The Pennsylvania State University

The Graduate School

Department of Energy and Mineral Engineering

AN EVALUATION OF A PILOT-SCALE PLATE-AND-FRAME FILTER PRESS FOR DEWATERING FINE COAL REFUSE AND SILICA SAND

A Thesis in

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by

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ABSTRACT

Laboratory testing was conducted to evaluate the performance of a pilot-scale plate-and-frame filter press for dewatering coal refuse slurries and silica-sand slurries. The fully automated filter press was manufactured by TH Minerals, Spain and is equipped with a hydraulic system, which operates the plate and diaphragm pumps. The filter press is capable of achieving an operating pressure of up to 150 psi. The unit contains a single set of plates having a filtration area 0.45 m x 0.45 m. Each plate is covered by a poly-propylene cloth with a pore size 0.051 mm.

The first slurry sample was obtained from an anthracite cleaning plant located in Pennsylvania. This sample was collected from the plant's refuse thickener underflow stream, which was feeding a belt-filter press at approximately 24% solids by weight. The sample was a nominal -0.2 mm and had an ash value of 50%. It contained approximately 50% of -0.025 mm material with an ash value of 68%. The second sample was collected from the thickener underflow stream of a bituminous coal cleaning facility located in Pennsylvania. This sample, which was approximately 35% solids by weight, was nominal -0.8 mm and had an ash value of 42%. It contained approximately 25% of -0.025 mm material with an ash value of 64%. The third sample was collected from the thickener underflow stream of another bituminous coal cleaning facility located in Pennsylvania. This sample, which was approximately 22% solids by weight, was nominal -0.14 mm and had an ash value of 15.0%. It contained approximately 65.3% of -0.025 mm material with an ash value of 20.9%. The fourth sample was collected from the thickener underflow stream of a silica-sand processing plant located in Pennsylvania. This sample, which was

approximately 10% solids by weight, was nominal -0.14 mm. It contained approximately 37% of -0.025 mm material.

A statistical design was developed for each sample using Minitab 15. The tests were carried out to evaluate the effects of feed solids concentration, filter time, probe level, air-drying time, and air-blow pressure on filtrate flow, filtrate solids content, final cake moisture, and filter press unit capacity. Overall it was found that the filter time and drying time had the most significant effects on product moisture and the unit capacity.

For Plant 1, product moistures ranged from 22% to 28% with filtrate solids content of approximately 0.2% solids by weight. The unit capacities ranged from 0.8 kg/hr/m^2 to 3.6 kg/hr/m^2 corresponding to filter cake moistures of 17.2% to 26% respectively. For Plant 2, product moistures ranged from 23.5% to 25.5% with filtrate solids content of approximately 1% solids by weight. The unit capacities ranged from 0.81 kg/hr/m^2 to 1.1 kg/hr/m^2 corresponding to filter cake moistures of 23.8% versus 25.6% respectively. For Plant 3, product moistures ranged from 16% to 21% with filtrate solids content of approximately 0.07% solids by weight. The unit capacities ranged from 2.2 kg/hr/m^2 to 4.2 kg/hr/m^2 corresponding to filter cake moistures of 16.9% versus 26.1% respectively. For Plant 4, product moistures ranged from 11.9% to 17.5% with filtrate solids content of approximately 0.09% solids by weight. The unit capacities ranged from 1.9 kg/hr/m^2 to 3.4 kg/hr/m^2 corresponding to filter cake moistures of 28.4% versus 11.9% respectively. The results indicate that the filter press is capable of producing handleable filter cakes without the use of additional flocculants.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Dewatering is done to increase the solids concentration of a slurry to facilitate subsequent processing or materials handling. In the case of product dewatering the objective is to produce a relatively dry concentrate. Filtration is one of the commonly used dewatering techniques. Filtration is the process of separating solids and liquids by passing the suspension through a porous medium, which retains the solids but allows the liquid to pass. The accumulated solids on the porous medium is called the filter cake, and the liquid is called the filtrate. The process is illustrated in Figure 1.1

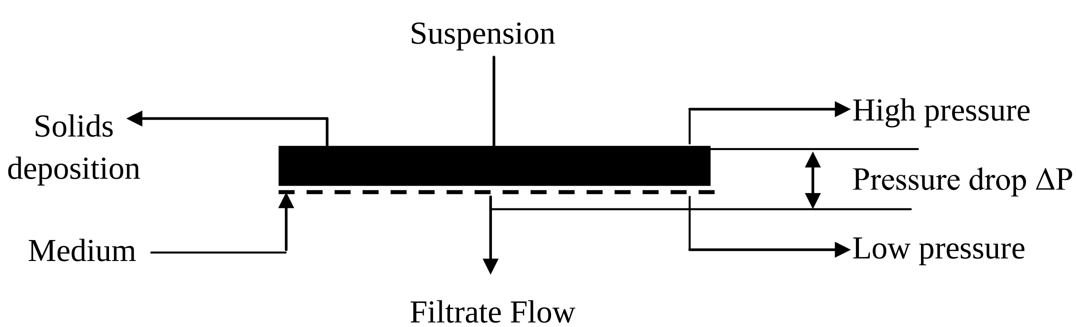


Figure 1.1 Filtration process illustration.

The porous medium, which can be a screen or a filter cloth, acts as a barrier between the filter cake and the filtrate. As soon as the solids deposit and the layer of solids build on the filter medium, deposition shifts to the cake itself and the medium acts only as a support. A perfect solid-liquid separation would result in a stream of filtrate free of solids and a dry filter cake. Unfortunately, the filtration devices do not make perfect separations. The result is that some liquid remains with the solids, while fine solids may be carried to the filtrate stream [Svarovsky, 1990].

The difference in pressure, ΔP, is the driving force for the process. In the case of vacuum filtration this driving force is the atmospheric pressure. Vacuum is created below the filter medium, providing a pressure drop of up to one atmosphere, which forces the suspension towards the filter medium.

Rather than creating a vacuum, the slurry can be forced towards the filter cloth at pressures greater than one atmosphere. This process is called pressure filtration. In pressure filtration, the driving force is usually the pressure exerted by the slurry that is pumped in the feed vessel. This pressure is usually 7 to 8 atmospheres. Also, additional liquid may be squeezed out of the cake, for example, by a piston pressed on the top of the cake, by mechanical action of an inflatable membrane or by blowing air through the cake. [Cox and Traczky, 2002]. The increase in pressure is often advantageous as it leads to higher output and drier cakes. However, this is not always true. For compressible cakes, a higher pressure drop decreases its permeability often producing a lower filtration rate relative to the given pressure drop [Tiller, 1975].

Pressure filters treat slurries containing typically greater than 10% solids by weight and usually containing large proportions of fines. In general, slurries in which 90% of the particles are less than 10 µm require pressure filtration and product moistures in the range of 15% to 25% are usually obtained [Svarovsky, 1985].

1.1 Plate-and-Frame Filter Press

One commonly used pressure filtration device is the plate-and-frame filter press. These devices have been used for the past 50 years and have found widespread applications in the food industry, pharmaceutical industry, mineral industry, coal industry, and for wastewater treatment. An example of an industrial unit is shown in Figure 1.2a. The filter press dewaters in a batch process by compressing the feed suspension between one or more sets of plates. The dewatered cake is discharged by self weight when the plates are opened. The plates are shown in Figure 1.2b. The plates are typically made of stainless steel, cast iron, rubber, polypropylene or wood. They have a thickness of about 40 mm with areas ranging from 150 mm^2 to 2 m^2. The plates are covered with a filter media, which can be a polymer cloth or paper.

A filter press consists of multiple chamber filter plates mounted vertically and suspended from an overhead beam (see Figure 1.2a). A unit may contain up to 100 plates and in exceptional cases up to 200 plates. The support beam is connected at one end to a fixed head, also known as the feed head, and at the other end to the closing head. The two faces of the filter plate have a drainage surface in the form of ribs, grooves or pipes to allow filtrate to drain behind the cloth to the drainage ports located in each corner of the filter plates. These ports, in turn, connect to the corner eyes, which carry the filtrate drainage to the fixed end of the filter press. A filter cloth is mounted over each of the two faces of the filter plate. The cloth is joined at the feed eye by an impervious sleeve or tube also known as a barrel neck. Typical operating pressures for a filter press range up to 8 atmospheres, however some manufacturers offer presses up to 20 atmospheres [Svarovsky, 1990].

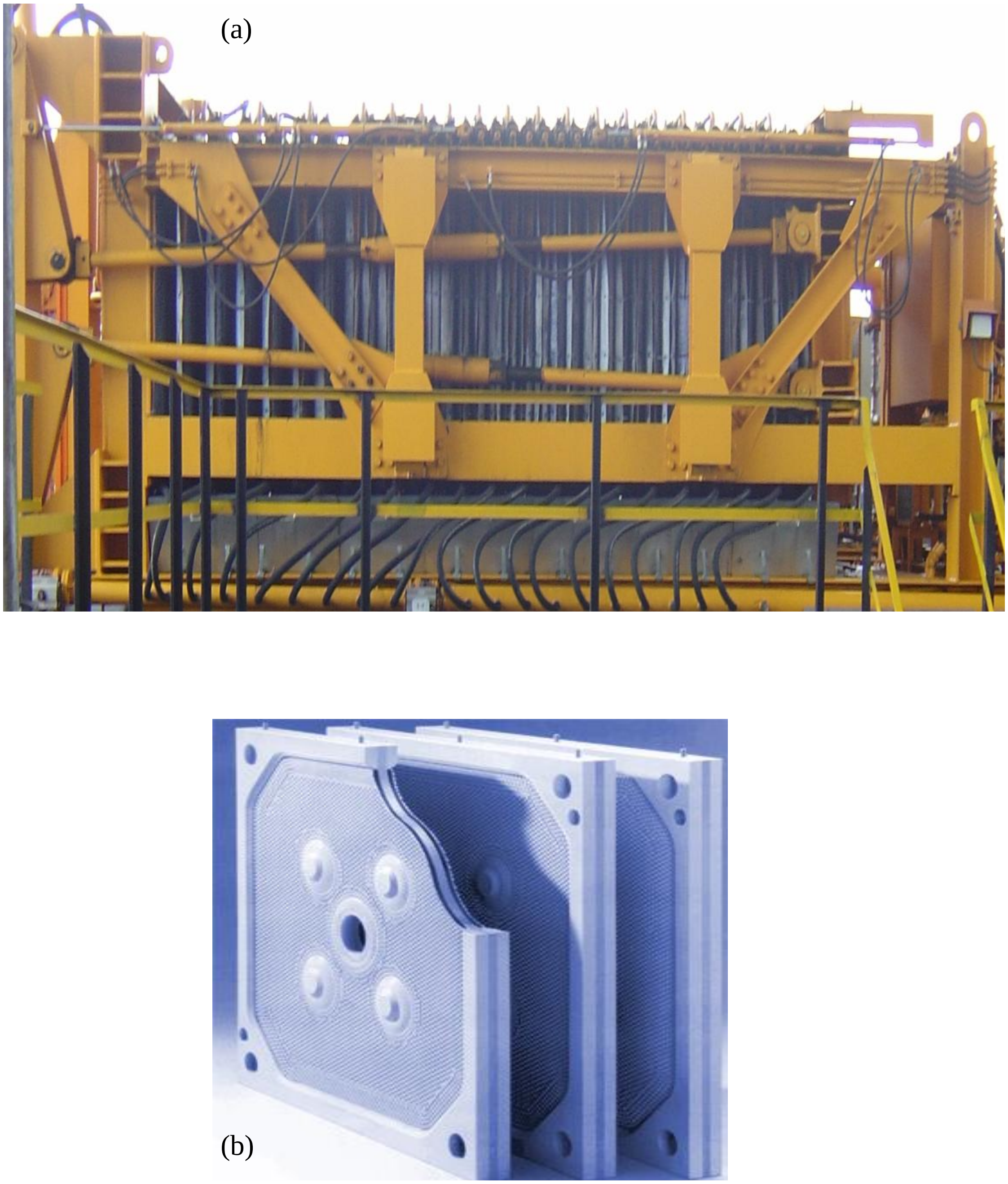


Figure 1.2 Filter press illustrations: (a) full-scale filter press unit; (b) filter plates (Source: PrepTech Inc.)

The filtration process of a plate-and-frame filter press is illustrated in Figure 1.3. At the initiation of the filtration cycle, the filter plates are closed and squeezed together hydraulically. After, the plates are closed, the slurry pump is activated, which begins to fill the filter compartment (space between the closed plates) with slurry as shown in Figure 1.3a. The filling is done very quickly so as to avoid filling the first chamber with solids before the last ones have been filled. As the filter compartment begins to fill, the slurry migrates axially inside the plates with the solid particles coating the filter cloth as the filtrate is driven out due to the pressure of the incoming slurry. The filtrate passes through the filter cloth and reaches the grooved filter plate surface. The filtrate travels through the grooves to the bottom of the plate where a filtrate discharge port is located. The dewatering in this stage is illustrated in Figure 1.3b. The solid particles deposit on the surface of the filter cloth forming the initial layer of filter cake referred to as the *pre-coat* layer. At this time, the pre-coat layer becomes the actual filtering medium, and the filter cloth acts only as a support. The filtrate continues to flow through the outlet.

The slurry is pumped in for a set amount of time or until no further pumping is possible due to the back pressure resulting from the cake buildup as seen in Figure 1.3c. In some units the filtration cycle is followed by a high pressure air-blow cycle or dry cycle to force out the water retained in the cake voids and replace it with air. The dry cycle is followed by opening of the plates to dislodge the cake from the filter media (see Figure 1.3d). After the filter cake has been fully discharged, the filter cycle is complete.

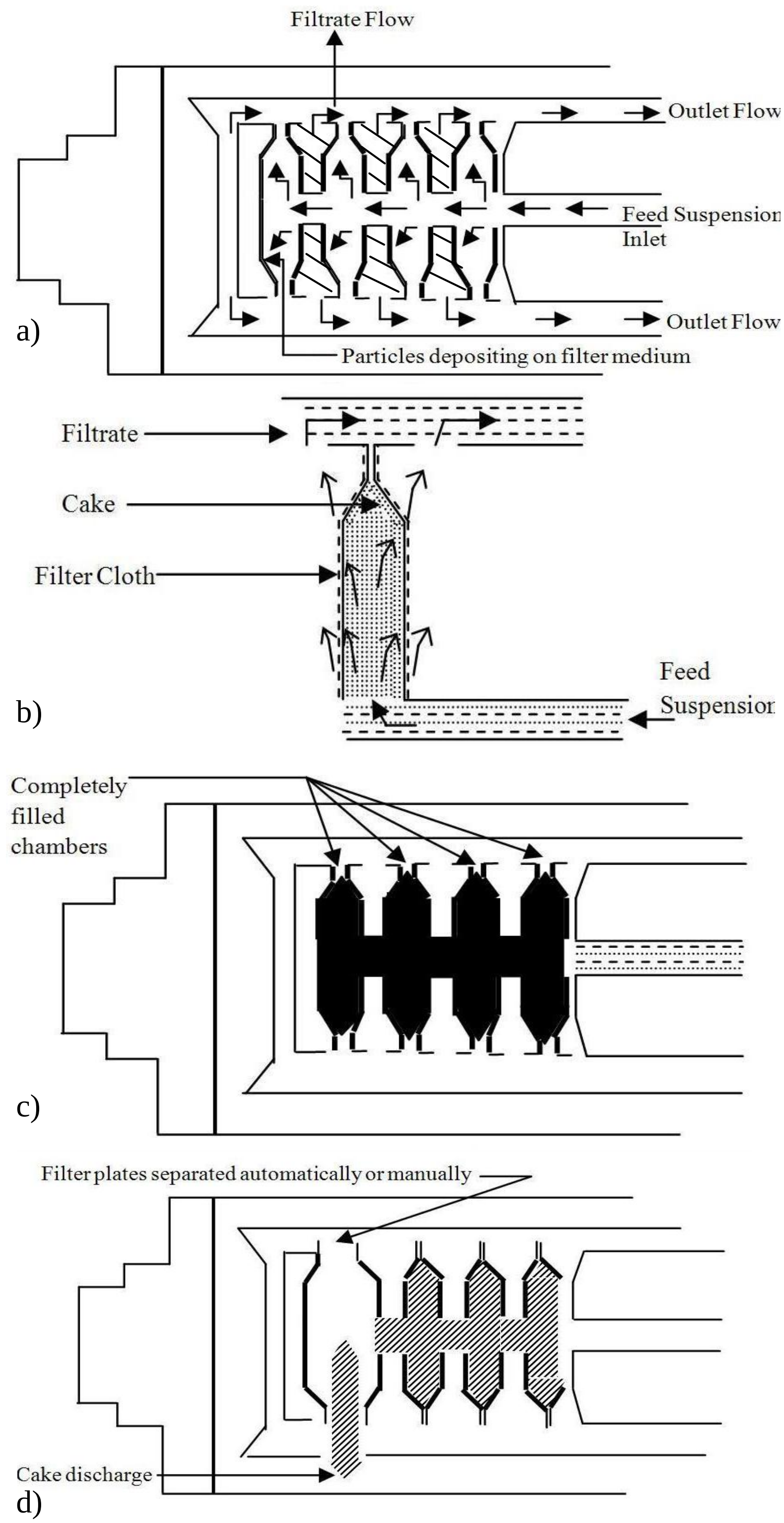


Figure 1.3 Filter press cycle: (a) feed stage; (b) dewatering stage; (c) cake build-up; (d) cake discharge.

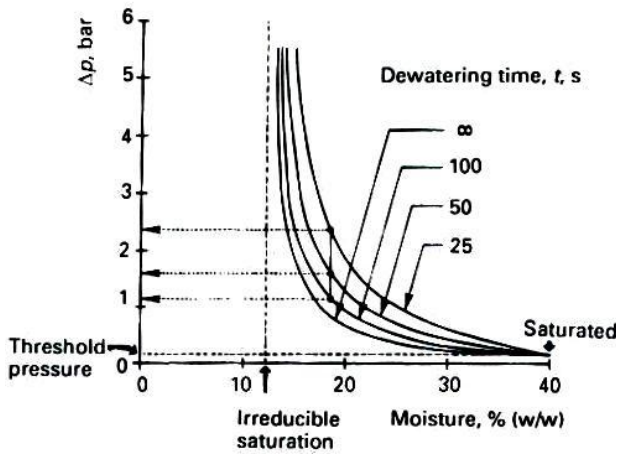


Figure 1.4 A capillary-pressure diagram for fine coal [Svarovsky, 1990].

1.2 Filter Press Operating Conditions

The main operating variables in filter press operation are filter time and dry time, which are fixed for a given filter cycle. The filter time is the time of feeding the slurry continuously to the filter press and usually ranges from 60 to 180 seconds. The dry time is the time during which the compressed air is forced through the filter cake to reduce the moisture further. The dry time usually ranges from 120 to 480 seconds [Chugh et al., 2003].

As proposed by Svarovsky [1990], Figure 1.4 shows a plot of the required air pressure as a function of filter cake moisture. As can be seen, for a given fine coal suspension, there is a minimum moisture content that cannot be reduced by air displacement at any pressure, which is called irreducible saturation. There is also a threshold pressure that must be exceeded for air to enter the filter cake. For example, figure 1.4 shows that to obtain a filter cake moisture of 20%, an air pressure of 1.5 bar is needed for a dewatering time of 50 s as compared to 0.75 bar for a dewatering time of 100 s. Hence the same filter cake moisture content can be obtained in shorter dewatering times if higher air pressures are used. Figure 1.4 also shows that at higher values of dewatering times, the moisture reduction by increasing air pressure is minimal.

1.3 Applications in Coal Preparation

The dewatering of fine coal and refuse is an important aspect in coal preparation plants. The increased generation of fines and the need to recover finer coal has increased the importance of dewatering. For example, flotation concentrates may contain up to 20% of -20 µm material and in exceptional cases, 20% of -7 µm material [Townsend, 2002]. This continual reduction of size requires an effective way to dewater coal fines to produce a saleable product. Filter presses also have the ability to dewater fine coal refuse such as from a thickener underflow. Coal refuse that was disposed in ponds was dewatered to as low as 20% moisture using a filter press [Patwardhan et al., 2003]. Another concern is the high recurring cost of flocculants during dewatering. In most cases, the plate-and-frame filter press eliminates the need of flocculant addition during dewatering as required in a belt filter press.

1.4 Objectives of the Study

The performance of a pilot-scale plate-and-frame filter press was evaluated for dewatering various slurries. Three different coal/refuse samples and one silica-sand sample were used as feed materials, which were obtained from the thickener underflow streams of operating processing plants. Testing was performed to evaluate the effects of operating conditions on filter press performance. These tests were performed as a series of statistical designs. The variables studied were feed solids concentration, filter time, drying time, and air pressure.

CHAPTER 2

SAMPLE PREPARATION AND MATERIAL CHARACTERIZATION

Representative slurry samples were taken from the thickener underflow streams of three coal cleaning plants and one silica-sand processing plant. All plants were located in Pennsylvania. Plant 1 was an anthracite cleaning plant, whereas Plants 2 and 3 were bituminous coal cleaning plants. Plant 4 was a silica-sand processing plant.

2.1 Sample Collection

The sample from Plant 1 was collected by plant personnel over a period of several days from the underflow stream of the refuse thickener that was being fed to a belt filter press (material A). During sampling, eight, 5-gallon buckets were filled with material A, the solids were allowed to settle, and the water was decanted. This was repeated multiple times to increase the solids concentration in each bucket. Another bucket was collected separately for determination of the belt filter press feed solids concentration and size distribution. No decanting was done with this slurry. A bucket of the belt filter press product was also collected (material B). All buckets were sealed with lids prior to transporting them to the lab.

The sample from Plant 2 was obtained by plant personnel from the underflow stream of the refuse thickener. These samples were collected in seventeen, 5-gallon buckets using a combination of settling and decanting in a similar manner as Plant 1. A separate bucket was also collected to determine the as-received solids concentration and size distribution of the thickener underflow stream.

The sample from Plant 3 was obtained by plant personnel from the thickener underflow stream. This sample was collected in one 55-gallon drum using a combination of settling and decanting to increase the solids concentration.

The sample from Plant 4 was obtained by plant personnel from the tailings thickener underflow stream in one, 20-gallon drum using a combination of settling and decanting to increase the solids concentration.

2.2 Sample Preparation

At the lab, the eight, 5-gallon buckets of material A from Plant 1 were decanted using a vacuum pump. In order to ensure representative samples for the filter press testing, the material in these buckets was split into twelve pre-weighed, 5-gallon buckets. These are referred to as the “new” buckets. A scoop of approximately one liter in volume was used to sample the plant buckets. The slurry was mixed using the scoop, and then one scoop of concentrated slurry was taken from the plant bucket and was put into the first new bucket. This was repeated for the other 11 buckets. In this manner all 8 plant buckets were divided into the 12 new buckets. These 12 buckets were weighed to determine the total weight of coal slurry. One of these buckets was used to estimate the slurry volume and later to calculate the solids concentration.

The plant bucket containing the as-received sample was transferred to a pre-weighed bucket to determine the slurry weight. The slurry was transferred into a pre-weighed stainless steel drying pan, which was placed in a convection oven set at 215°F for approximately 24 hours. The pan was removed and weighed. The bigger agglomerates were broken, and the pan was placed into the oven for at least 2 hours. The pan was removed from the oven and weighed. This was repeated to ensure that the solids weight remained constant. The feed solids concentration was determined using this weight of dry solids.

Any remaining agglomerates were broken using a rolling pin to ensure accurate sampling. This was followed by the coning-and-quartering method of sampling to obtain two representative samples of approximately 200 g each for size and ash analyses. The remaining solids were bagged and saved.

The sample preparation procedure for the Plant 2 sample was similar to the Plant 1 procedure except that the seventeen, 5-gallon plant buckets were transferred to seventeen, 5-gallon (new) buckets. This was done in the same manner as for the Plant 1 sample. After drying the solids from one bucket, two representative samples of approximately 200 g each were taken by coning-and-quartering for size and ash analyses. The remaining solids were bagged and saved.

The Plant 3 and Plant 4 samples were prepared differently for filter press testing. The entire 55-gallon drum containing the Plant 3 sample was transferred to the make-up circuit, which is described in Section 3.1. For the Plant 4 sample, the entire 20-gallon sample was transferred to the make-up circuit. For the Plant 3 material, size and ash analyses were done using the samples of the filter cake obtained after the filter press testing. Size analysis of the Plant 4 material was also done using the samples of the filter cake obtained after the filter press testing.

2.3 Solids Characterization

For each plant, a 200 g sample of dried solids was dispersed in a 5-liter beaker containing 0.5% sodium metaphosphate solution. The beaker was placed in an ultrasonic bath with a stirrer inserted in the beaker. After approximately 30 minutes of mixing, the dispersed sample was wet screened at 0.149 mm on a 100 U.S. mesh screen. While wet screening, the screen surface was gently rubbed by hand to ensure all agglomerates were broken. The -100 mesh slurry was further wet screened at 0.025 mm on a 500 U.S. mesh screen. The +100 mesh fraction from the first wet screening was combined with the +500 mesh fraction from the second wet screening and were placed in an oven set at 215 °F for drying. The -500 mesh fraction was decanted and dried separately. After overnight drying, the +500 mesh fraction was weighed and dry screened at 1.190, 0.841, 0.595, 0.420, 0.297, 0.210, 0.149, 0.105, 0.074, 0.053, 0.037 and 0.025 mm on 16, 20, 30, 40, 50, 70, 100, 140, 200, 270, 400 and 500 U.S. mesh screens using a RoTap sieve shaker. After 10 minutes the bottom sides of the screens were de-blinded, and the sample was screened for an additional 15 minutes. The individual size fractions were weighed and bagged. The -500 mesh fraction was combined with the -500 mesh fraction obtained from wet screening. A representative sample of approximately 5 g of -500 mesh material was obtained for sub-sieve size analysis using a Microtrac X100 particle size analyzer.

To obtain sufficient material for ash analyses, a representative sample of approximately 3 g of each size fraction was obtained by random sampling. All material larger than 200 mesh was ground using an agate mill. All these samples were analyzed for ash content by weight using a LECO TGA-501. A coal standard was used with each test to ensure accurate results.

Another representative sample of approximately 30 g was obtained from the bagged sample using coning and quartering. This sample was used for density determination using a helium stereopycnometer (Quantachrome Model SPY-2). A detailed description of each test procedure listed in this section is given in Appendix A.

CHAPTER 3

EXPERIMENTAL PROCEDURES

Tests were conducted to study the dewatering behavior of three coal slurries and one silica-sand slurry using a plate-and-frame filter press. The effects of feed concentration, filling time, filtration time, drying time, and drying air pressure were tested.

3.1 Plate-and-Frame Filter Press Test Circuit

Tests were carried out using a pilot-scale, plate-and-frame filter press manufactured by T.H. Minerals, Spain and distributed by PrepTech. Inc. The filter press (Figure 3.1) consists of a 100-liter feed tank equipped with a variable speed mixer, two hydraulically driven diaphragm pumps, a filtrate collection tank and probe, and a set of two filter plates with a hydraulic system for opening and closing the plates. Each plate is 0.63 m high and 0.63 m wide and has a filtration surface area of 0.45 m x 0.45 m, which is covered with a polypropylene monofilament cloth with satin weave. The cloth is heat set and calendered, has a pore size of 0.051 mm, and has a permeability of 0.25 m/s. The feed tank is equipped with a side drain valve. A second drain valve was installed on the bottom of the tank to ensure that the entire slurry was drained when needed. Another valve was installed in between the slurry feed line and the filter plates. This was done to

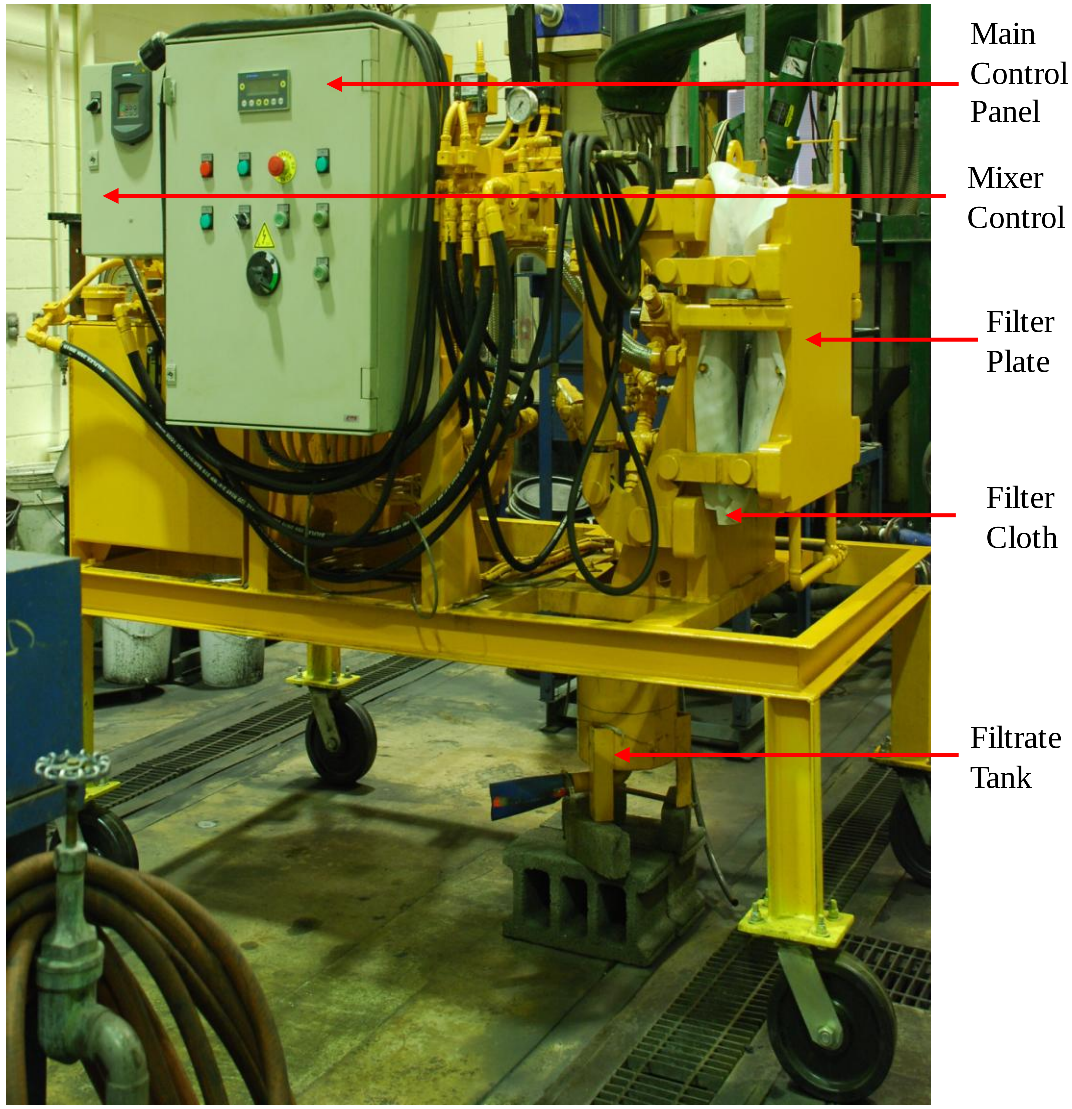


Figure 3.1 The pilot-scale plate-and-frame filter press manufactured by T.H. Minerals.

provide a discharge line to remove any residual slurry in the feed line to prevent mixing with the final filter cake. Plastic wheels, 30 mm in diameter, were installed on the filter press legs to improve access to the filtrate discharge and to allow the unit to be moved easily. The filtrate collection tank (see Figure 3.2) is equipped with a probe, which is used to optimize the cycle duration. Filtrate from the plates is collected in the filtrate tank and then discharged through the filtrate discharge line. The probe height of the filtrate tank can be adjusted to control the fill and filter cycles as discussed in the next section.

Compressed house air available at approximately 60 psi was used to control the solenoid valves. Also, a portable air compressor was used to provide the compressed air for the dry cycle. This compressor produced air at a maximum of 100 psi.

For some tests, a separate slurry make-up circuit was used to supply material to the filter press feed tank. This make-up circuit (see Figure 3.3) consisted of a 100-gallon steel sump, a mixer, a centrifugal pump, and a 15 Hp motor with a variable frequency controller. A 3-way valve arrangement was installed to circulate the slurry into the 100-gallon sump through the bypass line or to divert the slurry to the filter press feed tank.

3.2 Plate-and-Frame Filter Press Testing

For samples from Plants 1 and 2, slurry was transferred from the sample buckets to the filter press feed tank with the mixer turning. The speed was adjusted depending on the solids concentration to prevent any vortex formation. For Plants 3 and 4, slurry in the plant drums was transferred to the make-up sump for mixing. This slurry was then transferred from the make-up circuit to the filter press feed tank with the mixer running.

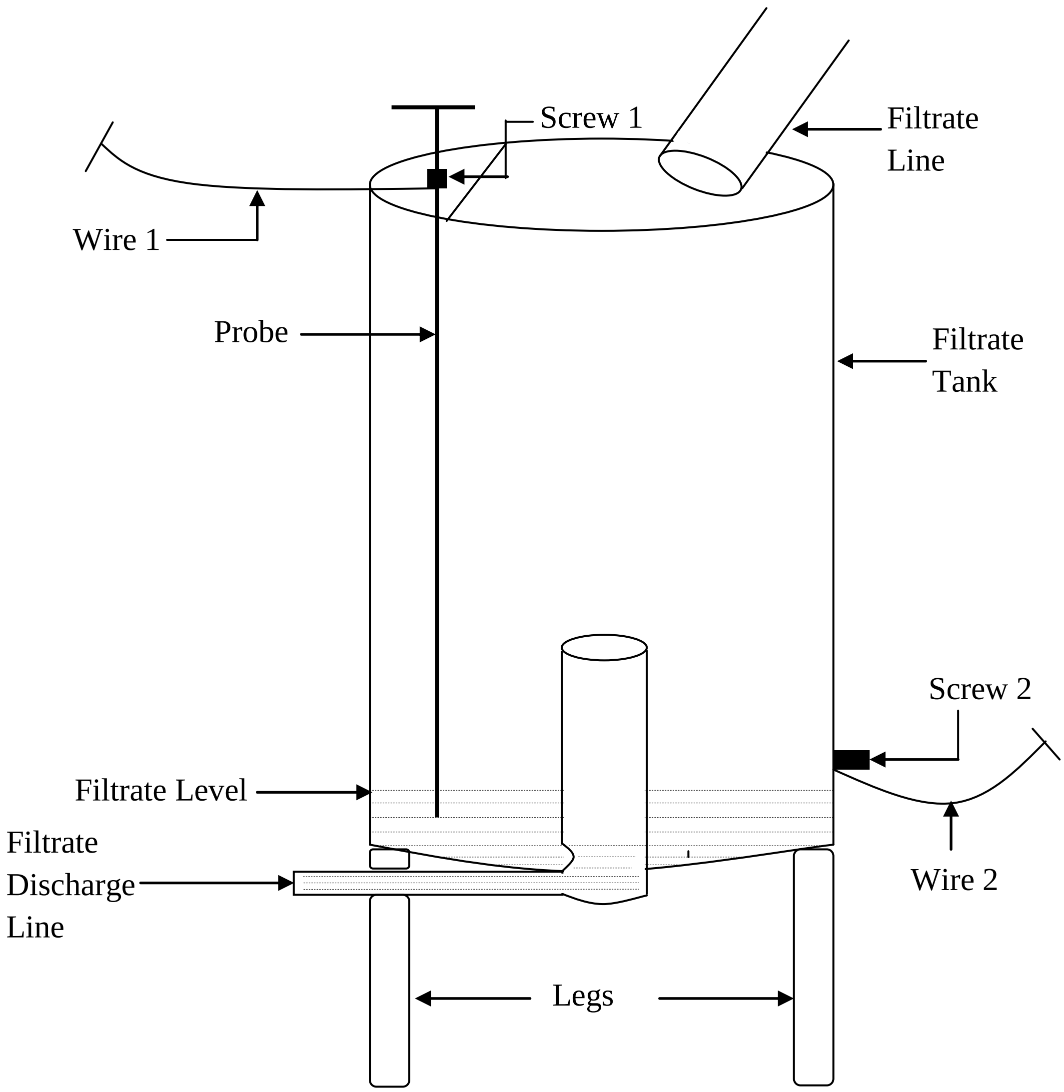


Figure 3.2 Diagram of a filtrate collection tank (not to scale).

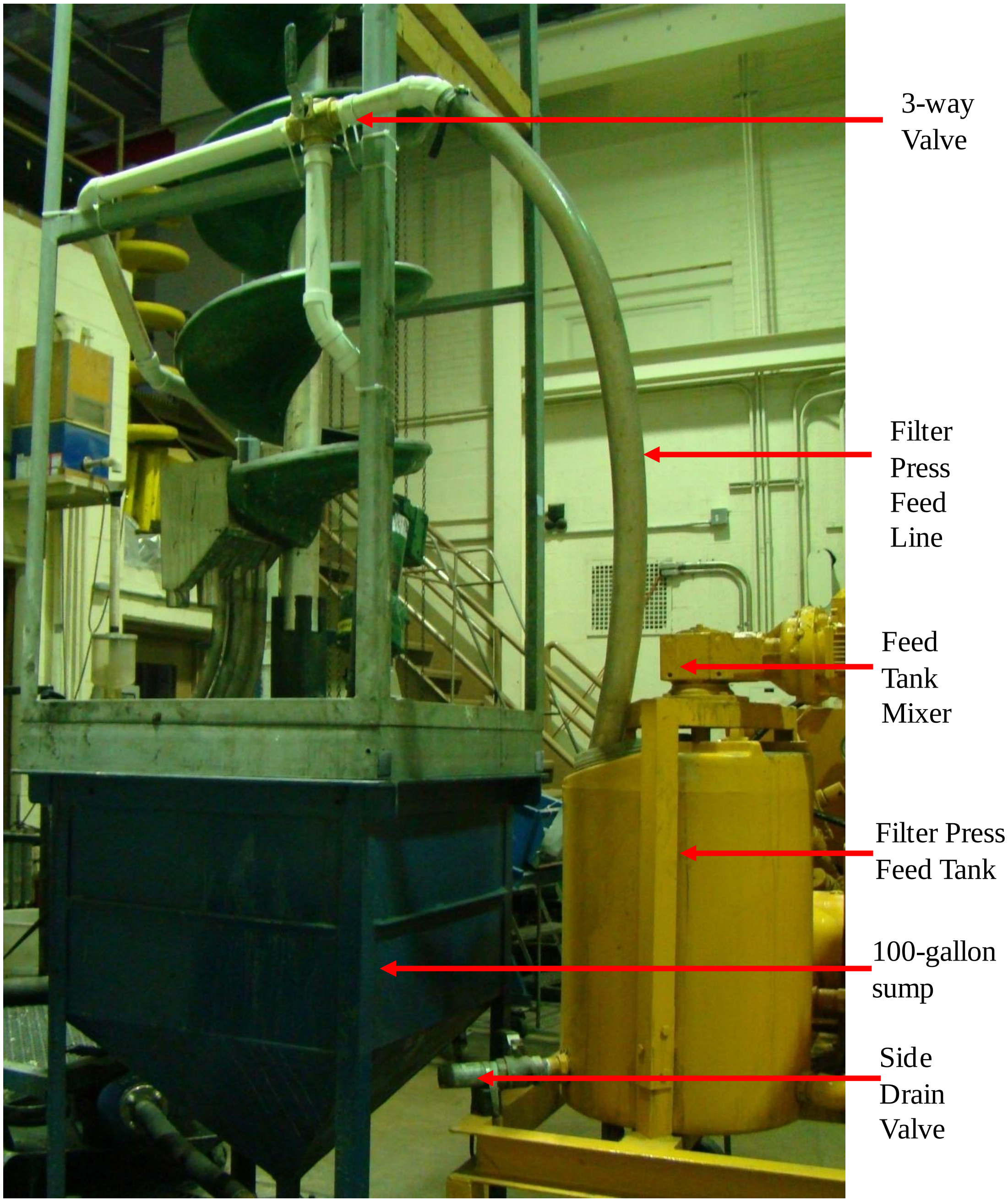


Figure 3.3 Slurry make-up circuit arrangement.

After mixing the slurry for approximately 5 minutes, a representative sample was taken from the side drain valve using a one-liter Marcy-scale bucket. The bucket was transferred to the Marcy gauge and the slurry relative density (RD) was noted. The solids concentration by weight was calculated as

$$S_W\% = \left(\frac{\rho}{1-\rho}\right)\left(1-\frac{1}{RD}\right)100 \qquad (3.1)$$

where ρ is the solids density as determined by the helium pycnometer. If necessary, water was added to reduce the solids concentration. For each desired concentration, a representative sample was taken from the side drain valve in a small pan and was placed in the convection oven set at 215°F. This verified the solids concentration of the slurry.

Prior to beginning each test, the operating variables - maximum fill time, maximum filter time, dry time, pause time, air pressure, and probe level - were set. At that point the filter press cycle was started. The filter plates were closed by the hydraulic system at the beginning of the cycle, and the diaphragm pumps began filling slurry between the plates. This step is called the fill cycle. The filter cake started building up, and the filtrate started coming out in the filtrate collection tank. As the cycle proceeded, more filtrate came out at a higher flow rate, and the filtrate level in the filtrate collection tank increased. As soon as the filtrate level touched the probe (usually within 30 s), the fill cycle was automatically terminated and the filter cycle started. If the filtrate level did not reach the probe during the fill cycle prior to reaching the predefined maximum fill time, the fill cycle was terminated automatically and the unit went to stand-by mode. A flowchart showing the overall filtration cycle is given in Figure 3.4.

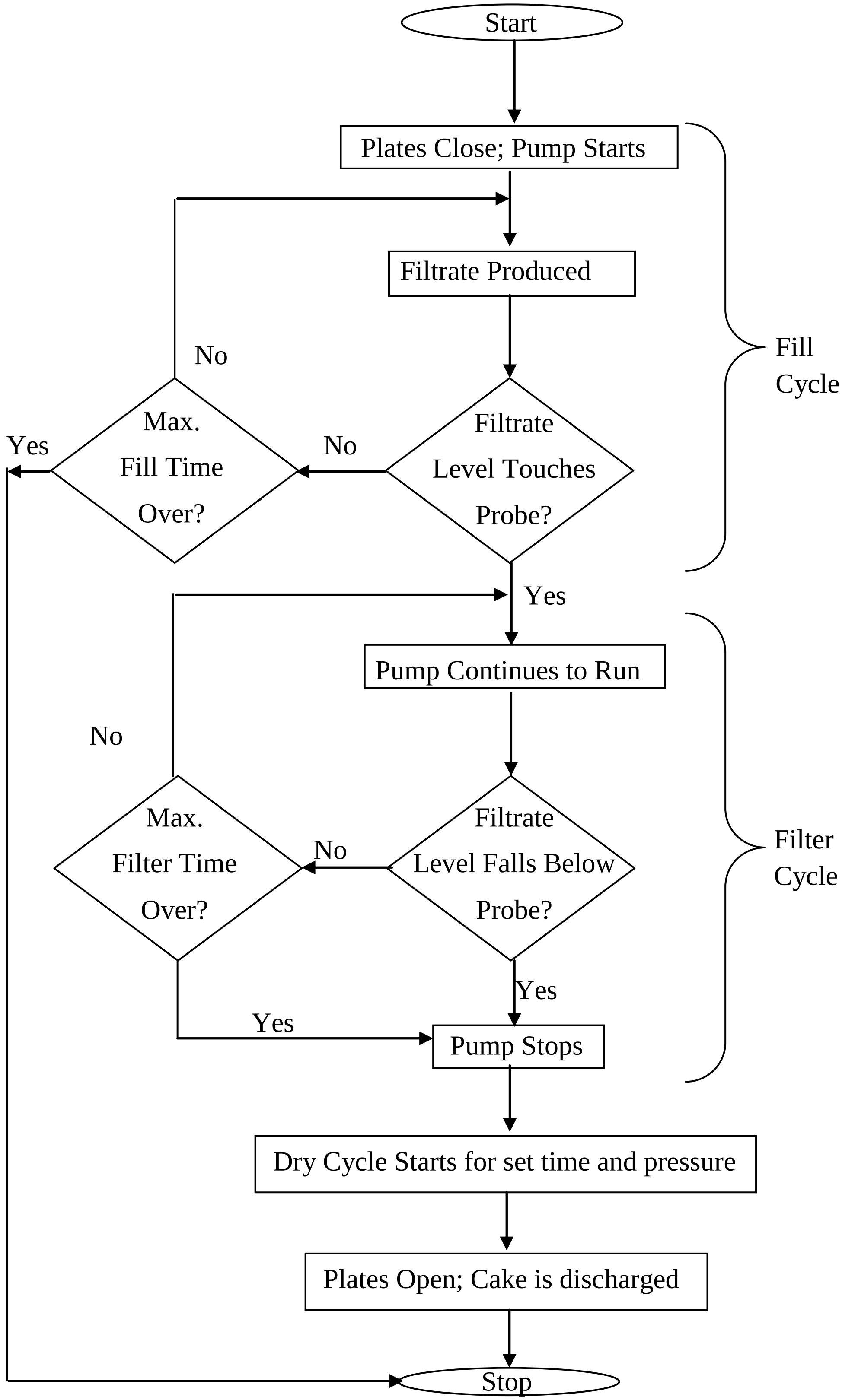


Figure 3.4 Flow chart illustrating the complete filtration cycle.

During the filter cycle, the pump continued feeding the plates, and the filtrate continued to discharge. While feeding, the pressure inside the chamber was approximately 125 psi. As the solids content increased inside the filter chamber, the filtrate rate decreased and the level of filtrate in the filtrate tank decreased. If the filtrate level fell below the probe level, the filter cycle was terminated. If the filtrate level did not fall below the probe level prior to reaching the predefined filter time, the filter cycle was terminated automatically and the dry cycle started.

During the dry cycle, compressed air at a pre-set pressure, either 80 psi or 100 psi, was blown into the filter chamber. This air blow de-blinded the cloth surface and extracted additional filtrate from the solid voids. After the dry cycle was completed and during the pause time, the residual slurry valve was opened manually, and the slurry retained in the feed line was collected. A screen with an opening size of 1.19 mm was placed above the filter cake collection pan. The filter plates were opened automatically, and the final cake was discharged by self weight. The screen was used to ensure that the filter cake was retained on the screen and to prevent it from mixing with any slurry still

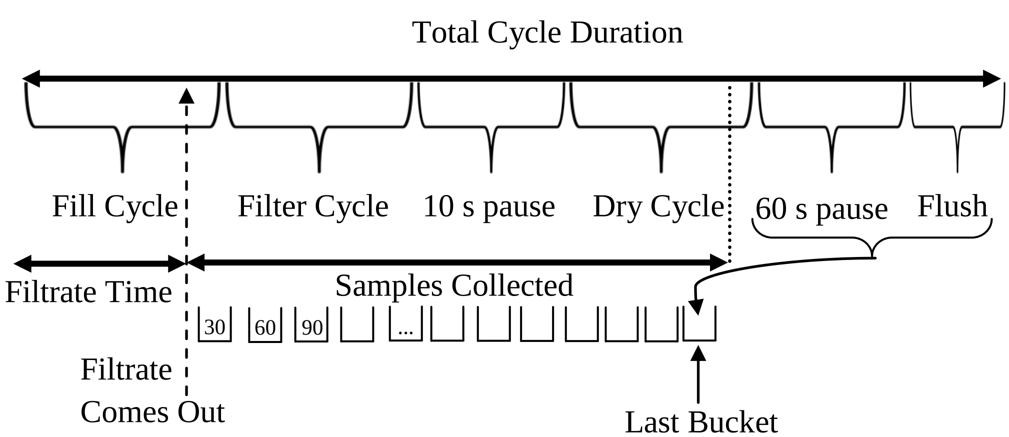


Figure 3.5 Filter press cycle times and filtrate collection.

remaining in the feed line.

For a given test, approximately 20 filtrate samples were collected at 30 seconds intervals. The different cycle times along with the filtrate collection times are shown in Figure 3.5. A total of five cake samples were collected from different parts of the cake (see Figure 3.6) to determine the moisture variation within the cake. These samples were weighed and then dried in convection oven set at 215 °F for approximately 24 hours. The remaining filter cake was separately weighed and stored in buckets. The timed filtrate samples were weighed to determine the mass flow rate of the filtrate. After weighing, the filtrate samples were combined, decanted, and dried in the convection oven set at 215 °F for approximately 24 hours to determine the total solids weight in the filtrate. For one test, all the timed filtrate samples were dried separately in convection oven set at 215 °F for approximately 24 hours to determine the filtrate solids content as a function of time. A detailed description of the operating procedure is given in Appendix A.

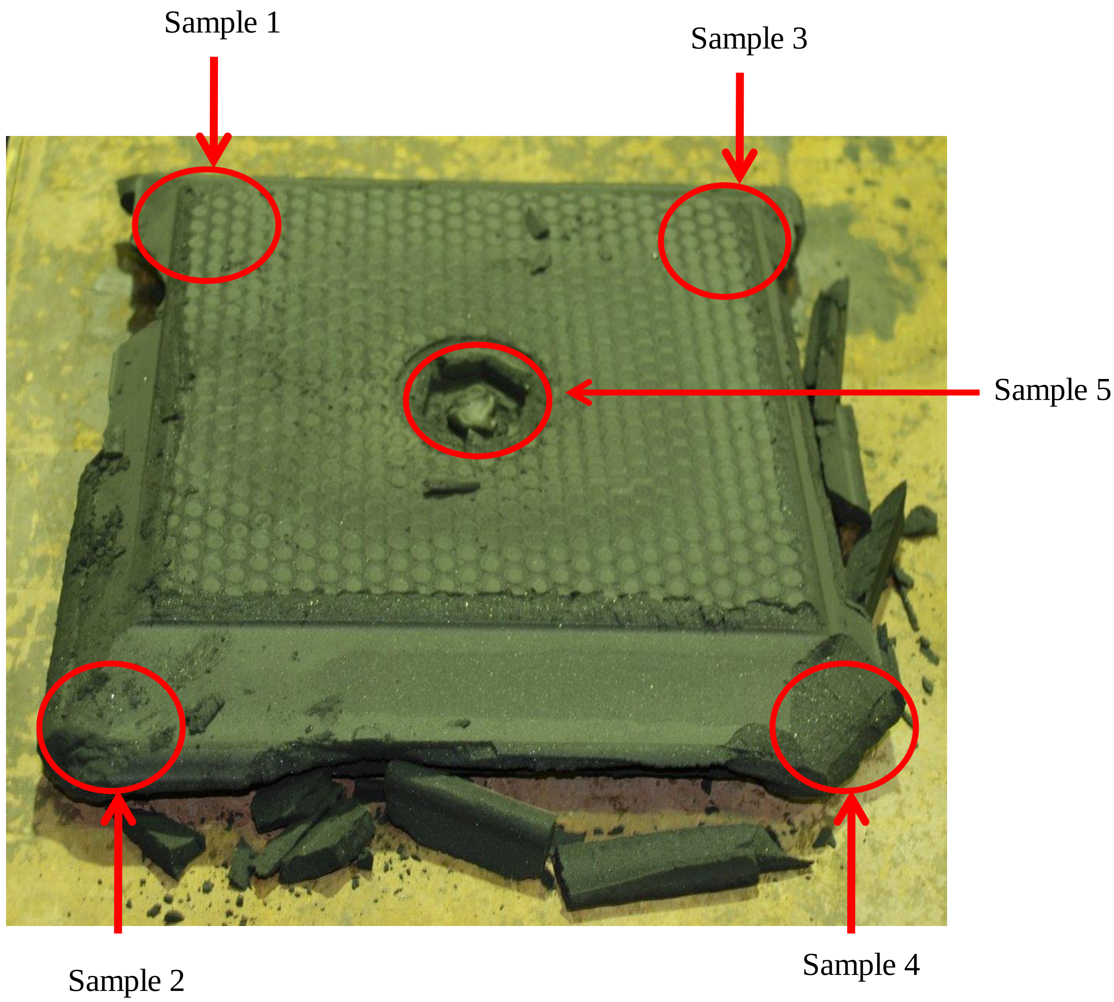


Figure 3.6 Sample collection points in a dewatered cake.

CHAPTER 4

RESULTS AND DISCUSSION – ANTHRACITE SAMPLE

In this chapter the results from filter press testing of the Plant 1 anthracite slurry are presented. The sample was collected from the underflow stream of the refuse thickener, which was being fed to a belt filter press. Being from thickener underflow, the sample had been flocculated at the plant. Tests were conducted at different operating conditions, including feed solids concentration, maximum filter time, dry time, air pressure, and probe height.

4.1 Feed Analysis

Figure 4.1 shows the direct weight and ash percentages of each size interval. The anthracite sample was nominal -70 mesh with an ash value of 50.6% based on analysis of a head sample. The +500 mesh material had an ash value of 34.2% and represented 45% of the material. The sample contained 55% of -500 mesh material with an ash value of 67.7%. Other than the -500 mesh fraction, the weights in the different size intervals were similar. The ash values increased with decreasing particle size. Based on these data, the calculated ash value was 52.6%. The difference in calculated ash value and the head sample ash value was due to the sampling error. The as-received slurry from the plant had a solids concentration of 24.6%, and the average density of the solids was 2.14 g/cm^3. The detailed size and ash interval data are tabulated in Appendix B.

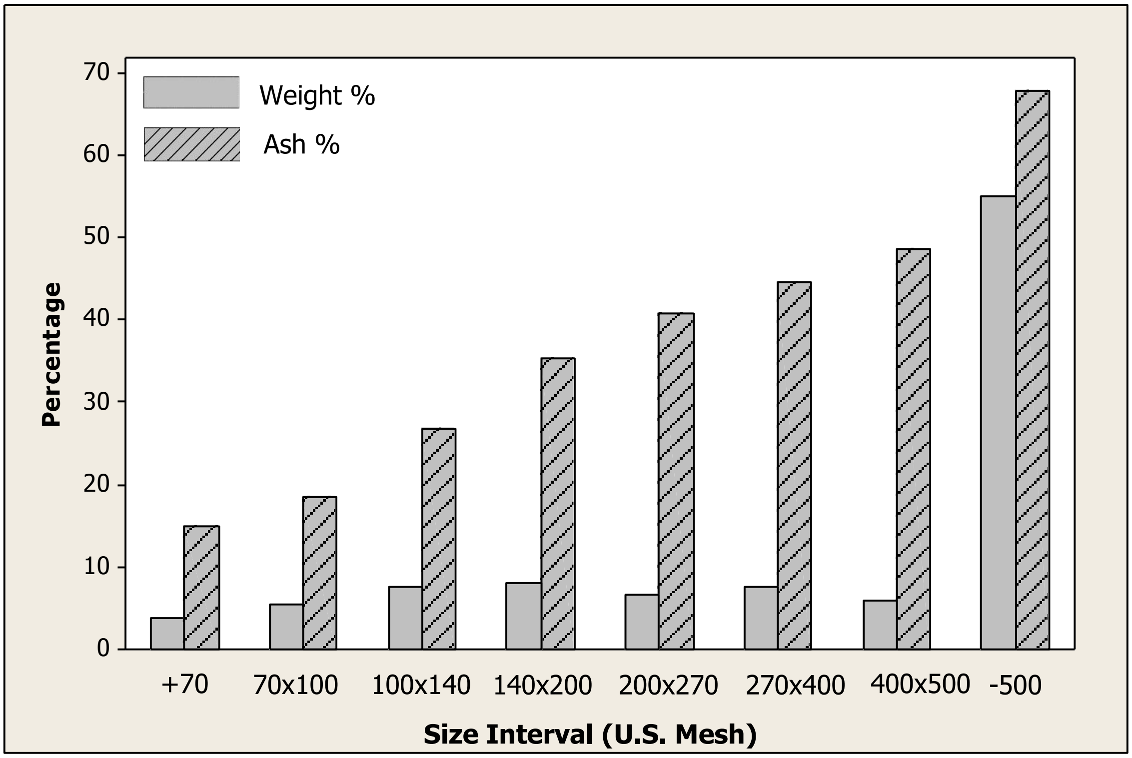


Figure 4.1 Weight and ash percentages of feed by size interval for Plant 1.

4.2 Determination of Test Matrix

Preliminary testing was done to determine the levels of variables to be used during filter press operation. For example, 20% solids slurry was fed to the filter press with a maximum filter time of 300 s and a dry time of 600 s. The probe height for this testing was kept constant at level 1, which was a distance of 40 mm from the bottom of the filtrate tank. It was observed that the filter time was approximately 120 s. Hence two levels of maximum filter time were chosen as 120 s and 240 s. Also, during the dry cycle, the filtrate flow rate after 300 s was negligible with only drops coming out. Therefore, the levels for the dry time were chosen as 120 s, 240 s, and 360 s. Two levels of the feed

Table 4.1 Summary of Plant 1 test conditions at probe level 1.

Run Order	**Feed Conc** (%)	**Max. Filter Time** (s)	**Dry Time** (s)	**Air Pressure** (psi)	**Calculated Solids** (%)	**Measured Solids** (%)
1	30	120	240	100	28.9	30.7
2	20	240	240	80	18.8	19.2
3	20	240	240	100	20.3	18.7
4	30	240	120	80	28.9	29.9
5	20	120	360	100	20.3	20.2
6	30	120	360	100	30.2	31.0
7	30	120	360	80	30.2	30.9
8	20	120	240	100	18.8	19.7
9	20	240	360	80	18.8	19.9
10	30	240	360	100	28.9	29.8
11	30	120	120	100	28.9	29.8
12	30	240	360	80	28.9	30.4
13	20	120	240	80	18.8	21.4
14	30	240	120	100	28.9	29.2
15	30	240	240	100	28.9	31.1
16	30	120	120	80	28.9	29.2
17	20	240	120	80	20.3	18.9
18	20	120	360	80	20.3	20.5
19	20	120	120	80	20.3	20.4
20	30	120	240	80	28.9	29.3
21	20	240	360	100	18.8	20.3
22	20	240	120	100	18.8	19.2
23	20	120	120	100	18.8	20.4
24	30	240	240	80	28.9	31.1
25[1]	20	240	240	100	18.8	18.9
26[2]	30	120	120	100	30.2	30.1
27[3]	30	240	360	100	30.2	31.1

[1] Replicate of run 3.

[2] Replicate of run 11.

[3] Replicate of run 10.

concentration, 20% and 30%, were chosen as the feed stream at the plant was close to 25% solids. Also, the available air compressor could achieve pressures up to a maximum of 100 psi, hence the two levels chosen for the air pressure were 80 and 100 psi.

A full-factorial experimental design was generated using Minitab 15 as shown in Table 4.1. This design generated a random sequence of filter testing for a total of 24 tests. The randomization of the experimental sequence ensured that there was no bias involved in the testing. Duplicates were done for three tests (runs 25, 26, and 27) to evaluate the test reproducibility. Since two levels of feed concentrations were tested, for consecutive runs with different feed solids concentration, the feed tank was emptied and refilled as required. The slurries with different concentrations were stored separately. Whenever slurry replacement was needed, the feed tank was emptied and the slurry was collected and weighed. The detailed results for the individual tests are given in Appendix B.

Testing was done in accordance with the Run Order shown in Table 4.1. For example, for the first test, the feed tank was filled with slurry at a solids concentration of 30%, and the maximum filter time and the dry time were set to 120 s and 240 s, respectively. The air pressure was set to 100 psi. The slurry concentration was calculated based on the Marcy gauge measurement and was also measured by drying a slurry sample. These values are included in Table 4.1. Similarly, the operating conditions were set for subsequent tests based on the experimental design.

Table 4.2 A comparison of filtrate time for 20% and 30% solids concentrations.

20% Solids		30% Solids	
Run Order	**Filtrate Time** (s)	**Run Order**	**Filtrate Time** (s)
2	14	24	13
3	18	15	18
5	16	6	14
8	20	1	12
9	24	12	16
13	15	20	16
17	16	4	15
18	19	7	15
19	20	16	20
21	14	10	13
22	14	11	14
23	15	14	13
Mean	17.0		14.9

4.3 Initial Filtrate Time

The time for the filtrate to come out after the slurry pumps started was recorded as the initial filtrate time. Different initial filtrate times were obtained for 20% and 30% solids concentration. A comparison of initial filtrate times for 20% and 30% slurries at the same levels of maximum filter time, dry time, and air pressure is given in Table 4.2. For example, comparing run 2 and run 24, the initial filtrate time for run 2 (20% slurry) was higher than for run 24 (30% slurry). Also the mean time for all 20% slurry tests was higher than that of the 30% slurry tests thereby indicating that on average, it took less

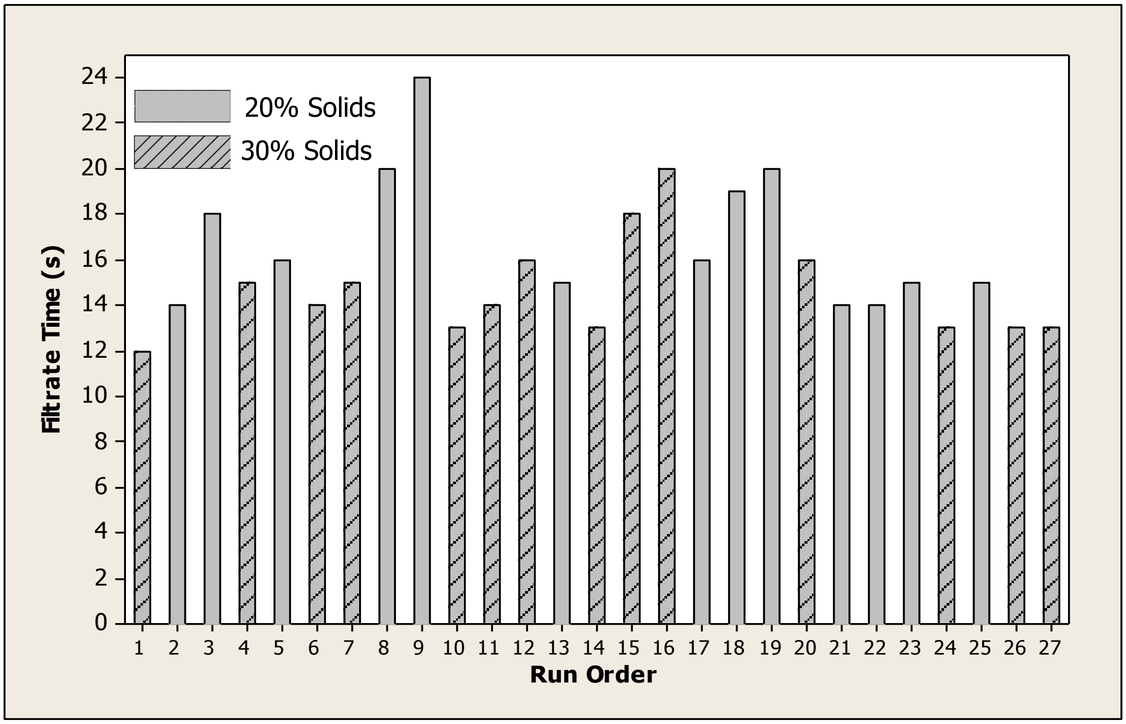


Figure 4.2 Variation of filtrate time with Run Order.

time for the filtrate to begin to come out at a higher solids concentration. Hence the cake formation time was shorter for the higher solids concentration slurry. This result agrees with previous research by Sung et al. [1994] in which they found that the cake formation time decreased significantly with the increase in solids concentration for vacuum filtration.

The head height of the slurry in the feed tank also had a slight effect on the initial filtrate time. A higher head in the feed tank caused the filtrate to come out faster. In the runs where slurry was replaced and the feed tank was filled to the top, the initial filtrate times were somewhat less. For consecutive runs at the same feed solids concentration done without slurry replacement, the initial filtrate time gradually increased as seen in

Figure 4.2. For example, a maximum difference of 7 seconds was observed in the case of 30% solids in runs 14 through 16. For the 20% solids tests, a maximum difference of 4 seconds was observed between runs 2 and 3.Because the 30% slurry was heavier than the 20% slurry, it took more time at low head levels to get pumped into the filter chamber.

4.4 Filter Cake Moisture Analyses

The variation of filter cake moisture with different test conditions was analyzed statistically using Minitab 15. The moisture values for the five filter cake samples (S1 to S5) are shown in Table 4.3. The mean of the five sample moistures (S1 to S5) was calculated as M5 as it was believed to give a better representation of the moisture content of the whole cake. However, the sample that was taken from the center of the cake (S5) had a very inconsistent moisture behavior as compared to the other four samples from the same cake. This was because the filter press was center fed, and some residual slurry was always present at the feed point. In spite of installing the residual slurry valve, this slurry remained in contact with center of the cake and hence increased the moisture of the central sample. To overcome the effect of this inconsistent central sample, the mean of the other four cake samples (M4) was calculated and analyzed for variance. The standard deviations corresponding to M5 and M4 are also included in Table 4.3.

Further, during some runs it was also observed that a small amount of residual slurry, which came out after opening the plates, splashed on the lower half of the filter cake. This could have increased the moisture of the lower half of the cake slightly. To take this factor into account, the mean of the two samples (M2) collected from the top of

Table 4.3 Filter cake sample moistures and filtrate results.

	Moisture Content (%)										Total Filtrate	Filtrate Solids
Run	**S1**	**S2**	**S3**	**S4**	**S5**	**M5**	s_{M5}	**M4**	s_{M4}	**M2**	**Wt (g)**	**Wt (g)**
1	25.7	25.8	26.5	28.3	39.1	29.1	5.7	26.6	1.2	26.1	5700.6	11.8
2	24.7	27.9	28.0	26.6	40.9	29.6	6.4	26.8	1.5	26.3	9735.3	8.6
3	25.1	26.2	26.2	26.3	39.9	28.9	6.2	26.1	0.6	25.7	9435.3	10.1
4	26.8	24.8	28.8	27.9	36.2	28.9	4.4	27.1	1.7	27.8	6225.8	10.2
5	22.5	24.4	21.2	22.6	40.1	26.1	7.9	22.6	1.3	21.8	6714.0	16.4
6	22.0	25.1	22.6	24.4	41.5	27.3	8.2	23.7	1.5	22.3	7429.9	18.1
7	23.6	24.5	23.1	25.6	46.1	28.6	9.8	24.2	1.1	23.4	6767.9	14.5
8	25.4	26.0	25.5	25.2	38.5	28.1	5.8	25.5	0.3	25.5	7110.0	18.1
9	23.1	23.5	24.9	26.9	36.0	26.9	5.3	24.6	1.7	24.0	9329.0	18.6
10	22.9	25.2	23.2	25.4	37.5	27.2	6.1	24.6	1.3	23.1	7303.6	17.5
11	26.4	29.1	27.0	31.1	40.4	30.8	5.7	28.4	2.2	26.7	5504.0	7.4
12	22.2	21.9	22.9	23.5	49.6	28.0	12.1	22.7	0.7	22.6	6659.9	15.5
13	25.4	28.3	28.9	25.3	37.9	29.2	5.2	27.0	1.9	27.2	5385.4	16.5
14	26.6	27.9	28.0	30.5	40.1	30.6	5.5	28.2	1.7	27.3	5138.5	6.6
15	24.3	26.2	25.5	27.3	39.1	28.5	6.0	25.8	1.2	24.9	5355.1	18.6
16	25.9	29.8	29.5	28.3	39.5	30.6	5.2	28.4	1.8	27.7	6222.4	15.7
17	27.3	25.4	25.5	29.7	38.1	29.2	5.3	27.0	2.0	26.4	5064.6	8.6
18	22.0	22.0	23.8	25.6	46.3	27.9	10.4	23.3	1.7	22.9	8149.6	17.6
19	26.1	24.8	28.5	28.7	41.4	29.9	6.6	27.1	1.9	27.3	6435.1	12.9
20	25.6	26.3	27.5	24.2	41.0	28.9	6.9	25.9	1.4	26.6	7726.6	12.3
21	22.5	25.2	22.9	25.6	40.2	27.3	7.3	24.0	1.6	22.7	8074.0	18.4
22	26.5	28.4	25.8	31.5	36.4	29.7	4.3	28.0	2.5	26.1	6645.9	10.8
23	25.8	28.1	25.7	30.1	34.7	28.9	3.7	27.4	2.1	25.7	7236.2	11.2
24	25.3	24.2	27.8	23.9	37.4	27.7	5.6	25.3	1.8	26.5	6434.9	18.1
25[1]	26.2	27.1	26.4	25.4	36.5	28.9	4.6	27.0	0.7	26.3	7048.7	12.4
26[2]	25.7	28.2	27.8	29.9	46.7	33.3	8.5	30.0	1.7	26.8	5293.2	9.6
27[3]	22.1	24.2	23.3	25.1	36.1	26.8	5.7	24.4	1.3	22.7	8820.7	12.0

[1] Replicate of run 3.

[2] Replicate of run 11.

[3] Replicate of run 10.

Table 4.4 Reproducibility of replicate tests.

	Moisture Content (%)							
Run Order	**S1**	**S2**	**S3**	**S4**	**S5**	**M5**	**M4**	**M2**
3	25.1	26.2	26.2	26.3	39.9	28.7	26.0	25.7
8*	25.4	26.0	25.5	25.2	38.5	28.1	25.5	25.5
25	26.2	27.1	26.4	25.4	36.5	28.3	26.3	26.3
Mean	25.6	26.4	26.0	25.6	38.3	28.4	25.9	25.8
s	0.55	0.59	0.48	0.60	1.69	0.32	0.38	0.44
11	26.4	29.1	27.0	31.1	40.4	30.8	28.4	26.7
14*	26.6	27.9	28.0	30.5	40.1	30.6	28.2	27.3
26	25.7	28.2	27.8	29.9	46.7	31.7	27.9	26.8
Mean	26.2	28.4	27.6	30.5	42.4	31.0	28.2	26.9
s	0.45	0.63	0.52	0.62	3.71	0.56	0.26	0.32
6	22.0	25.1	22.6	24.4	41.5	27.1	23.5	22.3
10*	22.9	25.2	23.2	25.4	37.5	26.8	24.2	23.1
27*	22.1	24.2	23.3	25.1	36.1	26.2	23.7	22.7
Mean	22.3	24.8	23.0	25.0	38.4	26.7	23.8	22.7
s	0.49	0.56	0.40	0.50	2.81	0.49	0.34	0.39

*The filter time never reached 240 s.

the filter cake was also calculated and analyzed for variance.

The filter cycle ran for approximately 85 s for the 30% solids slurry and approximately 110 s for the 20% solids slurry after which the probe was exposed and the filter cycle stopped. As the filter time never reached the maximum values of 120 or 240 s, the maximum filter time was not included for the Design of Experiment (DOE) analyses. As such, the tests conducted at different values of maximum filter time became replicates of each other. On combining these replicates with the three replicate tests done (Run Order 25-27), three sets of replicate tests were obtained, each set comprising three runs at

Table 4.5 Correlation coefficient results for the different models.

Sample	s	R^2	p-values		
	(%)	(%)	Feed Concentration	Dry Time	Air Pressure
S1	0.79	95.66	0.77	0.00	0.87
S2	0.62	95.61	0.78	0.00	0.02
S3	0.47	97.05	0.12	0.00	0.01
S4	0.51	95.28	0.29	0.00	0.00
S5	3.74	79.52	0.28	0.23	0.23
M5	0.50	93.89	0.22	0.00	0.61
M4	0.39	97.33	0.63	0.00	0.03
M2	0.51	96.76	0.27	0.00	0.06

the same conditions. From these sets, the reproducibility of the testing was calculated as shown in Table 4.4. The standard deviation (s) of samples S1 to S4 was approximately 0.55% for all tests. The standard deviation for M4 was approximately 0.30%. The value of s for sample S5 was unusually high. This was due to the residual slurry coming out at the center, which led to inconsistent results for S5.

With the eight models represented by the samples S1, S2, S3, S4, S5, M5, M4, and M2, full-factorial DOE analyses were done to quantify the effects of feed variables on the different moisture samples. The detailed results of the DOE analyses are given in Appendix B. To quantify the degree of correlation between moisture contents of different samples and feed variables, the values of s and R^2 for the eight models are shown in Table 4.5. The standard deviation represents the average difference between the actual moisture values and the predicted moisture values. R^2 explains the percentage of observed variation in the moisture values. These values of s and R^2 include variable interactions.

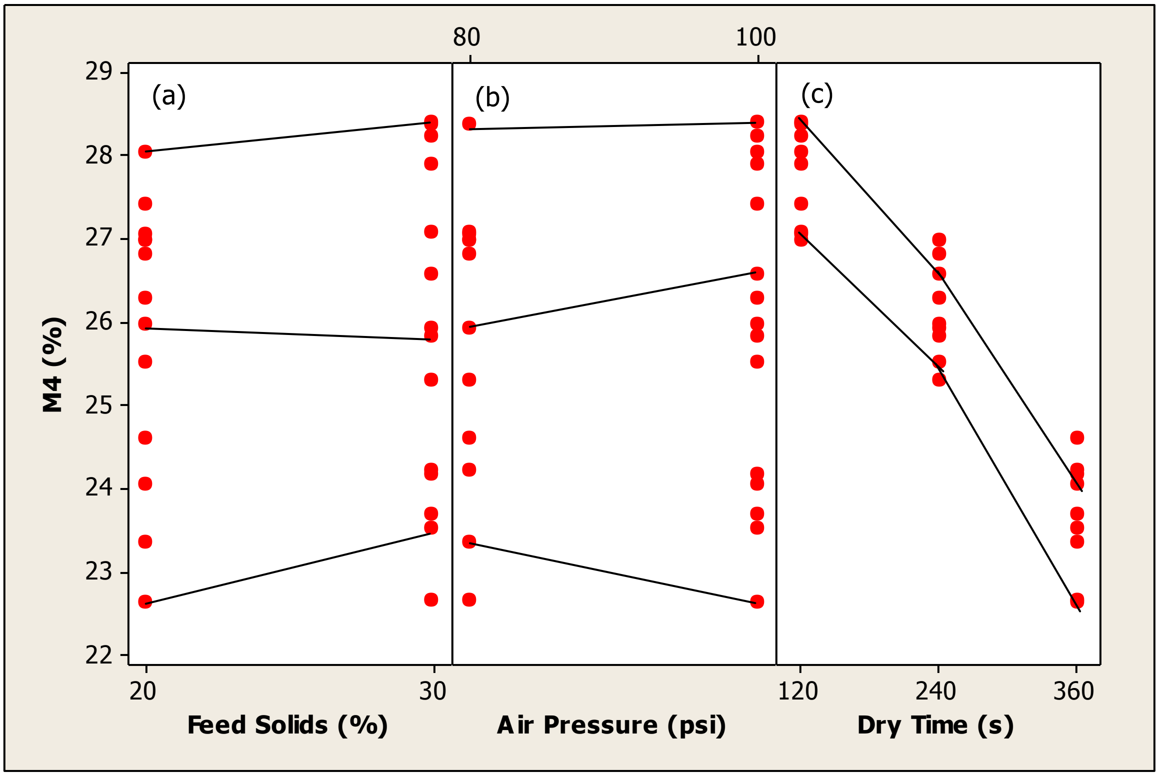


Figure 4.3 Matrix-plot of sample moistures with feed variables for M4 versus: (a) feed solids concentration; (b) air pressure; (c) dry time.

Table 4.5 shows that the model M4 explained 97.33% of the observed variation in the moisture content, and it had the minimum s value of 0.39%. Hence, this model was the best as compared to the other models. The model containing only S5 had the lowest value of R^2 and the highest s value, which was due to the inconsistent moisture values of S5.

A plot of sample moistures with operating variables for the M4 model is illustrated in Figure 4.3. The points on the graph represent filter cake moistures for different operating conditions. For example, for Figure 4.3a, the highest data point at

20% solids, which corresponds to run 22, is joined to run 11 (30% solids). The other lines represent the same operating conditions except for the variable in question. For feed solids concentration and air pressure, the moisture behavior was inconsistent. On the other hand, the moisture content consistently decreased with an increase in dry time (see Figure 4.3c).

For all the statistical analyses done using Minitab, a p-value of 0.05 was predefined, which corresponds to a 95% confidence level. If there is no significant change in a Y variable when changing the X variable, the p-value will be greater than 0.05 [Neter et al., 2005]. From the DOE analyses, the p-values of the feed solids concentration were all higher than 0.05. This indicates that feed solids concentration was insignificant in explaining the moisture behavior. The solids concentration inside the filter chamber continuously increased as the slurry pumps fed the filter plates. Different values of feed concentration only impacted the filling time as it took longer to fill the chamber with slurry of lesser solids concentration. As the 20% slurry was pumped, at some point, the concentration inside the chambers increased to 30% from where it dewatered in a similar manner as the slurry of an initial solids concentration of 30%. For vacuum filtration it was found that lower moisture values corresponded to higher solids concentration [Sung et at., 1994]. This was explained by a decrease in the particle segregation at higher solids concentrations. However, in a filter press chamber, as the chamber fills, the particle segregation effects are reduced, minimizing the effect of initial solids concentration.

Previous research using a similar model of filter press showed feed solids concentration was a significant variable [Patwardhan et al., 2005]. In that study, the maximum filter time was used to terminate the filter cycle as opposed to the probe level as used for this series of tests. In the current study, the filter cycle terminated when the filtrate dropped below the probe level. The filter time depended on the feed solids concentration and was lower for the 30% slurry (85 s) as compared to the 20% slurry (110 s). For slurries of different solids concentration, the final filter cake moistures would be different if the filter time was the same. This would result in more dewatering for the higher concentration slurry and hence lower filter cake moisture.

Air pressure was expected to be a significant variable because higher air pressures should force more filtrate from the particle voids. In most cases, including M4, the p-values for air pressure were less than 0.05. Hence, air pressure was considered significant overall. This result agrees with Mishra [1988], who showed a decrease in moisture content with an increase in air pressure in a vacuum filtration process.

Dry time was found to be a significant variable in all models (except for S5) as its p-value was less than 0.05. During the dry cycle, the air flow deblinded the filter membrane. The air flow also extracted more filtrate from the particle voids producing a drier cake. More filtrate came out for the longer dry cycle. Hence, dry time had the most significant impact on the cake moisture. This result agrees with the findings of Patwardhan et al. [2005] and Truatman [1992], who used filter presses for testing different slurries.

On the basis of the above results, the model represented by M4 is considered to be the best model for explaining the variation in moisture values. Only the interaction

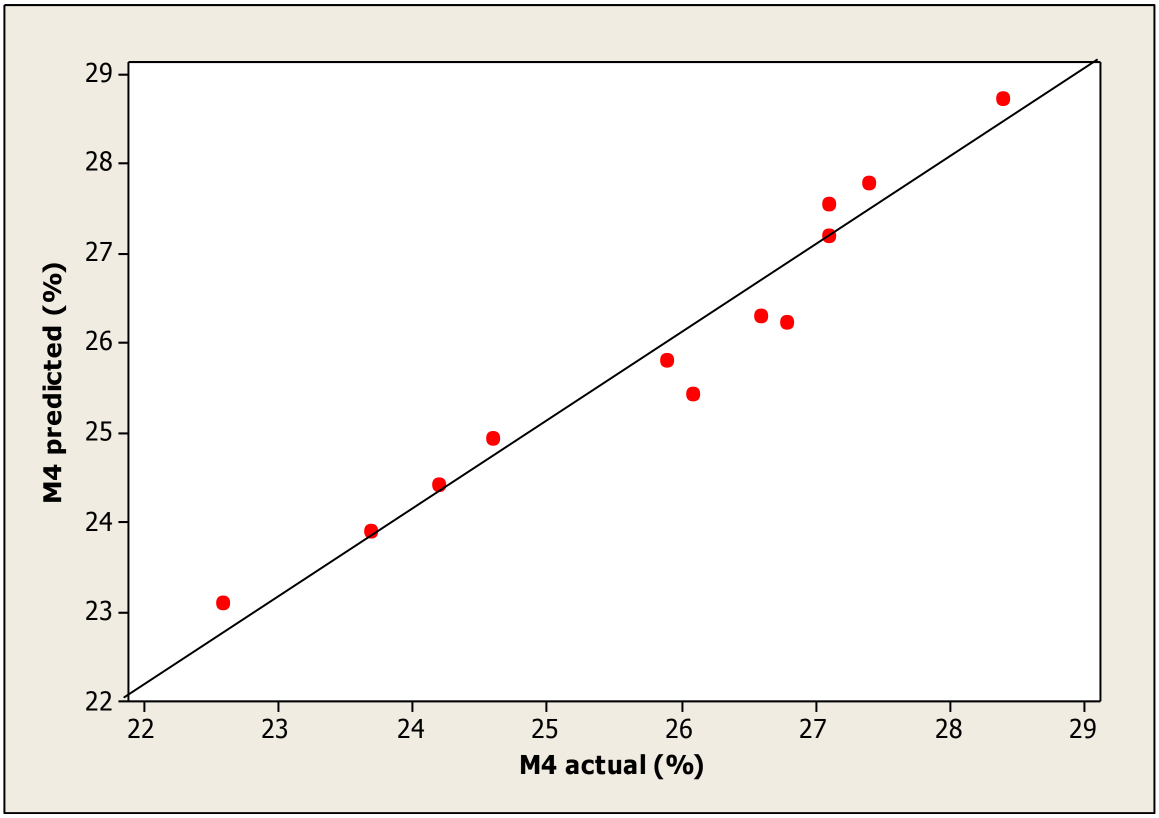


Figure 4.4 Plot of predicted values of M4 versus actual values of M4 including the interaction effects.

between air pressure and dry time was statistically significant. Increasing the dry time at a higher air pressure had a statistically significant impact on the filter cake moisture as compared to increasing the dry time at lower air pressure. Figure 4.4 shows the variation of M4 predicted versus the actual M4 values.

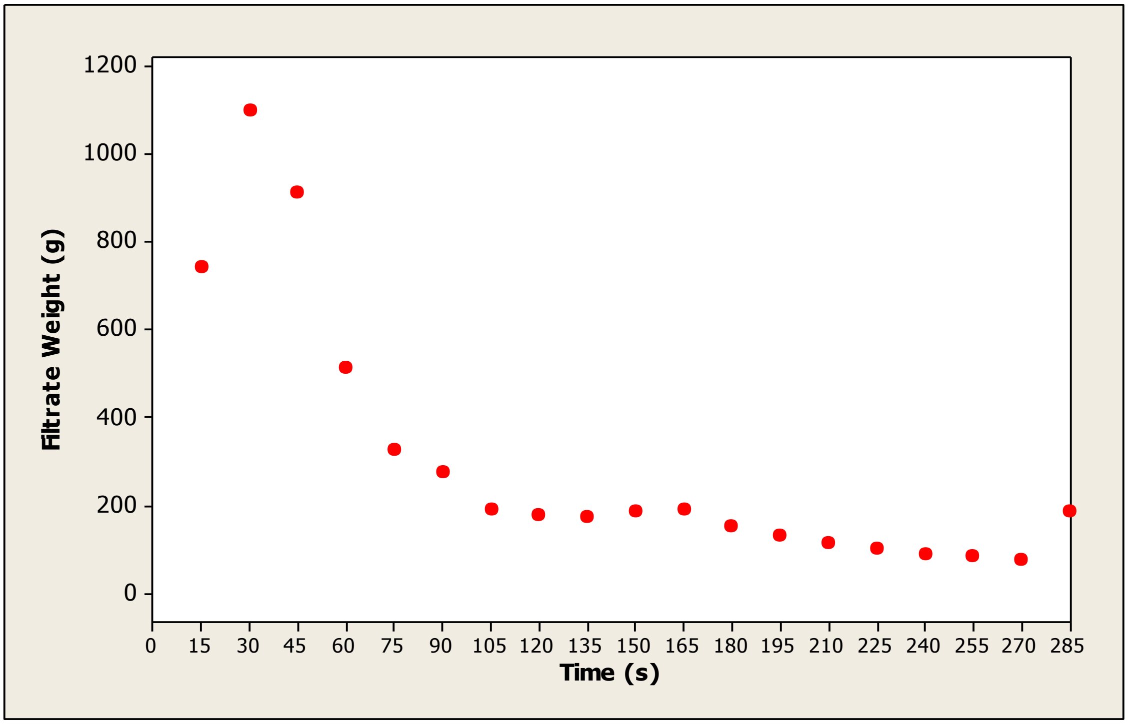


Figure 4.5 Variation of filtrate weight with filtrate collection time for run 1.

4.5 Filtrate Mass Flow Rate

The weights of different filtrate samples were measured to calculate the filtrate mass flow rates. The variation of filtrate weights collected at different times for run 1 is shown in Figure 4.5. For this test, the filtrate was collected for 285 seconds of which 240 s was the dry cycle and 10 s was the pause time between the filter cycle and the dry cycle. Hence, the time between the filtrate coming out and end of the filter cycle was 35 s. Also, from Table 4.2, the initial filtrate time for run 1 was 12 s. Therefore the total cycle time for run 1 was 297 s. The different values of filtrate weights for all the Plant 1 tests are given in Appendix B.

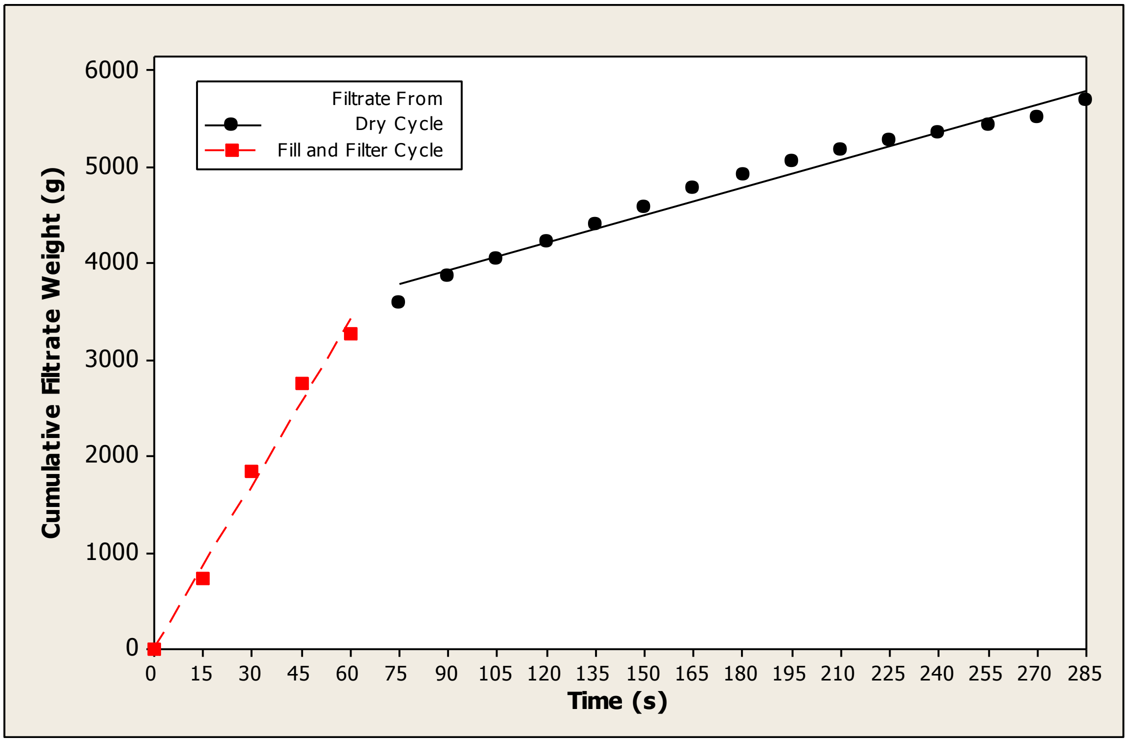


Figure 4.6 Variation of cumulative filtrate weight with time for run 1.

The dry cycle started at 45 s, i.e., after 35 s of the fill and filter cycles and 10 s of the pause time. From Figure 4.5, it can be seen that the incremental filtrate weight increased up to 30 s and then decreased. At 165 s, a slight increase in filtrate weight occurred, which was due to a change in air pressure. The air compressor supplied air at 100 psi and then stopped. As the compressed air was used, the pressure in the air line decreased below 100 psi, and the compressor restarted automatically, increasing the pressure to 100 psi. This cycling led to some fluctuations in filtrate mass flow rate. Also, the last bucket was used to collect any filtrate flushed out of the filtrate lines using the air-blow after the cake discharge. Therefore it collected filtrate beyond 285 s. Hence, it had a higher weight than expected for that sampling duration.

The cumulative weight of the filtrate as a function of cycle time is shown in Figure 4.6. As can be seen the filtrate weight increased steeply until 60 s and then increased at a lesser rate over the remaining 285 s. The mass flow rate of filtrate was approximately 56.5 g/s up to 60 seconds and then decreased to approximately 9.6 g/s over the remainder of the run. This result agrees with those of Almy and Lewis [1990], who obtained similar behavior of filtrate flow using wastewater sludge in a filter press and with Voit et al. [1995], who obtained similar behavior of filtrate flow using hafnium oxide sludge in a filter press. The regression model for the variation of cumulative filtrate mass flow with time for run 1 is

$$\text{Cumulative Filtrate Wt(t)} = \begin{cases} 30 + 56.5\,\mathrm{t}, & 0 \leq \mathrm{t} \leq 60 \\ 3074 + 9.56\,\mathrm{t}, & 75 \leq \mathrm{t} \leq 285 \end{cases} \tag{4.1}$$

The rate of filtrate flow for the fill and filter cycles was 5 times higher than for the dry cycle. This indicates that if the fill and filter cycles would have run for a longer duration, the filtrate may have continued to come out at a faster rate. However, it might have been possible that at 60 s, the bulk of the filtrate from the fill and filter cycles was extracted and only an air blow could extract more filtrate. To evaluate this, additional runs were conducted at higher values of filter time, which is discussed in Section 4.7.

Run 8 had the same test conditions for 20% slurry as run 1 for 30% slurry. The variation of cumulative filtrate weight for run 1 and run 8 with time is shown in Figure 4.7.

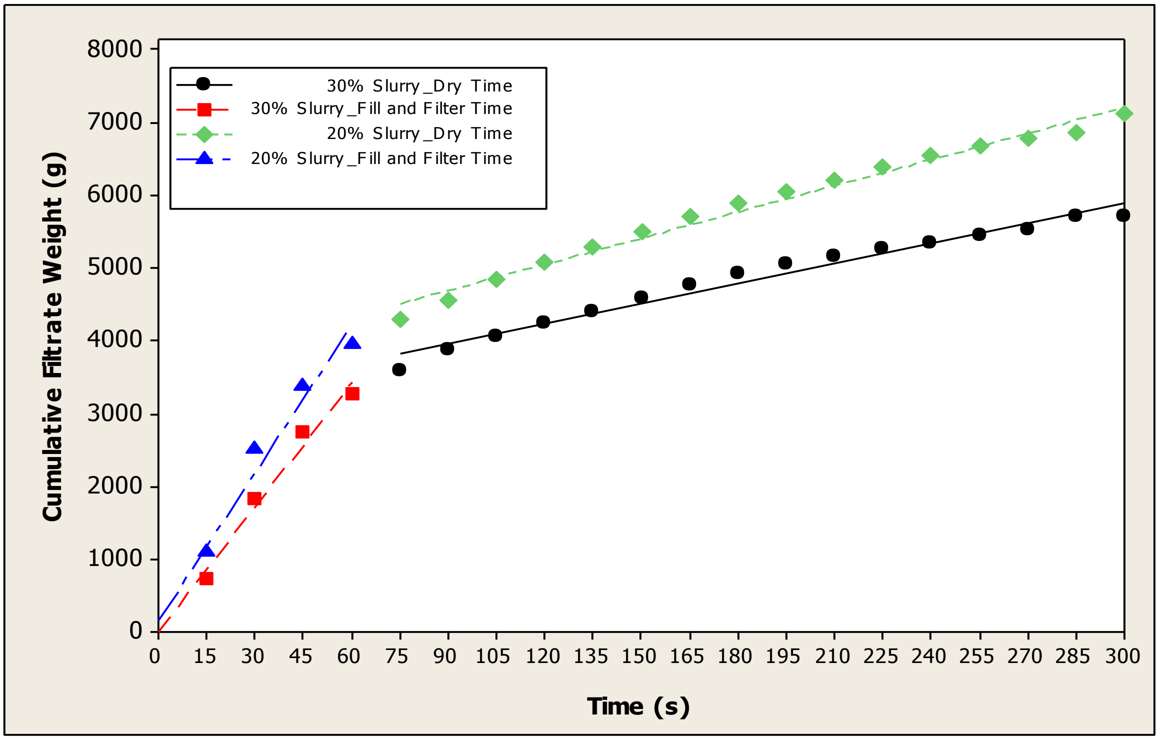


Figure 4.7 Variation of cumulative filtrate weight with time for run 1 and run 8.

The regression model for the set of curves for run 8 is

$$\text{Cumulative Filtrate Wt(t)} = \begin{cases} 154 + 67.7\,t\,, & 0 \le t \le 60 \\ 3608 + 12\,t, & 75 \le t \le 300 \end{cases} \qquad (4.2)$$

The slopes of the regression lines in Equation 4.2 are higher than those in Equation 4.1. This indicates that the 20% slurry dewaters at a faster rate than the 30% slurry, as seen in Figure 4.7. Also, it is evident from Figure 4.8 that the individual weight fractions of filtrate for 20% slurry were higher than those of 30% slurry for the same times and at the same test conditions.

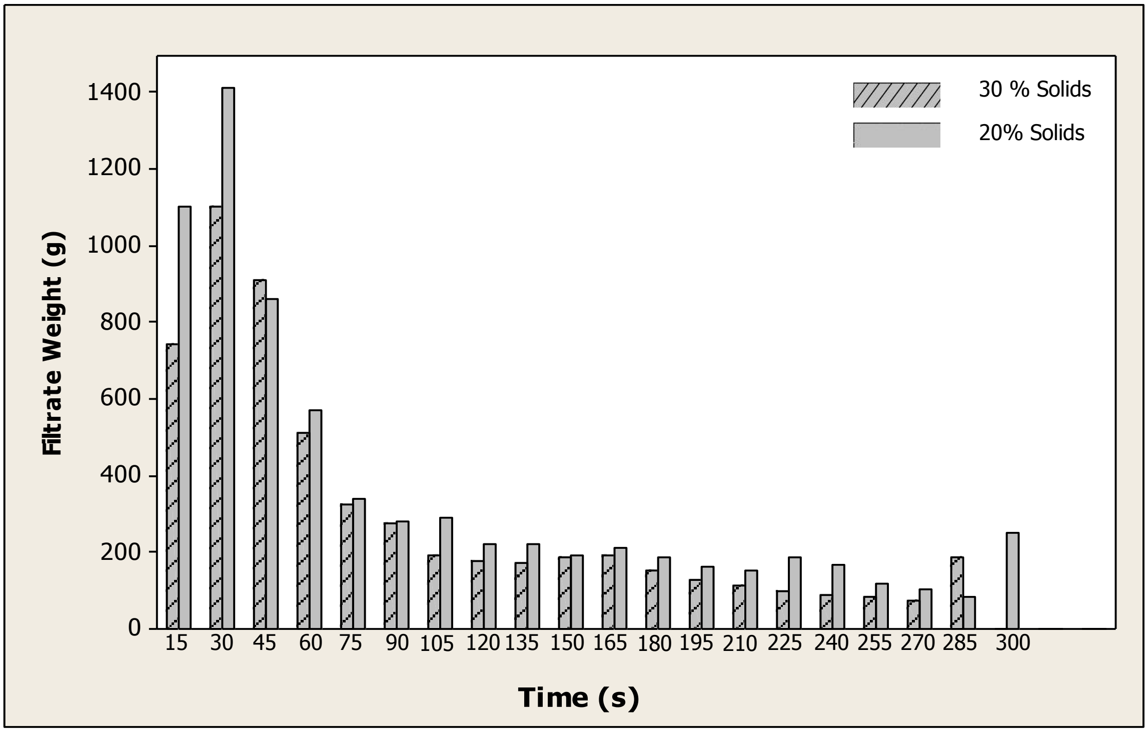


Figure 4.8 A comparison of filtrate weights for run 1 and run 8.

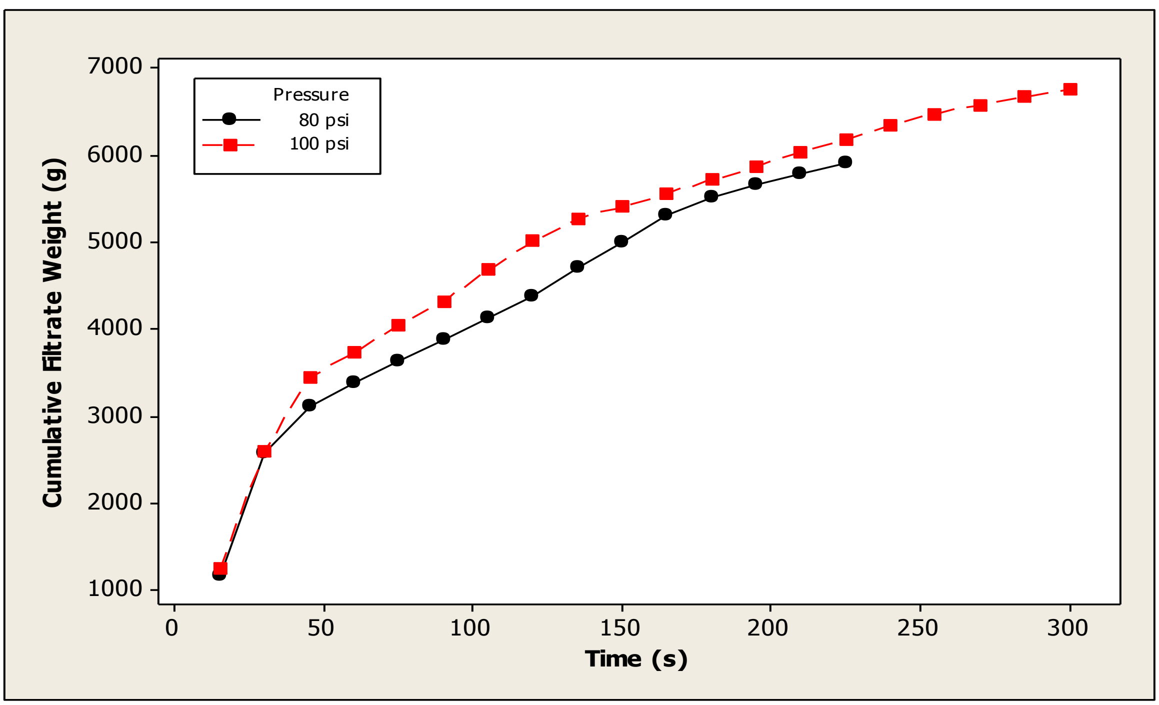


Figure 4.9 Variation of cumulative filtrate weight with time for different pressures.

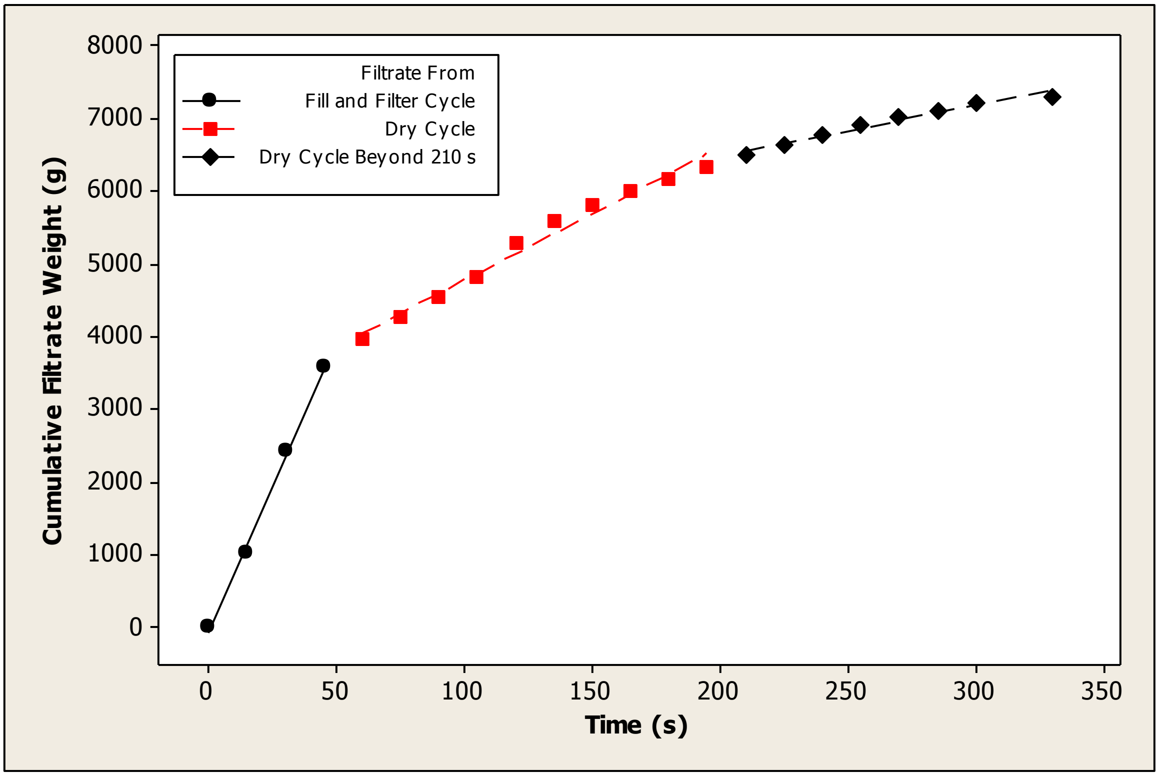


Figure 4.10 Variation of cumulative filtrate weight with time for run 21.

Figure 4.9 shows the variation of cumulative filtrate weight with time for different air pressures. The filtrate flow rate for 100 psi (run 6) was higher than that of 80 psi (run 7) with the other conditions constant. A higher pressure forced the filtrate from the filter cake voids at a faster rate. The total weight of filtrate collected was also higher for the higher pressure. However, after approximately 160 s, the filtrate flow rates at both 80 psi and 100 psi were similar.

Figure 4.10 shows the variation of cumulative filtrate weight with time for run 21. It can be seen that at longer dry times, the rate of filtrate flow decreased. The cumulative

Table 4.6 Distribution of solids weight for the filtrate samples.

Time (s)	**Filtrate Wt** (g)	**Solids Wt** (g)	**Solids Concentration** (%)
15	740.5	3.9	0.52
30	1100.7	2.5	0.23
45	910.7	0.4	0.04
60	510.7	1.9	0.37
75	325.6	1.1	0.33
90	275.6	0.8	0.29
105	190.5	0.4	0.23
120	175.4	0.3	0.18
135	170.4	0.2	0.11
150	185.3	0.1	0.04
165	190.3	0.0	0.02
180	150.3	0.0	0.00
195	130.2	0.0	0.00
210	114.2	0.0	0.00
225	98.1	0.0	0.00
240	86.1	0.0	0.00
255	84.1	0.0	0.00
270	76.1	0.0	0.00
285	186.0	0.3	0.14
Total	5700.6	11.8	0.21

filtrate mass flow rate for the fill and filter cycles was 81 g/s, which decreased to 19 g/s during the dry cycle until 210 s and then further decreased to 6 g/s until the end of the dry cycle. Hence, dry times beyond 210 s had very little effect as the bulk of the filtrate was already extracted from the filter cake voids.

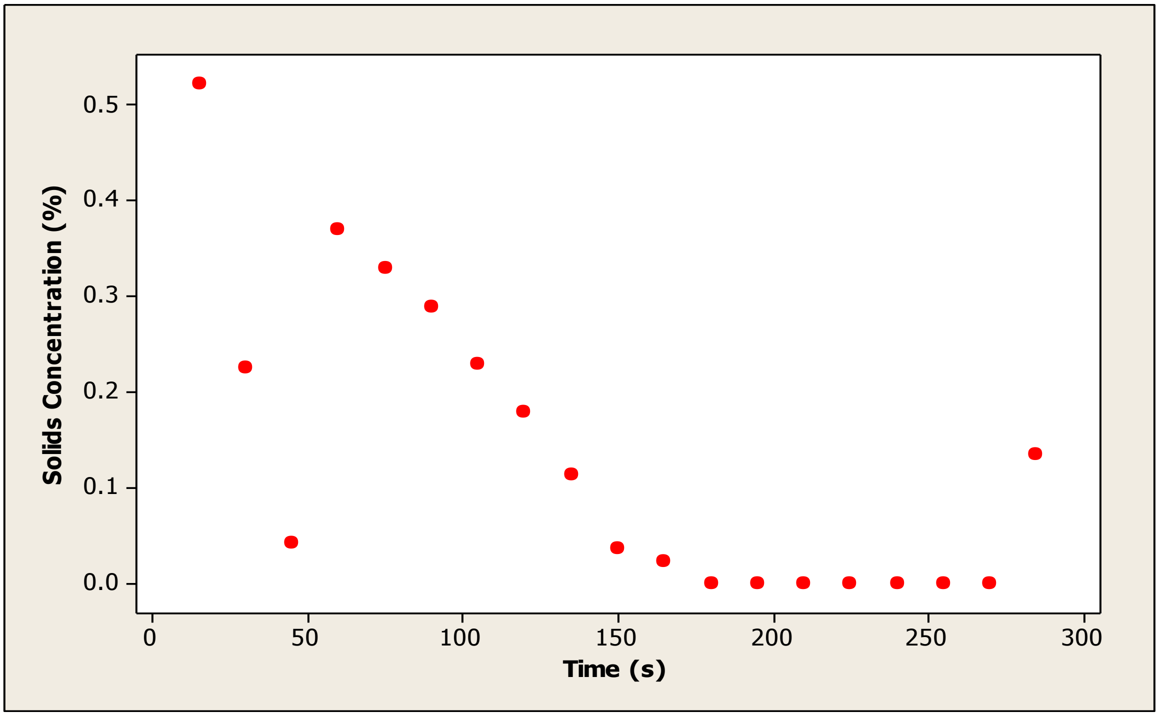


Figure 4.11 Variation of solids concentration in timed filtrate samples for run 1.

4.6 Filtrate Solids Content

Table 4.6 shows the distribution of solids for the filtrate samples for run 1. The variation of solids concentration of the filtrate samples with time is shown in Figure 4.11. The first filtrate sample had the highest solids concentration. (0.52%) After which the solids concentration decreased to 0.04% at 45 s. As the feed slurry entered the chamber and was deposited on the filter cloth, some fine solids passed through the filter cloth until a layer of solids was formed. After the layer of solids was formed, no more fine solids came out with the filtrate. The solids concentration again increased to 0.37% at 60 s, which was the time when the dry cycle started. Air flow during the dry cycle deblinded the filter cloth surface, which caused additional particles to be carried to the filtrate.

As the dry cycle proceeded, the solids concentration again decreased and became zero. Since the last sample contained all the flushed-out filtrate in the lines, it contained some solids. The entire filtrate sample contained 11.8 grams of solids and had an average solids concentration of 0.21%. The total weight of filtrate and total filtrate solids content for all the runs is given in Table 4.3.

4.7 Long Filter Cycle Runs

As noted in section 4.5, for run 1, the rate of filtrate flow during the filter cycle was 5 times higher than for the dry cycle, which may have been due to the short duration of the filter cycle. The duration of the filter cycle was controlled by the probe height and the maximum filter time setting. If the filtrate level in the filtrate tank dropped below the probe height and the probe was exposed, the filter cycle stopped. In such cases, the maximum filter time was never attained. On the other hand, if the filtrate level was above the probe height then the filter cycle ended when the maximum filter time was reached.

To evaluate the effects of filter time on filtrate rate and filter cake moisture content, tests were conducted at longer filter times. For these tests probe level 2 was used, which was 25 mm above the bottom of the filtrate tank. This would allow the filter cycle to run for a longer duration as the probe would be exposed only when the filtrate level fell below 25 mm. The four filter times were 200 s, 500 s, 1000 s, and 2000 s. Even at 2000 s, the filtrate was still in contact with the probe. The summary of test conditions is given in Table 4.7.

Table 4.7 Summary of test conditions for long filter times for probe level 2.

Run Order	**Feed Conc** (%)	**Max Filter Time** (s)	**Dry Time** (s)	**Air Pressure** (psi)	**Calc Solids** (%)	**Measured Solids** (%)
28	20	200	240	100	20.3	18.7
29	20	500	240	100	18.7	16.9
30	20	1000	240	100	20.3	20.8
31	20	2000	240	100	18.7	15.9

As before, slurry concentration was calculated based on the Marcy gauge measurement and was confirmed by drying a slurry sample. These values are included in Table 4.7. These tests were done at 20% solids concentration with a dry time of 240 s and an air pressure of 100 psi. These results were compared to runs 1, 3, 8, 15, and 25, which were conducted at the same conditions except for the filter time. The filter time for these runs was approximately 50 s, and the average cake moisture content was 26.2%. Figure 4.12 shows the variation of mean moisture content (M4) with filter time. Similar curves have been obtained by Wakeman and Tarloton [1994] for the variation of filter time with moisture content who tested wastewater sludge on a filter press.

A filter cake moisture of 17.2% was obtained after a filter time of 2000 s. Hence by increasing the maximum filter time from 50 s to 2000 s, the final moisture content can be reduced an additional 10%. However, very long cycle times have a significant effect on the unit capacity, which is discussed in section 4.9.

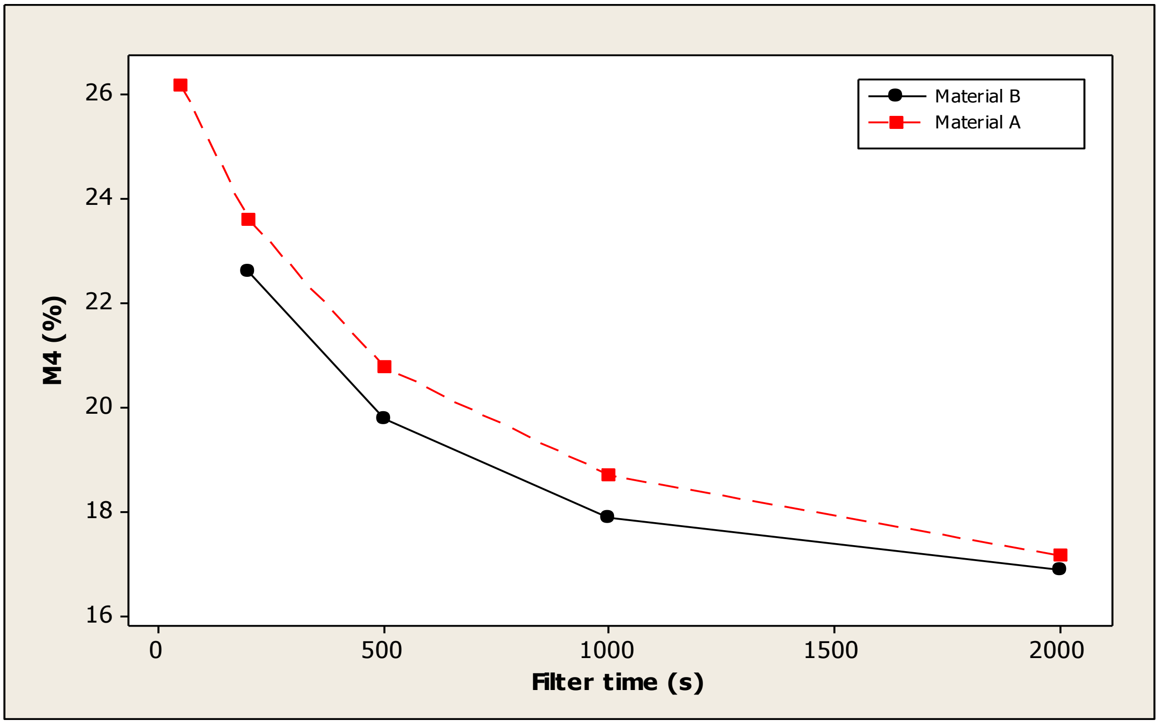


Figure 4.12 Variation of moisture content with filter time.

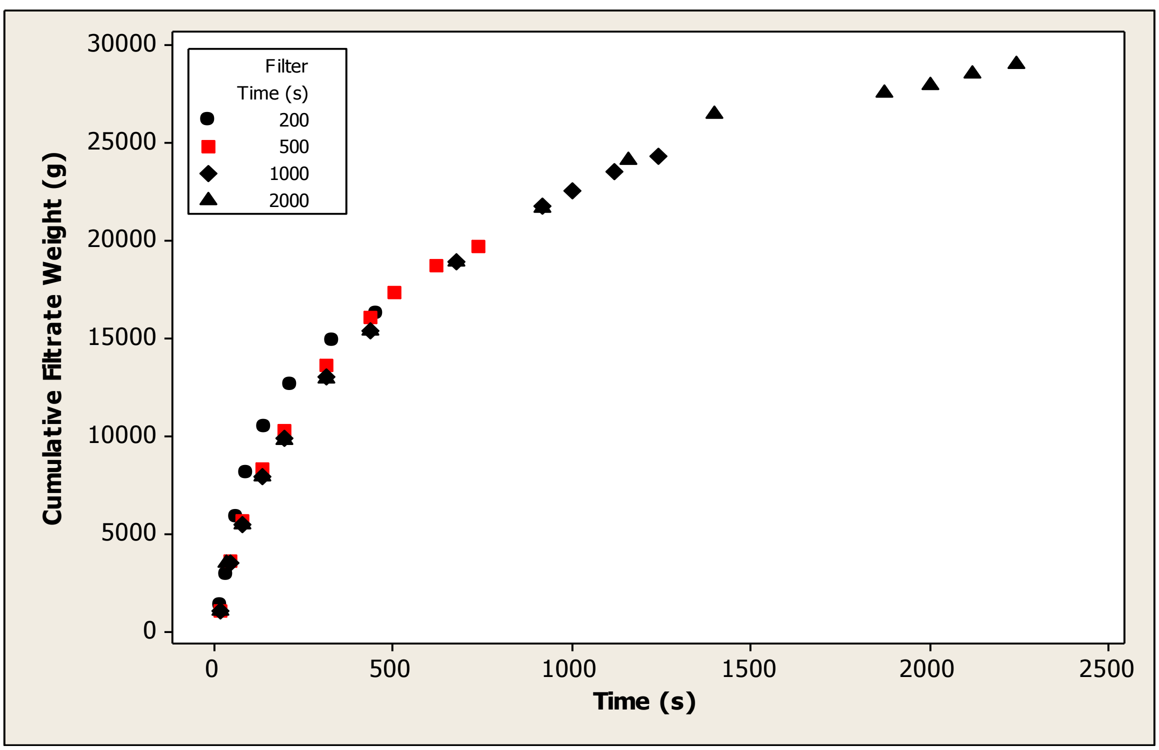


Figure 4.13 Variation of cumulative filtrate weight at long filter times.

Table 4.8 Summary of test results for long filter times.

Run Order	Moisture Content, (%)					Wet Cake Wt (g)	Total Filtrate Wt (g)
	S1	**S2**	**S3**	**S4**	**M4**		
28	23.2	23.9	23.1	24.2	23.6	5500	16247
29	20.5	21.2	19.9	21.6	20.8	5735	19755
30	18.2	19.0	19.1	18.5	18.7	7253	24302
31	16.9	17.3	17.0	17.5	17.2	7491	29012

The variation of cumulative filtrate weight for runs 28-31 is given in Figure 4.14. As was seen in the previous testing, the slopes of all four curves decrease with time, which indicates that the rate of filtrate flow decreases with time. At longer filter times, the cumulative filtrate flow rates tended to become constant. Figure 4.13 also indicates that the tests done were reproducible.

Table 4.8 shows the different sample moistures for these runs along with total cake weight for each test. In between runs 28 to 31, the greatest increase in the total cake weight occurred between filter times of 500 seconds and 1000 seconds. This result was in agreement to the results obtained by Mishra [1988], who found that during vacuum filtration, the weight of the filter cake increased faster initially.

4.8 Long Filter Cycle Runs – Material B

As noted in Chapter 1, an advantage of a plate-and-frame filter press is that no flocculants are needed during normal operation. However, to determine if there were any improvements in the dewatering behavior due to additional flocculants, another series of tests were conducted on a sample of flocculated slurry, which was obtained from the belt

Table 4.9 Summary of test conditions for material B for probe level 2.

Run Order	**Feed Conc.** (%)	**Max. Filter Time** (s)	**Dry Time** (s)	**Air Pressure** (psi)	**Calc Solids** (%)	**Measured Solids** (%)
32	20	200	240	100	18.7	18.1
33	20	500	240	100	17.2	16.6
34	20	1000	240	100	20.3	18.5
35	20	2000	240	100	20.2	18.9

filter press product (material B). The belt filter press was producing filter cake at an average moisture content of 25%. Tests were conducted on material B at maximum filter times of 200 s, 500 s, 1000 s, and 2000 s. As shown in Table 4.9, these tests were conducted at the same conditions as runs 28 to 31. The summary of results is shown in Table 4.10.

The variation of the average cake moisture with filter time for material B is included in Figure 4.12. For a given filter time, a lower cake moisture was obtained using material B. This difference was approximately 1% until 1000 s. At 2000 s, the final cake moistures were nearly the same for material A and material B. Similar results were obtained by Sung [1994] who found that the addition of flocculants produced lower cake moistures during vacuum filtration of coal slurry. However, since material B was remixed, the floccs might be broken, negating any effect of additional flocculants.

Material B slurry dewatered faster initially, which is seen in Figure 4.14. This result agrees with Meenan [1988] and Ginistry et al. [2007], who tested the effect of flocculants on coal slurry using vacuum filters. For longer filter times, the presence of more solids in the chamber negates the effect of flocculants. It can be seen that after

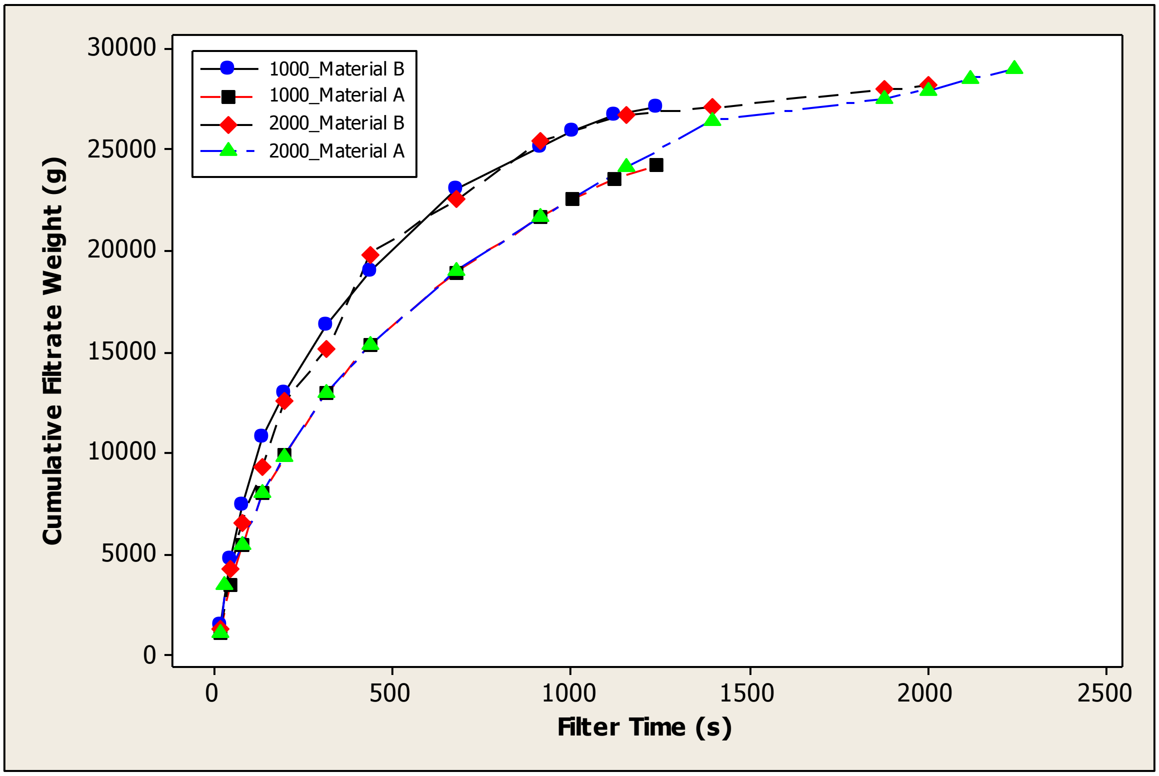


Figure 4.14 Comparison of filtrate flow rates for material A and material B.

1500 s, the filtrate flow rates for material A and material B were approximately the same.

The total cake weight and total filtrate weight for material B were similar to those obtained for material A. A comparison of filter cake moistures for the plate-and-frame filter press with those of the belt filter press indicates that the filter press is capable of achieving lower moisture contents even without the use of additional flocculants. This result was in agreement with the results obtained by Mayer [2008], who made a comparison between a plate-and-frame filter press and a belt filter press when dewatering wastewater sludge. Based on these results it can be concluded that additional flocculant addition is not needed in a normal filter press operation but it can have some benefits in

Table 4.10 Summary of test results for material B.

Run Order	S1 (%)	S2 (%)	S3 (%)	S4 (%)	M4 (%)	Total Cake Wt (g)	Total Filtrate Wt (g)
32	22.3	23.2	22.1	22.9	22.6	5951	18687
33	19.8	20.2	19.6	19.9	19.8	6719	24393
34	17.4	18.5	18.1	17.7	17.9	8604	26546
35	16.8	17.3	17.1	16.8	16.9	9119	28166

terms of increasing the rate of filtrate flow and producing slightly lower moisture content. The filtrate solids content of the material B runs was slightly lower as compared to material A. The impact on the unit capacity is discussed in the next section.

4.9 Unit Capacity Calculations

The unit capacity of the filter press is defined as

$$C = \frac{\text{Total Weight of Dry Cake (kg)}}{\text{Total Cycle Time (hr)} \times \text{Area of Filter Plates (m}^2\text{)}} \tag{4.3}$$

The unit capacity calculations were done for the longer filter times (runs 28 to 31) and compared to a short filter time (run 1). Calculations were also done for the tests using material B (runs 32 to 35). The total weight of dry cake was the sum of main cake weight and all the five sample weights times the average dry solids content (100 – M4) of the cake. The total cycle time was the sum of initial filtrate time and the filtrate collection time. A pause time of 10 seconds was incorporated between the fill cycle and the filter cycle to take the pressure readings and a pause time of 60 seconds was incorporated between the filter cycle and the dry cycle to drain the residual slurry from the feed lines

Table 4.11 Unit capacities of selected runs.

Run Order	**Total Cycle Time** (s)	**Total Wet Wt** (g)	**M4** (%)	**Total Dry Cake** (g)	**Unit Capacity** (kg/hr/m^2)
1	302	5013	26.0	3709.6	3.6
28	458	5500	23.6	4202.0	2.7
29	755	5735	20.8	4543.0	1.8
30	1260	7253	18.7	5896.5	1.4
31	2261	7491	17.2	6204.8	0.8
32	455	5951	22.6	4604.4	3.0
33	755	6719	19.8	5388.6	2.1
34	1256	8604	17.9	7061.7	1.7
35	2256	9119	16.9	7577.9	1.0

in each run. However, the pause times were not included in the unit capacity calculations as they would not be the part of a typical filtration cycle. A summary of the unit capacities runs is given in Table 4.11.

The variation of unit capacity with M4 for the above runs is shown in Figure 4.15. The filter unit capacity decreases significantly for the lower cake moistures. For material B, the unit capacity is slightly higher than for material A at the same value of M4, which was due to higher filtrate flow rates. The highest unit capacity of 3.6 kg/hr/m^2 was obtained for run 1 due to its lowest cycle time. Although, the total dry cake weight increased with increasing cycle time, the high values of total cycle time superseded this increase and reduced the capacity. The maximum and minimum values of unit capacities for material A were 3.6 kg/hr/m^2 (for M4 of 26%) and 0.8 kg/hr/m^2 (for M4 of 17.2%).

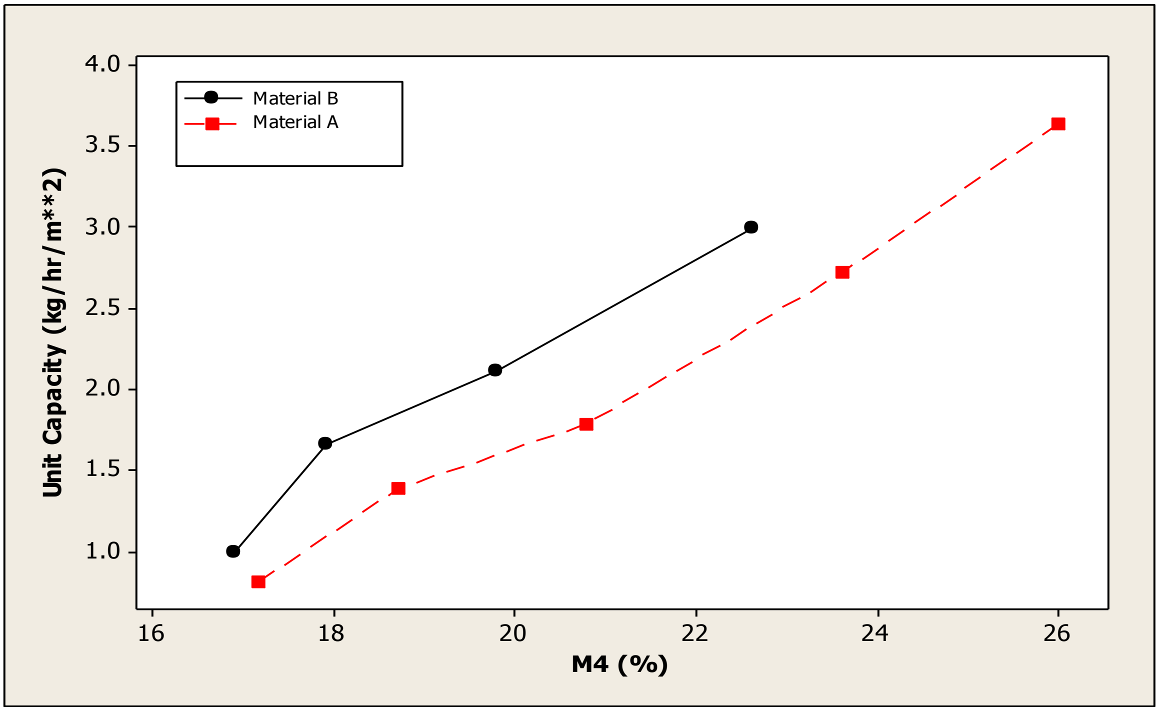


Figure 4.15 The variation of unit capacity with M4.

4.10 Process Applications

A graphical approach was developed to relate the total filter press cycle times with the filter cake moistures and the unit capacities. Figure 4.16 shows the combined plot of M4 with unit capacity, filter time, and total cycle time for dry times of 120 s and 240 s for material A. For example, a filter cake moisture of 22.1% was obtained for both dry times at different conditions. As seen in Figure 4.16a, for the 120 s dry time, a longer filter time was needed to attain 22.1% moisture as compared to the 240 s dry time run (2000 s versus 400 s). Consequently, as seen in Figure 4.16b, the total cycle time was much higher for the 120 s dry time run as compared to the 240 s dry time run (2141 s versus 700 s). In spite of the higher dry cake weight for the 120 s dry time run, due to the longer total cycle time, the unit capacity for the 120 s dry time run was lower than for the 240 s dry time run as seen in Figure 4.16c (0.9 kg/hr/m^{2}versus 2.2 kg/hr/m^2). Figure 4.16d gives the direct variation of unit capacity with M4 for the two dry times. Similarly, at a predefined total cycle time different values of filter time, M4, and unit capacities can be obtained. Hence this approach can be used to estimate the different operating conditions needed to obtain a given product. Moreover these values provide scale-up information when processing similar feed material.

Figure 4.17 shows the combined plot of M4 with unit capacity, filter time, and total cycle time at the dry time of 240 s for material A and material B. For example, a filter cake moisture of 18.7% was obtained for both material A and material B at different conditions. As seen in Figure 4.17a, for material B, a shorter filter time was needed to attain 18.7% moisture as compared to material A (750 s versus 1000 s). Consequently, as seen in Figure 4.17b, the total cycle time was shorter for material B as compared to the material A (1100 s versus 1260 s). Also since for the material B the dry cake weight was higher as compared to material B (5388 g versus 5896 g), therefore the unit capacity for material B was higher than for material A as seen in Figure 4.17c (1.9 kg/hr/m^2 versus 1.4 kg/hr/m^2). Figure 4.17d gives the direct variation of unit capacity with M4 for material A and material B slurry. Similarly, at a predefined total cycle time different values of filter time, M4, and unit capacities can be obtained.

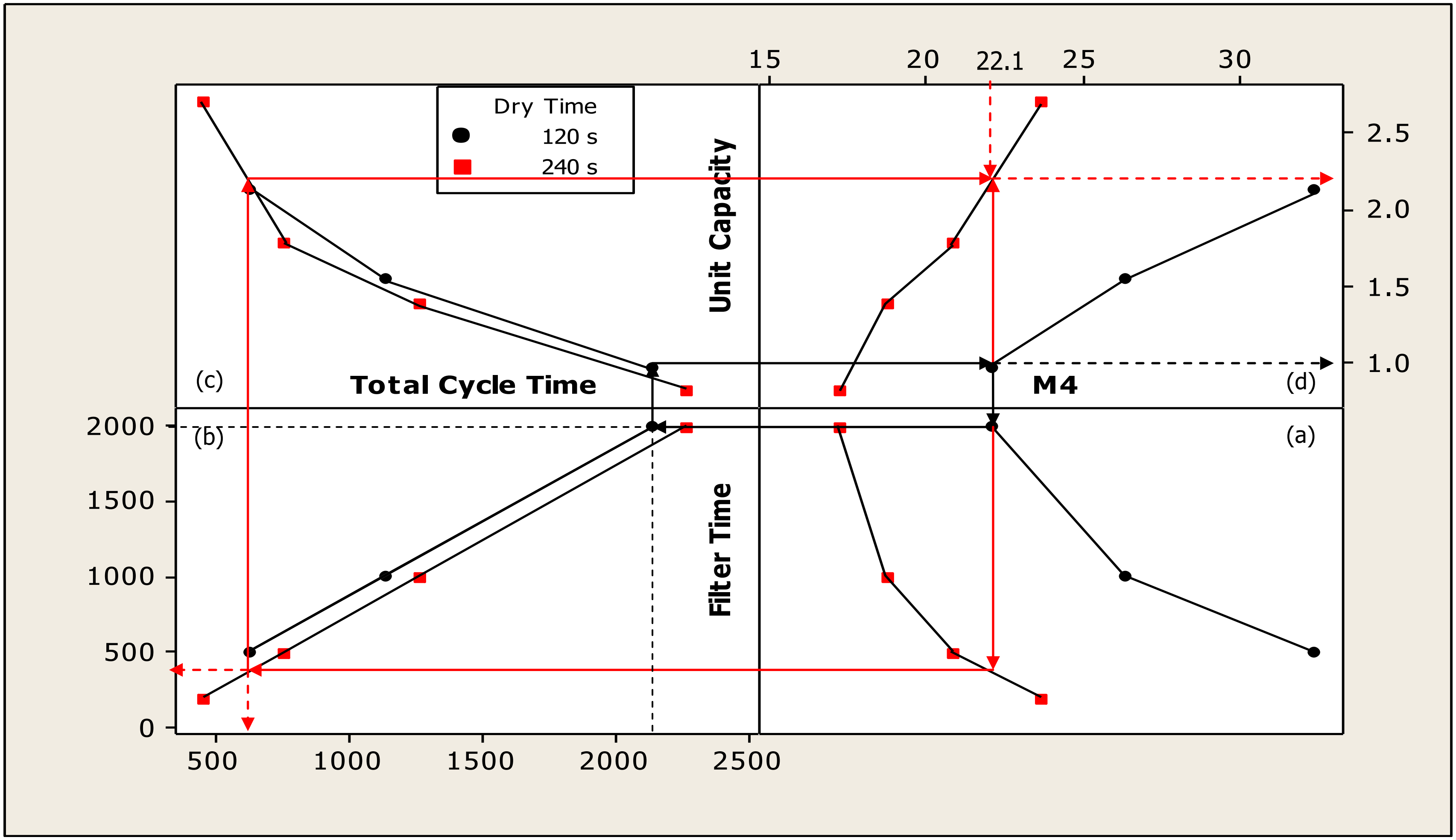


Figure 4.16 Variation of (a) M4 (%) with filter time (s); (b) filter time (s) with total cycle time (s); (c) total cycle time (s) with unit capacity (kg/hr/m^2); and (d) unit capacity (kg/hr/m^2) with M4 (%) for material A.

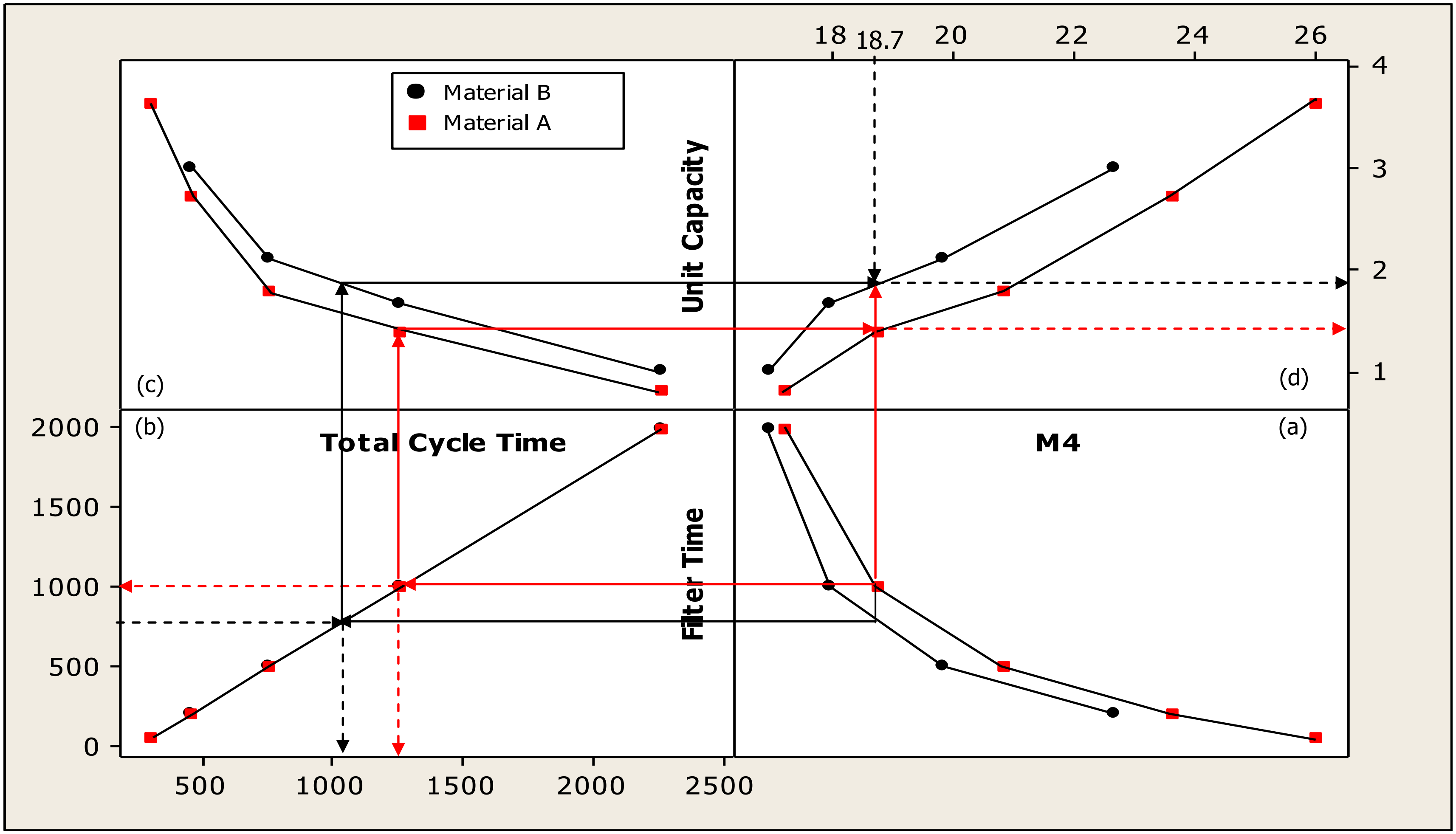


Figure 4.17 Variation of (a) M4 (%) with filter time (s); (b) filter time (s) with total cycle time (s); (c) total cycle time (s) with unit capacity (kg/hr/m^2); and (d) unit capacity (kg/hr/m^2) with M4 (%) at a dry time of 240 s.

CHAPTER 5

RESULTS AND DISCUSSION – BITUMINOUS COAL SAMPLES

In this chapter the results from the filter press testing of the bituminous coal samples collected from Plant 2 and Plant 3 are presented.

5.1 Plant 2

The sample from Plant 2 was collected from the underflow steam of the refuse thickener. Because this slurry was processed in the thickener, it had been flocculated. Testing was carried out to evaluate filter press performance with variations in maximum filter time and dry time.

5.1.1 Feed Analysis

Figure 5.1 shows the direct weight and ash percentages of each size interval for this material. The sample was nominal -20 mesh with an overall ash value of 42.2% based on analysis of a head sample. The +500 mesh material had an ash value of 26.2% and represented 65.7% of the material. The sample contained 34.3% of -500 mesh material with an ash value of 64.4%. In general, the weight % and ash values increased with decreasing particle size. Based on these data, the calculated ash value was 39.2%. The difference in calculated ash value and the head sample ash value was due to the

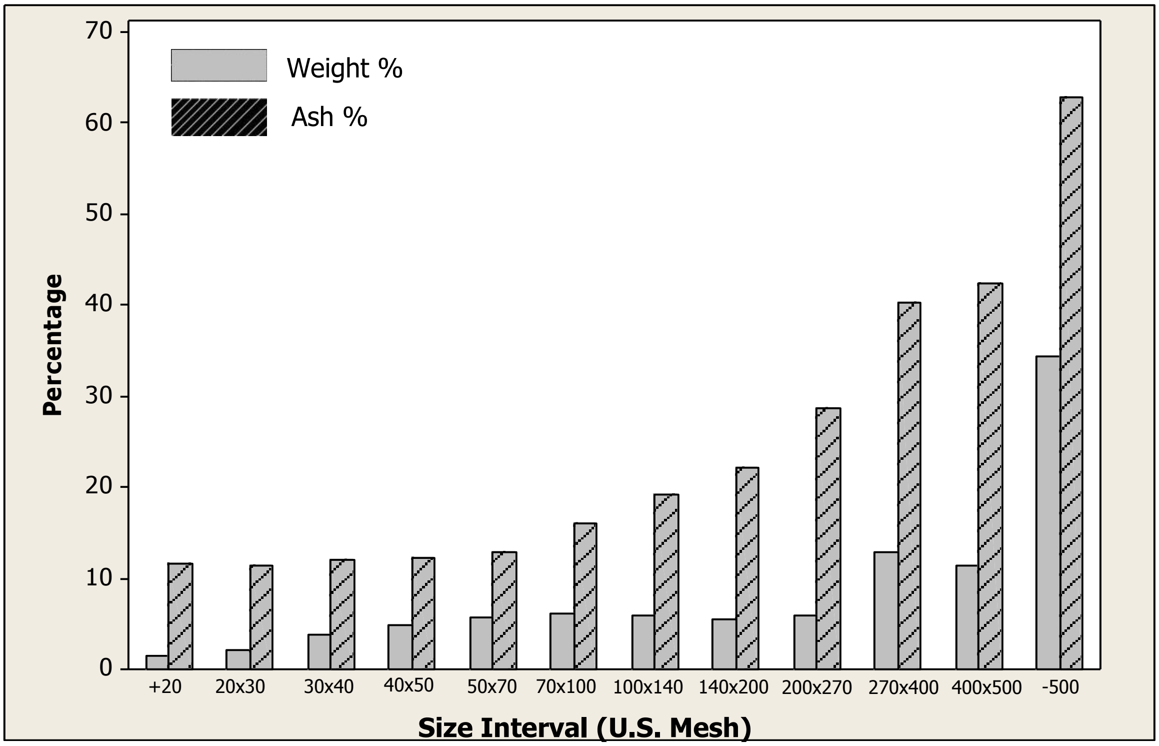


Figure 5.1 Weight and ash percentages of feed by size interval for Plant 2.

sampling error. The as-received solids concentration was 35.3%, and the average solids density was 1.72 g/cm^3. The detailed size and ash interval data are tabulated in Appendix C.

5.1.2 Determination of Test Matrix

Preliminary testing was done to establish the test matrix. A solids concentration of approximately 35% was used for all tests. The high solids concentration of this slurry produced less filtrate during the fill and filter cycles. As a result, the fill cycle to filter cycle transition did not take place at probe level 1. The filter press went to a standby

Table 5.1 Summary of Plant 2 test conditions at an air pressure of 100 psi and probe level 2.

Run Order	**Filter Time** (s)	**Dry Time** (s)	**Calc Solids** (%)	**Measured Solids** (%)
1	500	240	34.7	35.2
2	400	240	34.7	35.7
3	600	240	34.7	34.3
4	400	120	36.4	34.4
5	300	240	36.4	35.1
6	300	120	34.7	34.2
7	500	120	36.4	34.8
8	600	120	36.4	35.1
9[1]	400	240	34.7	35.2
10[1]	400	240	36.4	34.9

[1]Replicate of run 2.

mode after the maximum fill time as indicated in Figure 3.4. Hence, the probe was lowered to level 2, for which the bottom end of the probe was 25 mm from the base of the filtrate tank. At this level, as soon as the filtrate came out, the transition from fill cycle to filter cycle occurred. Also, the filtrate level never fell below the probe level during the entire filter cycle. Hence, the maximum value of the filter cycle was varied to stop pumping after a predefined time.

Based on the preliminary tests, it was observed that by 600 s, the rate of filtrate discharge had decreased significantly. Hence four levels of maximum filter time were chosen as 300 s, 400 s, 500 s, and 600 s. Also, by 240 s of the dry cycle, the filtrate flow rate was negligible with only drops coming out. Therefore, levels for dry time were set to 120 s and 240 s.

A full-factorial experimental design was generated using Minitab 15 as shown in Table 5.1. This design generated a random sequence for filter testing of a total of 8 tests. This randomization of the experimental sequence ensured that there was no bias involved in the testing. Two duplicate tests (runs 9 and 10) were done for run 2 to determine the test reproducibility.

As per the experimental design, the variables were set before every run. For example, for run 1, the feed tank was filled with slurry of 35% solids concentration, the air pressure was set to 100 psi, the maximum fill time was set to 200 s, the maximum filter time was set to 500 s, the dry time was set to 240 s, and the probe was set at level 2. The slurry concentration was calculated based on the Marcy gauge measurements and was measured by drying a sample of the feed slurry. These values are included in Table 5.1.

Soon after the slurry pumps started, the filtrate came out and contacted the probe, initiating the filter cycle. The filter cycle ran for the maximum pre-defined time, which was 500 seconds for run 1, after which the dry cycle started. The filtrate was collected from the start of the filter cycle to the end of the dry cycle. However, in some cases, particularly for longer cycle times, very little filtrate came out in the final filtrate samples during the duration of the dry cycle. Hence, the last few samples were collected in a single filtrate bucket. The detailed results of all the runs are shown in Appendix C.

Table 5.2 Filter cake sample moistures and filtrate results (Plant 2).

Run	**Moisture Content** (%)							**Total**	**Filtrate**
Order	**S1**	**S2**	**S3**	**S4**	**S5**	**M5**	**M4**	**Filtrate Wt**(g)	**Solids**(g)
1	22.5	24.2	23.8	24.6	28.6	24.8	23.8	2717.9	27.6
2	22.8	25.2	24.2	24.9	24.7	24.4	24.3	3269.1	49.2
3	23.1	23.4	23.2	24.7	27.5	24.4	23.6	4025.4	56.6
4	24.1	25.9	23.9	25.1	28.4	25.5	24.7	3232.2	36.4
5	24.2	25.6	24.5	26.2	28.8	25.9	25.1	2950.0	29.3
6	24.9	26.3	25.5	25.9	26.4	25.8	25.6	2616.8	50.6
7	23.9	24.7	23.5	24.9	27.2	24.8	24.2	3192.9	53.3
8	23.1	24.2	22.9	24.7	27.3	24.4	23.7	3568.0	69.3
9[1]	23.9	24.9	25.1	26.0	27.6	25.5	25.0	3399.1	48.6
10[1]	23.0	26.1	24.4	25.4	28.2	25.4	24.7	3660.3	52.3

[1]Replicate of Run 2.

5.1.3 Filter Cake Moisture Analyses

The variation of filter cake moisture with different test conditions was analyzed statistically using Minitab 15. A summary of these results is shown in Table 5.2. The columns S1 to S5 give the values of moisture for the 5 cake samples taken. M5 and M4 are the average cake moistures and were calculated as described previously.

Test reproducibility was determined using runs 2, 9, and 10 as shown in Table 5.3. Standard deviations, s, in the range of 0.4% to 0.6% were obtained for the four filter cake samples, which were similar to those obtained for Plant 1. The standard deviation of M4 was 0.36%. The s value for sample S5 was unusually high, which was due to the residual slurry being in contact with S5.

Table 5.3 Reproducibility for replicate tests (Plant 2).

Run Order	**Moisture Content** (%)						
	S1	**S2**	**S3**	**S4**	**S5**	**M5**	**M4**
2	22.8	25.2	24.2	24.9	24.7	24.4	24.3
9	23.9	24.9	25.1	26.0	27.6	25.5	25.0
10	23.0	26.1	24.4	25.4	28.2	25.4	24.7
Mean	23.2	25.4	24.6	25.4	26.8	25.1	24.7
s	0.59	0.64	0.47	0.56	1.86	0.63	0.36

With these seven models (S1, S2, S3, S4, S5, M5, and M4), a complete full-factorial DOE analysis was done to quantify the effects of feed variables on the different moisture samples. The detailed results of the DOE analyses are given in Appendix C. To quantify the degree of correlation between the moisture content of different samples and feed variables, the standard deviation and R^2 for the seven models were determined and are shown in Table 5.4. The model represented by M4 had the highest R^2 value (91.58%) and the lowest s value (0.26%). The model represented by S5 had the lowest value of R^2 and the highest value of s, which was due to the inconsistent moisture values of S5.

Figure 5.2 shows the variation of M4 predicted with M4 actual using Equation 5.1.

Table 5.4 Correlation coefficient results for the different models. (Plant 2)

Model	**s** (%)	**R^2** (%)	**p-values** Filter Time	**p-values** Dry Time
S1	0.48	77.14	0.05	0.07
S2	0.41	89.26	0.08	0.07
S3	0.51	77.31	0.04	0.60
S4	0.38	76.96	0.05	0.60
S5	1.50	7.26	0.90	0.70
M5	0.41	72.35	0.07	0.60
M4	0.26	91.58	0.04	0.18

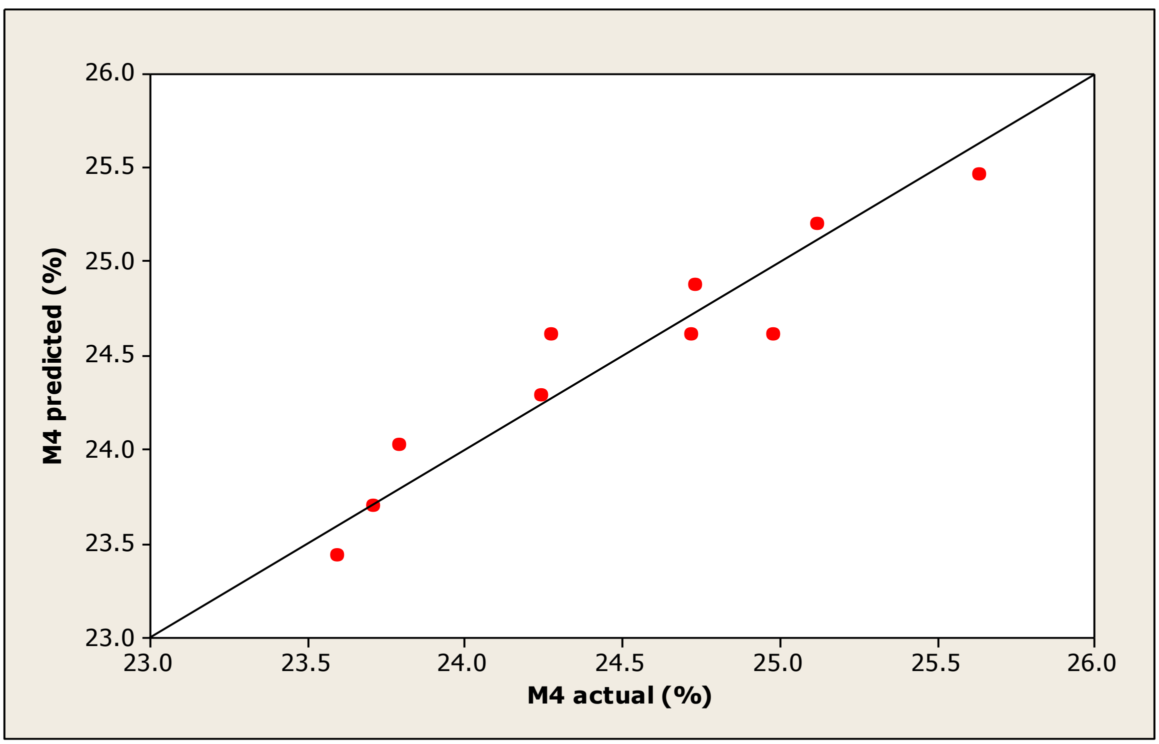


Figure 5.2 Plot of predicted values of M4 versus actual values of M4 (Plant 2).

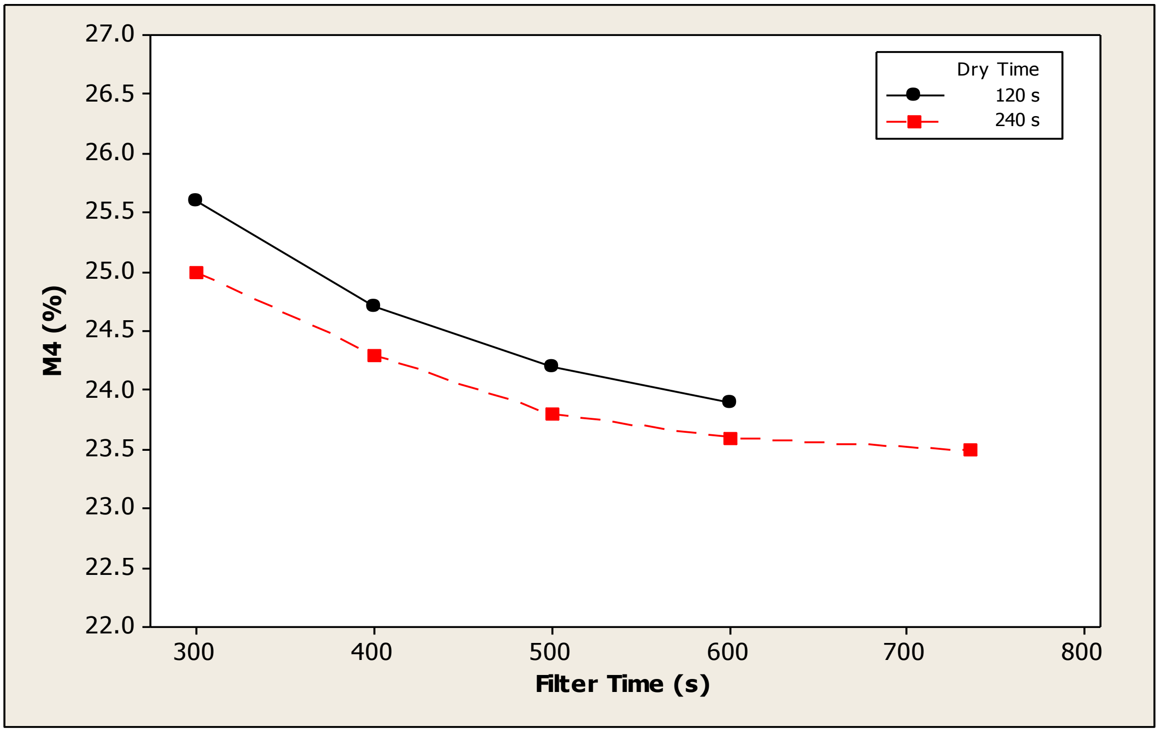


Figure 5.3 Variation of M4 with maximum filter time (Plant 2).

Figure 5.3 shows the variation of M4 with different values of maximum filter time at two levels of dry time. As expected, M4 decreases with an increase in maximum filter time. Likewise, the moisture values were also lower for the higher dry time. At lower values of maximum filter time, dry time had a greater effect as compared to longer filter times. This was because for the cycles with lower values of filter time, more filtrate remained in the filter cake, which came out during the dry cycle. At longer filter times, most of the filtrate was extracted and very little filtrate remained for the dry cycle to extract.

The DOE analyses gave p-values of less than 0.05 for maximum filter time for all model cases (excluding S5). Hence, maximum filter time was a significant variable at the

95% confidence level. The duration of pumping in the tests was governed by the maximum filter time, and tests at higher values of maximum filter time produced lower moistures. Also as seen in Figure 5.3, by running the dry cycle twice as long, M4 decreased by only 0.5%. Dry time was expected to be a statistically significant variable based on Plant 1 results. However, from the statistical analyses, the p-values for dry time were higher than 0.05 in all model cases, and hence it was insignificant at 95% confidence level for these runs. This was because higher values of filter time brought the bulk of the filtrate out of the filter cake and the filtrate obtained during the dry cycle was insignificant as compared to the filtrate obtained during the filter cycle. The detailed results of the DOE analyses are given in Appendix D.

5.1.4 Filtrate Mass Flow Rate

For a given run, the weights of different filtrate samples were measured to determine the filtrate mass flow rates. As with Plant 1 results, the filtrate flow rates were higher initially and decreased with time. The flow rates increased again when the dry cycle started and then decreased. The variation of cumulative filtrate weight for run 3 with time is shown in Figure 5.4. The maximum filter time for this test was 600 s. For the first filtrate sample collected at 30 s, the average filtrate mass flow rate was 16.4 g/s. After 200 s, the average filtrate mass flow rate became almost constant for approximately 400 s at 7.8 g/s and then again decreased. The last data point included the weight of flushed out filtrate and hence it was higher than expected.

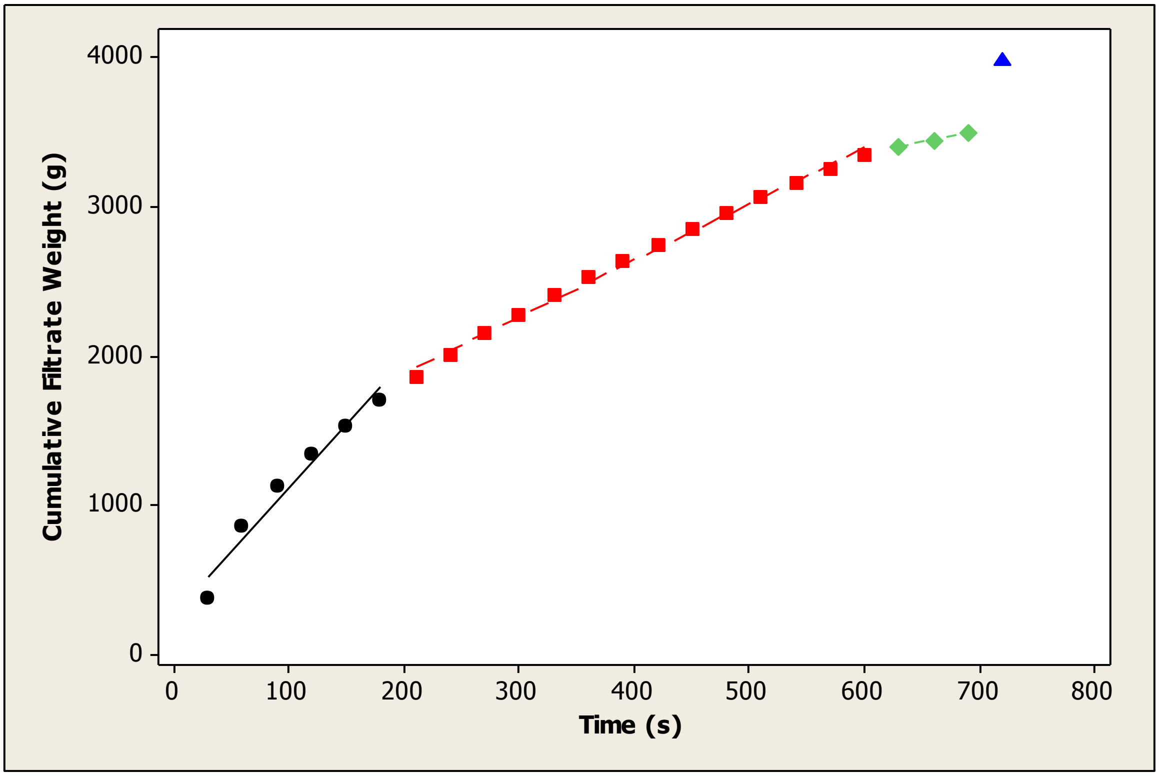


Table 5.4 Variation of cumulative filtrate weight with time for run 3 (Plant 2).

As compared to the filter cycle, much less filtrate came out during the dry cycle. This was confirmed by comparison of filtrate weights of two cycles of different filter times but at the same dry time. For run 6 (filter time 300 s and dry time 120 s), 601 grams of filtrate came out during the dry cycle whereas 501 grams of filtrate came out during the dry cycle for run 8 (filter time 600 s and dry time 120 s). Also, 676 grams of filtrate were extracted during the dry cycle for run 3 (filter time 600 s and dry time 240 s). Comparing run 3 and run 8 indicates that for the same levels of filter time, slightly more filtrate was extracted during the higher dry cycle. This again confirms that for longer filter times longer dry times do not generate significant amounts of filtrate.

Table 5.5 Distribution of the solids weight for the filtrate samples of run 3 (Plant 2).

Time (s)	**Filtrate Wt** (g)	**Solids Wt** (g)	**Solids Concentration** (%)
30	365.6	22.1	6.04
60	493.8	10.4	2.11
90	268.1	5.8	2.16
120	205.2	3.7	1.80
150	195.2	2.5	1.28
180	170.1	1.8	1.06
210	162.0	1.1	0.68
240	144.7	0.6	0.41
270	144.3	0.7	0.49
300	130.4	0.4	0.31
330	127.4	0.3	0.24
360	116.0	0.5	0.43
390	116.3	0.5	0.43
420	107.9	0.2	0.19
450	109.0	0.2	0.18
480	101.9	0.2	0.20
510	107.2	0.1	0.09
540	94.9	0.1	0.11
570	93.7	0.1	0.11
600	95.1	0.1	0.11
630	56.2	0.1	0.18
660	42.2	0.1	0.24
690	43.3	0.1	0.23
720	534.9	4.9	0.92
Total	4025.4	56.6	1.41

5.1.5 Filtrate Solids Content

Table 5.5 shows the weights and the solids concentrations for the filtrate samples for run 3. A total of 56.6 g of solids was recovered in the filtrate. The first filtrate sample had a maximum solids concentration of 6.04% after which the solids concentration

Table 5.6 Test conditions and results for the long filter time test at a maximum filter time of 1000 s (Plant 2).

Run Order	**Feed Solids** (%)	**Filter Time** (s)	**Dry Time** (s)	**Moisture Content** (%)				
				S1	**S2**	**S3**	**S4**	**M4**
11	35	735	240	22.5	23.9	22.8	23.1	23.1

decreased to 0.09%. At 600 s, the solids concentration increased when the dry cycle started. Air flow during the dry cycle deblinded the filter cloth and brought down some fine particles along with the filtrate, and the solids concentration again increased to 0.24%. Since the last sample contained all the flushed-out filtrate, it had slightly higher solid concentration. The entire filtrate sample had a solids concentration of 1.41%. The solids concentration of filtrate was higher as compared to Plant 1. In this case, the feed solids concentration was 35% as compared to 20% for Plant 1.

5.1.6 Long Filter Cycle Runs

An additional test was conducted at a maximum filter time of 1000 s. Feed slurry of 35% solids concentration, a maximum filter time of 1000 s, a dry time of 240 s, and an air pressure of 100 psi were used. The filter cycle ran for 735 s and then the probe was exposed initiating the dry cycle. A summary of these results is given in Table 5.6. The average moisture from this test is included in Figure 5.3. The moisture content at a filter time of 735 s was close to that of 600 s (run 3). Since the probe was exposed at 735 s of filter time, tests at higher filter times were not conducted. The variation of cumulative

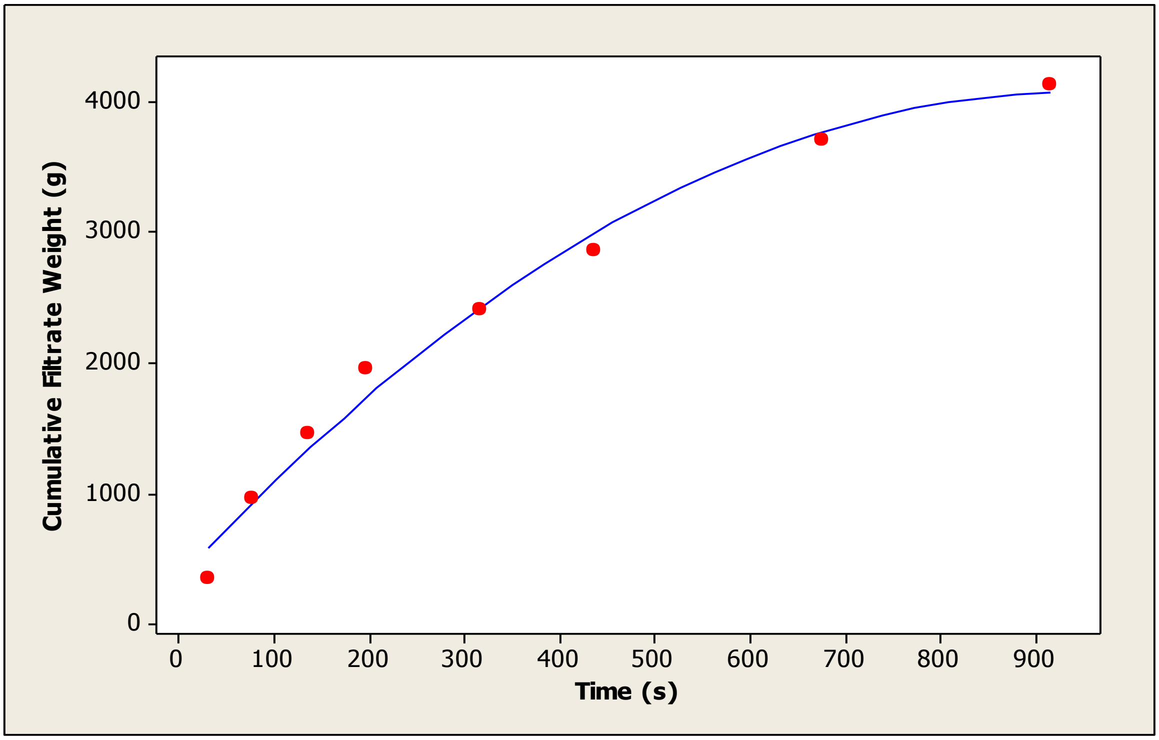


Figure 5.5 Variation of cumulative filtrate weight with time for run 11(Plant 2).

filtrate weight with time is given in Figure 5.5. A second order regression between cumulative filtrate mass with time, t, for run 11 gave

$$\text{Cumulative Filtrate Mass} = 352.9 + 7.87\ t - 0.004170\ t^2 \qquad (5.1)$$

The value of filtrate mass flow rate at the point when the probe was exposed at 735 s was 1.74 g/s as opposed to 16.45g/s for the first filtrate sample at 30 s. This was calculated by differentiating Equation 5.2 with respect to time and setting the time as 735 s.

Table 5.7 Unit capacities for Plant 2 samples.

Run Order	**Total Cycle Time** (s)	**Total Wet** Wt (g)	**M4** (%)	**Total Dry Cake** (g)	**Unit Capacity** (kg/hr/m^2)
1	770	2765.5	23.8	2107.4	0.81
2	670	2664.2	24.3	2017.5	0.89
3	870	3358.7	23.6	2566.1	0.87
4	550	2744.5	24.7	2065.6	1.11
5	570	2338.5	25.1	1751.1	0.91
6	450	2391.5	25.6	1778.4	1.17
7	650	2944.9	24.2	2230.8	1.02
8	750	3215.5	23.7	2452.9	0.97

5.1.7 Process Applications

The graphical approach as developed for Plant 1 was used to relate the total filter press cycle times with the filter cake moistures and the unit capacities. Table 5.7 shows a summary of unit capacities for different runs. Figure 5.6 shows the combined plot of M4 with unit capacity, filter time, and total cycle time. The filter cake moisture values were not very sensitive in the range of operating conditions. To achieve the same M4 value, a shorter filter cycle time required a longer dry time. For example, as seen in Figure 5.6a, an M4 value of 24.2% was obtained at filter times of 400 s and 500 s. For the 400 s filter time, the dry time was 240 s, whereas at 500 s, the dry time was 120 s. As seen in Figure 5.6b, the total cycle time for the 400 s filter time run was slightly longer than for the 500 s filter cycle run (670 s versus 650 s). Also, as seen in Figure 5.6c, the unit capacity of the 400 s filter time run was lower than that of the 500 s filter time run (0.89 kg/hr/m^2 versus 1.02 kg/hr/m^2). Higher unit capacities were obtained for longer filter cycles as the weight of dry filter cake solids increased more relative to the increase in the filter time. For the same value of total cycle time, the shorter filter time run produced the lower filter cake moisture but at a lower unit capacity. Figure 5.6d gives the direct variation of unit capacity with M4 for the different values of filter time. Similarly, at a predefined total cycle time different values of filter time, M4, and unit capacities can be obtained. Hence this approach can be used to estimate the different operating conditions needed to obtain a given product. Moreover these values provide scale-up information when processing a similar feed material.

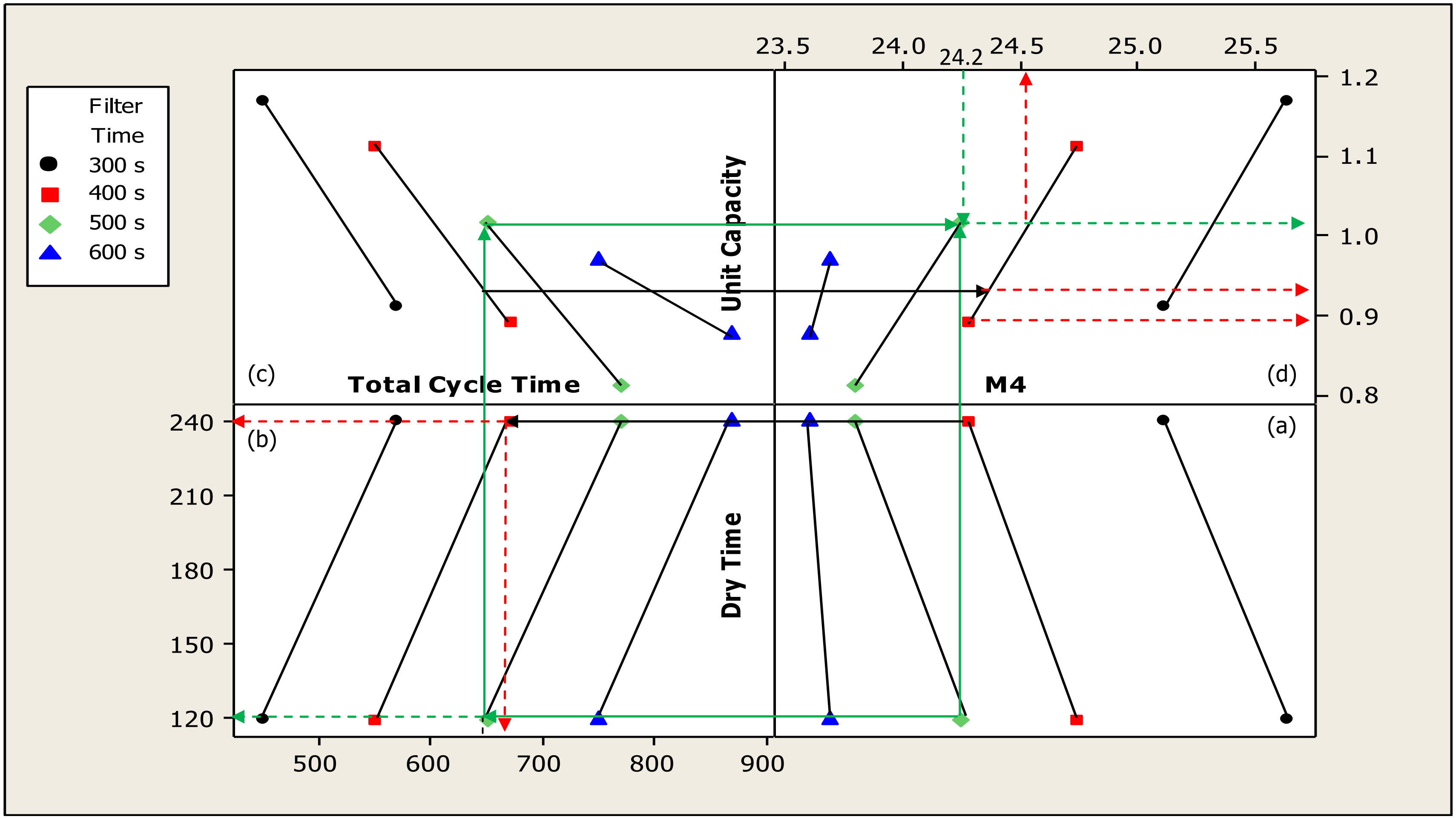


Figure 5.6 Variation of (a) M4 (%) with dry time (s); (b) dry time (s) with total cycle time (s); (c) total cycle time (s) with unit capacity (kg/hr/m^2); and (d) unit capacity (kg/hr/m^2) with M4 (%).

5.2 Plant 3

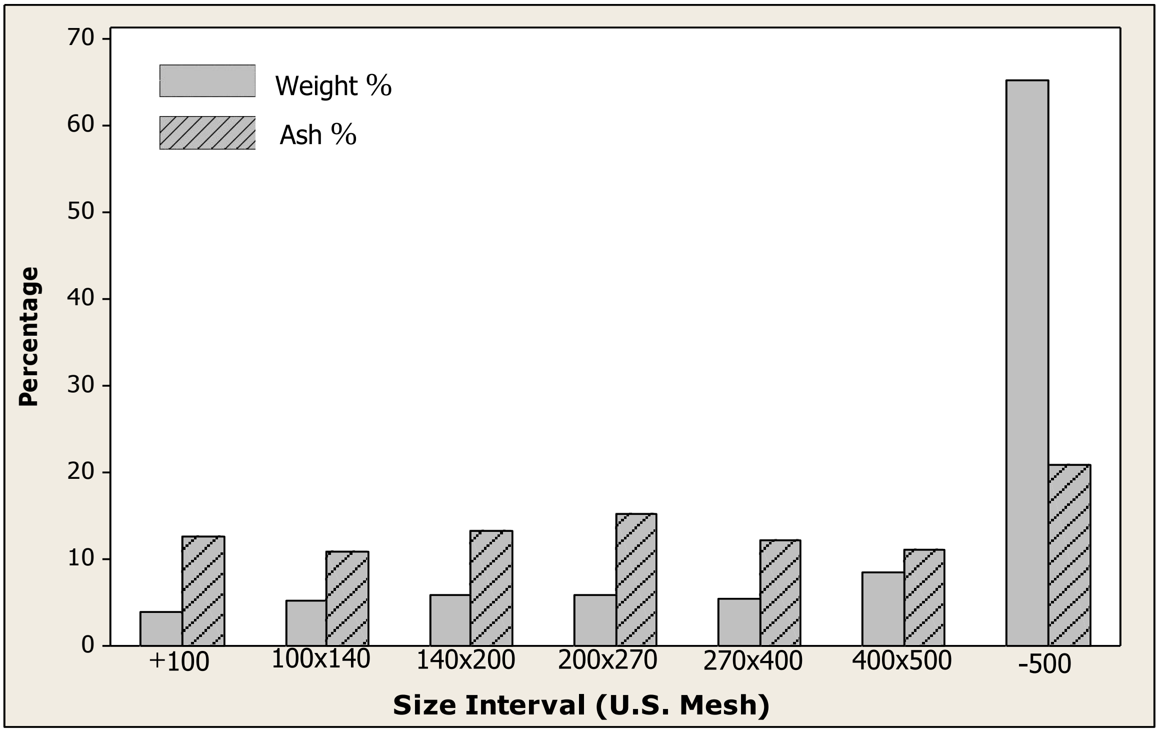
The sample from Plant 3 was collected from the thickener underflow stream and was flocculated as part of the normal thickener operation. This sample was tested for variations in probe height, dry time, and air pressure.

5.2.1 Feed Analysis

Figure 5.7 shows the direct weight and ash percentages of each size interval for this material. The sample was nominal -100 mesh with an overall ash value of 15%. The +500 mesh material had an ash value of 12.4% and represented 34.7% of the material. The weight % and ash values were approximately constant for the +500 mesh size intervals. The sample contained 65.2% of -500 mesh material with an ash value of 20.9%. The calculated ash value of the feed material using the ash and size interval data was 17.5%. The difference in calculated ash value and the head sample ash value was due to the sampling error. The average solids density was 1.51 g/cm^3. The detailed size and ash interval data are tabulated in Appendix D.

5.2.2 Determination of Test Matrix

Preliminary testing was done to establish the test matrix. A solids concentration of 20% was used for all the tests based on the expected solids concentration of the plant stream. Testing was done at probe heights of 40 mm (probe level 1) and 25 mm (probe level 2).



5.7 Weight and ash percentages of feed by size interval for Plant 3.

In the preliminary tests, the 20% slurry was fed to the filter press with a maximum fill time of 300 s, maximum filter time of 600 s, a dry time of 600 s, and using probe level 1. The fill cycle lasted for approximately 15 s and then the filter cycle started. The probe was exposed after approximately 300 s of the filter cycle. It was observed that very little filtrate was coming out at 480 s of dry time. Since at probe level 2, more filtrate would come out during the fill and the filter cycles compared to that at probe level 1, less filtrate would remain in the cake for the dry cycle to extract. As 480 s of dry time brought out most of the filtrate for probe level 1, it would be sufficient for probe level 2. Hence, 480 s of dry time was an appropriate upper limit for dry time for both probe levels.

Table 5.8 Summary of Plant 3 test conditions.

Run Order	**Probe Level**	**Air Pressure** (psi)	**Dry time** (s)	**Calc Solids** (%)	**Measured Solids** (%)
1	1	100	360	22.3	22.4
2	1	80	360	22.3	20.6
3	1	100	480	22.3	19.8
4	2	100	240	22.3	22.2
5	2	80	480	22.3	23.7
6	1	80	240	22.3	18.9
7	2	80	240	15.0	14.6
8	2	100	360	22.3	22.7
9	2	100	480	22.3	22.0
10	1	100	240	22.3	22.6
11	2	80	360	22.3	19.9
12	1	80	480	22.3	21.9
13[1]	1	100	360	22.3	22.1
14[1]	1	100	360	22.3	23.8

[1]Replicate of run 1.

Hence, three levels of dry time (240 s, 300 s, and 480 s) were used. The two levels of air pressure chosen were 80 psi and 100 psi.

A full-factorial experimental design was generated using Minitab 15 as shown in Table 5.8. This design generated a random sequence of filter testing for a total of 12 tests. This randomization of the experimental sequence ensured that there was no bias involved in the testing. Two replicate tests were done (runs 13 and 14) for run 1 to determine the test reproducibility.

Based on the experimental design, the variables were set before every run. For example for run 1, the feed tank was filled with 20% solids slurry from the make-up circuit as discussed in Section 3.1. The probe was set to level 1, the dry time was set to

Table 5.9 Filter cake sample moistures and filtrate results (Plant 3).

Run Order	**Moisture Content** (%)							Total Filtrate Wt (g)	Filtrate Solids (g)
	S1	**S2**	**S3**	**S4**	**S5**	**M5**	**M4**		
1	17.0	18.9	18.6	17.5	19.8	18.4	18.0	24974.7	15.3
2	17.8	19.2	18.9	18.6	19.4	18.8	18.6	22491.4	9.6
3	16.1	17.2	17.2	17.1	18.2	17.2	16.9	22492.9	17.2
4	18.3	18.2	18.7	19.8	21.4	19.3	18.7	21895.3	16.1
5	17.3	16.8	16.0	17.4	19.7	17.4	16.8	24679.0	11.1
6	19.8	19.8	20.0	20.7	22.9	20.6	20.1	20019.8	6.5
7	18.3	18.5	19.2	18.1	20.8	19.0	18.5	24793.9	8.8
8	16.7	17.4	18.0	17.7	20.8	18.1	17.5	29018.4	17.6
9	15.3	16.4	15.7	16.8	17.1	16.3	16.1	29689.8	18.5
10	21.2	22.6	20.2	22.5	25.3	22.4	21.6	20238.8	13.1
11	18.1	18.7	17.4	18.4	21.0	18.7	18.1	22028.4	6.4
12	17.6	18.8	18.1	17.6	25.9	19.6	18.0	21196.8	8.9
13[1]	17.9	18.4	17.6	18.9	25.9	19.7	18.2	24988.6	14.8
14[1]	17.8	18.8	18.2	17.6	23.5	19.2	18.1	24958.5	15.7

[1]Replicate of Run 1.

360 s and the air pressure was set to 100 psi. The slurry concentration was calculated based on the Marcy gauge measurements, and it was measured by drying a slurry sample. These values are included in Table 5.8. Timed filtrate samples were taken as soon as filtrate began to discharge until the end of the dry cycle. However, in some cases particularly for probe level 2 and longer dry times, very little filtrate came out in the final filtrate samples during the duration of the dry cycle. Hence, the last few samples were collected in the last filtrate sample bucket. The filter cycle lasted for approximately 300 s for probe level 1 and for approximately 360 s for probe level 2. The individual data for all the 14 runs are given in Appendix D.

Table 5.10 Reproducibility results for replicate tests (Plant 3).

Run Order	Moisture Content (%)						
	S1	**S2**	**S3**	**S4**	**S5**	**M5**	**M4**
1	17.0	18.9	18.6	17.5	19.8	18.4	18.0
13	17.9	18.4	17.6	18.9	25.9	19.7	18.2
14	17.8	18.8	18.2	17.6	23.5	19.2	18.1
Mean	17.6	18.7	18.1	18.0	23.1	19.1	18.1
s	0.50	0.29	0.51	0.79	3.08	0.69	0.09

5.2.3 Filter Cake Moisture Analyses

The variation of moisture with different test conditions was obtained experimentally and analyzed statistically using Minitab 15. A summary of these results is shown in Table 5.9. The values for S1 to S5 are the moistures for the 5 filter cake samples. M5 and M4 are the average cake moistures as described previously.

Test reproducibility was determined using runs 1, 13, and 14, as shown in Table 5.10. Standard deviations, s, in the range of 0.3% to 0.8% was obtained for the filter cake samples, which were similar to those obtained for Plant 1 and Plant 2. The standard deviation of M4 was 0.1%. The value of s for sample S5 was unusually high, which was due to the residual slurry being in contact with S5.

With these seven models (S1, S2, S3, S4, S5, M5, and M4), a complete full-factorial DOE analyses was done to quantify the effects of variables on the different moisture samples. To quantify the degree of correlation between moisture content of different samples and feed variables, the standard deviation and R^2 for the seven models

Table 5.11 Correlation coefficients results for the different models (Plant 3).

Model	s (%)	R^2 (%)	p-values		
			Probe Level	**Air Pressure**	**Dry Time**
S1	0.39	92.74	0.01	0.05	0.00
S2	0.79	91.51	0.02	0.67	0.02
S3	0.52	94.96	0.01	0.33	0.00
S4	0.56	96.12	0.02	0.56	0.00
S5	2.77	69.81	0.19	0.75	0.52
M5	0.70	93.30	0.19	0.50	0.01
M4	0.30	98.43	0.00	0.24	0.00

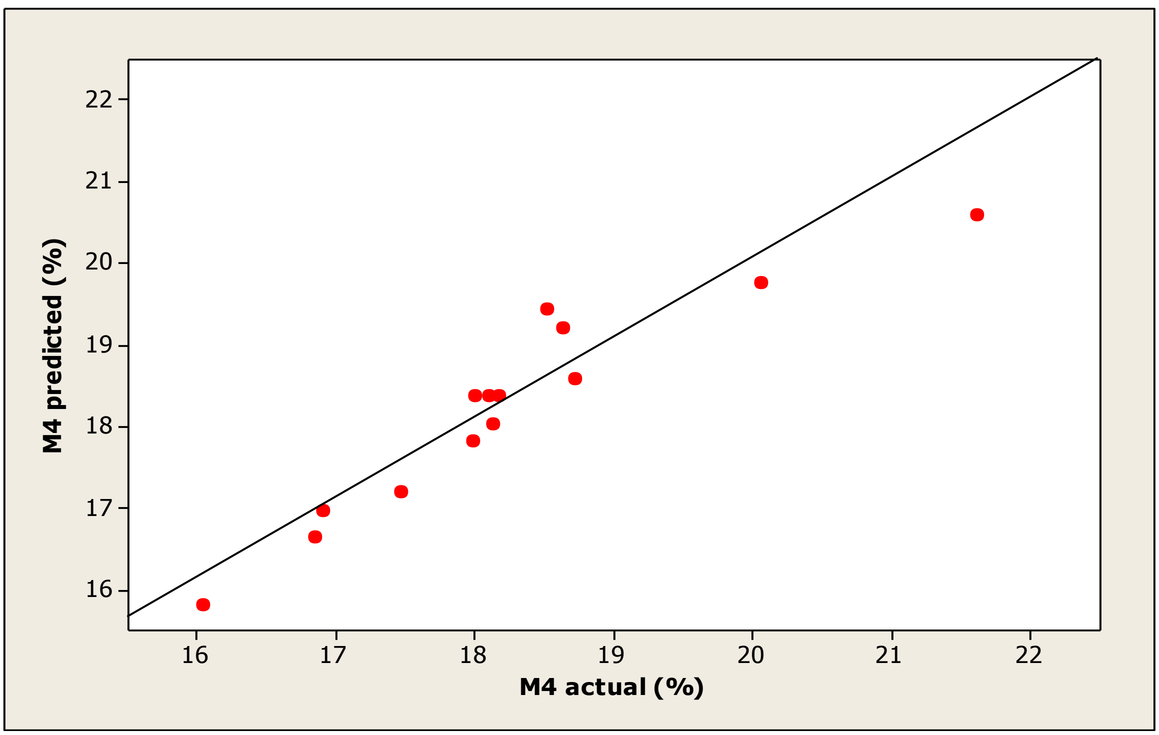


Figure 5.8 Plot of predicted values of M4 versus actual values of M4 (Plant 3).

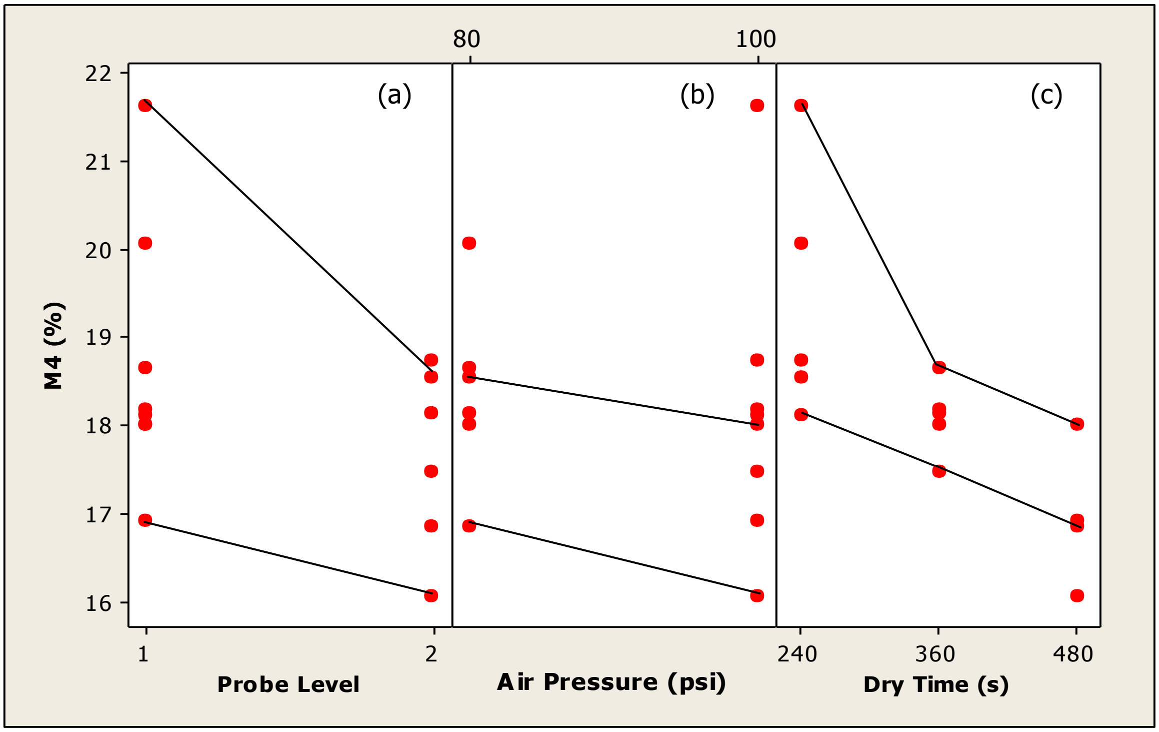


Figure 5.9 Matrix-plot of sample moistures with feed variables for M4 versus: (a) probe level; (b) air pressure; (c) dry time (Plant 3).

were determined and are shown in Table 5.11. The model represented by M4 had the highest value of R^2 (98.4%) and the lowest s value (0.3%). Figure 5.8 shows the variation of M4 predicted with M4 actual.

Figure 5.9 shows the variation of M4 with different values of probe level, air pressure, and dry time. The points on the graph represent filter cake moistures for different operating conditions. For example, for Figure 5.9a, the highest data point at probe level 1, which corresponds to run 10, is joined to run 4 (probe level 2). The other lines represent the same operating conditions except for the variable in question. As expected, M4 decreases for probe level 2, which was due to an increase in filter time. Similarly, higher air pressure and higher dry times also led to lower values of M4.

As seen in Table 5.11, the DOE analyses gave p-values of less than 0.05 for probe level and dry time. Hence, both probe level and dry time were significant variables at the 95% confidence level. More dewatering took place at probe level 2 as the filter cycle ran for a longer duration. The longer filter cycle, due to lower probe height, extracted more filtrate reducing the final cake moisture. The longer dry cycle was also effective in extracting more filtrate from the filter cake voids. The p-values for probe level and dry time were approximately same and hence they were equally significant. The air pressure was insignificant at the 95% confidence level. The detailed results of the DOE analyses are given in Appendix D.

5.2.4 Filtrate Mass Flow Rate

For a given run, the weights of different filtrate samples were measured to determine the filtrate mass flow rates. As with Plant 1 and Plant 2, the filtrate flow rates were higher initially and then decreased with time. The flow rates increased again when the dry cycle started and then decreased. Figure 5.10 shows the variation of cumulative filtrate weight with time for run 9 (probe level 2) and run 3 (probe level 1), which were at the same conditions except for the probe level. For both the curves, the filtrate mass flow rate was approximately 138 g/s at the start of the filter cycle. As expected, the cumulative filtrate weights were very similar until approximately 300 s. At this time, the probe was exposed and the filter cycle ended for run 3 (probe level 1).

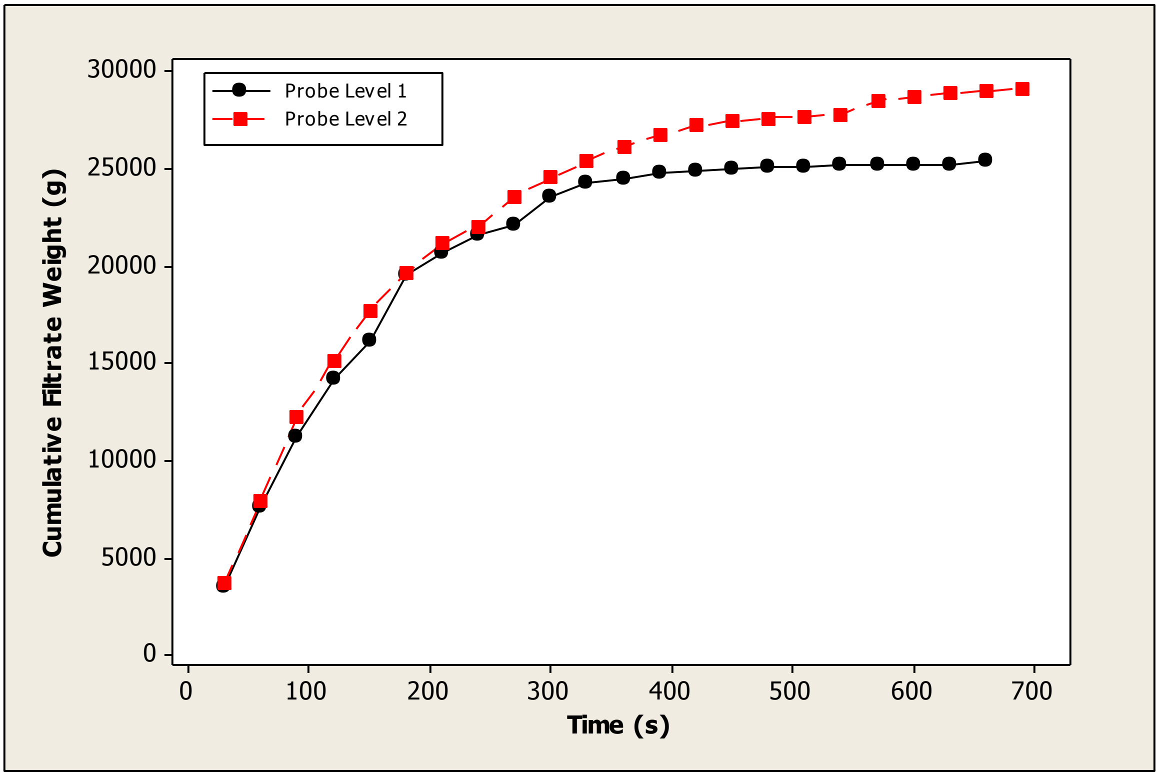


Figure 5.10 Variation of cumulative filtrate weight with time at different probe levels (Plant 3).

After that, the cumulative filtrate flow rate for run 3 (probe level 1) became approximately constant, whereas the cumulative filtrate flow rate for run 9 (probe level 2) continued to decrease. For probe level 2, the probe was exposed at approximately 360 s, and the filter cycle ended. Run 9 produced a filter cake with an average moisture content of 16%, whereas run 3 produced filter cake at an average moisture content of 17%. Hence by lowering the probe from level 1 to level 2, which led to an increase in filter time, the filter cake moisture was reduced approximately 1%.

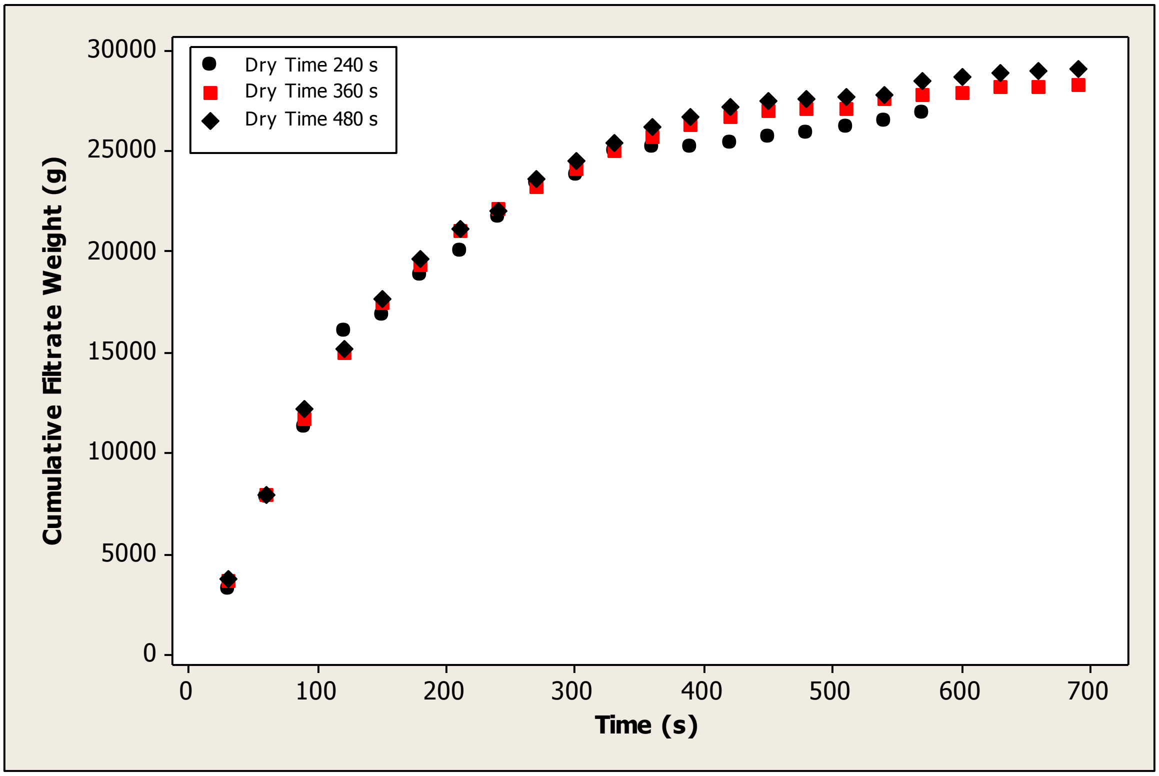


Figure 5.11 Variation of cumulative filtrate weight with time at different dry times (Plant 3).

Figure 5.11 shows the variation of cumulative filtrate mass with time for run 9 (dry time 480 s), run 8 (dry time 360 s), and run 4 (dry time 240 s), which were at the same conditions except for the dry time. The cumulative filtrate weights were reproducible for the filter cycle duration (360 s), which was the same for all tests due to the same probe level.

The longer dry cycle extracted more filtrate out of the filter cake voids. Run 4 produced filter cake at an average moisture content of 18.7%, run 8 produced filter cake at an average moisture content of 17.4%, and run 9 produced filter cake at an average

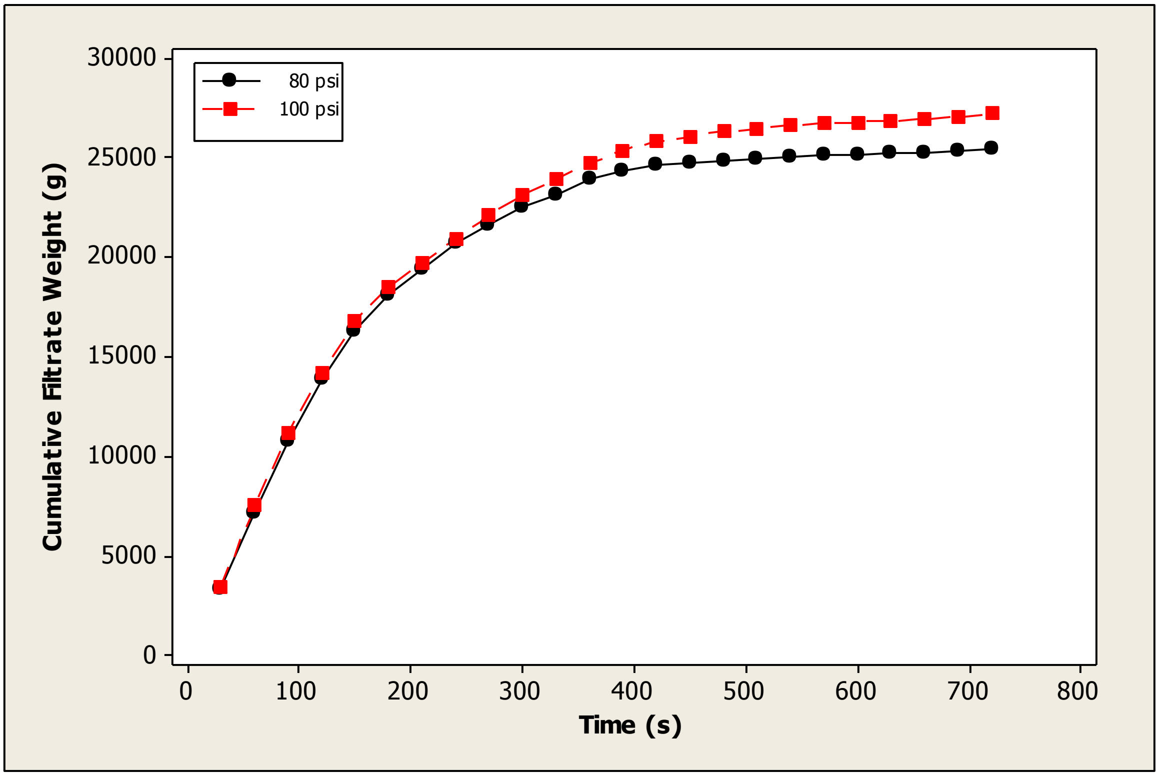


Figure 5.12 Variation of cumulative filtrate weight with time at different air pressures.

moisture content of 16%. Hence the moisture decreased by approximately 1.3% for each 120 s increase in dry time.

Figure 5.12 shows the variation of cumulative filtrate weight with time for run 9 (100 psi) and run 5 (80 psi), which were at the same conditions except for the air pressure. The cumulative filtrate weights were reproducible over the duration of the filter cycle, which was the same due to the same probe level. For the duration of the dry cycle, run 9 (100 psi) extracted filtrate at an average filtrate flow rate of 7.6 g/s, compared to run 5 (80 psi), which extracted filtrate at an average filtrate flow rate of 4.7 g/s. The higher pressure also extracted more filtrate as compared to the lower pressure. Run 5 produced filter cake at an average moisture content of 16.8%, whereas run 9 produced filter cake at an average moisture content of 16%. Hence by increasing the air pressure from 80 psi to 100 psi, an additional 0.8% was removed under the same conditions of probe level and dry time. However, this small decrease in moisture was not significant at 95% confidence level.

5.2.5 Filtrate Solids Content

Table 5.12 shows the weights and the solids concentrations for the filtrate samples for run 9. A total of 18.5 g of solids was recovered in the filtrate. The first filtrate sample had a maximum value of solids concentration of 0.26% after which the solids concentration decreased to 0.0%. The dry cycle started at 360 s and the solids concentration of the filtrate increased around 390 s. Air flow in the dry cycle deblinded the filter cloth and brought down some fine particles along with the filtrate, and the solids concentration again increased to 0.1%. Since the last sample contained all the flushed-out filtrate, it had a slightly higher solids concentration. The entire filtrate sample had a solids concentration of 0.07%.

Table 5.12 Distribution of the solids weight for the filtrate samples of run 9 (Plant 3).

Time (s)	**Filtrate Wt** (g)	**Solids Wt** (g)	**Solids Concentration** (%)
30	3487.4	9.2	0.26
60	4024.5	4.4	0.11
90	3685.5	2.1	0.06
120	3025.5	0.8	0.03
150	2554.4	0.4	0.02
180	1754.5	0.1	0.01
210	1166.6	0.0	0.00
240	1254.4	0.0	0.00
270	1147.7	0.0	0.00
300	1022.7	0.0	0.00
330	825.4	0.0	0.00
360	789.7	0.0	0.00
390	645.5	0.0	0.00
420	452.5	0.2	0.04
450	258.4	0.3	0.10
480	224.1	0.1	0.04
510	187.7	0.0	0.00
540	125.1	0.0	0.00
570	97.7	0.0	0.00
600	77.7	0.0	0.00
630	85.7	0.0	0.00
660	69.9	0.0	0.00
690	72.4	0.0	0.00
720	214.4	0.8	0.39
Total	27249.4	18.5	0.07

Table 5.13 Unit capacities for Plant 3 tests.

Filter Time (s)	**Dry Time** (s)	**Total Cycle Time** (s)	**Total Wet Wt** (g)	**M4** (%)	**Unit Capacity** (kg/hr/m2)
300	60	390	8137.7	27.3	4.5
300	120	450	7670.8	22.9	3.9
300	180	510	7468.7	20.8	3.4
300	240	570	7339.9	19.4	3.1
300	300	630	7276.8	18.7	2.8
300*	480	810	7117.7	16.9	2.2
360	60	450	9708.8	26.1	4.7
360	120	510	9226.3	22.3	4.2
360	180	570	8957.5	19.9	3.7
360	240	630	8834.6	18.8	3.4
360	300	690	8759.6	18.1	3.1
360*	480	870	8542.2	16.1	2.4

*Experimental

5.2.6 Process Applications

The graphical approach developed for the analysis of the Plant 1 and Plant 2 results was used to relate the filter press cycle times with the filter cake moistures and the unit capacities. Table 5.13 shows a summary of the unit capacities for different runs. These calculations were done for the two probe levels for which the filter times were 300 s and 360 s. Figure 5.13 shows the combined plot of M4 with unit capacity, filter time, dry time, and total cycle time. To attain the same value of filter cake moisture, a shorter filter cycle run would need a longer dry time. The total cycle times for both the runs were approximately the same, however the longer filter cycle run had the higher capacity. For example, as seen in Figure 5.13a, an M4 value of 18.7% was obtained at filter times of 300 s and 360 s. For 300 s filter time, the dry time was 300 s, whereas for 360 s, the dry time was 240 s. Also, as seen in Figure 5.13b, the total cycle time for these runs was the same (600 s). Consequently, as seen in Figure 5.13c, the 300 s filter time run had a lower unit capacity as compared to the 360 s filter time run (2.8 $kg/hr/m^2$ versus 3.4 $kg/hr/m^2$). Higher unit capacities were obtained for longer filter cycle runs as the weight of filter cake solids increased more relative to the increase in the filter time. Figure 5.13d gives the direct variation of M4 with unit capacities for the different values of filter times. Similarly, at a predefined total cycle time different values of filter time, M4, and unit capacities can be obtained. Hence this approach can be used to estimate the different operating conditions needed to obtain a given product. Moreover these values provide scale-up information when processing a similar feed material.

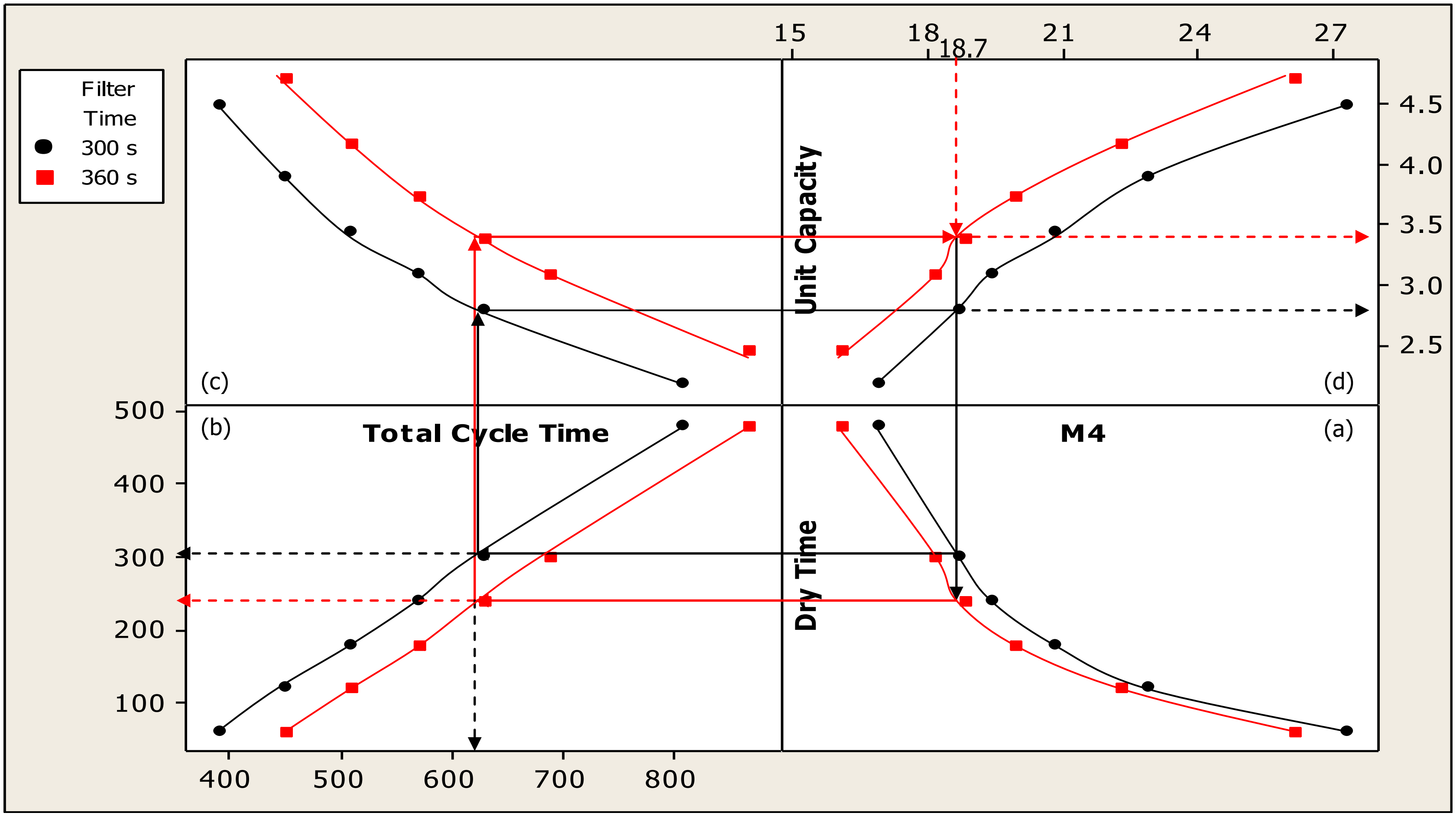


Figure 5.13 Variation of (a) M4 (%) with dry time (s); (b) dry time (s) with total cycle time (s); (c) total cycle time (s) with unit capacity (kg/hr/m^2); and (d) unit capacity (kg/hr/m^2) with M4 (%).

CHAPTER 6

RESULTS AND DISCUSSION – SILICA SAND SAMPLE

In this chapter the results from filter testing of the Plant 4 silica-sand slurry are presented. This sample was collected from the underflow stream of the tailings thickener. Because this slurry was processed in the thickener, it had been flocculated. Tests were conducted at different operating conditions, including dry time, air pressure, and probe height.

6.1 Feed Analysis

Figure 6.1 shows the direct weight percentages of each size interval for this material. It was a nominal -100 mesh and approximately 75% of the material was finer than 200 mesh and 37% was finer than 500 mesh. The average density of the solids was 2.65 g/cm^3. The size interval data are tabulated in Appendix E.

6.2 Determination of Test Matrix

Preliminary testing was done to determine the maximum fill time, maximum filter time, and the levels of dry time. For example, a slurry of solids concentration 20% by weight was fed to the filter press at probe level 2, maximum fill time of 200 s, maximum filter time of 600 s, dry time of 400 s, and an air pressure of 100 psi. The fill cycle lasted

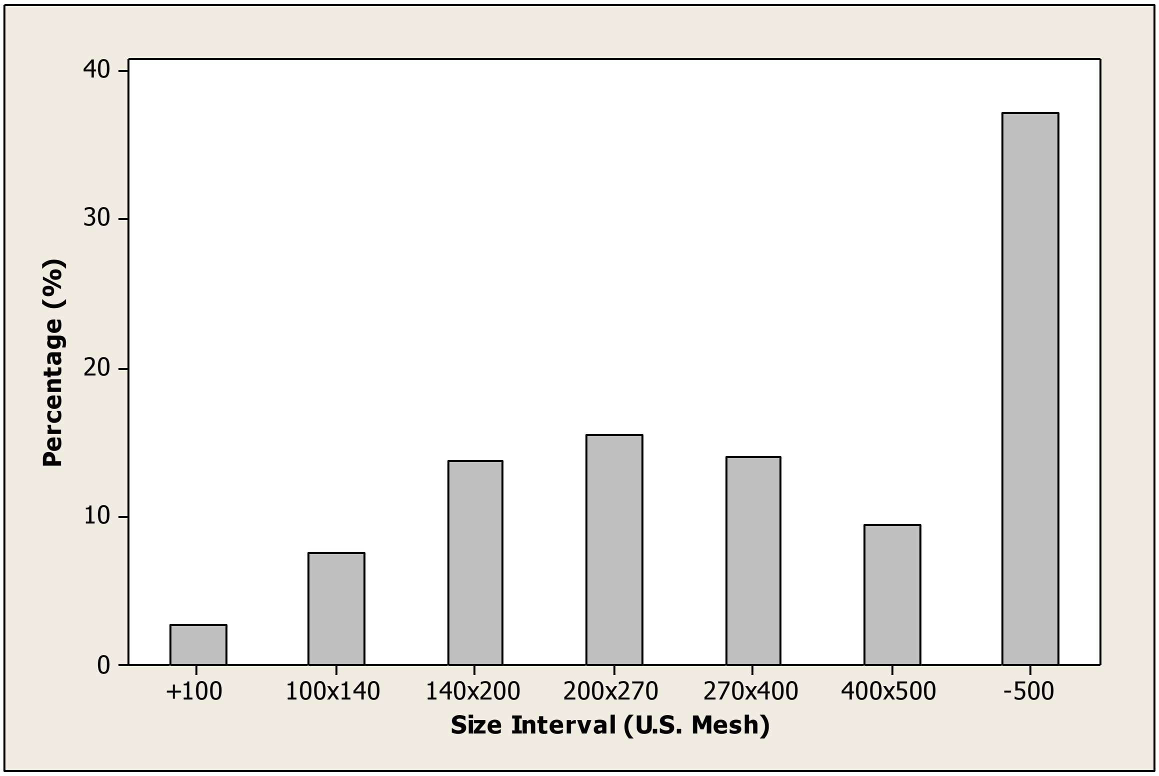


Figure 6.1 Weight percentages of feed by size interval for Plant 4.

approximately 20 s and then the filter cycle started. The filter cycle reached the maximum filter time of 600 s, and the probe was still not exposed. Hence the maximum fill time was fixed at 100 s and the maximum filter time at 1000 s. By 300 s of the dry cycle, the filtrate flow rates were negligible with only drops coming out. Hence two levels of dry time were chosen as 240 s and 360 s. The two levels of air pressure were 80 psi and 100 psi.

A full-factorial experimental design was generated using Minitab 15 as shown in Table 6.1. This design generated a random sequence of filter testing for a total of 8 tests. This randomization of the experimental sequence ensured that there was no bias involved

Table 6.1 Summary of Plant 4 test conditions at a maximum filter time of 1000 s.

Run Order	**Probe Level**	**Dry Time** (s)	**Air Pressure** (psi)	**Calc Solids** (%)	**Measured Solids** (%)
1	2	240	100	19.7	19.9
2	2	360	100	19.7	20.2
3	2	360	80	18.4	17.2
4	1	360	80	18.4	19.2
5	2	240	80	19.7	18.7
6	1	240	80	20.9	19.9
7	1	360	100	20.9	19.4
8	1	240	100	19.7	19.9
9[1]	2	360	80	18.4	17.0
10[1]	2	360	80	18.4	19.4

[1] Replicate of run 3.

in the testing. Two duplicate tests were done (runs 9 and 10) for run 3 to determine the test reproducibility.

As per the experimental design, the variables were set before every run. For example, for the first test, the feed tank was filled up with slurry of 20% solids concentration by weight from the make-up circuit as discussed in Section 3.1. The probe was set to level 2, the dry time was set to 240 s, and the air pressure was set to 100 psi. The slurry concentration was calculated based on the Marcy gauge measurements, and it was measured by drying a sample of the feed slurry. These values are included in Table 6.1. Timed filtrate samples were taken as soon as filtrate begun discharging until the end of the dry cycle. For probe level 1, the filter cycle lasted for approximately 240 s, and then the dry cycle started. At probe level 2, the probe was not exposed even at 1000 s, and the filter cycle stopped due to reaching the maximum filter time.

Table 6.2 Filter cake sample moistures and filtrate results.

Run Order	Moisture Content (%)							Total Filtrate (g)	Filtrate Solids (g)
	S1	S2	S3	S4	S5	M4	M5		
1	12.3	13.0	12.5	13.3	21.5	12.8	14.5	39653.7	21.6
2	11.2	12.9	11.1	12.7	15.9	12.0	12.8	42274.5	25.2
3	11.2	14.6	11.2	11.6	20.3	12.1	13.8	35798.8	17.7
4	15.6	17.0	17.9	16.9	19.2	16.9	17.3	27002.6	19.9
5	12.5	12.9	13.5	14.2	24.5	13.3	15.5	36755.7	18.2
6	16.8	18.2	17.1	17.9	26.5	17.5	19.3	24826.6	20.4
7	15.2	17.0	17.4	17.0	22.1	16.6	17.7	29477.4	20.5
8	15.5	16.5	16.9	18.6	23.4	16.9	18.2	25375.2	21.2
9[1]	11.5	13.6	12.4	12.9	15.5	12.6	13.2	33950.1	28.6
10[1]	11.8	13.0	11.4	12.4	18.4	12.1	13.4	35866.8	26.6

[1]Replicate of run 3.

The filtrate samples were collected in separate buckets at 30 s intervals until 720 s. As very little filtrate came out beyond 720 s, the remaining filtrate was collected in the last filtrate bucket. The individual data for all 10 runs are given in Appendix E.

6.3 Filter Cake Moisture Analyses

The variation of filter cake moisture with different test conditions was analyzed statistically using Minitab 15. A summary of these results is shown in Table 6.2. The columns S1 to S5 give the values of moisture for the 5 filter cake samples taken. M5 and M4 are the average cake moistures and were calculated as described previously.

Table 6.3 Reproducibility results for replicate tests.

Run Order	Moisture Content (%)						
	S1	**S2**	**S3**	**S4**	**S5**	**M4**	**M5**
3	11.2	14.6	11.2	11.6	20.3	12.1	13.7
9	11.5	13.6	12.4	12.9	15.5	12.6	13.1
10	11.8	13.0	11.4	12.4	18.4	12.1	13.4
Mean	11.5	13.7	11.7	12.3	18.1	12.2	13.4
s	0.31	0.79	0.65	0.68	2.40	0.27	0.29

Table 6.4 Correlation coefficients results for the different models.

Model	**s** (%)	R^2 (%)	**p-values**		
			Probe Level	**Dry Time**	**Air Pressure**
S1	0.32	97.23	0.00	0.02	0.07
S2	0.85	94.51	0.00	0.91	0.32
S3	0.55	98.71	0.00	0.28	0.25
S4	0.69	97.56	0.00	0.07	0.81
S5	2.25	86.78	0.17	0.04	0.40
M5	0.35	99.20	0.00	0.00	0.07
M4	0.22	99.70	0.00	0.02	0.06

Test reproducibility was determined using runs 3, 9, and 10, which is shown in Table 6.3. Standard deviations, s, in the range of 0.3% to 0.8% were obtained for the four filter cake samples, which were similar to those obtained for the previous plants. The standard deviation of M4 was 0.27%. The reproducibility of S5 was the lowest (highest s) due to it being in contact with the residual slurry.

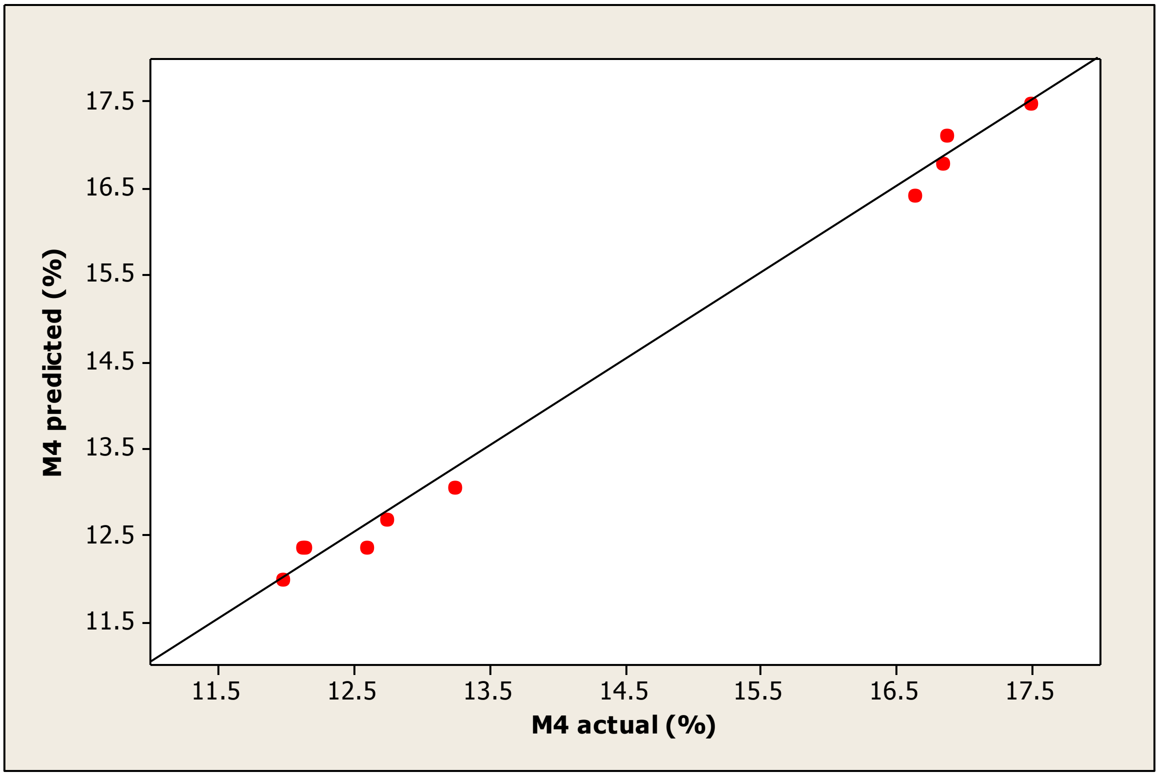


Figure 6.2 Plot of predicted values of M4 versus actual values of M4.

With these seven models (S1, S2, S3, S4, S5, M5, and M4), a complete full-factorial DOE analysis was done to quantify the effects of the test variables on the different moisture samples. The standard deviation and R^2 values for the seven models were determined and are shown in Table 6.4. The model represented by M4 had the highest value of R^2 (99.7%) and the lowest value of s (0.22%). Figure 6.2 shows the variation of M4 predicted with M4 actual.

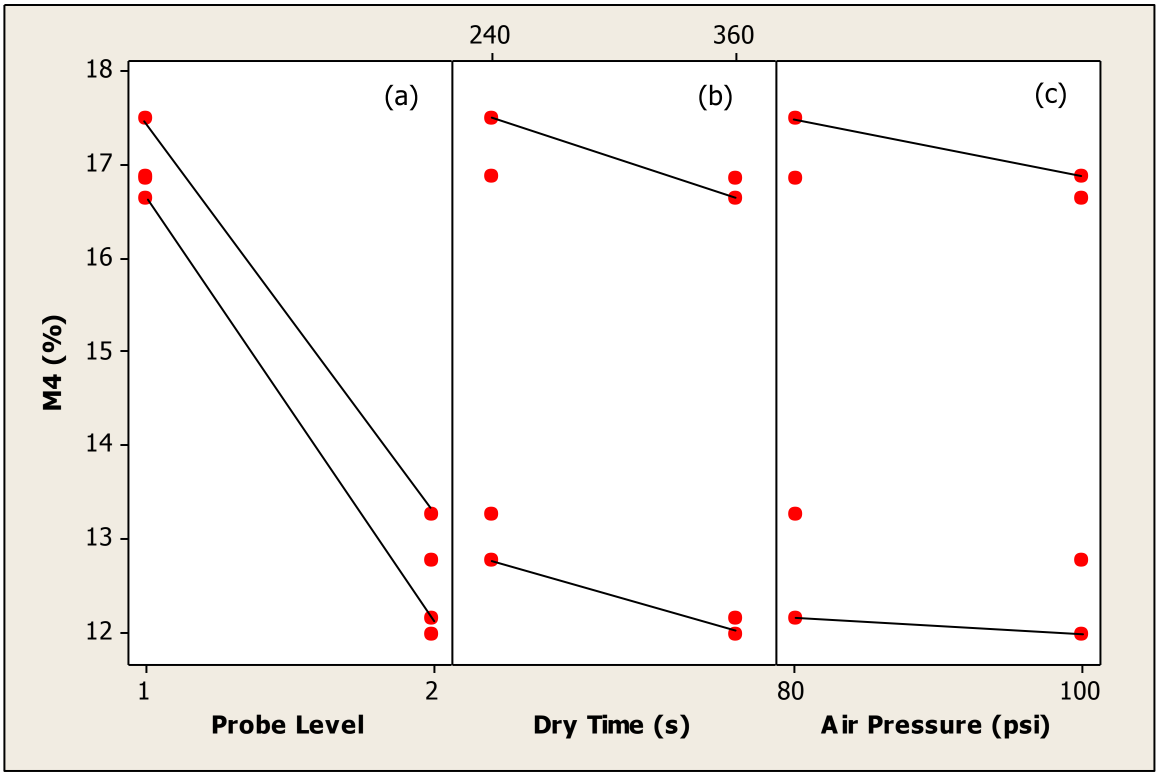


Figure 6.3 Matrix-plot of sample moistures with feed variables for M4 versus: (a) probe level; (b) dry time; (c) air pressure.

Figure 6.3 shows the variation of M4 with different values of probe level, dry time, and air pressure. The points on the graph represent filter cake moistures for different operating conditions. For example, for Figure 6.2a, the highest data point at probe level 1, which corresponds to run 6, is joined to run 5 (probe level 2), all other conditions constant. The other lines represent the same operating conditions except for the variable in question. As expected, M4 decreased at probe level 2, which was due to an increase in the filter time. Similarly, a longer dry time and a higher air pressure also led to lower values of M4.

For M4, the DOE analyses gave p-values of less than 0.05 for probe level and dry time. Hence, both probe level and dry time were significant variables at the 95% confidence level. More dewatering took place at probe level 2 rather than at probe level 1 as the filter cycle was longer for probe level 2. The longer filter cycle extracted more filtrate and hence reduced moisture significantly. The longer dry cycle was also effective in extracting more filtrate from the filter cake voids. The air pressure was insignificant at the 95% confidence level as the p-values for air pressure were higher than 0.05. The detailed results of the DOE analyses are given in Appendix E.

6.4 Filtrate Mass Flow Rate

For a given run, the weights of different filtrate samples were measured to determine the filtrate mass flow rates. As with Plants 1, 2, and 3, the filtrate flow rates were higher initially and decreased with time. The flow rates increased again when the dry cycle started and then decreased. Figure 6.4 shows the variation of cumulative filtrate weight with time for run 2 (probe level 2) and run 7 (probe level 1), which were at the same conditions except the probe level. For both the curves, the average filtrate mass flow rate was 155.7 g/s at the start of the filter cycle. The flow rates were similar until approximately 240 s. At this the time, the probe was exposed and the filter cycle ended for run 7 (probe level 1). The cumulative filtrate weight for probe level 1 continued to increase during the dry cycle but at a slower rate as compared to run 2 (probe level 2). The filter cycle for probe level 2 lasted for 1000 s. The filtrate mass flow rate was 4.0 g/s for probe level 2 at the end of its filter cycle and was 11.7 g/s for probe level 1 at the end

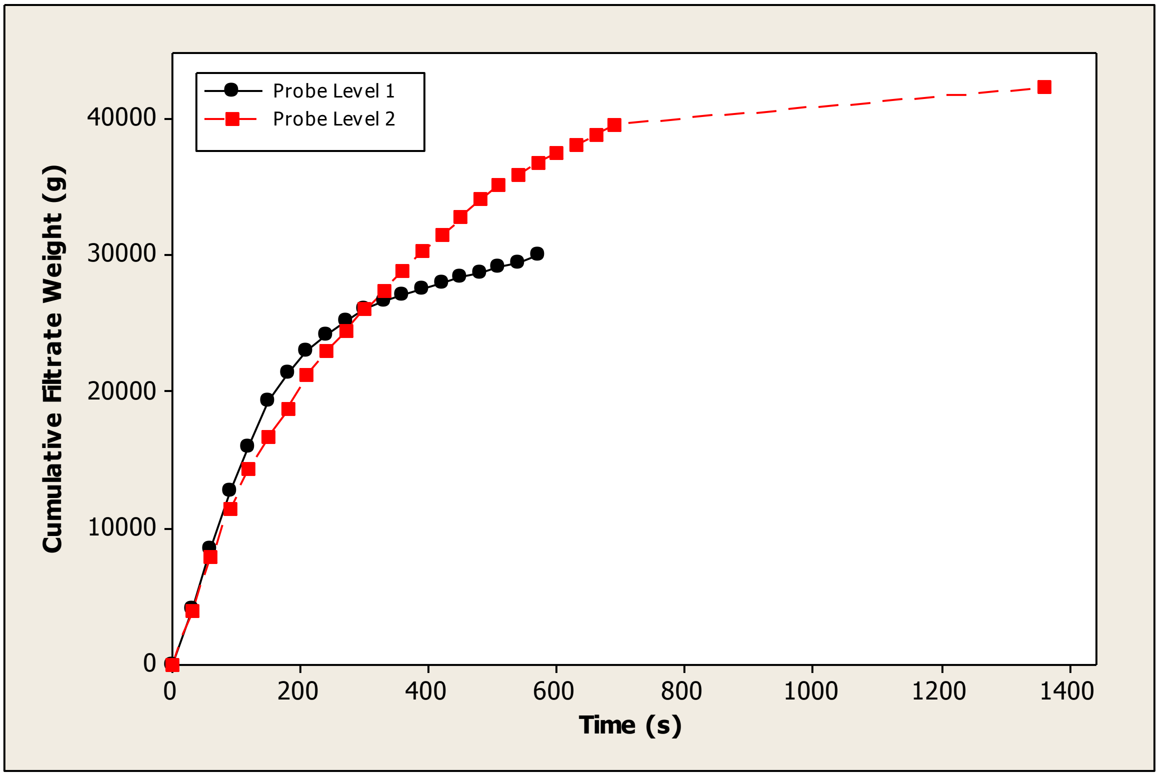


Figure 6.4 Variation of cumulative filtrate weight with time at different probe levels.

of its filter cycle. Run 2 produced a filter cake with an average moisture content of 11.9%, whereas run 7 produced filter cake at an average moisture content of 16.6%. Hence by lowering the probe from level 1 to level 2, which led to an increase in the filter time of 750 s, the overall cake moisture was reduced by approximately 4.7%. The effect on unit capacity will be discussed in a later section.

Figure 6.5 shows the variation of cumulative filtrate weight with time for run 1 (dry time 240 s) and run 2 (dry time 360 s), which were at the same conditions except for the dry time. The longer dry cycle extracted more filtrate out of the filter cake voids. Run 1 produced filter cake at an average moisture content of 12.7% and run 2 produced filter

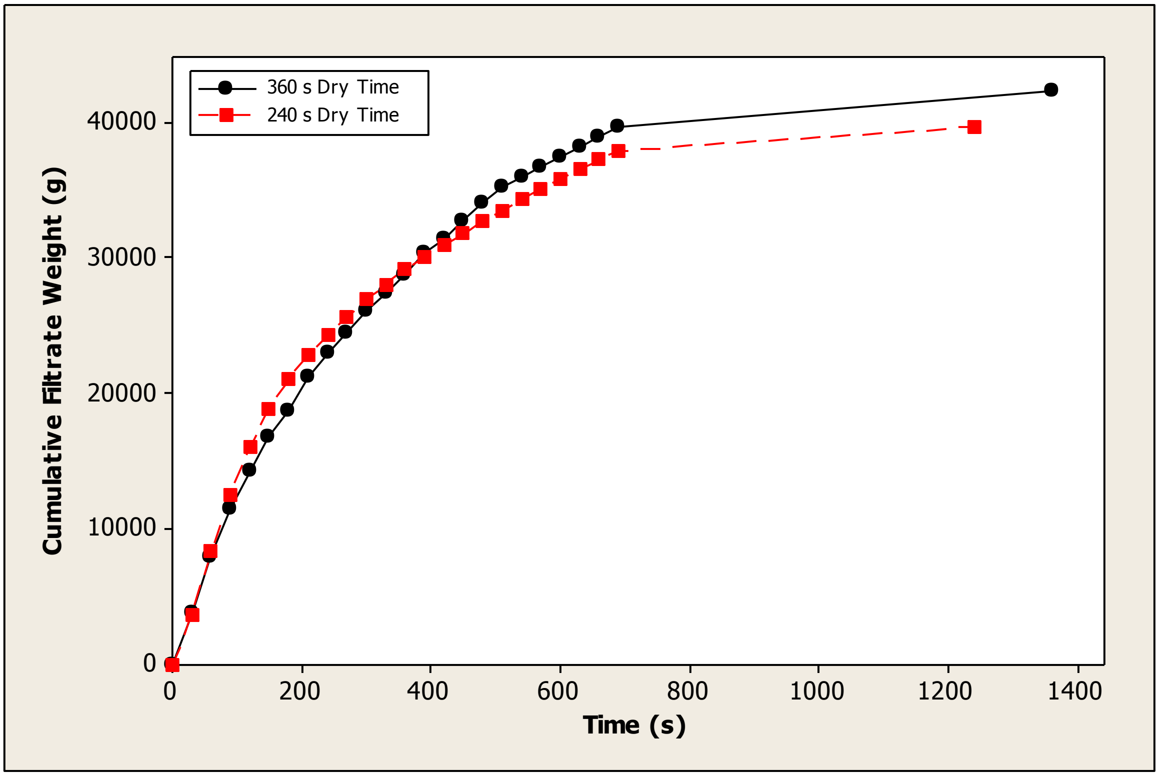


Figure 6.5 Variation of cumulative filtrate weight with time at different dry times.

cake at an average moisture content of 11.9%. Hence the moisture decreased by approximately 0.8% for a 120 s increase in dry time.

Figure 6.6 shows the variation of cumulative filtrate weight with time for run 2 (100 psi) and run 3 (80 psi), which were at the same conditions except the air pressure. The cumulative filtrate weights were nearly identical over the duration of the filter cycle. During the dry cycle, run 2 (100 psi) extracted slightly more filtrate as compared to run 3 (80 psi). The initial cumulative filtrate mass flow rate was 155.7 g/s, which reduced to 4.0 g/s for the air pressure of 100 psi and to 1.8 g/s for the air pressure of 80 psi. Run 2 produced a filter cake with an average moisture content of 11.9%, whereas run 3

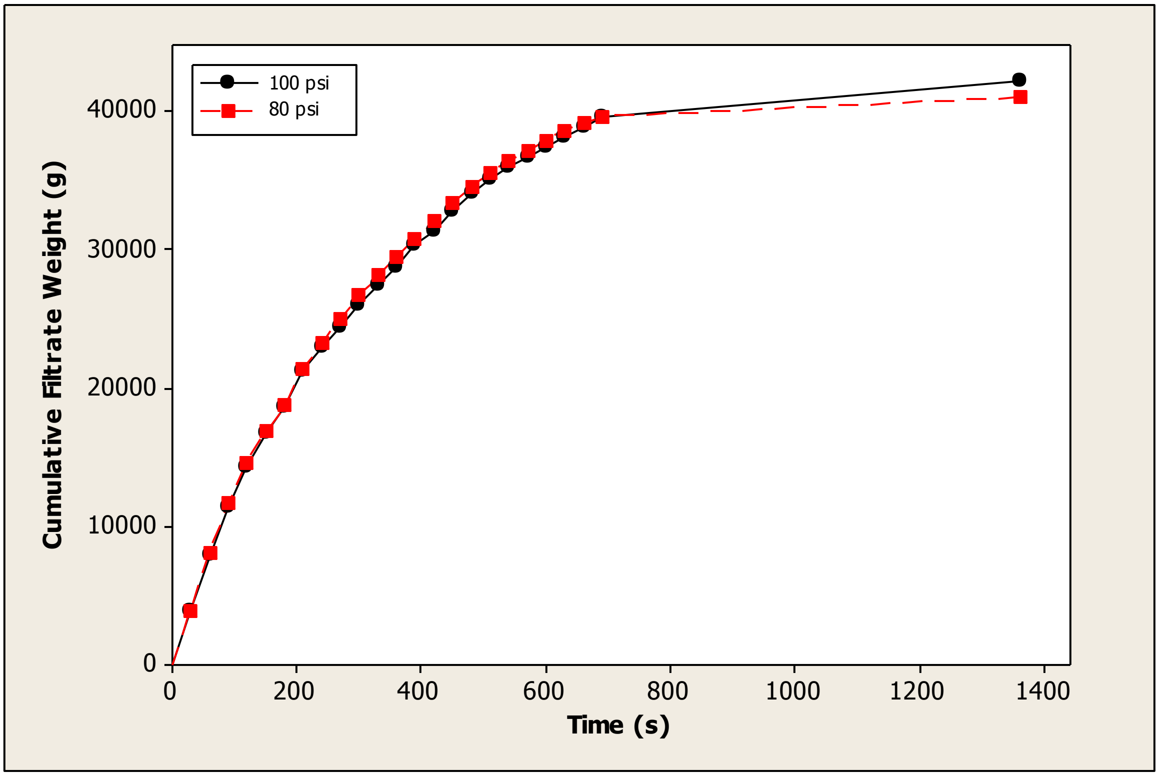


Figure 6.6 Variation of cumulative filtrate weight with time at different air pressures.

produced filter cake at an average moisture content of 12.1%.This small decrease in the moisture content due to increasing pressure is also reflected by the insignificance of air pressure at 95% confidence level in the statistical analyses of filter cake moisture content as seen in Section 6.3.

Table 6.5 Distribution of the solids weight for the filtrate samples of run 2.

Time (s)	**Filtrate Wt** (g)	**Solids Wt** (g)	**Solids Concentration** (%)
30	3895.1	21.5	0.55
60	4050.0	8.2	0.20
90	3518.5	5.6	0.16
120	2903.4	0.9	0.03
150	2372.8	0.4	0.02
180	1977.4	0.1	0.01
210	2532.4	0.0	0.00
240	1735.0	0.0	0.00
270	1496.6	0.0	0.00
300	1594.1	0.0	0.00
330	1358.8	0.0	0.00
360	1354.9	0.1	0.01
390	1503.9	0.3	0.02
420	1146.5	0.1	0.01
450	1332.7	0.1	0.01
480	1311.9	0.1	0.01
510	1079.6	0.0	0.00
540	761.4	0.0	0.00
570	777.5	0.0	0.00
600	726.3	0.0	0.00
630	686.5	0.0	0.00
660	734.2	0.0	0.00
690	743.8	0.0	0.00
720	2681.2	2.3	0.09
Total	42274.5	39.7	0.09

6.5 Filtrate Solids Content

Table 6.5 shows the weights and the solids concentrations for the filtrate samples for run 2. A total of 39.7 g of solids was recovered in the filtrate. The first filtrate sample had a maximum solids concentration of 0.55% after which the solids concentration

Table 6.6 Test conditions and results for the long filter time test at a maximum filter time of 2000 s.

Run Order	**Filter Time** (s)	**Dry Time** (s)	**Wet Cake Wt** (g)	**Filtrate Wt** (g)	(%)				
					S1	**S2**	**S3**	**S4**	**M4**
11	1521	240	10407.1	42415	11.5	13.0	12.0	12.4	12.2

decreased to 0.0%. Since the last sample contained all the flushed-out filtrate, it had slightly higher solids concentration. The entire filtrate sample had a solids concentration of 0.09%.

6.6 Long Filter Cycle Run

An additional test was conducted at a maximum filter time of 2000 s at probe level 2. Feed slurry of 20% solids concentration, a maximum filter time of 2000 s, a dry time of 240 s, and an air pressure of 100 psi were used. The filter cycle ran for 1521 s and then the probe was exposed initiating the dry cycle. A summary of these results is given in Table 6.6. The cake moisture content (12.2%) at a filter time of 1521 s was slightly lower to that at 1000 s from run 1 (12.8%). The cumulative filtrate mass flow rate at 1521 s was approximately 2.9 g/s, hence the cumulative filtrate mass flow rate dropped from 155.7 g/s to 2.9 g/s over the duration of filter cycle for probe level 2.

Table 6.7 Summary of unit capacities for Plant 4 runs.

Filter Time (s)	**Dry Time** (s)	**Total Cycle Time** (s)	**Total Wet Wt** (g)	**M4** (%)	**Unit Capacity** (kg/hr/m^2)
240	240	480	7900.8	28.4	3.49
240	300	540	7154.7	20.9	3.10
240*	360	600	6605.2	14.3	2.79
1000	0	1000	11829.9	25.1	2.62
1000	60	1060	11529.9	23.2	2.48
1000	120	1120	11229.9	21.1	2.34
1000	180	1180	10829.9	18.2	2.22
1000	240	1240	10529.9	15.9	2.12
1000	300	1300	10329.9	14.2	2.02
1000*	360	1360	10055.9	11.9	1.93

*Experimental

6.7 Process Applications

The graphical approach developed for the other 3 plants was used to relate the total filter press cycle times with the filter cake moistures and the unit capacities. Table 6.7 shows a summary of the unit capacities for the different runs. The unit capacities were calculated as with previous plants. These calculations were done for the two probe levels for which the filter times were 300 s and 360 s. The experimentally obtained capacities for these two runs are also shown in Table 6.7. Figure 6.7 shows the combined plot of M4 with unit capacity, filter time, dry time, and total cycle time. To attain the same value of filter cake moisture, the shorter filter cycle run needed a longer dry time. The total cycle times for both the runs were approximately the same, however the longer filter cycle run had the higher capacity. For example, as seen in Figure 6.7a, an M4 value of 14.3% was obtained at filter times of 240 s and 1000 s. For the 240 s filter time, the dry time was 600 s, whereas for the 1000 s filter time, the dry time was 300 s. Also, as seen in Figure 6.7b, the total cycle time for the 240 s run was approximately 600 s and that of 1000 s run was approximately 1300 s. Consequently, as seen in Figure 6.7c, the shorter filter cycle run had a higher unit capacity (2.79 kg/hr/m^2 versus 2.02 kg/hr/m^2).

Higher unit capacities were obtained for shorter filter cycle runs as the weight of filter cake solids increased less relative to the increase in the filter time. Figure 6.7d gives the direct variation of M4 with unit capacities for the different values of filter times. Similarly, at a predefined total cycle time different values of filter time, M4, and unit capacities can be obtained. Hence this approach can be used to estimate the different operating conditions needed to obtain a given product. Moreover these values provide scale-up information when processing a similar feed material.

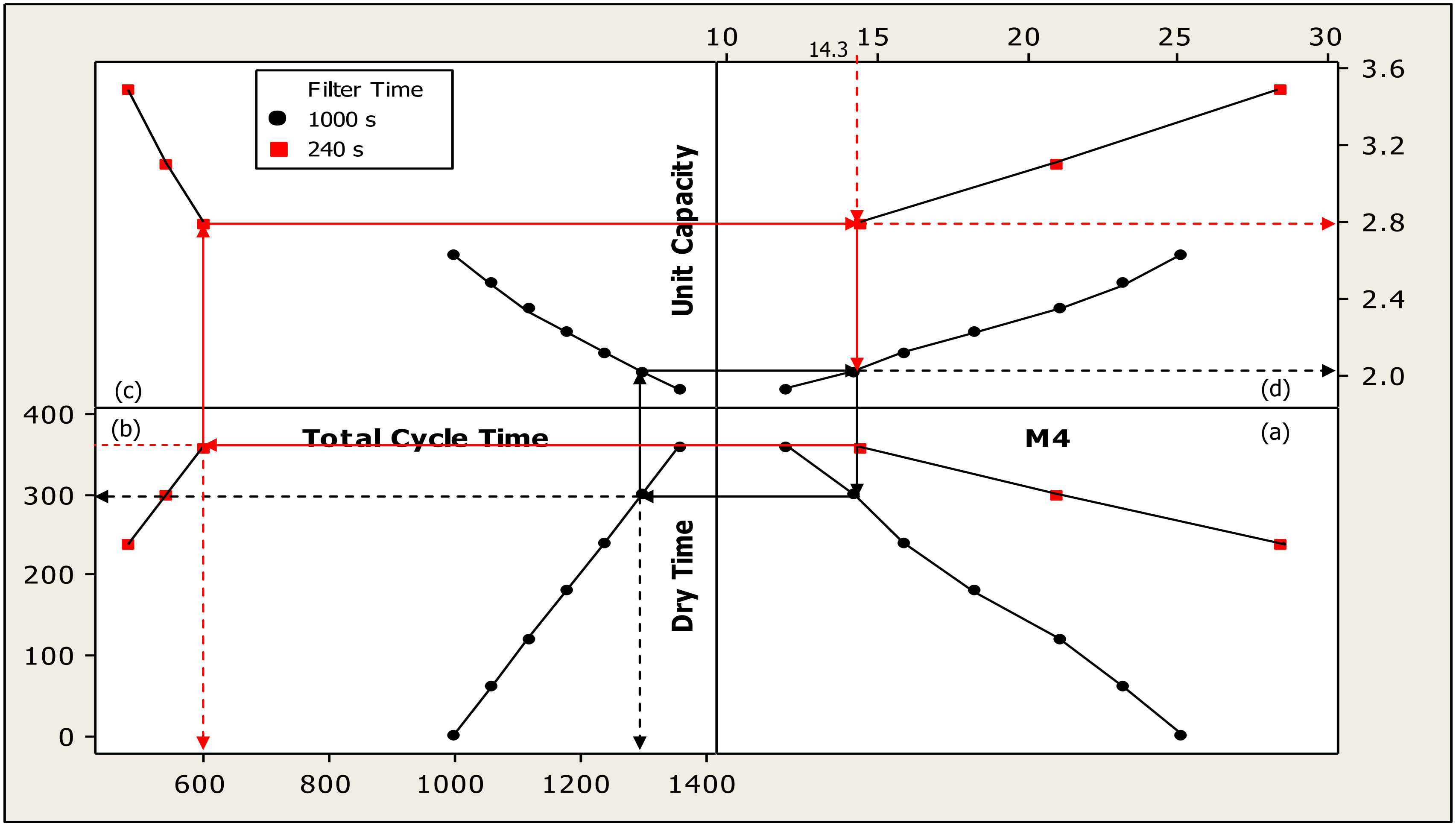


Figure 6.7 Variation of (a) M4 (%) with dry time (s); (b) dry time (s) with total cycle time (s); (c) total cycle time (s) with unit capacity ($kg/hr/m^2$); and (d) unit capacity ($kg/hr/m^2$) with M4 (%).

CHAPTER 7

SUMMARY AND CONCLUSIONS

A total of seventy-one plate-and-frame filter press tests were conducted using four different plant slurries. One coal refuse sample was collected from an anthracite cleaning plant (Plant 1), two coal refuse samples were collected from bituminous coal cleaning plants (Plants 2 and 3), and the other sample was collected from a silica-sand processing plant (Plant 4). Testing was done to evaluate filter press performance while dewatering these slurries under various conditions. A statistical design was developed for each sample using Minitab 15. The test variables included feed solids concentration, maximum filter time, dry time, air pressure, and probe level.

The anthracite refuse sample (nominal -70 mesh) was obtained from the underflow stream of a refuse thickener that was feeding a belt filter press. The as-received sample had a solids concentration of 24.6%. This material had an ash value of 50.6% and contained 55% of -500 mesh material. Twenty-seven filter tests were carried out with this sample (material A) at maximum filter times of 120 s and 240 s, dry times of 120 s, 240 s, and 360 s, air pressures of 80 psi and 100 psi, and feed solids concentrations of 20% and 30% by weight. DOE analyses were done on the entire test sequence. The statistical model developed was able to explain 97.3% of the variation in moisture based on the different variable levels. Dry time was found to be the most significant variable, and a minimum of 22.6% moisture was obtained at these variable levels. The moisture content for most of the runs ranged from 23% to 27%. A separate set of four tests was conducted at longer filter times (200 s, 500 s, 1000 s, and 2000 s) to evaluate the effect of longer filter times on the filter cake moistures. A filter cake with a moisture content of 17.2% was obtained at a filter time of 2000 s. However, at the long cycle times, the unit capacity decreased. For example, a unit capacity of 1.8 kg/hr/m^2 could be obtained for a filter cake containing 20% moisture compared to 0.8 kg/hr/m^2 for a filter cake containing 17.2% moisture.

Another set of four tests were conducted at the long filter times using material B, which had been obtained from the belt filter press product stream. The 2000 s filter cycle run produced filter cake at a moisture content of 16.9% compared to 17.2% for material A. At the shorter times, the filter cake moistures using material B were about 1% lower compared to when using material A. Higher filtrate mass flow rates were also obtained using material B thereby reducing the total cycle time. The results were that the unit capacities for material B were approximately 0.3 kg/hr/m^2 higher at a given filter time compared to material A.

One bituminous coal refuse sample (nominal -20 mesh) was obtained from the thickener underflow stream of plant 2. The as-received sample had a solids concentration of 35.3%. This material had an ash value of 42.2% and contained 34.2% of -500 mesh material. Ten filter tests were carried out with this sample at filter times of 300, 400, 500, and 600 s, and dry times of 120 s and 240 s. DOE analyses were done on the entire test sequence. The statistical model developed was able to explain 91.5% of the variation in moisture based on the different variable levels. Filter time was found to be the most significant variable, and a minimum of 23.6% moisture was obtained at these variable levels. Another test was conducted at a maximum filter time of 1000 s, which produced a filter cake of 23.4% moisture. Although longer cycles times produce drier filter cakes, this resulted in lower unit capacities. For example, a unit capacity of 1.1 kg/hr/m^2 could be obtained for a filter cake containing 25.6% moisture compared to 0.8 kg/hr/m^2 for a filter cake containing 23.6% moisture.

The other bituminous coal sample (nominal -100 mesh) was also obtained from the thickener underflow stream of plant 3. This material had an ash value of 15% and contained 62.5% of -500 mesh material. Fourteen filter tests were carried out on this sample at two probe levels, dry times of 120 s, 240 s, and 360 s, and air pressures of 80 psi and 100 psi. DOE analyses were done on the entire test sequence. The statistical model developed was able to explain 98.4% of the variation in moisture based on the different variable levels. Probe level and dry time were found to be the most significant variables. A minimum of 16.1% moisture was obtained at these levels of variables. As indicated previously, longer cycles times produce drier filter cakes, this resulted in lower unit capacities. For example, a unit capacity of 2.4 kg/hr/m^2 could be obtained for a filter cake containing 16.1% moisture compared to 3.1 kg/hr/m^2 for a filter cake containing 18.1% moisture, and 3.7 kg/hr/m^2 for a filter cake containing 20% moisture.

The silica-sand sample (nominal -100 mesh) was obtained from the thickener underflow stream of plant 4. This material contained 37% of -500 mesh material. Ten filter tests were carried out on this sample at two probe levels, dry times of 240 s and 360 s, and air pressures of 80 psi and 100 psi. DOE analyses were done on the entire test sequence. The statistical model developed was able to explain 99.7% of the variation in moisture based on the different variable levels. Probe level and dry time were found to be most significant variables. A minimum of 11.9% moisture was obtained at these variable levels. As indicated previously, longer cycles times produce drier filter cakes, this resulted in lower unit capacities. For example, a unit capacity of 1.9 $kg/hr/m^2$ could be obtained for a filter cake containing 11.9% moisture compared to 2.7 $kg/hr/m^2$ for a filter cake containing 14.3% moisture.

In all tests, feed solids concentration was not a significant variable in regard to explaining the moisture variation in the filter cake for tests in which the filter cycle was terminated due to exposure of probe. The filter time depended on the feed solids concentration and was lower for the 30% slurry as compared to the 20% slurry. For slurries of different solids concentration, the final filter cake moistures would be different if the filter cycle would have been equal.

In the tests where maximum filter time was used to terminate the filter cycle, the filter time was a significant variable to explain the moisture variation in the filter cake. As the pump ran for the duration of filter cycle, longer filter times produced drier cakes. However, this generally led to a decrease in unit capacity as indicated previously.

In most cases, dry time was a significant variable in regards to explaining the moisture variation in the filter cake. A longer dry cycle deblinded the filter cloth better and extracted more filtrate out of the particle voids as compared to shorter dry cycles. However, after a particular time, which varied for different samples, a longer dry cycle extracted very little filtrate. For filter tests with longer filter cycles, dry time was not significant as a longer filter cycle extracted the bulk of the filtrate.

In general, air pressure was a significant variable in regards to explaining the filter cake moisture variation only for shorter filter cycles. For such runs, more filtrate was remaining in the filter cake, which was extracted by the dry cycle. The dry cycle at higher pressure extracted significantly more filtrate as compared to the lower pressure cycle.

The filtrate mass flow rates consistently increased during the start of the fill and filter cycles and then decreased. The flow rates were reproducible for all tests for the same cycle times. Flow rates increased again during the dry cycle for a short time and then decreased. For tests with different solids concentrations, flow rates were higher for the more dilute slurry. A higher air pressure during the dry cycle also produced higher filtrate mass flow rates.

For all tests, the solids concentration in the filtrate samples increased during the start of the fill and filter cycles as the fines passed through the filter cloth. It then quickly decreased as a layer of filter cake was formed on the filter cloth. The filtrate solids content for all the plant runs were low and averaged approximately 0.1%. For Plant 1, tests at 30 % solids concentration produced approximately 0.2% solids in filtrate as compared to 0.1% for the 20% solids concentration tests. Similarly for Plant 2, since tests were conducted at 35% solids concentration, the filtrate solids content on an average was approximately 1%.

Figure 7.1 shows the comparison between four different plant materials. For coal samples, the unit capacities were highest for plant 3 material and lowest for plant 2 material. This was due to the shorter total cycle times and lower moisture values for the plant 3 material. The plant 3 material had highest amount of -500 mesh fraction (68%), followed by plant 1(50%), and lowest for plant 2 (34%). Also plant 3 material had an head sample ash value of 15% versus 51% for plant 1, and 42% for plant 3. The slope of

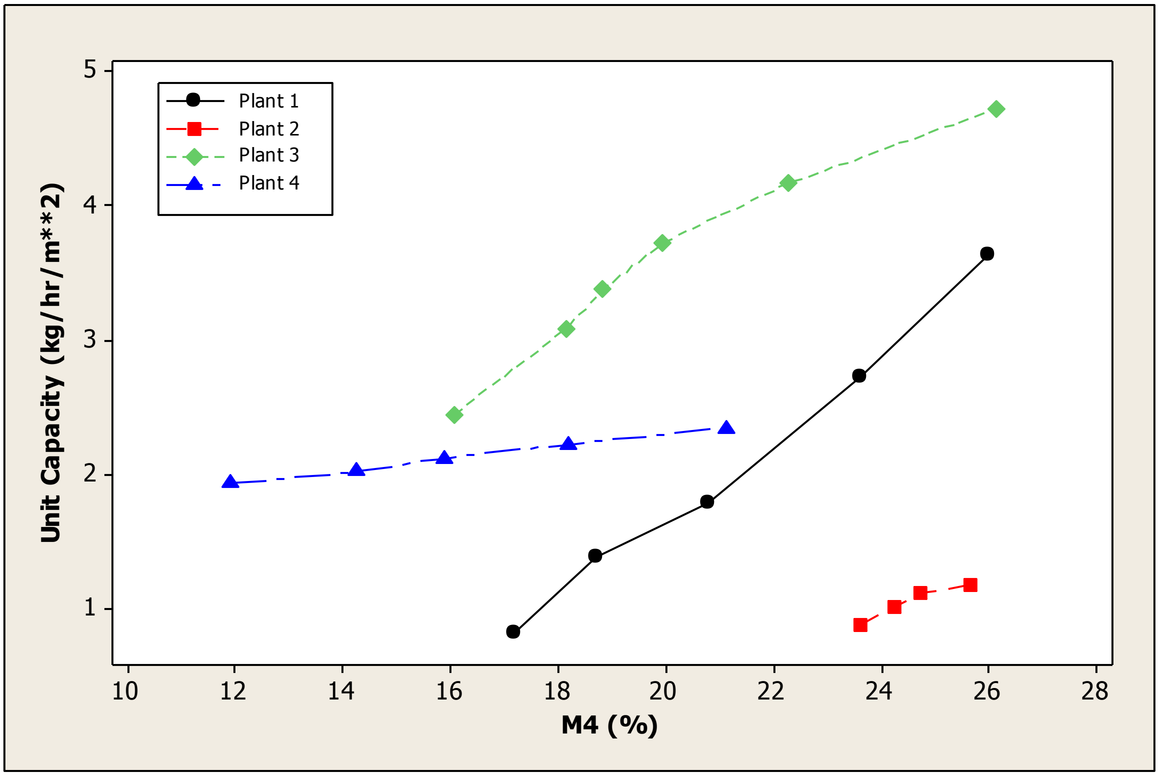


Figure 7.1 Comparison of different plant materials.

curve for plant 4 is minimum, which indicates that the unit capacity for plant 4 was not very sensitive to the moisture values. Silica, being a clayey material took longer to get packed and hence the total cycle times went higher, which resulted in reduced unit capacities.

Based on these tests, the following conclusions can be drawn:

- M4 gives the best representation of the filter cake moisture.
- The use of probe facilitates the control over variations in the feed solids concentration by adjusting the duration of filter cycle accordingly. For dilute slurry the filter cycle is run for a longer duration.

- Lower filter cake moistures can be obtained at higher cycle times, however this reduces unit capacities. The moisture reduction is minimal at longer filter times like 2000 s.
- The dry cycle extracts substantial filtrate but only till a certain time for example 240 s, beyond which very little filtrate is extracted.
- A combination of filter time and dry time may be chosen from the process application graphs that provide an approach for selecting operational parameters. The graph gives an idea of how a specific value of filter cake moisture may be obtained at different cycle times. The effect of cycle times on unit capacity can be determined. The graph may be used to scale up when processing similar feed material.

Recommendations for future filter press dewatering studies are the following:

1. Correlate the filter cake moistures to the ash values, particle size, and/or clay content of the feed material. For coal slurries, prepare material of incremental ash values and specific size fractions and perform tests at the same conditions to develop these correlations.
2. Conduct filter tests at different flocculant dosages to determine their effect on filter cake moisture and the filtrate mass flow rate behavior.
3. Evaluate the effect of pH of the slurry, temperature of the slurry, and temperature of the compressed air on dewatering behavior.

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APPENDIX A

OPERATING PROCEDURES

Ash Analysis Procedure

1. Crush several grams of any sample larger than 200 mesh (0.074 mm) in a mortar and pestle or agate mill prior to analysis.
2. Open the main valves completely on the oxygen and nitrogen tanks. Ensure that the pressure gauges on each tank register a minimum of 500 psi. Ensure that the regulator for each tank is set to 40 psi.
3. If not on already, switch the furnace on, followed by the CPU.
4. Press F1 to bring up the menu of analysis options and enter sample identification.
5. Press F2 to analyze using the modified moisture and ash protocol.
6. Remove the crucibles and empty any material. Wipe the inside of each crucible with a clean, dry rag. Do not wet the crucibles, and do not remove the reference crucible immediately to the right of the indicator arrow.
7. Return the required number of crucibles to the oven including one for the coal standard. Ensure that they are evenly distributed so that the tray is balanced. Press the ENTER SAMPLE button on the furnace to close the furnace lid.
8. After each crucible has been automatically tared and the alarm has sounded (after approximately 5 minutes), press ENTER SAMPLE to open the furnace lid.
9. Load the first crucible, which is designated by the indicator arrow pointing to it. Add approximately 1 g of the sample material to the crucible. Note that the minimum sample weight to ensure proper analysis is approximately 0.3 grams, while the maximum weight should not exceed 1.5 g to prevent a long burnout time. On the CPU enter a label that

describes the sample. Press ENTER SAMPLE to close the lid. The sample will then be weighed.

10. After approximately 10 seconds the alarm will sound and the lid will open automatically, allowing the next sample to be loaded. Repeat steps 9 and 10 until all crucibles are loaded. Note that the last crucible was reserved for a standard coal sample to be used as a reference. Do not place any material into the reference crucible.
11. After the last crucible is loaded, the machine will begin analyzing. Approximately four hours are needed to complete the analysis of the maximum 18 samples plus the standard.
12. When finished, the lid will open to cool the furnace. Print the results. Close the main air value and close the main valves on both the oxygen and nitrogen tanks.

Helium Steropycnometer Density Measurement Procedure

1. Turn the power on, and allow the instrument to warm up for 15 to 20 minutes.
2. Select the proper volume sample cell. Use the larger cell it sufficient material is available.
3. Weigh and record the weight of the selected cell.
4. Fill the cell approximately ¾ of the cell volume with the powder sample. Weigh and record the weight of the cell and sample.
5. Close the FLOW toggle valve and the VENT toggle valve (the toggle handle should be parallel to the panel). The FLOW toggle valve is located in the lower corner of the instrument panel and the VENT toggle valve is in the upper right corner.
6. Completely close the VENT and FLOW control needle valves by turning each clockwise. Be sure not to over tighten the needle valves.
7. Ensure that the 4 way SELECTOR valve is pointing to *Va out.*
8. Lift the cell VENT toggle the open the valve.
9. Open the cell VENT needle valve by turning the knob counter clock wise.
10. Set the reading in the display to ZERO by adjusting the ZERO knob.
11. Open the helium tank and adjust the regulator to slightly above 20 psi. Ensure that all values in the line are open. *Caution: a pressure setting greater than 25 psi can damage the pressure transducer.*
12. Open the cell chamber and place the cell containing the sample into the chamber. For the small cell, ensure that the holder is placed in the chamber first. Ensure that the rubber gasket is lightly coated with vacuum grease. When closing the chamber, do not over tighten the lid. The threads are easily crossed.

13. Attach one end of the hose to the VENT hose connection and place the other end in a beaker of water,
14. Turn the 4 way SELECTOR valve to *Va in.*
15. Open the FLOW toggle valve by lifting the toggle handle and very carefully adjust the gas flow rate with the flow needle valve. If the FLOW needle valve is opened too quickly, particles from the sample will be drawn into the system. If this occurs, the inline filter may require cleaning. Allow the flow rate to stabilize after each time the valve is adjusted. Once a slow rate of bubbling is obtained (1-2 bubbles per second), remove the hose from the water.
16. Allow the gas to pass through the sample for 10- 20 minutes to purge the system.
17. Stop the flow of the gas by closing the FLOW toggle valve. The system must be purged each time the cell chamber has been opened.
18. Completely close the cell VENT control valve by turning it clockwise. Slightly open the valve by turning the knob about ½ turn counter-clockwise.
19. Readjust the display to zero with the ZERO knob.
20. Turn the 4 way SELECTOR valve to the *Va out* position.
21. Close the cell VENT toggle valve to release any built up pressure by depressing the toggle valve tip (toward the instrument panel).
22. Open the FLOW toggle valve and allow the gas to pass through the system. Adjust the rate with the FLOW needle valve if necessary. Pressurize the system to slightly less than 20 psi and then close the FLOW toggle valve. Allowing the reading to stabilize. If the reading steadily decreases ensure that the chamber lid is snug. When the regulator on the

helium tank is less then 20 psi, the maximum reading will be equal to the pressure passing through the regulator.

23. Record this reading as P_2.
24. Turn the 4-way SELECTOR valve to the *Va in* position, and allow the reading to stabilize.
25. Record this reading as P_3.
26. Depressurize the system by opening the cell VENT toggle valve. Once the reading is at zero, turn the 4-way SELECTOR valve to the *Va out* position and remove the sample.
27. Repeat the procedure for all the samples.

The true powder volume, V_p, is calculated by:

$$V_p = V_C + \frac{V_a}{1 - \frac{P_2}{P_3}}$$

For the large cell, V_c = 154.57 cm^3. For the small cell, V_c = 33.53 cm^3. The reference volume, V_a = 88.17 cm^3 in both cases. The powder density is calculated by dividing the sample weight by, V_p.

Microtrac Size Analysis Procedure

1. Turn on the power to the computer, monitor and Microtrac analyzer.
2. When prompted by the computer, press ENTER to select:

   "1. Microtrac Various Revisions," then

   "1. Windows (MT Windows Soft)"
3. Using the mouse pointer, double click on the MICROTRAC 5.0. Click OK at the next prompt.
4. After the Microtrac window comes up, click on the SELECT pull down menu and chose MEASURE X100 to put the device into the proper mode.
5. Click the SETUP pull down menu and choose MEASUREMENT (make sure that the laser is on at this point).
6. Under the Measurement setup window, select a previous user name from the pull down menu or type in the new user name.
7. While in the Measurement Setup window, choose Analysis. Under Particle Information, either select a previously entered setup for certain materials from the pull down menu or type in the new Refractive Index (R.I.). Coal was used as a previously entered material from the pull down menu.
8. Click OK twice to close the setup windows and return to the Microtrac analysis screen.
9. Fill ½ of the volume of the glass sump with distilled water containing dispersants. For the coal samples, a 0.1% sodium metaphosphate solution was used as the dispersant. Turn on the pump (forward direction). Adjust the speed to 5 (50% maximum speed). Continue to add dispersant to the sump until the sump is approximately ½ full.

10. Click to Set Zero button in the upper left corner of the screen. When the computer prompt indicates that the auto align process is complete, enter OK.
11. Click the ID button in the upper left corner of the screen to bring up the sample identification template. Enter the sample identification information and select OK to close the window.
12. Place approximately 0.1 grams of sample in a 25 ml beaker and add the appropriate dispersant. Mix the sample by hand with a stirring rod. Disperse the sample with ultrasonic energy using the probe at amplitude of 20% for 5 seconds.
13. Click on the LOAD SAMPLE button to normalize the device. When the Add Sample prompt appears, rinse the sample into the sump using a wash bottle.
14. Click the RUN button. The return tube from the analyzer that feeds the sump should be continually circulated in the sump to prevent the particles from settling.
15. The analysis averages three 10 second runs. Following the completion of the size analysis for that sample, click on the print button.
16. Direct the return tube from the analyzer into the spill basin to drain the sample. Use a wash bottle with the same dispersant mixture to rinse down the walls of the sump. Add distilled water to the circuit to flush the tubing before adding more dispersant solution for the next run. Repeat steps 9 through 16 until all samples are complete.

Plate-and-Frame Filter Press Operating Procedure

The plate-and-frame filter press is used for dewatering of slurries typically greater than 10% solids concentration by weight. For a single test, the following supplies are needed:

I. A pre-weighed large pan that goes under the filter plate to collect the cake.
II. A large screen (30 mesh) that goes over the large pan to retain the cake.
III. Five pre-weighed small pans to collect cake samples. Additional pans may be needed.
IV. Approximately 15, pre-weighed plastic buckets/beakers to collect the filtrate. Calculate the number of buckets required depending on the duration of total cycle and filtrate collection intervals. Atleast 5 of these buckets should be able to hold 2 gallons of filtrate.
V. Two stop watches.
VI. A pre-weighed bucket (5 gallon) that goes under the outlet from the residual slurry valve.
VII. Approximately 5 pre-weighed buckets (5 gallon) for slurry collection from the feed tank.
VIII. Marcy pulp gauge with a 1 liter stainless-steel bucket.

1. Ensure that the filter cloth on the filter plates is clean. Hose the cloth to remove any solids attached to the cloth.
2. Close the residual slurry valve behind the filter plate.
3. Locate the hose for the air line of the pneumatic system on the right hand side of the control panel. Attach that hose to the house air line. Open the air line valve.
4. Attach the air line from the compressor to the air inlet behind the filter plate. Compressed air at approximately 100 psi is required for this purpose. The air pressure must **never**

exceed 150 psi. Switch the compressor to auto and adjust the air pressure to the desired value by turning the control knob next to the air inlet.

5. Place the large, dry and clean pan beneath the plate opening to collect the filter cake.
6. Place the large screen (30 mesh) on the pan to collect the dewatered cake.
7. Connect the filter press power cable to the specified electric outlet and turn the power on by turning the central black round knob counter clockwise (0 to 1).
8. Gently close **both** drain valves on the side and on the bottom of the feed tank.
9. Prepare the slurry of desired concentration in the feed tank. First, add water of known volume and then turn on the mixer control (0 to 1) knob located on the panel left to the main control panel and adjust its rotation as desired using the knob.
10. Add solids required to achieve the desired solids concentration. As an approximation, for slurry ≥ 20% solids, slurry volume greater than 70 liters should be used to ensure that the feed pump will work properly feeding slurry to the filter plates.
11. Allow the solids to mix for about 5 minutes in the tank. Measure the solids concentration for verification using the Marcy gauge. Ensure that a bucket is under the gauge. While mixer in the tank is running, take a sample using the Marcy gauge small metallic bucket by opening the side drain valve slightly. Quickly hang the bucket over the balance. The needle shows the relative density (R.D.) of the slurry. Calculate the weight % solids (S_w) using the following formula where ρ is the density of the solids

$$S_w\ \% = \left(\frac{\rho}{1-\rho}\right)\left(1-\frac{1}{RD}\right)100$$

12. Arrange the filtrate collection buckets near the filtrate discharge and set the stop watches to measure the initial filtrate time and the intervals between filtrate collection.

13. The probe level in the filtrate tank needs to be adjusted as per the filter time requirements. Higher values of filter time would be obtained by lowering the probe.
14. On the control panel display press ► to enter the "Maximum fill time", "Maximum filter time", "Pause time", and "Dry time" to the desired values. Use the MOD button to navigate between parameters Use the ▲ and ▼ keys to increase and decrease the values.. Press enter to confirm the values.
15. Set the Pause time between the Dry Cycle and Discharge to 60 seconds to allow sufficient time for residual slurry collection from the residual slurry valve between these steps. Press enter to confirm. To go back press ESC twice.
16. When the slurry is well mixed, place the selector MAN – AUTO to MAN, get ready with the stop watches and press the MAN button twice. The plate will start closing.
17. Start timing with one stop watch as soon as the pump starts and time it until the filtrate comes out. Record this time as the initial filtrate time.
18. As soon as filtrate starts coming out, start timing with the other stop watch and collect filtrate at predefined time intervals if desired in the labeled buckets.
19. The Filter Cycle is determined by the probe level inside the filtrate tank. As soon as the level of filtrate falls below the probe level in the tank, the pump stops and no more feeding is done.
20. Note the feed line pressure shown on the pressure gauge behind the plate while the pump is running.
21. As soon as Filter Cycle is completed, the machine pauses for 5 seconds and then automatically switches to the Dry Cycle for air blow.

22. In this cycle air from the compressor is blown in the filter plates and more filtrate comes out. Continue collecting the filtrate in the buckets at the desired time intervals.
23. As soon as the Dry cycle is complete, open the residual slurry valve slowly behind the filter plate. Collect the excess slurry present in the feed line in a bucket for the mass balance. If not collected, this slurry would come out with the dry cake increasing moisture significantly. This must be done within the defined pause time defined.
24. After the pause time is over, the plates open and the filter cake drops into the screen. After the plates open, dislodge any solids sticking to the cloth using a wooden stick being careful not to damage the cloth.
25. Take five samples of the cake, four from each corner and one from the center, put all samples into a sample pan, weigh it and keep it for drying.
26. Weigh the total cake and place it in the oven for drying.
27. Weigh the filtrate buckets to determine filtrate weights
28. Combine all the filtrate samples and dry them to find the total solids weight in the filtrate.
29. Weigh the residual slurry bucket for use in establishing the mass balance.
30. With the mixer in the feed tank running, gently open the side drain valve on the feed tank and collect the slurry in pre-weighed buckets.
31. When the flow from side drain valve drops close it and put another bucket under the residual valve at the bottom of the tank. Turn off the mixer in the feed tank.
32. Using both hands, very gently open the drain valve at the bottom of the tank and allow the slurry to drain into the pre-weighed bucket. Weigh all the buckets for use in establishing the mass balance.

33. When the feed tank is empty, pace another bucket under the drain valve and hose the tank thoroughly. Drain the tank and repeat until no solids remain.
34. Hose the filter cloth until the cloth is clean. Carefully hose the plates and unit to ensure that the unit is clean.
35. Fill the feed tank with water and run the entire cycle by pressing the MAN button to clear all the feed lines from solids.
36. Turn off the power by turning the central knob on main control panel back to 0.
37. Unplug all the electrical and air line connections and clean the work area.
38. After the cake samples have been dried over-night, weigh and record the dry weights to calculate the moisture contents.

A sample data sheet is given along with pictures that illustrating the unit and the test process.

Run Order	Relative Density	Max Filter Time (s)	Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)

Bucket	Time (s)	Bucket Wt	Total Wt	Filtrate Wt
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
Total				

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt					
Initial Wt					
Final Wt					
% Moisture					

Dry Sample for % solids

Pan Wt	
Initial Wt	
Final Wt	
% Solids	

Dry Residual

Pan Wt	
Initial Wt	
Final Wt	
% Solids	

Ease of discharge

Dry Filtrate Wt

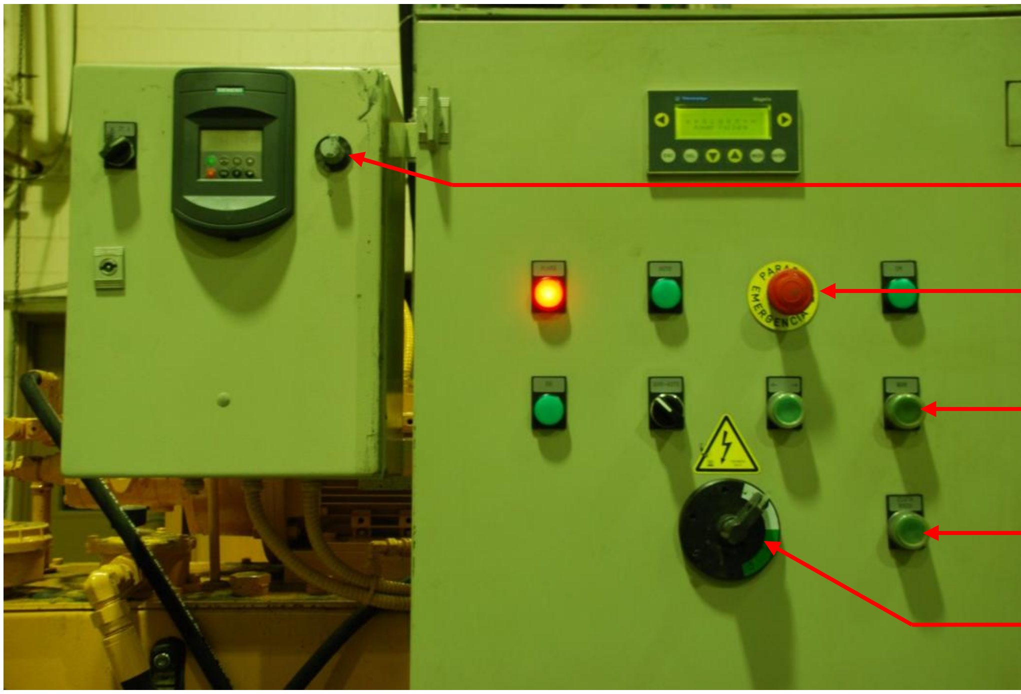
Total Wt	
Pan Wt	
Solids Wt	

Residual Slurry

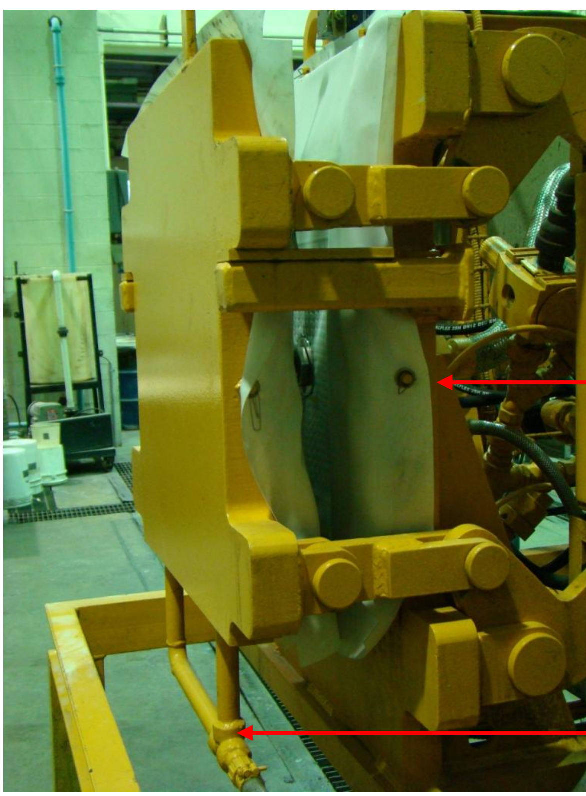
Total Wt	
Initial Wt	
Residual Wt	

Main Cake Wt

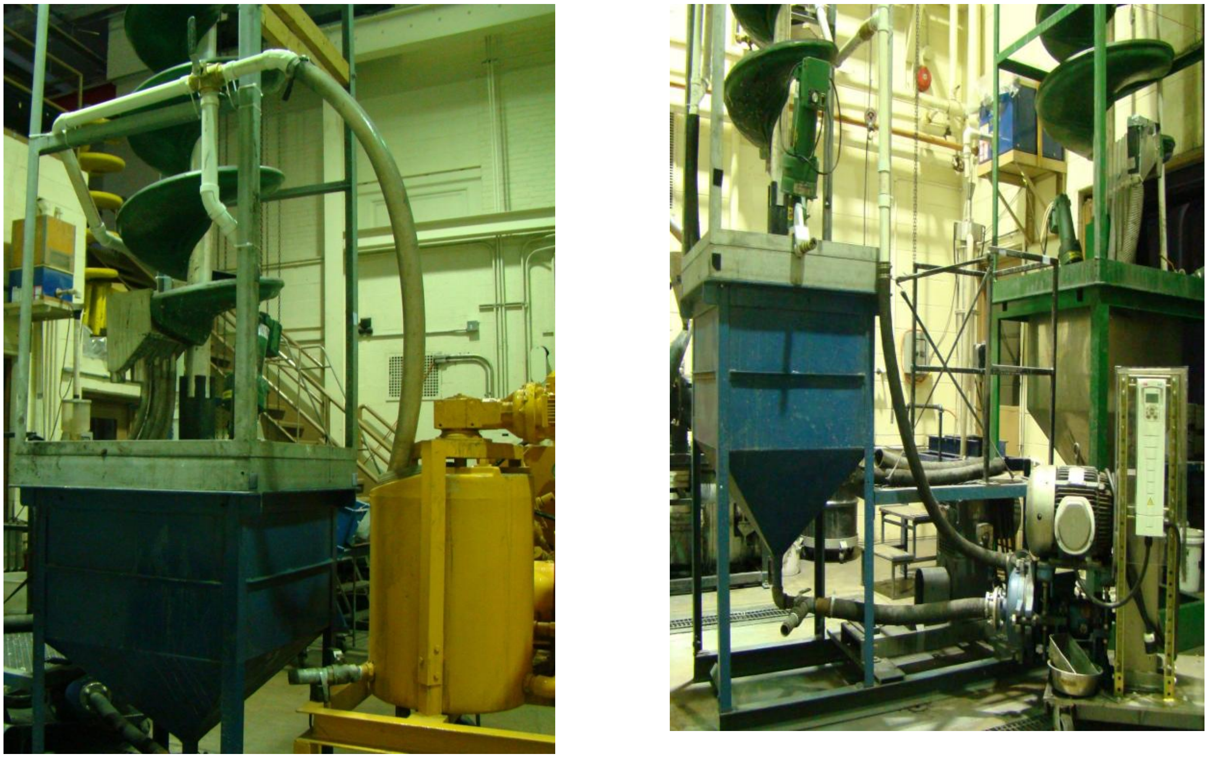
Total Wt	
Pan Wt	
Solids Wt	



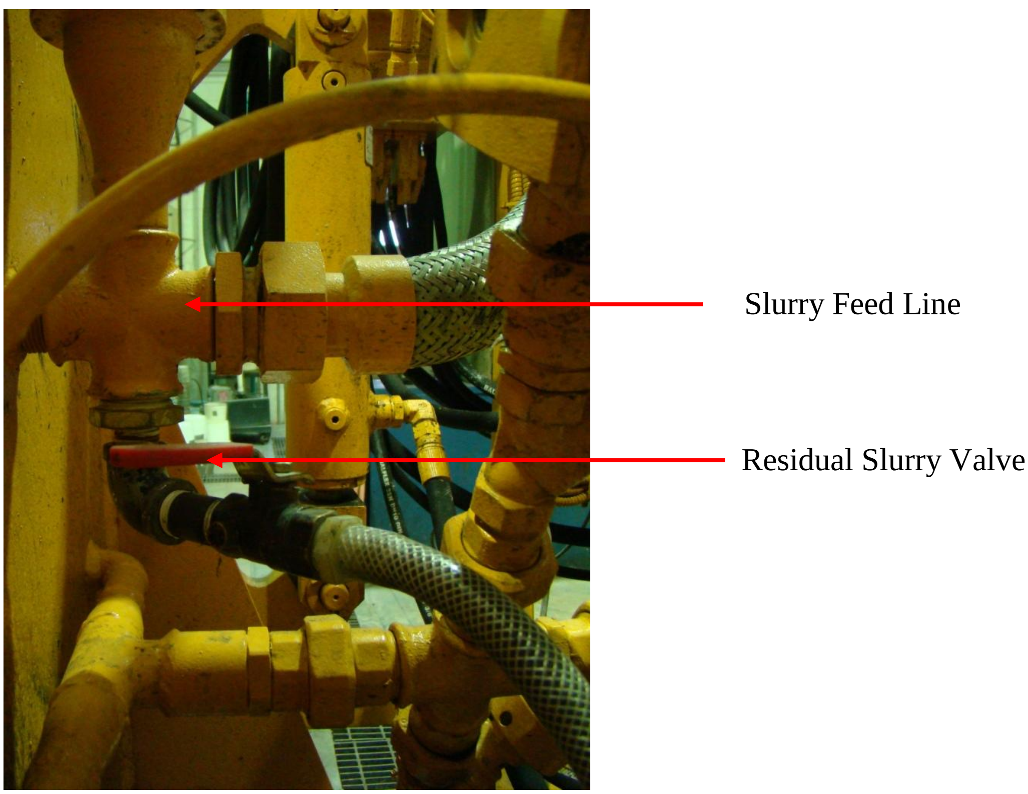
A1. Filter Press Control Panel and Mixer Control Box



A2. Filter Plates with the Filter Cloth



A3. Slurry Make-up Circuit Arrangement



A4. Residual Slurry Value Arrangement

A5. Side Drain Valve

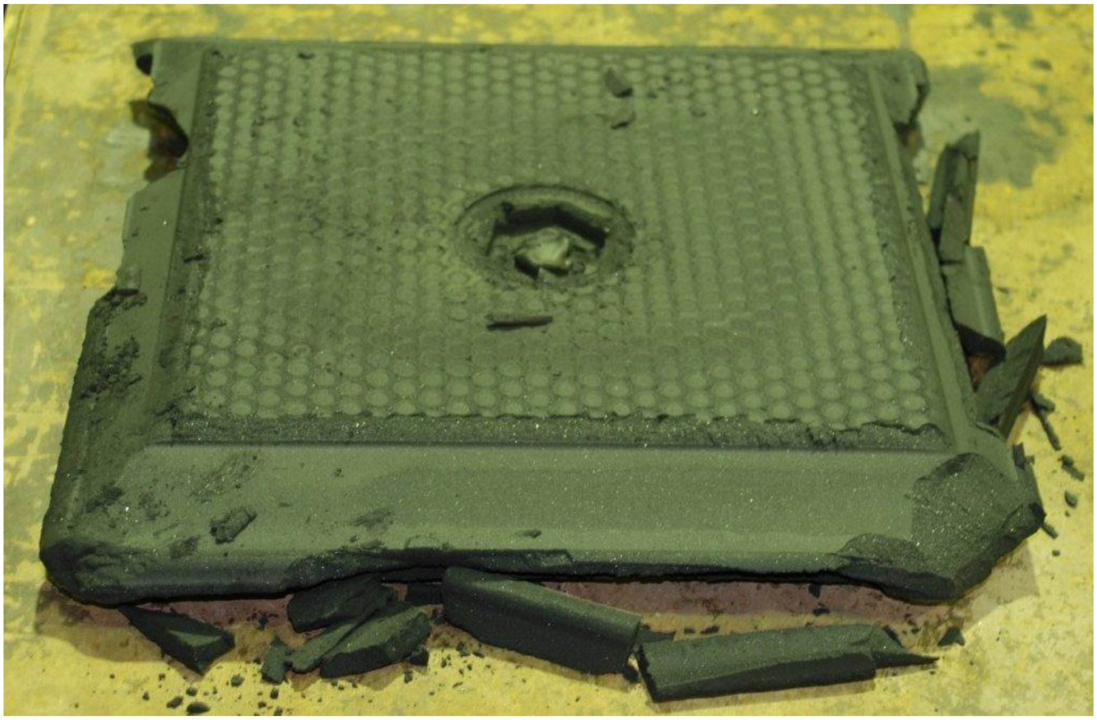
A6. Bottom Drain Valve

A7. Probe Level Adjustor Screw

A8. Filter Cake Sample and Filtrate Collection Arrangement

A9. Large Pan and Screen Arrangement for Main Cake Collection.

A10. Main Cake Collected on Screen After Discharge



A11. Total Filter Cake

A12. Filtrate Samples Collected Over Time

APPENDIX B

PLANT 1 TEST RESULTS

Size and Ash Interval Data for Plant 1

	Direct		Cumulative Retained		Cumulative Passing	
Size Interval (U.S. Mesh)	**Weight** (%)	**Ash Value** (%)	**Weight** (%)	**Ash Value** (%)	**Weight** (%)	**Ash Value** (%)
+70	3.7	14.8	3.7	14.8	100.0	52.7
70 X 100	5.5	18.4	9.2	17.0	96.3	54.1
100 X 140	7.5	26.7	16.7	21.3	90.8	56.3
140 X 200	8.1	35.3	24.8	25.9	83.3	59.0
200 X 270	6.7	40.8	31.5	29.1	75.2	61.5
270 X 400	7.6	44.7	39.1	32.1	68.5	63.5
400 X 500	6.0	48.7	45.0	34.3	60.9	65.9
- 500	55.0	67.8	100.0	52.7	55.0	67.8

Microtrac Size Analysis

Size, µm	**% Passing**	**Size, µm**	**% Passing**	**Size, µm**	**% Passing**
704.0	100.0	37.00	100.0	1.95	15.42
592.0	100.0	31.11	99.81	1.64	13.10
497.8	100.0	26.16	98.95	1.38	11.09
418.6	100.0	22.00	96.82	1.16	9.08
352.0	100.0	18.50	92.53	0.97	7.02
296.0	100.0	15.56	86.14	0.82	5.10
248.9	100.0	13.08	78.91	0.69	3.59
209.3	100.0	11.00	71.82	0.58	2.48
176.0	100.0	9.25	64.99	0.49	1.66
148.0	100.0	7.78	58.19	0.41	1.01
124.5	100.0	6.54	51.34	0.34	0.45
104.7	100.0	5.50	44.64	0.29	0.00
88.00	100.0	4.63	38.36	0.24	0.00
74.00	100.0	3.89	32.57	0.20	0.00
62.23	100.0	3.27	27.21	0.17	0.00
52.33	100.0	2.75	22.40	0.15	0.00
44.00	100.0	2.31	18.43		

RunOrder	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe
1	30	120	240	100	12	85	1

Bucket No	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1469.5	740.5
2	30	788	1888.7	1100.7
3	45	400	1310.7	910.7
4	60	378	888.7	510.7
5	75	381	706.6	325.6
6	90	377	652.6	275.6
7	105	379	569.5	190.5
8	120	219	394.4	175.4
9	135	245	415.4	170.4
10	150	164	349.3	185.3
11	165	210	400.3	190.3
12	180	211	361.3	150.3
13	195	217	347.2	130.2
14	210	118	232.2	114.2
15	225	121	219.1	98.1
16	240	113	199.1	86.1
17	255	121	205.1	84.1
18	270	117	193.1	76.1
19	285	120	306.0	186.0
20	300	120		
21	330	121		
22	360	120		
Total				5,700.6

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	102.0	109.0	111.0	99.0	121.2
Initial Wt.	361.0	272.0	301.0	453.0	138.6
Final Wt.	294.4	230.0	250.6	353.0	131.8
Moisture	25.7	25.8	26.5	28.2	39.1

	Dry Filtrate Wt.		Main Cake Wt.
Total Wt.	1034.9	Total Wt.	8973
Pan Wt.	1023.1	Pan Wt.	3977
Solids Wt.	11.8	Solids Wt.	4996

Ease of discharge

Good

	Residual slurry
Total Wt.	1872
Initial Wt.	690
Residual Wt.	1182

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
2	20	240	240	80	14	105	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1849.4	1120.4
2	30	788	1988.6	1200.6
3	45	400	1950.7	1550.7
4	60	378	1438.5	1060.5
5	75	381	1261.5	880.5
6	90	377	757.5	380.5
7	105	379	729.4	350.4
8	120	219	549.3	330.3
9	135	245	585.3	340.3
10	150	164	444.2	280.2
11	165	210	440.2	230.2
12	180	211	411.2	200.2
13	195	217	407.2	190.2
14	210	118	308.1	190.1
15	225	121	351.1	230.1
16	240	113	333.1	220.1
17	255	121	301.1	180.1
18	270	117	257.0	140.0
19	285	120	240.0	120.0
20	300	120	230.0	110.0
21	330	121	231.0	110.0
22	360	120	440.0	320.0
Total				9,735.3

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	110.2	101.4	343.9	301.3
Initial Wt.	132.2	147.1	137.5	391.6	335.3
Final Wt.	124.3	136.8	127.4	378.9	321.4
Moisture	24.69	27.94	27.98	26.62	40.88

	Dry Filtrate Wt.
Total Wt.	5024.8
Pan Wt.	5016.2
Solids Wt.	8.6

	Main Cake Wt.
Total Wt.	8927
Pan Wt.	3977
Solids Wt.	4950

Ease of discharge
Bad

	Residual slurry
Total Wt.	3084
Initial Wt.	800
Residual Wt.	2284

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
3	20	240	240	100	18	109	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1949.4	1220.4
2	30	788	2208.6	1420.6
3	45	400	1700.7	1300.7
4	60	378	1478.5	1100.5
5	75	381	931.5	550.5
6	90	377	717.5	340.5
7	105	379	719.4	340.4
8	120	219	579.3	360.3
9	135	245	625.3	380.3
10	150	164	424.2	260.2
11	165	210	440.2	230.2
12	180	211	431.2	220.2
13	195	217	437.2	220.2
14	210	118	318.1	200.1
15	225	121	321.1	200.1
16	240	113	273.1	160.1
17	255	121	271.1	150.1
18	270	117	257.0	140.0
19	285	120	260.0	140.0
20	300	120	240.0	120.0
21	330	121	501.0	380.0
22	360	120		
Total				9435.3

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	111.0	103.9	104.3	111.8	300.6
Initial Wt.	146.0	180.0	153.0	187.0	315.4
Final Wt.	137.2	160.1	140.2	167.2	309.5
Moisture	25.14	26.20	26.28	26.32	39.86

	Dry Filtrate Wt.
Total Wt.	314.2
Pan Wt.	304.1
Solids Wt.	10.1

	Main Cake Wt.
Total Wt.	8518
Pan Wt.	3977
Solids Wt.	4541

Ease of discharge
Bad

	Residual slurry
Total Wt.	2023
Initial Wt.	1025
Residual Wt.	998

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
4	30	240	120	80	15	83	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1879.8	1150.8
2	30	788	2208.9	1420.9
3	45	400	1500.9	1100.9
4	60	378	748.8	370.8
5	75	381	681.5	300.5
6	90	377	507.4	130.4
7	105	379	649.4	270.4
8	120	219	579.4	360.4
9	135	245	525.3	280.3
10	150	164	379.2	215.2
11	165	210	415.1	205.1
12	180	211	631.1	420.1
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				6,225.8

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	104.7	105.2	105.2	113.9	300.6
Initial Wt.	139.8	163.6	256.5	198.9	315.5
Final Wt.	130.4	149.1	212.9	175.2	310.1
Moisture	26.75	24.79	28.84	27.88	36.24

	Dry Filtrate Wt.
Total Wt.	319.5
Pan Wt.	309.3
Solids Wt.	10.2

	Main Cake Wt.
Total Wt.	8100
Pan Wt.	3977
Solids Wt.	4123

Ease of discharge
Bad

	Residual slurry
Total Wt.	3918
Initial Wt.	799
Residual Wt.	3119

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
5	20	120	360	100	16	110	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1649.9	920.9
2	30	788	1954.9	1166.9
3	45	400	1250.9	850.9
4	60	378	818.8	440.8
5	75	381	636.8	255.8
6	90	377	609.7	232.7
7	105	379	614.5	235.5
8	120	219	419.5	200.5
9	135	245	345.5	100.5
10	150	164	324.4	160.4
11	165	210	379.4	169.4
12	180	211	494.3	283.3
13	195	217	347.3	130.3
14	210	118	246.2	128.2
15	225	121	248.2	127.2
16	240	113	233.2	120.2
17	255	121	241.2	120.2
18	270	117	267.1	150.1
19	285	120	240.1	120.1
20	300	120	231.1	111.1
21	330	121	201.1	80.1
22	360	120	729.0	609.0
Total				6,714.0

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.5	100.2	100.6	173.3	295
Initial Wt.	162.7	133.6	120.1	195.9	326.9
Final Wt.	148.5	125.5	116.0	190.8	314.1
Moisture	22.47	24.34	21.18	22.57	40.13

	Dry Filtrate Wt.
Total Wt.	317.7
Pan Wt.	301.3
Solids Wt.	16.4

	Main Cake Wt.
Total Wt.	9695
Pan Wt.	3977
Solids Wt.	5718

Ease of discharge
Bad

	Residual slurry
Total Wt.	2118
Initial Wt.	992
Residual Wt.	1126

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
6	20	120	360	100	14	106	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1979.9	1250.9
2	30	788	2138.9	1350.9
3	45	400	1241.0	841.0
4	60	378	668.8	290.8
5	75	381	691.8	310.8
6	90	377	647.7	270.7
7	105	379	749.7	370.7
8	120	219	549.6	330.6
9	135	245	505.4	260.4
10	150	164	294.4	130.4
11	165	210	370.4	160.4
12	180	211	361.4	150.4
13	195	217	367.4	150.4
14	210	118	288.3	170.3
15	225	121	271.3	150.3
16	240	113	273.2	160.2
17	255	121	251.2	130.2
18	270	117	217.2	100.2
19	285	120	210.2	90.2
20	300	120	200.0	80.0
21	330	121	801.0	680.0
22	360	120		
Total				7,429.9

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	292.2	301.3	302.1	118.0	289.0
Initial Wt.	307.2	339.0	353.4	158.5	312.6
Final Wt.	303.9	329.5	341.8	148.6	302.8
Moisture	22.00	25.09	22.55	24.44	41.53

	Dry Filtrate Wt.	Main Cake Wt.
Total Wt.	310.30	9154
Pan Wt.	292.20	3977
Solids Wt.	18.10	5177

Ease of discharge
Bad

	Residual slurry
Total Wt.	1823
Initial Wt.	969
Residual Wt.	854

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
7	30	120	360	80	15	88	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,899.8	1,170.8
2	30	788	2,188.8	1,400.8
3	45	400	950.9	550.9
4	60	378	638.7	260.7
5	75	381	621.7	240.7
6	90	377	627.7	250.7
7	105	379	629.7	250.7
8	120	219	479.6	260.6
9	135	245	575.6	330.6
10	150	164	454.5	290.5
11	165	210	510.3	300.3
12	180	211	411.2	200.2
13	195	217	367.2	150.2
14	210	118	238.1	120.1
15	225	121	261.0	140.0
16	240	113	963.0	850.0
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				6,767.9

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	104.7	103.2	104.2	113.9	302.0
Initial Wt.	179.1	159.8	164.4	144.7	312.2
Final Wt.	161.5	145.9	150.4	136.8	307.5
Moisture	23.63	24.56	23.14	25.58	46.08

	Dry Filtrate Wt.
Total Wt.	316.8
Pan Wt.	302.3
Solids Wt.	14.5

	Main Cake Wt.
Total Wt.	9287
Pan Wt.	3977
Solids Wt.	5310

Ease of discharge
Bad

	Residual slurry
Total Wt.	2392
Initial Wt.	985
Residual Wt.	1407

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
8	20	120	240	100	20	106	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,829.9	1,100.9
2	30	788	2,198.9	1,410.9
3	45	400	1,260.9	860.9
4	60	378	948.8	570.8
5	75	381	721.8	340.8
6	90	377	658.8	281.8
7	105	379	669.7	290.7
8	120	219	440.6	221.6
9	135	245	465.5	220.5
10	150	164	355.5	191.5
11	165	210	420.4	210.4
12	180	211	396.3	185.3
13	195	217	379.3	162.3
14	210	118	268.3	150.3
15	225	121	306.3	185.3
16	240	113	278.2	165.2
17	255	121	241.2	120.2
18	270	117	222.2	105.2
19	285	120	205.2	85.2
20	300	120	370.1	250.1
21	330	121		
22	360	120		
Total				7,110.0

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	111.0	104.3	103.9	111.8	300.0
Initial Wt.	134.6	132.4	132.9	157.1	325.2
Final Wt.	128.6	125.1	125.5	145.7	315.5
Moisture	25.42	25.98	25.48	25.17	38.49

	Dry Filtrate Wt.
Total Wt.	318.9
Pan Wt.	300.8
Solids Wt.	18.1

	Main Cake Wt.
Total Wt.	9146
Pan Wt.	3977
Solids Wt.	5169

Ease of discharge
Bad

	Residual slurry
Total Wt.	2141
Initial Wt.	799
Residual Wt.	1342

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
9	20	240	360	80	24	112	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,929.9	1,200.9
2	30	788	2,138.9	1,350.9
3	45	400	1,561.0	1,161.0
4	60	378	1,048.8	670.8
5	75	381	981.8	600.8
6	90	377	957.7	580.7
7	105	379	789.6	410.6
8	120	219	669.6	450.6
9	135	245	500.6	255.6
10	150	164	354.6	190.6
11	165	210	420.6	210.6
12	180	211	401.5	190.5
13	195	217	397.5	180.5
14	210	118	288.3	170.3
15	225	121	281.2	160.2
16	240	113	263.1	150.1
17	255	121	321.1	200.1
18	270	117	232.1	115.1
19	285	120	245.1	125.1
20	300	120	240.0	120.0
21	330	121	221.0	100.0
22	360	120	854.0	734.0
Total				9,329.0

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	101.2	170.8	171.1	163.1	301.0
Initial Wt.	139.0	222.8	194.8	206.3	325.2
Final Wt.	130.3	210.6	188.9	194.7	316.5
Moisture	23.12	23.54	24.85	26.85	35.95

	Dry Filtrate Wt.
Total Wt.	318.6
Pan Wt.	300
Solids Wt.	18.6

	Main Cake Wt.
Total Wt.	8706
Pan Wt.	3977
Solids Wt.	4729

Ease of discharge
Bad

	Residual slurry
Total Wt.	1658
Initial Wt.	1021
Residual Wt.	637

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
10	30	240	360	100	13	87	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,829.8	1,100.8
2	30	788	2,138.9	1,350.9
3	45	400	1,100.9	700.9
4	60	378	708.7	330.7
5	75	381	731.7	350.7
6	90	377	687.7	310.7
7	105	379	699.7	320.7
8	120	219	479.6	260.6
9	135	245	500.6	255.6
10	150	164	354.4	190.4
11	165	210	410.4	200.4
12	180	211	421.4	210.4
13	195	217	422.3	205.3
14	210	118	283.3	165.3
15	225	121	286.2	165.2
16	240	113	228.2	115.2
17	255	121	251.2	130.2
18	270	117	212.2	95.2
19	285	120	215.2	95.2
20	300	120	205.1	85.1
21	330	121	186.0	65.0
22	360	120	719.0	599.0
Total				7,303.6

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	99.5	100.2	100.6	173.3	304.0
Initial Wt.	175.9	186.7	176.5	227.1	313.6
Final Wt.	158.4	164.9	158.9	213.4	310.0
Moisture	22.91	25.20	23.19	25.46	37.50

	Dry Filtrate Wt.
Total Wt.	310.62
Pan Wt.	293.1
Solids Wt.	17.52

	Main Cake Wt.
Total Wt.	8706
Pan Wt.	3977
Solids Wt.	4729

Ease of discharge
Bad

	Residual slurry
Total Wt.	1558
Initial Wt.	823
Residual Wt.	735

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
11	30	120	120	100	14	81	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,794.6	1,065.6
2	30	788	2,123.6	1,335.6
3	45	400	950.7	550.7
4	60	378	678.6	300.6
5	75	381	781.4	400.4
6	90	377	747.3	370.3
7	105	379	679.3	300.3
8	120	219	449.2	230.2
9	135	245	460.2	215.2
10	150	164	384.0	220.0
11	165	210	725.0	515.0
12	180	211		
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				5,504.0

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	110.2	101.4	343.9	304.0
Initial Wt.	152.0	137.0	162.5	375.7	321.1
Final Wt.	138.3	129.2	146.0	365.8	314.2
Moisture	26.37	29.10	27.00	31.13	40.35

	Dry Filtrate Wt.
Total Wt.	300.7
Pan Wt.	293.3
Solids Wt.	7.4

	Main Cake Wt.
Total Wt.	9110
Pan Wt.	3977
Solids Wt.	5133

Ease of discharge
Bad

	Residual slurry
Total Wt.	2936
Initial Wt.	851
Residual Wt.	2085

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
12	30	240	360	80	16	85	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,494.9	765.9
2	30	788	2,168.9	1,380.9
3	45	400	1,311.0	911.0
4	60	378	728.8	350.8
5	75	381	831.8	450.8
6	90	377	642.7	265.7
7	105	379	599.6	220.6
8	120	219	404.6	185.6
9	135	245	430.6	185.6
10	150	164	330.6	166.6
11	165	210	375.5	165.5
12	180	211	361.3	150.3
13	195	217	347.3	130.3
14	210	118	258.3	140.3
15	225	121	261.2	140.2
16	240	113	238.2	125.2
17	255	121	231.2	110.2
18	270	117	212.1	95.1
19	285	120	200.1	80.1
20	300	120	190.1	70.1
21	330	121	191.0	70.0
22	360	120	619.0	499.0
Total				6,659.9

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	101.2	100.2	104.2	111.8	301.3
Initial Wt.	130.0	144.0	150.4	169.6	325.3
Final Wt.	123.6	134.4	139.8	156.0	313.4
Moisture	22.22	21.92	22.94	23.53	49.58

	Dry Filtrate Wt.
Total Wt.	308.6
Pan Wt.	293.1
Solids Wt.	15.5

	Main Cake Wt.
Total Wt.	9382
Pan Wt.	3977
Solids Wt.	5405

Ease of discharge
Bad

	Residual slurry
Total Wt.	1801
Initial Wt.	1024
Residual Wt.	777

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
13	20	120	360	80	15	106	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,639.9	910.9
2	30	788	1,928.9	1,140.9
3	45	400	595.9	195.9
4	60	378	938.9	560.9
5	75	381	681.8	300.8
6	90	377	602.7	225.7
7	105	379	599.7	220.7
8	120	219	499.7	280.7
9	135	245	455.6	210.6
10	150	164	319.6	155.6
11	165	210	340.6	130.6
12	180	211	336.6	125.6
13	195	217	332.5	115.5
14	210	118	228.5	110.5
15	225	121	221.3	100.3
16	240	113	208.1	95.1
17	255	121	216.1	95.1
18	270	117	197.1	80.1
19	285	120	190.1	70.1
20	300	120	380.1	260.1
21	330	121		
22	360	120		
Total				5,385.4

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	170.8	101.4	343.9	76.1
Initial Wt.	138.0	226.7	132.2	383.1	88.5
Final Wt.	128.4	210.9	123.3	372.0	83.8
Moisture	25.40	28.26	28.90	28.32	37.90

	Dry Filtrate Wt.
Total Wt.	318.8
Pan Wt.	302.3
Solids Wt.	16.5

	Main Cake Wt.
Total Wt.	8577
Pan Wt.	3977
Solids Wt.	4600

Ease of discharge
Bad

	Residual slurry
Total Wt.	1928
Initial Wt.	824
Residual Wt.	1104

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
14	30	240	120	100	13	84	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,654.5	925.5
2	30	788	2,023.6	1,235.6
3	45	400	1,075.7	675.7
4	60	378	688.5	310.5
5	75	381	701.4	320.4
6	90	377	677.3	300.3
7	105	379	679.2	300.2
8	120	219	439.2	220.2
9	135	245	425.1	180.1
10	150	164	319.0	155.0
11	165	210	725.0	515.0
12	180	211		
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				5,138.5

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.9	104.3	101.4	113.9	120.6
Initial Wt.	132.9	126.9	120.7	175.2	136.3
Final Wt.	125.2	120.6	115.3	156.5	130.0
Moisture	26.55	27.88	27.98	30.51	40.13

	Dry Filtrate Wt.
Total Wt.	307.9
Pan Wt.	301.3
Solids Wt.	6.6

	Main Cake Wt.
Total Wt.	8216
Pan Wt.	3977
Solids Wt.	4239

Ease of discharge

Bad

	Residual slurry
Total Wt.	3270
Initial Wt.	1021
Residual Wt.	2249

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
15	30	240	240	100	18	87	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,639.9	910.9
2	30	788	1,928.9	1,140.9
3	45	400	595.9	195.9
4	60	378	938.8	560.8
5	75	381	681.8	300.8
6	90	377	602.7	225.7
7	105	379	599.6	220.6
8	120	219	499.6	280.6
9	135	245	450.6	205.6
10	150	164	314.6	150.6
11	165	210	340.5	130.5
12	180	211	331.4	120.4
13	195	217	332.4	115.4
14	210	118	223.3	105.3
15	225	121	216.3	95.3
16	240	113	203.3	90.3
17	255	121	216.3	95.3
18	270	117	197.2	80.2
19	285	120	190.2	70.2
20	300	120	380.0	260.0
21	330	121		
22	360	120		
Total				5,355.1

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.7	110.2	163.1	76.1
Initial Wt.	149.5	123.2	142.8	204.2	89.9
Final Wt.	137.5	118.4	134.8	193.0	84.5
Moisture	24.34	26.22	24.54	27.25	39.13

	Dry Filtrate Wt.
Total Wt.	319.4
Pan Wt.	300.8
Solids Wt.	18.6

	Main Cake Wt.
Total Wt.	9573
Pan Wt.	3977
Solids Wt.	5596

Ease of discharge
Bad

	Residual slurry
Total Wt.	2212
Initial Wt.	823
Residual Wt.	1389

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
16	30	120	120	80	20	84	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,539.9	810.9
2	30	788	2,068.9	1,280.9
3	45	400	1,200.9	800.9
4	60	378	643.8	265.8
5	75	381	631.8	250.8
6	90	377	637.7	260.7
7	105	379	804.7	425.7
8	120	219	469.7	250.7
9	135	245	440.5	195.5
10	150	164	329.5	165.5
11	165	210	380.4	170.4
12	180	211	621.3	410.3
13	195	217	477.2	260.2
14	210	118	383.2	265.2
15	225	121	530.0	409.0
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				6,222.4

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.5	343.9	171.1	173.3	304.0
Initial Wt.	151.6	381.4	238.1	211.5	325.5
Final Wt.	138.1	370.2	218.3	200.7	317.0
Moisture	25.87	29.79	29.54	28.25	39.53

	Dry Filtrate Wt.
Total Wt.	317.8
Pan Wt.	302.1
Solids Wt.	15.7

	Main Cake Wt.
Total Wt.	8944
Pan Wt.	3977
Solids Wt.	4967

Ease of discharge
Bad

	Residual slurry
Total Wt.	3122
Initial Wt.	851
Residual Wt.	2271

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
17	20	240	120	80	16	104	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,569.7	840.7
2	30	788	2,214.9	1,426.9
3	45	400	1,514.0	1,114.0
4	60	378	748.5	370.5
5	75	381	758.4	377.4
6	90	377	712.4	335.4
7	105	379	614.3	235.3
8	120	219	398.2	179.2
9	135	245	430.0	185.0
10	150	164		
11	165	210		
12	180	211		
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				5,064.6

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	111.0	170.8	100.6	111.8	292.3
Initial Wt.	134.9	200.3	127.0	137.2	300.7
Final Wt.	127.9	192.8	120.3	129.7	297.5
Moisture	29.29	25.42	25.53	29.69	38.10

	Dry Filtrate Wt.
Total Wt.	311.2
Pan Wt.	302.6
Solids Wt.	8.6

	Main Cake Wt.
Total Wt.	8869
Pan Wt.	3977
Solids Wt.	4892

Ease of discharge
Bad

	Residual slurry
Total Wt.	6073
Initial Wt.	823
Residual Wt.	5250

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
18	20	120	360	80	19	109	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,919.8	1,190.8
2	30	788	2,343.9	1,555.9
3	45	400	1,475.9	1,075.9
4	60	378	713.7	335.7
5	75	381	681.7	300.7
6	90	377	642.6	265.6
7	105	379	644.6	265.6
8	120	219	467.5	248.5
9	135	245	635.5	390.5
10	150	164	452.5	288.5
11	165	210	382.4	172.4
12	180	211	386.4	175.4
13	195	217	387.4	170.4
14	210	118	266.4	148.4
15	225	121	261.3	140.3
16	240	113	245.2	132.2
17	255	121	271.2	150.2
18	270	117	270.2	153.2
19	285	120	225.1	105.1
20	300	120	213.1	93.1
21	330	121	203.1	82.1
22	360	120	829.0	709.0
Total				8,149.6

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	101.2	103.2	104.5	100.2	294.2
Initial Wt.	128.5	125.0	120.5	113.6	306.3
Final Wt.	122.5	120.2	116.7	110.2	300.7
Moisture	21.98	22.02	23.75	25.60	46.28

	Dry Filtrate Wt.
Total Wt.	306.6
Pan Wt.	289
Solids Wt.	17.6

	Main Cake Wt.
Total Wt.	8698
Pan Wt.	3977
Solids Wt.	4721

Ease of discharge
Bad

	Residual slurry
Total Wt.	1530
Initial Wt.	992
Residual Wt.	538

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
19	20	120	120	80	20	110	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,919.8	1,190.8
2	30	788	2,343.9	1,555.9
3	45	400	1,475.9	1,075.9
4	60	378	713.8	335.8
5	75	381	681.7	300.7
6	90	377	642.6	265.6
7	105	379	644.5	265.5
8	120	219	467.5	248.5
9	135	245	635.4	390.4
10	150	164	452.4	288.4
11	165	210	382.3	172.3
12	180	211	386.2	175.2
13	195	217	387.2	170.2
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				6,435.1

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	103.9	171.1	101.4	113.9	76.1
Initial Wt.	129.5	186.5	126.9	139.2	98.3
Final Wt.	122.8	182.7	119.6	131.9	89.1
Moisture	26.13	24.81	28.55	28.74	41.44

	Dry Filtrate Wt.
Total Wt.	314.2
Pan Wt.	301.3
Solids Wt.	12.9

	Main Cake Wt.
Total Wt.	7752
Pan Wt.	3977
Solids Wt.	3775

Ease of discharge
Bad

	Residual slurry
Total Wt.	3127
Initial Wt.	969
Residual Wt.	2158

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
20	30	120	240	80	16	85	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,629.5	900.5
2	30	788	2,068.7	1,280.7
3	45	400	1,510.7	1,110.7
4	60	378	1,188.7	810.7
5	75	381	881.6	500.6
6	90	377	637.6	260.6
7	105	379	629.5	250.5
8	120	219	469.4	250.4
9	135	245	495.4	250.4
10	150	164	384.3	220.3
11	165	210	460.3	250.3
12	180	211	431.3	220.3
13	195	217	427.2	210.2
14	210	118	298.2	180.2
15	225	121	286.1	165.1
16	240	113	243.1	130.1
17	255	121	236.1	115.1
18	270	117	317.1	200.1
19	285	120	210.0	90.0
20	300	120	180.0	60.0
21	330	121	391.0	270.0
22	360	120		
Total				7,726.6

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	101.2	170.8	171.1	163.1	303.0
Initial Wt.	121.1	209.6	201.6	224.1	342.0
Final Wt.	116.0	199.4	193.2	209.3	326.0
Moisture	25.63	26.29	27.54	24.23	41.03

	Dry Filtrate Wt.		Main Cake Wt.
Total Wt.	1198.9	Total Wt.	9016
Pan Wt.	1186.6	Pan Wt.	3977
Solids Wt.	12.3	Solids Wt.	5039

Ease of discharge
Bad

	Residual slurry
Total Wt.	2191
Initial Wt.	985
Residual Wt.	1206

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
21	20	240	360	100	14	113	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,744.8	1,015.8
2	30	788	2,188.9	1,400.9
3	45	400	1,555.9	1,155.9
4	60	378	773.8	395.8
5	75	381	691.6	310.6
6	90	377	637.6	260.6
7	105	379	654.6	275.6
8	120	219	679.5	460.5
9	135	245	550.5	305.5
10	150	164	399.4	235.4
11	165	210	400.4	190.4
12	180	211	381.4	170.4
13	195	217	377.4	160.4
14	210	118	278.4	160.4
15	225	121	261.4	140.4
16	240	113	248.3	135.3
17	255	121	246.3	125.3
18	270	117	252.3	135.3
19	285	120	200.2	80.2
20	300	120	215.2	95.2
21	330	121	211.1	90.1
22	360	120	894.0	774.0
Total				8,074.0

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.7	110.2	104.3	120.3
Initial Wt.	120.2	119.0	118.1	116.0	144.2
Final Wt.	115.7	115.4	116.3	113.0	134.6
Moisture	22.50	25.17	22.91	25.64	40.17

	Dry Filtrate Wt.
Total Wt.	313.4
Pan Wt.	295
Solids Wt.	18.4

	Main Cake Wt.
Total Wt.	8615
Pan Wt.	3977
Solids Wt.	4638

Ease of discharge
Bad

	Residual slurry
Total Wt.	1287
Initial Wt.	690
Residual Wt.	597

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
22	20	240	120	100	14	113	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,674.8	945.8
2	30	788	2,178.9	1,390.9
3	45	400	1,490.9	1,090.9
4	60	378	923.7	545.7
5	75	381	751.7	370.7
6	90	377	722.7	345.7
7	105	379	684.4	305.4
8	120	219	514.3	295.3
9	135	245	530.2	285.2
10	150	164	389.2	225.2
11	165	210	410.1	200.1
12	180	211	856.1	645.1
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				6,645.9

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	99.5	343.9	173.3	163.1	304.0
Initial Wt.	130.1	384.1	229.4	186.3	322.4
Final Wt.	122.0	372.7	215.0	179.0	315.7
Moisture	26.50	28.36	25.76	31.47	36.41

	Dry Filtrate Wt.
Total Wt.	312.14
Pan Wt.	301.3
Solids Wt.	10.84

	Main Cake Wt.
Total Wt.	8504
Pan Wt.	3977
Solids Wt.	4527

Ease of discharge
Bad

	Residual slurry
Total Wt.	2831
Initial Wt.	800
Residual Wt.	2031

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
23	20	120	120	100	15	105	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,814.9	1,085.9
2	30	788	2,343.9	1,555.9
3	45	400	1,570.9	1,170.9
4	60	378	953.8	575.8
5	75	381	691.7	310.7
6	90	377	672.4	295.4
7	105	379	669.4	290.4
8	120	219	734.3	515.3
9	135	245	610.3	365.3
10	150	164	429.3	265.3
11	165	210	435.2	225.2
12	180	211	791.1	580.1
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				7,236.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	300.0	293.4	249.3	303.3	301.2
Initial Wt.	320.2	326.2	328.4	348.1	322.5
Final Wt.	315.0	317.0	308.0	334.6	315.1
Moisture	25.74	28.05	25.74	30.13	34.74

	Dry Filtrate Wt.
Total Wt.	312.5
Pan Wt.	301.3
Solids Wt.	11.2

	Main Cake Wt.
Total Wt.	8548
Pan Wt.	3977
Solids Wt.	4571

Ease of discharge
Bad

	Residual slurry
Total Wt.	3007
Initial Wt.	1025
Residual Wt.	1982

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
24	30	240	240	80	13	87	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,989.9	1,260.9
2	30	788	2,068.9	1,280.9
3	45	400	955.9	555.9
4	60	378	663.9	285.9
5	75	381	686.8	305.8
6	90	377	592.8	215.8
7	105	379	624.7	245.7
8	120	219	614.6	395.6
9	135	245	500.5	255.5
10	150	164	339.5	175.5
11	165	210	370.5	160.5
12	180	211	351.4	140.4
13	195	217	362.4	145.4
14	210	118	258.2	140.2
15	225	121	256.2	135.2
16	240	113	248.2	135.2
17	255	121	276.2	155.2
18	270	117	237.2	120.2
19	285	120	445.2	325.2
20	300	120		
21	330	121		
22	360	120		
Total				6,434.9

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	293.0	304.0	293.0	118.0	301.1
Initial Wt.	334.8	346.2	332.9	161.1	318.2
Final Wt.	324.2	336.0	321.8	150.8	311.8
Moisture	25.26	24.17	27.82	23.90	37.43

	Dry Filtrate Wt.
Total Wt.	310.2
Pan Wt.	292.1
Solids Wt.	18.1

	Main Cake Wt.
Total Wt.	9313
Pan Wt.	3977
Solids Wt.	5336

Ease of discharge
Bad

	Residual slurry
Total Wt.	2422
Initial Wt.	799
Residual Wt.	1623

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
25	20	240	240	100	15	112	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1,504.8	775.8
2	30	788	2,038.8	1,250.8
3	45	400	1,485.8	1,085.8
4	60	378	823.7	445.7
5	75	381	686.7	305.7
6	90	377	707.6	330.6
7	105	379	794.5	415.5
8	120	219	464.5	245.5
9	135	245	500.4	255.4
10	150	164	384.3	220.3
11	165	210	410.3	200.3
12	180	211	405.3	194.3
13	195	217	382.3	165.3
14	210	118	273.2	155.2
15	225	121	291.2	170.2
16	240	113	305.2	192.2
17	255	121	261.1	140.1
18	270	117	227.0	110.0
19	285	120	510.0	390.0
20	300	120		
21	330	121		
22	360	120		
Total				7,048.7

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.5	104.7	110.2	173.3	120.6
Initial Wt.	123.7	119.8	160.5	223.4	128.0
Final Wt.	117.4	115.7	147.2	210.7	125.3
Moisture	26.20	27.15	26.44	25.35	36.49

	Dry Filtrate Wt.
Total Wt.	312.4
Pan Wt.	300.0
Solids Wt.	12.4

	Main Cake Wt.
Total Wt.	8983
Pan Wt.	3977
Solids Wt.	5006

Ease of discharge
Bad

	Residual slurry
Total Wt.	2347
Initial Wt.	992
Residual Wt.	1355

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
26	30	120	120	100	13	84	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	1549.7	820.7
2	30	788	2053.7	1265.7
3	45	400	1340.8	940.8
4	60	378	718.6	340.6
5	75	381	731.6	350.6
6	90	377	717.5	340.5
7	105	379	689.4	310.4
8	120	219	409.2	190.2
9	135	245	420.2	175.2
10	150	164	327.2	163.2
11	165	210	355.2	145.2
12	180	211	461.0	250.0
13	195	217		
14	210	118		
15	225	121		
16	240	113		
17	255	121		
18	270	117		
19	285	120		
20	300	120		
21	330	121		
22	360	120		
Total				5293.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	111.0	103.2	100.6	113.9	304.3
Initial Wt.	202.3	162.9	135.3	143.1	317.8
Final Wt.	178.8	146.1	125.7	134.4	311.5
Moisture	25.70	28.20	27.80	29.90	46.67

	Dry Filtrate Wt.
Total Wt.	302.9
Pan Wt.	293.3
Solids Wt.	9.6

	Main Cake Wt.
Total Wt.	9384
Pan Wt.	3977
Solids Wt.	5407

Ease of discharge
Bad

	Residual slurry
Total Wt.	3100
Initial Wt.	969
Residual Wt.	2131

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
27	30	240	360	100	13	87	1

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	729	2,359.5	1,630.5
2	30	788	1,758.7	970.7
3	45	400	1,960.7	1,560.7
4	60	378	1,418.7	1,040.7
5	75	381	851.6	470.6
6	90	377	897.6	520.6
7	105	379	764.5	385.5
8	120	219	529.4	310.4
9	135	245	500.4	255.4
10	150	164	359.3	195.3
11	165	210	430.3	220.3
12	180	211	316.3	105.3
13	195	217	342.2	125.2
14	210	118	243.2	125.2
15	225	121	236.1	115.1
16	240	113	213.1	100.1
17	255	121	233.1	112.1
18	270	117	189.1	72.1
19	285	120	196.0	76.0
20	300	120	258.0	138.0
21	330	121	195.0	74.0
22	360	120	337.0	217.0
Total				8,820.7

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	121.1	125.3	130.4	105.9	292.0
Initial Wt.	166.0	264.0	200.0	180.0	318.0
Final Wt.	156.1	230.5	183.8	161.4	308.6
Moisture	22.12	24.18	23.28	25.13	36.12

	Dry Filtrate Wt.
Total Wt.	1797
Pan Wt.	1785
Solids Wt.	12

	Main Cake Wt.
Total Wt.	9598
Pan Wt.	3977
Solids Wt.	5621

Ease of discharge
Bad

	Residual slurry
Total Wt.	1135
Initial Wt.	836
Residual Wt.	299

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
28	18.7	200	240	100	18	200	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	2176	1392
2	30	809	2394	1585
3	60	725	3663	2938
4	90	782	3026	2244
5	140	724	3093	2369
6	210	377	2523	2146
7	330	373	2573	2200
8	450	377	1750	1373
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				16247

Cake Samples

	S1	S2	S3	S4
Pan Wt.	89.7	305.8	292.9	292.5
Initial Wt.	116.6	328.0	341.5	339.1
Final Wt.	110.4	322.7	330.3	327.8
Moisture	23.21	23.89	23.10	24.22

	Dry Filtrate Wt.
Total Wt.	313.5
Pan Wt.	293.0
Solids Wt.	20.5

	Main Cake Wt.
Total Wt.	6189
Pan Wt.	833
Solids Wt.	5356

Ease of discharge
Bad

	Residual slurry
Total Wt.	2229
Initial Wt.	693
Residual Wt.	1536

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
29	18.7	500	240	100	15	500	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	1927	1143
2	45	809	3274	2465
3	75	725	2812	2087
4	135	782	3453	2671
5	195	724	2694	1970
6	315	377	3691	3314
7	435	373	2809	2436
8	500	377	1657	1280
9	620	378	1782	1404
10	740	164	1149	985
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				19755

Cake Samples	S1	S2	S3	S4
Pan Wt.	301.7	306.0	302.9	303.1
Initial Wt.	375.4	346.4	354.0	388.6
Final Wt.	360.3	337.8	343.8	370.2
Moisture	20.45	21.22	19.89	21.56

	Dry Filtrate Wt.
Total Wt.	357.6
Pan Wt.	304.1
Solids Wt.	53.5

	Main Cake Wt.
Total Wt.	6177
Pan Wt.	693
Solids Wt.	5484

Ease of discharge
OK

	Residual slurry
Total Wt.	3201
Initial Wt.	693
Residual Wt.	2508

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
30	20.2	1000	240	100	20	1000	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	1893	1109
2	45	809	3208	2399
3	75	725	2686	1961
4	135	782	3302	2520
5	195	724	2611	1887
6	315	377	3502	3125
7	435	373	2761	2388
8	675	377	3928	3551
9	915	378	3160	2782
10	1000	164	988	824
11	1120	210	1210	1000
12	1240	219	975	756
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				24302

Cake Samples

	S1	S2	S3	S4
Pan Wt.	293.6	294.2	302.6	302.7
Initial Wt.	338.7	323.2	344.0	335.0
Final Wt.	330.5	317.7	336.1	329.0
Moisture	18.21	18.96	19.11	18.52

	Dry Filtrate Wt.
Total Wt.	358.1
Pan Wt.	293.4
Solids Wt.	64.7

	Main Cake Wt.
Total Wt.	7938
Pan Wt.	833
Solids Wt.	7105

Ease of discharge
Good

	Residual slurry
Total Wt.	3592
Initial Wt.	693
Residual Wt.	2899

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
31	18.7	2000	240	100	21	2000	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	1889	1105
2	30	809	3206	2397
3	75	725	2695	1970
4	135	782	3303	2521
5	195	724	2596	1872
6	315	377	3499	3122
7	435	373	2768	2395
8	675	377	3961	3584
9	915	378	3122	2744
10	1155	164	2610	2446
11	1395	210	2505	2295
12	1875	219	1309	1090
13	2000	218	640	422
14	2120	245	823	578
15	2240	211	682	471
16				
17				
18				
19				
20				
21				
22				
Total				29012

Cake Samples

	S1	S2	S3	S4
Pan Wt.	304.7	295.7	305.0	305.1
Initial Wt.	337.1	340.6	338.0	332.8
Final Wt.	331.6	332.9	332.4	328.0
Moisture	16.92	17.25	17.01	17.50

	Dry Filtrate Wt.
Total Wt.	494.4
Pan Wt.	426.6
Solids Wt.	67.8

	Main Cake Wt.
Total Wt.	8186
Pan Wt.	833
Solids Wt.	7353

Ease of discharge
V Good

	Residual slurry
Total Wt.	3599
Initial Wt.	693
Residual Wt.	2906

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
32	18.7	200	240	100	15	200	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	2380	1596
2	30	809	2524	1715
3	60	725	3831	3106
4	90	782	3094	2312
5	150	724	3756	3032
6	210	377	2559	2182
7	330	373	2703	2330
8	450	377	2791	2414
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				18687

Cake Samples

	S1	S2	S3	S4
Pan Wt.	100.6	163.6	104.5	110.4
Initial Wt.	130.1	196.7	123.7	145.0
Final Wt.	123.5	189.0	119.5	137.1
Moisture	22.30	23.20	22.11	22.90

Dry Filtrate Wt.

Total Wt.	128.4
Pan Wt.	111.2
Solids Wt.	17.2

Main Cake Wt.

Total Wt.	6528
Pan Wt.	693
Solids Wt.	5835

Ease of discharge

OK

Residual slurry

Total Wt.	*
Initial Wt.	
Residual Wt.	

*No residual

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
33	17.2	500	240	100	15	500	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	1891	1107
2	45	809	3594	2785
3	75	725	3072	2347
4	135	782	4261	3479
5	195	724	3109	2385
6	315	377	4111	3734
7	435	373	3380	3007
8	500	377	1910	1533
9	620	378	1923	1545
10	740	164	2635	2471
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				24393

Cake Samples

	S1	S2	S3	S4
Pan Wt.	104.8	111.6	102.5	104.4
Initial Wt.	152.6	144.2	135.5	119.2
Final Wt.	143.1	137.6	129.0	116.3
Moisture	19.78	20.21	19.56	19.90

	Dry Filtrate Wt.
Total Wt.	148.8
Pan Wt.	103.2
Solids Wt.	45.6

	Main Cake Wt.
Total Wt.	7284
Pan Wt.	693
Solids Wt.	6591

Ease of discharge
Good

	Residual slurry
Total Wt.	2972
Initial Wt.	693
Residual Wt.	2279

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
34	18.5	1000	240	100	16	1000	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	2310	1526
2	45	809	4030	3221
3	75	725	3456	2731
4	135	782	4102	3320
5	195	724	2861	2137
6	315	377	3794	3417
7	435	373	3023	2650
8	675	377	4482	4105
9	915	378	2396	2018
10	1000	164	1025	861
11	1120	210	936	726
12	1240	219	710	491
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				27203

Cake Samples	S1	S2	S3	S4
Pan Wt.	172.0	104.2	101.6	102.2
Initial Wt.	220.9	132.0	147.4	161.7
Final Wt.	212.4	126.9	139.1	151.2
Moisture	17.40	18.50	18.10	17.70

	Dry Filtrate Wt.		Main Cake Wt.
Total Wt.	152.4	Total Wt.	9114
Pan Wt.	100.6	Pan Wt.	692
Solids Wt.	51.8	Solids Wt.	8422

Ease of discharge
V Good

	Residual slurry
Total Wt.	2996
Initial Wt.	693
Residual Wt.	2303

Run	Feed Conc (%)	Max Filter Time (s)	Dry Time (s)	Air Pressure (psi)	Initial Filtrate Time (s)	Filter Time (s)	Probe Level
35	18.9	2000	240	100	16	2000	2

Bucket	Time (s)	Bucket Wt. (g)	Total Wt. (g)	Filtrate Wt. (g)
1	15	784	2138	1354
2	45	809	3707	2898
3	75	725	3010	2285
4	135	782	3590	2808
5	195	724	3920	3196
6	315	377	2959	2582
7	435	373	5104	4731
8	675	377	3064	2687
9	915	378	3289	2911
10	1155	164	1457	1293
11	1395	210	566	356
12	1875	219	1103	884
13	2000	218	399	181
14				
15				
16				
17				
18				
19				
20				
21				
22				
Total				28166

Cake Samples

	S1	S2	S3	S4
Pan Wt.	104.4	101.1	174.6	426.6
Initial Wt.	142.0	149.3	228.3	445.3
Final Wt.	135.7	141.0	219.1	442.2
Moisture	16.78	17.25	17.06	16.82

	Dry Filtrate Wt.
Total Wt.	167.4
Pan Wt.	113.9
Solids Wt.	53.5

	Main Cake Wt.
Total Wt.	9653
Pan Wt.	692
Solids Wt.	8961

Ease of discharge

V Good

	Residual slurry
Total Wt.	3720
Initial Wt.	693
Residual Wt.	3027

Design of Experiment Analysis Results

General Linear Model: S1, S2, ... versus Feed %, Max. Filter Time, ...

Factor	Type	Levels	Values
Feed %	fixed	2	20, 30
Dry Time	fixed	3	120, 240, 360
Air Pressure	fixed	2	80, 100

Analysis of Variance for S1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.1893	0.0055	0.0055	0.01
Dry Time	2	68.7571	65.0647	32.5323	57.66
Air Pressure	1	0.2365	0.2061	0.2061	0.37
Feed %*Dry Time	2	0.0746	0.0645	0.0323	0.06
Feed %*Air Pressure	1	0.1918	0.1597	0.1597	0.28
Dry Time*Air Pressure	2	0.2285	0.2177	0.1088	0.19
Feed %*Dry Time*Air Pressure	2	0.7186	0.6913	0.3457	0.61
Error	5	2.8210	2.8210	0.5642	
Total	26	76.0390			

Source	P
Feed %	0.775
Dry Time	0.000
Air Pressure	0.872
Feed %*Dry Time	0.945
Feed %*Air Pressure	0.617
Dry Time*Air Pressure	0.830
Feed %*Dry Time*Air Pressure	0.578
Error	
Total	

S = 0.791136   R-Sq = 95.66%   R-Sq(adj) = 80.71%

Analysis of Variance for S2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.0002	0.0480	0.0480	0.12
Dry Time	2	53.0499	50.7154	25.3577	65.60
Air Pressure	1	9.3172	7.9344	7.9344	20.53
Feed %*Dry Time	2	6.6840	8.2734	4.1367	10.70
Feed %*Air Pressure	1	0.1057	0.0002	0.0002	0.00
Dry Time*Air Pressure	2	9.2283	8.2731	4.1366	10.70
Feed %*Dry Time*Air Pressure	2	5.8909	5.8134	2.9067	7.52
Error	5	1.9328	1.9328	0.3866	
Total	26	107.8057			

Source	P
Feed %	0.789
Dry Time	0.000
Air Pressure	0.026
Feed %*Dry Time	0.016
Feed %*Air Pressure	0.984
Dry Time*Air Pressure	0.016
Feed %*Dry Time*Air Pressure	0.031
Error	
Total	

S = 0.621734   R-Sq = 95.61%   R-Sq(adj) = 90.68%

Analysis of Variance for S3, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.8255	1.7352	1.7352	7.71
Dry Time	2	101.6247	98.1403	49.0701	217.99
Air Pressure	1	14.2194	15.3331	15.3331	68.12
Feed %*Dry Time	2	6.8843	7.6008	3.8004	16.88
Feed %*Air Pressure	1	1.5153	1.4477	1.4477	6.43
Dry Time*Air Pressure	2	0.7813	0.9160	0.4580	2.03
Feed %*Dry Time*Air Pressure	2	1.6559	1.5951	0.7975	3.54
Error	5	1.1255	1.1255	0.2251	
Total	26	137.5741			

Source	P
Feed %	0.129
Dry Time	0.000
Air Pressure	0.010
Feed %*Dry Time	0.006
Feed %*Air Pressure	0.052
Dry Time*Air Pressure	0.226
Feed %*Dry Time*Air Pressure	0.110
Error	
Total	

S = 0.474448   R-Sq = 97.05%   R-Sq(adj) = 92.75%

Analysis of Variance for S4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.0326	0.7013	0.7013	2.66
Dry Time	2	117.5726	106.9856	53.4928	202.72
Air Pressure	1	5.2788	5.3265	5.3265	20.19
Feed %*Dry Time	2	1.1194	0.8338	0.4169	1.58
Feed %*Air Pressure	1	10.1488	9.9003	9.9003	37.52
Dry Time*Air Pressure	2	10.0386	10.9246	5.4623	20.70
Feed %*Dry Time*Air Pressure	2	2.9684	2.8447	1.4224	5.39
Error	5	1.3194	1.3194	0.2639	
Total	26	157.8441			

Source	P
Feed %	0.294
Dry Time	0.000
Air Pressure	0.006
Feed %*Dry Time	0.294
Feed %*Air Pressure	0.002
Dry Time*Air Pressure	0.004
Feed %*Dry Time*Air Pressure	0.057
Error	
Total	

S = 0.513689   R-Sq = 95.28%   R-Sq(adj) = 91.65%

Analysis of Variance for S5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Feed %	1	20.78	20.35	20.35	1.45	0.282
Dry Time	2	34.81	55.65	27.83	1.99	0.232
Air Pressure	1	19.93	25.41	25.41	1.81	0.236
Feed %*Dry Time	2	8.38	5.39	2.69	0.19	0.831
Feed %*Air Pressure	1	0.04	0.32	0.32	0.02	0.886
Dry Time*Air Pressure	2	38.41	30.04	15.02	1.07	0.410
Feed %*Dry Time*Air Pressure	2	70.67	71.11	35.56	2.54	0.174
Error	5	70.09	70.09	14.02		
Total	26	342.22				

S = 3.74396   R-Sq = 79.52%   R-Sq(adj) = 0.00%

Analysis of Variance for M5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.9357	0.8826	0.8826	3.47
Dry Time	2	34.1436	28.6256	14.3128	56.29
Air Pressure	1	0.4546	0.7348	0.7348	2.89
Feed %*Dry Time	2	1.7632	1.5227	0.7613	2.99
Feed %*Air Pressure	1	0.8124	0.8203	0.8203	3.23
Dry Time*Air Pressure	2	2.9369	2.6297	1.3149	5.17
Feed %*Dry Time*Air Pressure	2	1.9733	1.9715	0.9857	3.88
Error	5	1.2714	1.2714	0.2543	
Total	26	51.2492			

Source	P
Feed %	0.221
Dry Time	0.000
Air Pressure	0.610
Feed %*Dry Time	0.140
Feed %*Air Pressure	0.132
Dry Time*Air Pressure	0.061
Feed %*Dry Time*Air Pressure	0.096
Error	
Total	

S = 0.504260   R-Sq = 93.89%   R-Sq(adj) = 87.10%

Analysis of Variance for M4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.0048	0.0022	0.0022	0.01
Dry Time	2	74.9334	70.8385	35.4192	223.11
Air Pressure	1	0.0746	0.0356	0.0356	0.22
Feed %*Dry Time	2	0.9142	1.2059	0.6029	3.80
Feed %*Air Pressure	1	1.1577	0.9817	0.9817	6.18
Dry Time*Air Pressure	2	0.7951	0.8503	0.4251	2.68
Feed %*Dry Time*Air Pressure	2	0.9871	0.9377	0.4688	2.95
Error	5	0.7938	0.7938	0.1588	
Total	26	84.6844			

Source	P
Feed %	0.632
Dry Time	0.000
Air Pressure	0.036
Feed %*Dry Time	0.099
Feed %*Air Pressure	0.055
Dry Time*Air Pressure	0.162
Feed %*Dry Time*Air Pressure	0.142
Error	
Total	

S = 0.398439   R-Sq = 97.33%   R-Sq(adj) = 95.13%

Analysis of Variance for M2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
Feed %	1	0.0560	0.3862	0.3862	1.32
Dry Time	2	83.7190	79.9798	39.9899	136.31
Air Pressure	1	4.5308	4.7737	4.7737	16.27
Feed %*Dry Time	2	1.5229	1.7381	0.8690	2.96
Feed %*Air Pressure	1	0.1572	0.1614	0.1614	0.55
Dry Time*Air Pressure	2	0.0452	0.0621	0.0310	0.11
Feed %*Dry Time*Air Pressure	2	0.2429	0.2478	0.1239	0.42
Error	5	1.4669	1.4669	0.2934	
Total	26	94.4290			

Source	P
Feed %	0.273
Dry Time	0.000
Air Pressure	0.060
Feed %*Dry Time	0.142
Feed %*Air Pressure	0.492
Dry Time*Air Pressure	0.902
Feed %*Dry Time*Air Pressure	0.677
Error	
Total	

S = 0.511640   R-Sq = 96.76%   R-Sq(adj) = 91.92%

Regression of M4 with two level interactions.

Regression Analysis: M4 versus Feed, Dry time, ...

The regression equation is
M4 = 34.8 - 0.548 Feed + 0.0245 Dry time - 0.0675 Air pressure
     - 0.000062 Feed%*Dry time - 0.000427 Dry time *Air pressure
     + 0.00650 Air pressure*feed%

Predictor	Coef	SE Coef	T	P
Constant	34.758	8.821	3.94	0.011
Feed	-0.5483	0.3142	-1.75	0.141
Dry time	0.02448	0.01768	1.38	0.225
Air pressure	-0.06750	0.09474	-0.71	0.508
Feed%*Dry time	-0.0000625	0.0003419	-0.18	0.862
Dry time *Air pressure	-0.0004271	0.0001709	-2.50	0.055
Air pressure*feed%	0.006500	0.003350	1.94	0.110

S = 0.580158   R-Sq = 94.9%   R-Sq(adj) = 88.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	6	31.3396	5.2233	15.52	0.004
Residual Error	5	1.6829	0.3366		
Total	11	33.0225			

APPENDIX C

PLANT 2 TEST RESULTS

Size and Ash Interval Data for Plant 2

	Direct		Cumulative Retained		Cumulative Passing	
Size Interval (U.S. Mesh)	**Weight** (%)	**Ash Value** (%)	**Weight** (%)	**Ash Value** (%)	**Weight** (%)	**Ash Value** (%)
+20	1.5	11.6	1.5	11.6	100.0	39.3
20 X 30	2.1	11.4	3.6	11.5	98.5	39.7
30 X 40	3.9	11.9	7.5	11.7	96.4	40.3
40 X 50	4.8	12.3	12.3	11.9	92.5	41.5
50 X 70	5.7	12.9	18.0	12.2	87.7	43.1
70 X 100	6.2	16.0	24.2	13.2	82.0	45.3
100 X 140	5.9	19.1	30.1	14.4	75.8	47.6
140 X 200	5.5	22.2	35.6	15.6	69.9	50.0
200 X 270	5.9	28.7	41.5	17.4	64.4	52.4
270 X 400	12.9	40.3	54.4	22.9	58.5	54.8
400 X 500	11.3	42.3	65.7	26.2	45.6	58.9
- 500	34.3	64.4	100.0	39.3	34.3	64.4

Microtrac Size Analysis

Size, µm	**% Passing**	**Size, µm**	**% Passing**	**Size, µm**	**% Passing**
704.0	100.0	37.00	79.08	1.95	0.340
592.0	100.0	31.11	63.01	1.64	0.000
497.8	100.0	26.16	44.70	1.38	0.000
418.6	100.0	22.00	29.49	1.16	0.000
352.0	100.0	18.50	20.23	0.97	0.000
296.0	100.0	15.56	15.49	0.82	0.000
248.9	100.0	13.08	12.94	0.69	0.000
209.3	100.0	11.00	11.16	0.58	0.000
176.0	100.0	9.25	9.525	0.49	0.000
148.0	100.0	7.78	7.800	0.41	0.000
124.5	100.0	6.54	6.095	0.34	0.000
104.7	100.0	5.50	4.635	0.29	0.000
88.0	99.81	4.63	3.505	0.24	0.000
74.0	99.38	3.89	2.625	0.2	0.000
62.2	98.25	3.27	1.905	0.17	0.000
52.3	95.60	2.75	1.290	0.15	0.000
44.0	89.81	2.31	0.770		

Run	Filter Time (s)	Dry Time (s)
1	500	240

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1033.1	303.9
2	60	788.4	1226.8	438.4
3	90	400.7	688.3	287.6
4	120	378.4	597.0	218.6
5	150	381.5	550.9	169.4
6	180	377.6	563.6	186.0
7	210	379.2	544.7	165.5
8	240	219.5	379.8	160.3
9	270	245.6	404.8	159.2
10	300	164.1	299.1	135.0
11	330	210.7	344.5	133.8
12	360	211.8	346.6	134.8
13	390	217.3	351.3	134.0
14	420	118.9	246.6	127.7
15	450	121.5	248.0	126.5
16	480	113.6	214.3	100.7
17	510	121.5	224.9	103.4
18	540	117.9	187.5	69.6
19	570	120.7	140.8	20.1
20	600	120.7	139.1	18.4
21	630	122.0	139.1	17.1
22	660	119.8	135.2	15.4
23	690	113.2	126.3	13.1
24	720	133.2	512.7	379.5
Total				3,618.0

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.2	173.3	343.9	120.6
Initial Wt.	141.4	113.5	211.8	373.9	131.1
Final Wt.	132.1	111.2	202.6	366.5	128.1
Moisture	22.54	24.20	23.80	24.65	28.57

	Dry Filtrate Wt.
Total Wt.	331.4
Pan Wt.	303.8
Solids Wt.	27.6

	Main Cake Wt.
Total Wt.	3346
Pan Wt.	710
Solids Wt.	2636

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
2	400	240

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1117.0	387.8
2	60	788.4	1120.1	331.7
3	90	400.7	670.2	269.5
4	120	378.4	586.5	208.1
5	150	381.5	585.8	204.3
6	180	377.6	530.7	153.1
7	210	379.2	555.1	175.9
8	240	219.5	363.5	144.0
9	270	245.6	396.7	151.1
10	300	164.1	288.5	124.4
11	330	210.7	346.2	135.5
12	360	211.8	322.2	110.4
13	390	217.3	363.0	145.7
14	420	118.9	173.5	54.6
15	450	121.5	168.4	46.9
16	480	113.6	156.9	43.3
17	510	121.5	166.4	44.9
18	540	117.9	157.4	39.5
19	570	120.7	164.8	44.1
20	600	120.7	163.1	42.4
21	630	122.0	533.9	411.9
22	660			
23	690			
24	720			
Total				3,269.1

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	103.2	100.6	170.8	111.8	171.1
Initial Wt.	140.4	121.5	188.8	124.1	188.9
Final Wt.	131.9	116.2	184.4	121.0	184.5
Moisture	22.80	25.20	24.20	24.90	24.72

	Dry Filtrate Wt.
Total Wt.	349.8
Pan Wt.	300.6
Solids Wt.	49.2

	Main Cake Wt.
Total Wt.	3483
Pan Wt.	925
Solids Wt.	2558

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
3	600	240

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1094.8	365.6
2	60	788.4	1282.2	493.8
3	90	400.7	668.8	268.1
4	120	378.4	583.6	205.2
5	150	381.5	576.7	195.2
6	180	377.6	547.7	170.1
7	210	379.2	541.2	162.0
8	240	219.5	364.2	144.7
9	270	245.6	389.9	144.3
10	300	164.1	294.5	130.4
11	330	210.7	338.1	127.4
12	360	211.8	327.8	116.0
13	390	217.3	333.6	116.3
14	420	118.9	226.8	107.9
15	450	121.5	230.5	109.0
16	480	113.6	215.5	101.9
17	510	121.5	228.7	107.2
18	540	117.9	212.8	94.9
19	570	120.7	214.4	93.7
20	600	120.7	215.8	95.1
21	630	122.0	178.2	56.2
22	660	119.8	162.0	42.2
23	690	113.2	156.5	43.3
24	720	133.2	618.1	484.9
Total				3,975.4

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.3	110.2	110.2	113.9
Initial Wt.	135.5	117.2	141.7	139.7	139.4
Final Wt.	127.3	114.2	134.4	132.4	132.4
Moisture	23.10	23.42	23.21	24.66	27.45

	Dry Filtrate Wt.
Total Wt.	
Pan Wt.	
Solids Wt.	56.6

	Main Cake Wt.
Total Wt.	3918
Pan Wt.	694
Solids Wt.	3224

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
4	400	120

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1099.3	370.1
2	60	788.4	1140.7	352.3
3	90	400.7	703.7	303.0
4	120	378.4	618.5	240.1
5	150	381.5	574.3	192.8
6	180	377.6	544.6	167.0
7	210	379.2	545.5	166.3
8	240	219.5	367.5	148.0
9	270	245.6	383.3	137.7
10	300	164.1	293.0	128.9
11	330	210.7	341.8	131.1
12	360	211.8	330.3	118.5
13	390	217.3	338.6	121.3
14	420	118.9	191.8	72.9
15	450	121.5	181.3	59.8
16	480	113.6	168.2	54.6
17	510	121.5	173.0	51.5
18	540	117.9	534.2	416.3
19	570	120.7		
20	600	120.7		
21	630	122.0		
22	660	119.8		
23	690	113.2		
24	720	133.2		
Total				3,232.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.2	100.6	170.8	111.8	171.1
Initial Wt.	122.5	121.1	191.7	142.0	190.5
Final Wt.	117.8	115.8	186.7	134.4	185.0
Moisture	24.10	25.88	23.86	25.11	28.35

	Dry Filtrate Wt.
Total Wt.	325.4
Pan Wt.	289
Solids Wt.	36.4

	Main Cake Wt.
Total Wt.	3337
Pan Wt.	703
Solids Wt.	2634

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
5	300	120

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1045.3	316.1
2	60	788.4	1124.8	336.4
3	90	400.7	692.1	291.4
4	120	378.4	647.7	269.3
5	150	381.5	631.3	249.8
6	180	377.6	549.2	171.6
7	210	379.2	542.6	163.4
8	240	219.5	347.1	127.6
9	270	245.6	390.1	144.5
10	300	164.1	236.6	72.5
11	330	210.7	273.6	62.9
12	360	211.8	268.2	56.4
13	390	217.3	277.4	60.1
14	420	118.9	172.3	53.4
15	450	121.5	175.0	53.5
16	480	113.6	166.3	52.7
17	510	121.5	174.5	53.0
18	540	117.9	533.3	415.4
19	570	120.7		
20	600	120.7		
21	630	122.0		
22	660	119.8		
23	690	113.2		
24	720	133.2		
Total				2,950.0

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.3	173.3	343.3	110.2
Initial Wt.	125.0	122.8	191.5	357.8	122.7
Final Wt.	119.0	118.1	187.0	354.0	119.1
Moisture	24.21	25.56	24.73	26.21	28.80

	Dry Filtrate Wt.
Total Wt.	149.9
Pan Wt.	120.6
Solids Wt.	29.3

	Main Cake Wt.
Total Wt.	2940
Pan Wt.	690
Solids Wt.	2250

Ease of discharge
Bad

Run	Filter Time (s)	Dry Time (s)
6	300	120

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1086.1	356.9
2	60	788.4	1122.8	334.4
3	90	400.7	687.4	286.7
4	120	378.4	590.5	212.1
5	150	381.5	564.2	182.7
6	180	377.6	542.9	165.3
7	210	379.2	527.1	147.9
8	240	219.5	352.8	133.3
9	270	245.6	372.9	127.3
10	300	164.1	232.5	68.4
11	330	210.7	284.6	73.9
12	360	211.8	264.3	52.5
13	390	217.3	274.5	57.2
14	420	118.9	597.2	478.3
15	450	121.5		
16	480	113.6		
17	510	121.5		
18	540	117.9		
19	570	120.7		
20	600	120.7		
21	630	122.0		
22	660	119.8		
23	690	113.2		
24	720	133.2		
Total				2,676.8

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.2	101.4	102.9	113.9
Initial Wt.	125.1	133.2	122.6	113.0	130.2
Final Wt.	118.9	125.6	117.2	110.4	125.9
Moisture	24.89	26.32	25.47	25.86	26.38

	Dry Filtrate Wt.
Total Wt.	350.7
Pan Wt.	300.1
Solids Wt.	50.6

	Main Cake Wt.
Total Wt.	2986
Pan Wt.	696
Solids Wt.	2290

Ease of discharge
Bad

Run	Filter Time (s)	Dry Time (s)
7	500	120

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1083.3	354.1
2	60	788.4	1118.3	329.9
3	90	400.7	685.5	284.8
4	120	378.4	584.3	205.9
5	150	381.5	567.7	186.2
6	180	377.6	534.8	157.2
7	210	379.2	526.1	146.9
8	240	219.5	349.9	130.4
9	270	245.6	400.8	155.2
10	300	164.1	263.2	99.1
11	330	210.7	321.0	110.3
12	360	211.8	327.1	115.3
13	390	217.3	319.9	102.6
14	420	118.9	221.6	102.7
15	450	121.5	217.0	95.5
16	480	113.6	179.3	65.7
17	510	121.5	173.1	51.6
18	540	117.9	163.2	45.3
19	570	120.7	167.4	46.7
20	600	120.7	528.2	407.5
21	630	122.0		
22	660	119.8		
23	690	113.2		
24	720	133.2		
Total				3,192.9

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.1	103.4	110.2	101.2
Initial Wt.	115.0	180.3	130.7	125.0	112.6
Final Wt.	111.4	176.0	124.3	121.3	109.5
Moisture	23.87	24.74	23.51	24.87	27.19

	Dry Filtrate Wt.
Total Wt.	350.7
Pan Wt.	300.1
Solids Wt.	50.6

	Main Cake Wt.
Total Wt.	2986
Pan Wt.	696
Solids Wt.	2290

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
8	600	120

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1120.6	391.4
2	60	788.4	1126.5	338.1
3	90	400.7	704.1	303.4
4	120	378.4	585.6	207.2
5	150	381.5	564.7	183.2
6	180	377.6	542.4	164.8
7	210	379.2	523.1	143.9
8	240	219.5	347.0	127.5
9	270	245.6	382.7	137.1
10	300	164.1	292.7	128.6
11	330	210.7	331.0	120.3
12	360	211.8	318.5	106.7
13	390	217.3	330.4	113.1
14	420	118.9	216.8	97.9
15	450	121.5	219.8	98.3
16	480	113.6	205.5	91.9
17	510	121.5	212.0	90.5
18	540	117.9	205.3	87.4
19	570	120.7	210.0	89.3
20	600	120.7	166.5	45.8
21	630	122.0	158.0	36.0
22	660	119.8	152.2	32.4
23	690	113.2	147.2	34.0
24	720	133.2	532.4	399.2
Total				3,568.0

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	304.3	301.3	301.3	300.0	301.2
Initial Wt.	336.6	331.6	317.3	329.5	333.7
Final Wt.	329.1	324.3	313.7	322.2	324.8
Moisture	23.10	24.21	22.81	24.65	27.31

	Dry Filtrate Wt.
Total Wt.	494.2
Pan Wt.	424.9
Solids Wt.	69.3

	Main Cake Wt.
Total Wt.	3767
Pan Wt.	693
Solids Wt.	3074

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
9	400	240

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1123.4	394.2
2	60	788.4	1129.9	341.5
3	90	400.7	679.3	278.6
4	120	378.4	587.6	209.2
5	150	381.5	595.5	214.0
6	180	377.6	539.3	161.7
7	210	379.2	561.1	181.9
8	240	219.5	364.6	145.1
9	270	245.6	402.9	157.2
10	300	164.1	296.1	131.9
11	330	210.7	348.2	137.5
12	360	211.8	326.3	114.5
13	390	217.3	370.7	153.4
14	420	118.9	181.7	62.8
15	450	121.5	176.3	54.8
16	480	113.6	159.6	46.0
17	510	121.5	174.4	52.8
18	540	117.9	162.3	44.5
19	570	120.7	173.8	53.0
20	600	120.7	171.7	51.0
21	630	122.0	535.5	413.5
22	660	119.8		
23	690	113.2		
24	720	133.2		
Total				3,399.2

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.3	173.3	343.3	110.2
Initial Wt.	115.4	120.3	185.2	359.2	121.2
Final Wt.	111.8	116.3	182.2	355.1	118.2
Moisture	23.90	24.90	25.10	26.02	27.56

	Dry Filtrate Wt.
Total Wt.	346.9
Pan Wt.	298.3
Solids Wt.	48.6

	Main Cake Wt.
Total Wt.	3227
Pan Wt.	686
Solids Wt.	2541

Ease of discharge
Good

Run	Filter Time (s)	Dry Time (s)
10	400	240

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	729.2	1078.3	349.1
2	60	788.4	1085.9	297.5
3	90	400.7	851.9	451.2
4	120	378.4	539.1	160.8
5	150	381.5	573.4	191.9
6	180	377.6	549.2	171.6
7	210	379.2	524.7	145.5
8	240	219.5	355.5	136.0
9	270	245.6	387.5	141.9
10	300	164.1	295.8	131.6
11	330	210.7	332.5	121.8
12	360	211.8	318.9	107.0
13	390	217.3	339.7	102.2
14	420	118.9	218.0	99.1
15	450	121.5	227.9	94.2
16	480	113.6	205.9	92.3
17	510	121.5	215.3	93.8
18	540	117.9	214.8	97.0
19	570	120.7	212.4	91.6
20	600	120.7	172.4	51.8
21	630	122.0	164.9	42.9
22	660	119.8	161.7	41.9
23	690	113.2	153.3	40.1
24	720	133.2	540.7	407.5
Total				3,660.3

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.3	110.2	110.2	113.9
Initial Wt.	139.5	135.2	129.2	136.3	141.2
Final Wt.	130.5	127.1	124.6	129.7	133.5
Moisture	22.98	26.12	24.39	25.41	28.21

	Dry Filtrate Wt.
Total Wt.	353.3
Pan Wt.	301.2
Solids Wt.	52.1

	Main Cake Wt.
Total Wt.	3465
Pan Wt.	720
Solids Wt.	2745

Ease of discharge
Good

Run	Max. Filter Time (s)	Dry Time (s)	Filter Time(s)
11	1000	240	735

Bucket	Time (s)	Bucket Wt.	Total Wt.	Filtrate Wt.
1	30	784.0	1138.4	354.4
2	75	809.0	1419.7	610.7
3	135	725.0	1212.6	487.6
4	195	782.0	1285.4	503.4
5	315	724.0	1180.7	456.7
6	435	377.0	818.4	441.4
7	675	373.0	1217.0	844.0
8	915	377.0	800.0	423.0
Total				4,121.2

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	104.2	173.3	343.9	120.6
Initial Wt.	125.2	132.8	215.3	367.5	142.2
Final Wt.	119.6	126.0	205.7	362.0	136.5
Moisture	22.74	23.87	22.82	24.54	26.41

	Dry Filtrate Wt.
Total Wt.	365.4
Pan Wt.	423.6
Solids Wt.	58.2

	Main Cake Wt.
Total Wt.	4356
Pan Wt.	702
Solids Wt.	3654

Ease of discharge
Good

General Linear Model: S1, S2, ... versus Filter Time, Dry Time

Factor	Type	Levels	Values
Filter Time	fixed	4	300, 400, 500, 600
Dry Time	fixed	2	120, 240

Analysis of Variance for S1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	2.6871	2.6153	0.8718	3.76	0.050
Dry Time	1	1.2247	1.2247	1.2247	5.28	0.070
Error	5	1.1592	1.1592	0.2318		
Total	9	5.0711				

S = 0.481506   R-Sq = 77.14%   R-Sq(adj) = 58.85%

Analysis of Variance for S2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	6.2097	6.7204	2.2401	13.15	0.008
Dry Time	1	0.8711	0.8711	0.8711	5.11	0.073
Error	5	0.8518	0.8518	0.1704		
Total	9	7.9327				

S = 0.412756   R-Sq = 89.26%   R-Sq(adj) = 80.67%

Analysis of Variance for S3, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	4.4768	4.3604	1.4535	5.47	0.049
Dry Time	1	0.0521	0.0521	0.0521	0.20	0.676
Error	5	1.3295	1.3295	0.2659		
Total	9	5.8584				

S = 0.515653   R-Sq = 77.31%   R-Sq(adj) = 59.15%

Analysis of Variance for S4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	2.4665	2.4292	0.8097	5.38	0.050
Dry Time	1	0.0455	0.0455	0.0455	0.30	0.606
Error	5	0.7522	0.7522	0.1504		
Total	9	3.2642				

S = 0.387863   R-Sq = 76.96%   R-Sq(adj) = 58.52%

Analysis of Variance for S5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	0.649	0.812	0.271	0.11	0.950
Dry Time	1	0.306	0.306	0.306	0.13	0.738
Error	5	12.206	12.206	2.441		
Total	9	13.161				

S = 1.56245   R-Sq = 7.26%   R-Sq(adj) = 0.00%

Analysis of Variance for M5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	2.2253	2.2515	0.7505	4.33	0.074
Dry Time	1	0.0437	0.0437	0.0437	0.25	0.637
Error	5	0.8672	0.8672	0.1734		
Total	9	3.1362				

S = 0.416455   R-Sq = 72.35%   R-Sq(adj) = 50.23%

Analysis of Variance for M4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Filter Time	3	3.54566	3.63766	1.21255	17.81	0.004
Dry Time	1	0.15967	0.15967	0.15967	2.34	0.186
Error	5	0.34045	0.34045	0.06809		
Total	9	4.04579				

S = 0.260942   R-Sq = 91.58%   R-Sq(adj) = 84.85%

APPENDIX D

PLANT 3 TEST RESULTS

Size and Ash Interval Data for Plant 3

	Direct		Cumulative Retained		Cumulative Passing	
Size Interval (U.S. Mesh)	**Weight** (%)	**Ash Value** (%)	**Weight** (%)	**Ash Value** (%)	**Weight** (%)	**Ash Value** (%)
+100	3.8	12.6	3.8	12.6	100.0	18.0
100 X 140	5.1	11.0	8.9	11.7	96.2	18.2
140 X 200	5.9	13.2	14.9	12.3	91.1	18.6
200 X 270	5.8	15.2	20.7	13.1	85.1	19.0
270 X 400	5.5	12.2	26.2	12.9	79.3	19.2
400 X 500	8.5	11.2	34.7	12.5	73.8	19.8
- 500	65.3	20.9	100.0	18.0	65.3	20.9

Microtrac Size Analysis

Size, µm	**% Passing**	**Size, µm**	**% Passing**	**Size, µm**	**% Passing**
704.0	100.0	37.0	49.2	1.95	1.26
592.0	96.5	31.1	44.1	1.64	0.84
497.8	92.3	26.2	38.6	1.38	0.47
418.6	89.2	22.0	32.8	1.16	0.23
352.0	85.7	18.5	27.3	0.97	0.11
296.0	83.2	15.6	22.4	0.82	0.00
248.9	79.3	13.1	18.4	0.69	0.00
209.3	77.3	11.0	15.0	0.58	0.00
176.0	75.3	9.3	12.1	0.49	0.00
148.0	73.1	7.8	9.5	0.41	0.00
124.5	70.7	6.5	7.6	0.34	0.00
104.7	66.0	5.5	6.0	0.29	0.00
88.0	65.0	4.6	4.8	0.24	0.00
74.0	61.6	3.9	3.8	0.20	0.00
62.2	57.9	3.3	2.4	0.17	0.00
52.3	53.8	2.8	2.3	0.15	0.00
44.0	49.2	2.3	1.7		

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
1	1	360	100	297

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4962.0	4232.8
2	60	788.4	5290.0	4501.6
3	90	400.7	4483.0	4082.3
4	120	378.4	3726.0	3347.6
5	150	381.5	2276.5	1895.0
6	180	377.6	1666.0	1288.4
7	210	379.2	1521.0	1141.8
8	240	219.5	1387.0	1167.5
9	270	245.6	988.0	742.4
10	300	164.1	710.0	545.9
11	330	210.7	438.0	227.3
12	360	211.8	384.2	172.4
13	390	217.3	242.8	25.5
14	420	118.9	395.2	276.3
15	450	121.5	360.1	238.6
16	480	113.6	294.2	180.6
17	510	121.5	270.2	148.7
18	540	117.9	256.1	138.2
19	570	120.7	195.2	74.5
20	600	120.7	183.5	62.8
21	630	122.0	602.5	480.5
22	660			
23	690			
24	720			
Total				24970.7

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	173.3	104.3	100.0	111.8	171.1
Initial Wt.	194.5	149.7	136.1	128.9	197.9
Final Wt.	190.9	141.1	129.4	125.9	192.6
Moisture	16.98	18.94	18.56	17.54	19.78

	Dry Filtrate Wt.
Total Wt.	616.9
Pan Wt.	601.6
Solids Wt.	15.3

	Main Cake Wt.
Total Wt.	7530
Pan Wt.	692
Solids Wt.	6838

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
2	1	6	80	297

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4480.0	3750.8
2	60	788.4	4830.0	4041.6
3	90	400.7	4032.0	3631.3
4	120	378.4	3207.0	2828.6
5	150	381.5	2361.0	1979.5
6	180	377.6	1800.0	1422.4
7	210	379.2	1448.2	1069.0
8	240	219.5	1112.0	892.5
9	270	245.6	915.6	670.0
10	300	164.1	911.4	747.3
11	330	210.7	682.8	472.1
12	360	211.8	389.9	178.1
13	390	217.3	371.0	153.7
14	420	118.9	272.2	153.3
15	450	121.5	193.3	71.8
16	480	113.6	195.8	82.2
17	510	121.5	198.9	77.4
18	540	117.9	168.7	50.8
19	570	120.7	162.0	41.3
20	600	120.7	153.5	32.8
21	630	122.0	266.9	144.9
22	660			
23	690			
24	720			
Total				22491.4

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	100.2	100.6	101.4	102.9	113.9
Initial Wt.	136.7	118.3	143.0	121.7	140.2
Final Wt.	130.2	114.9	135.1	118.2	135.1
Moisture	17.81	19.21	18.94	18.62	19.39

	Dry Filtrate Wt.
Total Wt.	434.2
Pan Wt.	424.6
Solids Wt.	9.6

	Main Cake Wt.
Total Wt.	8184
Pan Wt.	1025
Solids Wt.	7159

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
3	1	8	100	296

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4216.0	3486.8
2	60	788.4	4917.0	4128.6
3	90	400.7	4008.0	3607.3
4	120	378.4	3306.0	2927.6
5	150	381.5	2928.9	2547.4
6	180	377.6	2232.5	1854.9
7	210	379.2	1508.0	1128.8
8	240	219.5	1244.2	1024.7
9	270	245.6	1232.8	987.2
10	300	164.1	1048.8	884.7
11	330	210.7	962.0	751.3
12	360	211.8	759.5	547.7
13	390	217.3	496.5	279.2
14	420	118.9	306.6	187.7
15	450	121.5	235.9	114.4
16	480	113.6	201.3	87.7
17	510	121.5	195.9	74.4
18	540	117.9	172.3	54.4
19	570	120.7	155.1	34.4
20	600	120.7	149.5	28.8
21	630	122.0	145.5	23.5
22	660	119.8	255.3	135.5
23	690			
24	720			
Total				24897.1

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.2	103.7	110.2	101.3
Initial Wt.	125.3	190.5	153.1	155.2	133.8
Final Wt.	121.2	185.8	144.6	147.5	127.9
Moisture	16.08	17.22	17.21	17.11	18.15

	Dry Filtrate Wt.
Total Wt.	620.7
Pan Wt.	603.8
Solids Wt.	16.9

	Main Cake Wt.
Total Wt.	7762
Pan Wt.	824
Solids Wt.	6938

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
4	2	4	100	361

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4170.4	3441.2
2	60	788.4	4710.9	3922.5
3	90	400.7	4055.1	3654.4
4	120	378.4	3323.8	2945.4
5	150	381.5	2726.0	2344.5
6	180	377.6	2356.5	1978.9
7	210	379.2	1726.6	1347.4
8	240	219.5	1160.6	941.1
9	270	245.6	1283.4	1037.8
10	300	164.1	1205.3	1041.2
11	330	210.7	1036.1	825.4
12	360	211.8	1099.2	887.4
13	390	217.3	858.4	641.1
14	420	118.9	631.3	512.4
15	450	121.5	375.9	254.4
16	480	113.6	315.0	201.4
17	510	121.5	285.9	164.4
18	540	117.9	255.6	137.7
19	570	120.7	237.8	117.1
20	600	120.7	318.50	197.8
21	630			
22	660			
23	690			
24	720			
Total				26593.5

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.2	104.2	171.8	425.5	110.2
Initial Wt.	143.6	137.1	216.7	460.2	125.6
Final Wt.	136.2	131.1	208.3	453.3	122.3
Moisture	18.31	18.15	18.71	19.75	21.43

	Dry Filtrate Wt.
Total Wt.	317.3
Pan Wt.	301.2
Solids Wt.	16.1

	Main Cake Wt.
Total Wt.	7548
Pan Wt.	704
Solids Wt.	6844

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
5	2	8	80	366

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4026.7	3297.5
2	60	788.4	4672.1	3883.7
3	90	400.7	3988.2	3587.5
4	120	378.4	3523.2	3144.8
5	150	381.5	2752.9	2371.4
6	180	377.6	2256.8	1879.2
7	210	379.2	1685.1	1305.9
8	240	219.5	1476.0	1256.5
9	270	245.6	1139.0	893.4
10	300	164.1	1068.0	903.9
11	330	210.7	863.6	652.9
12	360	211.8	960.1	748.3
13	390	217.3	665.1	447.8
14	420	118.9	417.3	298.4
15	450	121.5	236.0	114.5
16	480	113.6	221.3	107.7
17	510	121.5	211.2	89.7
18	540	117.9	199.4	81.5
19	570	120.7	186.2	65.5
20	600	120.7	178.4	57.7
21	630	122.0	163.4	41.4
22	660	119.8	159.6	39.8
23	690	113.2	148.7	35.5
24	720	133.3	321.0	187.7
Total				25492.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	173.3	104.3	100.2	111.8	171.1
Initial Wt.	186.6	124.0	117.7	133.7	182.8
Final Wt.	184.3	120.7	114.9	129.9	180.5
Moisture	17.29	16.75	16.00	17.35	19.66

	Dry Filtrate Wt.
Total Wt.	376.2
Pan Wt.	365.1
Solids Wt.	11.1

	Main Cake Wt.
Total Wt.	7511
Pan Wt.	700
Solids Wt.	6811

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
6	1	4	80	289

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4475.0	3745.8
2	60	788.4	4800.0	4011.6
3	90	400.7	3920.0	3519.3
4	120	378.4	3176.0	2797.6
5	150	381.5	2420.0	2038.5
6	180	377.6	1985.8	1608.2
7	210	379.2	1083.8	704.6
8	240	219.5	614.4	394.9
9	270	245.6	550.9	305.3
10	300	164.1	371.9	207.8
11	330	210.7	377.8	167.1
12	360	211.8	331.5	119.7
13	390	217.3	298.9	81.6
14	420	118.9	436.8	317.9
15	450			
16	480			
17	510			
18	540			
19	570			
20	600			
21	630			
22	660			
23	690			
24	720			
Total				20019.8

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	292.4	300.8	300.0	120.6	292.4
Initial Wt.	303.0	321.0	311.0	145.7	302.9
Final Wt.	300.9	317.0	308.8	140.5	300.5
Moisture	19.81	19.80	20.00	20.72	22.86

	Dry Filtrate Wt.
Total Wt.	587.9
Pan Wt.	581.4
Solids Wt.	6.5

	Main Cake Wt.
Total Wt.	7038
Pan Wt.	701
Solids Wt.	6337

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
7	2	4	80	357

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4430.0	3700.8
2	60	788.4	4773.0	3984.6
3	90	400.7	4516.0	4115.3
4	120	378.4	2919.0	2540.6
5	150	381.5	2462.0	2080.5
6	180	377.6	1911.5	1533.9
7	210	379.2	928.3	549.1
8	240	219.5	2071.9	1852.4
9	270	245.6	1415.4	1169.8
10	300	164.1	1151.2	987.1
11	330	210.7	1140.4	929.7
12	360	211.8	712.4	500.6
13	390	217.3	649.0	431.7
14	420	118.9	232.8	113.9
15	450	121.5	251.0	129.5
16	480	113.6	306.4	192.8
17	510	121.5	262.2	140.7
18	540	117.9	237.4	119.5
19	570	120.7	228.5	107.8
20	600	120.7	209.2	88.5
21	630	122.0	214.3	92.3
22	660	119.8	181.2	61.4
23	690	113.2	238.6	125.4
24	720			
Total				25547.9

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	100.6	101.4	102.9	113.9
Initial Wt.	127.5	121.7	119.6	121.7	123.5
Final Wt.	122.5	117.8	116.1	118.3	121.5
Moisture	18.32	18.48	19.23	18.09	20.83

	Dry Filtrate Wt.
Total Wt.	309.4
Pan Wt.	300.6
Solids Wt.	8.8

	Main Cake Wt.
Total Wt.	7855
Pan Wt.	690
Solids Wt.	7165

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
8	2	6	100	363

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4378.0	3648.8
2	60	788.4	5036.0	4247.6
3	90	400.7	4170.0	3769.3
4	120	378.4	3658.0	3279.6
5	150	381.5	2893.0	2511.5
6	180	377.6	2225.0	1847.4
7	210	379.2	2063.0	1683.8
8	240	219.5	1307.2	1087.7
9	270	245.6	1351.4	1105.8
10	300	164.1	1129.0	964.9
11	330	210.7	1060.0	849.3
12	360	211.8	911.3	699.5
13	390	217.3	861.0	643.7
14	420	118.9	508.6	389.7
15	450	121.5	334.8	213.3
16	480	113.6	274.2	160.6
17	510	121.5	178.2	56.7
18	540	117.9	653.7	535.8
19	570	120.7	300.8	180.1
20	600	120.7	210.2	89.5
21	630	122.0	390.8	268.8
22	660	119.8	175.3	55.5
23	690	113.2	165.8	52.6
24	720	133.3	507.2	373.9
Total				28715.4

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.7	104.2	171.8	425.5	110.2
Initial Wt.	125.8	139.2	209.1	456.5	127.5
Final Wt.	122.1	133.1	202.4	451.0	123.9
Moisture	16.74	17.43	17.96	17.74	20.81

	Dry Filtrate Wt.
Total Wt.	320.2
Pan Wt.	303.0
Solids Wt.	17.2

	Main Cake Wt.
Total Wt.	7717
Pan Wt.	693
Solids Wt.	7024

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
9	2	8	100	362

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4216.6	3487.4
2	60	788.4	4812.9	4024.5
3	90	400.7	4086.2	3685.5
4	120	378.4	3403.9	3025.5
5	150	381.5	2935.9	2554.4
6	180	377.6	2132.1	1754.5
7	210	379.2	1545.8	1166.6
8	240	219.5	1473.9	1254.4
9	270	245.6	1393.3	1147.7
10	300	164.1	1186.8	1022.7
11	330	210.7	1036.1	825.4
12	360	211.8	1001.5	789.7
13	390	217.3	862.8	645.5
14	420	118.9	571.4	452.5
15	450	121.5	379.9	258.4
16	480	113.6	337.7	224.1
17	510	121.5	309.2	187.7
18	540	117.9	243.0	125.1
19	570	120.7	218.4	97.7
20	600	120.7	198.4	77.7
21	630	122.0	207.7	85.7
22	660	119.8	189.7	69.9
23	690	113.2	185.6	72.4
24	720	133.3	347.7	214.4
Total				27249.4

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.80	163.20	103.70	110.20	101.3
Initial Wt.	115.50	194.30	139.30	140.00	117.7
Final Wt.	113.10	189.20	133.70	135.00	114.9
Moisture	15.29	16.40	15.73	16.78	17.07

	Dry Filtrate Wt.
Total Wt.	
Pan Wt.	
Solids Wt.	18.5

	Main Cake Wt.
Total Wt.	8465
Pan Wt.	696
Solids Wt.	7769

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
10	1	4	100	297

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4229.0	3499.8
2	60	788.4	4820.0	4031.6
3	90	400.7	3997.0	3596.3
4	120	378.4	3152.0	2773.6
5	150	381.5	2525.6	2144.1
6	180	377.6	2045.6	1668.0
7	210	379.2	1210.3	831.1
8	240	219.5	636.1	416.6
9	270	245.6	568.8	323.2
10	300	164.1	426.4	262.3
11	330	210.7	410.2	199.5
12	360	211.8	348.1	136.3
13	390	217.3	313.6	96.3
14	420	118.9	379.1	260.2
15	450			
16	480			
17	510			
18	540			
19	570			
20	600			
21	630			
22	660			
23	690			
24	720			
Total				20238.8

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	293.4	293.0	302.1	304.0	301.0
Initial Wt.	320.0	317.0	330.1	336.9	316.8
Final Wt.	314.4	311.6	324.5	329.5	312.8
Moisture	21.19	22.58	20.17	22.53	25.32

	Dry Filtrate Wt.
Total Wt.	607.3
Pan Wt.	594.2
Solids Wt.	13.1

	Main Cake Wt.
Total Wt.	7134
Pan Wt.	690
Solids Wt.	6444

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
11	2	6	80	366

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	3925.9	3196.7
2	60	788.4	5420.7	4632.3
3	90	400.7	3814.5	3413.8
4	120	378.4	5247.6	4869.2
5	150	381.5	1233.6	852.1
6	180	377.6	2196.0	1818.4
7	210	379.2	1662.1	1282.9
8	240	219.5	2014.4	1794.9
9	270	245.6	1869.3	1623.7
10	300	164.1	539.7	375.5
11	330	210.7	687.8	477.1
12	360	211.8	592.9	381.1
13	390	217.3	314.7	97.4
14	420	118.9	196.1	77.1
15	450	121.5	171.4	49.9
16	480	113.6	425.2	311.7
17	510	121.5	407.8	286.3
18	540	117.9	363.8	245.9
19	570	120.7	496.2	375.5
20	600	120.7	409.7	289.0
21	630	122.0	225.4	103.4
22	660	119.8	224.1	104.3
23	690	113.2	216.2	103.0
24	720			
Total				26761.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	292.2	300.0	301.2	289.0	303.
Initial Wt.	306.0	315.0	331.1	303.7	319.5
Final Wt.	303.5	312.2	325.9	301.0	316.1
Moisture	18.12	18.67	17.39	18.37	20.99

	Dry Filtrate Wt.
Total Wt.	306.4
Pan Wt.	300
Solids Wt.	6.4

	Main Cake Wt.
Total Wt.	7807
Pan Wt.	703
Solids Wt.	7104

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
12	1	8	80	298

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4196.0	3466.8
2	60	788.4	4771.0	3982.6
3	90	400.7	4018.0	3617.3
4	120	378.4	3228.0	2849.6
5	150	381.5	2558.0	2176.5
6	180	377.6	2069.0	1691.4
7	210	379.2	1615.0	1235.8
8	240	219.5	904.7	685.2
9	270	245.6	613.5	367.9
10	300	164.1	362.9	198.8
11	330	210.7	368.5	157.8
12	360	211.8	316.9	105.1
13	390	217.3	293.6	76.3
14	420	118.9	198.5	79.6
15	450	121.5	179.8	58.3
16	480	113.6	167.4	53.8
17	510	121.5	170.0	48.5
18	540	117.9	161.6	43.7
19	570	120.7	161.1	40.4
20	600	120.7	157.5	36.8
21	630	122.0	155.2	33.2
22	660	119.8	311.1	191.3
23	690			
24	720			
Total				21196.8

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.2	103.7	110.2	101.3
Initial Wt.	113.1	191.9	127.9	124.2	118.3
Final Wt.	110.8	186.5	123.5	121.7	113.9
Moisture	17.56	18.78	18.07	17.57	25.88

	Dry Filtrate Wt.
Total Wt.	602.3
Pan Wt.	593.4
Solids Wt.	8.9

	Main Cake Wt.
Total Wt.	7762
Pan Wt.	824
Solids Wt.	6938

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
13	1	6	100	302

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4966.8	4237.6
2	60	788.4	5285.0	4496.6
3	90	400.7	4483.3	4082.6
4	120	378.4	3731.1	3352.7
5	150	381.5	2284.6	1903.1
6	180	377.6	1663.4	1285.8
7	210	379.2	1527.0	1147.8
8	240	219.5	1387.2	1167.7
9	270	245.6	987.1	741.5
10	300	164.1	704.8	540.7
11	330	210.7	442.5	231.8
12	360	211.8	386.9	175.1
13	390	217.3	246.3	29.0
14	420	118.9	392.9	274.0
15	450	121.5	361.9	240.4
16	480	113.6	293.4	179.8
17	510	121.5	266.7	145.2
18	540	117.9	251.1	133.2
19	570	120.7	202.2	81.5
20	600	120.7	663.2	542.5
21	630			
22	660			
23	690			
24	720			
Total				24988.6

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.2	103.7	110.2	101.3
Initial Wt.	125.3	190.5	153.1	155.2	133.8
Final Wt.	120.7	185.5	144.4	146.7	125.4
Moisture	17.87	18.38	17.56	18.92	25.88

	Dry Filtrate Wt.		Main Cake Wt.
Total Wt.	614.2	Total Wt.	7762
Pan Wt.	599.4	Pan Wt.	824
Solids Wt.	14.8	Solids Wt.	6938

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
14	1	6	100	305

	Time (s)	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4960.2	4231.0
2	60	788.4	5295.3	4506.9
3	90	400.7	4485.8	4085.1
4	120	378.4	3723.4	3345.0
5	150	381.5	2275.5	1894.0
6	180	377.6	1664.7	1287.1
7	210	379.2	1516.7	1137.5
8	240	219.5	1383.4	1163.9
9	270	245.6	993.2	747.6
10	300	164.1	708.1	544.0
11	330	210.7	434.5	223.8
12	360	211.8	385.2	173.4
13	390	217.3	239.4	22.1
14	420	118.9	394.5	275.6
15	450	121.5	357.0	235.5
16	480	113.6	294.8	181.2
17	510	121.5	267.2	145.7
18	540	117.9	260.0	142.1
19	570	120.7	190.1	69.4
20	600	120.7	668.3	547.6
21	630			
22	660			
23	690			
24	720			
Total				24958.5

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.7	104.2	171.8	425.5	110.2
Initial Wt.	125.3	147.2	245.1	488.2	133.8
Final Wt.	121.4	139.1	231.8	477.2	128.2
Moisture	17.83	18.82	18.21	17.55	23.54

	Dry Filtrate Wt.
Total Wt.	313.8
Pan Wt.	298.1
Solids Wt.	15.7

	Main Cake Wt.
Total Wt.	7762
Pan Wt.	824
Solids Wt.	6938

Ease of discharge
Good

DOE Results

General Linear Model: S1, S2, ... versus Probe Level, Air Pressure, ...

Factor	Type	Levels	Values
Probe Level	fixed	2	1, 2
Air Pressure	fixed	2	80, 100
Dry time	fixed	3	4, 6, 8

Analysis of Variance for S1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	2.1330	3.0923	3.0923	20.03	0.011
Air Pressure	1	1.7263	1.1919	1.1919	7.72	0.050
Dry time	2	16.8093	16.6194	8.3097	53.83	0.001
Probe Level*Air Pressure	1	0.6436	0.8642	0.8642	5.60	0.077
Probe Level*Dry time	2	2.2966	2.2064	1.1032	7.15	0.048
Air Pressure*Dry time	2	3.0791	3.0791	1.5396	9.97	0.028
Error	4	0.6175	0.6175	0.1544		
Total	13	27.3053				

S = 0.392891   R-Sq = 92.74%   R-Sq(adj) = 82.65%

Analysis of Variance for S2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	8.4466	9.6096	9.6096	15.29	0.017
Air Pressure	1	0.3593	0.1328	0.1328	0.21	0.670
Dry time	2	12.2436	12.1537	6.0769	9.67	0.029
Probe Level*Air Pressure	1	0.3151	0.6090	0.6090	0.97	0.381
Probe Level*Dry time	2	2.5679	2.2441	1.1221	1.78	0.279
Air Pressure*Dry time	2	3.1631	3.1631	1.5815	2.52	0.196
Error	4	2.5147	2.5147	0.6287		
Total	13	29.6103				

S = 0.792886   R-Sq = 91.51%   R-Sq(adj) = 72.40%

Analysis of Variance for S3, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	4.0486	4.7353	4.7353	17.00	0.015
Air Pressure	1	0.5400	0.3281	0.3281	1.18	0.339
Dry time	2	15.4929	15.4234	7.7117	27.69	0.005
Probe Level*Air Pressure	1	0.2505	0.1950	0.1950	0.70	0.450
Probe Level*Dry time	2	0.5610	0.5760	0.2880	1.03	0.435
Air Pressure*Dry time	2	0.0931	0.0931	0.0465	0.17	0.852
Error	4	1.1140	1.1140	0.2785		
Total	13	22.1001				

S = 0.527735   R-Sq = 94.96%   R-Sq(adj) = 83.62%

Analysis of Variance for S4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	2.2310	3.7080	3.7080	11.74	0.027
Air Pressure	1	0.0143	0.1235	0.1235	0.39	0.566
Dry time	2	20.8200	19.7981	9.8990	31.35	0.004
Probe Level*Air Pressure	1	0.0294	0.0060	0.0060	0.02	0.897
Probe Level*Dry time	2	4.5160	4.1251	2.0626	6.53	0.055
Air Pressure*Dry time	2	3.7039	3.7039	1.8520	5.86	0.065
Error	4	1.2632	1.2632	0.3158		
Total	13	32.5779				

S = 0.561965   R-Sq = 96.12%   R-Sq(adj) = 87.40%

Analysis of Variance for S5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	20.889	18.854	18.854	2.45	0.192
Air Pressure	1	0.593	0.841	0.841	0.11	0.757
Dry time	2	11.714	11.795	5.897	0.77	0.522
Probe Level*Air Pressure	1	0.259	0.142	0.142	0.02	0.898
Probe Level*Dry time	2	3.587	5.521	2.760	0.36	0.719
Air Pressure*Dry time	2	34.008	34.008	17.004	2.21	0.225
Error	4	30.731	30.731	7.683		
Total	13	101.781				

S = 2.77178   R-Sq = 69.81%   R-Sq(adj) = 1.87%

Analysis of Variance for M5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	6.1932	7.0779	7.0779	14.33	0.019
Air Pressure	1	0.5007	0.2693	0.2693	0.55	0.501
Dry time	2	15.0589	14.9135	7.4567	15.10	0.014
Probe Level*Air Pressure	1	0.0577	0.1187	0.1187	0.24	0.650
Probe Level*Dry time	2	1.7310	1.7917	0.8958	1.81	0.275
Air Pressure*Dry time	2	3.9695	3.9695	1.9848	4.02	0.110
Error	4	1.9753	1.9753	0.4938		
Total	13	29.4863				

S = 0.702723   R-Sq = 93.30%   R-Sq(adj) = 78.23%

Analysis of Variance for M4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	3.8736	5.0177	5.0177	52.25	0.002
Air Pressure	1	0.4788	0.1759	0.1759	1.83	0.247
Dry time	2	16.0406	15.7537	7.8768	82.03	0.001
Probe Level*Air Pressure	1	0.0299	0.1132	0.1132	1.18	0.339
Probe Level*Dry time	2	1.7617	1.5961	0.7980	8.31	0.038
Air Pressure*Dry time	2	1.9284	1.9284	0.9642	10.04	0.028
Error	4	0.3841	0.3841	0.0960		
Total	13	24.4972				

S = 0.309880   R-Sq = 98.43%   R-Sq(adj) = 94.90%

APPENDIX E

PLANT 4 TEST RESULTS

Size Interval Data for Plant 4

Size Interval (U.S. Mesh)	**Direct Weight** (%)	**Cumulative Weight Retained** (%)	**Cumulative Weight Passing** (%)
+100	2.7	2.7	100.0
100 X 140	7.5	10.2	97.3
140 X 200	13.7	24.0	89.8
200 X 270	15.5	39.5	76.0
270 X 400	14.0	53.5	60.5
400 X 500	9.4	62.9	46.5
- 500	37.1	100.0	37.1

Microtrac size analysis

Size, µm	**% Passing**	**Size, µm**	**% Passing**	**Size, µm**	**% Passing**
704.0	100.0	37.0	77.5	1.95	11.83
592.0	100.0	31.1	74.8	1.64	9.73
497.8	100.0	26.2	71.4	1.38	7.86
418.6	100.0	22.0	66.8	1.16	6.13
352.0	99.4	18.5	61.3	0.97	4.55
296.0	97.8	15.6	55.4	0.82	3.21
248.9	95.2	13.1	49.7	0.69	2.18
209.3	92.7	11.0	44.8	0.58	1.41
176.0	90.7	9.3	40.4	0.49	0.83
148.0	89.0	7.8	36.5	0.41	0.37
124.5	87.6	6.5	32.9	0.34	0.00
104.7	86.3	5.5	29.5	0.29	0.00
88.0	86.0	4.6	26.3	0.24	0.00
74.0	83.8	3.9	23.2	0.20	0.00
62.2	82.5	3.3	20.1	0.17	0.00
52.3	81.0	2.8	17.1	0.15	0.00
44.0	79.5	2.3	14.3		

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
1	2	240	100	1000

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4460.3	3731.1
2	60	788.4	5460.9	4672.5
3	90	400.7	4483.5	4082.8
4	120	378.4	3940.1	3561.7
5	150	381.5	3254.2	2872.7
6	180	377.6	2555.9	2178.3
7	210	379.2	2111.6	1732.4
8	240	219.5	1663.8	1444.3
9	270	245.6	1641.7	1396.1
10	300	164.1	1401.3	1237.2
11	330	210.7	1373.4	1162.7
12	360	211.8	1294.0	1082.2
13	390	217.3	1129.1	911.8
14	420	118.9	1004.1	885.2
15	450	121.5	985.3	863.8
16	480	113.6	972.6	859.0
17	510	121.5	965.5	844.0
18	540	117.9	909.3	791.4
19	570	120.7	896.6	775.9
20	600	120.7	845.1	724.4
21	630	122.0	846.3	724.3
22	660	119.8	811.5	691.7
23	690	113.2	783.9	670.7
24	1240	133.3	1890.8	1757.5
Total				39653.7

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	302.1	303.8	292.4	120.6	301.6
Initial Wt.	333.0	336.4	312.6	156.0	328.6
Final Wt.	329.2	332.2	310.1	151.3	322.8
Moisture	12.25	13.01	12.50	13.25	21.50

	Dry Filtrate Wt.
Total Wt.	321.7
Pan Wt.	300.1
Solids Wt.	21.6

	Main Cake Wt.
Total Wt.	10569
Pan Wt.	925
Solids Wt.	9644

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
2	2	360	100	1000

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4624.3	3895.1
2	60	788.4	4838.4	4050.0
3	90	400.7	3919.2	3518.5
4	120	378.4	3281.8	2903.4
5	150	381.5	2754.3	2372.8
6	180	377.6	2355.0	1977.4
7	210	379.2	2911.6	2532.4
8	240	219.5	1954.5	1735.0
9	270	245.6	1742.2	1496.6
10	300	164.1	1758.2	1594.1
11	330	210.7	1569.5	1358.8
12	360	211.8	1566.7	1354.9
13	390	217.3	1721.2	1503.9
14	420	118.9	1265.4	1146.5
15	450	121.5	1454.2	1332.7
16	480	113.6	1425.5	1311.9
17	510	121.5	1201.1	1079.6
18	540	117.9	879.3	761.4
19	570	120.7	898.2	777.5
20	600	120.7	847.0	726.3
21	630	122.0	808.5	686.5
22	660	119.8	854.0	734.2
23	690	113.2	857.0	743.8
24	1360	133.3	2814.5	2681.2
Total				42274.5

Cake Samples	S1	S2	S3	S4	S5
Pan Wt.	103.2	104.2	171.8	425.5	110.2
Initial Wt.	128.3	118.7	200.2	464.5	129.1
Final Wt.	125.5	116.8	197.0	459.5	126.1
Moisture	11.15	12.89	11.14	12.74	15.87

	Dry Filtrate Wt.
Total Wt.	
Pan Wt.	
Solids Wt.	25.2

	Main Cake Wt.
Total Wt.	10855
Pan Wt.	925
Solids Wt.	9930

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
3	2	360	80	1000

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4695.0	3965.8
2	60	788.4	4912.0	4123.6
3	90	400.7	4078.6	3677.9
4	120	378.4	3254.6	2876.2
5	150	381.5	2666.8	2285.3
6	180	377.6	2216.8	1839.2
7	210	379.2	3070.5	2691.3
8	240	219.5	2031.5	1812.0
9	270	245.6	1966.6	1721.0
10	300	164.1	1852.1	1688.0
11	330	210.7	1700.1	1489.4
12	360	211.8	1557.0	1345.2
13	390	217.3	1538.4	1321.1
14	420	118.9	1413.1	1294.2
15	450	121.5	1377.8	1256.3
16	480	113.6	1276.8	1163.2
17	510	121.5	1106.7	985.2
18	540	117.9	952.4	834.5
19	570	120.7	931.8	811.1
20	600	120.7	871.0	750.3
21	630	122.0	776.4	654.4
22	660	119.8	664.4	544.6
23	690	113.2	623.3	510.1
24	1360	133.3	1518.6	1385.3
Total				41025.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	301.3	304.3	300.8	301.8	76.1
Initial Wt.	331.9	355.6	326.8	320.1	95.8
Final Wt.	328.5	348.1	323.9	318.0	91.8
Moisture	11.18	14.57	11.21	11.57	20.30

	Dry Filtrate Wt.
Total Wt.	318.2
Pan Wt.	300.5
Solids Wt.	17.7

	Main Cake Wt.
Total Wt.	10220
Pan Wt.	694
Solids Wt.	9526

Ease of discharge
Very Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
4	1	360	80	243

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4657.2	3928.0
2	60	788.4	5383.4	4595.0
3	90	400.7	4723.6	4322.9
4	120	378.4	3568.5	3190.1
5	150	381.5	3658.8	3277.3
6	180	377.6	2565.8	2188.3
7	210	379.2	1801.6	1422.3
8	240	219.5	1254.9	1035.3
9	270	245.6	1254.5	1008.9
10	300	164.1	585.6	421.5
11	330	210.7	517.5	306.8
12	360	211.8	417.4	205.6
13	390	217.3	372.1	154.8
14	420	118.9	269.9	151.0
15	450	121.5	260.1	138.6
16	480	113.6	236.2	122.6
17	510	121.5	233.1	111.6
18	540	117.9	248.7	130.8
19	570	120.7	411.9	291.2
20	600			
21	630			
22	660			
23	690			
24	720			
Total				27002.6

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.2	103.4	110.2	101.3
Initial Wt.	133.6	208.3	148.0	167.1	129.9
Final Wt.	128.3	200.6	140.0	157.5	124.4
Moisture	15.60	17.04	17.89	16.90	19.23

	Dry Filtrate Wt.
Total Wt.	130.1
Pan Wt.	110.2
Solids Wt.	19.9

	Main Cake Wt.
Total Wt.	7160
Pan Wt.	696
Solids Wt.	6464

Ease of discharge
OK

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
5	2	240	80	1000

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4283.8	3554.6
2	60	788.4	4875.6	4087.2
3	90	400.7	4125.9	3725.2
4	120	378.4	3835.3	3456.9
5	150	381.5	3346.5	2965.0
6	180	377.6	2578.8	2201.2
7	210	379.2	2344.4	1965.2
8	240	219.5	1585.0	1365.5
9	270	245.6	1533.8	1288.2
10	300	164.1	1418.3	1254.2
11	330	210.7	1235.9	1025.2
12	360	211.8	1187.0	975.2
13	390	217.3	1071.5	854.2
14	420	118.9	877.4	758.5
15	450	121.5	971.7	850.2
16	480	113.6	934.8	821.2
17	510	121.5	910.7	789.2
18	540	117.9	863.1	745.2
19	570	120.7	889.9	769.2
20	600	120.7	804.9	684.2
21	630	122.0	744.3	622.3
22	660	119.8	671.0	551.2
23	690	113.2	534.4	421.2
24	1240	133.3	1158.8	1025.5
Total				36755.7

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.2	103.7	110.2	101.3
Initial Wt.	124.1	182.9	124.4	132.7	124.3
Final Wt.	121.1	180.4	121.6	129.5	118.7
Moisture	12.51	12.88	13.50	14.15	24.52

	Dry Filtrate Wt.
Total Wt.	121.9
Pan Wt.	103.7
Solids Wt.	18.2

	Main Cake Wt.
Total Wt.	10217
Pan Wt.	696
Solids Wt.	9521

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
6	1	240	80	238

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4301.2	3572.0
2	60	788.4	5424.9	4636.5
3	90	400.7	4603.2	4202.5
4	120	378.4	3414.2	3035.8
5	150	381.5	3236.2	2854.7
6	180	377.6	3013.0	2635.4
7	210	379.2	1633.3	1254.1
8	240	219.5	974.3	754.8
9	270	245.6	793.8	548.2
10	300	164.1	400.0	235.9
11	330	210.7	403.5	192.8
12	360	211.8	341.7	129.9
13	390	217.3	372.8	155.5
14	420	118.9	372.8	253.9
15	450	121.5	486.1	364.6
16	480			
17	510			
18	540			
19	570			
20	600			
21	630			
22	660			
23	690			
24	720			
Total				24826.6

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.2	104.2	171.8	425.5	110.2
Initial Wt.	142.4	139.0	233.4	451.6	123.9
Final Wt.	135.8	132.7	222.9	446.9	120.3
Moisture	16.80	18.20	17.10	17.90	26.47

	Dry Filtrate Wt.
Total Wt.	605.6
Pan Wt.	585.2
Solids Wt.	20.4

	Main Cake Wt.
Total Wt.	7165
Pan Wt.	694
Solids Wt.	6471

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
7	1	360	100	240

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4831.4	4102.2
2	60	788.4	5246.9	4458.5
3	90	400.7	4526.6	4125.9
4	120	378.4	3643.9	3265.5
5	150	381.5	3779.7	3398.2
6	180	377.6	2423.4	2045.8
7	210	379.2	1948.4	1569.2
8	240	219.5	1348.2	1128.7
9	270	245.6	1370.7	1125.1
10	300	164.1	961.3	797.2
11	330	210.7	775.9	565.2
12	360	211.8	731.3	519.5
13	390	217.3	654.5	437.2
14	420	118.9	534.4	415.5
15	450	121.5	516.6	395.1
16	480	113.6	496.1	382.5
17	510	121.5	499.0	377.5
18	540	117.9	486.5	368.6
19	570	120.7	670.2	549.5
20	600			
21	630			
22	660			
23	690			
24	720			
Total				30026.9

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	100.2	100.6	101.4	102.9	113.9
Initial Wt.	154.7	109.5	116.9	117.7	151.4
Final Wt.	147.2	108.2	114.7	115.5	143.1
Moisture	13.80	14.50	14.20	14.90	22.13

	Dry Filtrate Wt.
Total Wt.	628.6
Pan Wt.	608.1
Solids Wt.	20.5

	Main Cake Wt.
Total Wt.	7443
Pan Wt.	969
Solids Wt.	6474

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
8	1	240	100	244

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4629.0	3899.8
2	60	788.4	5317.5	4529.1
3	90	400.7	4364.0	3963.3
4	120	378.4	3650.8	3272.4
5	150	381.5	2948.2	2566.7
6	180	377.6	2379.3	2001.7
7	210	379.2	1903.5	1524.3
8	240	219.5	1287.4	1067.9
9	270	245.6	1086.5	840.9
10	300	164.1	715.8	551.7
11	330	210.7	611.1	400.4
12	360	211.8	472.7	260.9
13	390	217.3	361.1	143.8
14	420	118.9	471.3	352.4
15	450			
16	480			
17	510			
18	540			
19	570			
20	600			
21	630			
22	660			
23	690			
24	720			
Total				25375.2

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	173.3	104.3	100.2	111.8	171.1
Initial Wt.	209.3	115.2	143.3	167.3	207.5
Final Wt.	203.7	113.4	136.0	157.0	199.0
Moisture	15.50	16.50	16.90	18.60	23.35

	Dry Filtrate Wt.
Total Wt.	325.1
Pan Wt.	303.9
Solids Wt.	21.2

	Main Cake Wt.
Total Wt.	6765
Pan Wt.	693
Solids Wt.	6072

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
9	2	360	80	1000

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4907.5	4178.3
2	60	788.4	4480.9	3692.5
3	90	400.7	4178.4	3777.7
4	120	378.4	3811.2	3432.8
5	150	381.5	3600.7	3219.2
6	180	377.6	2622.2	2244.6
7	210	379.2	1885.6	1506.4
8	240	219.5	1442.2	1222.7
9	270	245.6	1211.4	965.8
10	300	164.1	1074.5	910.4
11	330	210.7	1036.1	825.4
12	360	211.8	956.2	744.4
13	390	217.3	986.7	769.4
14	420	118.9	899.7	780.8
15	450	121.5	793.6	672.1
16	480	113.6	654.8	541.2
17	510	121.5	664.5	543.0
18	540	117.9	737.0	619.1
19	570	120.7	645.6	524.9
20	600	120.7	483.1	362.4
21	630	122.0	525.1	403.1
22	660	119.8	512.5	392.7
23	690	113.2	466.2	353.0
24	720	133.3	1401.5	1268.2
Total				33950.1

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	99.8	163.2	103.4	110.2	101.3
Initial Wt.	136.4	187.2	125.4	141.8	137.1
Final Wt.	132.2	183.9	122.7	137.7	131.5
Moisture	11.51	13.58	12.41	12.91	15.54

	Dry Filtrate Wt.
Total Wt.	328.7
Pan Wt.	300.1
Solids Wt.	28.6

	Main Cake Wt.
Total Wt.	8575
Pan Wt.	686
Solids Wt.	7889

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
10	2	360	80	1000

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	30	729.2	4842.0	4112.8
2	60	788.4	4517.3	3728.9
3	90	400.7	4095.5	3694.8
4	120	378.4	3852.6	3474.2
5	150	381.5	3509.4	3127.9
6	180	377.6	2592.7	2215.1
7	210	379.2	3887.7	3508.5
8	240	219.5	1544.5	1325.0
9	270	245.6	1187.3	941.7
10	300	164.1	1057.0	892.9
11	330	210.7	1127.2	916.5
12	360	211.8	946.4	734.6
13	390	217.3	969.3	752.0
14	420	118.9	931.3	812.4
15	450	121.5	773.2	651.7
16	480	113.6	776.5	662.9
17	510	121.5	623.5	502.0
18	540	117.9	619.3	501.4
19	570	120.7	633.8	513.1
20	600	120.7	585.1	464.4
21	630	122.0	545.9	423.9
22	660	119.8	538.4	418.6
23	690	113.2	420.7	307.5
24	720	133.3	1317.3	1184.0
Total				35866.8

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	302.1	303.8	292.4	120.6	301.6
Initial Wt.	315.5	337.5	316.7	164.2	326.4
Final Wt.	313.9	333.1	313.9	158.8	321.8
Moisture	11.79	13.01	11.36	12.41	18.41

	Dry Filtrate Wt.
Total Wt.	326.7
Pan Wt.	300.1
Solids Wt.	26.6

	Main Cake Wt.
Total Wt.	9074
Pan Wt.	925
Solids Wt.	8149

Ease of discharge
Good

Run	Probe Level	Dry Time (s)	Air Pressure (psi)	Filter Time (s)
11	2	240	100	1521

	Time in Sec.	Bucket wt.	Bucket+filtrate	Filtrate
1	15	784	2326	1542
2	30	809	3142	2333
3	75	725	7104	6379
4	135	782	7070	6288
5	195	724	4327	3603
6	315	377	6779	6402
7	435	373	3700	3327
8	675	377	6144	5767
9	915	378	2278	1900
10	1155	164	1164	1000
11	1395	210	1523	1313
12	1875	219	1657	1438
13	2000	218	573	355
14	2240	187	955	768
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
Total				42415.0

Cake Samples

	S1	S2	S3	S4	S5
Pan Wt.	103.2	104.2	171.8	425.5	110.2
Initial Wt.	127.4	138.9	210.2	452.1	139.4
Final Wt.	124.6	134.4	205.6	448.8	134.0
Moisture	11.56	13.01	12.01	12.41	18.41

	Dry Filtrate Wt.		Main Cake Wt.
Total Wt.	332.7	Total Wt.	10950
Pan Wt.	310.1	Pan Wt.	696
Solids Wt.	22.6	Solids Wt.	10254

Ease of discharge
Very Good

General Linear Model: S1, S2, ... versus Probe Level, Dry Time, ...

Factor	Type	Levels	Values
Probe Level	fixed	2	1, 2
Dry Time	fixed	2	240, 360
Air Pressure	fixed	2	80, 100

Analysis of Variance for S1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	39.3822	33.6104	33.6104	308.83	0.000
Dry Time	1	1.7690	1.6791	1.6791	15.43	0.029
Air Pressure	1	0.6181	0.7694	0.7694	7.07	0.076
Probe Level*Dry Time	1	0.0784	0.0423	0.0423	0.39	0.577
Probe Level*Air Pressure	1	0.1531	0.1306	0.1306	1.20	0.353
Dry Time*Air Pressure	1	0.0783	0.0783	0.0783	0.72	0.459
Error	3	0.3265	0.3265	0.1088		
Total	9	42.4056				

S = 0.329894   R-Sq = 97.23%   R-Sq(adj) = 95.69%

Analysis of Variance for S2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	35.6973	35.1280	35.1280	48.61	0.006
Dry Time	1	0.0744	0.0105	0.0105	0.01	0.912
Air Pressure	1	1.0745	0.9997	0.9997	1.38	0.324
Probe Level*Dry Time	1	0.3145	0.3682	0.3682	0.51	0.527
Probe Level*Air Pressure	1	0.1046	0.0933	0.0933	0.13	0.743
Dry Time*Air Pressure	1	0.0271	0.0271	0.0271	0.04	0.859
Error	3	2.1680	2.1680	0.7227		
Total	9	39.4604				

S = 0.850102   R-Sq = 94.51%   R-Sq(adj) = 83.52%

Analysis of Variance for S3, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	67.543	58.175	58.175	186.90	0.001
Dry Time	1	0.735	0.533	0.533	1.71	0.282
Air Pressure	1	0.376	0.624	0.624	2.01	0.252
Probe Level*Dry Time	1	2.865	2.871	2.871	9.22	0.056
Probe Level*Air Pressure	1	0.077	0.082	0.082	0.26	0.644
Dry Time*Air Pressure	1	0.010	0.010	0.010	0.03	0.869
Error	3	0.934	0.934	0.311		
Total	9	72.540				

S = 0.557902   R-Sq = 98.71%   R-Sq(adj) = 96.14%

Analysis of Variance for S4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	54.1310	45.0192	45.0192	92.58	0.002
Dry Time	1	3.9824	3.7102	3.7102	7.63	0.070
Air Pressure	1	0.0280	0.0310	0.0310	0.06	0.817
Probe Level*Dry Time	1	0.0021	0.0015	0.0015	0.00	0.959

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level*Air Pressure	1	0.1222	0.1446	0.1446	0.30	0.623
Dry Time*Air Pressure	1	0.1052	0.1052	0.1052	0.22	0.674
Error	3	1.4589	1.4589	0.4863		
Total	9	59.8298				

S = 0.697350   R-Sq = 97.56%   R-Sq(adj) = 92.68%

Analysis of Variance for S5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	28.352	15.826	15.826	3.12	0.175
Dry Time	1	57.016	55.266	55.266	10.90	0.046
Air Pressure	1	4.206	4.828	4.828	0.95	0.401
Probe Level*Dry Time	1	1.462	1.346	1.346	0.27	0.642
Probe Level*Air Pressure	1	3.267	4.138	4.138	0.82	0.433
Dry Time*Air Pressure	1	5.552	5.552	5.552	1.09	0.372
Error	3	15.213	15.213	5.071		
Total	9	115.069				

S = 2.25190   R-Sq = 86.78%   R-Sq(adj) = 60.34%

Analysis of Variance for M5, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	43.9590	36.0945	36.0945	291.05	0.000
Dry Time	1	5.2545	5.0930	5.0930	41.07	0.008
Air Pressure	1	0.7463	0.8793	0.8793	7.09	0.076
Probe Level*Dry Time	1	0.2653	0.2331	0.2331	1.88	0.264
Probe Level*Air Pressure	1	0.1183	0.1654	0.1654	1.33	0.332
Dry Time*Air Pressure	1	0.4159	0.4159	0.4159	3.35	0.164
Error	3	0.3720	0.3720	0.1240		
Total	9	51.1313				

S = 0.352156   R-Sq = 99.27%   R-Sq(adj) = 97.82%

Analysis of Variance for M4, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Probe Level	1	48.3932	42.4491	42.4491	846.14	0.000
Dry Time	1	0.9557	0.9263	0.9263	18.46	0.023
Air Pressure	1	0.3217	0.3879	0.3879	7.73	0.069
Probe Level*Dry Time	1	0.1166	0.0983	0.0983	1.96	0.256
Probe Level*Air Pressure	1	0.0005	0.0000	0.0000	0.00	0.999
Dry Time*Air Pressure	1	0.0471	0.0471	0.0471	0.94	0.404
Error	3	0.1505	0.1505	0.0502		
Total	9	49.9854				

S = 0.223982   R-Sq = 99.70%   R-Sq(adj) = 99.10%