OSHA INSTRUCTION

U.S. DEPARTMENT OF LABOR — Occupational Safety and Health Administration

DIRECTIVE NUMBER: CPL 02-01-041 | **EFFECTIVE DATE:** 9-16-04

SUBJECT: Alternative Abatement Method for 29 CFR 1910.261(g)(17) – Over-pressure Protection for Batch Digesters Used in the Pulp Processing Industry

ABSTRACT

Purpose: This directive clarifies the options available to employers in providing over-pressure protection for batch digesters used in the pulping process under 29 CFR 1910.261(g)(17), *Pressure Vessels (safety devices).* This directive is intended to outline an enforcement policy specifically in regard to 29 CFR 1910.261(g)(17), and does not apply to any other provision or standard, nor to any other type of pressure vessel.

Scope: This instruction applies OSHA-wide.

References: See paragraph III.

State Plan Impact: See paragraph VII.

Action Offices: National, Regional, and Area Offices.

Originating Office: Directorate of Enforcement Programs.

Contact: Directorate of Enforcement Programs
200 Constitution Avenue, NW, Room N3107
Washington, DC 20210
Phone: (202) 693-1850

By and Under the Authority of

John L. Henshaw
Assistant Secretary

Executive Summary

Pursuant to paragraph 6(a) of the OSH Act, the Occupational Safety and Health Administration (OSHA) adopted in 1971 the standard for *Pulp, Paper and Paperboard Mills*, 29 CFR 1910.261. The Agency derived the standard from a national consensus standard issued by the American National Standards Institute – ANSI P1.1-1969, *Safety Requirements for Pulp, Paper and Paperboard Mills*. The OSHA standard has remained unchanged since that time. The ANSI committee responsible for the source consensus standard disbanded, and ANSI withdrew the standard on March 30, 1983; no comprehensive consensus standard addressing the pulp, paper and paperboard mill industry is available at this time.

The paper industry has undergone many changes since OSHA adopted ANSI standard P1.1-1969. There have been changes in manufacturing technology, equipment, and work practices. Presently there exist methods, in addition to those detailed in 29 CFR 1910.261(g)(17), that provide employees with effective protection against the hazards associated with over-pressurization of batch digesters. Therefore, this directive recognizes measures that will permit the paper industry to use newer technology to prevent over-pressurization of batch digesters.

This directive clarifies the options available to employers in providing over-pressure protection for batch digesters used in the pulping process under 29 CFR 1910.261(g)(17), and provides guidance to OSHA compliance safety and health officers (CSHOs) in assessing the adequacy of the control measures implemented for each batch digester at a given site. This directive applies only to sulfate (kraft) and sulfite batch cooking processes using one or more direct and/or indirect heating methods.

Significant Changes

This is a new directive describing policies and procedures regarding pulp digesters.

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I. Purpose.

This directive clarifies the options available to employers in providing over-pressure protection for batch digesters used in the pulping process under 29 CFR 1910.261(g)(17), *Pressure Vessels (safety devices).* The information in this directive applies to pulp digesters used in both the sulfate (kraft) and sulfite batch cooking processes using one or more direct and/or indirect heating methods.

This directive is intended to outline an enforcement policy specifically in regard to 29 CFR 1910.261(g)(17), and does not apply to any other provision or standard, nor to any other type of pressure vessel. Further, this directive provides guidance to CSHOs in assessing the adequacy of the protective control measures implemented for each batch pulp digester in accordance with the requirements outlined in Section X of this directive.

II. Scope.

This directive applies OSHA-wide.

III. References.

A. ASME Boiler and Pressure Vessel Code, Section VIII (1969).

B. ASME Code Case 2211M, Code Case for Section VIII, Division 1 and 2 Pressure Vessels with Over-pressure Protection by System Design (1996).

C. "Determining the Heat of Reaction of Kraft Pulping," Project 3977, Institute of Paper Science and Technology (August 1995).

D. "Guide for Pressure-Relieving and Depressuring Systems," API Recommended Practice 521, ANSI/API RP521-1992, 3rd edition, November 1990.

E. "Guidelines for Batch Digester Inspections," TAPPI Technical Information Paper 0402-22 (rev. 1995).

F. National Board Inspection Code (NBIC – ANSI/NB-23).

G. OSHA's Standard for Pulp, Paper, and Paperboard Mills. 29 CFR Section 1910.261 and, in particular, Section 1910.261(g)(17) – Pressure Vessels (safety devices).

H. Final Report for the OSHA Project on Reliability Assessment of Systems Approach to Batch Digester Overpressure Protection (May 25, 2001).

IV. Cancellations.

None

V. Action Information.

A. Responsible Office. Office of General Industry Enforcement.

B. Action Offices. Regional Offices, Area Offices.

C. Information Offices. State Plan Offices, Consultation Offices.

VI. Actions Required.

Regional Administrators and Area Directors shall ensure that the General Inspection Procedures (Section X) of this directive are followed. Regional Administrators shall also take steps in accordance with Section XI to provide CSHOs with training adequate to implement the provisions of this directive.

VII. Federal Program Change.

This instruction describes a Federal program change. State adoption is not required.

Note: Compliance staff needs guidance in order to effectively enforce safety and health standards. States are expected to have health and safety standards, enforcement policies and procedures that are at least as effective as those of Federal OSHA.

VIII. Application.

This instruction applies to pulp, paper, and paperboard mills nationwide.

IX. Background.

The vast majority of digesters used in the paper industry are American Society of Mechanical Engineers (ASME) Coded pressure vessels. While not a factor in the accident, investigations in connection with a 1994 explosion revealed that typically batch digesters were not equipped with safety valves. The paper industry provided documentation indicating that safety valves would not work to control over-pressurization on batch digesters due to the three-phase nature of the process and the associated fouling of the safety valves. For additional information, Appendix B provides a detailed description of the chemical pulping processes. Appendix A provides terms (and their definitions) that are relevant to this directive.

OSHA believes ASME Code Case 2211 (1996) provides protection that is at least equivalent to the protection afforded by the existing standard for workers in this industry by using a system design approach in lieu of the safety valves. This Code Case is intended for use in conditions where process fouling or environmental restraints indicate that the Code Case would be more effective than traditional safety valve over-pressure protection. Additionally, for over 10 years, the State of Washington has allowed pulp mills within its jurisdiction to use electronic system design (redundant trip systems) in lieu of safety relief valves for over-pressure protection by way of variances.

OSHA gathered facts and information from a variety of sources familiar with the pulp, paper, and paperboard mill industry. OSHA also hired independent consultants to consider and model batch digester pressure control systems. These efforts permitted identification of feasible controls to prevent over-pressurization in batch digesters, as well as redundancies necessary to achieve an acceptable level of safety for employees working with and around batch digesters. Based upon this information, the Agency is publishing two checklists in this directive -- one for the sulfate (kraft) process (Table 2) and one for the sulfite process (Table 3). These checklists are based on information that incorporates best practices available in the industry at this time.

X. General Inspection Procedures.

To avoid citation for a violation of 29 CFR 1910.261(g)(17), employers must implement one of the options listed in Table 1 below or obtain a variance pursuant to Section 6(d) of the OSH Act. If the CSHO determines that an employer has not implemented one of the options in Table 1 or obtained a variance pursuant to Section 6(d) of the OSH Act, the CSHO may recommend a citation under 29 CFR 1910.261(g)(17).

TABLE 1: OPTIONS

Option	Action – An employer demonstrates that it has implemented one of the following options:	Compliance Status
1	Utilize a safety valve for each digester as required by OSHA's standard, 29 CFR 1910.261(g)(17); *OR*	In Compliance
2	Protect each digester with **<u>any</u>** relief device acceptable under ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 (1969);[1] *OR*	De minimis violation
3	Adopt a safety systems approach that complies with ASME Code Case 2211M, Code Case for Section VIII, Division 1 and 2 Pressure Vessels with Over-pressure Protection by System Design (1996);[2] *OR*	De minimis violation
4	Comply with all of the items listed in Table 2 below for sulfate (kraft) batch digesters, or all of the items listed in Table 3 below for sulfite batch digesters; *OR*	De minimis violation
5	Secure a variance from the state in states operating an OSHA-approved State Plan	In Compliance

[1] If ASME publishes subsequent versions of the Code, an employer can adopt such provisions and still qualify for de minimis status, provided the employer can demonstrate that the subsequent version provides equal or greater employee protection.

[2] If ASME publishes subsequent versions of the Code Case, an employer can adopt such provisions and still qualify for de minimis status, provided the employer can demonstrate that the subsequent version provides equal or greater employee protection.

TABLE 2: SAFETY-SYSTEMS APPROACH TO OVER-PRESSURE MANAGEMENT – CHECKLIST OF MINIMUM SYSTEM REQUIREMENTS FOR SULFATE (Kraft) BATCH DIGESTERS

[For Option 4 in Table 1 above]

Component	Requirement		Verified
Vent Valves	1	An automatic vent/pressure control valve (fail-safe/open) at the top of the digester.	
Vent Valve Protection	2	A screen located at the (top) neck of the digester or in-line to the vent valve to prevent pulp from clogging the vent valve.	
	3	Blowback steam to clear the screen, or pressure sensors in the digester headspace and the vent line downstream of the screen to detect any pressure drop due to screen plugging.[3]	
Digester Inventory Control	4	Chip Charge Determination:[4] Documentation of the following: a. A baseline measurement of the approximate chip weight and volume that reflects current chip filling/charging practice; and b. A new measurement whenever there is a change in the chip filling practice that would require an increase in the cooking liquor or steam added to the digester.	
	5	Chip Charge Control-Limit Determination. Documentation demonstrating either of the following:[5,6]	

[3]This alternative is included in the basic design approved by the Washington State Office of Boiler Inspections through the WISHA variance process.
[4]The determinations made to satisfy this item may be based on an actual measurement or a documented quantitative method.
[5]The control-limit determination may be made on the basis of actual measurements or by a documented quantitative method.
[6]It is common practice within the industry to fill a digester with chips (with or without the assistance of steam-packing or liquor-packing techniques) to the neck at the top of the digester. A mill may rely on this "fill to the top" approach as a way of properly controlling chip fill when the following conditions are met: 1) A baseline chip charge determination (as described in Item 4 above) has been made based on a "fill to the top" approach that reflects the current chip filling/charging practice; **and** 2) The control-limit determination demonstrates that the "fill to the top approach" provides an adequate headspace (freeboard) at the time the chemical reaction of the cook is well underway.

Component		Requirement	Verified
		a. The maximum chip loading (by volume and weight) that will provide an adequate freeboard (headspace) in the digester (above the chip pile and below top cap) at the time the chemical reaction of the cook is well underway; or b. The baseline measurement of chip weight and volume as described in Item 4 above that will provide an adequate headspace (freeboard) in the digester (above the chip pile and below top cap) at the time the chemical reaction of the cook is well underway.	
	6	An automatic or manual control of chip loading that limits the addition of excess chips by, for example, assuring the maximum chip loading limit in Item 5 above is not exceeded.	
	7	Documentation of the total liquor charge volume or weight for each batch.	
	8	An automatic or manual control that limits addition of excess liquor (white and black). These controls must include protection from double liquor charging.	
	9	<u>Measurement or Estimate of Delivered Direct (Live) Steam Into Digester</u>. Documentation of the following: a. A baseline measurement of direct live steam injected into the digester that reflects current chip and liquor filling/charging practice. b. A new measurement on a monthly basis or whenever there is a change in the chip or liquor filling practices/procedures or the cooking practices/ procedures. (This change would be based on an increase in the steam added to the digester of such a magnitude that it would significantly reduce the headspace (freeboard) in the digester at the time the chemical reaction of the cook is well underway. Such a	

Component		Requirement	Verified
		change might result if there was a cook with cold liquor or a seasonal change that led to the cooking of frozen chips. See also footnote 4.)	
	10	An automatic or manual control that limits the addition of excess steam whenever there is a change in the chip or liquor filling practices/procedures or the cooking practices/procedures. (This change would be based on an increase in the steam added to the digester of such a magnitude that it would significantly reduce either the total void space in the digester or the headspace (freeboard) in the digester at the time the chemical reaction of the cook is well underway.)	
	11	Targets. Documentation of the following: a. The concentration of liquor feed (consistent with the targeted range of liquor charge) or the nominal total liquor-to-wood ratio; and b. The temperature of liquor feed (consistent with targeted range of steam usage) or the total steam-to-wood ratio that will allow safe headspace (freeboard) during cooking.	
Pressure Measurement and Recording	12	Pressure measurement with high-pressure alarm capability.	
	13	Pressure measurement and recording updates at 15-second intervals.	
	14	On-line data storage capabilities of temperature and pressure for at least the previous 24-hour period, with provisions to detect and archive any 24-hour period that recorded over-pressure excursions or near misses. Software may utilize data compression.	
Pressure and Temperature Control	15	Documentation of alarm logic, supporting algorithms, and controls for effective pressure management.	

Component	Requirement		Verified
	16	Documentation of alarm logic, supporting algorithms, and controls for effective temperature management.	
	17	Two automatic sensors (which could be two pressure sensors, two temperature sensors, or one pressure sensor and one temperature sensor) linked to controls so that the steam supply is reduced or cut off as necessary to prevent an over-pressure event.	
	18	Manual or automatic blowing procedures for emergency pressure control that can be activated within 10 minutes of reaching a high-pressure alarm (i.e., set at no higher than 10 psi below the MAWP (MAWP-10 psi)), or within 5 minutes of reaching a high-pressure alarm (i.e., set at no higher than 5 psi below the MAWP (MAWP-5 psi)).	
Vent Valve Maintenance	19	Records showing periodic maintenance of the vent/pressure valve conducted using a generally recognized good engineering practice.	
System Safety Evaluation Procedures	20	Documentation showing periodic review of system safety design at least every five years, or whenever there is a change in the system's controls, whichever comes first.	
	21	Practice drills for responding to potential over-pressurization incidents as necessary to maintain proficiency.	
	22	Retraining for operators and supervisors at least every three years or as necessary to maintain proficiency.	

TABLE 3: SAFETY-SYSTEMS APPROACH TO OVER-PRESSURE MANAGEMENT – CHECKLIST OF MINIMUM SYSTEM REQUIREMENTS FOR SULFITE BATCH DIGESTERS

[For Option 4 in Table 1 above]

Component	Requirement(s)		Verified
Vent Valves	1	An automatic vent/pressure control valve (fail-safe open) at the top of the digester.	
Vent Valve Protection	2	A screen located at the (top) neck of the digester or in-line to vent valve to prevent pulp from clogging the vent valve.	
	3	Blowback steam to clear the screen, or pressure sensors in the digester headspace and the vent line downstream of the screen to detect any pressure drop due to screen plugging. (See footnote 3 in Table 2.)	
Digester Inventory Control	4	Chip Charge Determination. Documentation of the following: a. A baseline measurement of the approximate chip weight and volume that reflects current chip filling/charging practice; and b. A new measurement whenever there is a change in the chip filling practice that would require an increase in the cooking liquor or steam added to the digester. (See footnote 4 in Table 2.)	
	5	Chip Charge Control-Limit Determination. Documentation demonstrating either of the following: a. The maximum chip loading (by volume and weight) that will provide an adequate freeboard (headspace) in the digester (above the chip pile and below top cap) at the time the chemical reaction of the cook is well underway; or b. The baseline measurement of chip weight and volume as described in Item 4 above that will provide an adequate freeboard (headspace) in the digester (above the chip pile and below	

Component	Requirement(s)		Verified
		top cap) at the time the chemical reaction of the cook is well underway. (See footnotes 5 and 6 in Table 2.)	
	6	An automatic or manual control of chip loading that limits addition of excess chips by, for example, assuring the maximum chip loading limit in Item 5 above is not exceeded.	
	7	Documentation of the volume or weight of the liquor side relief for each batch.[7]	
	8	An automatic or manual control that ensures that minimum liquor side relief is withdrawn, and no excess liquor is subsequently added.	
	9	Measurement or Estimate of Delivered Direct (Live) Steam Into Digester. Documentation of the following: a. A baseline measurement of direct live steam injected into the digester that reflects current chip and liquor filling/charging practice. b. A new measurement on a monthly basis or whenever there is a change in the chip or liquor filling practices/procedures or the cooking practices/ procedures. (This change would be based on an increase in the steam added to the digester of such a magnitude that it would significantly reduce the headspace (freeboard) in the digester at the time the chemical reaction of the cook is well underway. Such a change might result if there was a cook with cold liquor or a seasonal change that led to the cooking of frozen chips. See also footnote 4 in Table 2.)	
	10	An automatic or manual control that limits the addition of excess steam whenever there is a change in the chip or liquor filling practices/procedures or the cooking	

[7] In contrast to the sulfate (kraft) process, a sulfite digester is initially hydraulically filled and then partially drained. The appropriate focus is on how much liquor is removed during side relief, rather than how much liquor is added initially.

Component		Requirement(s)	Verified
		practices/procedures. (This change would be based on an increase in the steam added to the digester of such a magnitude that it would significantly reduce either the total void space in the digester or the headspace (freeboard) in the digester at the time the chemical reaction of the cook is well underway.)	
	11	<u>Targets</u>. Documentation of the following: a. The concentration of liquor feed (consistent with withdrawal of at least the minimum liquor side relief) or the nominal total liquor-to-wood ratio; and b. The temperature of liquor feed (consistent with targeted range of steam usage) or the total steam-to-wood ratio that will allow safe headspace (freeboard) during cooking.[8]	
Pressure Measurement and Recording	12	Pressure measurement with high-pressure alarm capability.	
	13	Pressure measurement and recoding updates at 15-second intervals.	
Pressure and Temperature Control	14	On-line data storage capabilities of temperature and pressure for at least the previous 24-hour period, with provisions to detect and archive any 24-hour period that recorded over-pressure excursions or near misses. Software may utilize data compression.	
	15	Documentation of alarm logic, supporting algorithms, and controls for effective pressure management.	
	16	Documentation of alarm logic, supporting algorithms, and controls for effective temperature management.	

[8]Unlike sulfate (kraft) digesters, sulfite digesters are not operated on the basis of liquor-to-wood ratios.

Component		Requirement(s)	Verified
	17	Two automatic sensors (which could be two pressure sensors, two temperature sensors, or one pressure sensor and on temperature sensor) linked to controls so that the steam supply is reduced or cut off as necessary to prevent an over-pressure event.	
	18	For sulfite digesters, manual or automatic acid side relief procedures for emergency pressure control that can be activated within 5 minutes of reaching a high-pressure alarm (i.e., the alarm set no higher than 10 psi below the MAWP (MAWP-10 psi)), or within 2 minutes of reaching a high-pressure alarm (i.e., the alarm set no higher than 5 psi below the MAWP (MAWP-5 psi)).	
Vent Valve Maintenance	19	Records showing periodic maintenance of the vent/pressure control valve conducted using a generally recognized good engineering practice.	
System Safety Evaluation Procedures	20	Documentation showing periodic review of system safety design at least every five years, or whenever there is a change in the system's controls, whichever comes first.	
	21	Periodic drills for responding to potential over-pressurization incidents as necessary to maintain proficiency.	
	22	Retraining for operators and supervisors at least every three years or as necessary to maintain proficiency.	

XI. Training:

Because of the technical nature of these inspections, Area Directors are encouraged to take steps to assure that CSHOs who conduct inspections under this directive have the training, experience, and/or resources sufficient to ascertain whether an employer has properly implemented one of the options detailed in this directive. The National Office will coordinate with OTI to provide training to CSHOs.

APPENDIX A

Definition of Terms

(Please note that definitions below denoted with an asterisk are not found in the directive. They are included to aid CSHOs who may come across them during the course of an inspection of the digesters.)

baseline measurement: An assessment of the conditions present in a batch digester at the start of the cook.

batch digester: A vertical, cylindrical steel vessel, usually having a conical bottom and hemispherical head. The volume of kraft digesters in the U.S. ranges from 500 to 9000 cubic feet. Historically, these digesters have been treated as unfired pressure vessels having no internal source of heat. The vessels have been designed and built to ASME codes, and are protected from over-pressure by the steam source as specified by ASME.

black liquor: Spent liquor from the pulping process, usually containing 10 to 18% solids, and is used to adjust the initial liquor-to-wood ratio of the digester charge.

blow back valve: This valve controls the steam used to clean the gas-off screen of debris.

blow tank: A closed tank designed to contain the contents of several digester cooks, and to deliver the pulp and spent liquor to the downstream process.

blow valve: A small valve, usually 6- to 14-inches in diameter, located at the bottom of digester. The purpose of this valve is to empty or blow the digester contents to the blow tank.

***capping valve**: A large valve, usually 20- to 30-inches in diameter, located in the top center of the digester head. The purpose of this valve is to provide an opening for the chips to enter the vessel. (Older digesters may have manual caps rather than valves.)

***chip bin**: Storage containers, usually found in older mills, located above digesters that hold one or two cooks of chips. (A sliding gate on the bottom of the bin is opened to permit chips to fall into the digester below.)

chip fill: The operation of placing wood chips in the digester.

chip packing: The process of compacting chip mass in a vessel so that a greater weight of wood is contained in a given volume. Compacting chips is induced by adding liquor or steam to the vessel during the chip fill step.

***constant chip volume**: A constant volume of chips determined by a gamma gauge, limit switch, chip bin, or manual measurement of the height of the chip mass. (The purpose of this determination is to deliver the same volume of chips to each cook.)

***cook complete or blow**: Defines the completion of the cooking sequence when the contents of the digester are released from the vessel under pressure into to a blow tank. (The digester is completely emptied in this step.)

cooking: The process of holding the vessel contents at the target temperature or pressure required to produce a specified amount of delignification for the product being made. (This step may be known as "time at temperature" or "time at pressure" in some operations.)

differential pressure: The pressure drop across the gas-off screen that compares the internal digester pressure to the pressure in the gas-off line. (An increase in the differential pressure is an indication of plugging and is used to trigger the blow back valve in the systems.)

***digester cooking sequence**: The step-by-step operation used to cook a batch digester.

direct steam: Heat introduced into a digester by condensing the steam into the vessel contents. (Thus, all the water condensed in the heating process is contained in digester.)

documented quantitative method: Involves either digester-specific calculations or comparing overall batch digester steam usage per appropriate unit (e.g., batch, ton of chips) for a group of digesters.

excess chips/liquor: The amount of chips/liquor that, when added to the digester, reduces the adequate freeboard space that is available at the time the chemical reaction of the cook is well underway.

***false pressure**: The difference between total pressure and water vapor pressure at system temperature. (Vents usually stay completely or partially open until false pressure drops to about zero.)

freeboard: Also known as headspace. It is the space in the digester not occupied by solids or liquids.

***gamma gauge**: A device used to measure the height of the chip pile in the digester, and to indicate the target level at which to shut off the chip feed. (The measurement is made from outside of the vessel using a radioactive source and a sensor.)

gas-off screen: A drilled plate or heavy mesh screen located in the neck of the vessel under the capping device that covers the opening leading to the gas-off line. The purpose of the screen is to prevent chips from entering and blocking the piping system. (In some systems, the gas-off screen is located in a line external to the digester.)

gas-off valve: A valve that controls the flow of non-condensable gases from the digester to the collection system, and is closed to permit blow back steam to purge or clean the gas-off screen.

H-Factor: Represents a combination of the driving physical forces of time and temperature in the pulping process. A numerical target is selected to deliver a given amount of thermal energy based on any combination of time and temperature within the ranges allowed by the process.

hydraulic overfill: Loading a digester with wood, water (i.e., from wood moisture), and cooking chemicals (i.e., liquor) to such an extent that it results in insufficient space to accommodate the water condensed from steam and the thermal expansion of the digester contents.

***integrator/accumulator**: Converts or sums rates of flow to total flow; for example, converting chip flow in tons per hour to total tons charged to a digester, or converting white liquor in gallons per minute to total gallons added to the digester.

limit switch: A device used to sense the chip level in a digester or in a chip chute. (Sensing elements may measure factors such as torque, load, or drag.)

liquor fill: The operation of adding a predetermined quantity of white and/or black liquor to the digester.

***liquor-fill valve**: A shut-off valve located near each digester to isolate the vessel from the liquor delivery piping. (The valve is opened only during the fill cycle.)

liquor-to-wood ratio: The ratio of the amount of liquid (including the water in the wood chips) to the weight of dry wood added to the digester.

***liquor test**: A quantitative measurement of the chemical concentration of white liquor, that may be reported as pounds/cubic foot, pounds/gallon, or grams/liter.

***magnetic flow meter**: A device used to measure the flow rate of liquids through a pipe.

manual measurement: A physical determination of the actual condition of a property. For example, a manual chip-level measurement in a digester could involve a person looking at, or using a measuring stick at the top of the chip mass.

***measuring tanks**: Small diameter tanks used to fill a digester with white and black liquor. (The small diameter is necessary for an accurate volumetric determination of the liquid drawdown. These tanks usually are found in older systems.)

near miss: An overpressurization event that could have resulted in an accident involving rupture of a digester.

non-condensable gas: Consists of air and gases formed in the digester that are relieved from the vessel through the gas-off system during the cook. The gases normally contain reduced sulfur compounds, methanol, and other volatiles.

significantly reduce: Means to reduce to a level that may cause an overpressurization event requiring some form of emergency action.

steam-flow control valve: Controls the rate of steam flow to a digester, and is used to stop this flow when needed.

***steaming**: The process during which the digester is closed or capped up, and steam is introduced to raise the temperature to the cooking target.

***strain gauges**: Devices that are attached to structural-support members of the digester that measure mechanical stress on the vessel, and thus the weight of the vessel and its contents.

***total liquor**: Total amount of liquor charged to a cook, including both black and white liquors.

***weightometer**: A device used to measure the weight of chips on a belt feeding the digester. (Some weightometers are used to measure chip moisture content as well as weight.)

well underway: A point during the cooking process when there is adequate headspace (freeboard) above the chip bed for vapor space.

white liquor: The chemical mixture (i.e., sodium hydroxide, sodium sulfide and sodium carbonate) used in the pulping process.

***wood bulk density**: A measure of the dry -wood charge expressed as pounds per cubic foot. (This measurement is used to calculate the amount of cooking chemical (white liquor) needed.)

APPENDIX B

BACKGROUND INFORMATION ON THE CHEMICAL PULPING PROCESS FOR BATCH DIGESTERS

I. OVERVIEW OF THE PULPING PROCESS

Cellulose-based fibers are the basic component of paper. The primary source of this fiber is pulp made from wood. Cellulosic and hemicellulosic materials comprise approximately 55 to 70 percent of the dry wood weight. The remaining portion of the wood composition is primarily lignin, a glue-like substance that holds the cellulose fibers together.

Many different methods may be used to manufacture pulp from wood. They range in type from purely mechanical to almost purely chemical. The mills covered by this instruction use the chemical pulping process in which alkaline chemicals (the sulfate (kraft) process) or acidic chemicals (the sulfite process) are used to break down and dissolve the lignin, and a minimal amount of mechanical force is used to release the cellulose-based fibers from the wood chips and complete the pulping process. The chemical pulping process removes approximately 60 to 90% of the lignin depending on the degree of cook, which is selected so that the final product has the desired characteristics.

The process begins when debarked wood is chipped and screened to a uniform size. The wood chips and cooking chemicals (liquor) are combined in a digester, where they are brought up to and maintained at a set pressure and temperature for an established time period ("the cook"). At the end of the cook in a conventional batch digester process, the softened chip mass/pulp is transferred to the blow tank.

II. PHYSICAL DESCRIPTION OF BATCH DIGESTERS

The physical make up of a batch digester has three major sections:

A. Bottom section – a conical bottom with an opening at the bottom, controlled by the blow valve;
B. Middle section – a cylindrical center section ranging from approximately 12 to 18 feet in diameter; and
C. Top section – hemispherical dome with a vertical cylindrical neck at the top.

At the top of the cylindrical neck is a removable cap (either manual or mechanized) that is removed between cooks to permit chips to be added to the digester. Attached to the neck of the digester is a vent line with a control valve (or a vent line header with multiple control valves) used to vent gases from the digester and control the pressure of the digester during the cooking and blowdown process. Mounted either inside the neck of the digester or in the vent line is a screen or strainer that prevents any solid material from getting into the seats of the valves on the piping manifold at the top of the digester.

Indirectly heated digesters, and all sulfite digesters, have a second set of internal circulation strainer plates mounted approximately 1/3 of the way up from the bottom of the digester. These cylindrical plates are approximately 30 inches tall, and are attached in a ring around the entire circumference of the digester. They provide a filtering mechanism for the system that circulates the cooking liquor from the bottom to the top of the sulfite digester and, in the case of indirectly heated digesters, pumps the cooking liquor through a heat exchanger before returning it to the top and the bottom of the digester.

III. OPERATION OF BATCH DIGESTERS

A. General Principles

A batch digester is a pressure vessel (in effect, simply a pressure cooker) used to cook wood chips in the cooking liquor to dissolve lignin. The digester is brought up to, and maintained at, the cooking temperature and pressure by direct heating (steam injection) and/or indirect heating (through a heat exchanger). For directly heated digesters, the steam flow to the digester is controlled to maintain temperature and pressure in the digester (as described below). For indirectly heated digesters, the steam flow to the heat exchanger is controlled to maintain the temperature and pressure in the digester.

The process parameters (e.g., liquor concentration, temperature, pressure, cook time) are designed to maximize the overall efficiency of the process and the quality of resulting fiber. Holding a batch beyond its normal cook time results in decreased production efficiency and low quality pulp. Initiating the chemical reaction before complete penetration of the cooking liquor into the chips, or cooking chips that with varies significantly in size, results in an uneven cook, decreased production efficiency, and low quality (and possibly even unacceptable pulp).

An off-gas relief system (of one or more vent lines) is used to bleed off water vapor, non-condensable gases, and wood volatiles during the cooking process to control the pressure in the digester. After the cook is over, the blow valve at the bottom of the digester is opened and the pulp, spent liquor, and any remaining gases are transferred to the blow tank.

B. The Sulfate (Kraft) Process

The various steps involved with a kraft cook are described below. These steps are common to all kraft batch digester systems. In modern systems, the process steps can be fully automated through a Distributive Control System. In older systems, these steps can be partially automated, or manually controlled, by the digester operator. Nearly all of the heat of the reaction is evolved while the gas-off valve is continuously open – during the cooking stage. Virtually all of the air is driven out of the digester during the impregnation phase (i.e., while the contents of the digester are being brought up to cooking temperature and pressure).

1. **Chip Fill**

- Wood chips are drawn from a storage area.
- Periodic analysis of chips may be performed to determine moisture content and density.
- The cap on the neck at the top of the digester is open (to atmosphere), and the empty digester is filled to the top with wet (green) chips from either an overhead chip bin or belt conveyor system. Frequently, steam or cooking liquor is injected along with the chips (a technique referred to as "steam packing" or "liquor packing") to create a loosely packed chip bed that is more dense and cylindrical in shape (i.e., less of an inverted cone) than otherwise would be achieved by simply dumping the chips in through the open neck.
- Impact on digester volume:
  - A typical chip fill would **initially** displace approximately 22 to 32% of the void space in the digester, initially leaving a remaining void space of 68 to 78%. The emphasis on the word "initially" indicates that, in addition to the remaining void space external to the chips, approximately 20% of the chip volume (equivalent to 4 to 6% of the digester volume) is void space filled with air.
  - Although the top of the chip bed typically reaches the top of the digester dome at the end of the chip filling stage, there is a significant amount of void space between the loosely packed chips in the digester, as well as some headspace in what is referred to as the "shoulders" of the digester.

2. **Liquor Fill**

- Cooking liquors are measured into the digester, which remains open and at atmospheric pressure. (Note: Steps 1 and 2 can be simultaneous operations.)[1]
- Conventional kraft batch digesters are not completely filled with liquid and chips. In general, they are charged in a manner calculated to produce the maximum yield of quality pulp that can be achieved

[1]The kraft cooking liquor is a mixture made up of a relatively large amount of white liquor with a pH of over 13.9, and a moderate amount of black liquor with a pH of 12.0 to 13. White liquor is primarily sodium hydroxide, sodium sulfide and water. Black liquor is basically the reaction product of white liquor that has been through the cooking process. It contains organics and small amounts of unreacted sodium hydroxide and sodium sulfide.

through the safe and cost-effective operation of the equipment. To achieve this objective, the process must satisfy the following criteria:

- o The amount of the white liquor charge is determined so as to maintain the specified active chemical-to-wood ratio;
- o The amount of the black liquor charge is determined so as to maintain the specified total liquor-to-wood ratio; and
- o At the time the delignification reaction gets underway at the top of the chip bed (chip-cooking liquor mixture), there must be an adequate volume above the chip bed (chip-cooking liquor mixture) for vapor space. The vapor space provides a gas/liquid equilibrium state necessary for quality control of the cooking process, and reduces the potential for plugging the screen protecting the vent line.

- **Impact on Free Volume in Digester** – A typical liquor charge would initially displace approximately 41 to 42% of the void space in the digester. When added to the 22 to 32% displacement created by the chip fill, the combination of the chip and liquor charges initially would displace approximately 63 to 74% of the volume in the digester, leaving a remaining void space of 25 to 37%. This void space would increase (by approximately 4 to 6%) to 29 to 43% as the air in the void spaces within the chips is replaced with cooking liquor (through capillary action).

- **Impact on Headspace Digester –** The specific gravity of the chips is approximately .45 to .50, whereas the specific gravity of the liquor is over 1.00. The effect of adding the cooking liquor to the digester initially makes the chips buoyant, gradually making them more flexible. This process functions as a lubricant, which allows the chips to rotate and collapse into a densely packed bed that is almost entirely submersed below the surface of the cooking liquor.[2]

3. **Pre-Cook Heating Stage**

- The digester is capped and heat is applied either directly (by injection of steam) or indirectly (through a heat exchanger) to bring the mixture to the desired cooking temperature. The temperature of the digester is generally raised to, and maintained at, approximately 330-355°F (165-180°C) for the duration of the cook. The operating pressure typically ranges from approximately 90 to 120 psig.
- Conditions inside the vessel are monitored, via sensors, to maintain

[2]This conclusion is based on observations from several different occasions where a sulfite digester was fully charged with chips and liquor and then had to be emptied before the cook was initiated to correct a mechanical problem. After draining out the cooking liquor, the chip beds have dropped between 10 and 15 feet from their initial level.

the desired cooking conditions inside the vessel.

- Air and other non-condensable gases produced during the rise in temperature are relieved through the gas-off system.
- The temperature of the incoming liquor is generally around 180°F; the temperature of the incoming chips is generally the ambient outdoor temperature at the mill. The kraft chemical reaction gets substantially underway at approximately 300°F.
- Under normal operating conditions, by the time there is a significant chemical reaction at the top of the chip bed, the buoyancy and compacting effects described above should have packed down the loosely packed and partially conical-shaped chip bed, and created the necessary headspace. It is likely that some further settling of the chips is caused by the steam flow (injected in the bottom of the directly heated digesters) or the flow of re-circulating cooking liquor (in indirectly heated digesters).

- **Impact of Heating on Digester Volume:**
  - Indirectly heated digesters: It is estimated that heating the chips and liquor causes a thermal expansion of approximately 8%. Applying that expansion to the initial net displacement of 59 to 68% yields an estimated displacement of 64 to 74%, leaving a void space of 26 to 36%.
  - Directly heated digesters: It is estimated that the direct steaming process would typically displace approximately 11 to 13% of the void space in the digester (with condensate). When added to the net 64 to 74% displacement created by the thermal expansion of the chip and liquor fill, one could conservatively estimate that the combination of the three ingredients would displace approximately 75 to 87% of the void space in the digester, leaving a void space of 13 to 25%.

4. **Cooking Stage**

- Cooking temperature is generally the primary parameter used for control of the cook.
- Once the digester reaches cooking temperature, the gas-off valve controls to a minimum opening and steam is added, when necessary, to maintain pressure and temperature.
- Conditions inside the vessel are monitored, via sensors, and the digester is vented during the cook to maintain the desired cooking conditions (i.e., temperature and pressure) inside the vessel.
- Non-condensable gases produced during the cook are relieved through the gas-off system.
- The blow-back steam system works in conjunction with the gas-off system to clean the internal screen(s).
- Each batch is cooked to a specified H-Factor, which is a function of

time and temperature, and determines when the mill blows the digester.

5. **Blow Stage**
    - After the prescribed cooking time, the vessel is emptied by discharging its contents while under pressure (the blow) through the blow line to a blow tank.

C. The Sulfite Process

The various steps involved with a sulfite cook are described below. These steps are common to all batch digester systems. In modern systems, the process steps can be fully automated through a Distributive Control System. In older systems, these steps can be partially automated or manually controlled by the digester operator. Cooking temperature and pressure are based on the sulfur dioxide vapor pressure at a given concentration and temperature. The pressure of the gas pocket at the top of the digester is allowed to rise to a predetermined level, and then is controlled by bleeding off sulfur dioxide gas (plus water vapor and inert gases, largely carbon dioxide) through the gas-off system. The non-condensable gases typically make up approximately 85% of the gases that are released.

1. **Chip Fill**
    - Wood chips are drawn from storage area.
    - Periodic analysis of chips may be performed to determine moisture content and density.
    - The cap on the neck at the top of the digester is open (to atmosphere), and the empty digester is filled to the top with wet (green) chips from either an overhead chip bin or belt conveyor system. Frequently, steam is injected with the chips to increase chip charge by creating a chip bed that is more cylindrical in shape (i.e., less of an inverted cone) than would be achieved by simply dumping the chips in through the open neck.

    - **Impact on a Free Volume in Digester**:
        - A typical chip fill would **initially** displace approximately 30 to 35% of the volume in the digester, initially leaving a remaining void space of 65 to 70%. The emphasis on the word “initially” indicates that, in addition to the remaining void space external to the chips, approximately 20% of the chip volume (equivalent to 6 to 7% of the digester volume) is void space filled with air.
        - Although the top of the chip bed typically reaches the top of the digester dome at the end of the chip filling stage, there is a significant amount of void space between the loosely packed chips in the digester, as well as some headspace in what is referred to as the shoulders of the digester.

2. **Liquor Fill**

- In contrast to the sulfate (kraft) process, sulfite digesters are completely filled with cooking liquor at the start of the cook. Before the cooking liquor is added, the digester is capped to avoid the complete evolution and release to atmosphere of the SO_2 entrained in the cooking liquor (acid).[3] (Note: For this reason, unlike the kraft process, Steps 1 and 2 are not simultaneous operations.)
- When the addition of the cooking liquor has raised the digester pressure to the pressure of the cooking liquor (acid) accumulators (approximately 75 psig), the vent valve is opened to release the displaced air and any other gases trapped in the digester.
- The liquor feed pump continues to pump in the cooking liquor until the digester is hydraulically full and a sensor detects liquid flow through the vent valve, at which point the liquor fill line is closed. No heat has been added to this point, and the chemical reaction has not been initiated. The maximum pressure in the digester would be the maximum cooking liquor pump pressure of approximately 85 to 95 psig, which is well below the vessel's MAWP.

- **Impact on Free Volume in Digester:**
    - The digester is hydraulically full; all void space outside the chips has been eliminated. The air in the void space inside the chips is slowly replaced by the cooking liquor through capillary action, which eventually creates an adequate headspace (freeboard).

      The specific gravity of the chips is approximately .45 to .50, whereas the specific gravity of the liquor is over 1.00. The effect of adding the cooking liquor to the digester initially makes the chips buoyant, gradually makings them more flexible, which allows them to rotate and collapse into a densely packed bed. The chip bed will be almost entirely submersed below the surface of the cooking liquor after side relief is implemented as described below.[4]

3. **Pre-Side Relief Heating Stage**

- Heat is applied at a programmed rate, either directly (by injection of steam) or indirectly (through a heat exchanger), to slowly increase the temperature of the mixture to a point just below the temperature

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[3]The liquor is a combination of sulfurous acid, bisulfites, and sulfur dioxide. Depending on the type of process, the pH of the liquor ranges from approximately 2.0 to 5.5.

[4]The conclusion is based on observations from several different occasions where a sulfite digester was fully charged with chips and liquor and then had to be emptied before the cook was initiated to correct a mechanical problem. After draining out the cooking liquor, the chip beds have dropped between 10 and 15 feet from their initial level.

at which the delignification reaction begins. This step takes 2 to 4 hours, and is designed to facilitate penetration of the cooking liquor into the chips.

Note: The sulfite process requires thorough penetration of the cooking liquor into the chips before the delignification reactions commence. Failure to allow the chips to become thoroughly penetrated with the cooking liquor before the chemical reactions begin will result in pulp of unacceptable quality. In this regard, some of the reaction byproducts inhibit the continued penetration of the cooking acid into the remainder of the chip. Furthermore, the two components of the cooking chemical penetrate at different rates. Failure to allow the chips to become thoroughly penetrated with both components of the cooking liquor before the chemical reactions begin may generate precipitates on the fibers and ruin the pulp. Adequate penetration of both components is critical. Hydraulically charging the digester, and slowing warming the cooking liquor while the vessel is hydraulically charged, promotes the penetrating process.

- Conditions inside the vessel are monitored, via sensors, to maintain the desired pre-cooking conditions inside the vessel. Typically, the temperature range for the penetration stage of the cooking process is 60° to 70°C at the start of the process, which is the temperature of the cooking liquor in the accumulator, and 100° to 120°C at the end, which is the temperature at which side relief (as described below) is initiated.
- Non-condensable gases produced during the pre-cook heating stage are relieved through the gas-off system. Most sulfite digesters have a blow-back steam system that works in conjunction with the gas-off system to clean internal screens. Some indirectly heated sulfite digesters rely on instrumented systems and alarms that measure any pressure differential across the internal screens. These systems respond to the pressure differential by cutting off the indirect heat (i.e., the steam to the heat exchanger) and, if necessary, opening the side relief valve.
- For directly heated sulfite digesters, some cooking liquor is removed as steam is injected.

4. **<u>Side Relief Stage</u>**

- Just prior to reaching the temperature at which the delignification reaction begins, side relief is removed from the digester. This process involves the removal of approximately 30 to 40% of the cooking chemical, which is returned to the accumulator system for future use.[5] Side relief is typically removed through a line attached

[5] For a typical 9000 ft^3 digester, side relief would involve releasing about 12,000 to 18,000 gallons (1600 to 2400 ft^3) of cooking chemical.

to the circulating line of the digester. The "circulating strainer plates" in the digester filter out any solid material of a size that could be detrimental to the equipment on the circulating system.

- **Impact on Free Volume in Digester:**
  - The removal of the side relief increases the existing headspace in the digester by approximately 15 to 25%.

5. **Pre-Cook Heating Stage**

- The temperature of the digester is raised to, and maintained at, a target temperature of approximately 125°C to 140°C (260°F to 285°F) for the duration of the cook. This increase in temperature may take an additional hour. The operating pressure typically ranges from approximately 85 to 125 psig.

6. **Cooking Stage**

- At the time the delignification reaction gets well underway at the top surface of the chip bed (i.e., chip-cooking liquor mixture), there must be an adequate volume above the chip bed for vapor space. This volume is achieved by removing the side relief as described above, in combination with the headspace created by filling the void space in the chips with liquor. The vapor space provides a gas/liquid equilibrium state necessary for quality control of the cooking process, and reduces the potential for screen plugging.
- Once the digester reaches cooking temperature, the heat generated by the exothermic chemical reaction of the sulfite pulping process is adequate to maintain the temperature in the digester. The steam valve to the heat exchanger then is closed and the digester continues to cook with circulation to a desired H-Factor or S-Factor.
- Conditions inside the vessel are monitored, via sensors, and the digester is vented during the cook to maintain the specified pre-cooking conditions (i.e., temperature and pressure) inside the vessel.
- Cooking temperature and pressure are based on the sulfur dioxide vapor pressure at a given concentration and temperature. The pressure of the gas pocket at the top of the digester is allowed to rise to a predetermined level, and then is controlled by bleeding off sulfur dioxide gas (plus water vapor and inert gases, largely carbon dioxide) through the gas-off system. Non-condensable gases typically make up approximately 85% of the gases that are released.

7. **Blow Stage**

- After the prescribed cooking time, the liquor circulation pump is shut down, and the vessel is emptied by discharging its contents (the blow) through the blow line to a blow tank. At some facilities, the contents are discharged under pressures up to 30 psig. In other facilities, the pressure in the digester is reduced almost to atmospheric pressure, and the pulp then is diluted with spent cooking liquor from previous cooks and pumped into a dump tank in preparation for the pulp washing process.

IV. POTENTIAL SOURCES OF OVER-PRESSURIZATION

A. Overview

The potential sources of digester over-pressurization, described below, are as follows:

1. The steam supply to the digester;
2. The action of heat sources on a hydraulically full, or almost hydraulically full, digester;
3. The heat and gases released in a kraft digester by the exothermic reaction of the kraft delignification process; and
4. The gases released in a sulfite digester by the sulfite delignification process.

B. The Steam Supply

The only significant source of external pressure on batch digesters is the direct steam supply used to achieve one or more of the following:

1. Bring the vessel to cooking temperature and pressure;
2. Maintain temperature and pressure throughout the cook;
3. Purge chips from the screen that protects the gas-off line from internal blockages (i.e., the blow-back system); and
4. Assist in transferring the contents of the digester to the blow tank at the end of the cook. Steam is usually supplied directly into the digester at some point in the cook whether the digester utilizes a direct or indirect cooking process.

Regardless of the source of the steam (boiler, turbine extractor, branch line), the digester vessels are protected from steam over-pressurization by a relief device (in the steam header) as defined and required by ASME BPVC UG-125(h). The installed relief devices are sized and rated according to ASME BPVC UG-125(c) and UG-131.

C. Thermal Expansion in a Hydraulically Full or Almost Hydraulically Full Digester (i. e., "Hydraulic Overfill")

Conventional batch digesters are designed to be operated with a gas/vapor headspace above the chip bed. Under unusual circumstances, a digester could become hydraulically full (or almost hydraulically full) and plugged. If the contents of the digester receive an infusion of heat, and the digester screen becomes plugged before completion of the thermal expansion associated with this heat transfer; this condition could result in a relatively rapid hydraulic over-pressurization. The pressure of any remaining vapor would rise due to both the increase in its temperature and the reduced headspace resulting from the thermal expansion of the liquid.

The two highly unusual/extraordinary conditions with the potential for creating a hydraulically full digester are: 1) adding a substantial volume of excess liquor to the digester at the beginning of the cook; and 2) operating under conditions that create an excessive amount of condensate in the digester. Thermal expansion could occur as the heat from the injected steam, the heat exchanger, and/or the exothermic reaction is transferred through the contents of the digester. If a digester becomes hydraulically full or almost hydraulically full, it is possible that the top surface of the liquid could carry a mixture of chips and fines into the screen at the base of the relief line that would be sufficient to completely plug it. In this event, the digester screen would be effectively plugged, and if the steam valve is closed, the digester becomes isolated, creating the potential for hydraulic over-pressurization from any thermal expansion.

Therefore, the system design must include reliable process and control measures to prevent a hydraulic overfill from occurring, and provide a reliable system for preventing any over-pressure occurrence from exceeding: 1) the MAWP of a digester with multiple relief systems by 16% or 4 psig, whichever is greater; or 2) the MAWP of a digester with a single relief device in the system (or substantially equivalent over-pressure protection provided by system design per either "Checklist of Minimum System Requirements," ASME Code Case 2211, or the WISHA variance) by 10% or 3 psig, whichever is greater. (See ASME Boiler and Pressure Vessel Code Section VIII, Division 1, UG-125.)

D. <u>Exothermic Reaction (Sulfate (Kraft) Process)</u>

The chemical reaction of the kraft pulping process is exothermic, but it is not substantially underway until the temperature reaches approximately 300°F. Nearly all of the heat of reaction is evolved while the gas-off valve is continuously open – during the cooking stage. Virtually all of the air is driven out of the digester during the impregnation phase (while the contents of the digester are being brought up to cooking temperature and pressure). If the digester gas-off screen becomes plugged after the reaction is initiated, additional energy is added to the system by the heat of reaction that is released as a result of the ongoing exothermic chemical reactions. Under these conditions, the pressure would rise as a function of the increase in temperature, and the resulting increase in vapor pressures of the materials in the digester.

The character of the exothermic energy release by the kraft process was investigated by the Institute of Paper Science and Technology, both in terms of the magnitude and the rate of release. The results were published in a report entitled “Determining the Heat of Reaction of Kraft Pulping," Project 3977, August 1995. The rate of reaction was found to be predictable and gradual, with no evidence of pressure spikes over the course of the reaction period. This slow release of energy did not result in a rapid pressure increase.

E. Release of Gases (Sulfite Process)

As the temperature is increased by the introduction of steam energy, either directly or indirectly, the pressure rises due to the increased vapor pressures of the materials in the digester. If the digester were to become isolated (i.e., gas-off/pressure-relief valves plugged) so as to prevent pressure relief, the sulfur dioxide and other non-condensable gases being released would continue to increase the pressure inside the digester.

V. CONTROLLING POTENTIAL SOURCES OF OVER-PRESSURIZATION THROUGH SYSTEM DESIGN

There are two factors to the system-design approach for controlling potential over-pressurization:

1. Design and operate the systems to avoid the conditions that have the potential to lead to over-pressurization of a digester; and

2. Design and operate the systems so that there is a back-up mechanism for managing conditions so as to avoid a significant over-pressurization incident.

It is important to follow generally applicable good engineering design, operating, and maintenance practices. In the case of pulp batch digesters, by maintaining an adequate headspace (freeboard) in the digester during the phase(s) of the cook when the primary chemical reaction is well underway, it is possible to avoid conditions that may lead to over-pressurization of the digester. This practice should ensure that the gas-off line is available to perform the function of releasing gases from, and relieving pressure in, the digester. Following this practice would avoid situations requiring non-routine alternative measures, such as taking a special side relief from a sulfite digester or briefly opening the blow valve on either a kraft or sulfite digester to provide pressure relief.