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Heating Methods in Gas Plant: Evaluation and Optimization

Abdelaziz A. Noaman[1,*]

[1]*Minia University, Faculty of Engineering, Chemical Eng. Dept., Minia, P.O. Box 61519, Egypt*

Abstract

There are a number of issues to consider when choosing the best source of energy for the heating system in the gas project. The three biggest are the application, environmental impact, and cost of operation.
This paper compares and evaluates the available heating methods required for the amine regenerator reboiler at 130 °C, glycol (TEG) regenerator reboiler at 204 °C, start-up heater at 60 °C and condensate stabilization column reboiler at 180 °C in the gas project. These available heating methods are indirect heating, direct heating, waste heat recovery unit (WHRU) and electric heating.
AspenTech process modelling “HYSYS” v14 software was provided to simulate the all processing facilities in the while PROMAX software v6 was provided to simulate the amine (MDEA) and TEG systems in the gas project.
Technical and economical comparisons were conducted between those available heating methods to select the best method required in the gas project. The comparisons were conducted also based on the subtility, availability, environmental impact and limitations for each method. It has been found that the hot oil with WHRU is the best solution because it’s safer, the OPEX is much lower and this This would make the WHRU more cost effective over a few years of operation. Also, hot oil is the better than hot water as a heating medium.

Keyword: TEG, heater, CAPEX, OPEX , PROMAX , HYSYS.

1. Introduction

There are many factors which should be taken into consideration when we choose the heating equipment in the gas plant[1]. Many processes do not take place at ambient temperature or pressures. To reach these non-ambient conditions, utilities will have to be used to raise or lower temperatures and compress gases[2,3]. Utilities contribute from 5 to 10% of the price of a product. These utilities may be public or private utility [4].
The heating systems can be classified into direct and indirect heating. In the direct fired systems, the medium which is to be heated contact directly with the electric element [5-7]. Heating medium is used for the indirect heating system to distribute heat to the required locations [8].
The direct fired heating is lower cost, achieve the high process temperatures and ideal for special applications[9,10]. Indirect heating option is the preferred choice for applications in which heat is desired in multiple areas like pre-heating of combustion gas and process reboilers [11,12].
The heat coming from the indirect heating systems may be supplied via steam, oil, or a water / glycol mixture[13]. Steam is inexpensive and an efficient heat transfer medium capable of achieving high temperatures at superheated conditions[14,15]. Oil mixtures are capable of operating at temperatures up to 750 °F and water/glycol up to 350 °F . The choice is dependent on a number of factors and can be evaluated based on the specific application[16-18].
The waste heat means energy which is generated in processes without use. The sources of waste heat include hot combustion gases discharged to the atmosphere, heated products and the heat transfer from hot equipment surfaces[19-21.These losses can be reduced by improving the efficiency of equipment or installing waste heat recovery technologies[22,23]. Waste heat recovery reuse the waste heat in the industrial processes for heating or for generating mechanical or electrical work[24]. Example uses for waste heat include generating electricity, preheating combustion air, preheating furnace loads, adsorption cooling and space heating[25].
The waste heat recovery system is an energy recovery heat exchanger that recovers heat from the hot streams i.e. hot gases from a diesel generator , turbines , different cooling processes such as in steel cooling[26-28].

1.1 Research Objective

The main objective of this study is to compare the heating methods required for the amine regenerator reboiler at 130 °C, glycol (TEG) regenerator reboiler at 204 °C, start-up heater at 60 °C and condensate stabilization column reboiler at 180 °C.

*Corresponding author e-mail: zizomoo@yahoo.com.; (Abdelaziz A. Noaman).
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These available heating medium methods are indirect heating, direct heating, waste heat recovery unit WHRU) and electric heating.
The selection of the best method for heating medium in the gas project is based on many criteria, these criteria are safety &environmental considerations, capital equipment costs & operating costs, operability and maintenance considerations.

2. Natural Gas Project Description

Figure 1 shows the block flow diagram for the major oil , condensate and water processing equipment in the natural gas project. Figure 2 illustrate a schematic diagram for the major oil , condensate and water processing units in the natural gas field. The natural gas field includes eight wells, manifold and central process facilities .The natural gas coming from the gas wells will be separated into condensate, water and gas for export. The natural gas equipment in the gas plant will include inlet three phase separator for natural gas , water and condensate separation, mercury removal, sweetening system for CO_2 removal , glycol system for water removal and chillers to achieve the required hydrocarbon dew point in the sales gas.
The raw condensate which was separated from in the inlet three phase separator should be treated in the stabilizer to meet the required RVP specification before exporting the condensate. The natural gas will be exported via existing export gas pipeline to the liquefied petroleum gas plant. The condensate will be exported via export condensate pipeline.
The mercury was found in the gas wells based on the sample analyses of the gas wells. The concentration of the mercury was 70 ng/Sm^3. There is no sulphur, no wax and no paraffin.

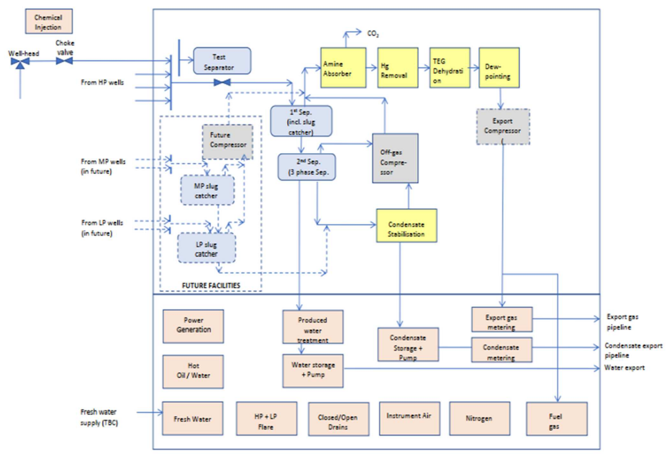

Figure 1: Gas Process Facilities Block Flow Diagram.

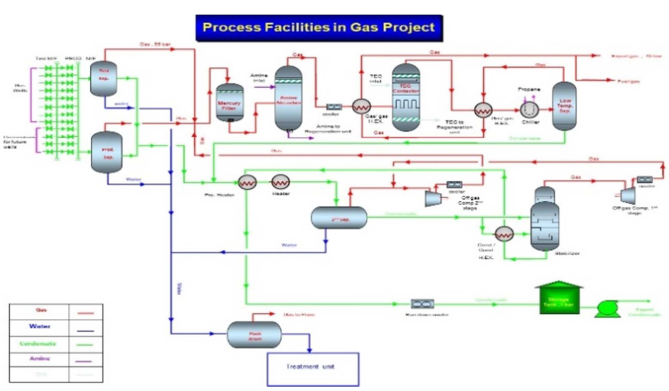

Figure 2: Gas Project Facilities Schematic.

3. Heating Sources Types

3.1. Electrical Heating

An electrical resistance heater in the exchanger/reboiler is immersed in the fluid and converts electrical energy directly into heat. electrical heating is commonly used for glycol reboilers, especially offshore but less often for amine regeneration due to the relatively large heat duties required[29,30].

Figure 3: Electrical Glycol Reboiler Bundle [31]

Table 1 illustrates the advantages and disadvantages of the electric heater [31-33].

Table 1: Advantages and Disadvantages of the Electric Heater

Advantages	Disadvantages
- Zero Pollution: the electric heater provides clean heating. No noise and radiating losses are quite low. - Homogeneous heating: - simple control -Controlled temperature - safe and respond quickly. Highest efficiency of utilization	-Electric heater is expensive compared to other heating systems. - Hazards i.e. electrical shock, fire, arc flash and explosions. - Electric heater needs a larger electrical service than normal. - High cost compared to the other heating system

3.2. Direct Fired Heater

This consists of a hydrocarbon burner or burners firing directly into a fire tube within the reboiler vessel. Radiant and convective heat transfer from the flame and combustion gases and is transmitted through the fire tube wall into the fluid to be heated. Exhaust gas from the burners is vented local to the reboiler at an elevated level[34-36].

Features for direct fired heaters include higher efficiency and more responsive to changes in heat demand than indirect fired heaters. However, they are considered less safe in process areas and also are subject to skin temperature concerns (limited heat flux) for temperature sensitive fluids leading to degradation of products[37,38].

Direct firing is common for onshore glycol reboilers and for amine reboilers up to 3 MW duty. Above this duty the physical size of the reboiler and fire tubes make direct firing an impractical solution[39].

Figure 4: Direct Fired Glycol Reboiler [39]

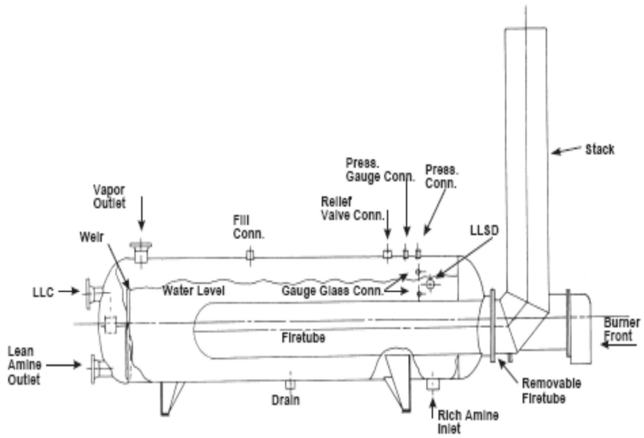

Figure 5: Direct Fired Amine Reboiler Schematic [40]

Table 2 reveals the advantages and disadvantages of the direct fired heater[40,41].

Table 2: Advantages and Disadvantages of the Direct Fired Heater

Advantages	Disadvantages
-low operating cost , transportation is easy - Lower maintenance costs , thermostat to control the temperature. Running without supervision.	Require good ventilation, exhaust is risky on the human and animals. -It is not recommended to use these heaters in areas containing flammable or combustible materials.

3.3. Indirect Heating

An indirect heating system uses an intermediate 'heating medium' rather than the heating device (e.g., the fire tube or electric heating bundle) being in direct contact with the fluid to be heated. The heating medium is heated remotely from the point of use and circulated to multiple end users[42,43]. The primary energy source may be electrical, hydrocarbon fuel, recovered waste heat or a combination of these.

Table 3 displays the advantages and disadvantages of the indirect fired heater[44,45].

Table 3: Advantages and Disadvantages of the Indirect Fired Heater

Advantages	Disadvantages
-High safety - The warm air generated by these units can be distributed to multiple spaces - Very low effect on the health or environment	- Higher cost , low efficiency - Electricity required ,requires Exhaust Ventilation -Harder to transport

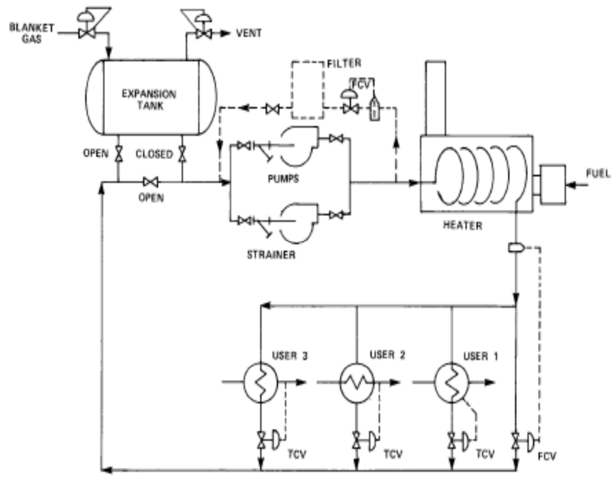

Figure 6: Indirect Heating Medium System Schematic[47]

A comparison of the two heating medium options hot oil (e.g., Dowtherm) and pressurized hot water is presented in the following table 4 [46-48]. From table 4, it can be noticed that hot oil as a heating medium is better than hot water for the indirect heating

Table 4: Heating Medium Comparison

Parameter	Hot Oil	Hot Water
Blending and ease in handling	Hot oil is blended for a specific temperature range; supplied for ready use by the manufacturer. Storage facilities for oil are required.	Hot water is prepared on-site by blending demineralized water with chemicals for anti-corrosion, anti-fouling, anti-freeze, etc. In addition to the availability of demineralized water, storage of the above chemicals is required at site.
Operating pressures	The oil will be in liquid phase even at high temperatures up to 300°C at atmospheric pressure. So hot oil circulation systems can be operated at a low pressure.	Hot water system will need to be a pressurized to maintain in liquid phase at high temperatures, e.g., pressurized to about 10 barg to operate at 160 °C.
Vapor release during leakages	A leakage from the hot oil loop will not cause a vapor release, as long as it is not operated at temperatures beyond specified limits.	A leakage from the hot water loop will cause a vapor (steam) release.
Losses	In the event the circulating pump stops, the circulating loop is still in liquid phase.	A reduction in the pressure within the circulating loop to a mal-operation will cause vaporization, and could lead to shut down and re-makeup of the solution.
Corrosion	Since these are pre-blended, there is less risk of corrosion.	Regular checking of the composition of circulating hot water and regular top-up of chemicals required in order to protect the system from corrosion and fouling.

3.4. Waste Heat

Turbine driver exhaust gases,can be used as a source of heat. Turbine is used in the gas project for electrical power generation [49,50].

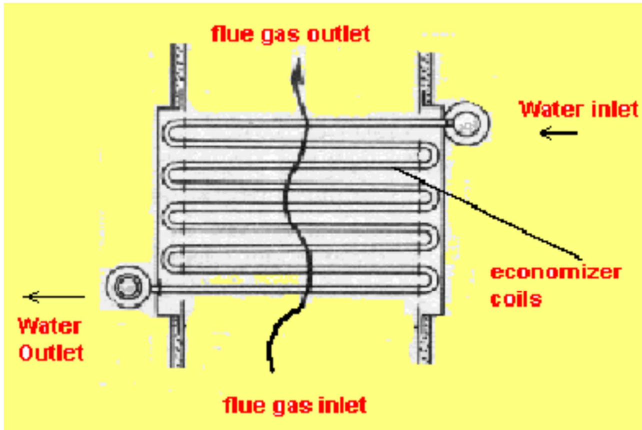

Figure 7: Waste Heat Recovery System Schematic [50]

Table 5 shows the advantages and disadvantages of the waste heat recovery unit (WHRU) [51,52]

Table 5: Advantages and Disadvantages of the Waste Heat Recovery Unit (WHRU)

Advantages	Disadvantages
The costs of fuel and energy consumption needed for that process decreased. -Reduction in pollution: -Reduction in the equipment sizes: -Reduction in auxiliary energy consumption:	-Capital cost: may outweigh the benefit gained in heat recovered. Waste heat is low quality

4. Methodology

4.1 Simulation Basis

The gas composition coming from the gas wells were simulated by using Aspen HYSYS software. different scenarios were proposed to choose the best gas composition for the design of the gas and condensate process facilities based on the design condensate production of 10,000 BOPD and design gas export of 2.7 MSCMD.
Four simulation cases were created, these methods are winter case and a summer case with a lean and rich composition each.

4.2 Simulation Software

4.2.1. HYSYS Simulation Software

The gas and condensate processing facilities were simulated by HYSYS simulation software version 14 [54]. Peng robinson equation of state was selected as a physical property.

4.2.2 ProMax Simulation Software

ProMax software was provided for the simulation of the amine (MDEA) and TEG systems [55]. ProMax is used for amine and TEG packages and give more accurate performance compared to other software.
SRK and SRK equations are used for vapor phase properties of the amine package and the electrolytic ELR and SRK models for liquid phase properties of the amine and TEG packages.

5. Results & Discussions

The gas and condensate facilities in the gas project will require heating for amine regenerator reboiler at 130 ^{o}C, Glycol (TEG) regenerator reboiler at 204 ^{o}C, start-up heater at 60 ^{o}C and condensate stabilisation column reboiler at 180 ^{o}C to achieve the required export gas and condensate specifications and improve the regeneration cycle of amine and glycol .
The amine regenerator reboiler, with a design duty of approximately 3200 kW, operates at maximum 130 °C. To allow for adequate heat transfer a heating medium temperature of approximately 140 to 160°C is required to regenerate amine. The maximum heating medium temperature to avoid amine degradation is 170 °C.

The condensate reboiler, with a design duty of 3556 kW, requires a heating medium temperature of approximately 180 to 210 °C. The same heating medium can be used for the start-up heater.
The TEG regenerator reboiler, with a design duty < 200 kW, requires a heating medium temperature range no hotter than 210 to 230 °C to restrict glycol degradation to acceptable levels.

5.1. Technical Comparison of Heating Methods

The Electric heaters have unlimited range of turndown (1:100 ratio), whereas fired heaters are much more limited (typically 1:10 ratio)
Electric heaters produce zero emissions and have 99% thermal efficiency during operation, whereas fired heaters typically have around 85% thermal efficiencies in their standard configurations. The fired heaters can be configured with additional equipment to further reduce emissions, such as economizers, air pre-heaters, and special burners.
Fouling of the elements over time will lead to the requirement to replace heating elements in the electric heater. It is mandatory to supply spare heating elements within a bundle to cater for possible element failures. There is a hazard associated with heater element over-heat but this can be protected by using element thermocouples to detect and shut-down defective heating elements.
The fired heaters must be designed for a specific flow rate range and if the flow rate goes lower than a certain point then the heater coils will be damaged because proper heat transfer doesn't occur.. The fired heaters can suffer from coking of the tubes in the heating section if burner controls suffer upset.
Electric or fired heater systems must be designed probably to avoid amage due to lack of flow. Due to the low heat flux requirement for amine regeneration in the gas project, an indirect heating using a heating medium (hot oil or hot pressurized water) is the best selection.
In comparison with a hot water system, a hot oil system offers advantages with its ease in handling, lower operating pressures, absence of vapors in the event of leakages, and lesser risk of corrosion .
The design of heating medium systems enables the fired heater to be located remotely from the heating duties and hence allows for more favorable footprints and spacing requirements for equipment layout.
The heating medium system has the potential to use waste heat recovery, typically from gas turbine drives used for power generation and large process machinery, e.g., compressors. Using waste heat energy typically requires a large heating medium duty to justify the additional capital cost and operating complexity. The power generation duties and the heating requirements in the gas project are relatively small and waste heat recovery is not considered.
An electric heater based reboiler is best selection for the glycol regeneration reboiler due to the small heating duties (< 200 kW).

5.2 Economical Comparison of Heating Alternatives

Figure 8 reveals the difference in CAPEX of the equipment for each heating medium methods in the gas project.
From figure 8, it can be seen that the CAPEX of the hot oil system with waste heat recovery unit (WHRU) is the highest compared to the other methods with around 3.6 MM$

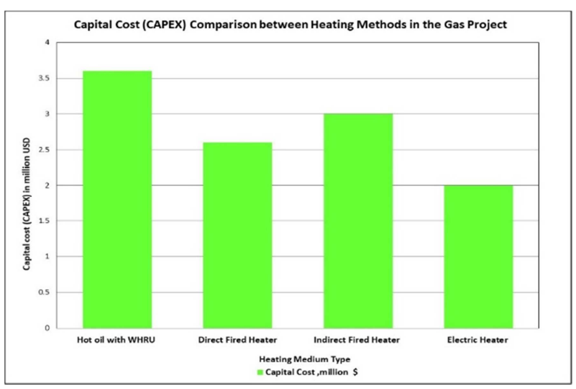

Figure 8: CAPEX Comparison between Heating Methods in the Gas Project

Figure 9 reveals the difference in OPEX of the equipment for each heating methods in the process facilities of the project.
From figure 9, it can be seen that the OPEX of the electric heater is the highest compared to the other methods with around 0.1 MM$

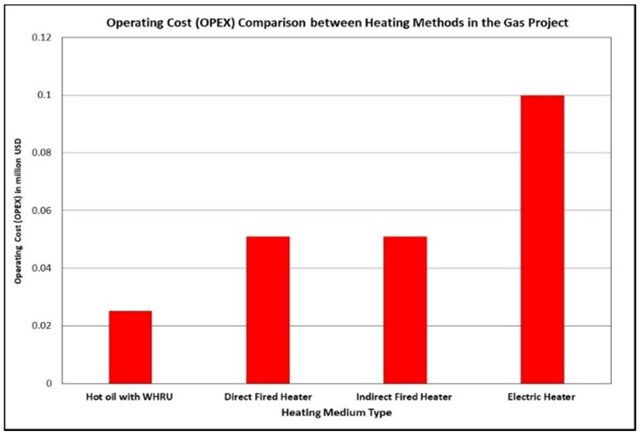

Figure 9: OPEX Comparison between Heating Methods in the Gas Project

Table 6 indicates the main differences between the available heating methods for the gas project , it can be seen that the best applicable method in the project is the hot oil with the waste heat recover unit (WHRU).

Table 6: Comparison Summary of the Heating Methods in the Gas Project

Technology Type	**Hot oil with WHRU**	**Direct Fired Heater**	**Indirect Fired Heater**	**Electric Heater**
Suitability	Yes	No	Yes	No
Limitation	None	▪Additional hazard ▪ Environmental impact	Additional hazard	▪Additional hazard ▪ Environmental impact
North Africa reference	Yes	Yes	Yes	Yes
Capital cost, million $	4.5	3	3.5	2.5
Operating cost, million $	0.025	0.051	0.051	0.1

6. Conclusions

The all available technologies required for heating amine in the amine regenerator reboiler at 130 ^{o}C, glycol (TEG) regenerator reboiler at 204 ^{o}C, start-up heater at 60 ^{o}C and condensate stabilization column reboiler at 180 ^{o}C in the gas project were studied in details to select the best heating method in the gas project.

These available heating methods are indirect heating, direct heating, waste heat recovery unit (WHRU) and electric heating. Technical and economical (CAPEX and OPEX) comparisons were performed between these method.

Using the electricity would be less efficient than direct heating and would use approximately double the amount of fuel gas for the same duty. This option is not considered further.

The hot oil with direct fired heater offers no benefit over the direct fired heater since there is more equipment required. Only the hot oil with WHRU will be considered further.

The direct fired heater is the least costly equipment is the direct fired heater. This option uses combusted fuel gas to provide the hot exhaust gases to heat the process stream, usually in the radiant and convective sections. The combustion of fuel gas will lead to higher emissions to air than the WHRU.

The hot oil with WHRU has a higher equipment cost although the operating costs would be much lower due to the use of recovered heat rather than fuel gas combustion. This would make the WHRU more cost effective over a few years of operation. Also, the hot oil as a heating medium is better than hot water.

Table 7 summarizes the main technical and economical differences between the available heating methods required for the gas project. The key lesson learnt from this study is to put safety issues as a top priority before selecting any technology to avoid any future possible hazards during gas plant operation. The most important factor when selecting the optimum technology also is the environmental effect. Also, the maintenance & inspection requirements must be taken into consideration before selecting the required technology for the heating requirements in the gas project.

The limitation of this research includes the total heat duty required for heating amine, natural gas and condensate. Also, the required temperature for the glycol which is 204 ℃ to avoid glycol degradation, required temperature for the amine is 130 ℃ , required temperature to heat the condensate in the condensate stabilization system to avoid off spec. condensate and finally the required temperature for the startup heater at 60 ℃ to avoid off spec. gas.

Table 7: Summary Table for the Heating Methods in the Gas Project

Type	Capital Cost, MM$	Operating Cost, MM$	Operability / Maintenance	Safety	Environmental Impact
Direct Fired Heater	Med	Med	Burner systems maintenance	Additional hazard on process tube rupture	Uses combusted fuel gas to heat process stream
Direct Electric Heater	Low	High	Simple, may require replacement elements.	Additional hazard	Uses combusted fuel gas to generate electricity, least efficient method
Indirect Heater	High	Med	Burner systems maintenance	Additional hazard on hot oil tube rupture but not significant	Degraded mineral oil disposal
WHRU	Highest	Lowest	Simple maintenance	No additional hazards	Degraded mineral oil disposal

7. Recommendations

It is recommended to consider hot oil with WHRU because it offers a less hazardous system than the direct fired heater which is an important consideration in this remote location. Also, hot oil is the better than hot water as a heating medium.

Nomenclatures

Abbreviation	Description
API	American Petroleum Institute
BPD	Barrel Per Day
BTU	British Thermal Unit
CAPEX	Capital Expenditure
CPF	Central processing facility
ELR	Extended Long Range
Kg	Kilogram
kW	kilowatt.
MDEA	Methyl Di-Ethanol Amine.
MMSCFD	Million Standard Cubic Feet per Day.
MSCMD	Million Standard Cubic Meter per Day.
MW	Megawatt.
ng	nano gram.
OPEX	Operating Expenditure.
RVP	Reid Vapor Pressure.
SRK	Soave-Redlich-Kwong.
TEG	Tri Ethylene Glycol.
TVP	True Vapor Pressure.
WHRU	Waste Heat Recovery Unit.
m^3	Cubic Meter.

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