8. TRANSIENT POLLUTANTS

(Section 8 was prepared by C. E. Jahnig and E. M. Magee and has not appeared previously as a process report.)

8.1 General

The discussion in previous sections of this report dealt primarily with effluents released during normal on-stream operation of the processes. In addition there can be very significant emissions of an intermittent nature, for example during startup, upsets, shutdown, maintenance, etc. Such emissions can be classed as transients. In order to make the environmental evaluation of an assessment of coal conversion processes complete, an evaluation of transient pollutants has been made. Results of this study of transients is presented in this section of the report.

A plant sized to produce 250 MM scfd of SNG is commonly used for projected commercial plants, and in the following discussions when reference is made to a large plant it will refer to this size.

Transient emissions have received little attention or study to date, particularly on coal conversion processes. One reason is that they are released intermittently and therefore are difficult or nearly impossible to sample and analyze in order to determine the nature and amount of emission. Occurrences such as failure of the main electrical power supply in a plant can cause a serious upset with many transient emissions and very visible effects, but trying to sample them is not a fruitful way to approach the problem. However, it is important to first define the transient emissions so that they can be evaluated, classified as to relative importance, and practical control measures defined. What is needed is to apply reasonable and achievable controls on transient emissions and this will probably require a different approach than has been used for normal or primary emissions.

The purpose of this study is to examine potential transient emissions from coal conversion processes in order to determine the nature and amount of each such emission, to give perspective on the relative environmental concern for each emission, and to discuss and evaluate control methods.

A preferred approach is to eliminate the problem by suitable disposal of the stream (e.g., by returning it to the process, as might be done with vent gas streams), or making use of the stream in the existing facilities. An example of the latter would be sending high-sulfur gas release to the boiler furnace instead of a flare, whereby the heating value of the gas is recovered rather than wasted. Moreover, emission may be better controlled than with flaring if the furnace is one that normally burns coal with stack gas cleanup to remove sulfur. For discussion purposes, results of the study on transients will be organized according to the following major areas:

- Startup
- Shutdown
- Operating upsets (in sequence of processing steps)
- Utilities and auxiliary facilities
- Design considerations
- Technology needs and opportunities

While there are a large number of coal gasification processes using somewhat different operating conditions, there are enough similarities that it has been possible to develop a generalized model for steam-oxygen gasification to give representative flow rates that can be used for environmental evaluation (13). Figure 8.1 presents flow rates for a typical large plant. Potential transient emissions that should be considered are summarized in Table 8.1.

8.2 Startup

During startup of a plant, the operating conditions will often be such that the products or byproducts are not suitable for sale. This poses special problems in disposing of off-specification materials, particularly in the case of gases which are costly to store relative to solids or liquids. Sulfur, syncrude, etc. could be stored and later reworked to meet quality requirements. However, in starting up a gasifier it may be necessary to incinerate or flare the entire output of a reactor until conditions are lined out and other parts of the plant such as acid gas removal and methanation are on stream. If the gas has been processed for sulfur removal, it generally will not result in major pollution problems when it is burned in a flare, although the heating value is then wasted. If raw gas is flared before sulfur removal, there can be a serious, though temporary, pollution problem. In some cases consideration can be given to sending this gas to a utility or other furnace where it is burned to recover the fuel value. When the furnace includes stack gas cleanup, a very desirable pollution control is achieved along with the recovery of heating value.

Depending upon plant size, there may be up to 30 gasifier vessels, each of which has to be started up in turn and brought up to system pressure. It has been reported for Lurgi type gasifiers (63) that they can be brought to operating conditions from a cold start in about 12 hours, so the exit gas might have to be flared for this length of time before it can be included in normal production. Flow rate of gas could correspond to the production of one gasifier, or up to 30 MM scfd of raw gas (8 MM scfd of SNG). Newer processes under development are expected to use as few as two gasifier reactors for the same production, in which case the transient gas flow would be roughly 15 times greater. For the latter case, roughly 200 MM scf of medium Btu gas may be involved in each instance, with a potential fuel value of $50,000 at a nominal $1/MM Btu. For a Koppers-Totzek type gasifier it has been reported that it can be started up and brought on stream in as little as 1 hour (64).

A common startup problem is waste water treating facilities, particularly the biox (biological oxidation) unit. It may take 1-2 weeks to develop and acclimate the bioculture so that it is highly effective for destroying the chemicals and other constituents present in the waste water. A final holding pond is usually provided, with a holding time of 1 week or more, which could alleviate waste water problems during startup.

Figure 8.1

Flowrates for a Representative Coal Gasification Process

(Tons per day unless specified otherwise)

(Reference 13)

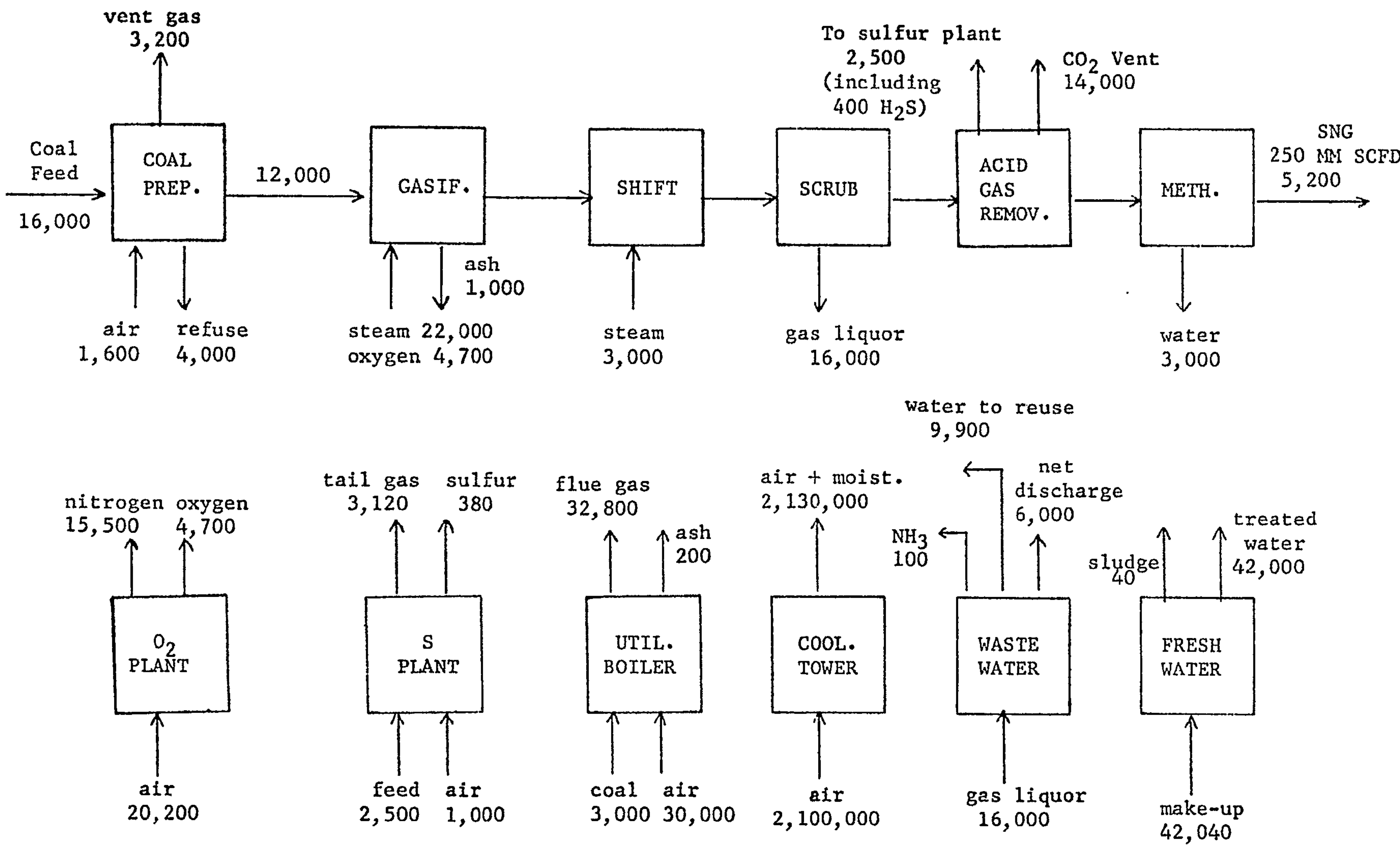


Table 8.1

Possible Sources of Transient Pollutants

Coal handling - broken belt, spills

Coal grinder - breakdown or motor failure

Coal screening - breakage, dust

Coal dryer - fire or broken bag filters

Coal pretreater (if used) - fines carryover, tar emulsion

Lock hoppers - valve failure, dust in vent gas, plugging

Coal pressurizer (slurry feeder) - breakdown or leaks

Slurry preparation - flashing of vapor if coal becomes wet

Ash removal - dust, steam cloud, odors, if valves fail

Tar handling - emulsions, solids, paste

Dust scrubber - plugging, spills of sour water

Shifting - plugging and cleanup, dust

Acid gas removal - chemical purge, sulfur or entrainment in CO_2 vented due to upset

Methanation - leaks of toxic CO, carbonyls, nickel dust

Sulfur plant - odors, fire, chemical wastes, burner failure

Hydrogen manufacture - similar to a complete gasification plant

Steam supply - failure, contamination with solids or gases

Power supply - failure

Motors, turbine drives, gear reduction, noise due to equipment malfunction

Pumps and seals - breakdown, leaks

Compressors and seals - breakdown, leaks

Valves, piping, flanges - leaks

Heat exchangers - leaks, rupture

Furnaces - flameout, smoke, or noise due to malfunction, tube rupture

Water treating - odors, oil, suspended solids, etc. from sudden surges upstream

Ponds - leaks, overflow

Solids disposal - dust, leaching, runoff due to erosion

Instrumentation - false readings, failure

Blowdown system - overloading, freeze up

Table 8.1 (Cont'd)

Possible Sources of Transient Pollutants

Pressure relief valves - leaks

Vacuum exhaust - on steam condensers, distillation, dust cleanup

Blind changing - leaks, spills

Sampling - purges, leaks, upsets

Product storage - vapor breathing, spills, tank cleaning

Other - corrosion, erosion, drains on equipment

Other concerns on the plant startup are associated with spills, leaks, vents, drains and purging. Spills of coal may occur on conveyors and handling, or from unplugging lines, hoppers, etc. Providing a vacuum cleanup system may be one answer, and of course dust control inside of buildings is essential for safety. Spills of heavy tar or oil may occur so plans for cleanup should be included, taking into account the carcinogenic nature of such materials. Similarly, leaks of liquids should be cleaned up, in some cases by flushing to a separate "oily water" sewer system. Leaks of gas, as on valves and compressors might best be controlled by a thorough program of inspection, monitoring, and maintenance.

Startup usually involves purging equipment with inert gas or nitrogen, drying of insulation etc., and then displacing with a combustible gas. Mixed gases are vented during the operation, and unless these are perfectly clean they should be collected and sent to a blow-down system and incinerator. Consideration can be given to using the utility furnace or a process heater to provide incineration. Considerable condensation of water is frequently encountered during startup, for example from drying out castable refractory linings. This can be removed via drains at low points on the equipment and included with makeup water.

Many proposed designs have planned on using clean products from the process (gasification or liquefaction) as plant fuel to control pollution. This fuel is of course not available at startup. Rather than add extra pollution controls or a separate fuel gas manufacturing systems, consideration should be given to storing low sulfur liquid fuels as required for startup. This applies to coal drying, process furnaces, utility boilers, etc.

One other example of environmental impact associated with startup will be given, relating to preparation and activation of catalysts. Methanation often uses a nickel base catalyst that is carefully reduced and activated in situ. Gas streams used in the treating operations may have to be disposed of by scrubbing or incineration. In addition, fines are rejected and should be reclaimed. Nickel carbonyl can form at temperatures below 400°F and is highly toxic. Therefore the catalyst must not be exposed to normal syngas containing CO except at temperatures above 400°F. The methanation catalyst can be pyrophoric in air, so precautions are needed. With other catalysts, such as shift or hydrotreating catalysts, other specialized treating and handling procedures are used, resulting in different streams and effluents that must be evaluated. Environmental concerns are similar. While this discussion on catalysts is brief, it is intended to illustrate the type of concerns and impacts that need to be covered by environmental planning, some of which can be unexpected and result in unnecessary problems if they are not addressed early enough in the program.

In planning startup procedures, the order in which the various units are activated should be considered from the standpoints of environmental controls and conservation of resources. Thus, by starting the utility furnace first, it is available for incineration (and sulfur control if it includes stack gas cleanup). Steam is then available to start up an oxygen plant which provides dry nitrogen for purging. Waste water treating can then be activated, followed by coal preparation and the sulfur plant. Hydrogen manufacture, with its acid gas removal, may have to be put in operation before the conversion unit (gasification or liquefaction) can be started. Then the conversion unit, ash handling, filters, etc. can be started, followed by systems for treating and handling products and byproducts (hydrotreating, ammonia, phenol, etc.). This may not be the actual order of startup decided upon, but is intended to call attention to its impact on environmental concerns so that the best overall decisions can be made.

A more quantitative evaluation of potential transient emissions will now be given, based on a specific process. For gasification, the BIGAS process will be taken as an example and will be based on the flow plan in Figure 8.2. Flow rates of the various streams are shown on the figure, while specific points of possible transient emissions are indicated by letters within a circle. These latter items are identified and described in Table 8.2, including information on quantity and composition where these can be estimated.

In the case of coal liquefaction, the example is based on the SRC process to make clean boiler fuel, as shown on the flowplan in Figure 8.3. This is representative of a liquefaction process using low severity and low hydrogen consumption, to make a clean fuel that can be burned without having to control sulfur or particulate emissions. Again, the potential transient emissions are indicated on the flowplan by letters within circles, while the amount and composition of these is given in Table 8.3 for the cases where they can be estimated.

8.3 Shutdown

Transient emissions can result when facilities are shutdown for inspection, maintenance, or as a result of some interruption. The shutdown may involve one unit such as a gasifier, or a train of equipment, and thorough preplanning can avoid or minimize pollution at these times. A planned shutdown will include the following steps at least, though not necessarily in this exact order.

- cut input of heat (e.g., oxygen flow)
- cool to above water condensation temperature
- transfer solids to storage
- cool further and remove liquids (oil, water)
- depressure system
- purge with inert gas, then air.

Cooling of a gasifier may take 24 hours or more. As gasifier temperature is decreased, gas composition will change so that normal operation of subsequent facilities cannot be continued, consequently a large flow of gas may have to be incinerated for disposal. The utility furnace should be suitable for this incineration. If the furnace is equipped with stack gas cleanup, sulfur emissions would also be controlled without relying on acid gas removal facilities. Flow rates would be similar to those discussed in Section 8.2 on startup.

Figure 8.2

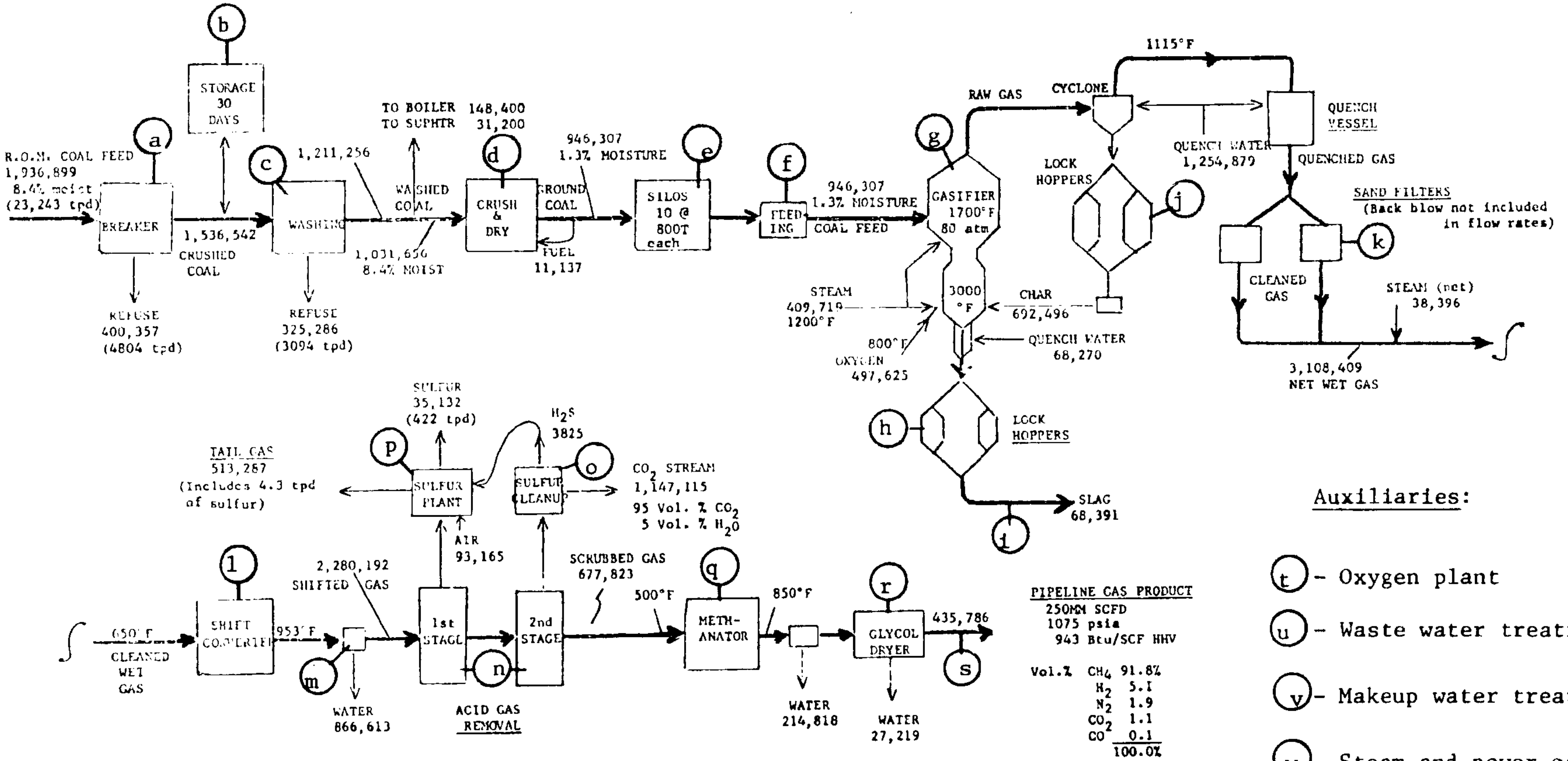
BIGAS PROCESS - POSSIBLE TRANSIENT EMISSIONS

FLOWPLAN AND FLOW RATES FOR PLANT MAKING 250 MM SCFD OF PIPELINE GAS FROM W. KENTUCKY NO. 11 COAL

(NUMBERS ARE LB/HR EXCEPT AS NOTED)

(Letters in circles refer to transients - see Table 8.2)

(Reference 7)



Auxiliaries:

(t) - Oxygen plant

(u) - Waste water treating

(v) - Makeup water treating

(w) - Steam and power generation

(x) - Flare

Table 8.2

Gasification - Possible Transient Emissions

(For Flowplan in Figure 8.2)

Item	Identification	Possible Transients and Amount
a	Refuse (gangue)	Dust loss at 0.1% would be 9600 lb/day Leaching of 10 ppm equals 100 lb/day
b	Coal Storage	Dust, runoff and leaching should be controlled. Fires must be prevented.
c	Cleaning refuse	Comparable to item a. in transients and amounts. If refuse includes 10% coal it amounts to a heating value of 7500 MM Btu/day.
d	Dust from dryer	Vent gas amounts to 45 MM scfd and broken bag filters could release 1-10 tons of dust in one minute.
e	Coal silos	Penumatic transport gas (nitrogen) is roughly 5 MM scfd and is normally recycled, but may be vented in upset, releasing dust.
f	Coal feeder	Medium Btu gas (270 Btu/cf) is used to pressurize lock hoppers and is normally recycled. Amount is about 35-70 MM scfd, which might be released to flare during upset. (see text)
g	Gasifier	Possible leaks on valves etc. while operating, plus dust and odors during maintenance.
h	Ash hoppers	Depressuring water slurry can release gas, vapors, and dust if normal cooling fails due to malfunction and external quench is required. Steam could be 15 MM scfd (see text).
i	Ash disposal	Dust loss at 0.1% would be 1670 lb/day Leaching of 10 ppm equals 17 lb/day
j	Cyclone hoppers	Possible leaks or venting in case of upset. Char flow is 2/3 of coal feed to lockhoppers (item f) but pressure swing may be only 5% as large. See original process report (7).

Table 8.2 (Cont'd)

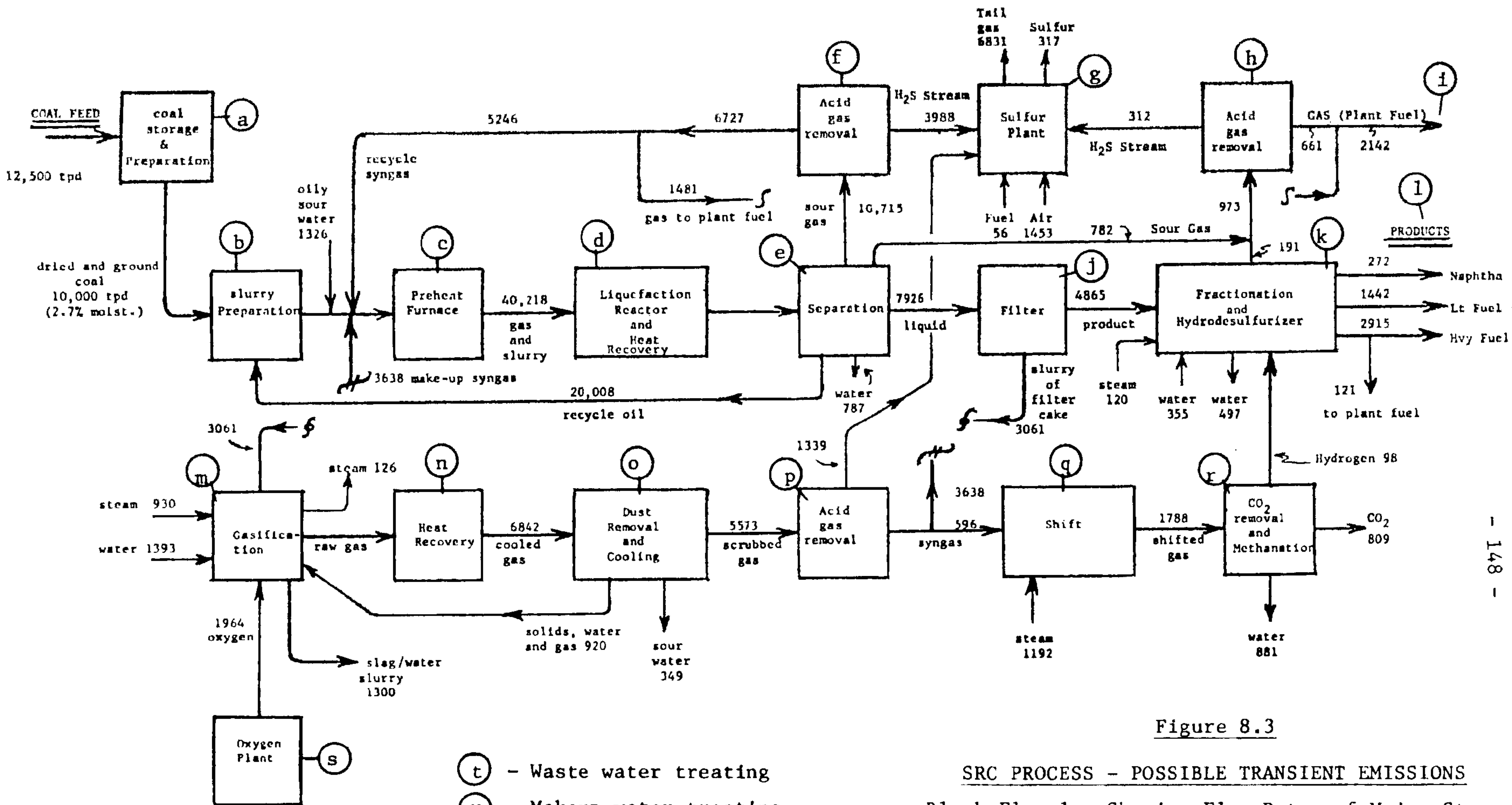
Gasification - Possible Transient Emissions

Item	Identification	Possible Transients and Amount
k	Sand filters	Collected dust is blown back to gasifier. Dust may be a problem in maintenance.
l	Shift converter	Iron catalyst may be pyrophoric, requiring controlled oxidation at shutdown.
m	Sour water	Flow of 866,613 lb/hr could release H_2S and NH_3 and should be diverted to storage in case of upset.
n	Acid gas removal	Chemicals purge may be 150 gal/day for hot carbonate scrubbing, or perhaps 5-8 times as much for amine scrubbing. Suitable disposal must be defined. (see text)
o	CO_2 vent	CO_2 purged to atmosphere is about 14,000 tons/day and may contain sulfur compounds combustible gases, or entrained chemicals during upset (see text).
p	Sulfur plant	Feed gas contains 426 tons/day sulfur; release must be prevented. Thus, three units could be onstream operating at 2/3 capacity and able to pick up load if one unit shuts down.
q	Methanator	Transients are associated with pretreating catalyst and with shutdown (see text)
r	Dryer	Glycol or other drying medium may absorb combustibles which would be released upon regeneration.
s	Product SNG	May have to be flared if product is "off-spec." Flowrate 250 MM scfd.
t	Oxygen plant	No specific emissions problems except possibly due to defrosting of exchangers.
u	Wastewater treating	Upsets or spills can release sour water, phenols, particulates, odors etc. Soluble salts and trace elements are introduced, build up, and must be taken care of. See text discussion in Section 8.4.11 on this very important area requiring control of transient emissions.

Table 8.2 (Cont'd)

Gasification - Possible Transient Emissions

Item	Identification	Possible Transients and Amount
v	Makeup water treating	Chemicals are used in water treatment (see Table 8.6) including sulfuric acid and caustic for back washing to regenerate ion exchange resins, resulting in intermittent waste streams that should be stored, neutralized, and sent to waste water treating.
w	Utilites	Sulfur in coal burned may be 100 tpd (see Figure 8.1) and would be released if stack gas cleanup fails, along with part of 200 tpd ash. Soot blowing or tube failure could cause transient emissions as discussed in text section 8.4.12.
x	Flare	Should be designed for complete combustion with control of smoke and noise. Recovery of condensibles should be maximized and no liquids (especially combustible ones) should be allowed to reach the flare (see text).



(t) - Waste water treating

(u) - Makeup water treating

(v) - Steam and power generation

(w) - Flare

Figure 8.3

SRC PROCESS - POSSIBLE TRANSIENT EMISSIONS

Block Flowplan Showing Flow Rates of Major Streams

Numbers are flow rates in tons/day. Letters in circles refer to transients - see Table 8.3

(Reference 42)

Table 8.3

Transient Emissions from SRC Process

(See Figure 8.3 for Identification of Streams)

Stream	Identification	Remarks
a	Coal preparation	Dust loss could result from rupture of bag filter on dryer vent gas e.g., due to moisture condensation during startup.
b	Slurry preparation	Coal is mixed with hot recycle oil and steam or oil vapors can flash off. Two % moisture in coal would amount to 200 tons/day. Recovery is needed as well as odor control.
c	Preheat furnace	Furnace is normally fired with clean fuel but imbalance on air/fuel can cause smoke. Tube failure could release a fraction of the 40,218 tons/day slurry flow rate. Oil fuel may be fired during plant startup (see text).
d	Liquefaction	Operation is at ultra high pressure so is subject to leaks of liquid, gases, and vapors. Thorough monitoring, inspection, and maintenance should be provided.
e	Separation	See item d. Also, sour water is separated and will release flash gases if depressured, that could amount to over 2 tons/day and must not be released.
f	Acid gas removal	See item d. Large volume of chemical solution is circulated and may require purge that could be a pollutant. Depressuring will release flash gas as in item e.
g	Sulfur plant	Upset or shutdown would release sulfur to atmosphere and suitable protection is needed, as by multiple units having excess capacity (see text). Maximum potential release is 317 tons/day sulfur in feed streams.

Table 8.3 (Cont'd)

Transient Emissions from SRC Process

Stream	Identification	Remarks
h	Acid gas removal	Similar to item f, but any failure to perform will release sulfur into plant fuel gas, (294 tons/day of sulfur in feed gas).
i	Plant fuel	Gas to fuel could contain sulfur if acid gas removal is inadequate. May have to be flared at times during startup resulting in smoke and noise.
j	Slurry filter	Heavy tar is filtered using precoat. A difficult operation subject to leaks and spills, especially when plant operation is not smooth. Containment curbing and hoods, etc. may be needed (see text)
k,l	Product treating	Fractionation and hydrodesulfurizing are similar to normal petroleum refining practice which provides background for proper pollution controls. Controls should be included on vents from vacuum pumps plus product handling and storage. Heavy product to plant fuel can cause smoky flame if not properly heated and atomized.
m	Gasification	Similar to gasification for SNG manufacture - see Figures 8.1 and 8.2, also Table 8.2.
n	Heat recovery	Possible transient emissions from tube failure or dust deposits which may contain trace elements - see item m.
o	Dust removal	Considerable handling of solids and sour water (1269 tons/day) could lead to spills, leaks, and flash gas. See items e,m,n.
p	Acid gas removal	Large amount of sulfur is separated (109 tons/day) and must not be released to atmosphere during startup or upsets (see text and item f).

Table 8.3 (Cont'd)

Transient Emissions from SRC Process

Stream	Identification	Remarks
q	Shift conversion	Similar to shift conversion in gasification (see Figure 8.2 and Table 8.2). Catalyst may be pyrophoric, and special pretreatment may be used.
r	CO_2 removal	Note that gas is free of sulfur at this point so CO_2 vent stream is less apt to be contaminated than is SNG manufacture. Also, CO_2 stream is smaller (809 vs over 13,000 tons/day) but combustible content is still a concern.
s	Oxygen plant	Similar to that in gasification process see Figures 8.1 and 8.2, also Table 8.2
t	Waste water treating	- see item s
u	Makeup water treating	- see item s
v	Utilities	- see item s
w	Flare	Should be designed for smokeless combustion and with noise control. Recovery of condensibles should be maximized and no liquids (especially combustible ones) should be allowed to reach flare (see text).

Transfer of solids to storage merits particular attention in that the flow rates are large and the facilities are used infrequently and for short times. Pneumatic transport is the usual method and specific dust recovery equipment must be provided, such as cyclone separators followed by bag filters. These might be the same ones used on coal preparation which could be designed to handle the transport gas.

Enclosed storage is needed for many of the liquids removed at shutdown. Heavy oils and tars from coal processing are carcinogenic, while these and lighter oils can have strong odors. Water layers generally contain various compounds of sulfur, nitrogen and oxygen that should not be allowed to escape to the atmosphere. In some cases these liquids may be stored until subsequent startup when they can be used to recharge the system, or are disposed of by working off, for example, through product treating or waste water cleanup.

When the system is depressured a large volume of gas is released which can contain combustibles, carbon monoxide, sulfur compounds, etc. For a large gasification plant it is estimated that up to 1 MM scf of gas could be released on depressuring. Preferrably, the gas should be incinerated before release, as in the utility furnace or a flare.

In preparation for maintainence, the system will be purged to remove toxic and combustible gases. Nitrogen may be used for this purpose, if available from an oxygen plant, and will usually be followed by purging with air. Consideration should be given to sending the purge gases to an incinerator or furnace, at least during the initial purging, depending upon the content of contaminants.

Special operating procedures are often used for shutting down specific facilities, which in each case should be reviewed for environmental impacts and controls. As an example, certain materials may be pyrophoric under normal operating conditions, such as iron base catalyst used for shift conversion, nickel methanation catalyst (65), or certain carbonaceous deposits. In such cases deactivation may be accomplished by purging with inert gas containing 1-2% oxygen, and gradually increasing oxygen content to that of air, while monitoring and regulating temperature levels (66). Treated gas in such operations will usually be recycled, but all purges from the system should be incinerated or suitably treated if they contain significant amounts of toxic or combustible materials.

As in the case of startup, the order in which individual sections of the plant are shutdown can greatly affect environmental impacts, and should be evaluated carefully on each project. The utility system will of course be one of the last areas to be shutdown, together with pollution control systems such as waste water treating, sulfur plant, etc.

After cooling and purging with air, the equipment is ready to be opened for routine maintenance, but before discussing this, it is appropriate to cover transient emissions associated with other interruptions of operation that are unintended rather than planned for. These are designated as operating upsets and will be discussed in detail in the following section, in the order of normal steps in the processing sequence, followed by auxiliary facilities such as utilities, sulfur plant, etc.

8.4 Upsets

8.4.1 General

One of the first considerations with regard to upsets resulting from equipment malfunction or other causes is that they happen so quickly that the generation and flow of process streams cannot be cutback fast enough, so part or all of the stream has to be diverted to the blowdown system or to an emergency flare. In the case of liquid or solid streams they can usually be diverted to storage. While storage of gases in such situations may be desirable, it is often impractical or uneconomic, so that a common practice is to flare gas streams during operating upsets. Flare systems have been developed that facilitate recovery of condensible portions of the stream before flaring (67), and that minimize undesirable smoke or noise from the flare burner (68). Consideration should be given to this background when defining specific facilities for a plant, as well as to assuring complete combustion.

A second consideration is that leaks and spills can be expected so that provisions for minimizing them and for cleanup should be included. Pumps and valves are known to be sources of emissions (69). In addition, solids storage, handling, and transport can cause transient emissions, as in the case of belt conveyors or bucket elevators that can break, jam, cause spills, or fires. Thus, failure of a belt or critical motor can disrupt operation and sometimes the only practical solution is to dump material on to the ground in order to make repairs and resume normal operation. Therefore facilities are needed to cope with various situations that can result in spills or leaks. Thus, vacuum cleanup trucks can be used to reclaim for reuse any solids that are spilled. Water flushing can be provided to wash residual solids to a recovery pond, and can also be used to flush oil spills to the "oily water" sewer system where they will be recovered to the maximum extent practical. In critical cases, curbing is needed around specific process areas to contain leaks and spills so that they can be flushed to cleanup and recovery facilities. In general, the objective should be to recover and reuse all miscellaneous losses to thereby assure that they do not leave the plant as undesirable and poorly defined effluents.

Fires are of course a most serious upset and can cause extreme and uncontrolled emissions. While the likelihood is not great, utmost consideration should be given to their prevention and control. Storage areas for solids or liquids are most vulnerable, and extensive background on coal storage as well as oil refinery practices should be used fully (70). A similar concern is possible tube failure in furnaces used to heat combustible materials such as oil or gas. Monitoring and control procedures have been developed in oil refining. Flow to the tube is stopped as soon as possible, while blanketing steam can be added to the furnace box to inhibit combustion and overheating. Instrumentation and automatic valves will often be warranted to minimize the impact of tube failures.

Tube failures or leaks in exchangers are an additional concern. With air cooling, such emissions can be dispersed in a large flow of air passing through the exchanger. In the case of water cooling, material can leak into the cooling water system and cause severe contamination of air passing through the cooling tower in addition to possible operating problems that could upset the plant. Coal conversion processes may operate at very high pressure 1000-2000 psig, which increases the environmental concern since the instantaneous flow rate through any given break will be approximately proportional to the upstream pressure. Prior consideration of such possibilities and plans for handling them are the best approaches to the problem, together with monitoring and automatic controls on critical services.

From the discussion so far it will be apparent that considerable environmental protection can and should be built in during the planning and design phases of a project. This is much more efficient and lower cost compared to add-on facilities. Factors to be considered include number of parallel trains to use, spares on pumps, exchangers etc., leak control on pumps, filters, and valves, emergency power source, etc. Further consideration of such factors will be given in a subsequent subsection entitled Design Considerations, after discussing potential transient emissions from specific processing areas.

To provide a reference framework of flow rates for examining transients, a generalized or representative coal gasification process has been developed as shown in Figure 8.1. While there are a large number of different gasification processes offered, for a given product rate they are quite similar in most of the major flow rates, such as the amount of CO_2 rejected to the atmosphere from acid gas removal. Thermal efficiencies are also similar in the range 65-70%; consequently, the coal feed rates do not differ greatly between processes when using the same coal feed. The generalized flow plan of Figure 8.1 facilitates analysis of transient emissions in coal conversion operations and will be referred to in the discussions that follow. Primary emphasis will be on gasification since it presents more difficult problems in that it is generally impractical to divert large flows of gas to storage and in an emergency they have to be vented or flared, whereas liquids or solids can more easily be diverted and stored. Liquefaction also includes most of the same operations as gasification, such as coal preparation, acid gas removal, utilities, etc. and frequently includes gasification for manufacturing hydrogen. Flow rates for one specific gasification process during normal operation are shown in Figure 8.2, while those for one specific liquefaction process are shown in Figure 8.3. Where reference is made in the text to flow rates for a typical large plant, the size refers to these figures.

8.4.2 Coal Storage and Preparation

The first operation is to receive and store the coal feed. It may be delivered by rail, in which case unloading of cars can result in excessive dust unless facilities are properly designed. Any oversight is then difficult and costly to correct. If coal is delivered by truck there is the additional concern of dust stirred up on roads. Some studies have found roads or other fugitive emissions to be a major source of pollution (71). Paving will help except that dust can accumulate on the road due to leakage from the trucks. Wetting or washing the road is often proposed but consumes valuable water. An environmentally engineered rail system may be a better method. Concerns on coal storage have been covered earlier in this report, however, special attention should be given to controlling dust emissions associated with unloading and stacking the coal on piles, and retrieving it by front end loaders or by bucket wheels. The objective is always to avoid emission of dust, rather than trying to recover it after it is airborne.

Conveyors of various types are used in the coal preparation area, all of which are subject to spills, plugs, jams, other failures, and fires. To the extent possible, conveyors should be enclosed and special hoods provided at transfer points to collect dust, using a vacuum collection system if needed or water sprays where appropriate. The magnitude of potential spills should be clearly recognized, since total flow rate of coal on conveyors can be 500 tons/hour on bituminous coal and 1000 tons/hour on lignite.

Effective provision for cleanup is an essential part of environmental planning for coal processing in general, and for coal preparation in particular. Effective backup on critical equipment is also needed, for example to maintain the vacuum system in case of mechanical or power failure.

8.4.3 Crushing and Screening

Crushing and screening is generally the next step and is subject to considerations much the same as for conveyors. In addition there is a possibility of off-specification non-usable material due to screen breakage or for other reasons. This may have to be diverted and reprocessed or discarded. For a typical coal conversion plant the flow rate is 500-1000 tons/hour, consequently a rapid response is needed. If the diverted material has a high content of combustibles it would be undesirable to discard it without recovering the heating value, with the additional concern that it could catch fire after disposal.

When coal washing and cleaning is part of the operation, large volumes of water and fine refuse are handled. Consideration should be given to spills, leaks, and other losses of wash water and all chemicals or additives used in the operations. Drying out of the area, equipment, or ponds can create a dust nuisance that should be avoided by good operating procedures and proper housekeeping. Disposing of the large amounts of refuse can cause transient emissions from dust, fires, leaching, etc. that must be protected against. Fine refuse from coal cleaning may amount to 1000-3000 tons/day for a large plant, while coarse refuse may be even more. Therefore a dusting or runoff loss of even a fraction of one percent could be excessive. Suitable gages have been developed and used to monitor local dust concentrations and to help identify sources of the dust (72).

8.4.4 Drying

Drying is nearly always included in coal conversion processes if only to assure reliable coal feeding and is particularly needed if fine grinding is involved or if the coal feed has been exposed to rain. Since conventional drying is accomplished by directly contacting ground coal with a large volume of hot combustion gases, very effective control of dust emissions is required. Typically, cyclones are used followed by bag filters. Upsets may occur such as rupture of bags that would suddenly release large amounts of dust to the atmosphere. Gas flow through the dryer is perhaps 30 MM scfd so release of only a fraction of this through a broken bag would be serious, even though it might be shut off within a few minutes.

Vent gas from the dryer may contain about 50% moisture, so that under certain atmospheric conditions it will form a fog or plume upon mixing with ambient air, and can affect public areas such as highways or air traffic (73). A simple solution is not available but the problem should be addressed. One approach is to use an indirectly heated coal dryer in which moisture removed from the coal would be contained and recovered (7). Alternatively the moist vent gas might be cooled to recover water and then reheated, although this route would obviously be costly and may not be warranted.

One final comment on the coal dryer deals with the emission of odors or combustibles. Depending upon the equipment operation and on the specific coal feed, some volatile materials may be present in the vent gas that could cause undesirable odors. This is more likely with reactive coals such as lignites, and when local overheating of coal particles may occur. Appreciable amounts of volatile combustibles are generally released when coal is heated above 500°F (6). Oxidation also becomes appreciable and may result in temperature runaway and fire, causing very extensive emissions and damage to bag filters, if used. Oxygen content of the drying gas is normally maintained at less than 10% for safety reasons. Additional information is needed to determine when and whether there is an odor problem in coal drying, but if there is, then incineration of the vent gas would be a possible solution.

8.4.5 Pretreatment

In some gasification processes the coal feed is pretreated to destroy caking properties that could cause operating problems (9). The usual pretreatment consists of mild oxidation in air at 700-800°F with considerable heat release. A large volume of air is used, typically 1.0 lbs air/lb coal, and tar, moisture, and other volatile matters are released requiring extensive cleanup and attention to pollution controls. Transient emission could occur if an upset causes formation of tar-water emulsions that do not separate. If this happens, there should be storage facilities for the emulsion so that it can be reprocessed at a convenient time, possibly requiring chemical treatment or distillation to break the emulsion. In one calculated example the amount of tar from pretreating was estimated to be 630 tons/day while the water emulsified could be several times this. Heat and material balances calculated for pretreating are given in Table 8.4.

The normal tar production will contain some fine solids. At a solids content of 2% the amount is 12.6 tons/day which may have to be removed and disposed of when the tanks are cleaned periodically. With cleaning twice a year, the accumulation could be as much as 2000 tons. Incineration in a fluid bed (with sulfur removal) is one possible disposal method for this oily waste.

Table 8.4

Coal Pretreatment - Calculated Yields and Balances

250 x 10^9 Btu/D Pipeline Gas

Coal Feed	Eastern bituminous, high sulfur	
Major streams (74)	Coal Feed	Pretreated Coal
Tons per day	14,700	12,720
% Moisture	0	0
Btu/lb. HHV	13,186	11,930 (est)
Analysis: wt. %		*
C	71.50	71.27
H	5.02	3.97
O	6.53	6.87
N	1.23	1.00
S	4.42	3.83
Ash	11.30	13.06
	100.00	100.00

Coal Pretreater

Oper. conditions	800°F, low press.
Char yield, wt. %	86.5
Air In, scfm	260,000**
Off gas Btu/cf HHV	39
Tar liquid by prod. tons/day	630***
By prod. steam made, lb/hr	946,000

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* Calculated from balances in reference 74.

** Air rate is estimated from heat required to generate steam and provide sensible heat load on preheater (75). Corresponds to 2.6 SCF oxygen per pound of coal feed, compared to 1.0-1.5 indicated to be minimum requirement in reference (76).

*** Estimated from yields and heat balance on pretreater.

Low Btu gas is also a product from pretreatment with air, and after sulfur removal it is used as fuel. However, its heating value is very low, 39 Btu/scf for example, so that special burners will be needed to assure complete combustion and high reliability is needed to avoid flame out that would result in emission of combustibles. As for solids handling and gas cleanup operations, it will be seen that these are much like a typical gasification process and therefore transient emission concerns are similar. These will be discussed further in the section 8.4.6 on Coal Conversion.

8.4.6 Coal Conversion

The techniques for converting coal to clean products that are pertinent to this discussion are gasification and hydroliquefaction. Both of these are subject to upsets that could result in unacceptable transient emissions. Both operate at high pressure - up to 1000 psig in the case of gasification, and about 2000 psig for liquefaction. High pressure increases the chance for leaks as well as their magnitude. Of particular concern are possible leaks in heat exchangers, valves, pumps, compressors, and connections as discussed earlier in Section 8.4.1. Also, the possibility of rupture of exchanger tubes and furnace tubes is of great concern, especially due to the high operating pressure. Thus, exchangers in cooling water service could leak contaminants into the cooling water system, while those in air cooling service could leak and contaminate the air used for cooling. Composition of the material leaked will of course depend on the gasification or liquefaction streams involved. Failure of a furnace tube could release combustibles into the combustion zone, or in the case of convection tubes the release would be into flue gas going to the stack. Therefore, such high pressure equipment will call for close attention and monitoring, with provision for immediate action and possible automatic instrument response in order to control undesirable transient emissions. Areas subject to upsets that are specifically pertinent to gasification or to liquefaction will be discussed in the next two subsections.

8.4.6.1 Gasification

Coal is usually fed to the high pressure system by means of lock hoppers in a cyclic operation. First a hopper is charged with coal feed, then it is brought up to system pressure by adding raw or product gas, and then it is fed into the reactor. At this point the empty hopper is filled with high pressure gas which must be released, recovered, and used. The gas may be cleaned up to remove dust, recompressed, and reused on the lock hoppers, or it may go to a low pressure fuel gas system but clean up is also required in this case. Since the operation is cyclic, the gas flow will take place in surges that can be many times the average flow. Upsets can aggravate the surges, for example a valve may plug with solids and suddenly break through. Such plugs can be caused easily by wet coal or moisture condensation. The gas recovery system needs to be capable of accommodating surges of dusty gas while giving dependable clean up.

The possibility of leaking valves must be guarded against and provided for in the off-gas recovery system, as it can greatly increase the amounts of gas and dust to be handled. Leaking may result from worn valves, or if particles are left between the seating surfaces. By way of illustration, an annulus 1/100 inch wide and 12 inches diameter could leak over 1 million scf per day of gas from a pressure of 500 psig.

Volume of gas remaining in the empty lock hopper after dumping to the reactor can also be calculated. It amounts to about 2000 scf of gas per ton of coal fed, for the same 500 psig operating pressure. Putting it another way, the total volume of gas from depressuring lock hoppers may be 5% of the raw gas volume or 10% of the SNG product volume.

Similar considerations apply on the lock hoppers used to remove ash or char from the gasifier. The tons of ash are much less than the tons of coal feed, although its density may be much less, depending upon the type of gasifier. In some cases the ash lock hoppers operate on a water slurry of ash, thereby alleviating the gas leakage problem. But the ash system has added potential for transient emissions due to the friable dusty nature of most ash (unless it has been slagged), and the possibility of withdrawing hot ash. If the ash is dry when withdrawn, it will generally be wetted down with water to control dusting, with only a small evolution of steam which can be collected and condensed. However, upsets could occur, for example in the lock hopper system, such that the ash could be quite hot as it is withdrawn. Then cooling it by water sprays could create extreme turbulence and dusting, requiring extra environmental controls to prevent transient emissions.

Sometimes the ash may be slagged in the gasifier, as in the Koppers or BIGAS processes. It is usually dropped into water to quench and shatter it, so that it can be handled as a slurry. The water slurry will be quite hot when withdrawn and tend to flash off steam and vapors that may contain sulfur compounds and cause undesirable odors, therefore all off gases should be contained, returned to the system, or properly cleaned up, or disposed of by incineration for example.

As in any high pressure process, all liquids that are withdrawn will tend to flash and give off vapors, since they have been saturated with gases and vapors within the high pressure system. The ash-slurry system is no exception and the water can be expected to be saturated with whatever gas it has been exposed to, such as raw gas containing sulfur. While carbon monoxide and hydrogen are only soluble in water to the extent of 1-2 vol. %, carbon dioxide solubility is much higher, about 0.4 to 1.1 volume per volume of water for 1 atmosphere partial pressure. At gasifier pressure, the partial pressures are much higher so that release of flash gas must be considered when defining environmental controls. Thus, variations in temperatures and flows during an upset can cause transient releases of flash gas. It may be possible to purge the ash or char system with steam to sweep out other gases so as to simplify the flash gas problem.

In those cases where the ash is dry as removed from gasification, there can be transient dust from handling operations. Covered conveyors, hoods, and other control measures such as water sprays should be used where practical.

Various other upsets can occur in the gasification system, such as: failure of pumps, drives, or other equipment, or stoppage of coal feed, deterioration of refractory lining, etc. Some of these will cause temporary interruption of the operation for minutes or hours without a full shutdown, while others will require cooling the unit down for maintenance. In all cases, control of transient emissions is needed, as discussed in this section 8.4 and section 8.2 on startup and 8.3 on shutdown considerations.

One other type of upset that should be discussed is the possibility of overpressuring the system, in which case the safety relief valves automatically open to release gases to the blowdown and flare system. To the extent possible without jeopardizing safety, it is desirable to cool the gases to recover any condensibles, scrub to remove particulates and then incinerate the combustibles (e.g. in a flare). In some cases the decision may be made to discharge pressure relief valves directly to the atmosphere, but this should only be done after a careful and thorough study justifies this as the best practical approach.

It is common for pressure relief valves to leak. Leaks are particularly likely after they have once been activated and, since the usual valve is spring loaded or weight loaded, relatively little force is available to make the valve seat properly. In addition, particles or dirt may interfere with reseating in dusty services as on the gasifier. Spring loaded safety valves give protection together with good prospects of keeping the unit onstream when the upset is minor and correctable. Frangible discs are sometimes used as an alternative for fastest possible depressuring, but generally result in a full shutdown of the system since they cannot be reclosed and have to be replaced. Recently a combination has been offered, using a basic spring loaded valve together with a frangible disc to assure against leakage prior to activation of the safety valve. Some safety valve practices are undergoing reexamination, and recent publications suggest the possibility of having gate valves upstream of the safety valves, (locked open!) to allow checking out the valves or replacing them while the plant is onstream. Others have proposed reliance on instrumentation for protection by isolating the main sources of pressure so that only a small pressure relief valve is needed rather than one to carry the entire process flow. Obviously, any changes in safety practices will only be made after very thorough study. The present discussion should not be taken as a recommendation for any changes, but rather that each situation should be examined and reviewed so that the best decisions are made regarding selection,sizing and point location of pressure relief valves.

8.4.6.2 Liquefaction

In coal liquefaction systems, the coal feed is mixed with hot recycle oil to form a slurry which is pumped to high pressure. A slurry system is also used in some gasification processes, in which case the following comments are pertinent. Dried coal may still contain 1-2% moisture, which flashes when it is mixed with hot oil. Provision is normally included to recover this as well as gas and vapors released from the oil when it is depressured. However, there may be occasions when the volume of flash gas is greatly increased due to unexpectedly high moisture in the coal, possibly caused by an upset on the dryer. If the flash gas passes through a cooler, as in some designs, then more cooling will be required and more water will be condensed and have to be disposed of or stored temporarily. Increase in flash gas will also result if there is an increase in the amount of light fractions in the recycle oil, as can happen unexpectedly due to an upset in the liquid separation facilities which supply the recycle oil.

Coal must be introduced and mixed with oil to form the slurry fed to liquefaction, and plugging is a common source of upsets on such systems. In case of plugging, the system may have to be flushed out with wash oil so suitable facilities should be provided together with storage to hold the wash stream so that it can be cleaned up for reuse.

The liquefaction reactants are a mixture of liquids, solids, and gases, whereas only solids and gases are present in gasification. Liquefaction is therefore more involved. For example, all liquid streams withdrawn from the high pressure system will contain dissolved gases and light fractions that can flash off upon depressuring. These flash gases should be recovered for use and adequate consideration and planning is needed so that recovery facilities are not overloaded by rapid removals during upsets. Plugging is again a possiblity and may call for flushing facilities as discussed for coal feeding. An upset may also carry heavy liquid from the reactor into gas handling systems, also calling for flushing facilities with adequate means for cleanup and reuse of the flushing liquid.

In designing the blowdown and flare systems, it is extremely important to protect against slugs of liquid hydrocarbons being discharged to the flare, as serious fires could result. Size of settling or knock-out drums should be made large enough to prevent any substantial entrainment of liquids in the gas being flared. If liquid combustibles were present, the radiant heat from the flare flame could increase greatly and become unacceptable. Moreover, drops of burning liquid might fall to ground level.

Again it should be emphasized that leaks in equipment are one of the major environmental concerns in coal liquefaction. Leaks in heat exchangers can contaminate the entire cooling water system, while in the case of air cooling leaks will cause releases directly to the atmosphere, as discussed in Section 8.1. Other possible equipment leaks to consider include pumps and compressors, valves, flanges, pressure relief valves, sample connections, etc. In addition, there is the possibility of rupturing furnace tubes, with consequent transient emissions. Liquefaction plants can easily have an odor problem as a result of leaks or spills of materials containing phenolic type compounds having a strong and persistent odor. These compounds can also cause undesirable taste if they get into drinking water, so special precautions are needed from this standpoint. In general, inspection monitoring and maintenance programs are an essential part of controlling transient emissions.

Liquefaction operations typically include some means to separate residual ash and solids from a heavy bottoms fraction of the reactor product. The method may use vacuum distillation or filtration. In vacuum distillation, a steam jet or mechanical pump is used to maintain the vacuum and return non condensibles to the atmosphere (77). Obviously, any surge of gases or low boiling materials into the system will appear as an emission from the vacuum pump, so the pollution control system (e.g. incinerator), must be designed to accommodate surges such as those caused by upsets. Emulsions can also occur in the overhead recovery system of vacuum units and may require provision for storage and reworking.

Filtration is the other method used to remove solids from the heavy liquid. If a vacuum filter is used, the above comments are applicable. An alternative is pressure filtration in which case leaks and spills can be a problem. Filtration is a difficult operation, complicated by the fact that removing filter cake is necessary. Filtration involves solid, liquid, and gas streams all of which can contribute to emissions, including transient ones. With rotary filters a cake is scraped off, which may be pasty, hard to handle, and contribute to plugging difficulties. If plugging occurs, operation may be interrupted to open up equipment and wash it out. Special cleanup and collection facilities should be available for this. Often a precoat is used and can introduce additional emission problems in its storage and handling, application, and removal to disposal.

8.4.7 Shift and Cooling

The shift reactor may be a fixed bed of iron based or cobalt-molybdenum catalyst. During operation it might become partially plugged by dust, in which case efforts may be made to clear it by steaming or backblowing. Emissions would not be expected since the flowing streams will be contained and handled in the gas cleanup system. If the shift reactor must be opened for servicing, then transient emissions of the catalyst or deposits might occur. Emissions of dust, sulfur compounds, or iron carbonyl from iron type catalysts should be considered and protection provided as needed. Trace elements such as arsenic, lead, etc. may very likely build up on the shift catalyst and in this general area of the plant, requiring special protective measures. However, sufficient data on the subject are not yet available to allow defining the situation and methods for environmental control. Charging, replacing, and discharging catalyst especially call for dust control. Spent catalyst should be returned for reworking or disposed of in a way to avoid transient pollution from dust or leaching.

Gas cooling and scrubbing is the next operation, typically using a waste heat boiler followed by heat exchangers and a scrubber. The boiler and exchangers may develop leaks due to erosion or corrosion, causing emissions directly or indirectly. Protective measures include careful design, monitoring and inspection, preventive maintenance, plus employee training and education.

Scrubbing to remove dust is a critical operation to avoid problems downstream. An upset may result if water circulation is lost for any reason such as pump or motor failure. Attendant overheating or over-pressuring may lead to additional upsets. Deposits can occur, requiring extensive flushing of dirty water to sewers or storage. Transient emissions of gases, liquids, and solids can be controlled by prior consideration and planning, including appropriate sparing of critical pumps and other items. Provision could be made for example to automatically divert any severely contaminated water (as could result from a tube failure) directly to waste water treating.

8.4.8 Acid Gas Removal

One of the transient emissions on a coal conversion plant that is of greatest environmental concern is from the acid gas removal in case of upset. If it gives inadequate cleanup for any reason, gas product can not be used and will have to be diverted to a flare since sizeable storage or a complete backup system is hardly practical. The flare should be designed for efficient combustion, smokeless operation, and noise control. Sulfur emission could be very high from the flare until the difficulties are corrected or operation is cut back to avoid diverting to the flare. Typical flow rate (Figure 8.1) to acid gas removal is 32 MM scfh containing 380 tons/day sulfur, that potentially would be flared if all of the gas had to be diverted to a flare. One proposed design has 2 trains of acid gas removal each sized for 75% of the total flow, which would require diverting 25% of the total flow in case one train shutdown, assuming that the other train could be quickly brought up to its full capacity. Depending on the type of upset, partial sulfur removal might be maintained thereby decreasing emissions, but clearly, very thorough and careful planning and operation are required to minimize this large potential source of transient emissions.

A second major concern is possible contamination of the CO_2 vent gas rejected to the atmosphere. It is a very large stream, and many acid gas removal systems have difficulty in achieving a satisfactorily low sulfur level in the rejected CO_2. Therefore, upsets are liable to cause a temporary increase in sulfur level that could be very objectionable. It is not certain that the waste CO_2 stream will always be incinerated before release, since it is so large a stream that incineration would consume considerable additional fuel; however, incineration is one available control method to oxidize sulfur compounds, combustibles, and other contaminants.

Entrainment of scrubbing liquid into the CO_2 vent stream is another possible source of contamination, especially if there are upsets and surges in flow or pressure. Incineration, if used, may take care of this -- or consideration can be given to use of entrainment separation devices for protection.

The circulating chemical or solution used for absorption is often filtered to remove solids that tend to accumulate and could cause fouling or other problems. The filters are cleaned periodically and the waste material must be disposed of (78). In addition, cyclic interruptions associated with filter cleaning may cause upsets or result in emissions or leaks of gas or liquid. Operating procedures should be defined to minimize all transient emissions. The waste solids may represent residual coal ash carried along with the acid gases, or there can be rust particles or degradation products. Washing or incineration may be needed before disposal, depending upon its exact nature.

All processes for acid gas removal have chemical losses or chemical purge streams to dispose of as a result of leaks, vapor pressure, side reactions, degradation caused by contaminants, etc. Makeup chemicals are required, possibly amounting to 1.6 tons/day in the case of Rectisol methanol scrubbing (79) or 150 gallons/day for a Benfield hot potassium carbonate system (80). Other chemicals are often added as activators or to combat corrosion, fouling, or foaming (81).

It should be clearly recognized that all chemicals used by the plant must be accounted for, generally showing up as effluents, in which case effective and adequate environmental controls or disposal should be provided as necessary. Upset could result in unexpected contamination or degradation of the scrubbing medium, such that it may have to be purged and replaced. Storage should be available for purge materials so that they can be retained for reclaimation or ultimate disposal. Of course, storage is also needed for the normal chemical solution inventory to use when the system is shut down or emptied for any reason.

An area of great uncertainty is the fate of trace elements (As, Cd, Se, Cl, F, etc.) in the gas cleanup facilities. Some may pass through the gas scrubber into acid gas removal where they may deposit, react with the solution, or otherwise accumulate and have to be removed as transient effluents. More information is needed to define the problem.

Following acid gas removal, final traces of sulfur are removed by a guard bed of zinc oxide in order to protect the methanation catalyst. It is estimated that the zinc oxide will be replaced every 3 to 6 months. Fixed bed reactors are used, requiring depressuring and purging with nitrogen or inert gas for catalyst replacement or maintenance. These vent streams should be collected and returned to the system or sent to blowdown facilities for disposal. The spent zinc oxide cannot be regenerated easily but can be returned to a manufacturer for reworking. The total sulfur removed by the guard is only a small fraction of a percent of the total sulfur contained in the coal feed since most of it has been removed previously. Adequate dust control should be provided during dumping and recharging of zinc oxide and other materials used in the guard system. Experience shows that loading and unloading of catalyst or solids handling can cause a dust nuisance, which may require shields, hoods, and a collection system with cleanup. There also may be unappreciated health effects.

8.4.9 Methanation, Compression and Drying

At this point in the process the streams are very clean with regard to sulfur and dust but the high operating pressure can lead to leaks. Prior to methanation the gases contain considerable CO which is toxic, so monitoring the process area and other precautions may be needed for protection. There is also a possibility of forming highly toxic nickel carbonyl as mentioned earlier, if upset conditions lead to a catalyst temperature, below 400°F for example. Startup of the methanation reactor generally involves pretreatment operation which can cause transient releases as discussed in Section 8.2 on startup, while Section 8.3 covers considerations related to shutdown of the facilities.

The large heat release of the methanation reaction is used to make steam by recirculating gas through waste heat boilers. Pressure on the gas side is usually higher than the pressure of steam generated; consequently any leakage in the exchanger will add gas to the steam system rather than vice versa. This gas leakage must then be removed from the steam, and shows up as purge gas on steam condensers. For example when the steam is used to drive a condensing turbine, there is also a vacuum pump to remove non-condensible gases from the steam condenser. The latter gases are pumped for release to the atmosphere, some times without cleanup or incineration. Clearly, such purges of "non-condensible" gases can constitute undesirable emissions and should be reviewed to see whether incineration or some other cleanup is needed. Certainly in the case of tube failure a considerable amount of carbon monoxide and other combustible gases could get into the steam system from which they would be rejected to the atmosphere.

Methanation forms water which is recovered and used for makeup. As shown in Figures 8.1 and 8.2 for SNG manufacture, this can amount to about 3000 tons/day. It is clean condensate, although dissolved gases will be released when it is depressured so these gases should be collected and may be sent to the fuel system. The gas still contains moisture which must be removed to meet pipeline specifications. Glycol drying is commonly used, although other liquid or solid dessicants may be used instead. The dessicant is regenerated by stripping or heating, releasing water vapor which may be vented to the atmosphere. If upsets occur, there is a possibility that glycol (or other dessicant) might also be released to the atmosphere, so environmental protection should be considered.

A booster compressor is sometimes needed to raise the product gas to pipeline pressure. Leaks and failures on this equipment could cause inadvertent releases of combustible gas, or of steam in the event that steam turbine drives are used. Final cooling of the gas by cooling water or air cooling may be used, in which case leaks could introduce combustible gas into the cooling water system and cooling tower, or directly to the atmosphere.

Starting up and pretreating of the methanation catalyst have already been discussed. Upsets during operation of the unit may require repeating the pretreat operation, or even replacing the catalyst, with associated environmental concerns as described.

8.4.10 Sulfur Plant

The sulfur recovery plant is vital, in that without it, operation of the coal conversion plant must be interrupted. As shown in Figure 8.1 and 8.2 about 2500-5000 tpd of sulfur containing gases are fed to the Claus plant, including perhaps 400 tpd of sulfur of which roughly 99% is probably recovered. For reliability, the sulfur plant consist of multiple units with excess combined capacity. Thus, some designs include 3 units each having 50% of base capacity, or two units of 75% capacity each. Since it is not possible to startup a sulfur plant instantaneously they must all be on stream all of the time, but running at part load. Then sudden changes in feed gas rate can be accomodated quickly.

Changes in composition of the feed gas can also cause upsets on the sulfur plant. It depends upon combustion of the proper fraction of feed gas to give the stoichiometric amount of SO_2 to just react completely with H_2S in the part that bypasses combustion. Hence any change that affects combustion air requirement can cause an upset. Change in H_2S content of the feed gas could be one factor, while a sudden change in the content of hydrocarbons is another. Loss of flame, or an unstable flame, would disrupt the sulfur recovery operation.

Upsets, for example excessive hydrocarbons, can throw the product sulfur off specification, such that it cannot be sold. If this happens the sulfur must be stored until it can be disposed of. Possibly it could be worked off by feeding through the sulfur plant feed gas incinerator after steady operation has been resumed.

The sulfur pit is a potential source of obnoxious odors, and even fires. H_2S is rather soluble in molten sulfur and could be released. Standard procedures and operating techniques are available from suppliers and should be reviewed to be sure that environmental controls are satisfactory.

The sulfur plant will usually include tail gas cleanup, using one of the various processes offered. Gas volume is the same as in the Claus plant, or larger, while the sulfur entering tail gas cleanup will be perhaps 5% of that to the Claus plant. Upsets on the sulfur plant can also upset the tail gas cleanup of course, and in addition it is subject to its own upsets. Scrubbing is usually used, introducing the possibility of deactivating or contaminating the solution such that it must be removed and replaced. All chemical purges could be sent to storage from which they can be cleaned up for reuse or otherwise disposed of in an acceptable manner.

Solids may have to be disposed of periodically. Catalyst used in the Claus reaction has an estimated life of 3-5 years (82) after which it is discarded. There may also be other solids resulting from cleanout, general maintenance, or salt deposits etc., that must be disposed of without excessive pollution.

8.4.11 Oxygen Plant

As in the case of primary emissions the oxygen plant is relatively clean; no major transient emissions are likely. The major potentially adverse impact of the oxygen plant would be in the event of an unexpected shutdown that would upset the gasification part of the plant. Fortunately the service factor on oxygen production is high and the likelihood of upsets is small, although this might be offset if only one train is used for oxygen production. Liquid oxygen storage equivalent to say 8 hours requirement is often provided to assure smooth operations.

Oxygen consumption for gasification is typically about 5000-6000 tons/day, giving a waste nitrogen stream of 15,000 to 20,000 tons/day that will be returned to the atmosphere. Transient emissions such as defrosting of exchangers, etc., should not present environmental problems.

8.4.12 Solids Disposal

For the large gasification plants being considered, ash from the gasifier to be disposed of may be 1000 tons/day on bituminous coal, or perhaps 3000 tons/day when feeding lignite. In addition, ash from coal used in the utility boiler and for plant fuel can add about 200-500 tons/day. Handling losses amounting to a fraction of 1% could be excessive. Spills, dusting, accumulation in tanks and ponds, etc. could total 1000 tons/year, so a program of cleanup and disposal should be part of the planning. Ash quenching can generate odors that may have to be contained, for example, calcium sulfide in the ash tends to react with moisture and CO_2 in the atmosphere to release H_2S. Also, if not contained, quenching could release clouds of steam, particularly if upsets result in insufficient quench water, amounting to an estimated 15 MM scfd of steam.

Leaching of ash, refuse from coal cleaning, sludge and other solid wastes could cause transient releases, for example in case of a storm or due to a spring thaw. Overflow or draining of retention ponds could give large temporary effluents. Other upsets might discharge sour water (amounting to 16,000 tons/day for example) if waste water treating is disrupted. Even though the water may have been processed in the sour water stripper it will have a strong odor and could contain large amounts of soluble salts, such as ammonium chloride.

Filter cake may be an oily waste from liquefaction processes. Usually it can be disposed of by gasification or incineration, but in case of upsets it may present a disposal problem. The slurry to be filtered is made up of very heavy oil or tar, so if it cools off or is spilled a difficult cleanup situation is faced. Again, satisfactory plans must be developed ahead of time. Oily waste from tank cleanings etc. presents somewhat similar problems, and fluid bed incineration would appear to be one good approach.

8.4.13 Water Treating

In general, the water systems on a plant will include process and sour water cleanup, a cooling water circuit, makeup water treating, collection of storm runoff, and a recirculating water system for coal cleaning where this step is included. Facilities can include ponds, an oil separator, cooling tower, exchangers, pumps, etc. all of which are subject to upsets in more ways than can be predicted, resulting in the release of transients. Chemicals are used in most of the water systems, such as chlorine, chromates, sulfuric acid, and caustic; consequently, they may appear as transient effluents, especially during operating upsets.

It is sometimes proposed to add treated sanitary waste to the cooling tower as makeup, although fouling problems may be thereby aggravated. In a typical design this could contribute 10-15% of total makeup water to the plant; however, the drift loss and spray from the cooling tower should be considered in that contamination could result, at least at times.

One pertinent study showed significant entrainment of water containing microorganisms when air was passed through a simulated cooling tower (83), suggesting that extensive pretreatment of sanitary waste may be needed if such use is contemplated. In some cases effluent from a municipal sewage treating plant has been used for industrial plant makeup water, so progress has been made in solving the attendant problems (84). However, the environmental factors may not have been adequately addressed.

The various water systems in the plant are closely interrelated, and an upset in one can affect the others to cause transient effluents. Thus, sour water is usually cleaned up to reuse as cooling tower makeup, so failure of the stripper could allow excessive amounts of H_2S, NH_3, etc. to be introduced to the cooling tower, causing serious emissions. Instrumentation to monitor the quality of makeup water going to the cooling water system may give the desired protection, with provision for diverting unsatisfactory water to covered storage. The water systems are discussed below with respect to transient emissions, covering the areas: waste water treatment, cooling water system, and makeup water treating.

Waste Water Treatment

The usual steps in industrial waste water treatment are:

- solids separation
- extraction of phenols
- sour water stripping
- oil removal
- biological oxidation
- filtration
- activated carbon if needed

All of these could contribute occasional or inadvertent emissions. Residual ash and solids scrubbed from the gas are separated in a clarifier or filter for disposal. Mal-operation may increase the amount of solids (e.g., plugging of dipleg on cyclone separator downstream of gasifier) and result in overloading or plugging of the solids separation facilities in waste water treatment. These solids may have to be flushed to storage, possibly to a pond if there is no problem due to odors or vapors. However, there is also a question on trace elements since many are appreciably volatile in gasification. Some, such as fumes of arsenic or lead may appear in the scrubbing water, or be associated with the ash fines and be susceptible to leaching when the ash is diposed of. The large amounts of trace elements that might be carried out of the gasifier with the raw gas are defined in the individual process reports. Spills of wet ash could lead to a dust nuisance when they dry out, and, therefore should be cleaned up promptly.

Extraction of phenols is the next step in waste water treatment except for those processes that do not make substantial amounts of phenols. Solubility of cresols and phenols in water may be 2-8 wt. %, and both low temperature gasification and liquefaction form considerable amounts of them. For example a design using Lurgi gasifiers shows 120 tons/day of crude phenols produced. If an upset in the extraction plant results in an abnormally high phenol content in the water going to biological oxidation, there could be a similar surge in phenol content of the water effluent which might then contaminate sources of drinking water. A level of only .001 mg/l causes objectionable taste, while even .0001 mg/l leads to off-flavor in fish (85). Chemicals used for extraction of phenol may also contribute to transient emissions.

Sour water stripping to remove NH_3 and H_2S from the waste water is a vital part of water treatment, and any departure from its normal performance could disrupt or overload subsequent water treating operations. Stripping is subject to the usual types of equipment failures, or to interruption of electrical power or steam, but is also liable to plugging of critical exchangers due to salts such as ammonium carbonate, etc. Furthermore, changes in the feed stream could decrease cleanup efficiency temporarily. In some large plant design studies it has been considered desirable to include 100% spare facilities for sour water stripping. that is, two independent trains each of which can handle the full design flow rate (86).

If sour water stripping were ineffective for some reason, such as steam failure, then the effluent could approach feed water composition. As reported for the Synthane process (4), sour water from the gasification typically may contain 5,000-11,000 mg/l of phenol. Because of the high level of contaminants it appears prudent to provide some closed storage for sour water to handle any surges in feed, or to temporarily retain off-specification water leaving the stripper so that it can be reprocessed and not allowed to become a transient effluent. Flow rate of sour water may be 16,000 tons/day (see Figure 8.1) which is very large, but storage equivalent to several hours to 1 day should be feasible, and useful during startup or shutdown of the plant.

It will be seen that there is a definite possibility of contaminated water being released to holding ponds in the water treatment system, giving rise to strong odors or evaporation of oil and other compounds. Therefore, the operations should be followed closely to protect against serious emissions from ponds or other areas, using continuous monitoring instruments where appropriate. Ammonia is often recovered as a byproduct and could contribute to emissions, but these can be controlled using facilities and operating procedures that are well established.

After sour water stripping the waste water is processed to separate oil, using for example an API separator followed by froth flotation. At times, oil vapors and other contaminants can be released, e.g., on hot windy days or if the water entering becomes too warm. A common practice now is to cover or enclose these facilities to control emissions.

Since biological oxidation is generally depended upon to clean up many minor contaminants in waste water, any upset could result in transient releases. Changes in entering composition, concentration, temperature, etc., are known to be detrimental (37) so some surge capacity is often provided on the feed to help maintain uniform conditions.

A proper balance of nutrients is needed for reasonably completed consumption of all components, and in some cases specific nutrients such as phosphate have to be added to balance high nitrogen entering. Careful monitoring and control may be needed (88).

The bioculture can be inhibited or killed by poisons such as chlorine and chromates which are frequently added to the cooling water circuit to control biofouling and corrosion, again introducing potential for upsets. The bioculture is associated with "activated sludge" retained in the biox system, and if it dies due to lack of food or from poisons the system can easily become anaerobic and generate very obnoxious sulfur and other type odors. Education and training of personnel plus close attention to operations is perhaps the best practical answer. A holding pond following biox is also desirable, and protects against suspended solids in the effluent in the event that the activated sludge becomes difficult to separate for recycle. Disposal of sludge requires attention as discussed in Section 8.4.12.

Sometimes a separate filtration step is included to remove particulates or any residue of sludge which would contribute BOD. Sand filters may be used, with periodic back flushing to return the solids to waste water treating, to incineration or to other disposal so as to control emissions. Activated carbon may be used for final polishing, in which case it is regenerated intermittently by stripping with hot combustion gases. This regeneration gas effluent should then be incinerated, of course, to destroy desorbed materials and any carbon dust.

Other possible transient sources of waste water to consider will include storm runoff. Initially, say during the first hour of a storm, most of the oil and dirt may be washed from the area giving contaminated water. Subsequent runoff should be relatively clean and useful as makeup without extensive treatment.

Pretreating of the coal to destroy caking properties is used in some operations, and can result in considerable sour water to be treated as mentioned in Section 8.4.3. Also coal cleaning to decrease ash and pyrites may be included at the coal conversion location, in which case there is an additional large water stream to be treated. Most of the water is cleaned up for reuse in washing, screening, or other operations, but after settling and clarifying the water, it still contains very fine particulates which are removed in a settling pond. Leaching is also of concern in coal cleaning operations and on ash from conversion or furnaces. These few examples will illustrate the broad approach that is needed in considering environmental controls on waste water cleanup.

Certain other items in water treating should be commented on, particularly those operations where chemicals are consumed. An example of typical consumption of chemicals for a projected gasification plant is given in Table 8.5. In treating makeup water, chemicals are used to precipitate hardness, while sulfuric acid, caustic, and salt may be

Table 8.5

Typical Catalyst and Chemicals Consumption in a Liquefaction Process

(Based on Ref. 42)

Item	Amount
Diatomaceous Earth Filter Precoat	20 tons/day
Monoethanolamine	3750 to 12,600
Cellulose, Asbestors, and Diatomaceous Earth	22 to 110 lb/day
Corrosion Inhibitor, A	3-1/4 to 6-1/2 gal/day
Antifoam	7-1/2 to 16 gal/day
Hydrogenation Catalyst	255,700 lb (3-yr life)
Sodium Hydroxide	340 lb/day
Active Carbon	50 to 100 lb/day
CO Shift Catalyst	2399 ft^3 (1-yr life)
Benfield Solution - K_2CO_3	986 lb/month
DEA	99 lb/month
V_2O_5	17 lb/month
Methanator Catalyst	140 ft^3 (3-yr life)
Zinc Oxide Pellets	71 ft^3 (3-yr life)
BSRP CoMo Catalyst	750 ft^3 (3-yr life)
Sulfur Recovery Catalyst	5200 (3-yr life)
Stretford Solution Chemical Makeup	$386/day
Corrosion Inhibitor, B	319 lb/day
Polymer Dispersant	319 lb/day
Sulfuric Acid	3209 lb/day
Chlorine	1766 lb/day
Phosphate Polymer Antifoam	383 lb/day
Hydrazine (oxygen scavenger)	2.7 lb/day
Lime	2072 lb/day
Aluminum Sulfate	1295 lb/day
Caustic soda	2135 lb/day

consumed in regenerating ion exchange resins used to demineralize boiler feed water. The operations are often cyclic, generating intermittent effluents; moreover, the storage and handling of the chemicals and effluents could cause transient emissions unless care and planning are adequate. Chemical cleaning of exchangers and equipment is another source of wastes (89). As in the case of barge washing (90), washing out storage tanks adds more water to be cleaned up.

8.4.14 Steam and Power Supply

A coal conversion plant requires steam and electric power which are usually supplied from a utilities section of the plant although there may be an emergency power tie-in with an outside supply. Fuel used for making steam may be clean low Btu gas made from coal, or the coal may be burned directly and stack gas cleanup used to control pollution. In the first case many of the concerns on transient emissions are transferred to the gasification operation which manufactures the low Btu gas. The second case combines the concerns of a coal fired boiler plus stack gas cleanup.

Combustion of coal necessarily produces ash refuse which calls for protection against transient emissions. Great care is needed in handling, storage and disposal to control dust, odors, or contribution of suspended solids in water streams. Leaching of trace elements from the ash is also of concern, and while some work has been done in this area (91), a great deal more is needed as has been pointed out earlier in this report.

Ash causes fouling of heat transfer surfaces in coal fired boilers, and cleaning is accomplished by "soot blowing" using a high velocity steam jet to blow deposits off the tubes. Soot blowing is done on stream, without interrupting the operation, consequently the disloged dust is dispersed in the flowing gas and carried down stream where it appears as a surge in dust content (92). The gas is usually passed through an electrostatic precipitator, which gives reasonably good cleanup of dust. Incidentally, the dust from soot blowing would be expected to have an unusually high content of relatively volatile and toxic trace elements. Where stack gas scrubbing is used for cleanup, backup dust control is thereby provided.

In an electrostatic precipitator the dust deposits on collection plates which are cleaned periodically by rapping (e.g., 2-10 minute cycles). While most of the dislodged dust falls into a hopper and is recovered, there is some increase in dust loss due to rapping. Consideration has been given to the interaction between soot blowing cycles, rapping cycles, etc. on dust loss (92). (This reference also presents operating experience on a large power plant.) In the past, occasions have arisen where particulates formed loose deposits in a stack, accumulated sulfuric acid and other contaminants, and then sometimes became dislodged, to blow out through the stack and fall in nearby areas as smut. The situation can and should be prevented. The explanation of deposition is related to condensation on the walls due to cooling. Dew point of flue gases is raised very considerably over the water dew point by the presence of only minor amounts of SO_3 which forms sulfuric acid. This phenomenon is well known in connection with corrosion of heat exchangers used for low temperature heat recovery on furnaces and boilers. Acid dew points of 320°F are common for flue gases from high sulfur fuels, whereas the dew point predicted from water vapor content alone may be only 120-130°F. In the stack, wall temperatures are cooler than the flue gases due to heat loss so significant condensation can result, for example in the range of 200-300°F. Furthermore, the concentration of sulfuric acid in the condensed liquid is surprisingly high. At a dew point of 200°F the equilibrium concentration of sulfuric acid is 65%, while at 300°F it is 83% for typical flue gases. A solution to the problem is simply to prevent possible condensation by maintaining all surface temperature above the acid dew point, using adequate insulation or other means.

Tube failure in the furnace can upset combustion and give severe smoke and dust in the furnace effluent. One possible approach is to be prepared to isolate and shut off the section of tubes involved as fast as possible.

Stack gas cleanup is perhaps the most critical part of the utilities system with regard to potential transient emission of pollutants, especially of dust, smoke, and sulfur. If it fails to operate properly for any reason, emissions become excessive and the boiler may have to be shut down unless a clean fuel can be substituted immediately. Perhaps a standby system to fire oil fuel could be used, and it would also be useful for startups. Otherwise, parallel trains might be considered with stack gas cleanup facilities, which may be convenient when the design provides, for example 3 boilers, each with a stack gas cleanup system and each supplying 50% of design requirement and all three intended to be operating at all times.

Stack gas cleanup often involves the use of chemicals, and usually with a sizeable consumption of them. Moreover it necessarily generates byproduct sulfur or sulfur compounds such as H_2S or gypsum. Again, there are concerns about inadvertent handling losses on chemicals, as well as possible intermittent purges of solution needed to maintain scrubbing capacity. Plans are needed for containing and disposing of such materials. Incineration of these materials may be an acceptable means of disposal.

One comment on boilers that may affect transients is that some state codes require that boilers be shut down for inspection at stated intervals. Thus, the quantity of transients is increased.

Electric power for the plant will usually be supplied from a generator driven by a condensing steam turbine. Heat from the condenser is dissipated to cooling water or by air cooling. As mentioned earlier, vacuum on the condenser (of 2-4 in. mercury absolute) is maintained by a pump that removes non-condensible gases and rejects them to the atmosphere. Thus, any gases that get into the steam system can become emissions at this point and may require controls.

It should be emphasized that extremely high reliability is needed on the power supply, since without it the plant will have to shutdown and may have serious transient emissions. One example is loss of power on an electrostatic precipitator. Extra efforts should be made to protect against interruption of electric supply to essential facilities, by using tie-ins to other sources, emergency generators, spares driven by steam turbines, etc.

8.5 Maintenance

Maintenance on the plant covers repairs, cleaning, additions, and general servicing of facilities. There are several categories of work including unscheduled or emergency repairs due to failure of pumps, heat transfer surfaces, etc. A second category is routine maintenance during turnarounds to inspect and recondition equipment as needed. A third type of maintenance is "preventive," such as scheduled servicing of seals, pumps, exchangers, etc. to replace worn parts and prevent upsets or leaks before they occur. This is somewhat like the normal oil-change or tune-up on an automobile. In a fourth group is "predictive" maintenance which is now becoming possible as a result of progress and sophistication in instrumentation and computer applications (93). It will be seen that the degree of concern on transient emissions is very directly related to the overall philosophy and planning on maintenance. Environmental aspects improve as the maintenance program proceeds in the direction of the third and fourth categories discussed above.

Before general maintenance is started on equipment, the plant will have been depressured and purged. Liquid and solids inventories will have been removed to the extent possible and sent to storage. Opening the equipment at this point should not cause serious emissions, although spills can be expected and will need to be cleaned up. Some parts of the system will then be flushed with oil or water to remove tar, sour water, dust, etc. The liquid used for washing should be contained and cleaned up, while the contaminants in it should be separated for disposal.

Cleaning is a necessary part of the procedure to remove solids deposits in vessels, piping, heat exchanger and the like. One method of cleaning uses a blast of air, containing sand or shot. Other methods use a high pressure water jet, or strong chemicals. Regardless of the method, precautions are needed to avoid transient releases of the deposits being removed, or the materials used in the cleaning operation. In some cases, the presence of toxic trace elements may require special consideration. Many such elements are partially volatile at gasification conditions (e.g., arsenic, lead, cadmium etc.) and are expected to deposit on surfaces downstream as the gas is cooled. Protection of personnel is needed in addition to plans for safe disposal of such trace elements. Additionally, consideration should be given to all chemicals and materials used in maintenance, as well as chemicals or residues that are used in the plant or that might remain in the unit at shutdown. The latter may include carcinogenic tar, chemical solutions in the acid gas removal system and on stack gas or Claus plant tail gas cleanup, or sour water. Plans should provide for collecting, storing, and disposing of all such miscellaneous wastes.

During the shutdown, various catalysts used in the process may be regenerated, screened to remove fines, or replaced. Dusting and emissions need to be controlled. Also, catalyst (e.g., methanation) or some deposits may be pyrophoric, requiring suitable precautions. Noise during a turnaround may be sufficient to be objectionable or even harmful, depending upon the situation. Truck traffic and the high level of activity can also cause problems but can be allieviated by prior consideration.

8.6 Chemicals and Catalyst Replacement

As previously mentioned, various chemicals and catalysts are used by the plant for acid gas removal or other scrubbing systems and in water treating, etc. In addition, catalysts are used for shifting, as sulfur guards, in methanation, the sulfur plant, etc. All of these chemicals and catalysts require environmentally sound storage and handling as well as provision for satisfactory disposal of spent materials. An illustration of chemicals consumed in coal conversion is shown in Table 8.5 for the SRC process.

Water gas shift catalyst may be regenerated and screened at intervals to remove deposits and fines which cause high pressure drop in fixed beds. It is estimated that the operation may take up to 5 days. The pyrophoric potential of this catalyst should be taken into account. Acid gas removal has a chemicals makeup that is sometimes taken care of by removing part of the inventory and replacing it with fresh solution. Disposal of the purge will have to be tailored to the specific chemical composition. In some cases it can be completely destroyed by incineration, while in other cases the presence of heavy metals (vanadium) or toxic elements (arsenic) will complicate the situation.

Replacement of zinc oxide guard ahead of the methanator will be needed perhaps 2-3 times a year, at which time the spent catalyst might be returned to a manufacturer for reprocessing. Methanation catalyst may have a life of a year or more but may lose activity and have to be replaced sooner. Again, the catalyst may be pyrophoric and in addition toxic carbonyls may be present. Standards for personnel protection may require respirators and other suitable precautions.

In those plants that include hydrotreating of liquid products or byproducts, the catalyst may be either nickel based or cobalt-molybdenum. Precautions for working with these and other catalyst are available from various manufacturers (66).

Hydrogen manufacture is needed in the liquefaction processes, and uses process steps very similar to gasification to make SNG, although the shifting and acid gas removal are intensified. Transient considerations are similar to those described for gasification. In addition, soot may be formed if partial oxidation of solids or heavy oil is used. While this is normally recycled to gasification and converted, it does represent an additional material that could lead to transient emissions.

Water treating uses many chemicals that require precautions as covered briefly at the beginning of this section. One other aspect should be mentioned, that is, the possible effect of corrosion of heat exchangers in cooling water services. Surface area may easily exceed 100,000 sq. ft. and at a modest corrosion rate of 1 mil/year, and with copper tubes this could introduce 5600 lb/year of copper into the cooling water circuit.

8.7 Storage of Products and Byproducts

Storage and handling of liquids and solids are well known sources of transient emissions, for example in oil refining and chemicals manufacture these can be the largest single source of emissions (69). Suitable precautions have been developed to control tank breathing and filling losses, as well as in product handling and shipping, and these are especially pertinent on coal liquefaction plants. Similarly, precautions are available for ammonia, sulfur, phenols and specific chemicals and should be followed when applicable. Storage of molten sulfur, for example, introduces the possibility of H_2S release or fires.

8.8 Design Considerations

Most transient emissions can be attributed to upsets, startup, shutdown, or other interruptions; therefore design features that improve reliability and service factor will generally be environmentally desirable. A basic consideration is the number of equipment trains to use. Gasifiers that are currently in commercial use have a limited capacity, less than 1000 tons/day of coal, so 30 units may be needed for a large plant. Service factors may be 85-90%, and provision is needed to allow shuting down any one unit for maintenance without disrupting the rest of the plant. Frequently the gasifiers will be grouped to feed two separate and independent trains of gas cleanup facilities. Similarly, parallel trains are used in other areas of the plant as illustrated in Table 8.6. For some gasification and liquefaction processes under development the use of only two reactors is projected for a large plant (94).

The order of starting up and shutting down individual sections of the process can affect emissions, as discussed. In general, stopping the flow of coal and oxygen to the gasifier will be a first step at shutdown, while environmental controls such as acid gas removal and the sulfur plant will be the last to be shutdown, along with the utilities system. Automatic shutdown of individual systems or pieces of equipment will be provided by "fail-safe" instrumentation. Again, preplanning can minimize adverse environmental effects by assuring that proper facilities are available when needed.

Blowdown and vent streams can often be sent to a common collection system where any condensible liquids will be recovered. The remaining gas will be incinerated, or where appropriate, it can be burned in a furnace to recover heating value. Streams released from pressure relief valves can often be handled in the same or a similar system, as well as vents from lock hoppers, vacuum systems, etc.

Table 8.6

Example of Number of Trains and Spares Proposed for Large Scale Gasification Plant

930 MM scfd of 215 Btu/scf gas from
10,000 tpd Illinois coal
(From Ref. 95)

	Operating/Spare
Air Compression	4/1
Air Separation	4/0
Oxygen Compression	4/0
Gasification	4/1
Particulate Removal and Gas Cooling	
Bulk Particulate Removal	4/1
High Temperature Cooling	4/1
Low Temperature Cooling	4/1
Acid Gas Removal	4/0
Expansion	4/0
Power Generation	1/0
Sulfur Recovery	2/1
Tail Gas Treating	2/1
Water Treating	1/0
Cooling Water System	1/0
Process Condensate Treating	1/0

Consideration should be given to having a supply of low sulfur fuel oil available for use as backup, in case of failures on cleanup systems used on furnaces that normally burn dirty fuel.

Mechanical seals on pumps, although more costly than simple packing, will minimize leaks. Blowback of gas, oil, etc. through the seal may also be used to prevent leakage, or a collection jacket could be used.

Areas of the plant where spills of oil, coal, ash, etc., are most likely should be identified and probably should be confined by curbing or wells so that any spills are contained and can be cleaned up. Vacuum cleanup truck and flushing facilities should be available where needed. A separate oily water system, such as those used in oil refineries usually should be provided. Protection against vapor emissions at sewer connections and junction boxes is sometimes needed. A separate storm sewer system and retention pond can be used to recover clean water from rain run-off. However, experience shows that the initial part of such run-off may be oily and contaminated so it should be diverted to the oily water sewer.

Protection against emissions from all storage and handling areas should be reviewed to be sure that it is adequate. Storage for "off-specification" production should be available so that it can be recovered and used rather than sent to waste disposal.

In designing a plant it should be recognized that all chemicals and material entering the plant must also leave in some form since they do not simply disappear. This includes dissolved solids in makeup water for example. It also applies to trace elements entering with the feed coal, some of which may accumulate as deposits on equipment and have to be removed by cleaning. Toxic elements such as arsenic, lead, etc., will require precautions and special consideration. If there is major uncertainty as to where the toxic elements will appear, and in what form, then it necessarily follows that there must be a corresponding uncertainty as to whether environmental controls are adequate.

Elements such as chlorine in the coal can form HCl during gasification or liquefaction which will appear in the downstream recovery system. It is not clear in what form it will ultimately leave the system, or whether pH control will be needed. One concern is that chlorides can cause stress corrosion cracking of alloy steels used for fabrication, resulting in tube failure or leaks that would be environmentally undesirable.

One of the most effective means for controlling transient emissions is to guard against failures and to be ready for fast response if they do occur. This calls for a thorough and effective program of monitoring inspection, and maintenance. Likewise, an intensive and recurring program to educate and train personnel can reduce losses, conserve resources, and protect the environment.