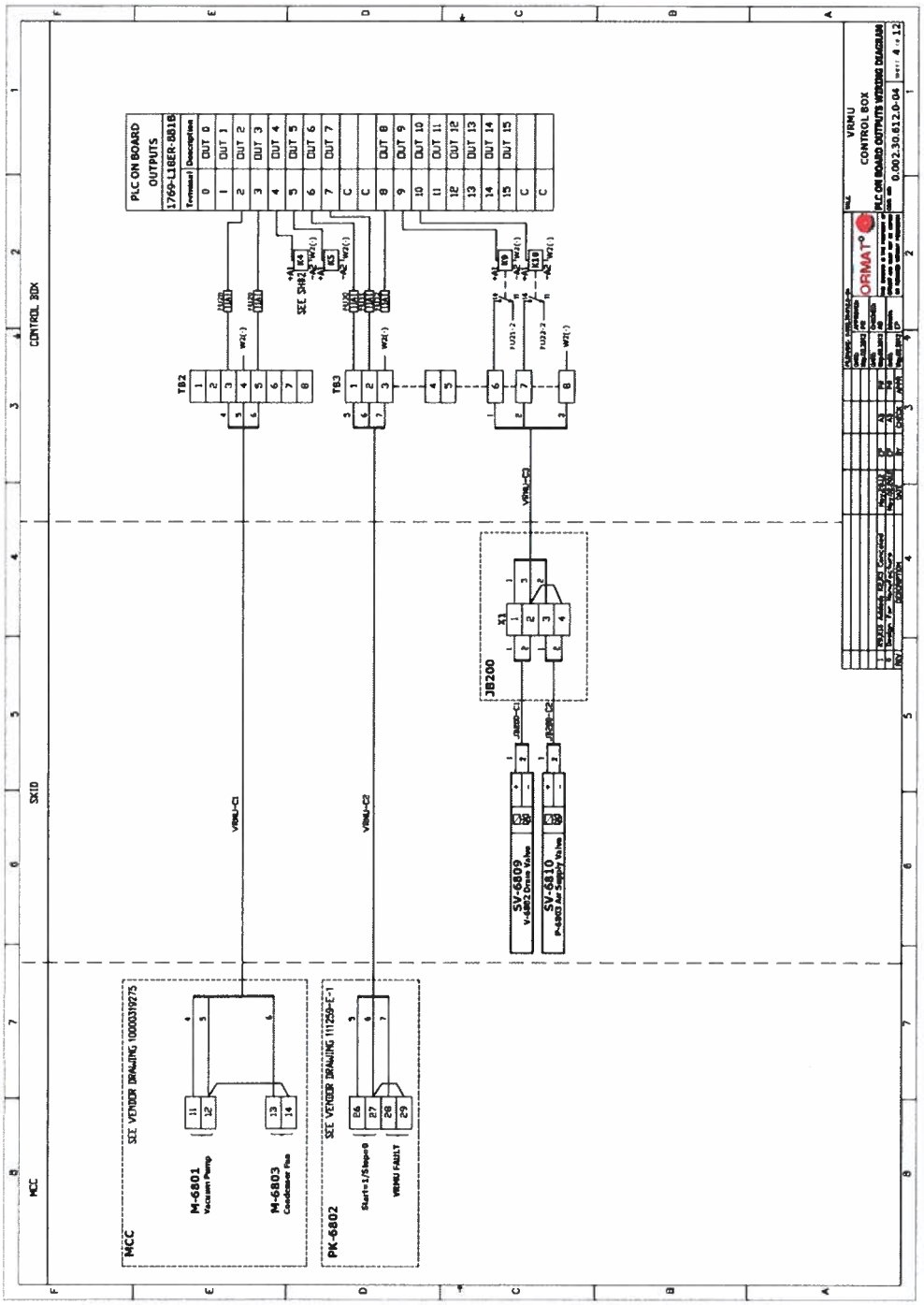


Figure 11-5 Power supply distribution - 5

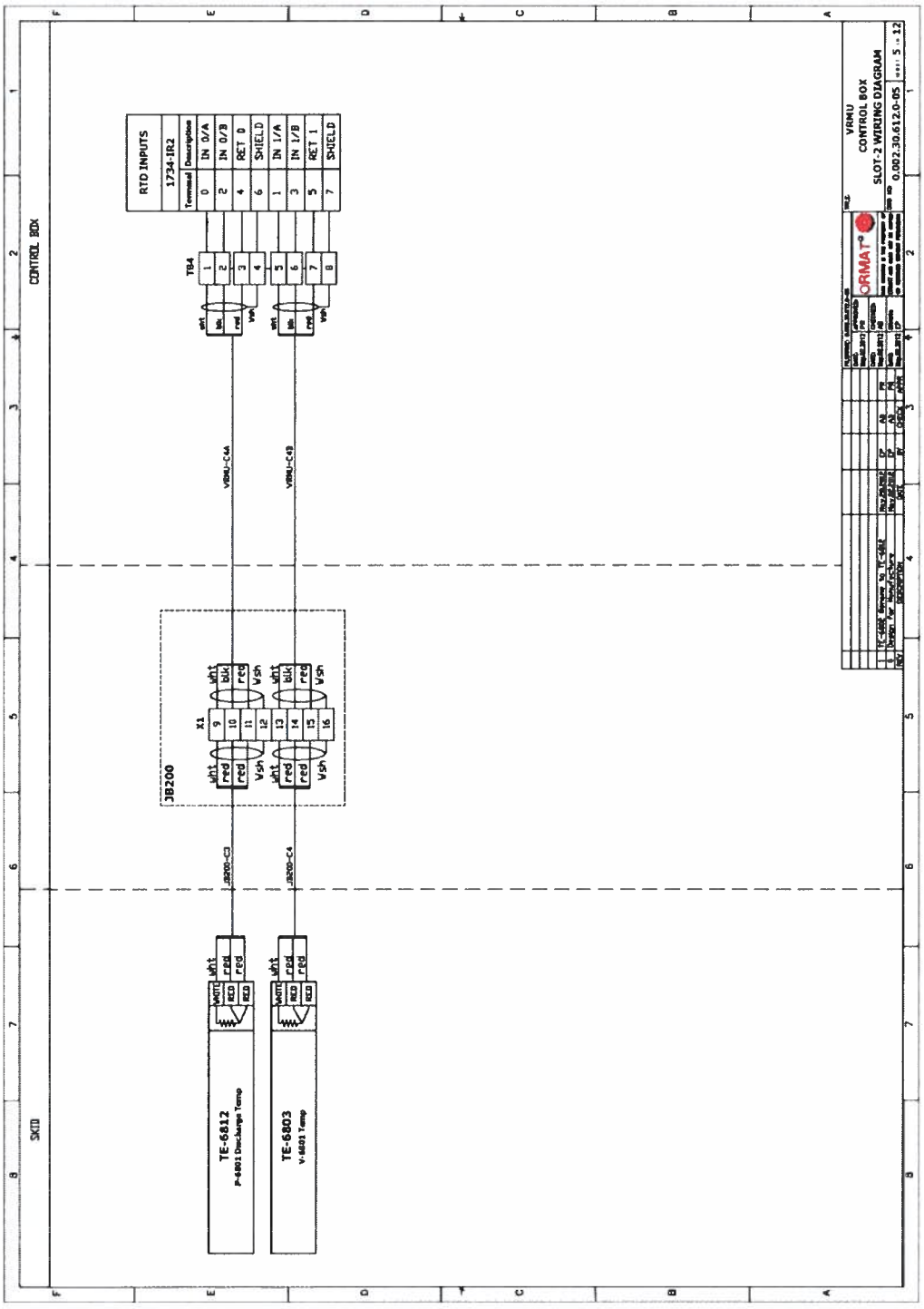


Figure 11-6 Power supply distribution - 6

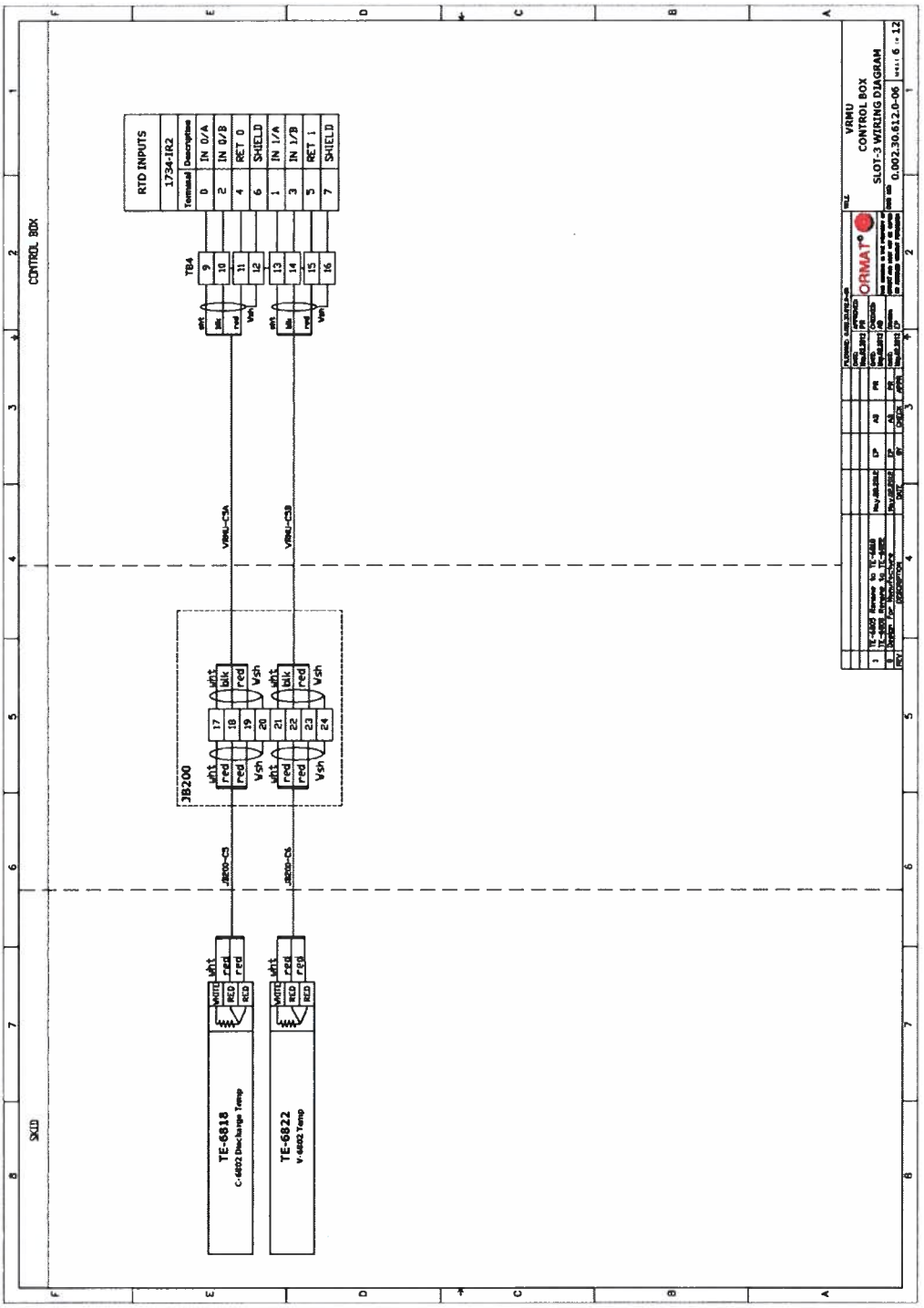


Figure 11-7 Power supply distribution - 7

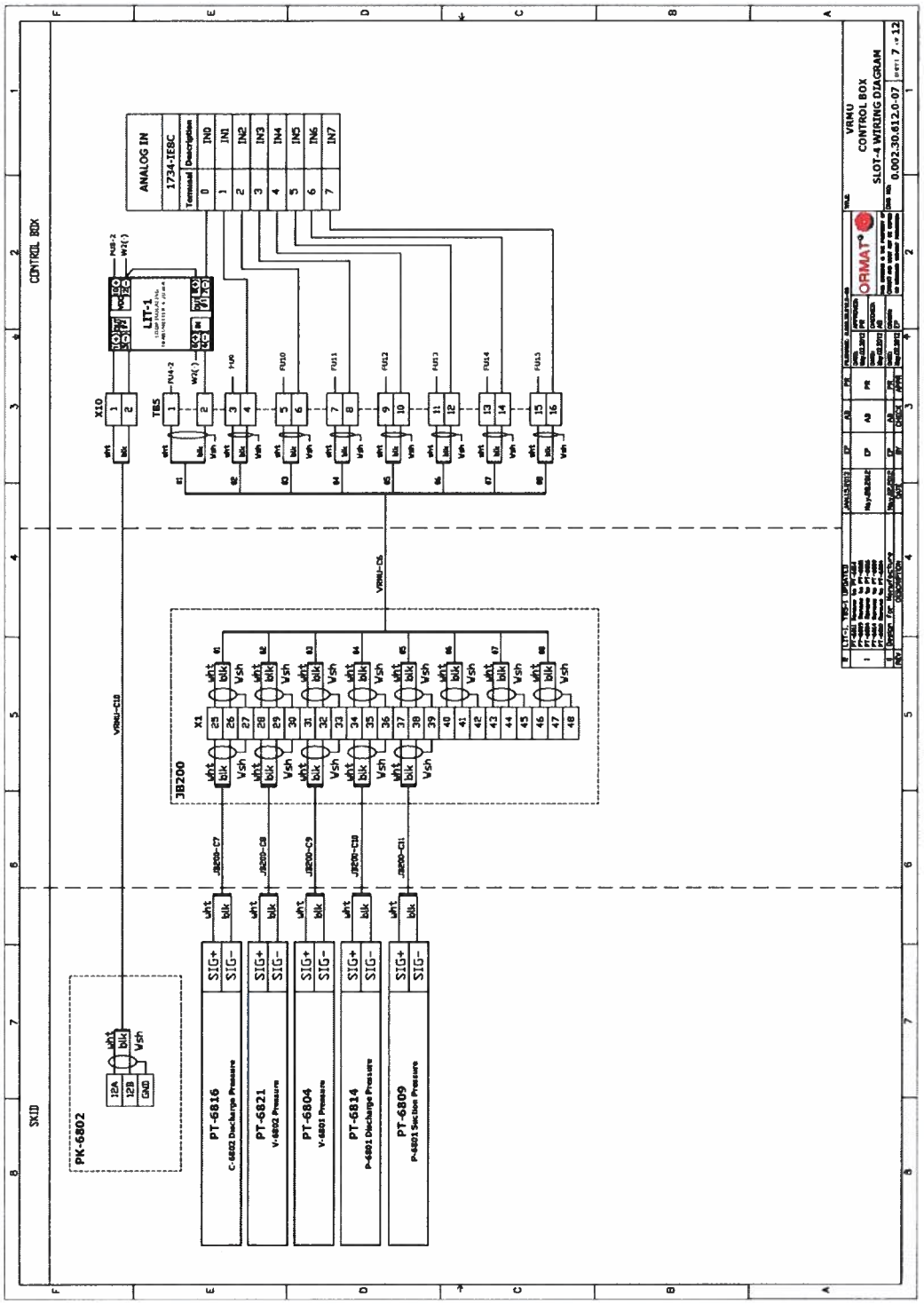


Figure 11-8 Power supply distribution - 8

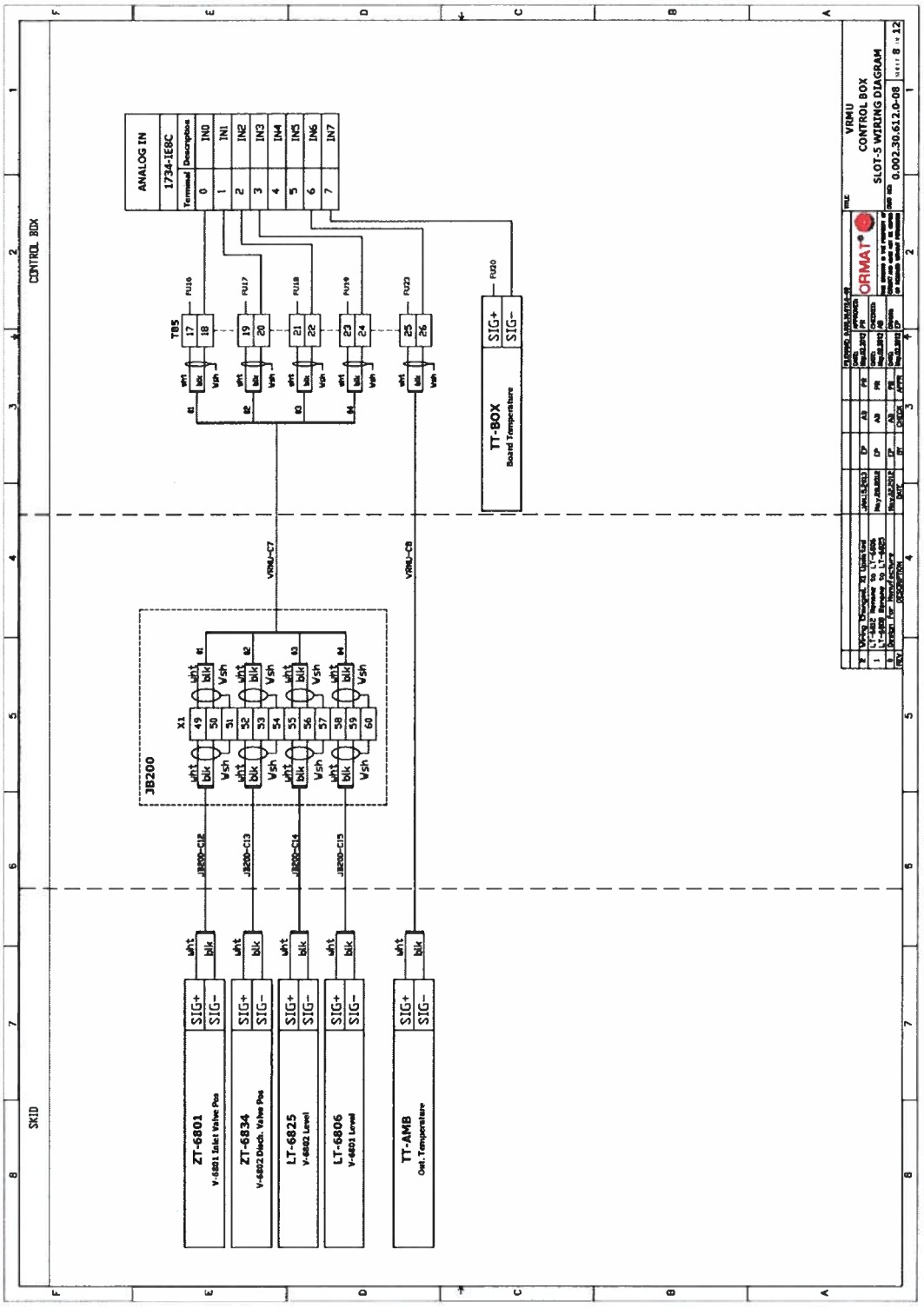


Figure 11-9 Power supply distribution - 9

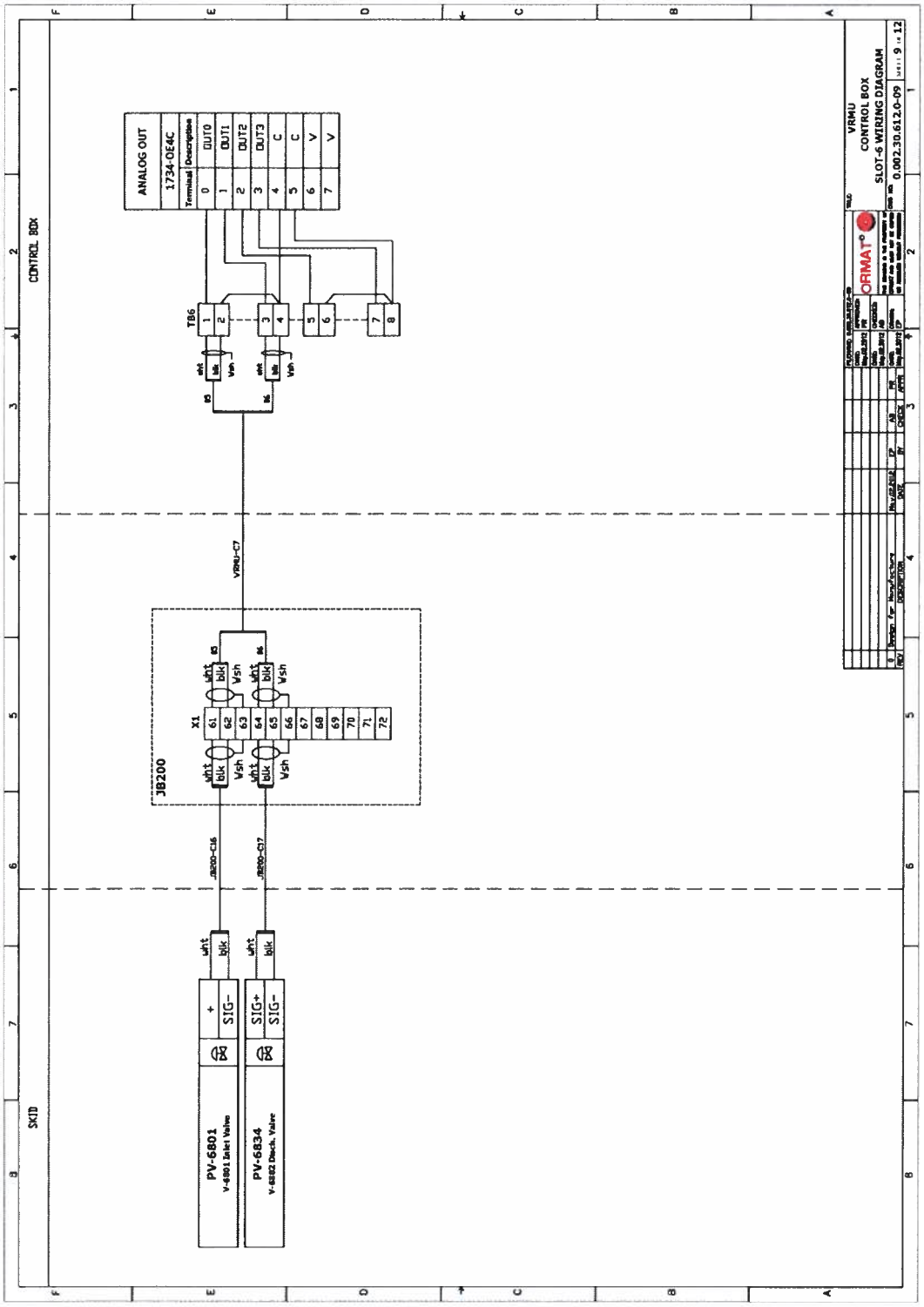


Figure 11-10 Power supply distribution - 10

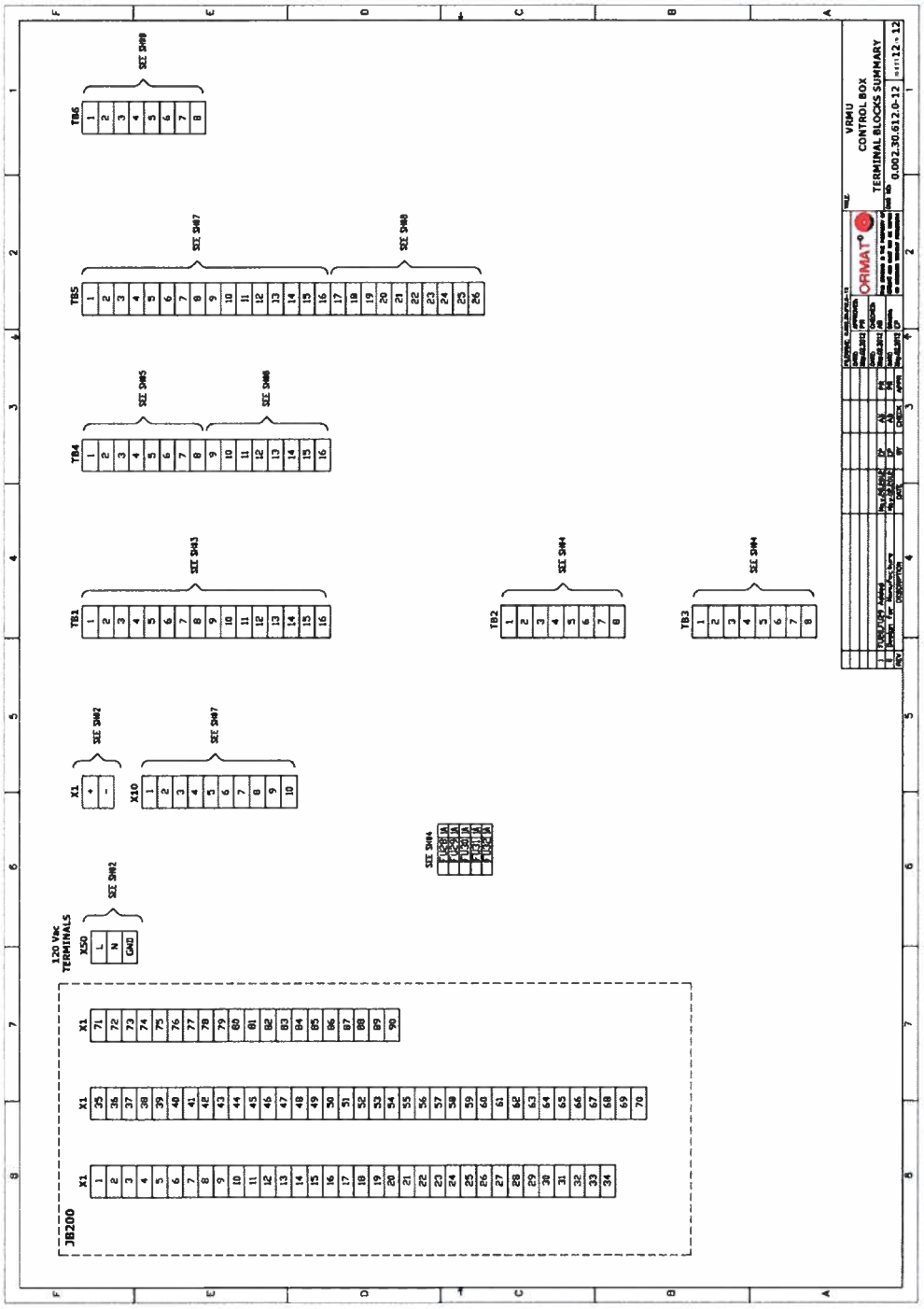


Figure 11-11 U3VRU single line diagram

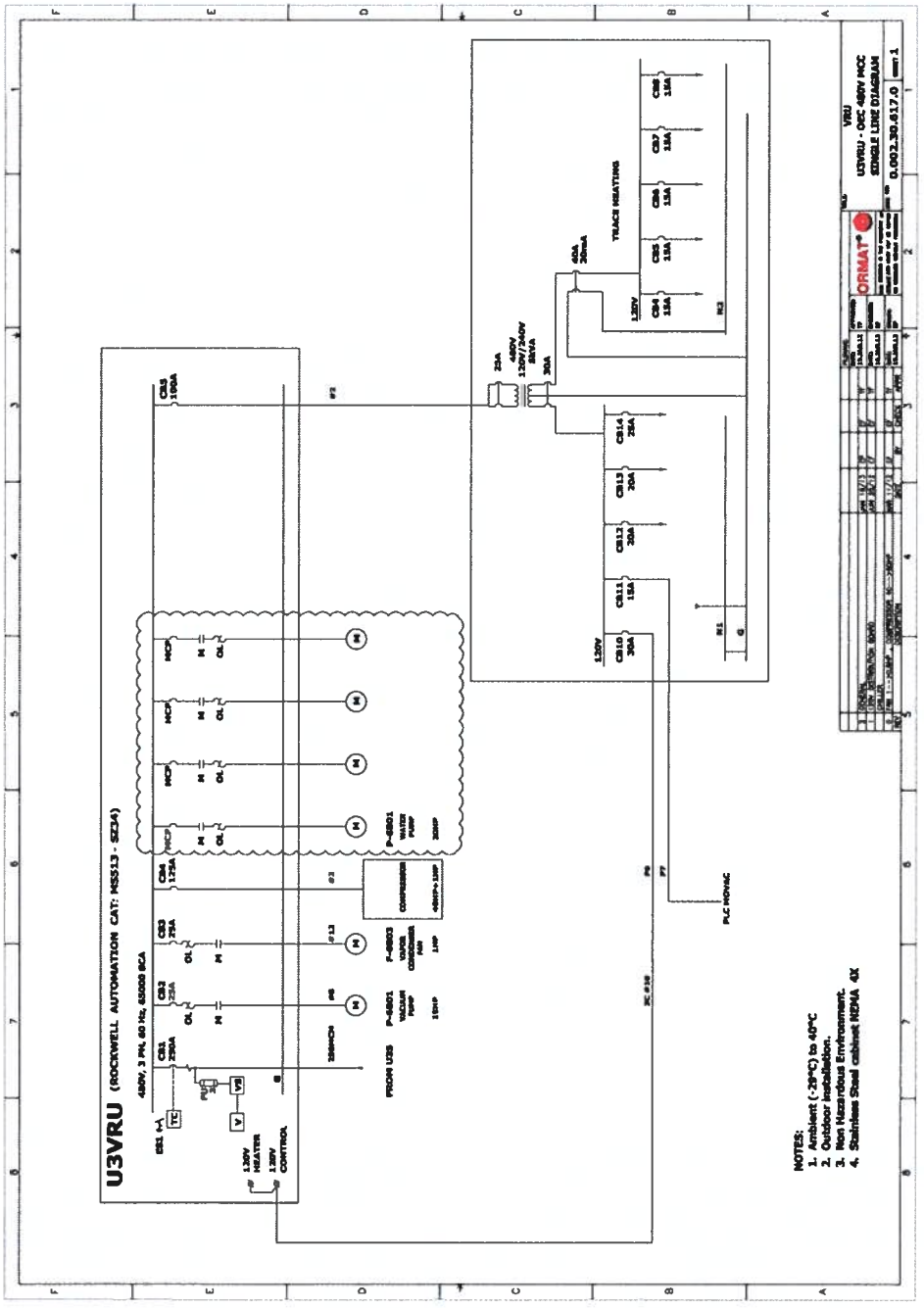


Figure 11-12 VRMU plan

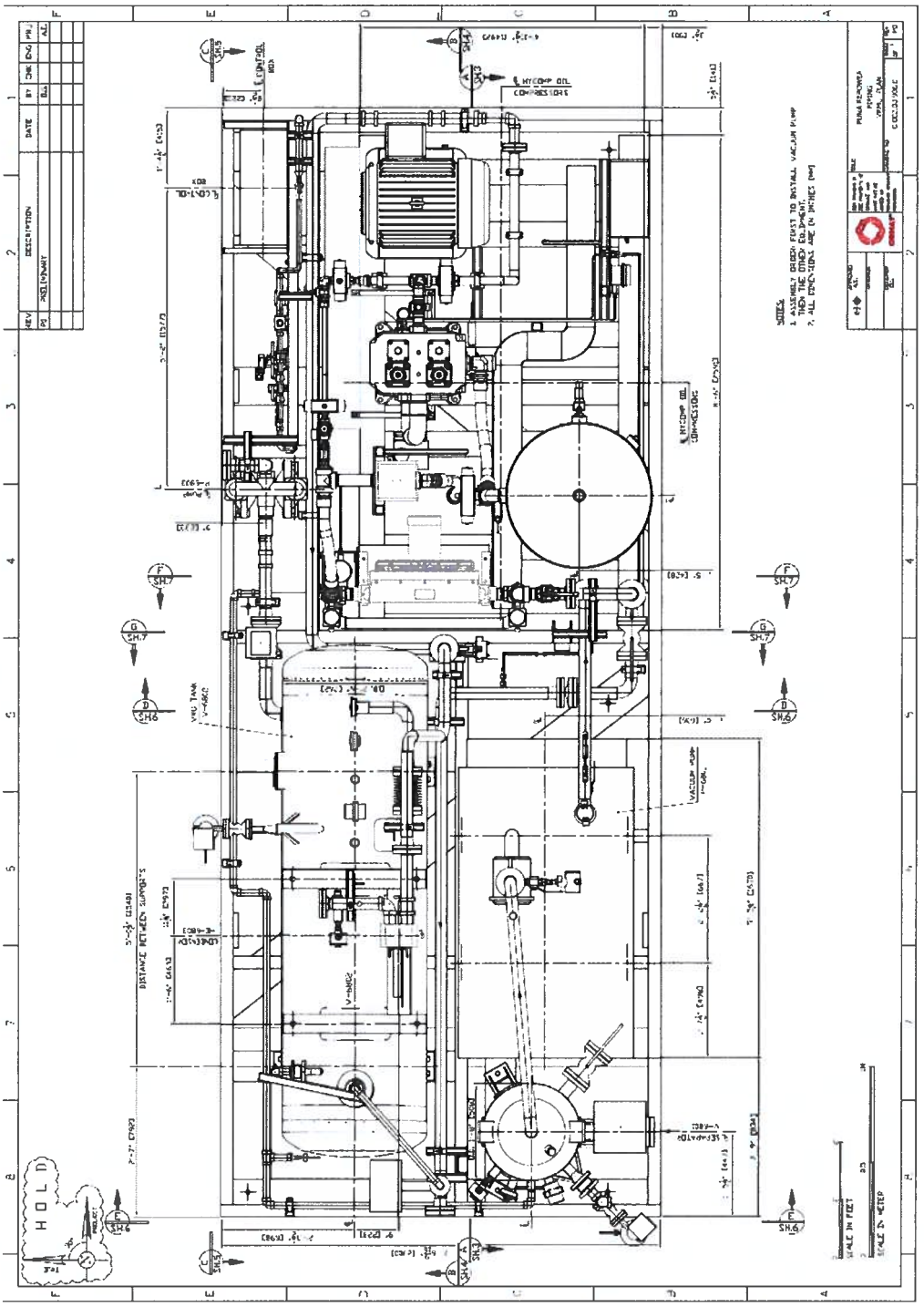


Figure 11-13 VRMU plan – piping

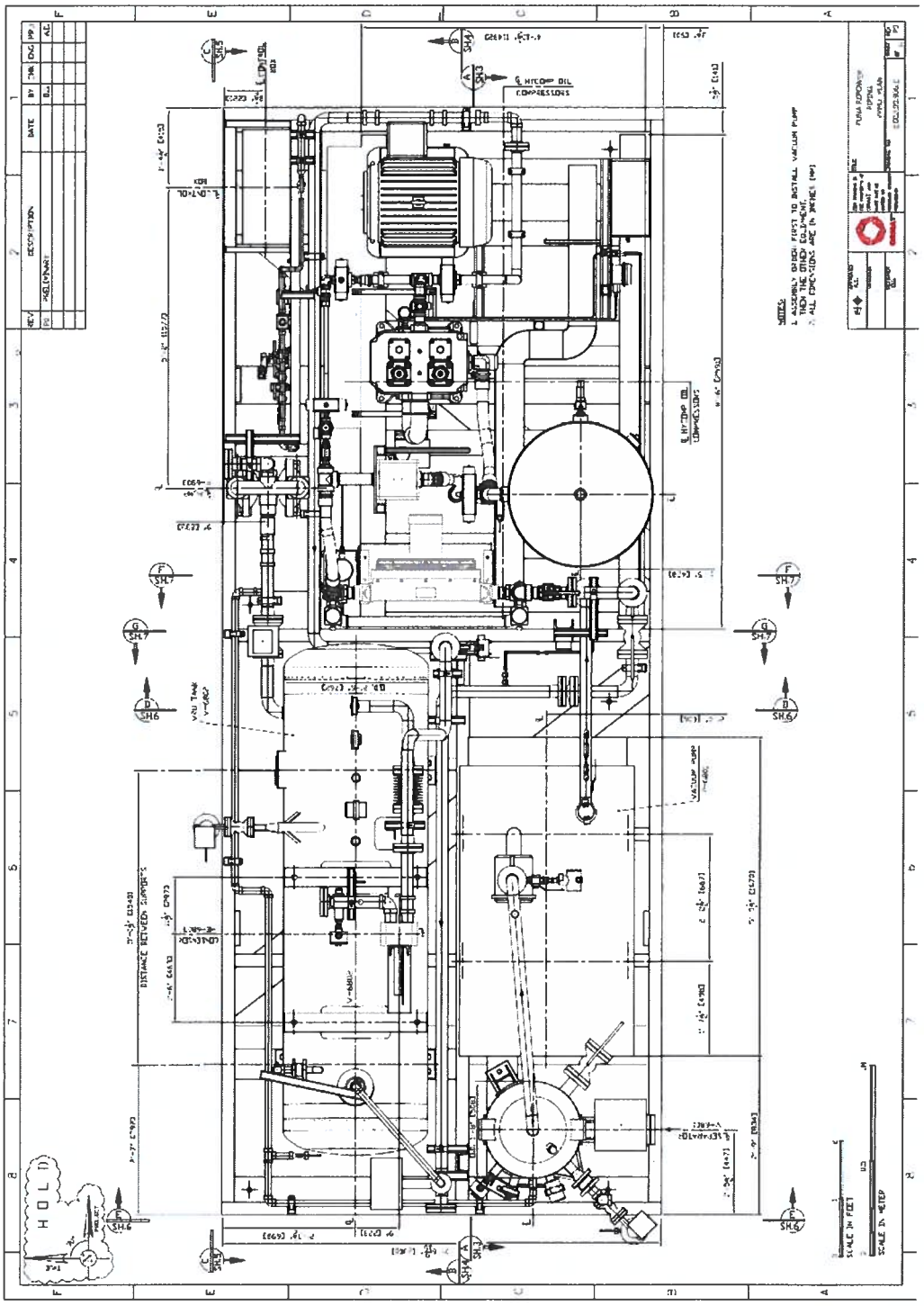


Figure 11-14 VRMU plan – piping

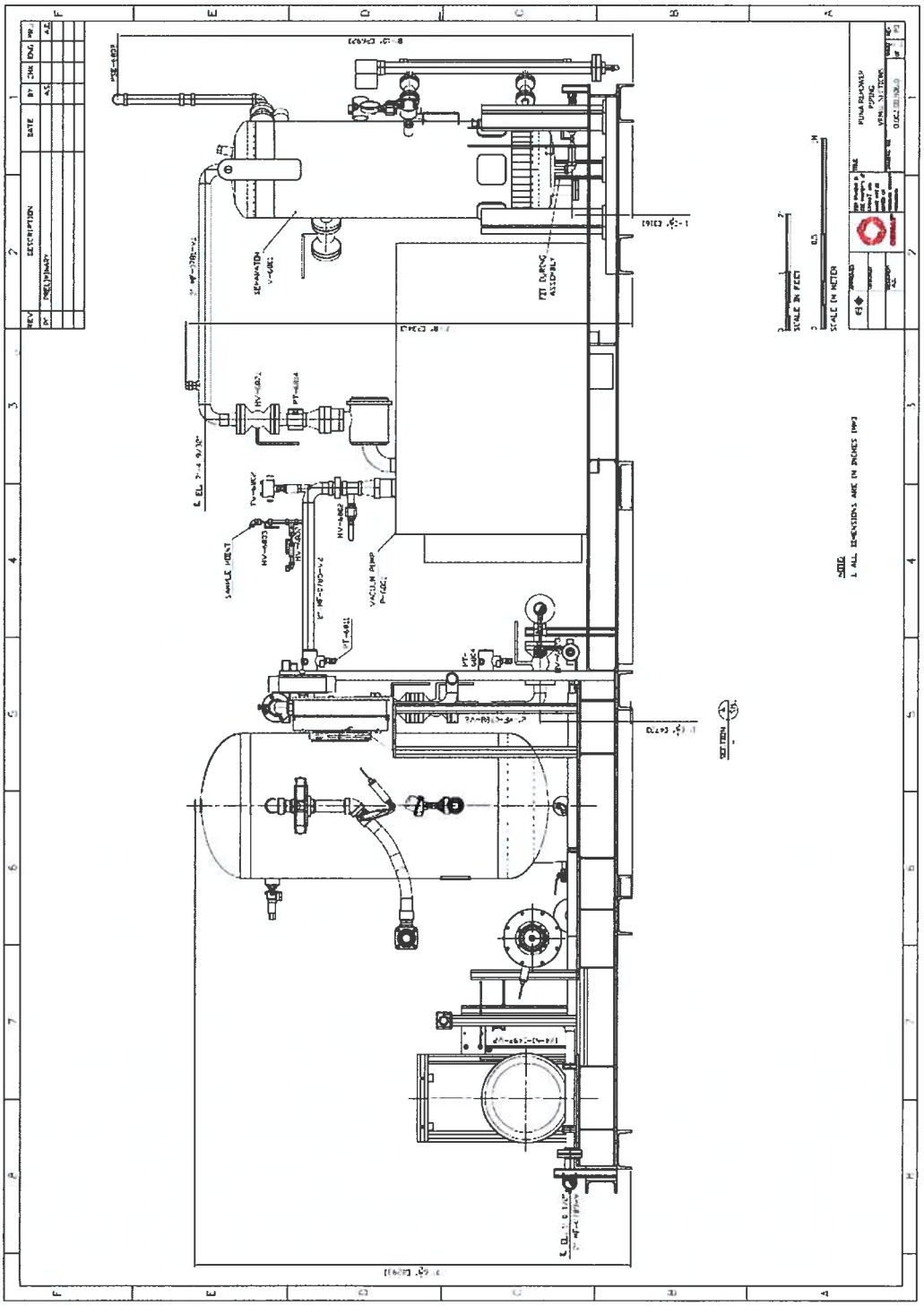


Figure 11-15 VRMU sections – piping

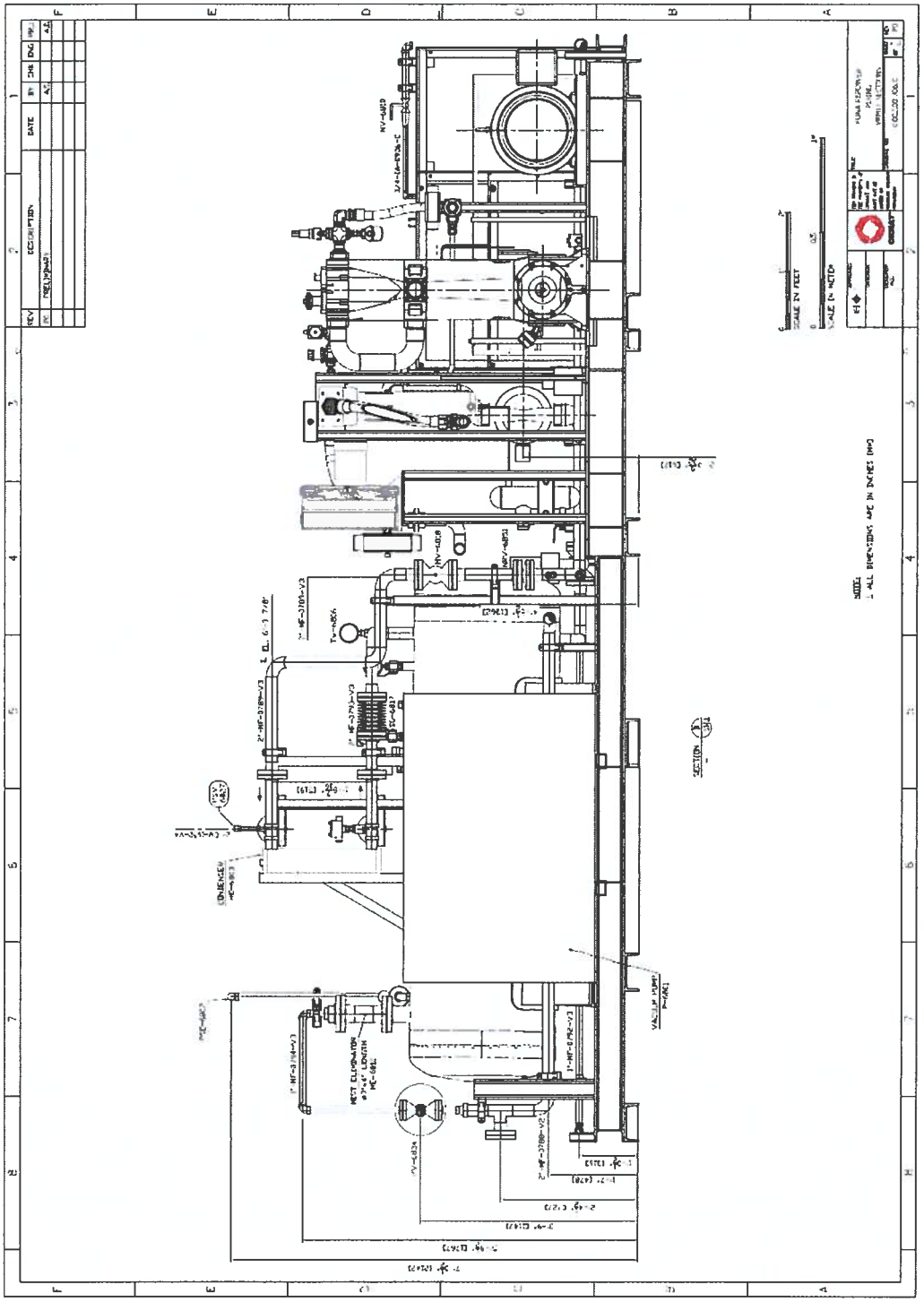


Figure 11-16 VRMU sections – piping

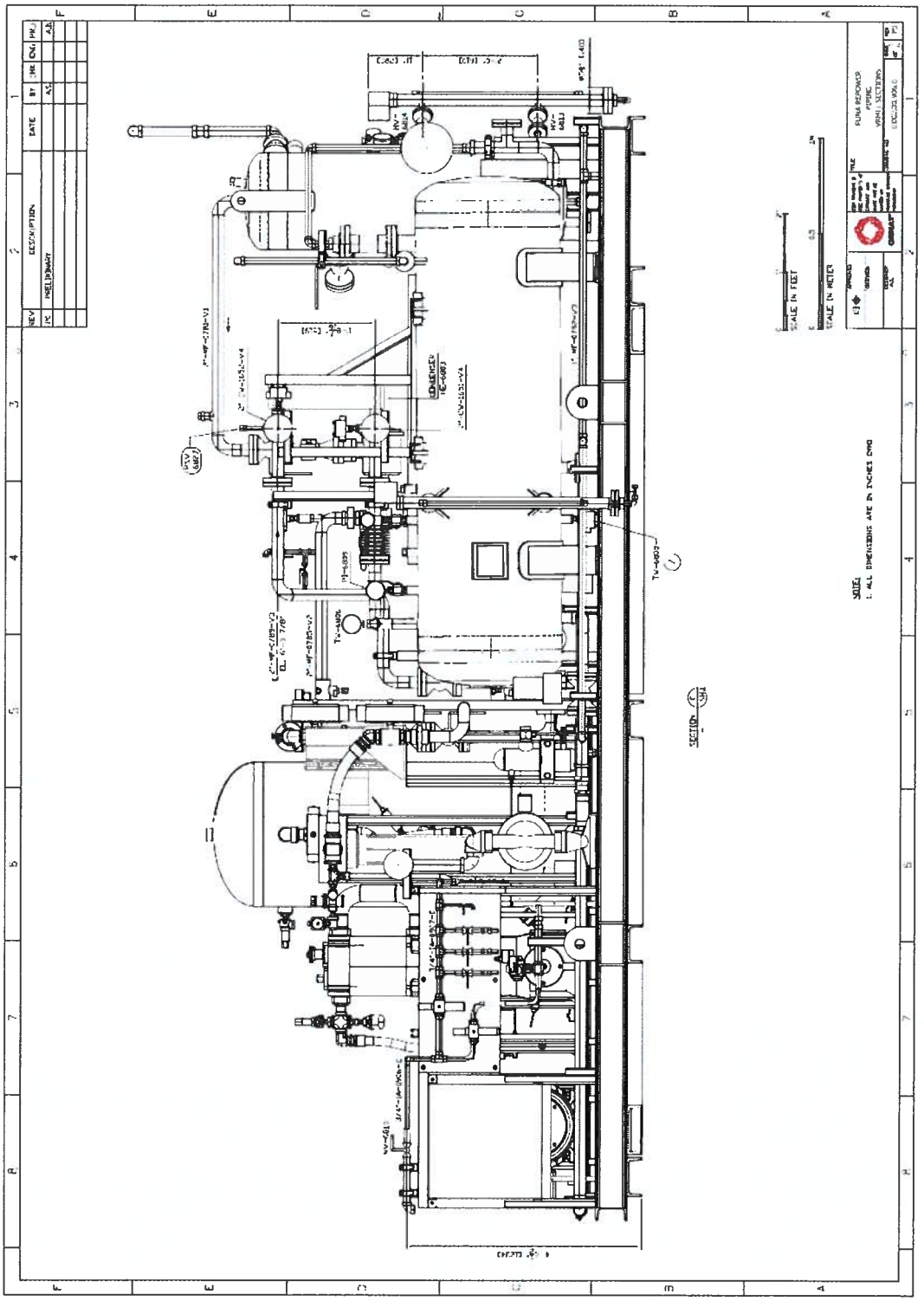


Figure 11-17 VRMU sections – piping

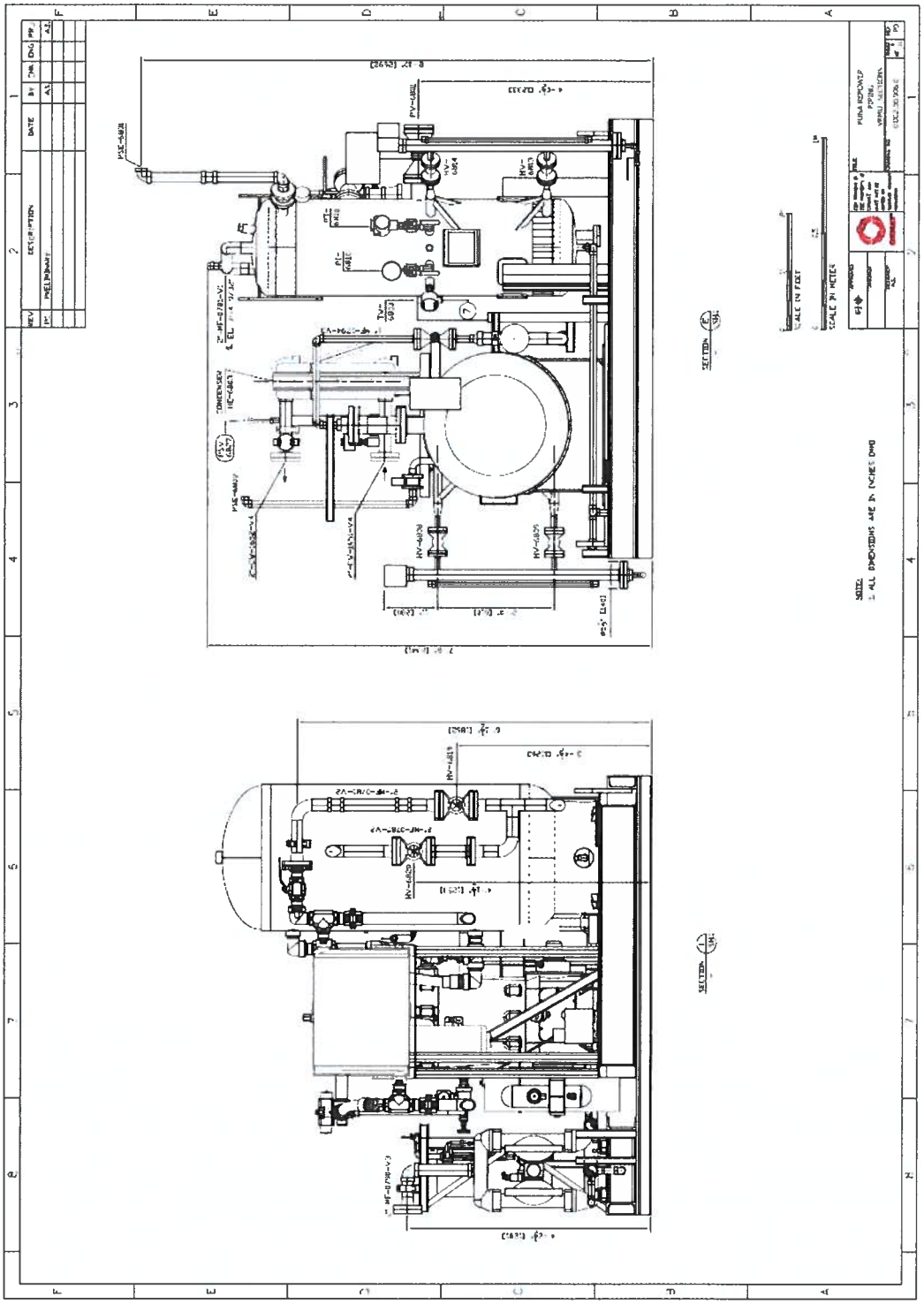


Figure 11-18 VRMU sections – piping

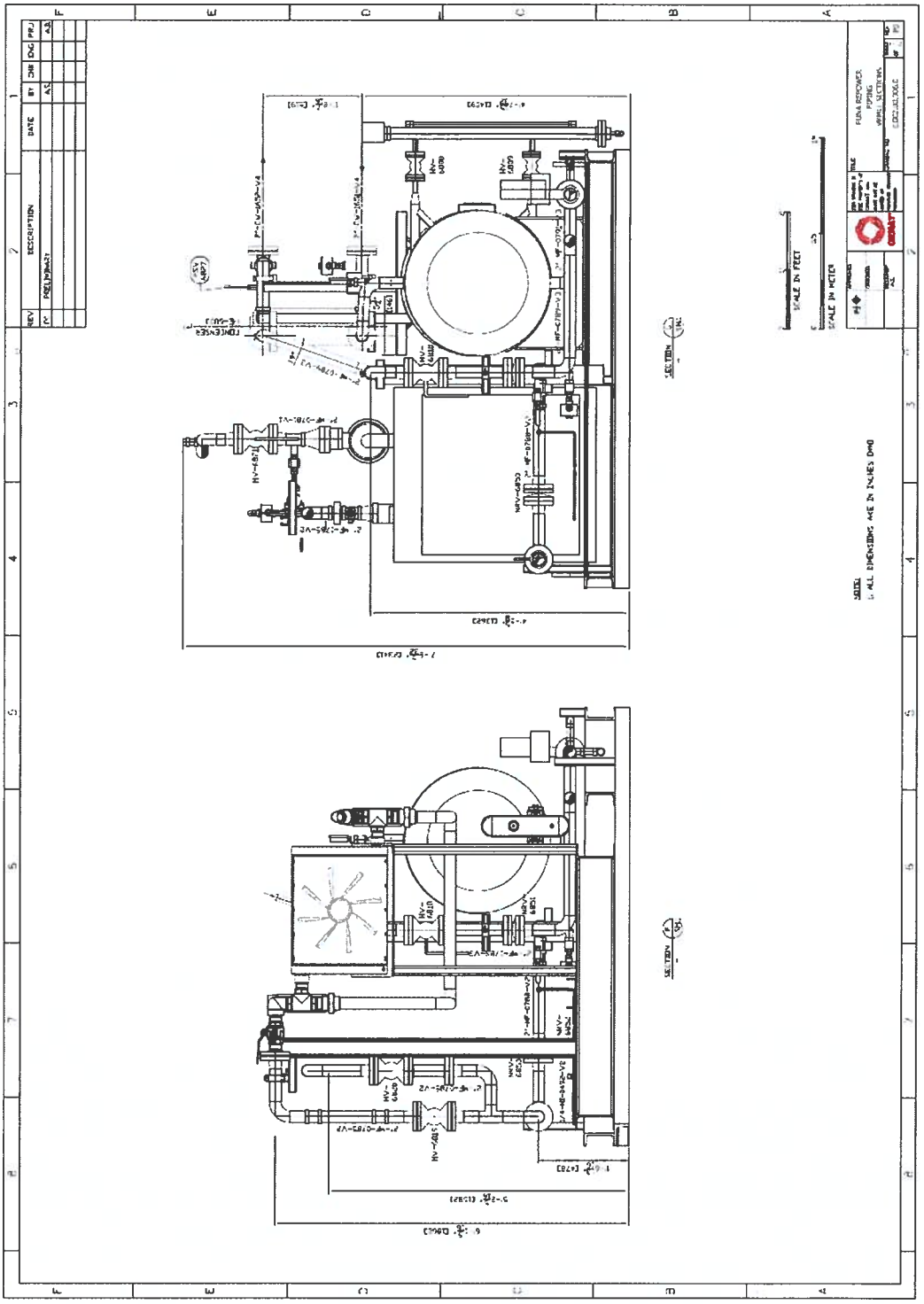
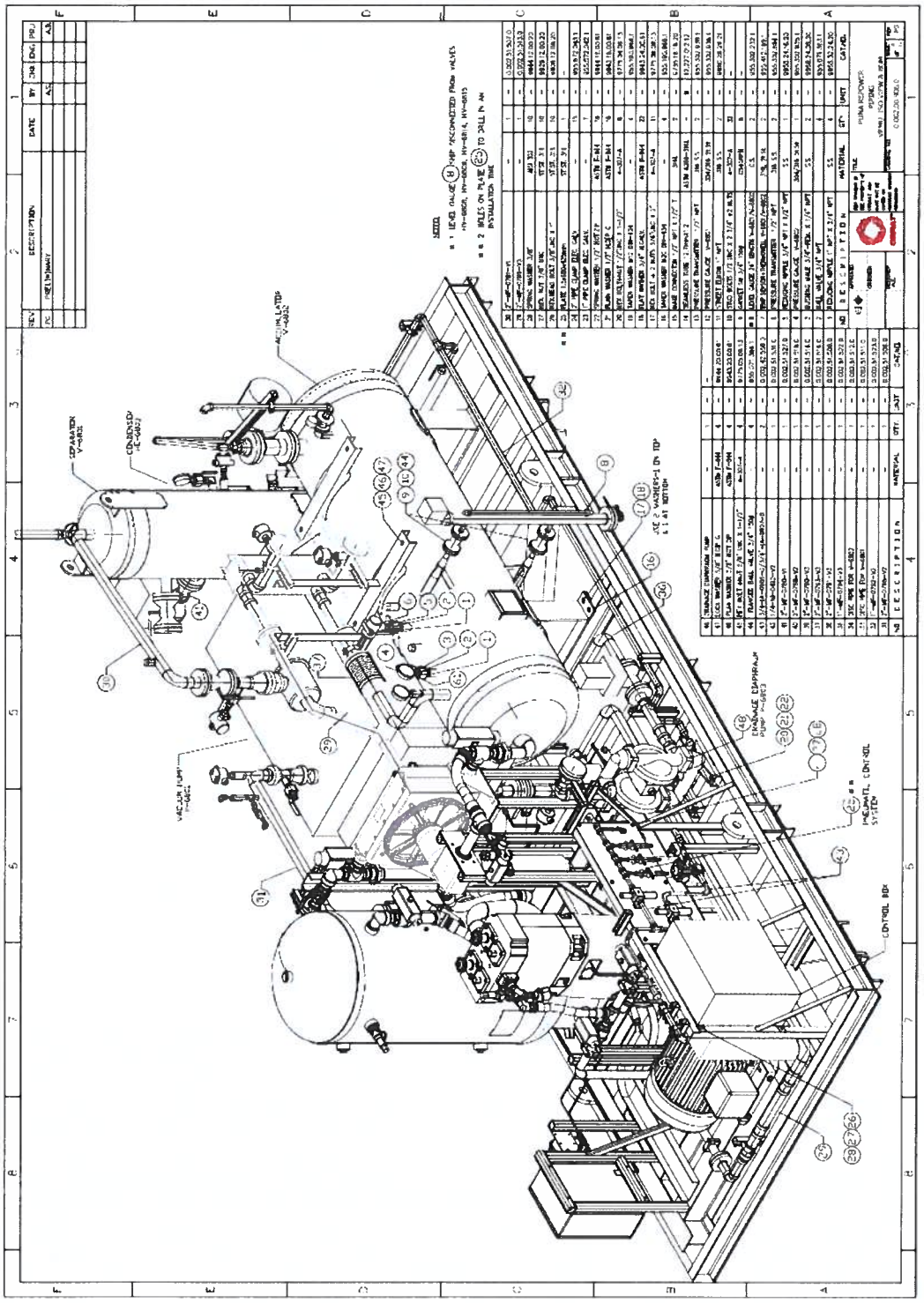
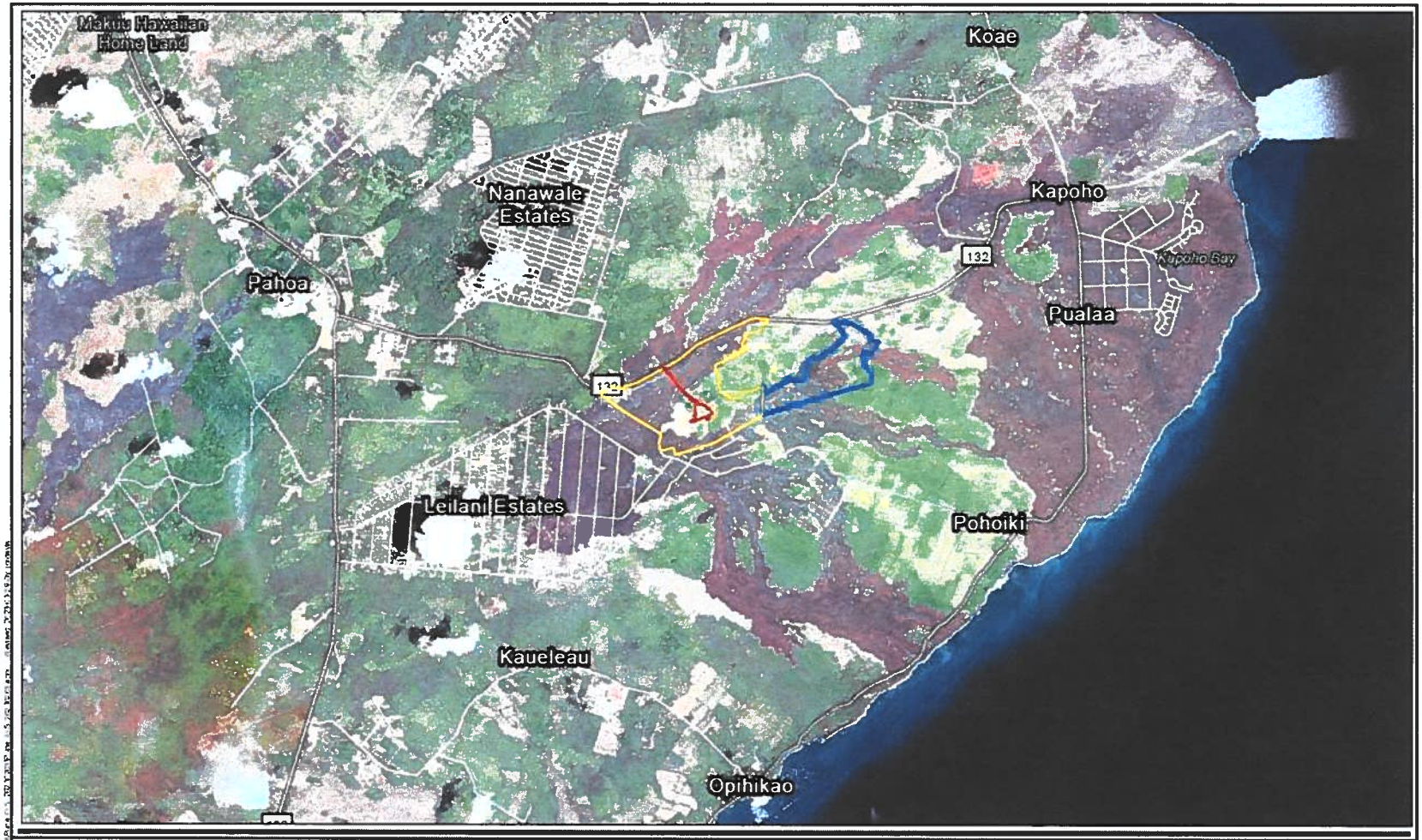


Figure 11-19 VRMU iso view





Legend

Parcel Number

- 140010010000
- 140010020000
- 140010190000

Note: The roads shown in the figures reflect the layout of County roads prior to the 2018 eruption.

Stantec

0 3,500 7,000 Feet

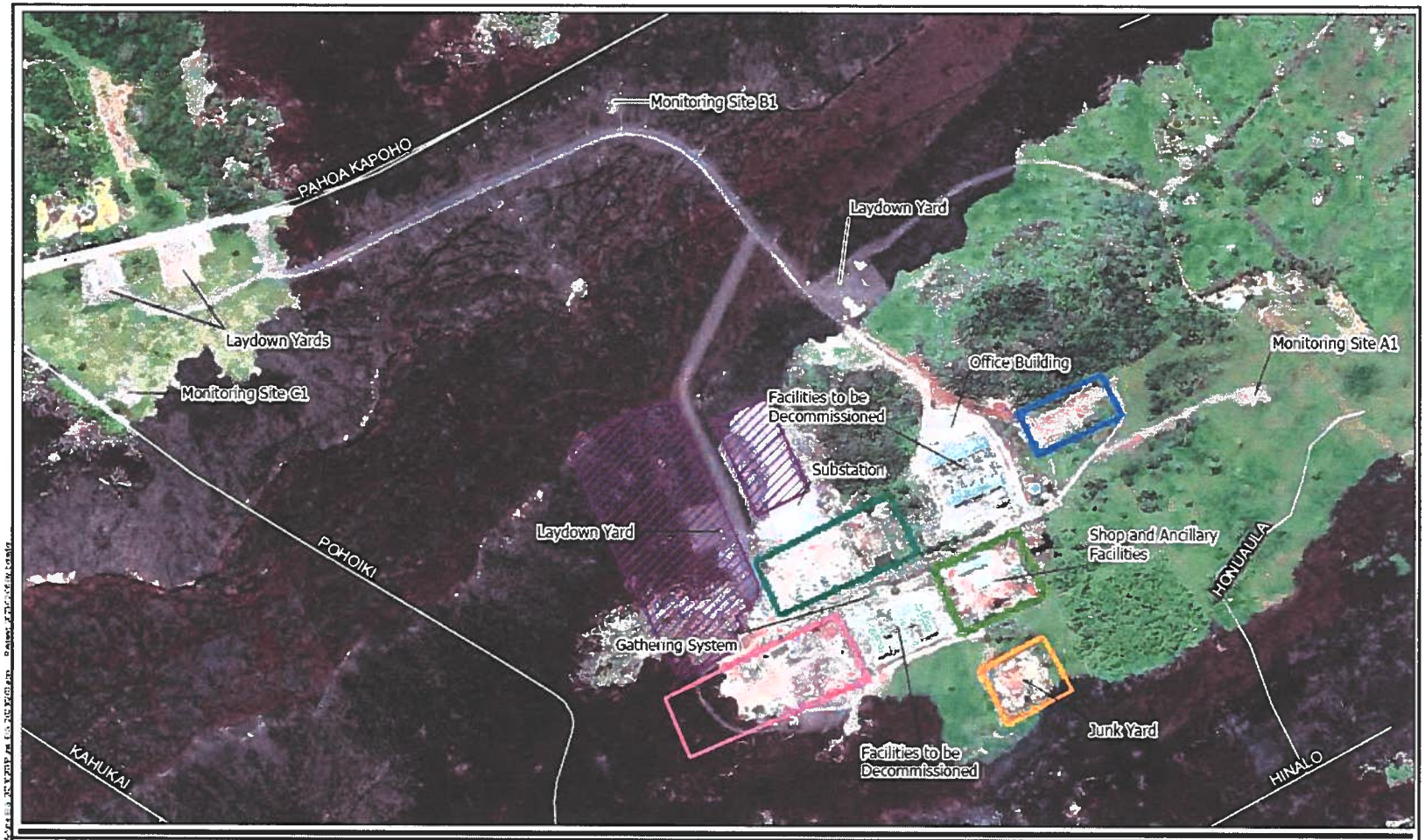
1 in = 7,000 feet

Hawaii County, HI
NAD 1983 StatePlane Hawaii 1 FIPS 5101 Feet

DRAWN BY: BT	1ST REVIEW: JT	2ND REVIEW: ML
DATE: 2023-03-29	PROJECT NO: 185305498	

PUNA GEOTHERMAL VENTURE
GEOTHERMAL REPOWER PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 1
Project Location



Legend

- Proposed Disturbance Area
- PGV Property Boundary

Existing Well Pads

- Pad A
- Pad B
- Pad D (no active wells as of 2022)
- Pad E
- Pad F (no active wells as of 2022)

Stantec

Feet
0 350 700
1 in = 700 feet

Hawaii County, HI
NAD 1983 StatePlane Hawaii 1 FIPS 5101 Feet

DRAWN BY: BT	1ST REVIEW: JT	2ND REVIEW: ML
DATE: 2023-02-06	PROJECT NO: 185805488	

PUNA GEOTHERMAL VENTURE
GEOTHERMAL REPOWER PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Figure 2
Existing Facilities

PGV Facility Map- New OEC Complex