EMERGENCY SAFETY VENT OPERATING PLAN
32 ROTARY KILN INCINERATOR

The Dow Chemical Company
Michigan Operation Incineration Complex
Midland, Michigan

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APPENDICES

1.0 Introduction

The 32 rotary kiln incineration system (32 Incinerator) located at the DOW facility in Midland, Michigan includes an emergency safety vent (ESV) as defined by the Hazardous Waste Combustor Maximum Achievable Control Technology (HWC MACT) regulations. The purpose of this plan is to fulfill the requirements of 63.1206(c)(4)(ii), which states:

(A) You must develop an ESV operating plan, comply with the operating plan, and keep the plan in the operating record.

(B) The ESV operating plan must provide detailed procedures for rapidly stopping the waste feed, shutting down the combustor, and maintaining temperature and negative pressure in the combustion chamber during the hazardous waste residence time, if feasible. The plan must include calculations and information and data documenting the effectiveness of the plan's procedures for ensuring that combustion chamber temperature and negative pressure are maintained as is reasonably feasible.

This plan will be maintained in the DOW operating record and modified as necessary.

2.0 Statement of Applicability [40 CFR 63.1206(C)(4)(i)]

The 32 Incinerator located at the DOW facility in Midland includes an emergency safety vent (ESV) as defined by the Hazardous Waste Combustor Maximum Achievable Control Technology (HWC MACT) regulations. The purpose of this section is to define specific scenarios when an ESV opening is not a reportable event.

On February 13, 2002 new interim standards were issued for Subpart EEE. These new standards ruled that a facility is not in violation when allowed emissions are exceeded and the startup, shutdown, and malfunction plan is followed. During the revision of this standard, EPA was concerned that this approach would decrease the regulatory requirements in instances where a facility's current RCRA permit was more rigorous. Accordingly EPA gave hazardous waste incinerators three choices:

- Meet the requirements of Sec. 264.345(a) or
- Meet revised RCRA permit conditions that minimize emissions from malfunctions; or
- Expand the incinerator's startup, shutdown, and malfunction plan to identify the actions that are being taken to minimize the frequency and severity of malfunctions as well as the corrective measures that will be taken when a malfunction occurs. If the facility wishes to use this plan it must be reviewed and approved by the delegated CAA authority. The preamble to this regulation change indicates that, if this alternative is chosen, relevant permit conditions addressing malfunctions from the hazardous waste

(RCRA) permit will be removed from the RCRA permit when the site is in compliance and requests their removal.

DOW chose to expand the incinerator's startup, shutdown, and malfunction plan and submitted the plan for approval by the delegated CAA authority. MDEQ-AQD approved the plan on May 20, 2003. Subsequent revisions have also been approved by MDEQ-AQD.

Appendix–B - Applicable Subpart EEE Regulations gives the Subpart EEE regulations that apply to this Emergency Safety Vent Plan.

40 CFR 63.1206 (c)(4)(i) reads:

> *"If an emergency safety vent (ESV) opens when hazardous waste remains in the combustion chamber (i.e., when the hazardous waste residence time has not expired) during an event other than a malfunction as defined in the startup, shutdown, and malfunction plan such that combustion gases are not treated as during the most recent comprehensive performance test (e.g., if the combustion gas by-passes any emission control device that was operating during the performance test), you must document in the operating record whether you remain in compliance with the emission standards of this subpart considering emissions during the ESV opening event."*

40 CFR 63.1 defines malfunction as:

> *"Malfunction means any sudden, infrequent, and not reasonably preventable failure of air pollution control equipment, process equipment, or a process to operate in a normal or usual manner. Failures that are caused in part by poor maintenance or careless operation are not malfunctions."*

When an ESV Opening is triggered by the control system, the following questions must be answered in order to determine the appropriate regulatory management of the event.

1. Did the ESV opening occur while hazardous waste was in the combustion system?

   If the answer to question 1 is **no** there is **no** further **regulatory requirement** for management or reporting of the event.

   If the answer to the question is **yes**, the **event must be reported** to Michigan Department of Environmental Quality (MDEQ) as outlined in Section 5.2 of this plan.

2. Were any HWC MACT emission standards or operating parameter limits exceeded?

   Whether the answer to the question is yes or no the event must be managed according to ESV Operating Plan Procedures.

If the answer to question 2 is **yes** the **event may also be reportable** to Michigan Department of Environmental Quality (MDEQ) as specified in Section 336.1912(3) and (5) of the Michigan Air Pollution Control Rules.

3. Was the ESV opening related to a malfunction event as previously defined in this section of the plan?

   Whether the answer to the question is yes or no the event must be managed according to ESV Operating Plan Procedures.

   If the answer to question 3 is **no** the **event may also be reportable** to Michigan Department of Environmental Quality (MDEQ) as specified in §63.1206(c)(4)(iv).

4. Was the malfunction identified in the Startup, Shutdown and Malfunction Plan?

   Whether the answer to question 4 is **yes or no** submit SSMP reports as outlined in Section 5.3 of this plan**.**

   If the answer to question 4 is **no** the **Startup, Shutdown and Malfunction Plan** must be revised within 45 days of the event to include detailed procedures for operating an maintaining the source during similar malfunction events and a program of corrective action.

3.0 ESV Operation

When designing any process, sound engineering practice and safety/hazardous operations (haz-op) analysis of the process requires that the system revert to a fail-safe condition in the event the equipment malfunctions or basic site utilities are interrupted. A well-engineered system design must provide a means of recognizing these conditions, terminating process feeds, and shutting down the process in a controlled manner that protects workers, the environment, and the process equipment. The 32 Incinerator is designed with consideration to such safeguards.

In any well-engineered solid waste incineration system, such as the 32 Incinerator, the gases are continuously subjected to high efficiency combustion in the secondary combustion chamber (SCC) and high efficiency cleaning in the air pollution control (APC) system. The design of any modern thermal treatment system provides a nominal flow path of gases through combustion zones, quenching zones, and air pollution control devices. A number of process malfunctions will automatically cutoff waste feeds, but in an incinerator treating solid wastes, a residual inventory of burning waste will exist in the system after waste feed cutoff and until the solids residence time has expired. As long as the SCC and APC system are functioning, the gases from this residual solid waste inventory follow their normal path through the system. If the APC malfunctions or a basic site utility (e.g., electric power) is interrupted, the gases will not, or cannot be allowed to take their normal flow path through the system. A safe alternative flow path must be provided. The alternative flow path for the 32 Incinerator is the ESV.

The ESV is a process safety device that automatically responds to specific process and utility malfunctions. The ESV prevents an over-pressurization of the system that could result in ground-level release of hot combustible gases, thermal damage to heat-sensitive equipment, or an explosion in the incineration system.

3.1 ESV Location and Operational Description

The SCC on the 32 Incinerator is a vertically oriented, up-fired design. The ESV is a cap valve located at the top of the duct exiting the SCC at a point the combustion gas is normally ducted from the SCC to the APC system. The initial component of the APC system is a reaction chamber for removal of nitrogen oxide. Since many of the downstream components of the APC system following the nitrogen oxide abatement chamber are heat sensitive, the next component of the APC system, the quench chamber, adiabatically cools and conditions the combustion gas via saturating water sprays. Downstream components then treat the cooled combustion gas to remove acid gases, particulate matter and metals before being discharged from the stack. When the ESV opens, the combustion gases bypass the heat sensitive APC equipment by being discharged through the ESV opening at the top of the SCC. When the ESV is open and the SCC's refractory is hot, a natural draft is created and the SCC in essence becomes a chimney. This natural draft draws the gases from the rotary kiln through the hot SCC and vents them to the atmosphere. All waste feeds are automatically stopped when the ESV system is activated, and waste feeds cannot be restarted until the ESV is closed and the incineration system is operating in conformance with applicable waste feed permissives.

3.2 Process Conditions Requiring ESV Activation

Most process upsets can be handled with automatic waste feed cutoffs (AWFCOs) and, if necessary, controlled system shutdowns. Only a limited number of specific process conditions require an ESV opening as presented below:

- Power failure
- ID Fan Failure
- High quench chamber temperature
- Low water flow to the quench chamber
- Extremely high pressure.

3.3 Importance of the ESV

An ESV provides a critical and fundamental process safety function. The purpose of an ESV is to protect human health, the environment, and the equipment from the effects of ground-level fugitive emissions, explosions, and thermal damage.

3.3.1 Loss of Induced Draft

The incineration and APC systems are a series of closed vessels, operated under a vacuum. The process equipment allows materials to be handled and burned in a controlled manner while confining combustion gases and preventing the uncontrolled release of partially treated gases to the atmosphere. The physical configuration of the APC system vessels does not allow them to operate under natural draft conditions, so a combustion gas mover is required. Combustion gas is moved through the incinerator by an induced draft fan. The induced draft fan imparts a vacuum on the entire system and pulls combustion gases out of the rotary kiln, through the SCC and APC system.

If the induced draft is interrupted, an AWFCO will occur. Although no liquid wastes remain in the incineration chambers, an inventory of burning solid wastes will remain in the rotary kiln. Without an induced draft from either an ID fan or an ESV, the gases from these hot smoldering wastes will accumulate in the combustion chamber and pressurize the rotary kiln, and eventually the SCC and APC.

Under these circumstances, the combustion air blowers must be automatically shut off to prevent further pressurization of the system. Even normal air infiltration into the rotary kiln through seals ceases when the system is pressurized. Without sufficient oxygen for complete combustion, the smoldering solids will generate partially oxidized, hot, combustible organic vapors. Without an ESV, these hot, combustible organic vapors would be released from the system as uncontrolled ground-level fugitive emissions from the same sites where air infiltration occurs during normal operation. The vapors could spontaneously ignite upon reaching ambient air (source of oxygen) posing an unacceptable hazard to nearby workers.

In addition, if the ESV does not open and the combustible gases are allowed to accumulate, then subsequent introduction of combustion air could develop an explosive fuel-air mixture that may detonate.

The ESV provides a way to safely sweep these gases out of the rotary kiln and vent them without threatening workers with a hazard that is immediately dangerous to their life and health. Venting these gases also minimizes the potential for a catastrophic equipment failure that would also threaten human health and the environment.

3.3.2 Loss of Gas Cooling

As listed above, certain process equipment and utility malfunctions can impair the performance of the combustion gas quenching equipment. The result would be a high combustion gas temperature leaving the quenching equipment and entering the downstream portions of the APC system that are constructed primarily of heat sensitive equipment. If exposed to hot combustion gases the heat sensitive APC equipment will suffer thermal damage and eventually begin to burn.

The ESV provides an alternative flow path for combustion gases when the quenching equipment is unable to provide the cooling necessary to protect the downstream APC equipment. Venting of combustion gases via the ESV is necessary to avoid immediate hazard to human health and damage to equipment due to a potential fire in the APC system.

3.4 ESV Emissions

The combustion gases exhausted via the ESV are only partially treated from the standpoint that the particulate and acid gases are not removed when the APC system is bypassed and gases are vented through the ESV. Residual heat in the combustion system refractory provides heat for combustion of organic constituents. The natural draft through the ESV draws limited ambient air into the kiln and SCC sustaining partial combustion of the organic vapors generated from the hot solids. The rotary kiln and SCC will continue to provide heat for partial organic combustion/destruction much longer than the time required for the residual solid material to discharge from the rotary kiln. The short and long term effects on human health and the environment of venting partially treated combustion gases to the atmosphere are much less severe than the potential short and long term effects on human health resulting from an explosion or fire.

3.5 MINIMIZING ESV INCIDENTS

In the May 23, 1991 joint U.S. EPA and OSHA report "Evaluation of Compliance with On-Site Health and Safety Requirements at Hazardous Waste Incinerators," the task force acknowledged the process requirement for ESVs and automatic waste feed cutoffs:

> *"Emergency by-passes are intended to prevent ground level fugitive emissions and possible explosions from excessive pressure in the combustion unit."*

The task force also noted:

> *"While both devices* [waste feed cut-offs and ESVs] *are designed for safety purposes, the frequent use of these devices at some facilities may indicate a need to improve operating practices."*

These remarks are echoed in proposed rules published in the Federal Register (Vol. 55, No. 82, April 27, 1990):

> *"While it is understood that there can be mitigating circumstances which require the use of emergency relief stacks, these instances should be minimized."*

DOW endorses the need to implement system design and operating practices that minimize ESV incidents, and has done so in this incineration system. As a general design philosophy, the ESV is considered a "last resort" method of protection allowing the system to transition to a safe resting state.

The instrumentation and control system is configured to provide early warnings to operators allowing them the opportunity to take corrective actions before an automatic waste feed cutoff is activated or an ESV incident is initiated. In addition, redundancy is built into critical components, instruments, and controls to minimize nuisance process interruptions and increase the plant's on-stream factor. In most cases, except for power failures, alarms and control system time delays give operators the opportunity to head off an ESV incident by actuating emergency cooling water, starting installed spare pumps, proceeding with a normal system shutdown, etc.

4.0 ESV Operating Plan [40 CFR 63.1206(c)(4)(ii)]

4.1 Procedures for Rapidly Stopping Waste Feed [40 CFR 63.1206(c)(4)(ii)(B)]

All waste feeds and fuels are automatically and immediately stopped when the ESV system is activated due to power failure, ID fan failure, high quench chamber temperature and low water flow to the quench chamber. In order to maintain combustion chamber temperature only waste feeds are stopped when the ESV opens due to brief high pressure spikes in the combustion chamber. Auxiliary fuels (natural gas, fuel oil) if stopped cannot be restarted until the problem is corrected and the ESV is closed. Waste feed cannot be restarted until the incineration system is operating in conformance with permitted waste feed permissives. Most process upsets can be handled with automatic waste feed cutoffs (AWFCOs) and, if necessary, controlled system shutdowns.

4.2 Procedures for Shutting Down the Combustor [40 CFR 63.1206(c)(4)(ii)(B)]

The following sections describe the procedures for shutting down the 32 Incinerator when an ESV opening occurs.

4.2.1 Loss of Induced Draft

The following can result in the loss of the induced draft fans:

- Mechanical failure of Induced draft fan or motor
- Sudden and excessive bearing or fan vibration
- Loss of electrical power.

If the induced draft fan operation is interrupted, all waste feeds are stopped automatically by the control system. The combustion air blowers are also shut off automatically to prevent further pressurization of the system and preclude the introduction of air to the combustion zones that could ignite the confined vapors and possibly result in an explosion. The ESV is activated to depressurize the system and prevent the ground-level release of fugitive emissions from the rotary kiln. If the loss of the induced draft fan is due to a loss of electrical power, the rotary kiln emergency drive system will keep the rotary kiln rolling to continue to move the solid waste inventory through the rotary kiln and prevent warping of the rotary kiln.

Once the ESV is closed and the ID fan is operating the combustion system can be restarted and the combustion gases can be routed through the APC system. Waste feed may then be resumed when all waste feed permissives are met.

If the induced draft fan outage is of an extended duration, the system operators will continue to monitor the 32 Incinerator operation until all solid waste residue is discharged from the rotary kiln. The rotary kiln will continue to roll to prevent warping.

4.2.2 Loss of Combustion Gas Cooling

The following can result in the loss of the combustion gas cooling:

- Mechanical failure of the quench water feed system
- Loss of power for recycle pump motor
- Loss of backup water systems

The process indication that there is a loss of combustion gas cooling is a high-high combustion gas temperature leaving the quenching equipment. In addition, the control system for the 32 Incinerator receives indication of cooling water flow and pump operation that also indicates correct operation of the combustion gas cooling system.

When combustion gas cooling is impaired (two or more thermocouples reading quench outlet temperature greater than 110 °C), all waste feeds and auxiliary fuels are stopped automatically by the control system and the emergency water flow to the quench is initiated.

4.3 Maintain Temperature and Negative Pressure [40 cfr 63.1206(c)(4)(ii)(b)]

When the ESV opens, the afterburner chamber and hot duct act as a large chimney and the draft created maintains a negative pressure in the kiln and afterburner. Appendix C - Natural Draft Calculation, summarizes the calculations used to estimate the amount of draft resulting from this effect.

Auxiliary fuels are left on during brief high pressure spikes in order to maintain the operating temperature in the combustion chamber. During other events that cause the ESV to be activated it is not feasible to run auxiliary fuels to maintain the combustion chamber operating temperature from both an operational and safety standpoint. Accordingly the auxiliary fuels are stopped and the temperature of the combustion chamber is left to cool.

4.4 ESV Corrective Measures [40 CFR 63.1206(c)(4)(iii)]

If an ESV opening as defined in this plan occurs due to factors other than general power failures, the Production Leader or their designate will initiate an investigation into the cause(s) and events leading to the ESV opening. This investigation will be conducted to determine the root-cause factors in an effort to determine any procedures and/or equipment changes that may be reasonably made to preclude a similar event from occurring in the future. A summary report will be prepared and placed in the operating record to document the investigation. The report will include a description of the incident, the information assessed, the determinations made, and the corrective actions taken.

5.0 ESV Reporting [40 CFR 63.1206(C)(4)(iv)]

The following sections delineate the requirements and level of reporting associated with ESV openings.

5.1 All ESV Openings

Any time the ESV opens during the treatment of wastes, an on-duty operator at the time of the ESV opening will complete an Incident Report Form (example form included in Appendix A). The data reported on the form includes the incinerator operating conditions at the time of the ESV, the duration of the ESV opening, the reason(s) for the ESV opening, and the immediate operator actions taken to correct the problem. This form is completed whether the ESV opening is a regulatory reportable opening or not. The completed form is given to the Production Leader or designate and forms the basis for any investigation into the causes of the ESV opening and any actions taken to resolve, preclude or minimize similar openings from reoccurring in the future. The Production Leader is responsible to make sure the identified corrective actions are completed. The incident report becomes part of the facility's operating record.

5.2 Reportable ESV Openings [40 CFR 63.1206I(4)(iv)]

If the ESV opens when hazardous waste remains in the combustion chamber (i.e., when the hazardous waste residence time has not expired) **during an event other than a malfunction as defined in the startup, shutdown, and malfunction plan** such that combustion gases are not treated as during the most recent CPT (e.g., if the combustion gas by-passes any emission control device that was operating during the performance test) and emissions exceed the emission standards of 40 CFR Part 63, Subpart EEE, during the ESV opening event, the permittee shall submit to the DEQ a written report within 5 days of the ESV opening documenting the result of the investigation and corrective measures taken.

If a reportable ESV opening occurs, DOW will submit to the Michigan Department of Environmental Quality (MDEQ) a written report within 5 days of the opening. The total duration of a reportable ESV opening is the length of time from when the ESV is activated (opens) to when the ESV is closed or all solid hazardous waste residues present in the rotary kiln at time of the ESV opening are discharged from the rotary kiln. This report will include documentation of the results of the investigations and any corrective measures resulting from the reportable ESV opening. This report will include the reason(s) for the ESV opening, the operating conditions of the unit just prior to the initiation of the ESV event, the total duration of the ESV event, the immediate actions taken to recover from the ESV event, and the corrective actions taken to minimize similar future ESV events.

5.3 Emergency Vent Openings Caused by Malfunctions [40 CFR 63.6, 40 CFR 63.10]

The following reports will be completed should a vent opening occur as a result of a malfunction:

- [40CFR 63.6(e)(3)(iii, iv)][40CFR 63.10(b)(2)(i, ii, iii)] An incident report will be completed. The report will include documentation that the opening resulted from a malfunction, the duration of the malfunction, and whether or not the actions taken were consistent with the startup, shutdown, and malfunction operating procedure. It will also include corrective actions that could avoid this malfunction in the future if that is feasible.
- [40CFR 63.6(e)(3)(iii)][40CFR 63.10(b)(2)(v)] The startup, shutdown, and malfunction procedure will be completed and kept as part of the operating record.
- [40CFR 63.6(e)(iv)][40 CFR 63.10(b)(2)(iv)][40 CFR63.10(d)(5)(ii)] If the action taken was not consistent with the SSMP or the ESV plan, the actions taken will be reported verbally or by fax to MDEQ within two working days after the end of the malfunction. A written report will follow within 7 working days after the end of the malfunction.
- [40 CFR 63.10(d)(5)(ii)] If the startup, shutdown, and malfunction procedures were followed, the malfunction shall be reported in the periodic startup, shutdown, and malfunction report required to be submitted semiannually.

5.4 Non-Reportable ESV Openings

Should a non-reportable ESV opening occur, the incinerator operating conditions, the duration of the ESV opening, the reason for the ESV opening and the actions taken to correct the problem, are recorded on the Incident Report Form and filed in the operating record.

Appendix A

Example Incident Report Form

AWFCO and Malfunction Log

Signature:	
Date of Event:	

Time of Event:	
Duration of Event:	

Description of Event and Reason:

Remedial Action Taken:

(✓) when complete	**Check Item:**
	Review and follow SSMP (if applicable)[1]
	Notify Run Plant Engineer[2]

[1] If a permit limit is exceeded, notification to the DEQ may be required within 2 days (See Procedure and contact on call immediately)

[2] Run plant Engineer to attach parameter data, information supporting preventing reoccurrence, and determination whether event is the 10th AWFCO in a 60 day period. Notification to EHS is required if an event is the 10th AWFCO in a 60 day period.

Note: Per the ESV Operating Plan, ESV openings will be documented on this form as well.

Appendix B

Applicable Subpart EEE Regulations

General Provision – Search for ESV found nothing

MACT Regs – Search for ESV found the following

63-1206(c)

(2) ***Startup, shutdown, and malfunction plan***.

(i) You are subject to the startup, shutdown, and malfunction plan requirements of §63.6(e)(3).

[§63.1206(c)(2)(i) revised at 67 FR 6813, Feb. 13, 2002]

(ii) If you elect to comply with §§270.235(a)(1)(iii), 270.235(a)(2)(iii), or 270.235(b)(1)(ii) of this chapter to address RCRA concerns that you minimize emissions of toxic compounds from startup, shutdown, and malfunction events (**including releases from emergency safety vents**):

(A) The startup, shutdown, and malfunction plan must include a description of potential causes of malfunctions, **including releases from emergency safety vents**, that may result in significant releases of hazardous air pollutants, and actions the source is taking to minimize the frequency and severity of those malfunctions.

(B) You must submit the startup, shutdown, and malfunction plan to the Administrator for review and approval.

63.1206(c)

4. ESV openings.—

(i) *Failure to meet standards.* If an emergency safety vent (ESV) opens when hazardous waste remains in the combustion chamber (*i.e.,* when the hazardous waste residence time has not expired) **during an event other than a malfunction as defined in the startup, shutdown, and malfunction plan** such that combustion gases are not treated as during the most recent comprehensive performance test (*e.g.,* if the combustion gas by-passes any emission control device that was operating during the performance test), you must document in the operating record whether you remain in compliance with the emission standards of this subpart considering emissions during the ESV opening event.

[§63.1206(c)(4)(i) revised at 67 FR 6814, Feb. 13, 2002]

(ii) ***ESV operating plan.***

(C) You must develop an ESV operating plan, comply with the operating plan, and keep the plan in the operating record.

(D) The ESV operating plan must provide **detailed procedures for rapidly stopping the waste feed, shutting down the combustor, and maintaining temperature and negative pressure in the combustion chamber during the hazardous waste residence time**, if feasible. The plan must include **calculations and information and data documenting the effectiveness of the plan's procedures for ensuring that combustion chamber temperature and negative pressure are maintained** as is reasonably feasible.

(iii) ***Corrective measures***. After any ESV opening that results in a failure to meet the emission standards as defined in paragraph (c)(4)(i) of this section, you must investigate the cause of the ESV opening, take appropriate corrective measures to minimize such future ESV openings, and record the findings and corrective measures in the operating record.

(iv) ***Reporting requirements.*** You must submit to the Administrator a written report within 5 days of an ESV opening that results in failure to meet the emission standards of this subpart (as determined in paragraph (c)(4)(i) of this section) documenting the result of the investigation and corrective measures taken.

[§63.1206(c)(4)(iv) revised at 67 FR 6814, Feb. 13, 2002]

Note: MI-ROP-A4033, EU32Incinerator-S1, VII.6 summarizes the HWC MACT requirements: If the ESV opens when hazardous waste remains in the combustion chamber (i.e., when the hazardous waste residence time has not expired) during an event other than a malfunction as defined in the startup, shutdown, and malfunction plan such that combustion gases are not treated as during the most recent CPT (e.g., if the combustion gas by-passes any emission control device that was operating during the performance test) and emissions exceed the emission standards of 40 CFR Part 63, Subpart EEE, during the ESV opening event, the permittee shall submit to the MDEQ a written report within 5 days of the ESV opening documenting the result of the investigation and corrective measures taken. **(40 CFR 63.1206(c)(4))** .

Appendix C

Natural Draft Calculations

1.0 Conclusions

When the vent is open, there is sufficient draft to remove the combustion gases from the kiln and afterburner.

2.0 Calculation Method

Combustion gases flow from the kiln to the afterburner through the hot duct and on to the gas cleaning section of the incinerator. The emergency vent is located in the hot duct following the afterburner at the high point of the kiln and is approximately 116 feet above the kiln center-line. When the ESV opens, the afterburner chamber and hot duct function as a chimney and create a draft that draws the combustion gases from both the afterburner and kiln.

Perry's Chemical Engineering Handbook , 4th Edition includes formulae for calculating the draft on pages 9-43 and 9-44. The method described is to calculate both a theoretical draft, based upon the difference in static head of equal volumes of atmospheric air and combustion gas, and subtract it from the friction losses for the chimney. The stack flow loss depends upon gas flow and the actual stack flow is that that will create a friction loss equal to the theoretical draft. This calculation uses the approach described in Perry's.

3.0 Calculation

Theoretical Draft

The formula given in Perry's Chemical Engineering Handbook , 4th edition is :

Stack draft (in. H_2O) = $0.256\ HP(1/T - 1/T_1)$

Where:

H = stack height above kiln center line, feet = 116 feet
P = barometric pressure, in Hg = 29.921in Hg
T = ambient temperature, °R = 460 + 60°F = 520°R
T_1 = average stack temperature, °R = 460 +1800°F = 2260°R

Substituting

Stack Draft (in. H_2O) = $0.256 * 116 * 29.921 * (1/520 - 1/2260) = 1.32$ in. H_2O

Stack Loss and Gas Flow

Again from Perry's:

Stack Loss (in. H_2O) = 0.0942 (T_1/D^4) $(W/100{,}000)^2$ $(1 + fH/D)$

Where:

D= stack diameter, feet = 6 feet (assuming the loss is in the ESV duct only)
W = gas flow lb/hr.
f = friction factor = assume .015 for first iteration
H = stack height above breeching = 7.6 feet (assuming length of duct only)

With a stack loss of 1.32 inches

$$(W / 100{,}000)^2 = 1.32/[(.0942 * (2260/1296) (1 +.015 * 7.6 / 6)] = 1.32/0.167 = 7.90419$$

Thus W/ 100,000 = 2.811, Therefore:

W = 281,100 lb/hr
= 4,685 lb/min
= 57,983 ft^3/ min at 0°C and 1 atm. (density =.0808 lb/ft^3)
= 98,516 m^3/hr.

Checking the friction factor:

$N_{Re} = 27{,}600W/(T_1/D) = 27{,}600 * 281{,}100/ (2260/6) = 2.06 \times 10^7$

And from the chart *f* = 0.012

Using this gives W = 281,700 lb/hr which is not a significant difference.

4.0 Results

These calculations estimate that there will be a significant amount of draft available, sufficient to draw combustion products from the kiln and afterburner.