

# Thermal oxidiser waste heat recovery

Capturing the heat energy used for waste gas destruction enables processing plants to enhance their efficiency and minimise operating costs

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As environmental regulations continue to grow more stringent, gas processing plants must continuously adapt to the requirements of the current regulatory environment. In an effort to keep up with emissions regulations, thermal oxidisers are being applied in a wider role. The majority of gas plants utilise regenerative chemical solvents in an absorption column to sweeten the gas stream. Elevated temperatures are used to regenerate these solvents. Heat recovery in the form of hot oil is a logical addition to many thermal oxidiser systems and one that can reduce the overall operating cost of solvent regeneration without introducing unnecessary complexity in overall plant operation.

While thermal oxidisers are not typically viewed as a profit centre, they are a necessity for maintaining environmental compliance. They can, however, be incorporated into a plant in a way that maximises plant efficiency while only marginally increasing the complexity of the overall system. This article will address the basics of

thermal oxidisers in gas processing plants and provide insight on how best to integrate thermal oil heat recovery into new or existing plants. Heat recovery can significantly reduce the fuel gas needed to regenerate solvent solutions, positively impacting the plant's bottom line.

## Thermal oxidiser's role

The basic theory of operation of a thermal oxidiser sounds simple —purification by fire. The waste streams to be destroyed by thermal oxidation are maintained for a set period of time at an elevated temperature in an oxygen-rich environment in order to achieve the desired destruction efficiency. Proper design of the burner and thermal oxidiser chamber ensures adequate mixing of the combustion products. This process is more commonly referred to as the "three Ts" of combustion: time, temperature and turbulence.

In a typical gas processing plant, the inlet gas is sweetened and dehydrated with solutions that depend on the addition of heat for regeneration. The vent

streams generated by the amine and glycol reboilers can contain hydrogen sulphide, BTEX (benzene, toluene, ethylbenzene and xylene) and hydrocarbons, which must all be oxidised in order to maintain environmental compliance for the plant. For the typical gas plant using amine sweetening and glycol dehydration, the stream with the largest flow rate is generally the flow from the amine reboiler. This stream is rich in carbon dioxide and saturated with water — a combination that can be considered the perfect fire extinguisher. Burning this stream in a thermal oxidiser at a temperature sufficient to destroy the hydrocarbons, hydrogen sulphide and BTEX requires a significant amount of heat input. This heat commonly originates from burning auxiliary fuel gas (sales gas). Flash gas can often be used to offset consumption, but it is generally not present in sufficient quantities to eliminate the usage of auxiliary fuel gas.

A less common process, but one that is gaining wider acceptance in the industry, is

the use of membrane technology to separate carbon dioxide from the inlet gas. This technology presents its own challenges, as the permeate gas from this process contains a significant amount of hydrocarbons, which represent a source of heating value that can be returned to the process, provided they can be burned effectively. This separation process employs a special selective membrane that allows the more permeable components of the inlet stream (carbon dioxide) to pass rapidly to the lower pressure side of the membrane. The slower components (methane) remain primarily in the residue gas. Both single- and two-stage membrane systems can be employed in a gas processing facility.

A single-stage membrane process may be insufficient to remove all of the carbon dioxide and water vapour from the inlet stream. In these particular situations, one option is to employ a hybrid system, where amine and glycol units are installed downstream of the primary membrane system to meet the sales gas specifications. In cases where a single- or two-stage membrane system is sufficient to meet sales gas specifications without any additional downstream dehydration or sweetening, some form of permeate off-gas must still be destroyed in a thermal oxidiser.

### Role of heat recovery in thermal oxidiser operation

The common element in the gas sweetening processes described is that in order to maintain compliance with environmental regulations, the

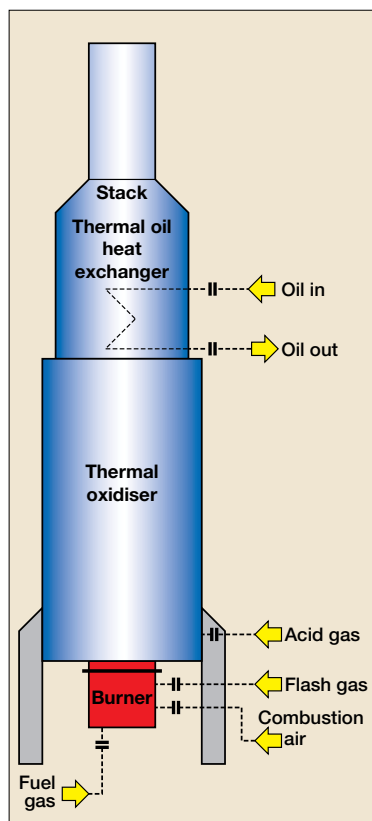


Figure 1 Vertical direct-fired thermal oxidiser

associated waste streams must be destroyed. The energy required to achieve proper destruction does not have to go to waste, however. Heat recovery through the use of a heat transfer fluid represents a valuable method to minimise the commercial impact of thermal oxidiser operation. Implementation of these technologies in a gas processing plant makes good business sense and demonstrates a commitment to minimising the environmental impact of the overall operation.

The use of heat transfer fluids in gas plants for the purpose of regenerating solvents is very common. In most applications, a fired heater is used to heat the circulating oil in the plant.

Thermal oil heat exchangers can be added to thermal oxidisers to offset the duty required from the fired heater. In certain applications, thermal oil heat exchangers may be able to replace the fired heater entirely. The thermal oil heat exchanger incorporated in the thermal oxidiser system shares its basic design with the convection coil commonly applied in fired heater applications. Plant efficiency and flexibility are enhanced while commonality is maintained to the maximum extent.

There are several ways to incorporate this capability in a thermal oxidiser and the best solution depends upon the overall process and the amount of operational flexibility desired.

### Thermal oxidiser heat recovery: theory of operation

#### Direct-fired or "straight through" design

The simplest application of thermal oil heat recovery in a thermal oxidiser is the direct-fired or "straight through" design. In this system (see Figure 1), the entire volume of flue gas generated by the thermal oxidiser passes through the coil. These units can be oriented vertically or horizontally, with the deciding factors usually being the available plot space and the size of the heat transfer coil. The vertical orientation is often attractive due to the smaller plot space required and the cost savings associated with the smaller vent stack mounted on the outlet of the coil. Most plants are already accustomed to accessing and maintaining the elevated convection coils on fired heaters, so placing the oil

coil at the outlet of a vertical unit does not usually pose an additional hardship.

For larger gas plants, a horizontal thermal oxidiser with the heat transfer coil located at grade is the preferred orientation due to the coil's size and easy access. While horizontal systems require a separate stand-alone vent stack, the stack generally represents a much smaller percentage of the overall equipment cost due to the larger size of the thermal oxidiser and coil.

### Advantages

The advantages of the direct-fired approach are readily apparent. The system is very simple, with a minimum amount of additional equipment required when compared to a basic thermal oxidiser design. Since all of the flue gas passes through the coil, the maximum amount of heat can be recovered subject only to the constraints of the thermal oil outlet temperature and any sulphur dew point issues. This makes the direct-fired design in the vertical orientation very cost effective from a capital equipment standpoint. The direct-fired configuration also offers advantages when over-firing the thermal oxidiser burner. For instance, the thermal oxidiser can be designed to fire excess fuel gas and air to supplement the waste gas duty in the thermal oxidiser coil to provide additional flexibility. This is especially helpful for cases where the flow from the amine reboiler vent may be temporarily routed to the flare. In these cases, an increase in the burner firing rate can compensate for the loss of mass

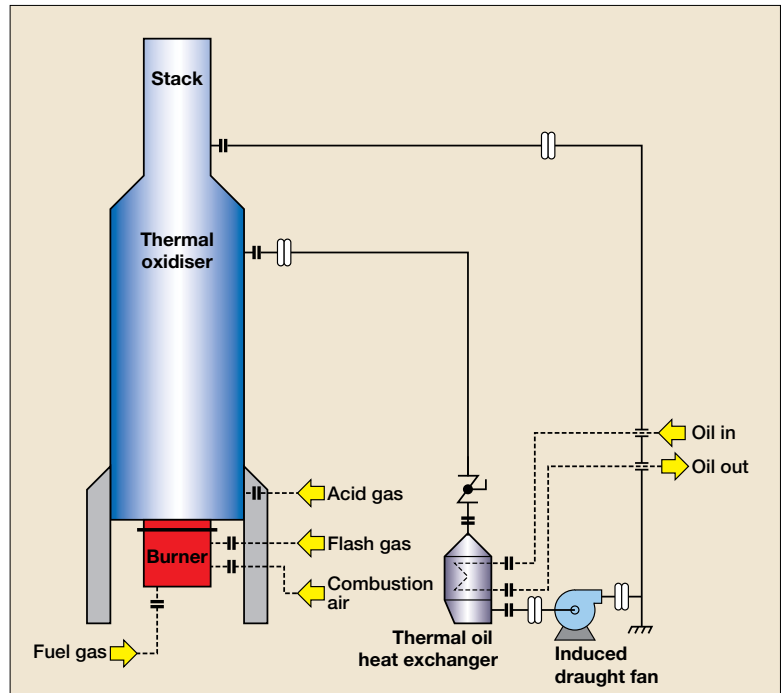


Figure 2 Vertical extractive thermal oxidiser

flow from the amine reboiler vent to maintain a reasonable duty in the coil. The additional cost to increase the capacity of the combustion air fan and burner is relatively small when compared with the overall cost of the equipment and the additional flexibility it provides.

### Application

Direct-fired systems are best applied in series with the direct-fired heater. First, the oil is heated by coil in the thermal oxidiser, with the oil generally flowing at a constant rate. The oil outlet temperature is allowed to fluctuate based on the duty generated in the thermal oxidiser. The oil then continues to the fired heater, where the desired outlet temperature is achieved through modulation of the heater's firing rate. The fired heater can be designed to generate enough duty to

operate the entire plant at a reasonable throughput. The thermal oxidiser offsets the required duty in the heater and this saves fuel gas by reducing the heater firing rate. While it is tempting to eliminate the fired heater entirely in this application, this action is at the expense of overall plant flexibility. Through careful planning of the hot oil circuit, such configurations are possible, but careful attention should be paid to the possible limitation of plant flexibility in various modes of operation. The thermal oxidiser is first and foremost a tool for waste destruction. Upstream process upsets generally find their way to the thermal oxidiser in one form or another, and it is helpful to have the fired heater available as a constant source of heat input that is not subjected to the potential fluctuations of the waste stream

flow rates and compositions.

### **Indirect or "extractive" design: theory of operation**

An alternative to the direct-fired approach is the extractive system. In this type of system (see Figure 2), the coil is located outside of the main flue gas path. The flue gases are pulled across the coil through a system of refractory lined duct work using an induced draft fan. The slipstream of flue gas is pulled from the main thermal oxidiser chamber and passed across the coil. The induced draft fan is located downstream of the coil, where it is protected from the high temperature of the flue gas. Through design of the coil and by maintaining flow rates in the proper operational range, outlet temperatures downstream of the coil are maintained in a range that does not jeopardise the overall reliability of the induced draft fan. After the flue gas passes through the induced draft fan, the cooled gases are returned to the thermal oxidiser chamber near the outlet, where they mix with the main flue gas stream prior to being exhausted to the atmosphere.

#### **Advantages**

The extractive configuration is an especially attractive option when the hot oil duty required from the coil is much smaller than the available duty present in the flue gas. The induced draft fan can be operated by variable frequency drive and set to only draw the required amount of flue gas across the coil. This allows for precise control of the total duty recovered in the coil. The extractive system can be used in vertical

and horizontal configurations. Vertical units are attractive due to the reduced plot space requirements coupled with the convenience of having the coil located at grade.

By using an isolation damper in the inlet ducting of the coil, the coil can be completely isolated from the flue gas flow, allowing for easy maintenance and inspection without the need to take the entire thermal oxidiser off-line. The ability to isolate the coil also offers advantages during start-up and commissioning. Basic commissioning and refractory dry-out for the main thermal oxidiser chamber can be conducted even if the oil circuit has yet to be commissioned.

#### **Application**

Extractive systems offer exceptional flexibility, especially when other sources of thermal oil heating sources are limited. The additional control provided by the induced draft fan allows for very precise regulation of the oil outlet temperature, even when faced with fluctuating waste flow rates.

Extractive systems are popular in gas plants utilising membrane technology. Due to the relatively high hydrocarbon content in the permeate gas from the membrane system, the available heat duty from the flue gas is often much greater than that which is needed to be returned to the plant. A thermal oil heat exchanger placed directly in the flue gas path would generate more duty than could be effectively returned to the plant, since the oil circulation rate required to prevent degradation of the oil places constraints on the coil design.

Hybrid plants using a single-stage membrane with downstream amine treating generate permeate gas with a considerable hydrocarbon content, providing a large amount of available energy for solvent regeneration. While the hydrocarbon content in the single-stage permeate is significant, it is still too lean to be used as a conventional fuel and must be burned in a specially designed thermal oxidiser. Thermal oil heat recovery can then be incorporated downstream of the oxidiser to meet or supplement the required reboiler duty.

In cases where the inlet gas may contain heavier hydrocarbons (C<sub>6</sub>+) or BTEX, gases that are known to be detrimental to membranes, molecular sieve units are commonly used upstream of the membranes to remove these components. Molecular sieves require periodic regeneration. Heat recovery incorporated in the thermal oxidiser can be used for this purpose as well as for any inter-stage heating required in two-stage membrane systems. Due to the intermittent nature of molecular sieve regeneration, the extractive system provides the flexibility to meet the changing heating demands during the regeneration cycles.

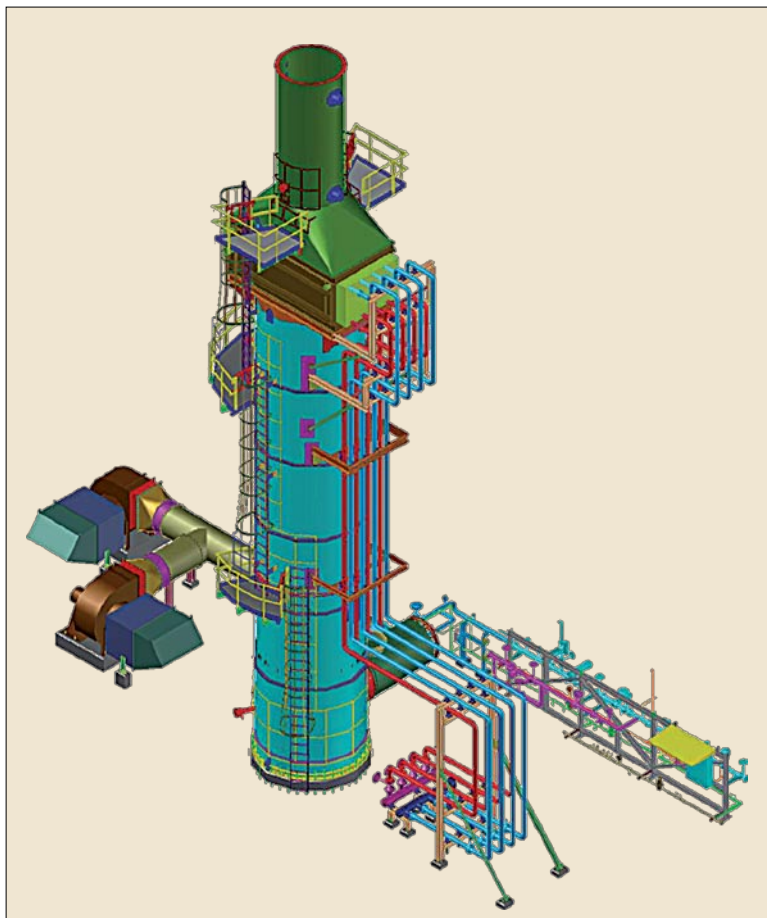
#### **Reliability**

The added efficiency and cost savings associated with incorporating thermal oil heating in the oxidiser also comes with an additional focus on the reliability of the oil circulation system. Constant oil flow is a requirement to avoid high film temperatures that can degrade

the heat transfer fluid. The thermal oxidiser safety system incorporates additional permissives that ensure that oil flow is maintained at all times during operation. For direct-fired systems, oil flow must be established through the coil before starting the thermal oxidiser and a minimum flow must be maintained at all times. The firing rate of the thermal oxidiser burner is correlated with the waste flow rates rather than the outlet temperature of the oil, so this limits the ability to modulate the burner firing rate to regulate oil temperature. Oil outlet temperature is monitored by the thermal oxidiser control system to ensure that it remains within acceptable limits. Overall, the reliability of the hot oil circulation system is paramount for any gas processing plant, regardless of whether the thermal oxidiser is part of the system. The most critical aspect of integrating a thermal oxidiser into the hot oil system is a thorough understanding of the basic thermal oxidiser control system and how it will respond to insufficient oil flow.

### Economics

The economics of the application of heat recovery in a thermal oxidiser are very simple. The thermal oxidiser must be operated to maintain environmental compliance. The amount of heat recovered offsets the fuel consumed elsewhere in the process. The payback period depends on the operator's cost for fuel compared with the additional cost of adding the heat recovery unit. Generally, in most applications, the payback



**Figure 3** 3D model of a direct-fired thermal oxidiser

period is less than one to two years.

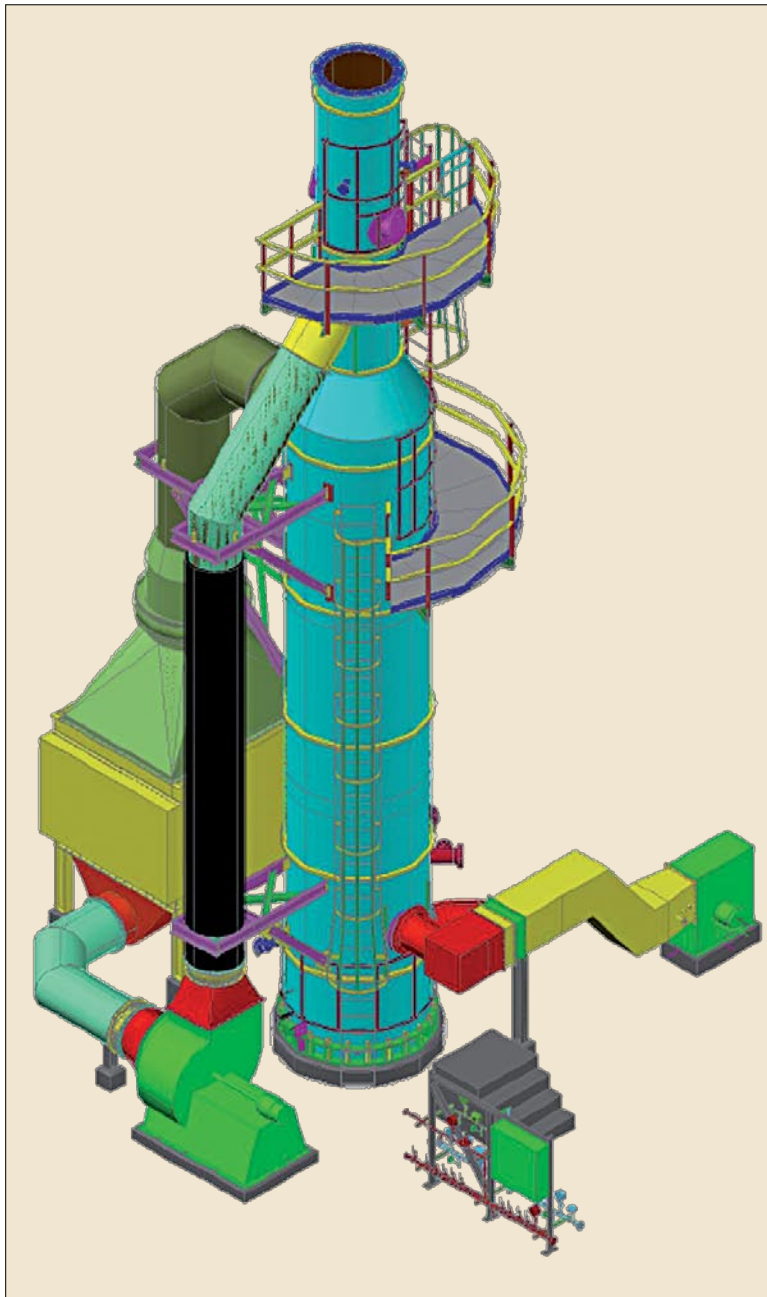
### Case studies

In the following case studies, specific examples of both types of thermal oil heat recovery configurations are examined to provide more insight on specific applications.

#### Case 1: 9.37 MMNm<sup>3</sup>/day cryogenic plant

This Western US cryogenic plant is designed for maximum ethane recovery and an inlet gas flow rate of 9.37 MMNm<sup>3</sup>/day. Molecular sieves are used for dehydration of the inlet gas. As Figure 3 shows, the thermal oxidiser is a direct-fired vertical

design. The main waste flow originates from the amine reboiler vent gases, along with a significant amount of flash gas that offsets the total burner fuel gas consumption. The balance of fuel gas comes from residue gas. The plant utilises a common heating oil header. Other heat inputs to the system include a conventional fired heater, along with waste heat recovery units installed on the exhaust of two turbine generators. Installing a control valve in series with each heat source and the common heating medium header provides additional flexibility. This allows the plant to modulate the flow of thermal oil to the thermal



**Figure 4** 3D model of an extractive system thermal oxidiser

oxidiser coil to achieve a desired outlet temperature. This flow rate is established within a predefined range calculated to ensure that maximum film temperature limitations are not exceeded for any operating condition. An air cooler is installed in the system

to allow for heat rejection to the atmosphere in cases where total heat generation exceeds plant capacity.

The capability of the thermal oxidiser burner to accommodate both flash gas and residue gas allows the plant the ability to generate a significant portion

of the total heat duty required at a very low cost. The maximum amount of flash gas is routed to the thermal oxidiser to be combusted in the burner until the thermal oxidiser reaches a specific temperature set point, at which point excess flash gases are flared.

**Case 2: 2.28 MMNm<sup>3</sup>/day membrane plus amine hybrid plant**

Based in Southeast Asia, this hybrid membrane plus amine plant operates in a gas field with a high carbon dioxide content. The single-stage membrane system performs the primary sweetening of the high carbon dioxide inlet gas (approximately 38% by volume). The permeate gas from the membrane skid along with the acid gas from the amine reboiler are destroyed in the thermal oxidiser. At maximum flow rates, the total heat release of the permeate gas, acid gas and fuel gas are approximately 50.4 MMkcal/h. Of that total, only 3.9 MMkcal/h of heat energy is required for the amine reboiler. This heat energy is recovered by an extractive system (see Figure 4) to allow the flexibility of operating the thermal oxidiser at high throughputs without jeopardising the thermal transfer oil due to high film temperatures. This also provides the plant the flexibility to handle varying compositions in the permeate gas stream without significantly impacting the operation of the thermal oil heat exchanger. An air cooler is not required by this system, as the heat recovery coil can be completely isolated from the system when heat recovery is not required.

This is especially useful during start-up operations such as refractory dry-out where the oil circuit may not be functional.

### **Conclusion**

Thermal oxidisers play an important role in emissions control for gas processing plants. Direct oxidation of the waste gas streams is a simple and effective way to ensure that emissions requirements are maintained, but it comes at the expense of fuel consumption.

By capturing a portion of the heat energy used for waste gas destruction and using this to meet some or all solvent regeneration needs, processing plants

can enhance their efficiency and minimise their overall operating costs. Through assessment of the total duty requirements of the plant, heat recovery can be implemented in a thermal oxidiser system for both new and existing plants with a positive impact on plant economics, flexibility and environmental impact. The important aspect is to understand the heating and process requirements for the plant and to pick the best configuration and coil size to suit that need. The economics are easily calculated. For most modestly sized plants, the option makes sound financial sense. Proper

integration of heat recovery in a thermal oxidiser system can enhance the efficiency of gas processing plants while still maintaining the high level of reliability and availability that is critical for profitable plant operation.

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