Crown Press™ Owner's Manual

 Written under contract by Environmental Process Dynamics Inc., Okemos, MI.

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Nomenclature

Table 1 is a list of the variables and definitions used in this manual. Equations of interest which utilize the various parameters may be found in the sections entitled "Recommended sludge sample volumes", "Establishing a Crown Press Test Tension Regime," and "Analysis of Data and Data Interpretation." All the equations in this manual are written using the specified units. The use of alternate units may require unspecified conversion factors which are the responsibility of the user.

Purpose of Crown Press

Belt filter presses were originally developed in Europe in the early 1970's for the paper industry. The technology spread quickly to the United States, first to the paper industry then later to the waste treatment industry. Despite the popularity of the belt press for full-scale applications, the ability of the laboratory technician to simulate the press operation on a small scale has lagged behind, largely due to the lack of widely available simulation hardware. The Crown Press was designed for the laboratory technician to fill this much needed analytical void.

The Crown Press is an instrument designed to simulate the action of a sludge dewatering belt filter press. The Crown Press was developed for designers of press belts, operators of wastewater plants, and manufacturers of sludge dewatering conditioners. It permits rapid evaluation of conditioners and belt materials for a given application. The Crown Press removes water from treated waste water in a fashion comparable to full-scale presses and allows users to collect data pertinent to the belt press process. The unit is compact and portable for easy transportation from one test site to another.

The Crown Press is unique, unlike any other laboratory press. The press features a pair of filtration belts between which a pretreated, gravity drained sludge cake is placed. Tension force is applied to the belts, drawing the belts and the sludge cake around a static, curved surface, or crown, which exerts pressure on the sludge cake, much as the rollers do in a working press. The user records the filtrate volume as a function of tension applied to the belt. Other unique features of the Crown Press include:

- Tension applied to the belt material is measured in pounds. When divided by the belt width, the force on the sludge is in units of pounds per inch, the unit of measure used in the adjustment of belt tension on full scale presses.

- The tension force applied pulls the belt material and the sludge cake around a curved surface. In addition to creating pressure on the sludge cake, the bending action shears the cake and opens micro-fissures along its surface. Bending the belt fabric opens capillaries which allow the filtrate to wick away from the sludge and further simulates the action of a full-scale press.

- Tension on the belt may be controlled in a timed fashion, simulating the process seen with the series of rollers in a full-scale press.

- The sludge cake, located between the pair of filter belts in the Crown Press is free to migrate at the outer edges as pressure is applied. The migration causes the sludge to contact open belt material which allows for further dewatering of the cake. The degree of migration can be measured; important information which cannot be collected with other laboratory presses.

- Pressure generated filtrate is free to flow across both the top and bottom belt faces; a feature no other laboratory press offers.

- The Crown Press permits easy exchange of belt fabric so a wide range of fabrics may be readily tested.

Table 1: List of Nomenclature

Parameter	Description	Units
A_{GT}	Gravity test filter area	Square centimeters
C_S	Initial sludge concentration	Weight percent
D_A	Diameter of cake axis on Crown Press	Centimeters
D_G	Diameter of forming cake in gravity test	Centimeters
d_{CP}	Diameter of Crown Press Crown	Centimeters
d_{FS}	Diameter of full scale roller	Centimeters
F_G	Gravity drainage concentration factor	Unitless
F_P	Pressure extrusion concentration factor	Unitless
F_T	Total concentration factor	Unitless
L_G	Length of gravity drainage section	Centimeters
M	Absolute Hard Migration	Centimeters
Q_D	Dilution water flow	Liters per second
Q_P	Polymer flow rate	Liters per second
Q_S	Sludge flow rate	Liters per second
Q_T	Total flow to operating belt press	Liters per second
R_S	Mass through-put of dry sludge	Grams per second
S	Gravity drainage belt speed	Centimeters per second
t	Elapsed time, gravity drainage test	Seconds
T_{CP}	Tension applied to the Crown Press	Force
T_{FS}	Tension applied to the Full Scale belt press	Force
t_G	Estimated full scale drainage time	Seconds
V_{CP}	Volume expressed at tension T	Milliliters
V_D	Volume of test dilution water	Milliliters
V_E	Excess water removed by plow action	Milliliters
V_F	Total volume of water collected at tension F	Milliliters

V_G	All water after gravity drainage plus plowed excess water	Milliliters
V_{Gt}	Gravity drained volume at time t	Milliliters
V_P	Volume of test polymer	Milliliters
V_S	Volume of test sludge	Milliliters
V_T	Volume of test, total	Milliliters
W_{CP}	Width of Crown Press Belt	Centimeters
W_D	Width of initial sludge distribution on full-scale press	Centimeters
W_{FS}	Width of full scale belt	Centimeters

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Mechanical Description of the Crown Press

Figure 1 is an illustration of the Crown Press which points out the major features of the instrument. Table 2 is a listing of the major components of the Crown Press and brief description of each component. Reference to the component parts will be made throughout this manual in accordance with the description presented in Table 2. The tension force measured on the Crown Press pressure face are to be read directly in pounds force. The maximum tension which may be read is 300 lbs. The nominal width of the Crown Press belt is six inches such that the nominal maximum tension is 50 pounds per inch (pli). Refer to the section "Establishing a Crown Press Test Tension Regime" for further details on correlating the Crown Press tension to a full-scale press.

Construction of Crown Press Belt Pairs

The Crown Press is designed to accommodate belting material from a wide range of material fabricators. A standard belt cloth is provided with the Crown Press. Contact your belt supplier for a sample of the belting used on your machine or to use a scrap piece of belt from a worn-out set of belts. You will need a piece of belt material at least 6.0 inches wide and 24 inches long.

The belt material is usually made of plastic and may be easily cut. The preferred cutting tool is the "hot knife" blade found with standard household wire soldering kits. Lay the scrap belt flat on a board or surface which will not be ruined with the heat of the soldering gun. Using a metal straight edge and a marking pen, mark the outline of the Crown Press Belt and cut out a section; 6.0 inches wide by 24 inches long. Use the metal straight edge to aid in cutting a straight line. Alternatively, you may cut the material with a scissors then melt the frayed edges with the "hot knife".

Fold the belt in half with the "smooth" side (side of weave which contacts the sludge) to the inside of the fold. Use a rubber hammer or a vice to crease the fold. You now have a belt "pair". Make a fold 0.33 inches (which incorporates both sides of the belt pair) from the first fold. Press the new fold with the vice or hammer. Change the soldering gun to the normal wire soldering tip. Place the rear edge of the outer belt of the pair against the attachment plate and mark the screw holes on the belt. Place the front face of the belt against the force plate and mark the holes. Melt or drill the holes as marked. Screw the face and backing to the belt. The belt is now complete.

Gravity Drainage Kit with Plow Simulator

Figure 2 is a schematic drawing of the Gravity Drainage and Plow Simulator test equipment labeled to identify the major features of the test kit. Note that the plow section of the drainage kit is attached to the filter retainer ring and may be removed for simulating presses without plows. Table 3 is a list of the major components of the Gravity Drainage Kit and a brief description of each component. Reference to the component parts will be made throughout this manual in accordance with the description presented in this table.

Description of the Belt Filter Press Process

A belt filter press is a complex machine which incorporates a number of physical processes for the purpose of removing water from sludges. Depending upon the sludge, the conditioners, the belt type, and other process variables, a belt press is capable of producing sludge cakes ranging from 10 to 45 percent dry solids.

Figure 3 is a schematic diagram of a typical belt filter press. In the belt filter press, there are four critical process zones, each of which can be the limiting factor to producing the optimum dewatering.

Zone 1: Conditioning, Blending, and Distribution
Zone 2: Gravity drainage
Zone 3: Cake Compression
Zone 4: Cake Release and Transport

The first step in optimizing a press is to define the likely failure points and to avoid loading the press to failure. Sludge enters in Zone 1 where it is conditioned with polymer. The first point of process failure occurs when the conditioned sludge fails to drain properly. This may manifest itself as leakage at the distribution seals at the tailing edge of the distribution.

The purpose of the gravity drainage section (Zone 2) is to remove freely drainable water from the forming cake. The second point of failure occurs at the end of the gravity drainage zone. If the sludge carries excess free water when entering the pressure zone, the excess free water lubricates the sludge. The extra height of the cake caused by free water is also directly redistributed by the advancement of the upper belt on the lower belt in the wedge zone (or low pressure zone). The lubricated sludge with excess cake height migrates (soft migration) off the edge of the belts creating housekeeping problems and inefficient solids capture.

In Zone 3 or high pressure section, sludge is pressed by the rollers. If the cake is too tall entering the pressure zone, the pressure squeezes the sludge to the side of the belt. This phenomenon, termed here as hard migration, is the third point of failure. Although less severe than a soft migration failure, hard migration also results in loss of capture efficiency. The cake formed at the outer edge of the belt is usually wetter than cake produced at the center of the belt, thus hard migration failure is an indication of undesirable wet sludge.

Zone 4 is the release and transport of the cake from the bottom belt at the end of pressing. Failure in this zone can be either by extrusion of the sludge into the belt weave or failure of the cake to release from the belt. These extruded solids create a dirty belt which may cause failure of the gravity drainage section of the press.

In defining the optimum belt filter press operation, it is important to consider the process output conditions. The definition of the optimum condition is case specific, dictated by the needs of the press operator. The typical process output conditions of interest are:

Solids through-put rate
Clarity of the filtrate
Cake dryness and
Polymer costs.

On an operating belt, the control of the process output conditions is limited by the available process variables. The variables which an operator can control in a short time frame are:

Sludge feed rate
Polymer feed rate
Belt tension and
Belt Speed

The process variables available to the operator on a long term basis are:

Belt material type and
Polymer type

The Crown Press is used to correlate the reaction of compression zone on the process output conditions by changes made in the process variables. To understand the entire belt filter process, however, it is also necessary to consider the effects of process variables on each of the process zones. The following experimental protocol is designed to provide data which delineate the effects of process variables on process outputs.

Figure 1: Features of the Crown Press

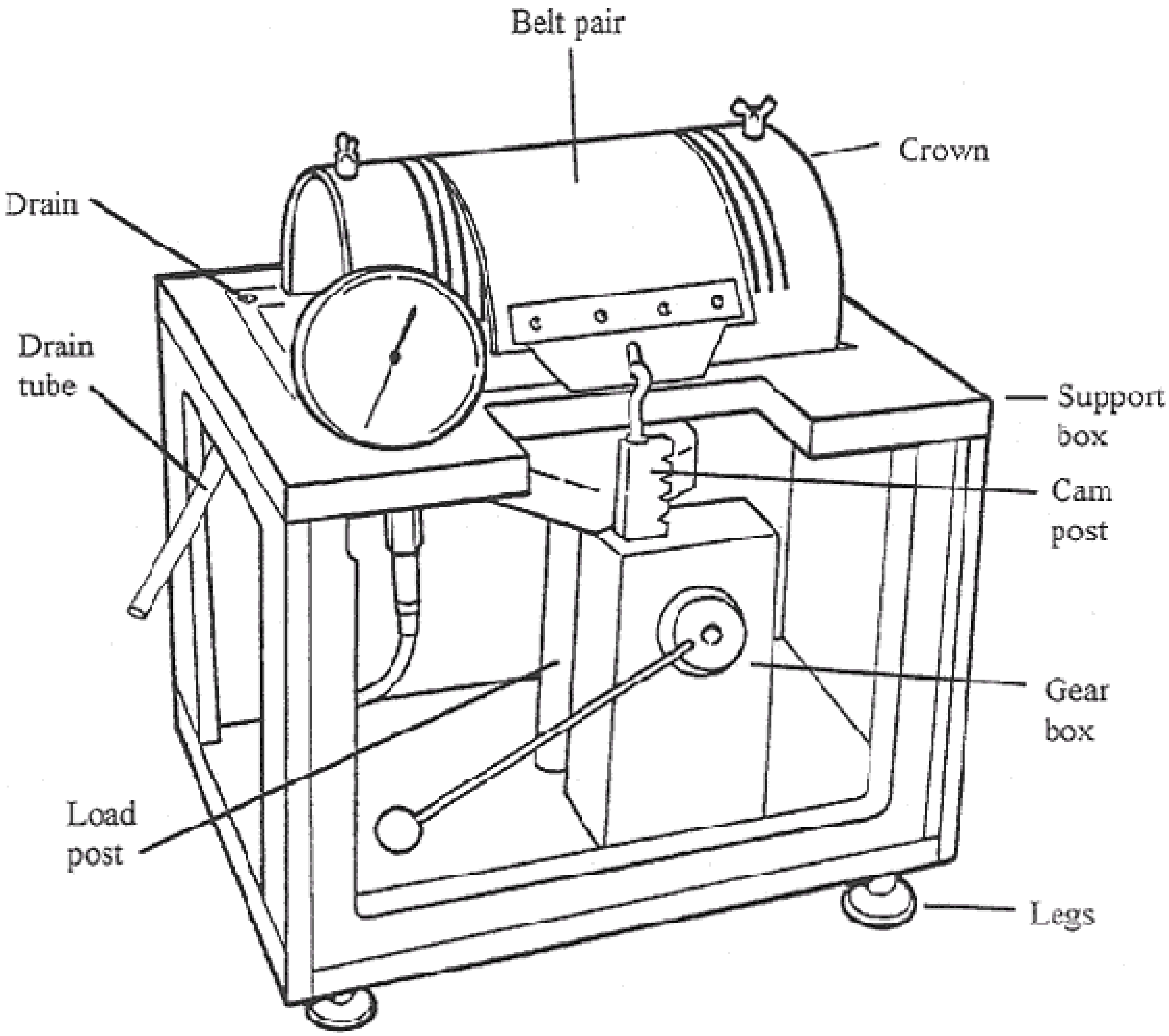


Table 2: List of Crown Press Component Parts

Part	Description	Specifications
Legs	Adjustable legs for changing drainage slope.	
Attachment bolts & plate	Hold rear of the belt pair to the support box.	
Support Box	Main structure of the Crown Press.	3/4 inch PVC, 11"D X 12-3/4"W X 9-1/2"H
Drain	Located in the top, left, rear side of the support box.	
Drain Tube	Flexible plastic hose connected at the drain.	
Crown	Consists of following units: pressure post, drainage plate, guide posts, pressure face.	
Drainage plate	Rolled galvanized steel plate attached to underside of pressure face.	
Pressure post	Located on bottom of pressure face, transmit force load to load cell.	
Guide posts	Two guide posts are located on the crown and fit into the guides on the structure box.	1/2" dia. X 3-1/2" stainless steel
Pressure face	Tension applied to the press belt is transmitted to a curved surface to create pressure on the test sample.	Half-round, 6.4" O.D. slotted PVC pipe
Load cell	Located beneath the top plate of the structure box and attached to the top of the load post.	1 square inch load surface, fluid filled
Pressure Gauge	Hydraulic fluid filled gauge reads pressure on the load cell in PSI. Directly converted to pounds force transmitted at the pressure face.	U.S. Gauge, 300 PSI
Load post	Supports the load cell and transmits the force to the bottom plate of the support box.	
Cam post	Toothed rod transmits force from the gear box to the force hook.	
Force hook	Attached to the Cam post, transmits force from the cam post to the press belt.	
Gear box	Transmits force from the handle to the cam post. Attached to the front of the bottom plate of the support box.	
Handle	Attached to the front of the gear box. Removable for packing.	
Force plate	Plate is attached to front of press belt and transmits force from force hook to press belt.	

Belt pair	Single folded belt creates a functional pair of belts. Top belt attaches to force hook through the force plate. Rear of belt pair attached to bottom of crown with attachment pins.	See "Construction of Crown Press Belt Pairs" for details.

Figure 2: Features of the Gravity Drainage Kit

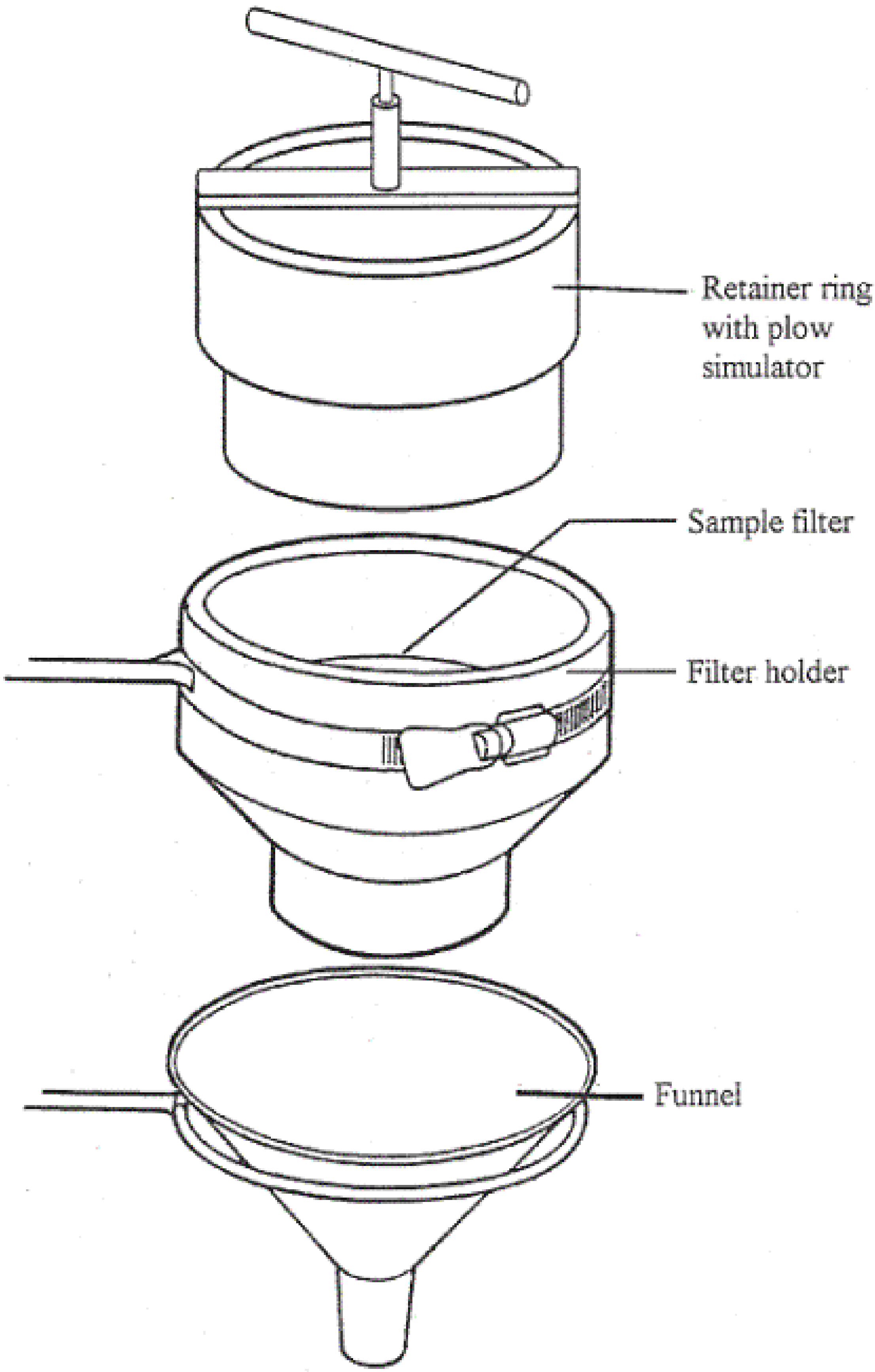
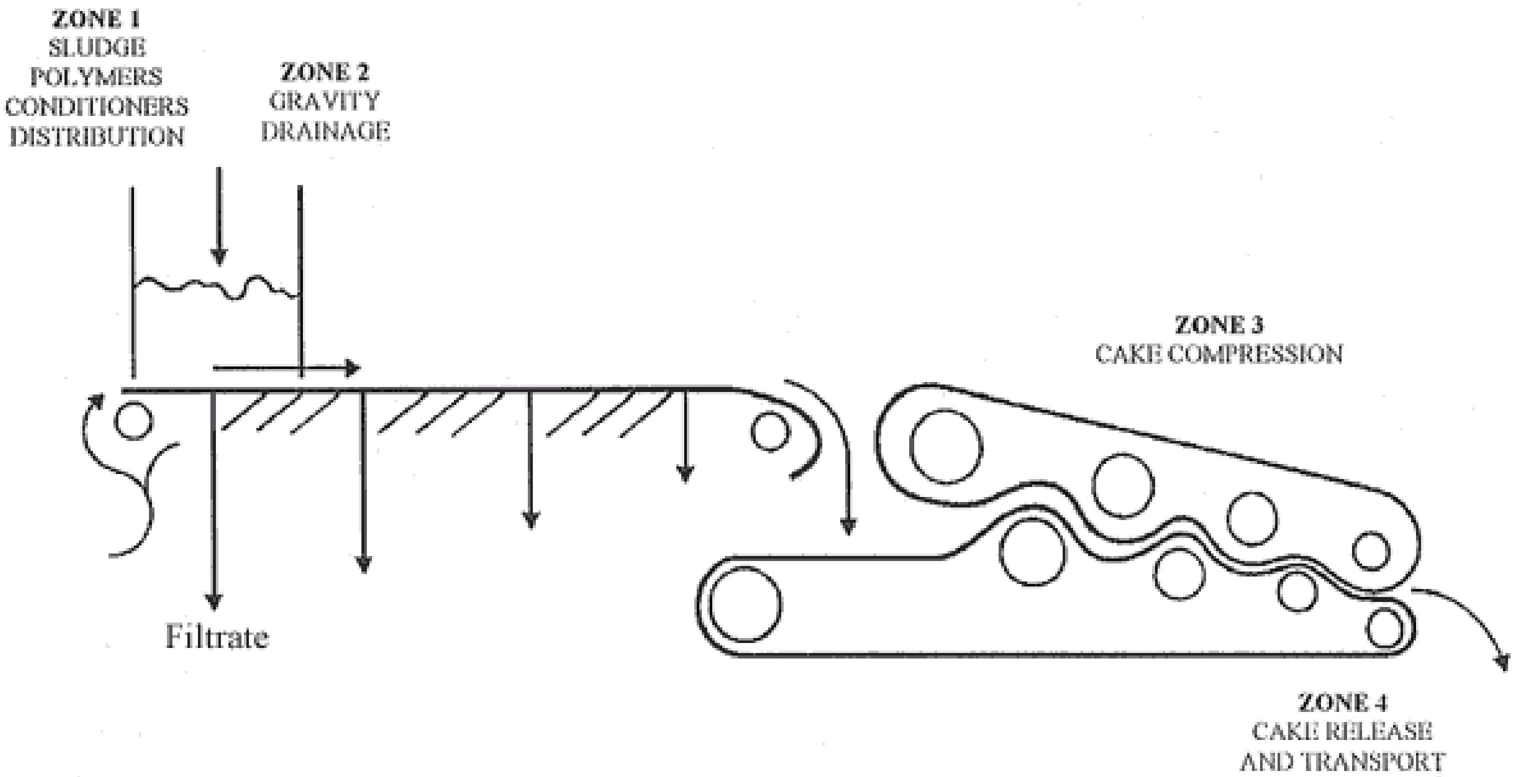


Table 3: List of Gravity Drainage Test Kit Components

Component	Description	Specifications
Mounting Rods	Two rods, fitted in mount holes at the right and left rear of top plate of support box. Used to hold mixing motor, and gravity drainage filter apparatus as desired	3/8" dia. stainless steel rod, 18 inch length approximate
Sample filter	Circular sample filter cut from full scale press belt material and used initially for the gravity drainage test.	Cut to fit inside the Filter holder, nominally 12 cm dia.
Filter holder		
Retainer ring with Plow Simulator	The retainer ring is capped with the plow simulator. The plow simulator is pvc cap, a squeegee and handle for rotating the squeegee.	4 inch pvc cap cut to support the plow
Mixing jar		Mason jar with flat sides
Funnel		
Graduated cylinder		250 ml recommended

Figure 3: Process Schematic of the Belt Press



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Procedures for the Gravity Drainage and Plow Test

The following customer data sheets, work sheets, information tables and graphs are designed to aid the Crown Press user in collecting and analyzing the pertinent data generated in the gravity drainage test and in the pressure expression test. The general protocol as outlined below is to identify a range of sample volumes which reflect expected loadings and belt speeds, find a suitable polymer dose to treat these loadings, identify loading conditions which may lead to soft migration failure.

Recommended Sludge Sample Volumes

The recommended sample volume for use in the static gravity drainage unit or the Crown Press are calculated from a flow balance around the dynamic press. Figure 4 is an illustration of the flow balance of sludge, polymer, and dilution water flows applied to a moving belt. The recommended sample volume, VS, is usually between 200 and 400 ml of raw sludge when using an 11 cm diameter gravity filter with an active gravity drainage diameter of 10 cm (AGT = 78.5 cm2) and a 12 cm wide press belt. The recommended test volume for a gravity drainage filter with a 7.5 cm diameter is between 100 and 250 ml. To properly choose the sample size, the active belt width (WG) and the range of belt speeds (S) for the full-scale machine must be known. Estimate the sludge sample volume from the sludge flow and the to the full-scale belt using Equation 1a:

1a) $V_s = 1000\ A_{GT}Q_S/(W_DS)$

Example: Estimate the range of sample sizes to be used to simulate the loading on a 1.5 meter press which is being operated with 65 g.p.m. (4.1 L/sec) raw sludge flow and a belt speed range between 10 and 20 cm/sec. The gravity drainage sector is actively loaded to 80% of the belt width (WD = 0.80 X 1.5 X 100 = 120 cm). The gravity drainage test filter has an active area of 78.5 cm2. Using Equation 1, check all units and plug in the appropriate numbers.

Belt speed = 10 cm/sec:

V_S = 1000 X 78.5 X 4.1/(10 X 120) = 268 ml

Belt speed = 20 cm/sec:

V_S = 1000 X 78.5 X 4.1/(20 X 120) = 134 ml

When using polymer conditioned sludge from an operating belt press conditioner box, the operating belt press is providing the polymer and polymer dilution water and these are already present in the conditioned samples. To estimate the volume of sludge to apply to the Crown Press, use the total flow numbers from the belt press and Equation 1b:

1b) $V_T = 1000\ A_{GT}Q_T/(W_DS)$

Tables 4, 5, 6 and 7 give approximate total sludge volumes (including polymer and dilution water) to be applied to a 10.0 cm diameter gravity filter to represent the belt speed and belt widths (1.0, 1.5, 2.0, and 2.5 meter) assuming 80% of the belt width is used for the initial sludge distribution. Note that the standard gravity drainage unit sold as an accessory to the Crown Press has a 10.0 cm diameter. The use of other drainage equipment of a diameter other than 10.0 cm will require recalculation of the information in these tables. Table 8 is an example of a useful data sheet for retaining gravity drainage data and information from the Crown Press tests. Record the initial sludge volumes (ml) in the column marked V_S.

Polymer Mixing and Addition

Polymers for dewatering sludges can be liquids, solids, or emulsions in light kerosene. These polymers are typically made into a water suspension prior to application to the sludge. A common suspension concentration is 0.5 % (gram solid per gram water) for solid polymers or 0.5 % (volume polymer per volume water) for liquid or emulsion type polymers. The recommended procedure for polymer make-up should be provided by the polymer manufacturer. Lacking manufacturer's instructions, the following set of instructions and equipment list for liquid or emulsion type is given as a guide. Instructions for preparation of solid type polymers are similar only replace milliliters of polymer for grams of polymer.

It is common for full-scale polymer make-up equipment to further dilute the 0.5% polymer with water prior to addition to the sludge. The following set of instructions presumes that some degree of further polymer dilution occurs. In any case, a small amount of dilution water added to the test sample aids in the thoroughness of mixing between the sludge and the polymer. Of course, the volumes of polymer and dilution water must be accounted for in the overall water balance around the sludge testing.

Another advantage of adding dilution water is that the total volume additives (polymer plus dilution) can be kept constant. This makes the calculation of the drainage rates and concentration factors uniform for a series of tests. Example: A 150 ml sample of 2.0 % sludge is to be tested at polymer doses from 11.9 to 17.9 pounds per ton which corresponds to additions of 3.0 to 4.5 ml of polymer. Consider making a dilution of between 7.0 and 5.5 ml excess water so that each the total volumetric additions each sludge is 10.0 ml.

Polymer Make-up equipment

1 L beaker	10 ml syringe
5 ml syringe	500 ml graduated cylinder
100 ml plastic cups	Braun high speed hand mixer

Procedure for Making 0.5% Polymer

1. Measure out 500 ml of water into the 1 L beaker. The water should be similar in chemistry to the process water used in the full-scale make-up system. Polymers are sensitive to chlorine,

chloride, calcium, total salts, and pH.

2. Draw 3.0 ml of neat polymer into the 5 ml syringe. Wipe off excess polymer from the outside of the syringe with a paper towel.
3. Place the Braun mixer in the 500 ml water, holding the blade encasement flat against the bottom of the beaker. Start the mixer.
4. Measure 2.5 ml of the polymer from the 5 ml syringe into the beaker, keeping the Braun mixer on.
5. Mix the polymer-water suspension for approximately 15 seconds. The degree of mixing will change with polymer type. Watch for variations in polymer consistency or test results which may be due to incomplete or over-mixing of the polymer suspension. Consult your polymer vendor for specific instructions on mixing if this method is inappropriate.
6. Age the 0.5% polymer suspension 15-30 minutes before using it in a test. This gives the polymer time to fully react with the water. The polymer suspension should remain good for at least eight hours after preparation. Consult your polymer vendor for specific instructions on polymer aging if this method is inappropriate.

Figure 4: Loading Parameters on the Gravity Drainage Section of a Belt Press

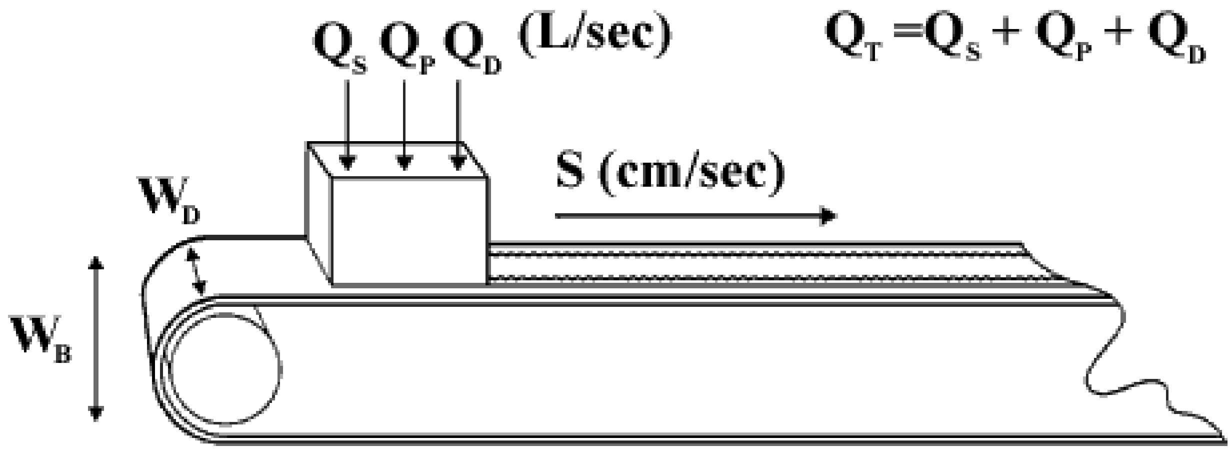

Table 4: Approximate Sample Volumes for a 1.0 Meter Press, ml applied to a 4 inch (10.0 cm) diameter filter to approximate a 1.0 meter belt operating at the specified belt speed, total flow rate, and assuming 80% initial coverage of belt in the drainage section.

Sludge Flow g.p.m.	Sludge Flow ml/sec	Belt Speed cm/sec							
		6	8	10	12	14	16	18	20
16	1000	169	127	101	84	72	63	56	51
24	1500	253	190	152	127	109	95	84	76
32	2000	338	253	203	169	145	127	113	101
40	2500	422	317	253	211	181	158	141	127
48	3000	507	380	304	253	217	190	169	152
55	3500	591	443	355	296	253	222	197	177
63	4000	676	507	405	338	290	253	225	203
71	4500	760	633	456	380	326	285	253	228
79	5000	845	697	507	422	362	317	282	253
87	5500	929	760	557	464	398	348	310	279

Table 5: Approximate Sample Volumes for a 1.5 Meter Press, ml applied to a 4 inch (10.0 cm) diameter filter to approximate a 1.5 meter belt operating at the specified belt speed, total flow rate, and assuming 80% initial coverage of belt in the drainage section.

Sludge Flow g.p.m.	Sludge Flow ml/sec	Belt Speed cm/sec							
		6	8	10	12	14	16	18	20
48	3000	338	253	203	169	145	127	113	101
55	3500	394	296	236	197	169	148	131	118
63	4000	450	338	270	225	193	169	150	135
71	4500	507	380	304	253	217	190	169	152
79	5000	503	422	338	282	241	211	188	169
87	5500	619	464	372	310	265	232	206	186
95	6000	676	507	405	338	290	253	225	203
103	6500	732	549	439	366	314	274	244	220
111	7000	788	591	473	394	338	296	263	236
119	7500	845	633	507	422	362	317	282	253

Table 6: Approximate Sample Volumes for a 2.0 Meter Press, ml applied to a 4 inch (10.0 cm) diameter filter to approximate a 2.0 meter belt operating at the specified belt speed, total flow rate, and assuming 80% initial coverage of belt in the drainage section.

Sludge Flow g.p.m.	Sludge Flow ml/sec	Belt Speed cm/sec							
		6	8	10	12	14	16	18	20
48	3000	253	190	152	127	109	95	84	76
55	3500	296	222	177	148	127	111	99	89
63	4000	338	253	203	169	145	127	113	101
71	4500	380	285	228	190	163	143	127	114
79	5000	422	317	231	211	181	158	141	127
87	5500	464	348	279	232	199	174	155	135
95	6000	507	380	304	253	217	190	169	152
103	6500	549	412	329	274	235	206	183	165
111	7000	591	443	355	296	253	222	197	177
119	7500	633	475	380	317	271	238	211	190
127	8000	676	507	405	338	290	253	225	203
135	8500	718	538	431	359	308	269	239	215
143	9000	760	570	456	380	326	285	253	228

Table 7: Approximate Sample Volumes for a 2.5 Meter Press, ml applied to a 4 inch (10.0 cm) diameter filter to approximate a 2.5 meter belt operating at the specified belt speed, total flow rate, and assuming 80% initial coverage of belt in the drainage section.

Sludge Flow g.p.m.	Sludge Flow ml/sec	Belt Speed cm/sec							
		6	8	10	12	14	16	18	20
63	4000	270	203	162	135	116	101	90	81
71	4500	304	228	182	152	130	114	101	91
79	5000	338	253	203	169	145	127	113	101
87	5500	372	279	223	186	159	139	124	111
95	6000	405	304	243	203	174	152	135	122
103	6500	439	329	263	220	188	165	146	122
111	7000	473	355	284	236	203	177	158	142
119	7500	507	380	304	253	217	190	169	152
127	8000	540	405	324	270	232	203	180	162
135	8500	574	431	345	287	246	215	191	172
143	9000	608	456	365	304	261	228	203	182
151	9500	642	481	385	321	275	241	214	193
159	10000	676	507	405	338	290	253	225	203

Customer:	Residue type:
Date:	Residue concentration:
Run by:	Polymer Type:
Gravity cake diameter, D_G:	Polymer concentration:
Crown Press belt width:	

Initial Volumes (ml)				Gravity Drainage (ml)									Pressure Expression (ml)		Cake Diameter (cm) D_A			
Sludge V_S	Polymer V_P	Dilution V_D	Total V_T	5 sec	10 sec	15 sec	20 sec	30 sec	45 sec	60 sec	final gravity filtrate	final plowed filtrate	( ) lbs	( ) lbs	Axis 1	Axis 2	Axis 3	Axis 4

Measured Cake Solids	Measured Solids Concentration Factor	Gravity Drainage Concentration Factor	Pressure Expression Concentration Factor	Total Water Balance Concentration Factor	Migration Factor

Table 8: Crown PressTM Gravity Drainage and Pressure Test Data Sheet

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Equipment and Set-up for the Gravity Drainage and Plow Tests

The gravity drainage section of a full-scale press is the first point of failure in the process. As such, the simulation of the Gravity drainage test is critical for initial screening of polymers and polymer dose requirements. Several drainage tests may be required to establish the range of polymer doses before proceeding to the belt filter pressure test. The following equipment are recommended for running the gravity drainage and plow simulator tests:

All equipment shown in Table 3
Variable speed Mixer, 1/16-1/8 HP
Flat bladed Paddle for mixer, blade 2" X 1"
Timer for 5,0,10,20,30,45, and 60 seconds sample recording
Chlorine solution (5-10 ml household bleach per 800 ml water)
One liter beaker or 1 quart container for the bleach solution
6 or more Plastic, non-wetting cups, 200 ml or less

Procedure for the Gravity Drainage and Plow Test

The following procedure is recommended for setting up the Gravity Drainage and plow simulator tests:

1. Mix the sludge sample well and keep a sample for total solids analysis.

2. Prepare a chlorine bleach solution for cleaning the filters. Use a 1 quart disposable cup or a 1 liter beaker large enough to accommodate the filters. The solution is made with 5 to 10 ml bleach in 800 ml water.

3. Estimate the range of sludge volumes to be run based on typical loading ranges for the full-scale press of interest. Typical sludge volumes for the Crown Press range from 200 to 400 ml.

4. Determine the proper polymer addition for the selected sample sizes. Tables 9, 10, and 11 give approximate pounds per ton of polymer as a function of sludge concentration (left column) and milliliters of 0.5% polymer (top row) added for 100, 150, and 200 ml initial sludge volumes, respectively. Example: A 150 ml sample of 2.0 % sludge is to be tested at polymer doses from 12 to 18 pounds per ton of polymer. Consult Tables 9, 10, or 11 and find the milliliters of polymer for a 2.0 % sludge which best match the range. A dose range of from 3.0 ml to 4.5 ml corresponds to 11.9 to 17.9 pounds per ton.

   Note 1: Typical sludges range in concentration from 1 to 4 % total solids by weight. For example, a 150 ml sample of sludge with a concentration of 2.5% contains 4.13 X 10-6 tons of dry solids.

Note 2: Polymer doses are typically given as pounds of neat polymer per ton of dry sludge processed. Assuming a specific weight for emulsion polymers of 10 lb per gallon, and a 0.5 % (by volume) polymer suspension, gives an approximate weight of 1.32 X 10-5 pounds neat polymer per ml polymer solution.

5. Polymers are usually diluted a second time prior to addition to the sludge. Consider the flow scheme for your full-scale belt press and determine if a dilution is warranted in your lab test. Dilutions in the lab test as described in step 5 have the added advantage of aiding mixing, and making sure the delivery of polymer to the sludge sample is uniform.

6. Prepare the polymer additive and the dilution water by adding them together in a small, not-wetting plastic cup (disposable polyethylene). Swirl the excess dilution water and polymer aliquot together. By this method you can pre-mix a series of polymer additions, placing each in separate cups. Record the polymer volume and the dilution water volumes on the data sheet.

7. Mix the sludge sample then measure out the predetermined sample volume with the graduated cylinder. Pour the sample into a clean Mason jar. Record the sludge volume on the data sheet.

8. Set up the gravity drainage kit as shown in Figure 2. Clean a sample filter in the chlorine bleach solution. Rinse the filter in tap water. Be sure the sample filter is wetted, but not dripping, and insert it into the drainage kit holder. Place the insert ring over the filter to hold it in place. Recheck the graduated cylinder for any excess water or sludge which may not have been placed into the Mason jar. Pour the excess into the Mason jar, or note the volume as "excess water" on the data sheet. This volume may amount to up to 2 milliliters and it is necessary to keep track of it for performing the water balance. Clean and drain the graduated cylinder and place it beneath the gravity drainage assembly.

9. Place the stirring paddle of the mixer into the Mason jar with the sludge. Turn on the mixer and mix the sludge at a predetermined speed which best simulates mixing in the full-scale belt press. Pour the aliquot of polymer and dilution water into the mixing sludge. Start the time clock and monitor the mixing time to a predetermined duration. Turn the speed of the mixed down to a lower, predetermined rate which simulates any gentle mixing provided on the full-scale belt press. Stop the mixing after a second predetermined duration. Alternatively, some technicians prefer to "box mix" the conditioned sludge, gently pouring it between two beakers until the sludge floc forms.

10. Reset the time clock. Pull the Mason jar with the conditioned sludge from the mixer. Gently swirl the jar as you position it to pour the conditioned sludge into the gravity drainage assembly. In one continuous, smooth motion, pour the conditioned sludge into the gravity drainage assembly. Start the time clock midway through the pour. The pour should not take more than 2 seconds to complete.

11. Record the drained volumes as a function of time. Recommended times are 5, 10, 20, 30, 45, and 60 seconds. The water drains rapidly and it is recommended to either use a partner to aid in the recording process, or to use a time clock with preset audible prompts. Record these data on the data sheet (Table 8).

12. Many new belt presses have plows on the gravity drainage section of the press. Plowing not only releases excess free water from the sludge, but also acts to flocculate the sludge making the sludge better conditioned for the pressure zone. Since it is difficult to plow the sludge while the cake is draining, an alternative plowing method has been devised. Simply allow the cake to gravity drain for one minute, then use the plow simulator subsequent to the gravity drainage. For each row of plows on the full scale press, use one full turn of the Crown Press Plow simulator. You may choose to turn the plow in one direction only, or you may alternate the direction of the turns. The plowing action will release excess free water, the volume of which must be recorded. This volume may be recorded in the column marked "excess water" in the Crown Press Data Sheet. If you desire to estimate the effect of the plow during the gravity test, it is recommended to reapportion the excess water value into the timed gravity drainage data. For example, if the gravity drained volume at the 10 second gravity drainage reading represents 40% of the total gravity drainage volume, then add 40% of the excess water volume to the 10 second reading. Apportion the entire excess water in this fashion to simulate the effect of plows.

13. At the end of the drainage run and the plowing routine, gently shake the drainage assembly to dislodge any excess water into the cylinder. Examine the polymer preparation cup and the Mason jar for any remaining liquid, tally this excess liquid plus any excess water gained by plowing in the excess water column on the data sheet. It is common to find 1 or 2 milliliters of excess water in the various test units plus several additional milliliters generated by the plowing action.

Table 9: Approximate polymer doses for a 100 ml sample (pounds polymer per dry ton sludge) for specified volume of 0.5% polymer (columns) applied to a 100 ml sludge sample of specified dry solids concentration (rows).

Initial solids % TS	Additions (ml of 0.5% polymer) to 100 ml Sludge								
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0	65.9	71.9
1.1	21.8	27.3	32.7	38.2	43.6	49.1	54.5	60.0	65.4
1.2	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
1.3	18.4	23.1	27.7	32.3	36.9	41.5	46.1	50.7	55.3
1.4	17.1	21.4	25.7	30.0	34.3	38.5	42.8	47.1	51.4
1.5	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0	48.0
1.6	15.0	18.7	22.5	26.2	30.0	33.7	37.5	41.2	45.0
1.7	14.1	17.6	21.2	24.7	28.2	31.7	35.3	38.8	42.3
1.8	13.3	16.7	20.0	23.2	26.6	30.0	33.3	36.6	40.0
1.9	12.6	15.8	18.9	22.1	25.2	28.4	31.6	34.7	37.9
2.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0	33.0	36.0
2.1	11.4	14.3	17.1	20.0	22.8	25.7	28.5	31.4	34.3
2.2	10.9	13.6	16.4	19.1	21.8	24.5	27.3	30.0	32.7
2.3	10.4	13.0	15.6	18.2	20.9	23.5	26.1	28.7	31.3
2.4	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
2.5	9.6	12.0	14.4	16.8	19.2	21.6	24.0	26.4	28.8
2.6	9.2	11.5	13.8	16.1	18.4	20.8	23.1	25.4	27.7
2.7	8.9	11.1	13.3	15.5	17.8	20.0	22.2	24.4	26.6
2.8	8.6	10.7	12.8	15.0	17.1	19.3	21.4	23.6	25.7
2.9	8.3	10.3	12.4	14.5	16.5	18.6	20.7	22.7	24.8
3.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0
3.1	7.7	9.7	11.6	13.5	15.5	17.4	19.3	21.3	23.2
3.2	7.5	9.4	11.2	13.1	15.0	16.9	18.7	20.6	22.5
3.3	7.3	9.1	10.9	12.7	14.5	16.4	18.2	20.0	21.8
3.4	7.1	8.8	10.6	12.3	14.1	15.9	17.6	19.4	21.2
3.5	6.9	8.6	10.3	12.0	13.7	15.4	17.1	18.8	20.6
3.6	6.7	8.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0

3.7	6.5	8.1	9.7	11.3	13.0	14.6	16.2	17.8	19.4
3.8	6.3	7.9	9.5	11.0	12.6	14.2	15.8	17.4	18.9
3.9	6.1	7.7	9.2	10.8	12.3	13.8	15.4	16.9	18.4
4.0	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0
4.1	5.8	7.3	8.8	10.2	11.7	13.2	14.6	16.1	17.5
4.2	5.7	7.1	8.6	10.9	11.4	12.8	14.3	15.7	17.1

Table 10: Approximate polymer doses for a 150 ml sample (pounds polymer per dry ton sludge) for specified volume of 0.5% polymer (columns) applied to a 150 ml sludge sample of specified dry solids.

Initial Solids % TS	Additions (ml of 0.5% polymer) to 150 ml Sludge								
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0	48.0
1.1	14.5	18.2	21.8	25.4	29.1	32.7	36.3	40.0	43.6
1.2	13.3	16.7	20.0	23.3	26.6	30.0	33.3	36.6	40.0
1.3	12.3	15.4	18.4	21.5	24.6	27.7	30.7	33.8	36.9
1.4	11.4	14.3	17.1	20.0	22.8	25.7	28.5	31.4	34.3
1.5	10.7	13.3	16.0	18.7	21.3	24.0	26.6	29.3	32.0
1.6	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
1.7	9.4	11.8	14.1	16.5	18.8	21.2	23.5	25.9	28.2
1.8	8.9	11.1	13.3	15.5	17.8	20.0	22.2	24.4	26.6
1.9	8.4	10.5	12.6	14.7	16.8	18.9	21.0	23.1	25.2
2.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0
2.1	7.6	9.5	11.4	13.3	15.2	17.1	19.0	20.9	22.8
2.2	7.3	9.1	10.9	12.7	14.5	16.4	18.2	20.0	21.8
2.3	7.0	8.7	10.4	12.2	13.9	15.6	17.4	19.1	20.9
2.4	6.7	8.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0
2.5	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2
2.6	6.1	7.7	9.2	10.8	12.3	13.8	15.4	16.9	18.4
2.7	5.9	7.4	8.9	10.4	11.8	13.3	14.8	16.3	17.8
2.8	5.7	7.1	8.6	10.0	11.4	12.8	14.3	15.7	17.1
2.9	5.5	6.9	8.3	9.6	11.0	12.4	13.8	15.2	16.5
3.0	5.3	6.7	8.0	9.3	10.7	12.0	13.3	14.7	16.0
3.1	5.2	6.4	7.7	9.0	10.3	11.6	12.9	14.2	15.5
3.2	5.0	6.2	7.5	8.7	10.0	11.2	12.5	13.7	15.0
3.3	4.8	6.1	7.3	8.5	9.7	10.9	12.1	13.3	14.5
3.4	4.7	5.9	7.1	8.2	9.4	10.6	11.8	12.9	14.1
3.5	4.6	5.7	6.9	8.0	9.1	10.3	11.4	12.6	13.7
3.6	4.4	5.6	6.7	7.8	8.9	10.0	11.1	12.2	13.3

3.7	4.3	5.4	6.5	7.6	8.6	9.7	10.8	11.9	13.0
3.8	4.2	5.3	6.3	7.4	8.4	9.5	10.5	11.6	12.6
3.9	4.1	5.1	6.1	7.2	8.2	9.2	10.2	11.3	12.3
4.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.1	3.9	4.9	5.8	6.8	7.8	8.8	9.7	10.7	11.7
4.2	3.8	4.8	5.7	6.7	7.6	8.6	9.5	10.5	11.4

Table 11: Approximate polymer doses for a 200 ml sample (pounds polymer per dry ton sludge) for specified volume of 0.5% polymer (columns) applied to a 200 ml sludge sample of specified dry solids concentration (rows).

Initial Solids % TS	Additions (ml of 0.5% polymer) to 200 ml Sludge								
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0	33.0	36.0
1.1	10.9	13.6	16.4	19.1	21.8	24.5	27.3	30.0	32.7
1.2	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
1.3	9.2	11.5	13.8	16.1	18.4	20.8	23.1	25.4	27.7
1.4	8.6	10.7	12.8	15.0	17.1	19.3	21.4	23.6	25.7
1.5	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0
1.6	7.5	9.4	11.2	13.1	15.0	16.9	18.7	20.6	22.5
1.7	7.1	8.8	10.6	12.3	14.1	15.9	17.6	19.4	21.2
1.8	6.7	8.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0
1.9	6.3	7.9	9.5	11.0	12.6	14.2	15.8	17.4	18.9
2.0	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0
2.1	5.7	7.1	8.6	10.0	11.4	12.8	14.3	15.7	17.1
2.2	5.5	6.8	8.2	9.5	10.9	12.3	13.6	15.0	16.4
2.3	5.2	6.5	7.8	9.1	10.4	11.7	13.0	14.3	15.6
2.4	5.0	6.2	7.5	8.7	10.0	11.2	12.5	13.7	15.0
2.5	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4
2.6	4.6	5.8	6.9	8.1	9.2	10.4	11.5	12.7	13.8
2.7	4.4	5.6	6.7	7.8	8.9	10.0	11.1	12.2	13.3
2.8	4.3	5.4	6.4	7.5	8.6	9.6	10.7	11.8	12.8
2.9	4.1	5.2	6.2	7.2	8.3	9.3	10.3	11.4	12.4
3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
3.1	3.9	4.8	5.8	6.8	7.7	8.7	9.7	10.6	11.6
3.2	3.7	4.7	5.6	6.6	7.5	8.4	9.4	10.3	11.2
3.3	3.6	4.5	5.5	6.4	7.3	8.2	9.1	10.0	10.9
3.4	3.5	4.4	5.3	6.2	7.1	7.9	8.8	9.7	10.6
3.5	3.4	4.3	5.1	6.0	6.9	7.7	8.6	9.4	10.3
3.6	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0

3.7	3.2	4.1	4.9	5.7	6.5	7.3	8.1	8.9	9.7
3.8	3.2	3.9	4.7	5.5	6.3	7.1	7.9	8.7	9.5
3.9	3.1	3.8	4.6	5.4	6.1	6.9	7.7	8.5	9.2
4.0	3.0	3.7	4.5	5.2	6.0	6.7	7.5	8.2	9.0
4.1	2.9	3.7	4.4	5.1	5.8	6.6	7.3	8.0	8.8
4.2	2.9	3.6	4.3	5.0	5.7	6.4	7.1	7.9	8.6

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Procedures for Operating the Crown Press

Several runs with the gravity drainage will be required to establish a good range of polymer doses. Once the polymer dose has been chosen, the entire gravity test regime and press cycle should be run. The steps in running the Crown Press are to be considered as a continuation of the gravity drainage test. The general protocol for this section is to identify loading conditions which may lead to hard migration failure, extrusion into the belt weave, poor release of cake from the belt, and to estimate the cake solids produced.

1. Be sure the legs of the Crown Press are set so that water drains freely down the drainage troughs to the drainage hole.

2. Position the Crown Press drainage hose into the graduated cylinder.

3. Lift the retainer ring (and plow assembly) from the gravity drainage assembly. Carefully lift out the sample filter so that the unpressed cake won't slide. A metal spatula with a crimped edge is often useful for grabbing up an edge of the filter from the filter holder.

4. Carefully remove the sludge from the filter and place it on the bottom belt of the Crown Press. Reform the cake into a patty of approximately 10 cm diameter of uniform height. Measure the diameter of the patty along four axes through the centroid of the cake. Record the diameter of the axes on the data sheet in the top four positions for each sample. Measure the cake height and record it on the data sheet. Alternatively, the height may be approximated from calculations of the reformed patty area and the volume of the plowed cake. The volume of the plowed cake is approximately the difference between the total sample volume and the final plowed filtrate.

5. Using the press lever, raise the cam and hook. Cover the filter sample with the press belt. Grab the press belt face plate with the hook and carefully draw down the cam and hook to apply pressure to the sample.

6. Slowly run the Crown Press through a predetermined pressure regime (see "Establishing a Crown Press Tension Regime"). Alternatively a simple regime might be to press the solids slowly to 100 pounds, release, press rapidly to 130, release, then rapidly to 170 pounds force. Be sure to make the first pressure pull even and slow to approximate the low pressure wedge zone on the press. Hold the press at each designated force to approximate the roller contact time at each roller. It may also be desired to raise the cam and hook to reveal the sample after reaching a predetermined force in order to measure the hard migration. Continue with the regime, stopping as often as desired and taking as many migration (see next step) and volume measurements as needed.

7. Measure the migration by locating the centroid of the pressed cake. Use a sharp edge of a spatula to mark an X across the centroid. Turn the sample 45o and mark a second X through the centroid so that there are now four axes laid out across the cake. Use a ruler to measure the diameter of the cake at each of the four axes. Record the diameters of the axes on the data sheet in the bottom four boxes for each sample.

8. Qualitatively check the cake for release properties from the filter and for penetration of the cake into the weave of the filter. Be careful to lift only one edge of the cake from the filter if the sample must be retained for solids testing. Record the observations about release properties.

9. Use the sharp edge of a spatula to shave off the outside edges of the cake. Discard the edges. Lift off the remaining center of the cake and retain it for solids analysis.

Establishing a Crown Press Test Tension Regime

As depicted in Figure 3, an operating belt press consists of a belt pair and a series of pressure rollers. To effectively simulate this process, you must manipulate the Crown Press in a regime which accomplishes the same timing and pressure cycles as on the full scale belt press. Table 12 is a work sheet to help you establish a test tension regime for your Crown Press.

Count the number of pressure rollers on your full-scale belt press. There may be as few as five or as many as a dozen rollers. The number of rollers represents the number of tensioning cycles to apply to a test sample using the Crown Press. Estimate the contact time of the belt material with each pressure roller on the full scale press. This represents the duration to apply tension to the Crown Press relative to each full-scale pressure roller. Estimate the time of travel of the full-scale belt between pressure rollers. This represents the relaxation time between tension applications on the Crown Press. The pressure exerted on the belts by the full scale rollers is directly proportional to belt tension, inversely proportional to the belt width, and inversely proportional to the diameter of the roller. To estimate the tension you should apply to the Crown Press at each tension cycle, you need to know the full scale belt tension and the diameter of each pressure roller and the width of the full scale belt. Equation 2 summarized the calculation needed to proportion the Crown Press tension to each of the pressures extant at each full-scale pressure roller:

$$2)\ T_{CP} = T_{FS} \times (d_{CP}/d_{FS}) \times (W_{CP}/W_{FS})$$

The tension on the full-scale press, TFS is the summation of the force applied to the belt by the tension roller plus friction losses created by the drive motor or motive forces. The motive forces may be considered to be 5 to 10 percent of the roller tension forces.

Example: A 150 cm belt press has seven pressure rollers with diameters ranging from 24 inches (53 cm) at the head end of the pressure zone to 8 inches (20.3 cm) at the end of the pressure zone. Estimate the tension of the first tension cycle and the last tension cycle to be used with your Crown Press. The diameter of the Crown is 6.25 inches (15.9 cm). The width of the Crown Press belt is 6.0 inches (15.25 cm). The full-scale press has a tension of 3500 pounds. Assume the motive force is equivalent to 200 pounds.

For the first roller estimate:

$$T_{CP} = (3500 + 200) \times (15.9/53) \times (15.25/150) = 112.9 \text{ pounds}$$

For the last roller estimate:

$$T_{CP} = (3500 + 200) \text{ X } (15.9/20.3) \text{ X } (15.25/150) = 294.6 \text{ pounds}$$

Figures 5, 6, 7, 8 give estimates of the tension (pounds) to be applied to the Crown Press (standard unit diameter = 6.25 inches, standard unit belt width = 6.00 inches) for 1, 1.5, 2, and 2.5 meter full scale belt width as a function of the full scale belt tension and the roller diameter.

Table 12: Tension Regime Work Sheet and Customer Data Sheet

Customer:
Belt Press Manufacturer:
Belt Press Width:
Belt Press Material:
Belt Tension:
Belt Speed:
Test Date:

Roller	Diameter	Roller Contact Time (seconds)	Time to Next Roller relaxation time (seconds)	Crown Press Tension (lbs)
Lead time to roller 1 (wedge time)	XXXXXXXX	XXXXXXXX		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Figure 5: Tension to be pulled on the Crown Press corresponding to the tension applies on a 1.0 M full-scale belt press. Calculated for the standard 6.0 inch wide Crown Press belt and the standard 6.25 inch diameter crown.

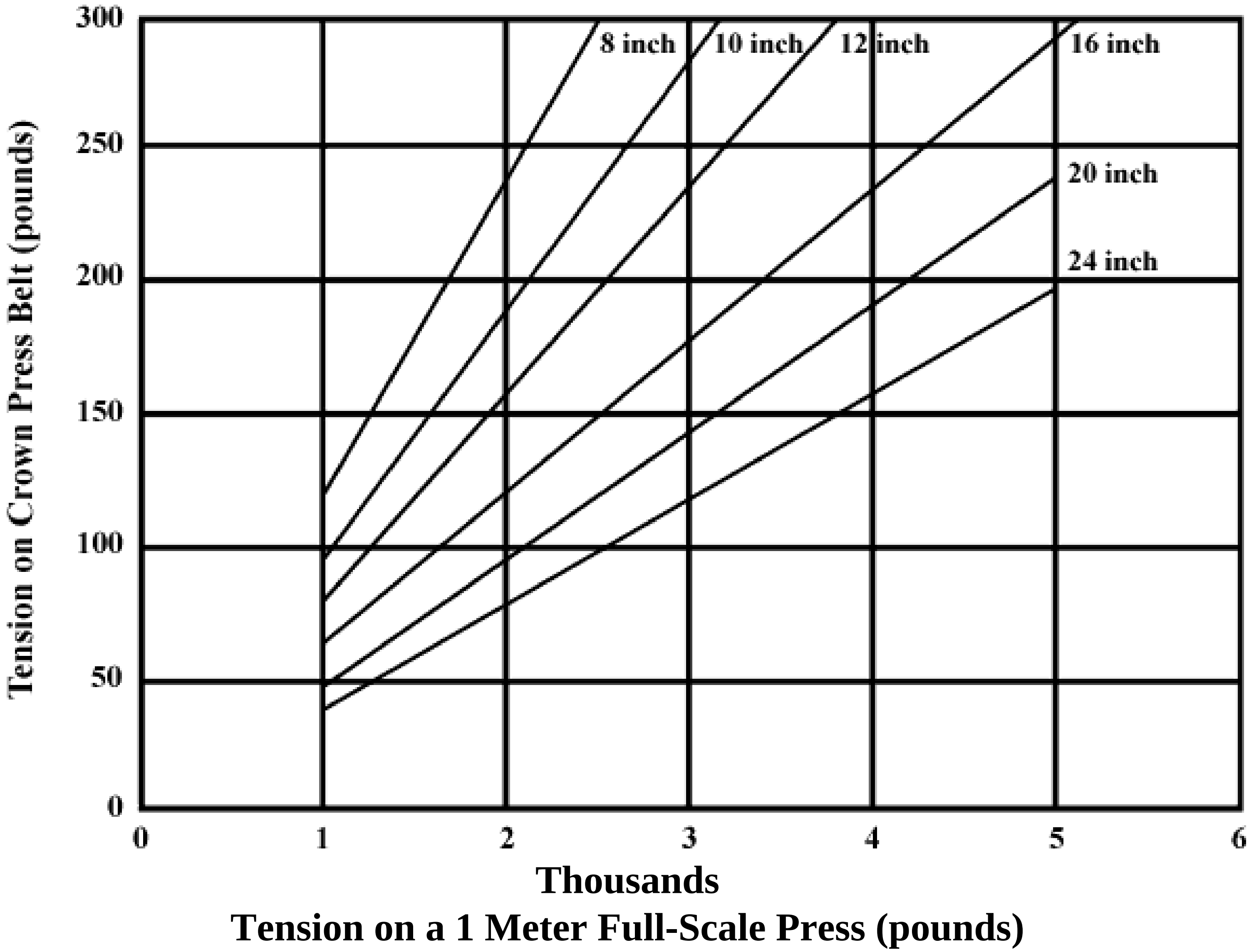


Figure 6: Tension to be pulled on the Crown Press corresponding to the tension applies on a 1.5 M full-scale belt press. Calculated for the standard 6.0 inch wide Crown Press belt and the standard 6.25 inch diameter crown.

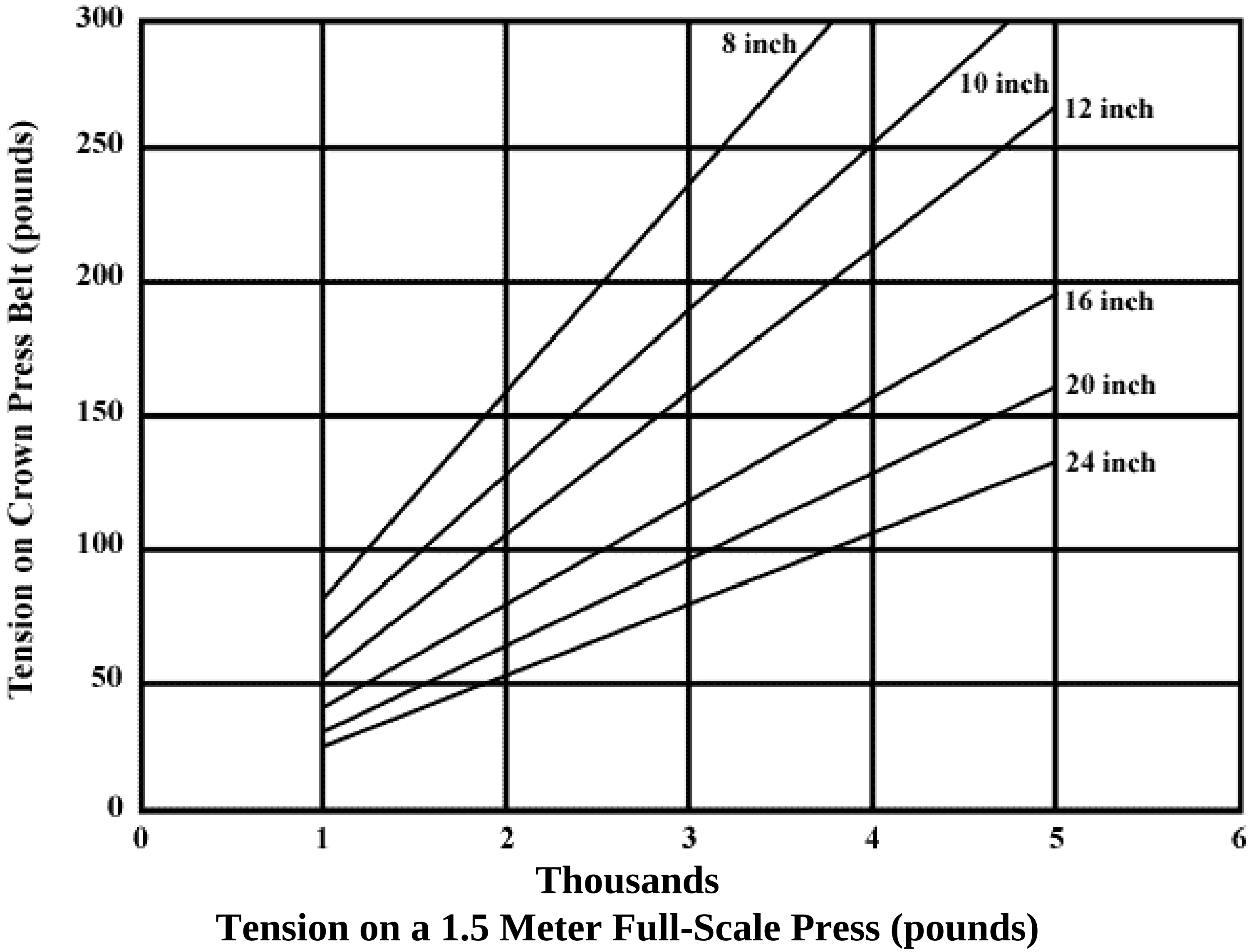


Figure 7: Tension to be pulled on the Crown Press corresponding to the tension applies on a 2.0 M full-scale belt press. Calculated for the standard 6.0 inch wide Crown Press belt and the standard 6.25 inch diameter crown.

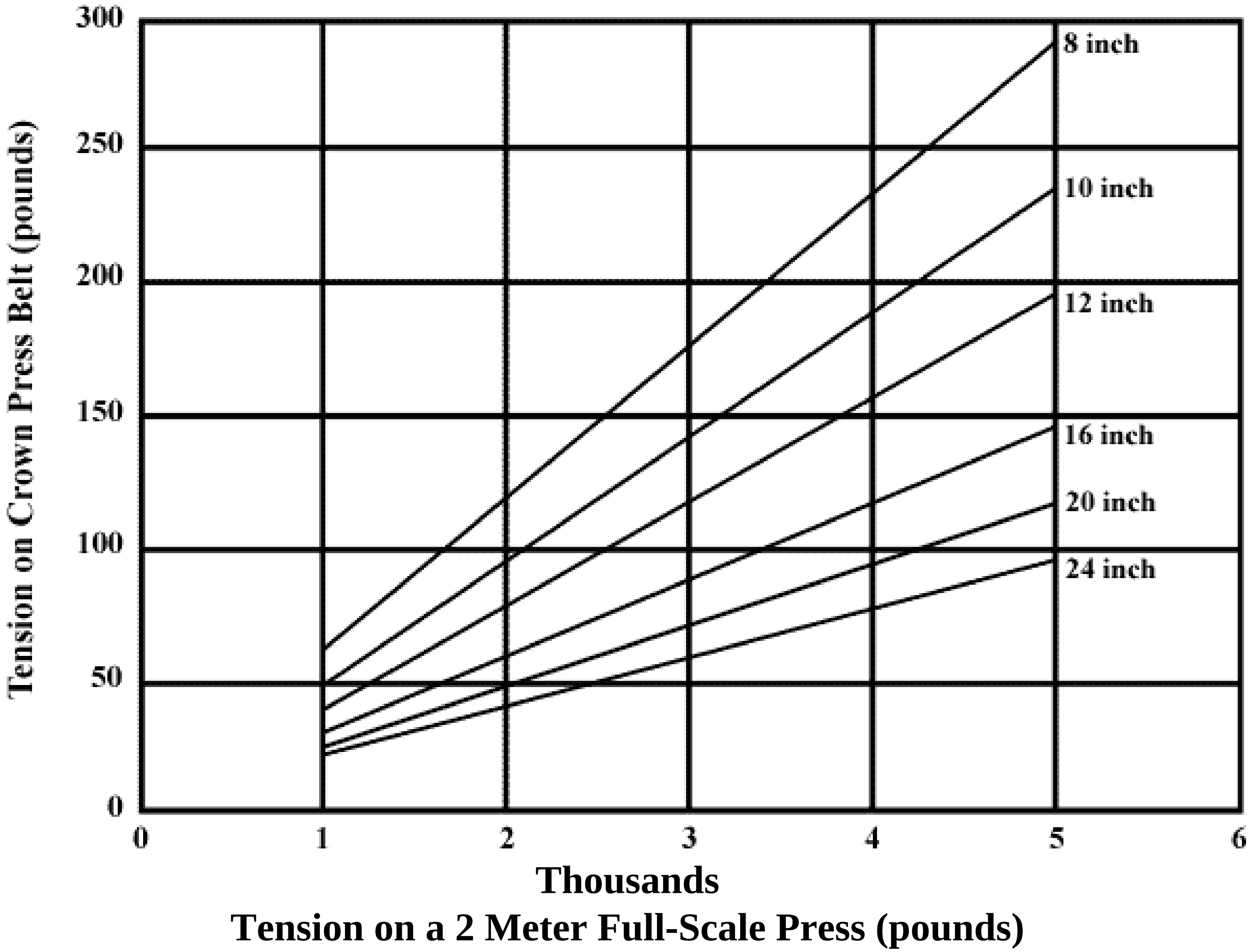
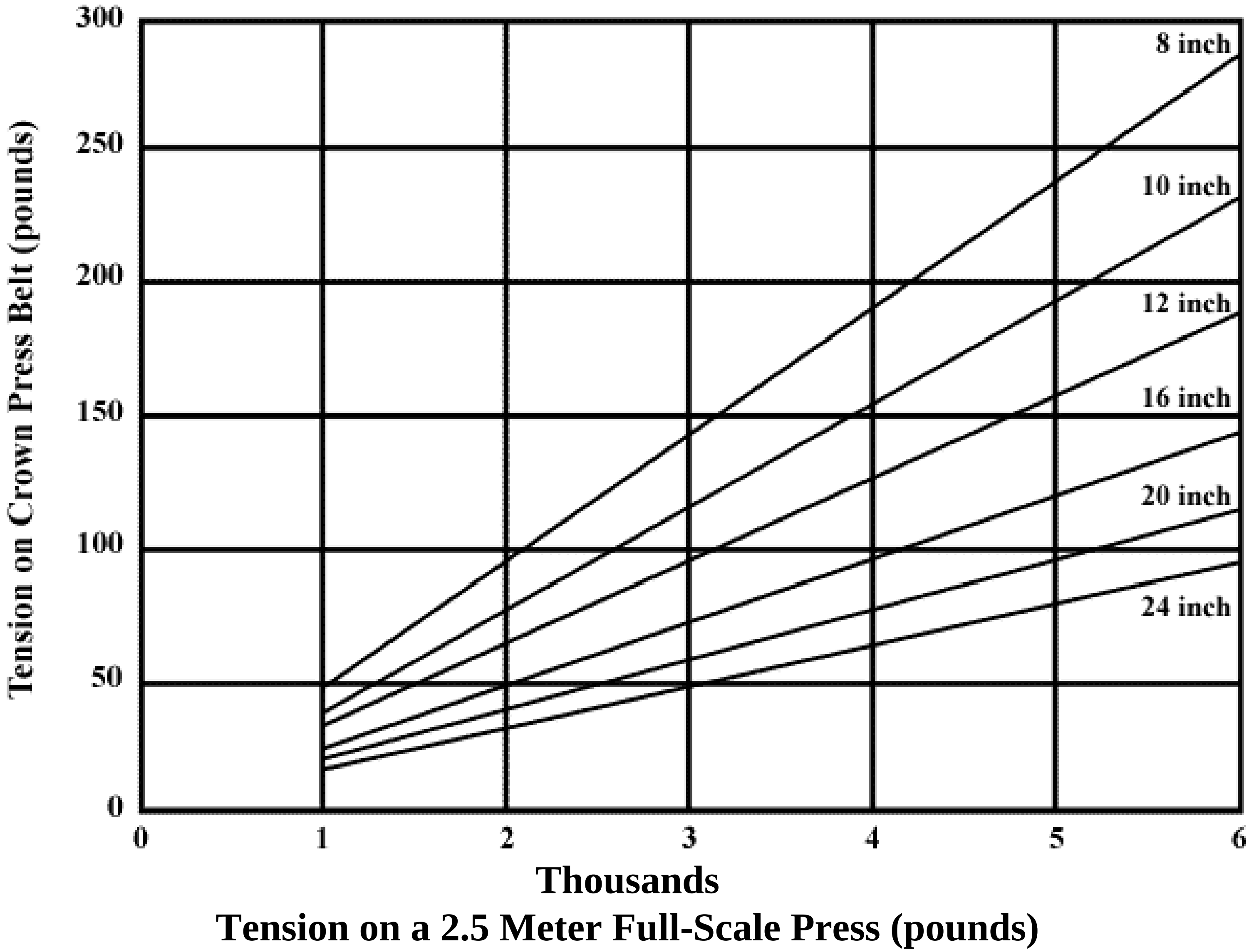


Figure 8: Tension to be pulled on the Crown Press corresponding to the tension applies on a 2.5 M full-scale belt press. Calculated for the standard 6.0 inch wide Crown Press belt and the standard 6.25 inch diameter crown.



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An Example Test Regime

Depending upon the circumstances, differing goals are set for a particular test regime. It is assumed in the following example that a full regime is required, and that the desired polymer dose, belt speed, sludge loading rate, or through-put rate are known. The regime is broken into a step-wise pattern:

1. Choose a sample size, for example 300 ml, as the base reference. Check with Tables 4, 5, 6, 7 to be sure the sample size represents a feasible belt speed and loading rate for your full-scale filter. Table 6 (for a 2.0 meter belt loaded at 80% of the width) shows that 300 ml represents a reasonable flow rate for belt speeds from 6 to 14 cm/sec. Choose one sample volume higher and one sample volume lower than the reference and check that these ranges represent reasonable loading rates and belt speeds for your press. For example, choose 200 and 400 ml as the low and high sample volumes. Judicious choices will cover the entire operating range of the full-scale press.

2. Find a range of polymer doses which give good drainage results. Use whatever method you consider best to focus in on the range. Some technicians find that a stir rod and beaker are adequate to define the first cut at the optimum range of dose. Others will a full gravity drainage test to determine the first cut range.

3. Choose one polymer dose and run a complete set of three volumes (for example, 200, 300, and 400 ml as discussed above) of sludge at a constant pounds of polymer per ton of dry sludge. This will simulate operation of the belt press at different belt speeds with constant sludge loading or different loadings at constant belt speed for presses with long wedge zones or low belt speeds. Run the complete set of gravity drainage and Crown Press tests described above. Consult Tables 9, 10 and 11 to help you determine the volume of polymer to add for each sludge volume. If the wedge zone of the press is short and the wedge contact time is low (less than 10 seconds), then the hard migration may be accentuated due to the rapid entry of sludge into the wedge zone. Choose the middle sample volume (this example, 300 ml) and rerun the tests with altered wedge times to simulate the effect of changing the belt speed.

4. Repeat step three with a second polymer dose.

5. Repeat step three with a third polymer dose. This completes a matrix for belts with a long wedge zone of three doses by three volumes for a total of nine tests.

Analysis of Data and Data Interpretation

The purpose of the testing regime described above is to obtain enough lab scale information to aid optimization of a full-scale press prior to running the full-scale press. Thus, every datum collected can be utilized, from the gravity settling tests through the belt press tests. Analysis of the data are based on water and solids balances and the scale-up of these data to a full-scale belt press.

1. For each polymer dose, plot the three sets of filtrate data as the fraction of free water remaining versus time (use the total volume of sludge minus the last filtrate volume reading as the denominator and the filtrate volume at each sample time as the numerator). If the press has plows, the excess water generated (V_E) by the plows in the tests may be apportioned back into the drained volumes. For example, if 40% of the free water drains in the first 5 seconds, then add 40% of the excess plow water to the 5 second sample volume.

2. Choose three belt speeds and calculate the drainage time ($t_G = L_G/S$) on the full-scale press corresponding to each belt speed. For each of the sample volumes, calculate the belt loading (volume/time) which corresponds to the chosen belt speed. Repeat this step several times for many belt speeds. Generate a table showing the fraction free water remaining as a function of belt speeds and loadings. In general, soft migration failure will occur if the sludge contains too much free water. Use your experience to develop an empirical limit for the process. Alternatively, you may wish to develop plots of the free water flow or the remaining sludge flow entering the pressure section which may be empirically related to process failure.

3. For each polymer dose, calculate the hard migration at the Crown Press force most close to the expected full scale pressure at the last roller for each of the three loading volumes. In general, the hard migration for a sludge will be linear with respect to the height of the cake entering the pressure section of the press. Choose an arbitrary limit of acceptable migration, such as two inches. Plot migration versus drained cake height. Extrapolate the height of cake which yields the failure condition. Back calculate the belt speed and sludge flows which correspond to the failure condition.

4. Use the sludge cake solids to determine if the press will fail any solids concentration limits.

5. Table 13 is an example report form which may be useful for summarizing the test results. The following sections give definitions of calculated parameters appearing in the summary report page.

Polymer Dose: Polymer Type: Belt Material:		Belt Speed: Drainage Time: Wedge Time:	Belt Width: Gravity Length: Wedge Length:	Customer: Sludge Concentration: Date:	
Test Volume (ml)	Belt Loading Corresponds to Speed	Free Water Loading to Pressure Zone	Pressure Zone Migration	Cake Solids	Dry Cake Throughput
Polymer Dose: Polymer Type: Belt Material:		Belt Speed: Drainage Time: Wedge Time:		Customer: Sludge Concentration: Date:	
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Test Volume (ml)	Belt Loading Corresponds to Speed	Free Water Loading to Pressure Zone	Pressure Zone Migration	Cake Solids	Dry Cake Throughput

Table 13: Example Report Summary Sheet

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Gravity Drainage Concentration Factor

The gravity drainage factor (FG) is the ratio of volumes occupied by the sludge prior to conditioning to the volume occupied at time (t) during the drainage test.

$$F_G = V_S/(V_T - V_{Gt})$$

Pressure Filtration Concentration Factor

The pressure filtration factor is the concentration of solids at applied force F due to filtration alone and excluding gravity drainage.

$$F_P = (V_T - V_{Gt})/(V_T - V_F)$$

Total Concentration Factor

The Total concentration factor is the product of the gravity drainage and the pressure extrusion concentration factors.

$$F_T = F_P \text{ X } F_G = V_S/(V_T - V_F)$$

Pressure Migration

Absolute hard migration is difference between the average cake diameter before pressing and the average cake diameter after cake pressing. The values of DA and DG may be approximated as the respective averages of the four diameters of the cake axes before and after pressing.

$$M = D_G - D_A$$

Estimation of Through-Put

Dry cake through-put is estimated from the applied flow rate of raw sludge solids and the initial sludge concentration.

$$R_S = 10 \text{ X } Q_S \text{ X } C_S$$