THERMOCHEM®
Empowering Energy Industries since 1985

# Specifications for Well Testing Facilities and Instrumentation

for High-Accuracy Well Testing Operations

**Thermochem 40 x 40 LECM**

# Contents

# 1 Well Test Facility Designs

Geothermal Well Testing has traditionally been performed using atmospheric cyclone separators with a James Tube at the inlet to measure total mass flow and a weir box at the outlet to measure brine flow (**Figure 1**). The James Tube calculation requires enthalpy as an input which can be determined by iteration of the total mass flow and the separated brine flow. This technique has been used without modification or improvement for over 40 years (James, 1966). Accuracy estimates for total mass flow by this method range from +/- 5 to +/- 25% (Jung, 2001).

Occasionally production separators are used at production operating pressures with conventional single-phase flowmeters to measure the separated steam and brine flowrates (**Figure 2**). This system can produce higher accuracy data than the James Tube / weir box method, but it is much costlier, has limited turn-down capability and generally not suitable for initial start-up and warming operations of geothermal wells which must be done at low pressures. Low-pressure steam would overwhelm the capacity of a high-pressure separator. Accuracy of total mass flow measurement by this method should be +/- 5 % or better, with enthalpy on the order of +/- 10 kJ/kg.

Thermochem developed an alternative Geothermal Well Testing Facility in 2010 based on a compact atmospheric separator system built around shipping containers. A James Tube is used at the inlet and brine metering manifold at the outlet equipped with high-accuracy Magnetic Flowmeters for brine measurement (**Figures 3** - **5**). This "Low-Emissions Compact Muffler" (LECM), utilizes baffles in the lower container separator unit and mist pads in the upper container dryer unit to minimize carry-over. A key aspect of the design is the large surface area of the dryer outlet to maintain steam exit velocity bellow a maximum, which if exceeded will result in brine carry-over (Easley, 2018). The James Tube method can produce remarkable accuracy for well testing when reliable brine flow measurement is available, with total mass flowrate accuracies within about +/- 5% or better, comparable to conventional single-phase flowmeters, and total fluid enthalpy accuracies within about +/- 12 kJ/kg, comparable to flowing PT survey enthalpy and TFT® measurements (Hirtz, 2001).

The LECM has inherent advantages over the conventional atmospheric cyclone separator design in lower brine droplet emissions at the same flowrate and steam exit velocity, and ease of transport. Commercial stainless-steel mist elimination pads remove fine droplets and aerosols, resulting in very low brine carry-over up to full load. Excessive brine carry-over leads to an under-estimation in brine flow and over-estimation of total enthalpy. This is critically important for high-enthalpy wells. Brine carry-over is also an important environmental and local community impact concern.

The 40 x 40 ft. LECM is fabricated with the same outside dimensions as ISO shipping containers (8 ft. wide), which allows the pre-fabricated mufflers to be transported by standard trucking and ocean freight shipping lines worldwide, even to very remote areas. An <u>equivalent capacity cyclone muffler would need to be at least 25 ft. in diameter</u>, which precludes transport on most public roads, requires fabrication on-site and would still not provide the same efficiency or accuracy as an LECM.

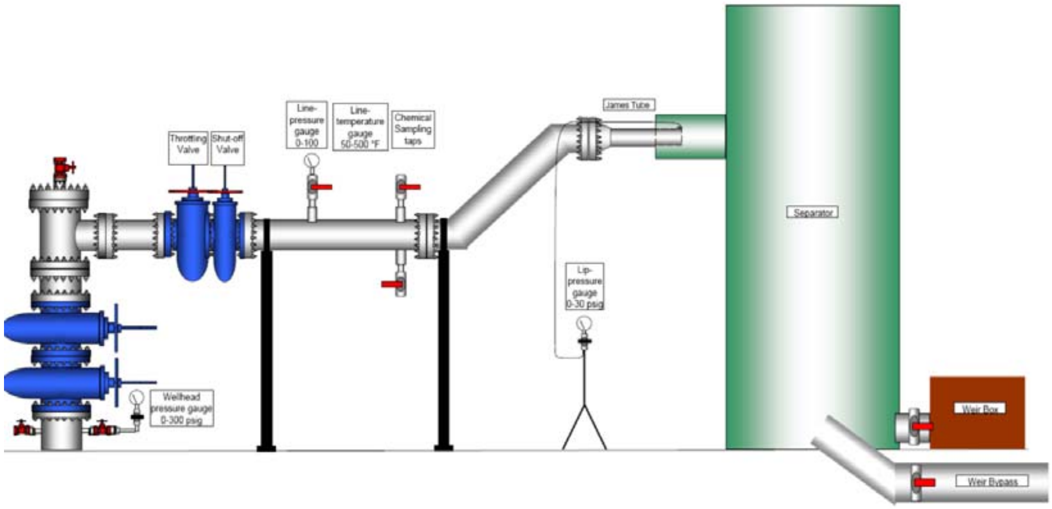
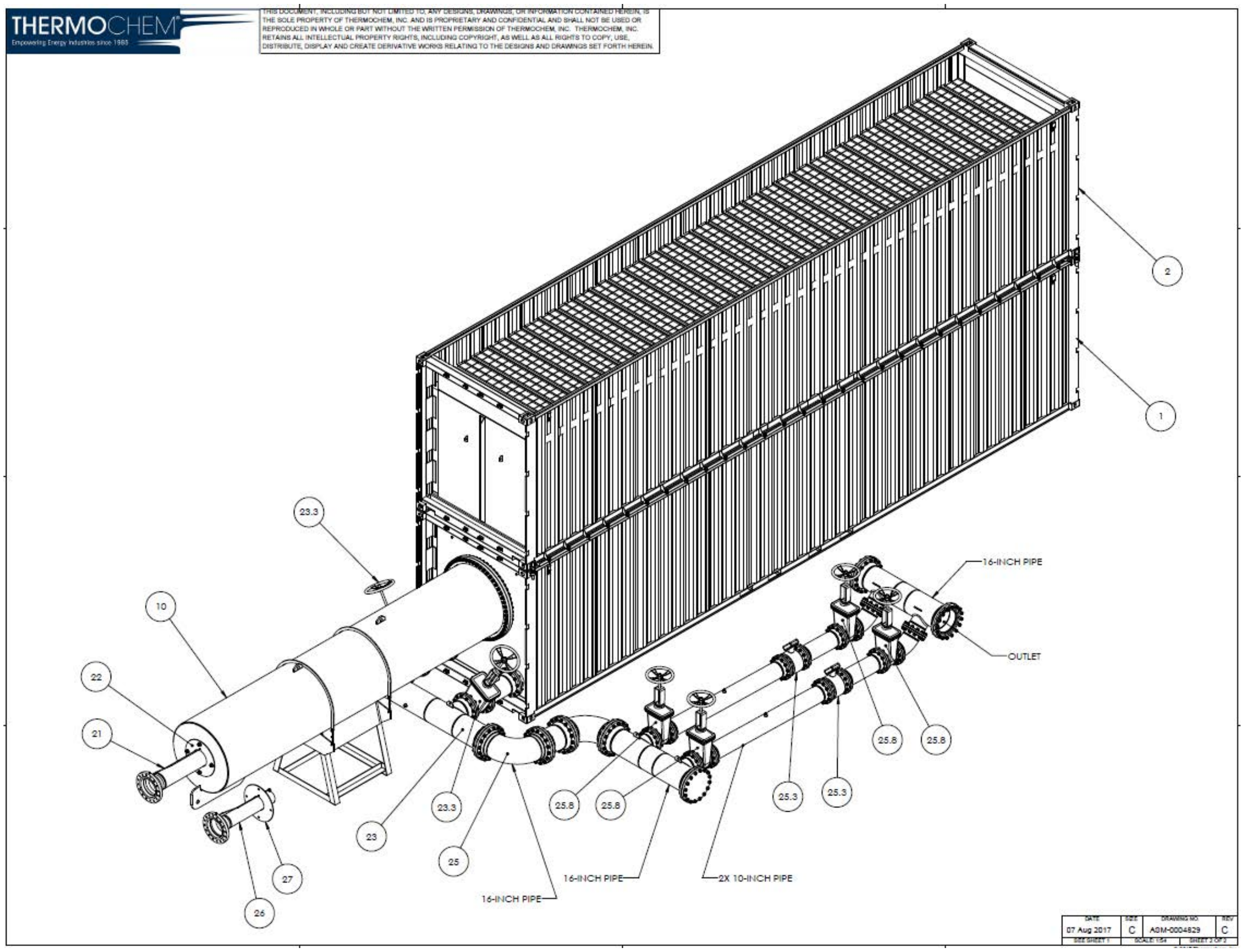



**Figure 1.** James-tube, Atmospheric Separator and Weir Box

**Figure 2.** Production Test Separator

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| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | ASM-0002287 | ASSEMBLY, 40FT LECM SEPARATOR | 1 |
| 2 | ASM-0002289 | ASSEMBLY, 40FT LECM DRYER | 1 |
| 10 | ASM-0002325 | 48-INCH EXPANSION PIPE, ASSEMBLY | 1 |
| 21 | ASM-0002521 | 10-INCH JAMES TUBE ASSEMBLY | 1 |
| 22 | PRT-0002652 | JAMES TUBE ADAPTER, 10-INCH, EXPANSION PIPE | 1 |
| 23 | ASM-0004219 | BRINE OUTLET HEADER, 16X12 | 1 |
| 23.3 | MTL-0001593 | GATE VALVE, 12-INCH NPS | 2 |
| 25 | ASM-0004232 | BRINE DRAIN MANIFOLD 16X10 | 1 |
| 25.3 | MTL-0001443 | FLOWMETER, ELECTROMAGNETIC, 10-INCH FLANGES | 2 |
| 25.8 | MTL-0004409 | GATE VALVE, 10-INCH NPS | 4 |
| 26 | ASM-0002519 | 8-INCH JAMES TUBE ASSEMBLY | 1 |
| 27 | PRT-0002651 | JAMES TUBE ADAPTER, 8-INCH, EXPANSION PIPE | 1 |

**Figure 3.** Thermochem 40 ft. x 40 ft. LECM (40 x 40)

**Figure 4.** LECM in Bolivia


**Figure 5.** LECM in Sumatra

## *1.1 Operating Specifications*

The typical maximum flowrates and normal operating pressures for a 40 x 40 LECM are summarized in **Table 1**.

| **Table 1.** **40 x 40 LECM Typical Max Flow Rating and Operating Pressures** | | |
|---|---|---|
| **Process Location** | **Max Pressure (psig)** | **Max Flow (ton/h)** |
| Diffuser Inlet, Total Fluid | 5.0 | 850 |
| Muffler, Steam Vent (upper stack) | 0.025 | 250 |
| Muffler, Brine Metering Manifold | 2.0 | 600 |

In order to achieve the required accuracy of an LECM, a brine metering manifold with multiple legs and Magnetic Flowmeters is required. A weir box or strap-on ultrasonic flowmeter cannot provide an adequate degree of accuracy. The critical design specifications for a 40 x 40 LECM are listed in **Table 2** below.

| **Table 2.** **Critical Design Specifications for LECM** | |
|---|---|
| **Process Location** | **Parameter** |
| Outlet, Total Steam Mass Flow | 250 t/h, 40 x 40 Maximum Capacity at atmospheric flash |
| Outlet, Total Brine Mass Flow | 600 t/h, 40 x 40 Maximum Capacity at atmospheric flash (3-leg manifold) |
| Inlet, Total Fluid Mass Flow | 850 t/h, 40 x 40 Maximum Capacity, limited by sum of maximum steam and brine flows above |
| Muffler Body, Liquid Containment | Baffle Plates to provide primary separation |
| Muffler Stack, Droplet Control | High-Efficiency Mist Eliminator Mesh Pads |
| Muffler Stack, Steam Vent Velocity | < 4 m/s |
| Muffler Stack, Brine Carry-over | < 0.25% of Inlet Brine Flow |
| Muffler Drain Water Level | Passive Level Control to ensure flooded meters |
| Muffler Drain Meter Run Velocity | 0.3 – 2 m/s |

# 2 Codes and Standards

**Table 3.** lists the codes and standards used in design of an LECM, two-phase piping and brine metering manifold piping, including flanges, structural steel, bolts and gaskets.

| **Table 3.** | **Codes & Standards** | |
|---|---|---|
| **Code & Standard** | **Title** | **Assembly** |
| ASME B31.1 | Power Piping | Two-Phase piping, Brine Manifold piping |
| ASME BPVC, SECTION IX | Welding Qualifications | Two-Phase piping, Brine Manifold piping |
| AWS D1.1 | Structural Welding | LECM, Supports |
| ASME B16.5 | Pipe flanges and fittings | Two-Phase piping, Brine Manifold piping |
| ASTM A106 | Pipe, Seamless carbon steel | Two-Phase piping |
| ASTM A53 | Pipe, welded and seamless | Brine Manifold piping |
| ASTM A36 | Structural carbon steel | LECM, Supports |
| ASME B16.9 | Wrought butt welding fittings | Two-Phase piping, Brine Manifold piping |
| ASTM A193 | Alloy steel bolting | Two-Phase piping, Brine Manifold piping |
| ASTM A194 | Carbon and alloy steel nuts | Two-Phase piping, Brine Manifold piping |
| ASME B16.20 | Metallic gaskets for pipe flanges | Two-Phase piping, Brine Manifold piping |
| EBTKE (Indonesia) | Requires review of WPS, and visual inspection of complete system on-site | |

# 3 Instrumentation

For an LECM well test facility designed to collect accurate flow testing data, the two-phase piping and brine metering manifold must be equipped with the instrumentation as listed in **Table 4.** This instrumentation as supplied by Thermochem typically includes a wellhead pressure transmitter, line pressure transmitter, line temperature transmitter, James tube lip pressure transmitter, and brine manifold magnetic flowmeters. A wellhead temperature transmitter is also recommended to allow estimation of NCG in fluid.

## *3.1 Required Instrument Specifications and Accuracy*

For most well test operations, the standard recommended instrument ranges and the required accuracies are listed in **Table 4.** A PLC-based data logging system is provided by Thermochem for accurate and reliable data logging with redundant storage to independent USB memory. This system includes a graphic HMI display for all parameters so well test personnel can quickly assess flow test facility status. The PLC-based system provides real-time processing of mass flowrates and enthalpy. This equipment is interfaced to a reliable power supply, such as a PV solar power system with battery back-up. Internet connection for data upload and remote access is a very useful option for remote monitoring.

**Table 4. Well Test Facility Instrumentation Typical Specifications**

| Process Location | Measurement Range | Calibrated Range | Accuracy |
|---|---|---|---|
| Wellhead Pressure | 0 – 3000 psia | 0 – 1000 psia | +/- 0.65 psia |
| Wellhead Temperature | 0 – 400 °C | 0 – 250 °C | +/- 0.2 °C |
| Two-Phase Line Pressure | 0 – 800 psia | 0 – 500 psia | +/- 0.32 psia |
| Two-Phase Line Temperature | 0 – 400 °C | 0 – 250 °C | +/- 0.2 °C |
| James Tube Lip Pressure | -300 – 300 psi | 0 – 120 psia | +/- 0.08 psia |
| Brine Manifold Leg (10 in.) | 50 – 500 $m^3/h$ | 50 – 500 $m^3/h$ | +/- 0.8 – 0.3 % |

## References

Easley, E., Nurlianto, “Geothermal Well Testing Using a New Atmospheric Separator and Metering System”, Proceedings, The 6th Indonesia International Geothermal Convention & Exhibition (IIGCE), 2018.

Hirtz, P., Kunzman, R., Broaddus, M., and Barbitta, J. “Developments in Tracer Flow Testing for Geothermal Production Engineering,” Geothermics, vol. 30, pp. 727–745, 2001.

James, R., “Measurement of Steam-water mixtures Discharging at the Speed of Sound to Atmosphere”. N.Z. Engineering, pp. 437 – 441, 1966.

Jung, D., “Geothermal Flow Metering Application and Error”, Geothermal Resource Council Flow Measurement Workshop, 2001.

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We provide solutions to our clients from the ground up: exploration through operations. Our extensive range of products and services includes greenfield exploration, well testing, geochemical modeling, chemical process engineering, analytical chemistry, reservoir engineering, permit support, due diligence and specialized instrumentation such as two-phase wellbore samplers, pH-modification equipment and on-line steam quality and purity meters.