SEPOR, INC
718 N FRIES AVE.
WILMINGTON, CA 90744
310 830 6601
Fax: 310 830 9336
info@sepor.com

OPERATING & MAINTENANCE MANUAL

SEPOR FC BOND MILL

The F.C. Bond Ball Mill is a small universal laboratory mill used in calculating the grindability of all ores.

GRINDABILITY IS THE NUMBER OF NET GRAMS OF SCREEN UNDERSIZE PRODUCED PER REVOLUTION.

This Ball Mill can be used for units of time (hours, minutes) or it can be used for any number of revolutions, according to the type of grind desired.

THE TEST: The standard Bond test, the feed is prepared by stage crushing to pass a 6 US mesh (3.36 mm) screen. Eighty per cent (80%) of the ore to be tested should pass 6 mesh but be retained on a 14 mesh screen (-6, +14). Ore to be tested is screened on a 6 mesh sieve with a 14 mesh sieve, a 60 mesh and fines pan. It is screen analyzed and packed into a 700 cm3 graduated cylinder, and the weight of 700 cm3 is placed in the mill and ground dry at 250 % circulating load. The mill runs at 70 rpm and has a grinding charge consists of 285 iron balls, ranging in size from 5/8 inch to 1 1/2 inch in diameter, weighing 20,125 grams. It has a calculated surface area of 842 sq. inches.

Because of variations in grinding ball sizes no exact number of balls of each size can be specified. The ball charge is prepared by starting with 285 balls, consisting of approximately equal weights of various sizes available these sizes include: 5/8 inch, 3/4 inch, 1 inch, 1 1/4 inch and 1 1/2 inch, about 400 grams of each size. For every 0.002” increase in ball diameter the ball weight varies 0.40% and the ball surface area varies 0.26%. Commercial grinding balls vary by 3% to10%, and often up to 20%, when grinding media is scarce.

With 285 balls always present, some balls of one size are removed and replaced with the smaller sized balls. This is continued until the total weight is as close to 44.5 pounds as possible, making the last adjustment with the smallest size of balls. Do not remove all the balls any size. It is a good idea to keep track of the number and size of balls required to make up a 285 ball, 44.5 pound weight FC Bond Ball Mill charge, for future reference. It can be used for future tests and adjusted as required. It is apparently important to remove the same number of balls that are being replaced, while adjusting the final weight as this insures the proper balance between media weight and surface area. See pages 7 & 8 for more information on the tall charge composition.

INSTRUCTIONS

Connect starting switch to power. Instructions are found on the inside of the starter. Position the cover facing up by turning the switch to JOG (momentary contactor switch) to rotate the mill. Alternately, the user can grab the mill by the handle on the lid and manually rotate the drum into position. Remove the cover and gasket, then insert the sample and the ball charge. Replace the gasket and cover. Set the counter to the desired number of revolutions, usually 50 for coarser grinding, 100 for fine grinding. Turn the switch to RUN and press the START button. The operator can stop the mill at any time by pressing the STOP button or by turning the switch to the center position.

After the number of desired rotations count is reached, the mill will stop automatically. Turn the switch to the center position. Using the JOG switch or grabbing the mill by the handle on the lid or mill, rotate the drum until the cover is facing up. Remove the cover and gasket. Now, using the handle on the bottom of the mill, or JOG switch, slowly turn the mill 180 degrees, so the opening is facing the discharge pan. Sample and ball charge will fall into the receiving pan.

After The product is dumped, the ball charge is screened out, the 700 cm^3 of material is screened on sieves of the mesh size tested, with a coarser protecting screen of 50 US mesh (300 µ) The undersize is weighed, and fresh feed is added to the oversize to bring its weight back to that of the original charge. Then, it is returned on to the balls in the mill and ground for the number of revolutions calculated to pro- duce a 250% circulating load, dumped and re-screened. The number of revolutions required is calculated from the results of the previous period to produce sieve undersize equal to $1/3.5^{th}$ of the total charge in the mill.
The locked-cycle grinding test continues until the net grams of sieve undersize produced per mill revolution reaches equilibrium and reverses its direction of increase or decrease. Then the undersize product and circulating load are screen analyzed, and the average of the last three net grams per revolution (Gbp) is the ball mill grindability. The ball mill work index, Wi (kWh/short ton) is calculated from the following equation (Bond 1961):[1]

$$W_i = \frac{44.5}{P_1^{0.23} x Gbp^{0.82} x \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}} \right)} \qquad \text{[Eq. 1]}$$

The mill should be cleaned by either blowing air into it or wiping the interior with a cloth and or brush.

The FC Bond ball mill is now ready for the next sample.

[1]REPRODUCIBILITY OF BOND WORK INDEX WITH DIFFERENT STANDARD BALL MILLS, E. Kaya and P. C. Fletcher, Phelps Dodge Mining Co and P. Thompson Dawson Metallurgical Lab, Inc.

FC BOND LAB TEST PROCEDURES

1. Crush ore to be tested to -6 mesh. Eighty per cent (80%) of the ore to be tested should pass 6 mesh but be retained on a 14 mesh screen (-6, +14). Ore to be tested is screened on a 6 mesh sieve with a 14 mesh sieve, a 60 mesh and fines pan. The minus 14 mesh ore should be screened and weighed to know the particle size distribution of the feed in the –14 mesh material. The test volume is 700 ml or cc's.

2. To determine the approximate weight of the 700 cc grinding test, take a 1000 cc graduated, clear cylinder, and place the retained 14 mesh particles into the cylinder, shaking the cylinder to compact the ore, and adding more until the ore compacts at 700 cc in volume. Weigh this volume (@ 2.6 g/cc this would weigh 1,820 grams) and record the weight.

3. Sample splitters may be used to split numerous increments of the feed, and each increment poured into the cylinder until the 700 cc volume is obtained.

4. The Ideal Period Product (IPP) is equal to the weight of the 700 cc sample in grams, divided by 3.5.

5. Conduct a screen analysis and record the weights of each size fraction of the 700 cc feed test sample.

6. Place the FC Bond Ball charge in the mill.

7. Place the feed sample in the mill.

8. Set the mill revolution counter for a specific number of revolutions for the first test. (Typically 50 for coarse or 100 for fine grinding). Push the mill start button. When the number of revolutions has been reached, the mill will shut off.

9. Empty the mill, through a screen to retain the grinding balls. Return the balls to the mill. Perform a screen analysis on the material and weigh each size fraction. Record the data.

10. Perform a screen analysis on the material and weigh each size fraction. Calculate the weight of the under size ((-106 microns (140 mesh screen) or the size fraction being reduced to in microns).

11. Determine the amount of undersize product present in test feed (if any).

12. Calculate the number of net grams produced per revolution, by dividing the undersize weight (in grams) by the number of revolutions the mill rotated.

13. Calculate the number of net grams produced per revolution, by dividing the undersize weight (in grams) by the number of revolutions the mill rotated.

14. Calculate the weight which should be ground in the next test in order to obtain the desired circulating load. This amount is the IPP minus the amount of product size material present in the feed. I.E., if the 700 cc sample were 1,820 grams the IPP, and the product were to be 106 microns, the feed was all between 6 mesh and 14 mesh, no product size material was in the feed, the weight would be (1,820/3.5 = 520 grams). This is the amount that it is desired to grind in the next test to the product size, in the example the product size is 106 microns.

15. Therefore, to determine the number of revolutions to set the counter for, for the next test, divide the number above (desired circulating load) (520 grams) by the number of grams produced per revolution. (In the example the mill ran for 100 revolutions, the undersize was 1260 grams, so 1260/100 = 12.6) Therefore, in the example 520/12.6= 41 revolutions.

16. Set the revolution counter to the number achieved in step no. 15.

Add new representative feed to replace the ground product size material (in the example 1,260 grams were ground in the first test, so 1,260 grams of feed would be added for the second test).

Again, place the grinding balls in the mill and start.

Repeat for at least 5 tests, recording the data each time. The grams per revolution value should vary a little, but should approach an equilibrium value. A plot of net grams per revolution vs. period number (test number) should show a upward or downward trend, and finally a reversal of the trend on the 5th test. If no reversal is seen, continue the testing until no significant change occurs in the net grams per revolution. Average the data of the last two or last three, or in a few instances, the last four tests and calculate the corresponding percentage circulating load and net grams per revolution.

The Bond Equation

$$W = \frac{10\ Wi}{\sqrt{P}} - \frac{10\ Wi}{\sqrt{F}}$$

Where:

W = Kilowatt Hours per Ton
Wi = Work Index
P = 80% passing size in microns in the product
F = 80% passing size in microns in the feed

The new Bond Work Equation:

$Wi = (44.5/(P_1)^{0.23} \times (G_{bp})^{0.82} \times (10/(P)^{0.5} - (10/(F^{0.5})))$

The value for G can be obtained by interpolating from the tables identified as Table II in the Bp

The F value, size in microns that 80% of the feed passes is recorded from screen tests, statistically with cumulative totals, and interpolation, or by plotting per cent of total weight vs screen size in microns.

The P value is from the grinding test, screen results with 80% or the ground sample passing the micron size screen.

So, if 80% passes through a 100 mesh screen, the P value is 150 (100 mesh = 150μ). Gb can be found from interpolating from TABLE II.

Table 1 is on Page 9 of this manual, while Table 2 is on page 10.

Actual FC Bond Mill Charge Weight versus the FC Bond Weight as prescribed by Fred Bond — Theory Meets Manufacturing Reality

1. Due to the varying tolerance in manufacturing of grinding balls, a fraction of an inch in diameter variance on a grinding ball will make a difference on the total weight of the grinding charge. This was addressed by Fred Bond in response to queries made as to his specified charge not meeting his own criteria, assuming they were spherical. Since it was (and is) very difficult to obtain exactly the correct weight with the specified number and size of grinding balls, it was decided that the number of balls, the total specific area of the grinding charge and the total weight of the grinding charge should be kept the same, but that these factors should be arrived at by substituting grinding balls of lesser weight and size until the 44.5 pound, 842 square inch total area charge is achieved with 285 grinding balls.

2. Extra grinding balls are supposed to be furnished with each ball charge, for this purpose of substitution, to achieve the desired weight.

The density of steel is 0.2834722 Lbs/Cubic Inch.

On the next page the tables compare steel spheres (perfectly machined steel, +/- 0.001”), to grinding balls being +/- a few percent of the specified diameter. Acknowledging reality of imperfect grinding balls, the Bond equation was modified to maintain the number of balls, 285, and substitute 5/8” balls until the 44.5 pound ball charge weight was obtained with 285 balls.

The two tables (A & B) on the next page show how it was done using a as received ball charge, with 40 extra 5/8” balls, to use for substitution.

Ball Dia (In)	Specified # of Balls	Ball Weight, Each, (Lb)	Ball Surface Area (In2)	Total Weight (Lbs)	Total Surface Area (In2)
1 1/2"	43	**0.5009**	**7.0686**	21.54026	303.9488
1 1/4"	67	**0.289894**	**4.9087344**	19.42288	328.8852
1"	10	**0.148426**	**3.14159**	1.484256	31.4159
3/4"	71	**0.062617**	**1.7671444**	4.44581	125.4673
5/8"	94	**0.036237**	**1.2271836**	3.406251	115.3553
Specified Totals by FC Bond				**44.5**	**842**
TOTAL	285			50.29945	905.0724

TABLE A. The above is FC Bonds Original Ball Specifications. It does not meet his requirement for total weight or area.

Sphere area = $4 \cdot \pi \cdot r^2$ Volume of sphere = $(4/3) \cdot \pi \cdot r^3$ Density of steel = 0.2834722 lbs/In^3

Ball Dia (In)	Specified # of Balls	Ball Weight, Each, (Lb)	Ball Surface Area (In2)	Total Weight (Lbs)	Total Surface Area (In2)
1 1/2"	41	**0.5009**	**7.0686**	20.538388	289.8117
1 1/4"	50	**0.289894**	**4.9087344**	14.494685	245.4367
1"	6	**0.148426**	**3.14159**	0.8905534	18.84954
3/4"	68	**0.062617**	**1.7671444**	4.2579586	120.1658
5/8"	120	**0.036237**	**1.2271836**	4.3484054	147.262
Specified Totals by FC Bond				**44.5**	**842**
TOTAL	285			44.529991	821.5258

TABLE B. The above table is based on substituting smaller balls for larger ones to achieve apx. 44.5 lbs weight, and apx. 842 SqIn total surface area

Fred Bond specified a grinding charge as itemized in Table 1, above. He essentially described the importance of there being 44.5 Lbs. Grinding charge, and 842 square inches of specific area for the total ball charge, and 285 steel balls, in the following diameters 1.5”, 1.25”, 1”, 3/4” and 5/8”.1 As can be seen in table one, the charge Mr. Bond originally used varied in diameters, but maintained the specific surface area and weight. This was most probably due to the tolerance in the steel grinding balls, and what was accepted for a 1.5” grinding ball, etc..

[1] Reproducibility of Bond Work Index With Different Standard Ball Mills, E. Kaya, P Fletcher, P. Thompson

Table 1

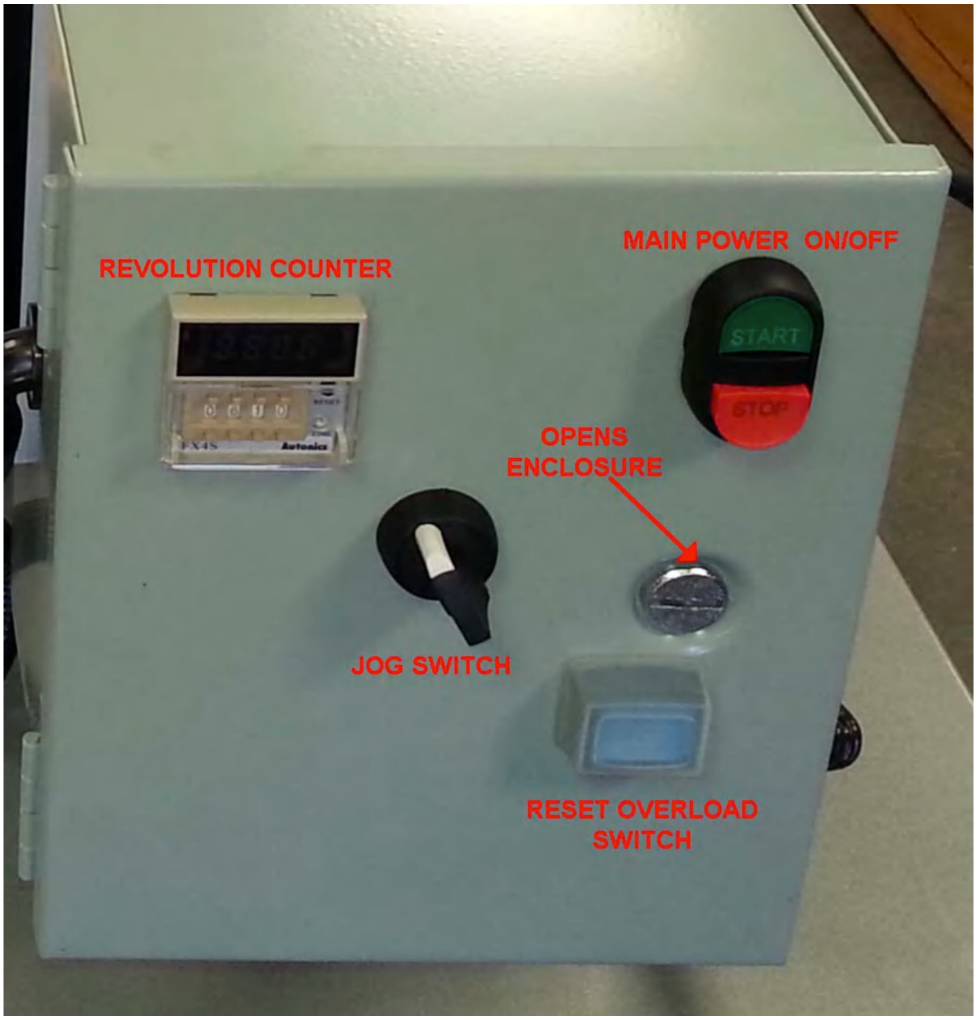
Ore No. (P)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
At 48 mesh P_o	252	242	237	242	233	226	233	234
Erf	.587	.500	.431	.540	.430	.294	.236	.383
Erp	.230	.271	.275	.212	.264	.248	.252	.288
Crp	26.3	28.7	29.0	26.0	28.7	28.3	28.2	29.5
Crf	18.7	16.7	16.0	17.0	15.0	12.7	11.1	14.5
Y (% on 48)	69.9	74.7	64.2	77.0	77.7	84.0	78.3	74.2
Wi_o (Test)	12.0	10.6	9.8	10.9	9.9	16.8	16.6	12.1
K (Eq. 7)	119.0	75.7	51.2	109.8	68.0	118.1	92.2	70.0
Wi_{100}	14.71	11.60	10.35	13.40	10.54	16.02	15.95	12.18
28 Mesh (453)								
Y (% on 28)	52.4	62.5	53.2	65.5	68.3	73.1	67.8	62.3
Crp	20.7	22.4	22.3	20.0	21.9	21.3	20.9	22.9
Wi_o (Test)	7.2	9.3	9.3	(12.0)	10.2	17.4	17.0	11.4
Wi (Eq. 7)	6.79	9.05	8.97	6.52	8.62	16.63	16.81	12.60
Wi (Eq. 8)	8.44	9.01	8.94	7.18	8.62	17.10	17.70	11.97
Wi_{100}	13.85	10.76	12.09	15.34	12.24	15.95	15.04	11.18
35 Mesh (323)								
Y (% on 35)	60.5	69.6	59.4	71.7	73.5	79.5	73.9	69.1
Crp	23.7	25.6	25.4	23.0	25.0	24.4	24.0	26.0
Wi_o (Test)	10.1	10.1	10.7	10.6	10.3	17.1	16.7	12.5
Wi (Eq. 7)	11.35	10.19	9.47	9.51	9.38	16.71	16.35	12.30
Wi (Eq. 8)	10.74	9.96	9.46	9.47	9.38	16.93	17.05	12.05
Wi_{100}	15.86	11.56	12.03	13.72	10.86	16.50	15.28	12.27
65 Mesh (161)								
Y (% on 65)	78.3	79.0	68.6	81.5	81.6	87.9	82.2	78.6
Crp	31.5	34.0	33.5	30.5	33.2	32.1	31.7	34.6
Wi_o (Test)	14.8	10.7	10.9	11.8	10.7	14.9	16.2	11.4
Wi (Eq. 7)	13.30	11.30	9.80	12.02	10.05	16.41	15.36	12.23
Wi (Eq. 8)	13.61	11.24	10.10	12.33	10.32	16.72	16.23	12.14
Wi_{100}	15.83	11.19	11.32	13.00	10.90	14.84	15.92	11.66
100 Mesh (114)								
Y (% on 100)	84.0	82.2	72.4	85.2	85.0	90.5	84.4	82.3
Crp	36.5	39.1	38.9	35.5	38.3	37.3	36.9	39.8
Wi_o (Test)	16.0	11.7	12.4	13.0	11.0	15.8	15.4	12.0
Wi (Eq. 7)	13.75	11.42	9.88	12.81	10.11	16.68	15.33	11.85
Wi (Eq. 8)	14.44	11.61	10.29	13.15	10.59	16.66	16.00	12.17
Wi_{100}	16.17	12.11	12.48	13.20	11.03	15.79	15.45	12.06
Averages								
Wi_o Test	12.02	10.48	10.62	11.66	10.42	16.40	16.38	11.88
Wi (Eq. 7)	11.43	10.51	9.58	10.47	9.61	16.65	16.09	12.22
Wi (Eq. 8)	11.85	10.48	9.72	10.61	9.76	16.84	16.72	12.09
Wi_{100}	15.28	11.44	11.65	13.73	11.11	15.94	15.53	11.87

Table 2

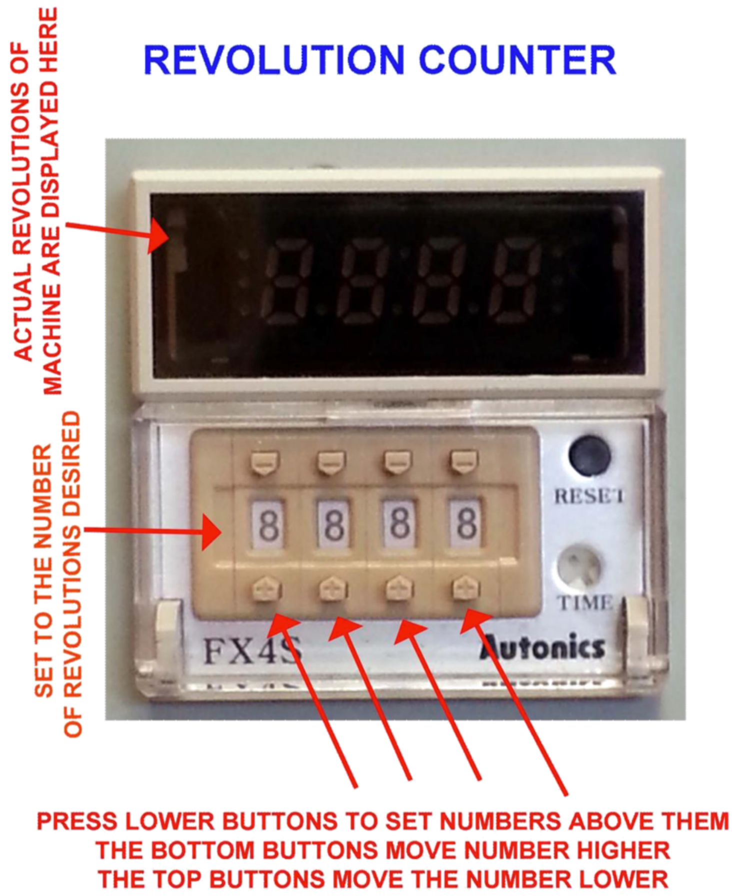
Ore No. (P)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	Average
At 48 Mesh P	240	240	232	225	220	237	237	235.3
Erf	.260	.246	.253	.360	.208	.174	.248	.315
Erp	.200	.239	.273	.335	.320	.308	.238	.262
Crp	25.3	27.3	29.0	32.0	31.9	30.4	27.1	28.51
Y (% on 48)	73.2	81.1	75.1	77.6	83.6	86.8	78.7	77.09
Wi_o (Test)	15.2	15.0	10.7	13.5	19.8	13.4	14.8	13.41
K (Eq. 7)	97.3	93.4	55.8	70.5	99.3	69.4	87.8	85.0
Wi_{100}	15.23	14.52	10.04	13.13	18.85	12.02	14.34	13.53
28 Mesh (453)								
Y (% on 28)	62.7	71.5	63.8	67.9	74.5	80.6	69.0	66.34
Crp	19.5	21.0	22.3	24.4	24.1	23.5	20.9	21.9
Wi_o (Test)	16.6	16.9	13.9	16.0	23.5	15.0	17.6	14.22
Wi (Eq. 7)	15.09	15.60	11.92	14.10	22.40	14.42	15.60	13.00
Wi (Eq. 8)	15.20	15.77	12.20	14.18	21.87	15.58	15.56	13.67
Wi_{100}	15.86	15.15	11.30	15.02	20.30	11.15	15.40	14.06
35 Mesh (323)								
Y (% on 35)	68.5	76.2	70.4	73.4	79.9	84.3	74.6	72.30
Crp	22.3	24.1	25.4	27.8	27.3	27.0	24.0	25.0
Wi_o (Test)	16.8	15.2	11.5	14.4	21.7	14.7	15.9	13.89
Wi (Eq. 7)	15.25	15.70	11.11	13.72	20.70	13.85	15.31	13.40
Wi (Eq. 8)	15.20	15.30	11.15	13.80	20.72	14.26	15.10	13.52
Wi_{100}	16.37	14.18	9.96	13.40	19.72	12.30	14.50	13.90
65 Mesh (161)								
Y (% on 65)	77.4	-----	79.2	80.8	86.4	89.0	82.2	80.91
Crp	29.8	-----	33.6-	36.8	36.2	35.9	31.7	33.1
Wi_o (Test)	15.4	-----	10.6	12.5	19.1	12.4	13.2	13.19
Wi (Eq. 7)	15.29	-----	10.42	13.45	19.20	13.33	14.80	13.33
Wi (Eq. 8)	15.20	14.62	10.35	13.18	19.28	12.64	14.53	13.32
Wi_{100}	15.25	-----	10.04	12.32	18.67	11.83	13.20	13.28
100 Mesh (114)								
Y (% on 100)	-----	88.3	82.9	83.0	-----	90.9	84.9	84.31
Crp	-----	37.0	39.0	42.1	-----	41.0	36.9	38.2
Wi_o (Test)	-----	16.4	10.7	12.0	-----	12.3	13.0	13.21
Wi_o (Eq. 7)	-----	14.40	10.05	13.28	-----	12.87	14.51	12.85
Wi (Eq. 8)	15.20	14.55	10.11	12.80	18.86	12.16	14.37	13.26
Wi_{100}	-----	16.28	10.61	12.04	-----	12.17	12.94	13.26
Averages								
Wi_o (Test)	16.00	15.88	11.48	13.68	21.02	13.56	14.90	13.59
Wi (Eq. 7)	15.21	15.18	10.84	13.61	20.53	13.57	15.00	13.30
Wi (Eq. 8)	15.20	15.05	10.90	13.49	20.10	13.61	14.87	13.44
Wi_{100}	15.68	15.03	10.39	13.18	19.39	11.89	14.04	13.75

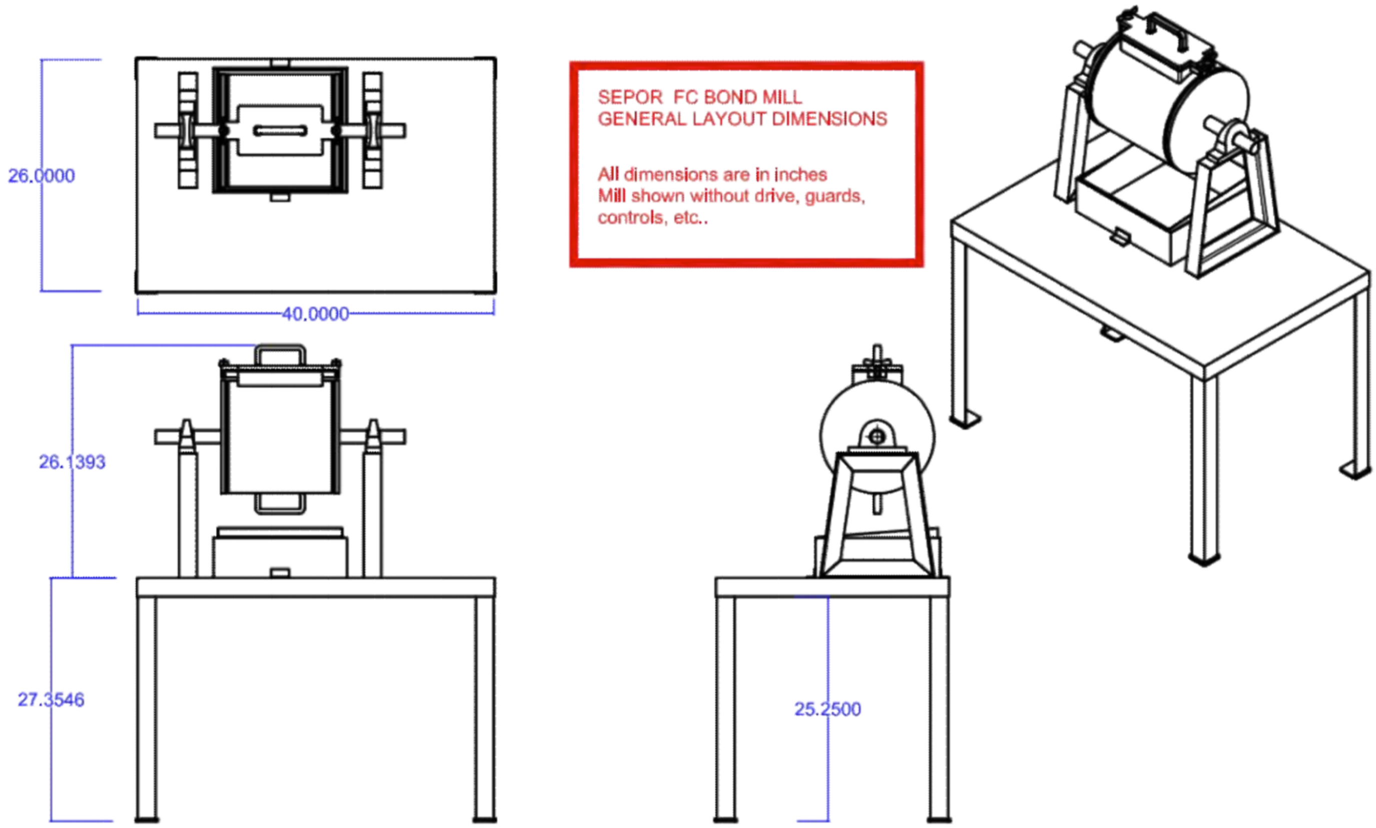
The control panel, pictured below, is simple, easy to operate, and virtually self explanatory. To operate, first, using the buttons on the revolution counter, as explained on the previous page, set the desired number of revolutions. Then make certain that the material to be tested and the ball charge is in the machine, the cover in on and secured, and everything is clear from the revolving path of the mill. Then, press the “Start” button, and the mill will begin to run, and will continue to run until the number of revolutions set is reached. To empty the mill, use the “Jog” switch by turning it to the right until the mill is in the desired position, then turn the switch back to the position shown (Left). With the discharge pan beneath the mill, remove the top and the balls and material will fall into the pan. The “Jog” switch can be used to “bump” the mill several times, dislodging any stuck material. A brush can be used to completely empty the mill.

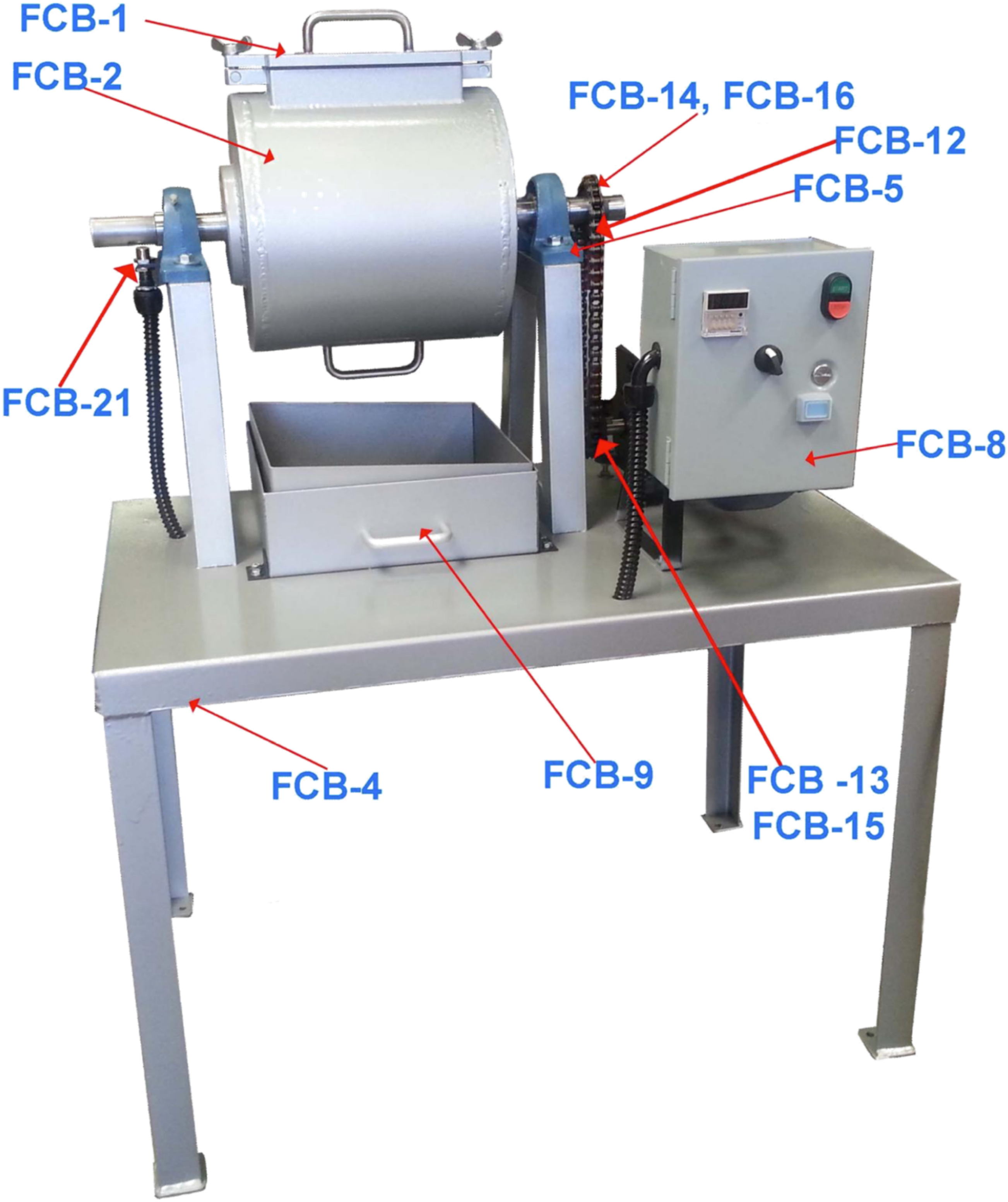
In the event the mill overloads, the overload circuit will disconnect power to the mill. The “Reset” button, below, has a blue color, and will reset the power by simply pushing it. The enclosure may be opened by inserting a flat blade screwdriver into the slot and turning until it releases.



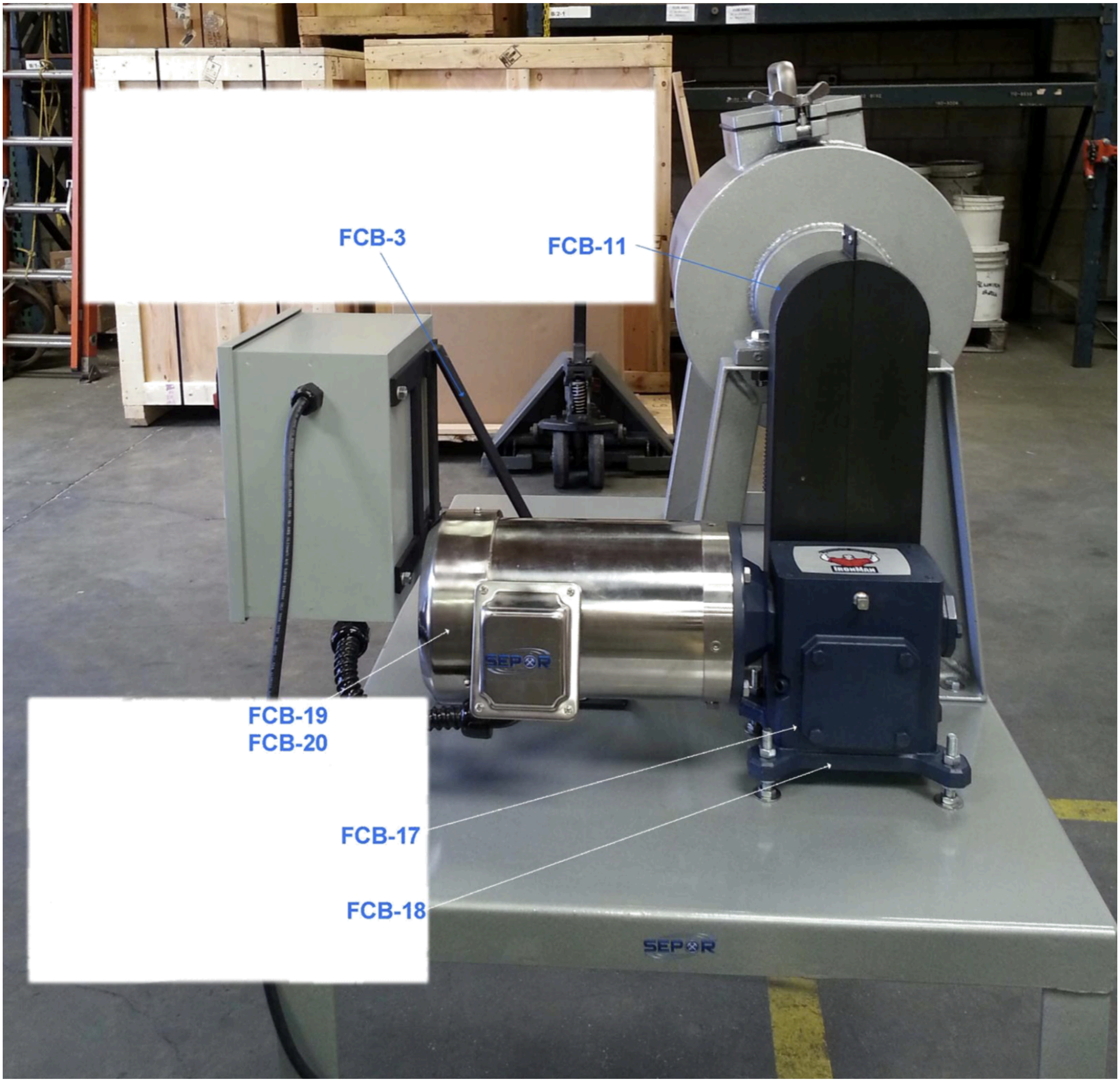
To set the revolution counter, refer to the photo below. By pushing the bottom row buttons, the counter number is increased. Pushing the top row of buttons decreases the counter number. The actual revolutions is displayed in the digital led display. Then the digital display reached the number input below, the mill shuts off.




SEPOR FC BOND MILL
GENERAL LAYOUT DIMENSIONS
All dimensions are in inches
Mill shown without drive, guards,
controls, etc..
26.0000
40.0000
26.1393
27.3546
25.2500

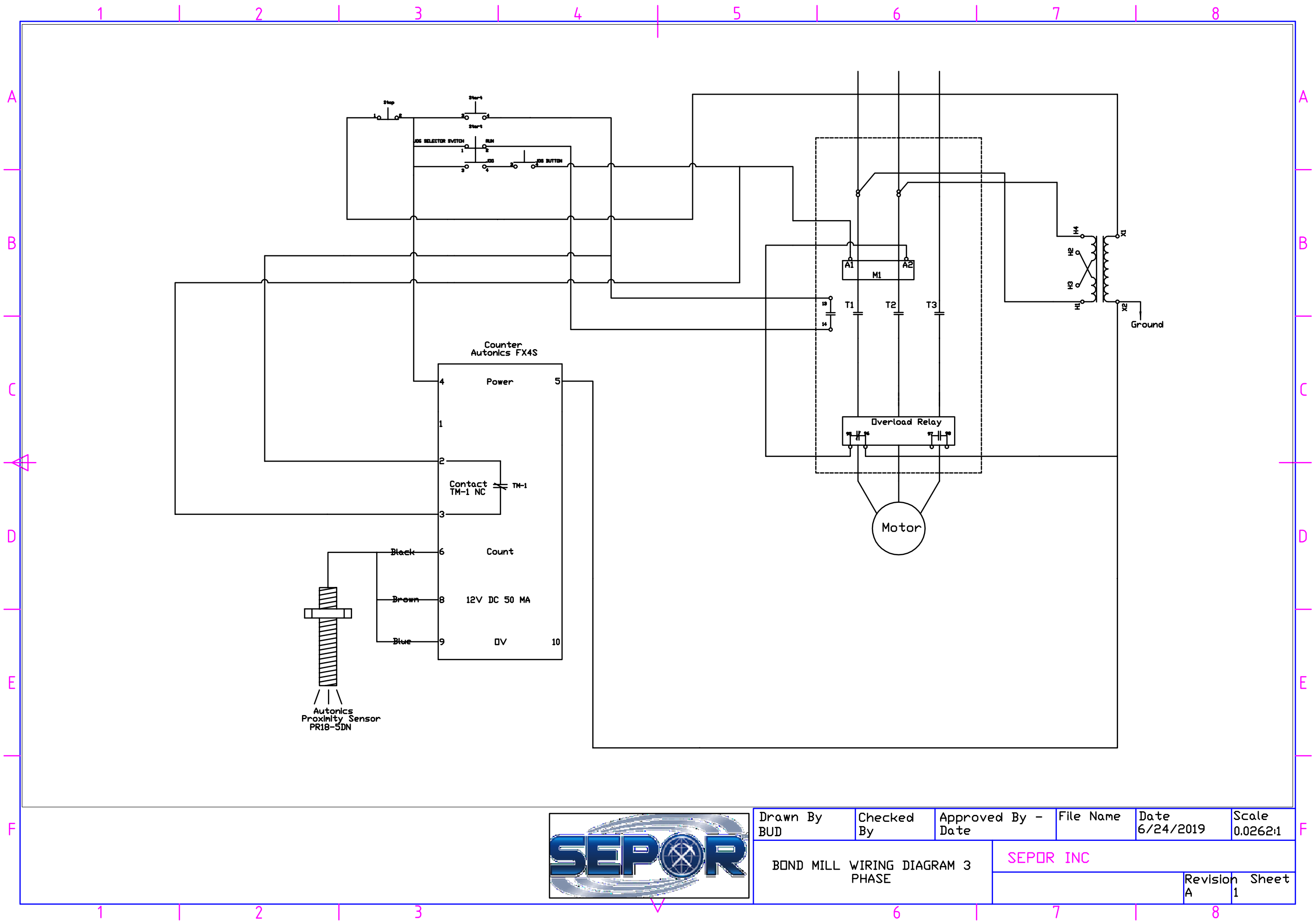


Spare Parts Diagram, 1 of 2



Spare Parts Diagram, 2 of 2

See following page for Spare Parts List


Stop
Start
RUN
JOG
Counter
Autonics FX4S
Power
Contact
TM-1 NC
TM-1
Count
12V DC 50 MA
0V
Black
Brown
Blue
Autonics
Proximity Sensor
PR18-5DN
A1
A2
M1
T1
T2
T3
Overload Relay
Motor
Ground
Drawn By
BUD
Checked By
Approved By - Date
File Name
Date
6/24/2019
Scale
0.0262:1
BOND MILL WIRING DIAGRAM 3 PHASE
SEPOR INC
Revision
A
Sheet
1

FC BOND MILL, 60HZ • 010E-124

ITEM ID	DESCRIPTION	QTY
010E-T001	FC Bond Mill Cylinder	1
010E-T002	Table Assembly For Bond Mill	1
010E-T004	Chain Guard F.C. Bond Mill	1
010E-T005	Mounting Bracket F.C. Bond Mil	1
010E-C125	F.C. Bond Mill Controller Box	1
810ST126	Sensing M18 NPN 8mm 3 Wire	1
810ST173	Counter Timer 1/16 DIN 4 Digit	1
MO-191564	1hp 208-230/460V 1725 RPM 56C	1
GR-BMQ82125L56	Gearbox GRL-BMQ821-25-L-56	1
741ST107	Roller Chain ANSI #50-5/8" Pit	3
784ST168	1-7/16" Pillow Block UCP207-23	2
784ST292	Sprocket #50BS15 1-7/16" Bore	1
784ST291	Sprocket #50BS15 7/8" Bore	1

FC BOND MILL, 50HZ • 010E-126

ITEM ID	DESCRIPTION	QTY
010E-T001	FC Bond Mill Cylinder	1
010E-T002	Table Assembly For Bond Mill	1
010E-T004	Chain Guard F.C. Bond Mill	1
010E-T005	Mounting Bracket F.C. Bond Mil	1
010E-C125	F.C. Bond Mill Controller Box	1
810ST126	Sensing M18 NPN 8mm 3 Wire	1
810ST173	Counter Timer 1/16 DIN 4 Digit	1
MO-114638	1hp 208-230/460V 1725 RPM 56C	1
GR-BMQ82125L56	Gearbox GRL-BMQ821-25-L-56	1
741ST107	Roller Chain ANSI #50-5/8" Pit	3
784ST155	1-7/16" Pillow Block UCPX07-23	2
784ST292	Sprocket #50BS15 1-7/16" Bore	1
784ST295	Sprocket #50BS15 1" Bore	1