CRYSTALLIZERS ARE FICKLE
(BUT CAN BE MANAGED)

BY SELWYN SCOGGIN
January 22, 2004

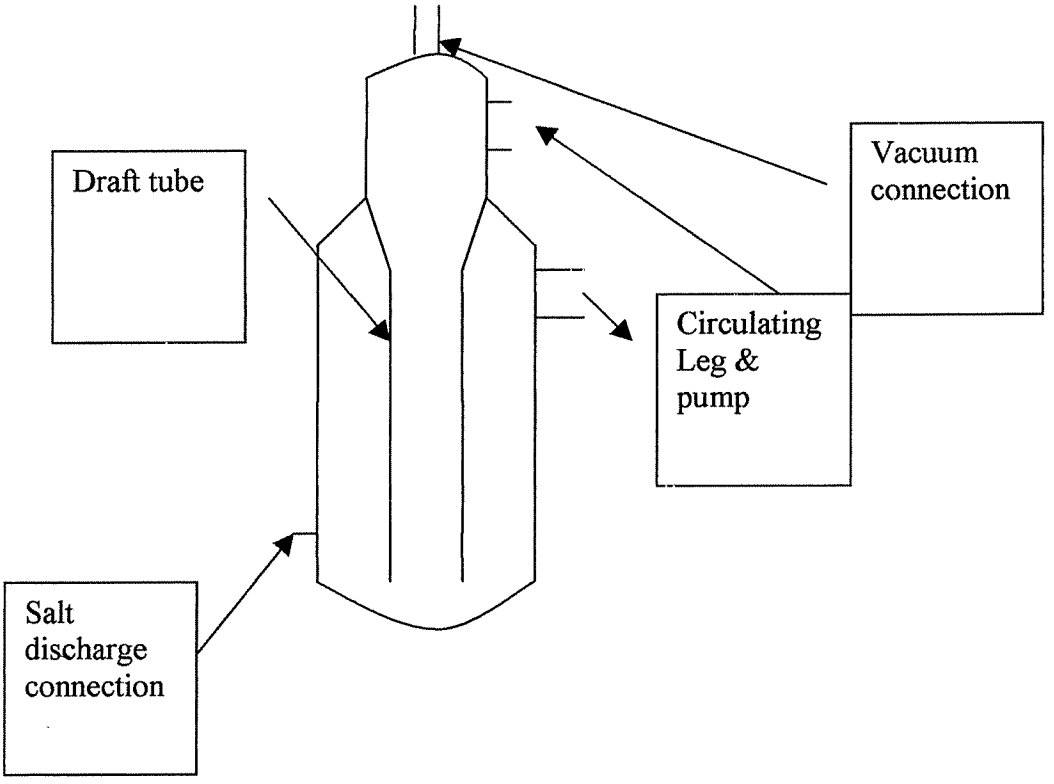
TABLE OF CONTENTS:

OVERVIEW

VESSEL

To fully understand how crystallizers work requires a good bit of technical knowledge and experience. However, I will try to give a general understanding of the operation in layman's terms. There are many different systems that must function together for a crystallizer to work properly. We will discuss these individually at first, and then try to describe how they all work together.

First we will try to explain how the crystallizer vessel itself is configured and functions. As they say a picture is worth a thousand words.



As you can see there are really two chambers stacked on top of each other, with a draft tube in between, and a circulating leg. These four items serve different but interrelated functions.

The bottom or growth chamber is where the crystals grow. There are several things that are essential for crystals to grow, and many more that affect growth rate. For crystals to grow they must remain suspended, and in contact with supersaturated brine. The suspension is dependant upon the velocity of the liquid coming down the draft tube. When the force generated by this velocity is not strong enough to overcome the weight of the crystals, they will settle out causing the crystallizer to "separate". Separation is when the crystals settle out to the bottom and the liquid keeps circulating, but no growth takes place. Since the circulation rate is usually a constant, the suspension density becomes a factor in the settling of the crystals. That is if the crystals get too thick and heavy then the discharge pump cannot function, or the crystallizer will separate. Sometimes the elbow pump can be speed up to increase the velocity of the brine to pick up the salt or increase the force to keep the crystals suspended. This is usually not effective. Also, if the circulation rate is too high the crystals will begin to circulate evenly throughout the upper and lower chambers causing the crystals to become smaller in size. This mode of operation is called mixed suspension, or forced cooling. If smaller crystals, consistent operation, and longer time between boil outs are desired, then this is where we want to be operating. Under these conditions if the elbow pump is slowed down too fast the crystals in the upper chamber will sink to the lower chamber causing the suspension density to suddenly increase and the crystallizer to separate. The circulation rate can be adjusted to control the crystal size to some degree. In general, the higher the speed the smaller the crystals, and the slower the speed of the elbow pump the bigger the crystals. Care must be taken when attempting to use this method, as when the crystals grow they become heaver, and the pump must be sped up or the crystallizer will separate. Since this takes constant vigilance and forethought, we usually find a circulation rate that is low enough to get good crystal size, but high enough to ensure that separation will not take place. Since there are many other factors that affect the crystal growth, we can't quantify what pump speed is required for a corresponding crystal size or growth rate, except for in the mixed suspension mode.

The other big factor that affects crystal growth is supersaturation. This is simply an enriching of the brine density to allow the crystals to attract the MgSO4. How this is accomplished is actually quite simple. As we know the upper chamber is under an intense vacuum, 0.8" Hg absolute. According to the vapor pressure – temperature relationship, this corresponds to a temperature of 30 deg. C. This is where we want the body temperature of the crystallizer to operate. We will discuss the vacuum system later. As the hot, 70 deg. C, brine is introduced into the upper chamber, the vacuum instantly lowers the temperature to 30 deg. C. This is accomplished by evaporative cooling, as the water flashes off. Also, when the water is evaporated, we not only get cooling, the density of the brine is increased as well. Thus we get instant supersaturation. Supersaturation simply put is when the density of the brine is so high that the MgSO4 cannot stay in solution. This excess of MgSO4 is then free to attach itself to the crystals in the growth chamber. As the crystals grow they deplete the free MgSO4. The weakened brine, mother liquor, is circulated back to the top, supersaturation chamber,

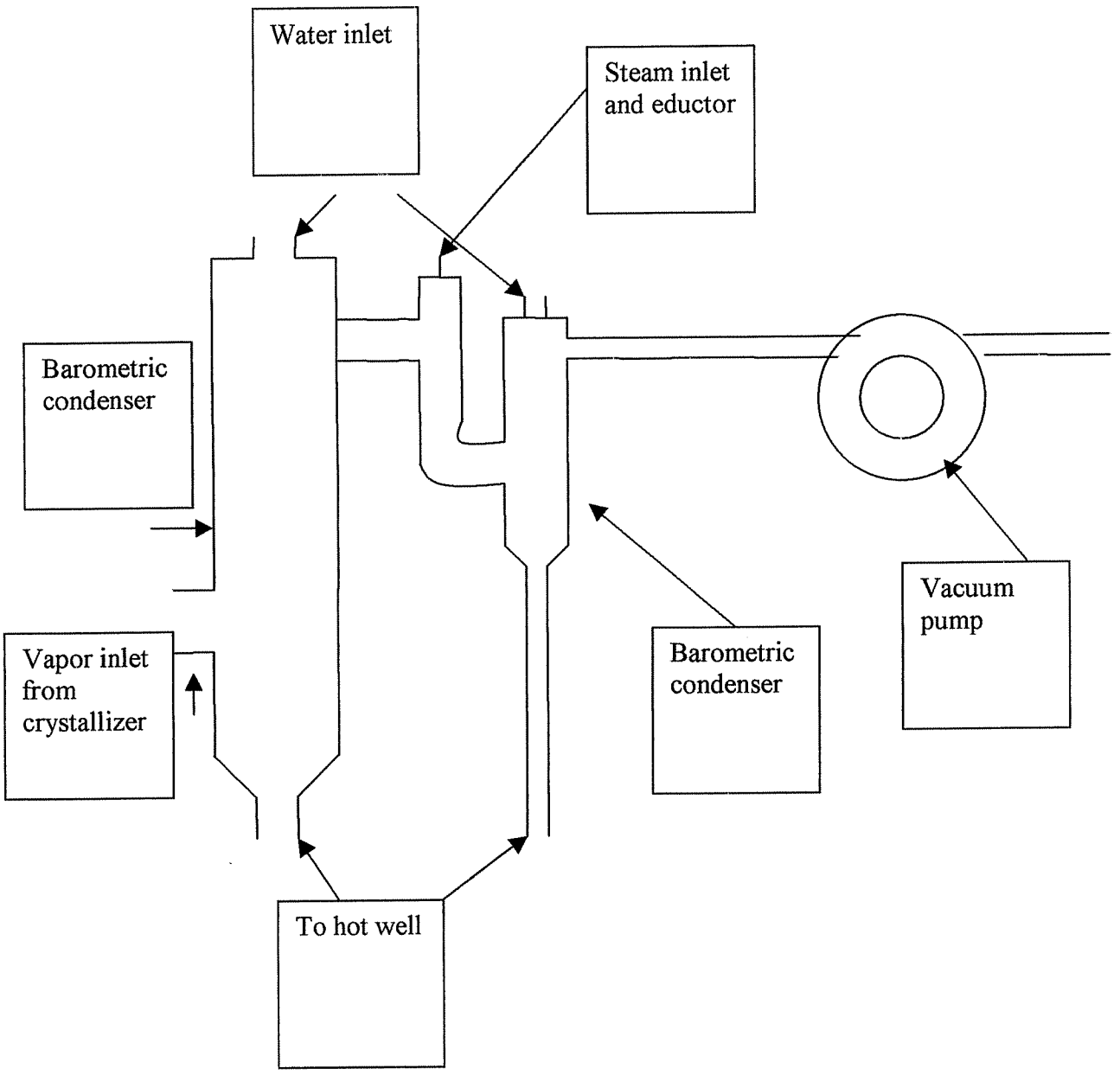
and fresh brine is added. This brine is cooled and supersaturated again and proceeds down the draft tube into the lower growth chamber. The bottom end of the draft tube is very close to the bottom of the vessel, about 6 ". As the supersaturated brine speeds down the draft tube, the opening at the bottom of the draft tube restricts the flow, and increases the velocity of the brine coming out into the growth chamber to about 200 ft/min. The force associated with this velocity is what keeps the crystals suspended. We now see how these systems must function together for the crystallizer to operate properly.

VACUUM SYSTEM

The way the crystallizer is cooled is another ingenious mechanism. According to the laws of physics, the temperature inside a closed vessel has a direct relationship to the pressure of the gas in the vessel. It is common knowledge that when steam pressure increases so does the temperature. Also, when the amount of vacuum in a vessel increases, pressure decreases, the temperature of the vapor in the vessel decreases. Fortunately for us our desired operating temperature is within reach of our vacuum system. The operating temperature is determined by the level of vacuum, while the operating capacity is determined by the heat removal capacity of the vacuum system. For us to be able to sustain a level of vacuum that we need requires a three stage system. A properly designed system must take into account two separate criteria. The first one is the non condensable load, and the second is the vapor load. The non condensable load is simply the amount of air that must be removed to keep the vacuum at an appropriate level. The vacuum pump that we have is capable of removing four pounds of air per hour. If the entrained air in the brine plus any infiltration from leaks is greater than this then we will not be able to sustain a vacuum. The vapor removal system that we have is capable removing 1000 BTU's of heat pre hour at its present operating parameters. This is equal to about three gallons of vapor. Any heat load that is introduced into the system that is greater than this will cause the vapor load to surpass the systems ability to remove it, and the temperature will increase. This rate is dependant upon other factors of course, such as water temperature and flow, and air entrainment. The first stage of the vacuum system that the entrained air and vapor see is the barometric condenser. This is a cylinder that has a water inlet in the top with baffles to disperse the water, and a drain in the bottom to let the water out. As the vapor enters the side of the condenser and comes in contact with the water spray it is condensed and flushed down the drain into the hot well, and out into the creek. If there is too much vapor for the water to condense, or to little water flow then vapor will bypass the condenser and overload the vacuum pump causing the vapor pressure to increase, thus increasing the temperature. With the barometric condenser alone, the vacuum will go down to 14 " Hg absolute. This is not low enough to reach our operating point. The nest stage in line is the steam eductor. We will discuss this after we talk about the vacuum pump, because of its roll in the process. The barometric condenser is important because it removes the bulk of the vapor. The vacuum pump is necessary because it removes the air in the system, but it also initiates the vacuum and keeps it active. We use what is called a liquid ring pump. In this style of pump the veins are very close to the side wall but do not touch. Water is injected into the pump to provide a seal and cooling. This water must be of sufficient flow and

temperature. If there is insufficient flow, less than 3 gpm, then the seal will not be maintained and the air will bypass the seal back into the system. If the temperature of the seal water is to high, above 70 deg., then some of the water will flash off when it sees the vacuum, and the vapor will overload the capacity of the pump. Either one of these conditions will cause the system to not maintain a vacuum. The best way to monitor the operation of the vacuum pump is with a compound gauge at the inlet of the pump, and a needle valve in the water supply. You should adjust the needle valve so that the compound gauge is between –5 and 0 in Hg. when the pump is operating at capacity. A quick test to check for air leaks is to clamp a six gallon trash can bag over the exhaust of the vacuum pump. If the bag takes longer than 30 seconds to fill with air, then there is a substantial leak, and the vacuum will not be adequate. To search for leaks you should use the ultrasonic leak detector to scan all the joints and seal areas for the hissing sound of an air leak. The vacuum pump in conjunction with the barometric condenser will get the vacuum down to about 5 in. Hg. However, this level of vacuum gives us an operating temperature above 40 deg. C. Still well above our operating point. This is why we require a third, or boost, stage to get the vacuum level down to below 1 in. Hg. A steam eductor is inserted between the barometric condenser and the vacuum pump. Since steam is used as the motive to generate the extra vacuum, this vapor must be condensed before it reaches the vacuum pump, or the pump will not handle the extra load. The outlet of the eductor is attached to a small 8 in. barometric condenser. This condenser flushes the steam down into the hot well, causing the inlet of the vacuum pump to only see the air in the system.

A detailed explanation of the operation of the vacuum system will be given during training sessions.



PARIFERRARY EQUIPMENT

The crystallizer by itself is just an empty vessel. We must be able to get stuff in, change it around, and get the product out. *Just like pulling a rabbit out of a hat.* Again we will discuss these individually at first, then collectively. The salt discharge pump is attached to the bottom of the vessel where the larger crystals are located. The discharge pump sucks the crystals out of the growth chamber and pumps them out to the centrifuge, where the crystals are separated from the liquor. The liquor goes to the mother liquor tank where it is reintroduced to the digester, and the moist crystals go to the dryer. The discharge pump is ran by a variable frequency drive. This is used to set the speed of the drive, and thus establish a production rate, by the amount of salt being pumped from the system. We run this in the manual mode in order to keep a constant rate of product going to the dryers. This allows the dryers to operate at a more even production rate offering better control. If the settled density of the crystals is more than fifty percent by volume, then the discharge pump will have trouble getting the product out to the crystallizer. Also, the centrifuge may have problems separating the liquor from the crystals. To determine the settled density you should use a graduated cylinder to get a sample of the flow going to the centrifuge. After the sample is taken, it is allowed to settle. The crystals should settle out at thirty to fifty percent of the liquid level. Anything less than this will not yield sufficient production. Anything more than this can cause the centrifuge to not function properly.

Now that we are removing product from the vessel, we must put brine back into the vessel in order to keep the level constant, and to provide for supersaturation. This is done by using the brine feed pump. The brine feed pump is connected to the brine feed tank. It is also connected to the recirculating leg of the crystallizer. The level control of the crystallizer is tied to the pump. In order to keep the level in the crystallizer in a constant place the pump is hooked to a variable frequency drive. We can either run the pump in the manual mode, or the automatic mode. The manual mode is used to overcome system anomalies, such as low levels and troubleshooting. In normal operation the pump is ran in the automatic mode. The differential pressure cells measure the weight of the product in the tank. To determine the level we must assume a density of 1.40 sg. If the density varies so will the level reading. Fortunately, in our normal operating range this is of little consequence. This signal is tied to a loop controller, which is tied to the drive that controls the pump speed. If the level in the crystallizer goes down, then the weight that the DP cells senses will decrease. This will send a signal to the level controller which will interpret this signal, and make a corresponding correction to speed the pump up. The amount of speed increase will depend on how low the level is. The lower the level the faster the pump speed, and more flow. Conversely, if the level is above the set point, normally 230 in., the pump will slow down, causing the flow to decrease and the level to lower.

The mother liquor pump is used to feed mother liquor into the crystallizer. It is ran at a constant speed. The flow is regulated by throttling back the valve coming out of the mother liquor tank. This flow range is between 0 and 10 gpm., and is regulated between 3 & 5 gpm. under normal conditions. Why do we feed mother liquor into the crystallizer? The density of the mix inside the crystallizer is determined by a lot of variables. Amongst these are evaporation rates, brine feed density, temperature, etc. Each of these are independent variables that affect the density of the crystallizer, but cannot be used to control it. If the density of the crystallizer is not controlled several undesirable conditions will result. If the density becomes to low then insufficient production will result. If the density is allowed to get to high then the crystal suspension density will increase and cause problems i.e....problems with the discharge pump, improper and unregulated crystal growth, separation of the crystallizer, etc. Under normal circumstances the density of the crystallizer has a tendency to increase. Therefore, the easiest way to regulate this is to use an auxiliary feed of a lesser density solution to continually dilute it. We could use water, but mother liquor is a much better solution. One reason is that we usually have an excess to get rid of, and it is easier to regulate. At this time the density control is completely manual, because of the long time it takes for the mother liquor to affect the density. The operator uses the density read out on the mass flow meter to determine how much mother liquor flow us required to keep the density at the desired set point (1.40). This is something that is completely dependant upon the operators experience and judgment.

The mass flow pump is located in the upper section of the growth chamber, and is used to circulate the body contents through the mass flow meter and back into the vessel. From the mass flow meter we get a lot of information. The mass flow meter works on what is called the Corollis affect. It consist of two tubes that the product flows through. One of these tubes has a power source that vibrates it, while the other tube has a sensor that senses the amplitude and phase shift of the vibration as it passes through the medium. From this we can determine the density of not only one product, but of two products if there is a mixture, the make up of each product as a percent of the total, the flow in gpm, pounds pre min., and several metric units. Also, we can measure temperature and pressure, and output these parameters to a controller or recorder. There is also a digital display that can be used to give the operator visual information. This is a valuable source of information that must be kept in proper operation. Sometimes the flow through the meter will stop. If this flow is not restarted then the piping will salt up and must be cleaned. This is a difficult process, and must be avoided. The operator must flush the system out frequently with water, and resume operation.

The fine salt loop is of particular interest to us. The bottom chamber has a stratification of crystals with the largest crystals in the bottom and the smallest, or fines, at the top. If we want larger crystals, and we do, then it makes sense that we should eliminate the smaller crystals (fines). Sort of like pruning a tree. Eliminating a lot of the smaller fruit so the larger ones can have more access to the nutrients and get even larger. How do we accomplish this? Most of the fines are at the top of the bottom chamber. We can therefore extract these fines dissolve them, reintroduce the brine back into the upper chamber and contribute to the supersaturation to grow the larger crystals in the bottom. At the very top of the growth chamber there is a two inch pipe connected to a pump. This pump has a flow capacity of 50 gpm. This mixture of brine and fine salt is pumped through a heat exchanger where the crystals are melted down. This brine is then returned to the recalculating leg and up to the supersaturation chamber. The heat exchanger is controlled at a temperature of 40 deg. C. This is sufficient to melt any crystals passing through. As you can see this is a fairly simple system, but it has a huge impact on the quality of the salt.

Common problems and
Frequently asked questions

PROBLEM: Body temperature is to high.
CAUSE: Loss of vacuum, loss of cooling water, vapor line restriction, too much heat input, level to high, leak in fine salt loop, air leak, no steam, vacuum separated, etc.

PROBLEM: Discharge pump quits.
CAUSE: Salt to thick, clumps of salt, air leak in pump suction, etc.

PROBLEM: Low production.
CAUSE: Density weak, temperature high, low feed rate, etc.

QUESTION: What causes the crystallizer to separate?
ANSWER: To many and/or to large crystals, elbow pump stopped or slow, pressure equalization pipe plugged, liquid level to low, etc.

PROBLEM: Crystals are fine.
CAUSE: Fines destruction system not functioning, elbow pump speed too high, temperature to high, density to low, production rate to high.

PROBLEM: Crystals are dingy.
CAUSE: Feed brine is dingy due to low pH, or bad filter cloth.

EMPLOYEE TRAINING

The training schedule will be set and scheduled by the Plant Manager. It is recommended that both classroom and field training take place for salt and liquid operators.

	Classroom	Field	Signature & date
Salt operator 1	_____	_____	_____
Salt operator 2	_____	_____	_____
Salt operator 3	_____	_____	_____
Salt operator 4	_____	_____	_____
Lqd operator 1	_____	_____	_____
Lqd operator 2	_____	_____	_____
Lqd operator 3	_____	_____	_____
Lqd operator 4	_____	_____	_____
Other	_____	_____	_____
Other	_____	_____	_____
Other	_____	_____	_____
Other	_____	_____	_____
Other	_____	_____	_____

Introduction

Crystal product is derived from $MgSO_4$ brine which has been filtered as described in the foregoing section. To achieve crystals it is necessary to cool the brine and evaporate some of the water. Brine is passed through vessels operated under high vacuum, emerging as a slurry of crystals and mother liquor. Two crystallizers are used, one so-called "old", the other "new". Both are operated in the same manner, the following operating instructions apply to each.

3.4.1. To Start a Crystallizer

1. Attach a hose from the Liquid Product loading pump to the belly valve at the bottom of the Crystallizer
2. Fill the crystallizer to the operating level (235 inches) with brine from the Liquid loading tank. Sp. Gr. 1.32 27% MgSO4.
3. Start the Mass flow and Fine Salt loop pumps.
4. When the liquid level is above the pump inlet, start the elbow pump to circulate brine within the Crystallizer body.

   Start the elbow pump on #1 crystallizer at 47 Hz. Gradually increase the speed to 53 Hz over the next four days, or sooner as crystal size develops. Start the elbow pump on # 2 crystallizer at 43 Hz. Gradually increase the speed to 48 Hz over the next four days, or sooner as crystal size develops.
5. Start the vacuum pump and the steam eductor, the body temperature will begin to decrease.
6. When the body temperature reaches 29 to 30 C, crystals will appear in the sight glass.
7. Start the 1.40 Brine and Mother Liquor feed.

   Brine Feed: 15 – 28 gpm

   Mother Liquor Feed 4 - 6 gpm
8. When crystals appear in the sight glass start the discharge pump to the centrifuge (60 – 70 Hz) and increase the speed of the elbow pump accordingly.

3.4.2 Attend the Crystallizer(s)

Check and record the following in the Salt Operators Log

1. Brine feed rate (15-28 gpm)
2. Brine feed specific gravity (1.39 –1.40)
3. Brine appearance.
4. Brine tank level.
5. Mother liquor feed rate (4-6 gpm)
6. Mother liquor tank level
7. Speed of the discharge pump (85 – 98 Hz)
8. Crystallizer body temperature (28-32°C)
9. Crystallizer contents specific gravity (1.39-1.41).
10. Level of contents in Crystallizers (230-240 in)

Relate a problem to the Plant Manager or Appropriate personnel

Vacuum Crystallizer Operation Cont'd

3.4.3. To Temporarily Shut down a crystallizer

1. Close the Brine feed valve and wash out the line with hot water.
2. Close the Mother Liquor feed valve and wash out the line with hot water.
3. Turn the discharge pump off and wash out the line with hot water.
4. Leave the Elbow Pump and all of the vacuum components running

3.4.4. To Shut Down a Vacuum Crystallizer for complete Clean-out

1. Reduce, if necessary, the level in one of the Liquid Product Load tanks to about one-fourth full. (Enough to hold the contents of the Crystallizer)
2. Stop the brine and mother liquor feeds to the crystallizer to be cleaned and wash out the lines with hot water.
3. Shut down the vacuum pump and steam eductor serving this Crystallizer.
4. Leave the water to both condensers on.
5. Continue running the discharge pump until the level gets below the middle sight glass (150 Inches)
6. Turn off the discharge pump.
7. Wash out the line going to the centrifuge with hot water.
8 Wash out the centrifuge and turn it off -- If the other crystallizer is not running.
9. Run out the contents of the dryer(s) and shut them down---(If the other crystallizer is not running.

3.4.5. To Completely Clean a Crystallizer

10. Turn off all auxiliary equipment, fans, blowers, pumps, etc. related to the dryer sequence – If the other crystallizer is not running.
11. Connect a steam hose to the bottom of the Crystallizer
12. Open the belly valve and turn the steam on.
13. When the temperature reaches 50° C, shut off the steam and the Elbow pump.
14. Shut off the Mass Flow pump and the Fine Salt pump, and wash out the lines.
15. Attach a pump inlet hose to the bottom outlet of the Crystallizer
16. Pump the remaining contents of the Crystallizer and the recirculation leg into the Liquid Product Load tank.
17. Keep watch to see that the Load tank does not overflow.
18. Fill the Crystallizer to the 230 in. level with warm water.
19. Start the Elbow pump and circulate for 30 minutes.
20. Stop the Elbow pump
21. Drain and waste the water from the Crystallizer and the recirculation leg.

This Crystallizer is now ready to put back into service
For start-up see 3.4.1

3.4.8 Revision History

DATE	SECTION / PAGE	PARAGRAPH	COMMENTS	APPROVAL

AFTER TEN (10) REVISIONS ENTIRE SECTION MUST BE RE-ISSUED

DIGESTER OPERATION

Digester Training Manual

Created and Maintained By: Jason Bumgarner

Date: 03 / 14 / 05

Change Control Log

Change Number	Change Request Date	Page	Paragraph	Row	Change Requested By	Change Implemented / Denied Date
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Change Number	Requested Change
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

INTRODUCTION:

This Manual provides a general overview as well as specific directions for Digester Operation. Giles Chemical uses digesters to produce $MgSO_4$ by combining Magnesite and Sulfuric Acid to produce liquid brine. This Liquid brine can be used for a liquid final product containing a specific percentage of $MgSO_4$, or further processed to produce $MgSO_4$-$7H_2O$ or Epsom Salt.

Giles Chemical's $MgSO_4$ manufacturing starts with two sets of digesters. Each set consists of a First digester in which the ingredients are introduced and allowed to react. In each set of digesters, brine overflows from the first digester to a Second digester where further reaction occurs and from there to a so-called Mud tank to await filtration.

Magnesite is conveyed from bulk silos to an intermediate receiver from which it is control conveyed via rotary valve to the consistently feed the First digesters. Sulfuric Acid is pressurized and piped from bulk storage tanks directly to the First digesters. The Acid feed passes through a control mechanism responding to demand prompted by Digester pH. Both sets of digesters use the same operating parameters, and the brines can be used interchangeably.

The Digesters are considered the starting point of all production here at Giles. The digesters must stay consistent and be within proper parameters if steady production is to be expected. Any upset in the first stage of production will easily upset the entire operation. Upsets can quickly cause loss in production, inadequate yields, and equipment problems, and possible down time resulting in more work for all employees bringing the plant back into proper conditions.

COURSE LEARNING OBJECTIVES:

Upon completion of this course you should be familiar with the following:

- A good understanding of how a digester works
- A good understanding of the controls and parameters of a $MgSO_4$ digester
- How to consistently operate a digester
- How to efficiently operate a digester
- General understanding and solutions to process problems

COURSE OUTLINE

- 10 to 15 minutes
  - Read overview
- 25 to 30 minutes
  - Instructor will go though Work Instructions step by step
  - Questions and Answers during
- 15 to 20 minutes
  - Aptitude test, answer and discussion time
- 60 minutes total

Table of Contents

COURSE CONTENT:

Section II
DIGESTER OVERVIEW

DIGESTER OPERATION
GENERAL OVERVIEW

By: Selwyn Scoggin

Date: 01 / 05 / 04

OVERVIEW

There is a difference between a digester and a reactor. A reactor is a sealed pressurized, and usually heated, vessel. Reactors are almost always operated in the batch mode. A batch mode being where you measure all of your ingredients into the vessel and mix them up. This mode of operation in a sealed reactor is not reliable for our purposes, because of the variability of our raw materials. There is no way to adjust the outcome. A digester on the other hand is open to the atmosphere, and the temperature is limited to the boiling point of the liquid inside. This a big advantage as far as safety is concerned. Digesters can be operated in the batch or continuous mode. All Epsom Salt manufacturers, except us, operate their digesters in the batch mode. This can be advantageous in that by measuring your ingredients in precise amounts you can theoretically get better yields. Again, since our MgO quality varies so widely, when the reaction is complete there are always final adjustments to be made. These adjustments can affect the filterability of the final product. Room will not allow a discussion of how this happens, but will be discussed during training. The other drawback to operating digesters in the batch mode is that of space. In our facility, space is at a premium. If we were to convert to a batch operation, we would need two or three main digesters, per side. The other mode of operation is the continuous mode, which we have used for years. This method is the most efficient when space and through put is considered. There are some special considerations. Constant monitoring must be maintained. This can be manual monitoring, which is not practical for manpower considerations, and is crude at best. Automatic controls are a must for these systems. These controls can, and do, compensate for product variability. However, they must have a certain level of manual oversight to insure proper calibration and operation. Eighty to ninety percent of the reaction takes place in the main digester, with the rest taking place in the second digester. There may be a small amount of reaction in the mud tank, but it is of little concern. Unfortunately there is no final adjustment that can be made to the end product, except by changing the parameters on the front end. This can be very effective when changes in raw materials, and other potential upsets are anticipated.

OPERATION

The operation of our digester seams complex, but the way we do it is fairly straight forward. There are some basic operating parameters that must be maintained in order to keep things going smoothly. We blend four ingredients into the digester on a continuous basis. These are water, acid, MgO, and mother liquor. All of these are necessary for efficient operation, and are controlled in different ways according to their functions.

The central ingredient is MgO. MgO is feed at a constant rate from the MgO hopper located above the digesters. It must be considered that the rotary valve that feeds the MgO is a volumetric feeder, and the feed rate must be adjusted slightly to compensate for variables in reactivity. This is because the bulk density of the MgO, and thus the amount of product going into the digester changes with the reactivity. This should be done only by a member of management. Reactivity, also affects the filterability of the product. This is because the higher reactivity products have most, or all, of their MgO used up so there are not much solids left to form a good filter cake. With the lower reactive products there is a significant amount of hard burned MgO, which is not very reactive. This can be a problem in that the filter cake can form to rapidly reducing the life of the press, and wasting product. Typically we would blend the two products to get the best results. The system usually runs well if all of the other ingredients are added properly, unless the reactivity is very low, below 12. All of the other ingredients are added relative to how much MgO is being added to the system. Because this is an exothermic reaction, it gives off heat, so the amount of MgO being added must not exceed set limits or there may not be enough cooling to keep the digester from boiling over. Also, it must be remembered that the filter press has a temperature limit of 85 deg. C. There is a misconception that the digester needs to boil for the density to increase. While it is true that trying to raise the density may cause the digester to boil, because less water is being added, boiling the digester does nothing to effect the density.

The next ingredient to be discussed is Sulfuric Acid, SO4. Since the MgO is a base with a high ph., and the acid has a low ph. The corresponding reaction is simply a neutralizing process. With the salt being the precipitate when the neutralization is complete. This is typical of all salting processes. In order to optimize the reaction process, and therefore yields, the final ph should be as close to 7 as possible. To accomplish this we use a ph probe in the recalculating leg of the digester. This probe is tied to a loop controller, which in turn controls the addition of acid through a Teflon lined valve. With proper tuning the acid addition is equal in reactivity to the MgO, thus maintaining the proper final ph. The proper control of the ph in the process is of critical importance for several reasons. The first of these is yield. Without proper ph control the final ph will be either high or low, resulting in an excess of MgO or acid. Filterability of the product is also greatly affected by ph. When the ph is too low, less than 5, the irons in the process will begin to be soluble, and pass through the filter press causing dingy brine, and possibly blinding the cloths. If the ph is to high there will be an incomplete reaction of the MgO, resulting in the formation of magnesium hydroxide, which is a slimy, snotty, gooey, gel that quickly blinds the filter cloths resulting in short press lives. Remember that varying reactivates of the MgO require slightly different set points for the acid addition. This is because of the speed at which the reaction takes place. Not because of the different amounts going into the digester. These set point adjustments need to be done by a member of management.

Mother liquor is what is recycled back from the centrifuge after the crystals have been separated. Mother liquor is simply depleted feed brine. Since there is a significant amount of MgSO4 still in this product it is feed back into the digester. There are several advantages in doing this. The primary reason is of course yield. During the crystallization process the brine is depleted by about twenty five percent. If we did not reuse this mother liquor we would be loosing seventy five percent of our raw materials. This is of course unacceptable. Also, because the mother liquor being reintroduced into the digester we need only to add back the twenty five percent to replace what was lost, not the entire amount. The mother liquor does provide some cooling, but the real trick is that less heat is created because less product has to be made. Balancing mother liquor addition and supply can be difficult. For instance, if the digester is not running and the crystallizers are, then the mother liquor can accumulate quickly and over flow the tank. Remember this is seventy five percent of your raw materials. Whenever the tank is overflowing it is imperative that we find a home for the excess liquor. If the digesters are running hard, and the crystallizers aren't, then the mother liquor can be used up. There are two remedies to this. You can pump some brine from the liquid side to the mother liquor tank, and use this. Provided that you have an excess of brine. Of course, this brine must be replaced. The other option is to reduce the amount of mother liquor, and use water instead. If you do this you must remember that you are going to have to make three times the production, and three times the heat being produced. Since the digester has a limited capacity to remove this heat the addition of raw materials being introduced must be reduced. In extreme cases it may be necessary to shut down the crystallizers until enough brine can be made to restart. Remember that if the crystallizers aren't running then no mother liquor is being produced. The mother liquor is also used to control the density of the finished brine.

Density is another very important aspect in running not only the digester, but the entire plant. If the density is too high, above a 1.40 sg., then the salt will begin coming out of solution prematurely. This will cause salt crystals to form in many unwanted places; piping, tanks, and in the filter press. When the salt starts forming in the press this not only causes the press life to be shortened, we are also discarding a lot of good product when the press is emptied. Also, if the density of the brine is to high the density of the crystallizers will get to high, causing them to not operate properly. This will be discussed when we get to the vacuum crystallizer manuals. If the density is too low, below 1.38 sp gr., then there is not enough MgSO4 in the brine to efficiently run the crystallizers. There will also be an excess of mother liquor being recycled back.

PROCEDURES

START UP: The start up of a continuous digester is not a big task, but it should be done properly. Hopefully, when the digester was shut down, the mud tank was drawn down to at least half. This will allow the mud that is in the tank to be heated by the incoming mud before being used in the press. When the digester is started up the first thing to do is to turn the manual valve behind the automatic valve on. This will allow the automatic addition of acid to begin. The valve will be fully open because the ph will be high. Ph is a non linear process. As an example it may take ten gallons of acid to bring the ph down from a 7 to a 6, five gallons from a 6 to a 5 and only one gallon from a 3 to a 2. These figures are for illustration purposes only, and are not exact. Therefore, you must remain at the digester to start the addition of MgO when the ph drops below 5. There is a reason for doing this. If the MgO addition is begun when the ph is to high, then unwanted reactions take place. When MgO, especially high reactive, is introduced into the digester with a high ph, high density, hot pot of MgSO4 there is no acid to react with the new MgO. This can cause two things. The formation of what we call oxysulphate cement, which is a complex compound of MgO and salt that is rock hard and will never react. These are typically in the form of nodules varying in size from a marble to a soft ball. The other thing that will form is flat chips of unreacted MgO. Of course since neither of these will ever dissolve, they either build up in the bottom of the tank, or get circulated through the system. Eventually the system will have to be shut down and cleaned. This is a long arduous process that needs to be avoided. When the ph drops below a 5, then the MgO addition can begin. You do this by turning the water on to the mix pot, and begin the addition of MgO into the mix pot by starting the DC Drive for rotary valve on the appropriate digester. The automatic acid valve will begin to control the acid addition at the set point (3.0 – 3.8 depending upon which product is being used). The determination of where to put the set point is dependant on the ph in the second digester. This ph should be kept in the 6 – 7 range. The MgO addition should be kept at a 35 – 50 percent setting on the dial of the DC Drive, depending on the reactivity of the product. Now that the reaction is taking place we must begin to provide some cooling and density control. At this time we have no automatic density control. Opening the valve from the mother liquor tank about half way is a good start. Begin to add some water as well, to make up for what is being shipped as crystal. The operator must read the density with a hydrometer every 15 min., and adjust the liquor flow accordingly. If the density cannot be regulated between 1.38 and 1.40 sp gr. with mother liquor, then water must be used to bring it down. Remember that water can bring the density down very quickly, so be careful, as it will take a long time to bring it back up.

RUNNING: After the digester has been in operation for about 15 min. it should be stabilized enough to begin monitoring for continuous operation. Although the addition of acid is automatically done to control the ph, it must be monitored to insure proper operation. As with all things made by man, automated controls can and do get out of calibration and fail. To minimize the amount of process upset caused by a control going out of wack, you must monitor the ph with litmus paper as often as possible. The density can be checked at the same time, and adjustments made to the mother liquor addition to control the density. Density changes are slow to respond, so a little anticipation and forethought is necessary to properly control it.

SHUT DOWN: When shutting a digester down, you must anticipate the level in the mud tank, and shut down the digester when the tank is a couple of feet down from the top. When the digester is shut down it will continue to overflow for a while, so room must be left in the mud tank to accommodate this. You should stop the MgO feed first, and let the mix pot clear of MgO, then cut the water off to the pot. Shut off the manual valve behind the automatic acid addition valve. The mother liquor and water addition can now be cut off. When the filter press is started the digester can be restarted to replenish the tank level.

Section III
WORK INSTRUCTIONS

DIGESTER OPERATION

Created and Maintained By: Jason Bumgarner

Date: 03 / 14 / 05

Explanatory Note

Giles Chemical's $MgSO_4$ manufacturing starts with two sets of digesters. Each set consists of a First digester in which the ingredients are introduced and allowed to react. In each set of digesters, brine overflows from the first digester to a Second digester where further reaction occurs and from there to a so-called Mud tank to await filtration.

Magnesite is conveyed from bulk silos to an intermediate receiver from which it is control conveyed via rotary valve to the consistently feed the First digesters. Sulfuric Acid is pressurized and piped from bulk storage tanks directly to the First digesters. The Acid feed passes through a controlled mechanisms responding to demand prompted by Digester pH. Both sets of digesters use the same operating parameters, and the brines can be used interchangeably.

The Digesters are considered the starting point of all production here at Giles. The digesters must stay consistent and be within proper parameters if steady production is to be expected. Any upset in the first stage of production will easily upset the entire operation. Upsets can quickly cause loss in production, inadequate yields, and equipment problems and possible down time resulting in more work for all employees bringing the plant back into proper conditions.

I. Digester Operation Parameters

A. 1st digester while running
   1. 1.395 specific Gravity
   2. 3.25 pH
   3. 95°C – 100°C

B. 2nd Digester
   1. 1.400 Specific Gravity
   2. 6.00 – 7.00 pH
   3. 80°C – 90°C

C. Mud Tank
   1. 1.400 – 1.410 Specific Gravity
   2. 6.50 – 7.50 pH
   3. 75°C – 85°C

II. Routine checks and Major focus

A. pH, Density and Temperature are very crucial and should be checked often

B. Make rounds and fill out Operator logs every 2 hours
   1. once every 2 hours is too long to go between checks
   2. A digester can turn acidic or week in a mater of minutes

C. A quick check on digesters, as often as possible, is essential in catching potential problems before they damage production

D. Never make big adjustments on MgO, Acid, Mother Liquor or water feeds to the digester, small changes will help keep the digesters stable and consistent.

E. The first sign of problems with temperature at the Mud tank or the press needs to be investigated and addressed immediately before causing major production problems

F. Any drop in gallons though the press needs to be investigated and addressed immediately before causing major production problems.

III. Filling 1st Digester From Empty

A. Fill 1st digester to ~~recirculating~~ line with Brine or Mother Liquor
   1. Water may be used only if Brine and / or Mother Liquor are not available
B. Check pH meter reading against pH paper
C. Start automatic acid feed, wait and start MgO feed when pH is below 4.5
D. Check specific gravity coming out of circulating line
   1. Add mother liquor and / or water as needed to achieve a 1.395

IV. Starting digesters after a Down period

A. Acid Feed (*ALWAYS START ACID FEED FIRST*)
   1. Open the valve to the automatic meter-feed
      a) If the pH meter is reading 3.5 or higher the Acid valve should be open.
   2. Check Acid line for Acid Flow. pH should begin to dropping slowly, and reach set point (3.2 – 3.6) within 30 min
   3. Only when absolutely necessary should the Manual Acid Valve be used.

B. MgO Feed (*NEVER STRAT MgO FEED AT pH OVER 4.50*)
   1. Fill MgO pot full with water and turn on mixer
   2. Back off water flow to a nonviolent steady flow.
   3. Start the screw conveyor using appropriate switch
   4. Start the correct rotary valve under the hopper
   5. Check to see that Magnesite is flowing properly into pot
   6. Check to see that Magnesite is mixing and flowing freely out of pot

V. Shutting down Digesters for a short Period (less than 3 hours)

A. MgO Feed
   1. Turn off rotary valves under the hopper
   2. Turn off screw conveyor to mixing pot chute
   3. Turn off Mother Liquor / water to mixing pot
   4. Drain mixing pot
B. Acid Feed
   1. Turn off automatic acid feed

VI. Shutting down Digester for a long period (more than 6 hours)

A. MgO Feed
   1. Turn off rotary valves under the hopper
   2. Turn off screw conveyor to mixing pot chute
   3. Turn off Mother Liquor / water to mixing pot
   4. Drain mixing pot
B. Acid Feed
   1. Turn off acid feed
C. Tanks Levels
   1. Pull ½ to ¾ out of second digester
   2. Mud tank should be empty

VII. Digester Density / Specific Gravity

A. Checking Density and Temperature

1. Density is to be checked in the 1st digester, 2nd digester and Mud tank.
2. All density adjustments should be made in the 1st digester
3. Check the density using the discharge of the circulating line.
   a) Using the long handle ladle, take a sample from the discharge end of the circulating line as it goes into the top of the 1st digester
   b) Using a 1.200 – 1.410 hydrometer, check the density and Temperature

B. Adjusting Density

1. Too High - above 1.400
   a) Increase Mother Liquor / water feed to digester
      (1) Increase by severity of out of specification specific gravity
      (2) If it is 1.410, slightly increase feed
      (3) If it is 1.420 or higher increase feed more aggressively
2. Too Low – less than a 1.385
   a) Slightly decrease Mother Liquor / Water feed to digester
   b) MgO feed can be increased only if it is needed for production and it does not effect pH.
   c) If problem continues,
      (1) Look for water leeks
      (2) Cheek MgO supply
      (3) Take sample for Laboratory analysis
      (4) Call Management

VIII. Trouble Shooting and problem solving

A. Temperature less than 70°C in Mud tank or at press

Possible Root / Solution

1. Retention time to long between digester to press
   a) Shut one digester down, increasing the other digester's MgO feed. If don't quickly and correctly, temperature will rise. Start second side up only when more mud is needed by filter press.
2. Too much water added in 1st digester, cooling digester to fast.
   a) This will also cause your density to drop rapidly. With proper running of the first digester will work this problem out, to speed up the recovery, shut one side down. Run the cold side harder to work the colder mud out.
3. Poor reactivity rate in 1st digester
   a) Contact Management. This can be caused by a number of ways, first thing to try is decreasing the MgO feed in the first digester, running slower to see what reaction is taking place.
4. pH problems
   a) Contact Management / Maintenance

B. Abnormal appearance in first digester

1. Deep Red
   a) Can be caused by a very good reaction. All the MgO has reacted leaving you with nothing to build a filter cake. Take a sample for laboratory analysis.
   b) Contact Management, set point may need to be raised
2. Milky color / Lighter tan color
   a) Can be caused by unreacted MgO, this will cause major pressing issues. Decrease MgO feed, and see if it clears up. If the coloring doesn't darken, digester may need to be drained.
   b) Contact Management for instructions
3. Oily looking Streaks
   a) This can be a mixture of reacted and unreacted MgO. Decrease MgO feed, slowing digester. This should allow unreacted MgO to catch up and start over fresh. If the problem persists call Management for instructions
4. Sandy Appearance and feel
   a) Usually unreacted MgO, but possibly Oxisulfate Cement. If the hydrometer can be place anywhere in ta cylinder of mud and it sticks, more than likely the digester is lost. Contact Management. Oxiculfate Cement will not react and go into solution. It takes days for it to work itself out of the digester so the first digester must be drained. In special conditions the digester can be saved if caught in time so notify management as soon as the problem is observed.

TRAINING DOCUMENTATION

	EMPLOYEE	TITLE	SIGNATURE	DATE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

IV
APTITUDE QUIZ

DIGESTER OPERATION

Created and Maintained By: Jason Bumgarner

Date: 03 / 14 / 05

(PLEASE JUST CIRCLE ONE)

1. When starting up the Digester what do you turn on first
   - A. MgO Feed
   - B. Automatic Acid Feed
   - C. Moth liquor Feed
   - D. Water Feed

2. At what specific gravity should the 1st digester be, while running?
   - A. 1.375
   - B. 1.380
   - C. 1.395
   - D. 1.410

3. While running, where do you check the Specific Gravity of the digester to make sure you are within proper parameters?
   - A. 2" ball Valve on the bottom of 2nd digester
   - B. From the circulating line of 1st digester
   - C. Top of the Second Digester
   - D. Top of the first Digester

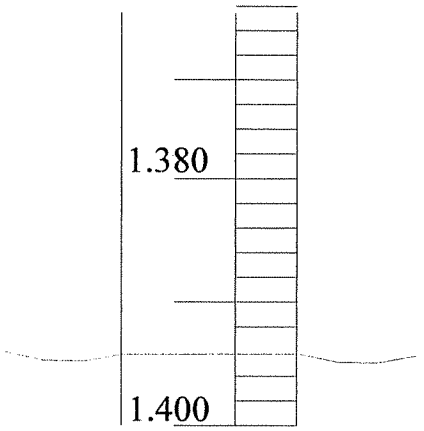
4. While running, the pH in the first digester should be around
   - A. 7.00
   - B. 2.50
   - C. 3.50
   - D. 4.50

5. What situation could cause pH in the first digester to consistently be too high?
   - A. MgO build up in Circulation line
   - B. pH meter is bad causing it to read high
   - C. MgO feed to high for acid feed to keep up
   - D. Week acid

6. What temperature should the 1st digest be while running?
   - A. 100°C – 110°C
   - B. 90°C - 100°C
   - C 80°C - 90°C
   - D. 70°C - 80°C

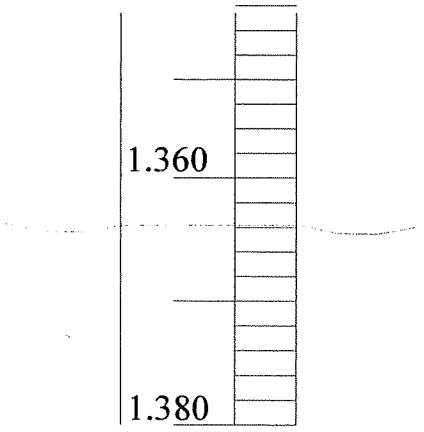
7. If your fist digester is 1.395 specific gravity and 96°C, the second digester should be
   - A. 1.370 specific gravity and 100°C
   - B. 1.380 specific gravity and 80°C
   - C. 1.390 specific gravity and 100°C
   - D. 1.400 specific gravity and 90°C

8. What the specific gravity on the hydrometer diagram below



A. 1.440
B. 1.394
C. 1.387
D. 1.406

9. What is the specific gravity on the hydrometer diagram below



A. 1.356
B. 1.376
C. 1.364
D. 1.386

10. If your specific gravity is 1.41 in the 1st digester you should
    A. Add water in the mixing pot
    B. 1.41 is still within acceptable parameters.
    C. Open water hose into top of the digester
    D. Slightly Increase Mother Liquor and/or Water feed

11. Is 65°C mud in the Mud tank an acceptable temperature?
    C. Yes
    D. No

12. To raise the density in your number one digester you should
    A. Decrease the amount of Mother liquor and/or Water
    B. Decrease the amount of Manual Acid
    C. Turn the MgO dial up
    D. Decrease the amount of water in the MgO pot

13. Is it acceptable for pH paper to be more than 1 point off of the pH meter reading
    A. Yes
    B. No

14. The recirculating line of the first digester is used for
    A. Circulating product in the tank
    B. pH control
    C. Mother liquor addition
    D. Controlling specific gravity

15. When first starting up the digester, when should the Acid be turned on?
    A. Acid should be turned on first
    B. After the specific gravity is 1.395
    C. When pH is below 4.50
    D. Acid and MgO should be turned on at the same time

16. When starting up the digester, when should the MgO be turned on?
    A. MgO should be turned on first
    B. After the specific gravity is 1.395
    C. When pH is below 4.50
    D. Acid and MgO should be turned on at the same time

17. If a change is made in digesters feeds (Acid feed, MgO feed, Mother liquor feed) it will take over 2 hours to show any noticeable difference in the digester. .
    A. True
    B. False

18. Should specific gravity in the first digester be checked every time you check on the digesters?
    A. yes
    B. no

19. During regularly scheduled rounds, should you check the specific gravity in 1st digester, 2nd digesters and the mud tank?
    A. yes
    B. no

20. If mud is less that 65°C at the press you should
    A. Increase the MgO feed. Run both sides harder, creating more heat
    B. Wait till both mud tanks are over 75% before starting press. Build mud in the tanks before running the press, so that you won't lose as much heat.
    C. Use all mud from one side and shut it down. Run one side only, increasing the MgO feed. Run one side till you reach +75°C
    D. 65°C is still in the acceptable range and will not hurt production.

21. How often should the MgO mixing pot be cleaned out using a pressure washer?
    A. Never use a pressure washer on the MgO pot
    B. Every two hours during scheduled rounds.
    C. Every Thursday during the down / clean up day
    D. Once per shift minimum, twice if needed.

22. What **IS NOT** a possible answer if you can not get the specific gravity / density in the 1st digester to increase.
    A. Check all pumps and seals for water leaks
    B. Cut everything off except MgO.
    C. Check the MgO Feed
    D. Check the Mother Liquor Feed

23. What **IS NOT** a possible answer if your digesters are running within parameters (pH, temp, density) but press is not running well, you should
    A. Check MgO feed, make sure Premier and Baymag are both feeding day hopper
    B. Check Mud line for restriction in flow
    C. Check pH calibration
    D. Check to see if Mud pump circulation is to high

24. If the 1st digester starts to boil over you should
    A. Turn everything off, and wait for it to settle down
    B. Use 1" water hose on top of digester to fight boil over
    C. Lower the level by opening the 3" valve at the bottom of the 1st digester
    D. Open Mother Liquor / Water feed to 100%

25. If the recirculating line stops, and will not start back, you should
    A. The recirculating line will not affect the production
    B. Use the pH from the second digester probe, and run the 1st digester on manual
    C. Shut digesters off till maintenance department can fix the problem
    D. Shut digester off, analyze and fix the problem, before trying to run manually.

Answers

1. **A** – acid should always be turned on first
2. **C** – The 1st digester should be kept at a 1.395 specific gravity
3. **B** – Specific gravity and pH should be check with the recirculating line
4. **C** – 1st digest set point is on 3.20 – the pH should stay around 3.10 – 3.60
5. **C** – pH is controlled by the Acid addition, if the volume of MgO is to high, the acid valve may not be able to keep up causing the pH to be too high.
6. **B** – Temperature in the 1st digester should be 90°C – 100°C while running
7. **D** – specific gravity slightly increases as the temperature drops
8. **B**
9. **C**
10. **D** – 1.41. can easily be corrected with a small increase in Mother Liquor and / or Water
11. **D** – No, the Mud tank should never be below 70°C – optimal conditions being 75°-80°
12. **A** – opposite of 10, slightly low density can easily be corrected with small decrease in the Mother Liquor and/or Water feed
13. **B** – No, the pH meter and pH paper should be fairly close at all time
14. **B** – The best mix is 2/3 down in the tank, the circulating line pulls from there for pH monitoring
15. **A** – Acid should always be turned on first
16. **C** – MgO should never be introduced to a high pH digester
17. **B** – A digester can turn acid very fast, density can also increase or decrease very rapidly under changing feed conditions
18. **A** – the Density and pH should constantly be monitored for better production results
19. **A** – The more places you check the density the better
20. **C** – If the mud is too cold, you should check temperatures on both sides, shut the coldest down, pulling 2nd digester down ½ way, running the other side hotter and harder until mud is at a acceptable temperature.
21. **D** – MgO Mixing pot should be cleaned using a pressure washer at the beginning of each shift
22.
23.
24. **B** – Adding water directly to the top will both fight the boil and help control density
    a. (boiling will increase density as excess water evaporates, but boiling should never be used to increase density, it is very unstable and volatile)
25. **D** – The circulating line is crucial to the proper digester operations and operators should notify proper personal as well as make every effort to get the circulating line back running as soon as possible.

Section V
COURSE SUMMARY

DIGESTER OPERATION

Created and Maintained By: Jason Bumgarner

Date: 03 / 14 / 05

Course Summary

The digester operation at Giles Chemical is considered the back bone of production. Therefore the operation of the digester needs to be taken very seriously. No other area demands or deserves more attention than the digesters. The digesters must stay consistent and be within proper parameters if steady production is to be expected. Any upset in the first stage of production will easily upset the entire operation. Any operator delegated the task of digester operation needs to be feel the sense of responsibility and magnitude of the first stage of production. Any and all upsets can quickly cause loss in production, inadequate yields, and equipment problems and possible down time resulting in more work for all employees bringing the plant back into suitable conditions.

For Zac

Growth Opportunity

For Zac

CREEK PUMP OPERATION

We have three vacuum crystallizers. Each with a capacity to handle 360 gpm of cooling water. This cooling water comes from the creek and is returned to the creek. The three condenser pumps draw water from a tank out back at a rate of 230 gpm. This tank is replenished using two self priming pumps rated at 500 gpm ea. Under normal operating conditions this is more than enough water to supply our needs.

However, over time trash can and does build up over the intake causing the pumps to operate at a reduced capacity and cavitate at times. This not only hinders our production capacity, but can cause damage to the pump. Therefore, it is imperative that we inspect and/or clean these intake screens once per shift. This can be done by using the discharge of one pump to back flush the intake of the other pump. These pumps are labeled #1 and #2.

If you desire to back flush pump #1 the first thing to do is to stop the pump (using the stop button located at the pump). Next, slowly open the valve at the cross over pipe going from the outlet of pump #2 to the inlet of pump #1. Now, slowly close the valve at the discharge op pump #2 going to the tank. This will direct the water from pump #2 through the suction line of pump #1 and flush any loosely held debris from the screen of pump #1. Let this continue for approx. 1 min. If the debris is not sufficiently removed, you will have to take a water hose and "rinse off" the build up. After you are satisfied that the screen is sufficiently clean redirect the flow from pump #2 to the tank by slowly opening the discharge valve going from pump #2 to the tank, and slowly closing the valve at the discharge of pump #2 that feeds the suction of pump #1. Restart pump #1.

If you desire to back flush pump #2 the first thing to do is to stop the pump (using the stop button located at the pump). Next, slowly open the valve at the cross over pipe going from the outlet of pump #1 to the inlet of pump #2. Now, slowly close the valve at the discharge op pump #1 going to the tank. This will direct the water from pump #1 through the suction line of pump #2 and flush any loosely held debris from the screen of pump #2. Let this continue for approx. 1 min. If the debris is not sufficiently removed, you will have to take a water hose and "rinse off" the build up. After you are satisfied that the screen is sufficiently clean redirect the flow from pump #1 to the tank by slowly opening the discharge valve going from pump #1 to the tank, and slowly closing the valve at the discharge of pump #1 that feeds the suction of pump #2. Restart pump #2.

If you need extra water for any reason, one of the old creek pumps can be used until the new pumps are restored.

Sometimes, the intake screens will shift position to a shallower part of the creek. When this happens, you must relocate them back to a deeper part until they are sufficiently covered with water.

TRAINING MANUAL

BAGGER

Created and Maintained By: Selwyn Scoggin
Brad Lindsey

Date: Mar 29, 2005

Training Approval

I have reviewed this training manual with respect to my job expertise and certify it to be adequate at educating employees on the intended subject matter.

_____

Name/Date/Title

_____

Name/Date/Title

_____

Name/Date/Title

_____

Name/Date/Title

_____

Name/Date/Title

Change Control Log

Change Number	Change Request Date	Page	Paragraph	Row	Change Requested By	Change Implemented/ Denied Date
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Change Number	Requested Change
1	
2	
3	
4	
5	
6	
7	
8	
9	

10	

INTRODUCTION:

The PSI Vertical FormFill and Seal Machine MK forms a flat film from a film reel to a tube, fills the specified amount of product into the package and closes the package by heat sealing. The ready-made packages are released by a carrying off conveyor with the printing on the upper side. The machine can be divided into the following components:

- Housing
- Film guide Unit
- Formatting Set
- Vertical Sealing Device
- Horizontal Sealing Device
- Pull Down Device with Film Grippers
- Carrying Off Conveyor
- Pneumatical Equipment
- Electrical Equipment

Each of these will be discussed in detail Course Content section.

COURSE LEARNING OBJECTIVES:

Upon completion of this course you should be familiar with the following (or able to do the following):

-
-
-
-
-
-
-
-

COURSE CONTENT:

Be descriptive and methodical here. Make sure that you start at point A and go straight through to point Z. Skipping around does not benefit the reader. This should be sectionalized into key topics with an approximate time for each section defined as follows:

1. Components
   The PSI MK4 Form-Fill Bagger can be broken down into the following key components:

   Housing

   The housing is made in a complete covered design. Therefore, all internal machine modules are protected against external influences like dust and splash water.

   Film Guide Unit

   The film guide unit comprises of several subunits such as film reel support, bobbin drive, sticking device, dancer roller and bag length detection drive unit. For tracking control on the forming shoulder, the film guide unit is adjustable by a motor driven device.

   Film Reel Support – Supports the bobbin shaft and film roll.

   Bobbin Drive – Controls the unrolling of the film. When the machine stops, a geared motor and v-belt stops, holding the film in position

   Sticking Device – Allows new film rolls to be loaded and threaded into the machine using the remaining film from the previous roll.

   Dancer Roller – The dancer roller is positioned film reel and the bag length detection drive unit. It assures constant tension of the film and controls the bobbin drive via position switches. The dancer roll also recognizes film availability.

   Bag Length Detection Drive – The bag length detection drive uses a variable speed geared motor with a brake and sensor eye to detect bag length. An eye mark ensures an exact position of the printing on the package.

   Formatting Set

   The formatting set forms the film tube. The formatting set consists mainly of the forming shoulder, the filling tube and the formatting set adaptor.

Vertical Sealing Device

The vertical seal is formed by a Teflon covered welding bar (Vertical Seal Bar). After welding occurs, the joint is immediately cooled by air through integrated nozzles. The welding bar is continuously heated, temperature controlled and pneumatically operated.

Horizontal Sealing Device

The horizontal sealing device consists of gripper elements, two Teflon covered welding bars and film knife to cut off the ready filled package. The horizontal welding bars similar to the vertical sealing bars in design. They are continuous heated, temperature controlled and pneumatically operated. The sealing is cooled by air through integrated nozzles.

Pull Down Device with Film Grippers

This device carries the horizontal sealing bars and gusset forming device. Movement is carried out pneumatically by two synchronized air cylinders.

Carrying-Off Conveyor

Horizontal conveyor belt for laying down and carrying off the ready filled packages.

Pneumatic Equipment

All linear movements of the machine are carried out pneumatically and all elements are designed for oil free operation.

Electrical Equipment

All functions of the machine are continuously controlled by a PLC (Primary Logic Controller). Operation of the machine is carried out via a touchscreen control panel with text display. Present operating parameters, errors and alarms, as well as product recipes are stored in the PLC and can be manipulated by the operator using the touchscreen.

2. Operation and Weekly Maintenance

Preparation of film roll

- Film reels should be transported on a pallet to avoid damaging the film and causing waste
- Damage to film and/or core must be avoided to ensure proper operation

- Remove any damaged film prior to loading reel in machine

- Insert bobbin shaft into the core of the prepared film reel. Make sure print position is correct. Tighten reel clamping device.

Loading film roll

- Open back door

- Place film reel with bobbin on film reel support using film loader

- Push the film reel carefully into the receptacle of the film reel support

Threading of new film
(this procedure only applies if machine is already threaded with previous film)

- Pull the film reel up to the sticking device, line up and match the prints of the old and new film.
- Clamp the film in position with the clamping device
- Cut both films along the slot of the sticking device
- Seal the joint with tape (3 runs overlapping) and trim the joint slightly smaller than the film width
- Lift the clamping device
- Turn the film roll by hand to get the dancer roller in a horizontal position
- Close the back doors
- Manually discharge the first few bags empty to check the seals ensuring that tape seal has worked it's way through the machine
- Restart bagging

General Startup

- Check air valve to ensure air is turned on to bagger
- Make sure air pressure is at least 6 bar
- Check that product for bagging is available (salt in hopper)
- Switch on main switch
- Switch on weigher and transport system
- Press "MK-ON" for Start preparation and check functions. The main supply valve for the air will be open and the heating system for the welding bars will be on.
- Press "START AUTO MODE". The control panel now instructs you through the sequences needed to operate the machine but waits until temperatures and air pressure are correct

Shutdown Procedure

- Press "STOP" – this stops automatic bag filling. The discharge of the weigher will not be activated further and the horizontal sealing device will stop at the upper position
- Press "EMPTY BAG" – this allows the last bag to be sealed and removed from the machine. An empty bag will be made.
- Press "EXIT" – to enter main screen
- Press "MK OFF" – main air valve will close and heating system will shut down
- Switch off main switch – Voltage will be completely disconnected and control panel will turn off.

Weekly Cleaning

- Clean lens of eyemark-sensor with a clean cloth
- Check Teflon tape at welding bars for wear
- Check gripper rubbers at horizontal sealer for wear and tear
- Check water separator for air supply and empty if needed
- Check v-belt at bobbin drive for proper tension and wear
- Check all hose fittings for tightness and retighten if needed
- Grease the following with food grade grease
    - Gusset Former
    - Horizontal Sealing Device
    - Pull Down Device
    - Film Guide Unit
- Thoroughly clean machine with air hose and wet rag. DO NOT USE WATER HOSE TO CLEAN ANY PART OF BAGGER

Key Points

Section XX. Title Here (XX minutes)
Content
Key Points

COURSE SUMMARY:

Simply reiterate in paragraph form each of the key points that you listed in each of the sections as a final refresher for the trainee.

APTITUDE QUIZ:

5-20 question Quiz with multiple choice and fill in blanks that would demonstrate the trainee has a fundamental understanding of the key points and alternative situations.

TROUBLESHOOTING GUIDE:

WEIGHT VARIATIONS	BULK FLOW RATE	Check the product flow rate by observing the dribble cycle time. If the time is less than 2 seconds, decrease the bulk feed opening until a satisfactory feed is achieved
	HOPPER DOOR SPEED	Ensure that the weigh hopper doors are opening long enough for all of the product to discharge, and are fully closed before the next weight cycle begins.
	VIBRATION	Check for vibration which may be transmitted to the weighing system. Other equipment in close proximity to the scale may also be a source of vibration and may require some vibration dampening
	MISC. INFLUENCE	Check for possible sources of influence to weighing system such as hoses or cables, product buildup, loose or missing hardware, etc.
MOTORS	MOTOR WILL NOT START	No power – Examine fuses or circuit breaker in control panel. Inspect for loose terminal connection. Replace electrical components if required.
		Overload – Inspect for obstruction to belt and material on belt. Look for frozen or sluggish pulley bearings. Check size of heaters to see they are large enough.
		Damage to exterior wiring – Inspect conduit and wiring

		to and from control panel and motor.
		Damage to interior wiring – If repairs are required, install replacement units.
	MOTOR SLOW TO START	Overload – Inspect for obstruction to belt and material on belt. Look for frozen or sluggish pulley bearings. Check size of heaters to see they are large enough.
		Low line voltage - Check line voltage
		Loss of one of three phases - Inspect fuses in control panel and replace as required
	REPEATED STALLING	Interruption of power – Excessive amperage causes heater to open circuit. Inspect for overload.
	MOTOR RUNS HOT	Overload, too much drag – Look for binding of mechanical devices, excessive belt tension, frozen or sluggish pulley bearings, etc.
		Low line voltage – Check line voltage
		Loss of one of three phases - Inspect fuses in control panel and replace as required
	EXCESSIVE NOISE	Insufficient belt tension – Properly tension belt, then tighten down drive.
		Drive sheaves misaligned – Reposition drive sheaves using a straight edge across the sheave faces. Properly tension belt, then tighten down drive.
BEARINGS	FROZEN BEARING	Damaged or worn bearing – Replace bearing
		Dry Bearing – Replace

		bearing
	EXCESSIVE NOISE	Lack of lubrication - Lubricate or replace as required
		Loose bearing – Tighten or replace as required

TRAINING FREQUENCY:
State the required frequency of retraining in annual units (annually, bi-annually, etc.)

TITLE OF TRAINING HERE
TRAINING DOCUMENTATION

	EMPLOYEE	TITLE	SIGNATURE	DATE	TRAINER
1					
2					
3					
4					

5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Objectives

Bellow you will find all objectives agreed upon on June 16, 2005
Additional Objectives will be added as these are accomplished and additional data will be available. All objectives are for the rest of 2005 and 2006.

Process/Project Engineer- Selwyn Scoggin

- Process flow diagram	6/24/05
- Process description	
- List of equipment to be described	6/17/05(done)
- Time line for the process equipment description	
-Digesters, Bagger	7/4/05
-Crystallizers	7/11/05
-Filter press	7/18/05
-MgO unload	8/1/05
-Sulfuric acid unload	8/8/05
-Acid storage	8/22/05
-Super sack filler	9/5/05
-Conveyors	10/3/05
-Centrifuge	10/10/05
-Dryers	10/17/05
-No safety incidents	ongoing
-Use the new capital expenditure system (being established by 7/12/05) to propose, submit, get authorization and complete projects (Project on target cost estimate + or – 10% and project on time)	
-Implement one cost reduction project	to be determined

Maintenance/Engineering Manager- Brad Lindsey

-Project System	7/12/05
-Critical Equipment mechanical reliability objective proposal	7/14/05
-Spare parts Inventory, description and location	9/15/05
-MP2 implementation	12/15/05
-Maintenance procedures	12/30/05
-Fiscal budget for 3Q, 05	7/29/05
-Fiscal budget for 2006	10/28/05
-Capital budget forecast for 2006 (With the management team's input)	10/28/05
-No OSHA recordable injuries	ongoing
-Housekeeping (keep your areas clean, keep the spare parts areas clean and neat)	
-Implement one cost reduction project	to be determined

-Administer the appraisal system so each of your subordinates get an appraisal at the appropriate time (90 days, 180 days and yearly)

Quality/Safety Manager-Ed Johnston

-Quality objectives:
  Internal 7/8/05
  (Jason, Selwyn, Zac will help)
  External (customer complaints) 7/15/05
-Documentation System 9/2/05
-Safety objectives
  Do the routine daily audits and corrections
  No OSHA recordable Injury in your area
-Fiscal Budget for 3Q/05 7/29/05
-Fiscal budget for 2006 10/28/05
-Housekeeping (Keep your area clean and neat)
-Implement one cost reduction project to be determined

- Administer the appraisal system so that each employee gets an appraisal (90 days, 180 days and yearly)

Operation Manager-Jason Bumgarner

-Volume (Sustainable production) 6/24/05
-MgO Yield:
  How to calculate and verify 7/22/05
  Yield objective to be determined
  -establish appropriate measurement and objective for uptime (occupancy) to be determined
-establish appropriate inventory levels and maintain to be determined
-meet established (7/8/05) internal quality objective to be determined
-Identify peak capacities (work with the rest of the team to identify bottlenecks, find and implement solutions) and establish new running rates and limits
-No more then one OSHA recordable injury
- No lost workday injury
-Rewrite operational procedures date to be determined
-Update operators' logs to reflect limits for each process variable to be controlled
-Housekeeping (keep the production area, warehouse and break room clean and neat)
Implement one cost reduction project to be determined

Plant Manager-Zac Guy

-Responsible for overall objectives (All subordinates objectives) on going

-Review Repack objectives 8/26/05
- Implement a training system 8/19/05
-Assure that each new operator is trained based on the new training system and existing operators are retained once new operating procedures are in place
-Fiscal budget for 3Q 2005 7/29/05
-Fiscal budget for 2006 10/28/05
-Time spent on the "floor" coaching, leading, training, etc. at least 30%
on going
-No more then one OSHA recordable injury
-No lost workday injury
-Implement one cost reduction project to be determined
-Housekeeping (maintain all areas clean and neat)
- Administer the appraisal system so that each of your subordinates gets an appraisal (yearly for exempt and 90 days, 180 days, yearly for wage roll)

DIGESTERS AREN'T MYSTERIOUS

BY SELWYN SCOGGIN

January 5, 2004

TABLE OF CONTENTS

OVERVIEW

There is a difference between a digester and a reactor. A reactor is a sealed pressurized, and usually heated, vessel. Reactors are almost always operated in the batch mode. A batch mode being where you measure all of your ingredients into the vessel and mix them up. This mode of operation in a sealed reactor is not reliable for our purposes, because of the variability of our raw materials. There is no way to adjust the outcome. A digester on the other hand is open to the atmosphere, and the temperature is limited to the boiling point of the liquid inside. This a big advantage as far as safety is concerned. Digesters can be operated in the batch or continuous mode. All Epsom Salt manufacturers, except us, operate their digesters in the batch mode. This can be advantageous in that by measuring your ingredients in precise amounts you can theoretically get better yields. Again, since our MgO quality varies so widely, when the reaction is complete there are always final adjustments to be made. These adjustments can affect the filterability of the final product. Room will not allow a discussion of how this happens, but will be discussed during training. The other drawback to operating digesters in the batch mode is that of room. In our facility, space is at a premium. If we were to convert to a batch operation, we would need two or three main digesters, per side. The other mode of operation is the continuous mode, which we have used for years. This method is the most efficient when space and through put is considered. There are some special considerations. Constant monitoring must be maintained. This can be manual monitoring , which is not practical for manpower considerations, and is crude at best. Automatic controls are a must for these systems. These controls can, and do, compensate for product variability. However, they must have a certain level of manual oversight to insure proper calibration and operation. Eighty to ninety percent of the reaction takes place in the main digester, with the rest taking place in the second digester. There may be a small amount left in the mud tank, but it is of little concern. Unfortunately there is no final adjustment that can be made to the end product, except by changing the parameters on the front end. This can be very effective when changes in raw materials, and other potential upsets are anticipated.

Our particular digester consists of a 12'dis. X 12' tall (10,000 gal.) tank, made of alloy 20 for corrosion resistance. There is a mixer from UET that turns the contents of the tank over 4 times per minuet. All of the ingrediance are introduced through the top of the tank. The MgO is wetted out in a mix pot and introduced as slurry, the water is added manually by the operator according to his density reading, and the acid is added automatically according to the Ph set point.

OPERATION

The operation of our digester seams complex, but the way we do it is fairly straight forward. There are some basic operating parameters that must be maintained in order to keep things going smoothly. We blend four ingredients into the digester on a continuous basis. These are water, acid, MgO, and mother liquor. All of these are necessary for efficient operation, and are controlled in different ways according to their functions.

The central ingredient is MgO. MgO is feed at a constant rate from the MgO hopper located above the digesters. It must be considered that the rotary valve that feeds the MgO is a volumetric feeder, and the feed rate must be adjusted slightly to compensate for variables in reactivity. This is because the bulk density of the MgO, and thus the amount of product going into the digester changes with the reactivity. This should be done only by a member of management. Reactivity, also affects the filterability of the product. This is because the higher reactivity products have most, or all, of their MgO used up so there are not much solids left to form a good filter cake. With the lower reactive products there is a significant amount of hard burned MgO, which is not very reactive. This can be a problem in that the filter cake can form to rapidly reducing the life of the press, and wasting product. Typically we would blend the two products to get the best results. The system usually runs well if all of the other ingredients are added properly, unless the reactivity is very low, below 12. All of the other ingredients are added relative to how much MgO is being added to the system. Because this is an exothermic reaction, it gives off heat, so the amount of MgO being added must not exceed set limits or there may not be enough cooling to keep the digester from boiling over. Also, it must be remembered that the filter press has a temperature limit of 85 deg. C. There is a misconception that the digester needs to boil for the density to increase. While it is true that trying to raise the density may cause the digester to boil, because less water is being added, boiling the digester does nothing to effect the density.

The next ingredient to be discussed is Sulfuric Acid, SO4. Since the MgO is a base with a high ph., and the acid has a low ph. The corresponding reaction is simply a neutralizing process. With the salt being the precipitate when the neutralization is complete. This is typical of all salting processes. In order to optimize the reaction process, and therefore yields, the final ph should be as close to 7 as possible. To accomplish this we use a ph probe in the recalculating leg of the digester. This probe is tied to a loop controller, which in turn controls the addition of acid through a Teflon lined valve. With proper tuning the acid addition is equal in reactivity to the MgO, thus maintaining the proper final ph. The proper control of the ph in the process is of critical importance for several reasons. The first of these is yield. Without proper ph control the final ph will be either

high or low, resulting in an excess of MgO or acid. Filterability of the product is also greatly affected by ph. When the ph is too low, less than 5, the irons in the process will begin to be soluble, and pass through the filter press causing dingy brine, and possibly blinding the cloths. If the ph is too high there will be an incomplete reaction of the MgO, resulting in the formation of magnesium hydroxide, which is a slimy, snotty, gooey, gel that quickly blinds the filter cloths resulting in short press lives. Remember that varying reactivities of the MgO require slightly different set points for the acid addition. This is because of the speed at which the reaction takes place. Not because of the different amounts going into the digester. These set point adjustments need to be done by a member of management.

Mother liquor is what is recycled back from the centrifuge after the crystals have been separated. Mother liquor is simply depleted feed brine. Since there is a significant amount of MgSO4 still in this product it is feed back into the digester. There are several advantages in doing this. The primary reason is of course yield. During the crystallization process the brine is depleted by about twenty five percent. If we did not reuse this mother liquor we would be loosing seventy five percent of our raw materials. This is of course unacceptable. Also, because the mother liquor being reintroduced into the digester we need only to add back the twenty five percent to replace what was lost, not the entire amount. The mother liquor does provide some cooling, but the real trick is that less heat is created because less product has to be made. Balancing mother liquor addition and supply can be difficult. For instance, if the digester is not running and the crystallizers are, then the mother liquor can accumulate quickly and over flow the tank. Remember this is seventy five percent of your raw materials. Whenever the tank is overflowing it is imperative that we find a home for the excess liquor. If the digesters are running hard, and the crystallizers aren't, then the mother liquor can be used up. There are two remedies to this. You can pump some brine from the liquid side to the mother liquor tank, and use this. Provided that you have an excess of brine. Of course, this brine must be replaced. The other option is to reduce the amount of mother liquor, and use water instead. If you do this you must remember that you are going to have to make three times the production, and three times the heat being produced. Since the digester has a limited capacity to remove this heat the addition of raw materials being introduced must be reduced. In extreme cases it may be necessary to shut down the crystallizers until enough brine can be made to restart. Remember that if the crystallizers aren't running then no mother liquor is being produced. The mother liquor is also used to control the density of the finished brine.

Density is another very important aspect in running not only the digester, but the entire plant. If the density is too high, above a 1.40 sg., then the salt will begin coming out of solution prematurely. This will cause salt crystals to form in many unwanted places; piping, tanks, and in the filter press. When the salt starts forming in the press this not only causes the press life to be shortened, we are also discarding a lot of good product when the press is emptied. Also, if the density of the brine is to high the density of the crystallizers will get to high, causing them to not operate properly. This will be discussed when we get to the vacuum crystallizer manuals. If the density is too low, below 1.38

sg., then there is not enough MgSO4 in the brine to efficiently run the crystallizers. There will also be an excess of mother liquor being recycled back.

PROCEDURES

START UP: The start up of a continuous digester is not a big task, but it should be done properly. Hopefully, when the digester was shut down, the mud tank was drawn down to at least half. This will allow the mud that is in the tank to be heated by the incoming mud before being used in the press. When the digester is started up the first thing to do is to turn the manual valve behind the automatic valve on. This will allow the automatic addition of acid to begin. The valve will be fully open because the ph will be high. Ph is a non linear process. As an example it may take ten gallons of acid to bring the ph down from a 7 to a 6, five gallons from a 6 to a 5 and only one gallon from a 3 to a 2. These figures are for illustration purposes only, and are not exact. Therefore, you must remain at the digester to start the addition of MgO when the ph drops below 5. There is a reason for doing this. If the MgO addition is begun when the ph is to high, then unwanted reactions take place. When MgO, especially high reactive, is introduced into the digester with a high ph, high density, hot pot of MgSO4 there is no acid to react with the new MgO. This can cause two things. The formation of what we call oxysulphate cement, which is a complex compound of MgO and salt that is rock hard and will never react. These are typically in the form of nodules varying in size from a marble to a soft ball. The other thing that will form is flat chips of unreacted MgO. Of course since neither of these will ever dissolve, they either build up in the bottom of the tank, or get circulated through the system. Eventually the system will have to be shut down and cleaned. This is a long arduous process that needs to be avoided. When the ph drops below a 5, then the MgO addition can begin. You do this by turning the water on to the mix pot, and begin the addition of MgO into the mix pot by starting the DC Drive for rotary valve on the appropriate digester. The automatic acid valve will begin to control the acid addition at the set point (3.0 – 3.8 depending upon which product is being used). The determination of where to put the set point is dependant on the ph in the second digester. This ph should be kept in the 6 – 7 range. The MgO addition should be kept at a 35 – 50 percent setting on the dial of the DC Drive, depending on the reactivity of the product. Now that the reaction is taking place we must begin to provide some cooling and density control. At this time we have no automatic density control. Opening the valve from the mother liquor tank about half way is a good start. The operator must read the density with a hydrometer every 15 min., and adjust the liquor flow accordingly. If the density cannot be regulated between 1.38 and 1.40 sg. with mother liquor, then water must be used to bring it down. Remember that water can bring the density down very quickly, so be careful, as it will take a long time to bring it back up.

RUNNING: After the digester has been in operation for about 15 min. it should be stabilized enough to begin monitoring for continuous operation. Although the addition of acid is automatically done to control the ph, it must be monitored to insure proper operation. As with all things made by man, automated controls can and do get out of calibration and fail. To minimize the amount of process upset caused by a control going out of wack, you must monitor the ph with litmus paper as often as possible. The density can be checked at the same time, and adjustments made to the mother liquor addition to control the density. Density changes are slow to respond, so a little anticipation and forethought is necessary to properly control it.

SHUT DOWN: When shutting a digester down the you must anticipate the level in the mud tank, and shut down the digester when the tank is a couple of feet down from the top. When the digester is shut down it will continue to overflow for a while, so room must be left in the mud tank to accommodate this. You should stop the MgO feed first, and let the mix pot clear of MgO, then cut the water off to the pot. Shut off the manual valve behind the automatic acid addition valve. The mother liquor and water addition can now be cut off. When the filter press is started the digester can be restarted to replenish the tank level.

EMPLOYEE TRAINING

The training schedule will be set and scheduled by the Plant Manager. It is recommended that both classroom and field training take place for salt and liquid operators.

	Classroom	Field	Signature & date
Salt operator 1	_____	_____	_____
Salt operator 2	_____	_____	_____
Salt operator 3	_____	_____	_____
Salt operator 4	_____	_____	_____
Lqd operator 1	_____	_____	_____
Lqd operator 2	_____	_____	_____
Lqd operator 3	_____	_____	_____
Lqd operator 4	_____	_____	_____
Other	_____	_____	_____
Other	_____	_____	_____

Other	_____	_____	_____
Other	_____	_____	_____
Other	_____	_____	_____