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APPENDIXES

Appendix A

Process Flowcharts And String Diagrams for the 10 products

Table 1A - Process Flowchart for Compression Screw, batch of 100

Step		Description	Time [min]	Distance [m]
1		Move from stock to lathe, LC4	0.57	33
2		Machine setup (once only)	70.00	
3		Lathe work	700.00	
4		Inspect (done during machining)	50.00	
5		Move to hydraulic pump H2	0.42	24
6		Pump - hexagon pattern	150.00	
7		Move to polishing dept	0.67	39
8		Polish/clean	18.00	
9		Move to QC	0.45	26
10		QC	400.00	
11		Move to outbound storage	0.42	24
12		wait for transport	2days	
13		Send to laser and wait	2.5days	
14		move from office to polishing dept	0.78	45
15		Boil	3.00	
16		Move to storage	0.98	57
		Total	1385.28	248

Table 2A - Process Flowchart for Cortical Screw, batch of 100

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	Move from stock to lathe, LC2	0.50	29
2	○ ⇨ □ ◗ ▽	Machine setup (once per batch)	70.00	
3	● ⇨ □ D ▽	Lathe work	600.00	
4	○ ⇨ ■ D ▽	Inspect (done during machining)	58.33	
5	○ ➡ □ D ▽	Move to hydraulic pump, H2	0.33	19
6	● ⇨ □ D ▽	Pump - hexagon pattern	150.00	
7	○ ➡ □ D ▽	Move to polishing dept	0.67	39
8	● ⇨ □ D ▽	Polish/clean	18.00	
9	○ ➡ □ D ▽	Move to QC	0.45	26
10	○ ⇨ ■ D ▽	QC	600.00	
11	○ ➡ □ D ▽	Move to outbound storage	0.42	24
12	○ ⇨ □ D ▼	wait for transport	2days	
13	○ ⇨ □ ◗ ▽	Send to laser and wait	2.5days	
14	○ ➡ □ D ▽	move from office to polishing dept	0.78	45
15	● ⇨ □ D ▽	Boil	3.00	
16	○ ➡ □ D ▽	Move to storage	0.98	57
		Total	1493.47	239

Table 3A - Process Flowchart for Pedicles Screw (part 1 of 2 – screw body), batch of 100

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	Move from stock to lathe, LC5	0.52	30
2	○ ⇨ □ ◗ ▽	Machine setup (once per batch)	70.00	
3	● ⇨ □ D ▽	Lathe work	2200.00	
4	○ ⇨ ■ D ▽	Inspect (done during machining)	50.00	
5	○ ➡ □ D ▽	Move to milling centre, MC6	0.37	21
6	○ ⇨ □ ◗ ▽	Machine setup (once per batch)	60.00	
7	● ⇨ □ D ▽	Milling work	1000.00	
8	○ ⇨ ■ D ▽	Inspect (done during machining)	66.67	
9	○ ➡ □ D ▽	Move to manual milling machine	0.55	32
10	○ ⇨ □ ◗ ▽	Machine setup (once per batch)	30.00	
11	● ⇨ □ D ▽	Milling work	500.00	
12	○ ➡ □ D ▽	Move to polishing dept	0.63	37
13	● ⇨ □ D ▽	Polishing/clean	18.00	
14	○ ➡ □ D ▽	Move to QC	0.45	26
15	○ ⇨ ■ D ▽	QC	600.00	
16	○ ➡ □ D ▽	Move to outbound storage	0.42	24
17	○ ⇨ □ D ▼	Wait for transport	2days	
18	○ ⇨ □ ◗ ▽	Send to laser and wait	2.5days	
19	○ ➡ □ D ▽	move from office to polishing dept	0.78	45
20	● ⇨ □ D ▽	Boil/clean	5.00	
21	○ ➡ □ D ▽	Move to storage	0.98	57
		Total	4594.37	272

Table 4A - Process Flowchart for Poly Screw (part 1 of 3 – screw body), batch of 100

Step		Description	Time [min]	Distance [m]
1		Move from stock to lathe, LC7	0.47	27
2		Latch setup (once per batch)	70.00	
3		Lathe work - threading	1000.00	
4		Inspect (done during machining)	75.00	
5		Move to hydraulic pump, H2	0.58	34
6		Pump hexagon pattern	100.00	
7		Move to manual milling centre	0.42	14
8		Machine setup	30.00	
9		Milling work	600.00	
10		Move to polishing dept	0.58	34
11		Polish	25.00	
12		Move to QC	0.45	26
13		QC	700.00	
14		Move to outbound storage	0.42	24
15		Wait for transport	2days	
16		Send and Laser and wait	2.5days	
17		move from office to H1	1.25	72
18		Assemble, hydraulic pump H1	500.00	
19		Move to boiler	0.70	40
20		Boil	5.00	
21		Move to storage	0.98	57
		Total	3100.85	328

Table 5A - Process Flowchart for Poly Screw (part 2 of 3 – U head), batch of 100

Step		Description	Time [min]	Distance [m]
1		Move from stock to lathe, LC5	0.52	30
2		Lathe setup (once per batch)	70.00	
3		Lathe work	700.00	
4		Inspect (done during machining)	50.00	
5		Move to milling centre, MC6	0.38	22
6		Machine setup (once per batch)	30.00	
7		Milling work	1100.00	
8		Inspect (done during machining)	66.67	
9		Move to polishing dept	0.13	8
10		Polish	5.00	
11		Move to QC	0.45	26
12		QC	600.00	
13		Move to outbound storage	0.42	24
14		Wait for transport	2days	
15		Send and Laser and wait	2.5days	
16		move from office to H1	1.25	72
17		Assemble - See sheet 1/3		
		Total	2639.82	182

Table 6A - Process Flowchart for Set screw (part 2 of 2 for Pedicle screw and part 3of 3 for Poly screw), batch of 100

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	Move from stock to lathe, LC6	0.57	33
2	○ ⇨ □ ◗ ▽	machine setup (once per batch)	55.00	
3	● ⇨ □ D ▽	Lathe work	600.00	
4	○ ⇨ ■ D ▽	Inspect (done during machining)	50.00	
5	○ ➡ □ D ▽	Move to hydraulic pump, H2	0.42	24
6	● ⇨ □ D ▽	Pump - hexagon pattern	100.00	
7	○ ⇨ ■ D ▽	Inspect	33.33	
8	○ ➡ □ D ▽	Move to polishing dept	0.68	39
9	● ⇨ □ D ▽	Polish	5.00	
10	○ ➡ □ D ▽	Move to QC	0.45	26
11	○ ⇨ ■ D ▽	QC	600.00	
12	○ ➡ □ D ▽	Move to storage	0.55	32
		Total	1436.00	154

Table 7A - Process Flowchart for Bone Plate 8H, batch of 65

Step		Description	Time [min]	Distance [m]
1		move from stock to milling centre, mc1	0.53	31
2		Machine set up (once per batch)	65.00	
3		milling work	585.00	
4		inspect (done during machining)	32.50	
5		move to polishing dept	0.60	15
6		Polishing and cleaning	21.00	
7		move to QC	0.45	26
8		QC	390.00	
9		move to outbound storage	0.42	24
10		wait for transport	2days	
11		send to laser and wait	2.5days	
12		move from office to polishing dept	0.78	45
13		boil	3.00	
14		move to storage	1.00	57
		TOTAL	1090.28	198

Table 8A - Process Flowchart for Y Plates, batch of 65

Step		Description	Time [min]	Distance [m]
1		Move from stock to bender, hydraulic pump H3	0.28	16
2		Bend	195.00	
3		Move to milling centre, MC5	0.13	7
4		Machine setup (once per batch)	70.00	
5		Milling work	1105.00	
6		Pre check	3.00	
7		Move to polishing dept	0.35	20
8		Polish	15.00	
9		Move to QC	0.45	26
10		QC	325.00	
11		Move to outbound storage	0.42	24
12		Wait for transport	2days	
13		Send to Laser and wait	2.5days	
14		move from office to polishing dept	0.78	45
15		Boil	3.00	
16		Move to storage	0.98	57
		Total	1709.400	195

Table 9A - Process Flowchart for Compression Pliers, batch of 10

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	move casting from office to manual lathe	1.03	60
2	○ ⇨ □ ◗ ▽	Lathe setup (once only)	90.00	
3	● ⇨ □ D ▽	Find pliers centre	35.00	
4	○ ➡ □ D ▽	Move to manual milling centre	0.13	8
5	○ ⇨ □ ◗ ▽	Machine setup (once only)	30.00	
6	● ⇨ □ D ▽	Mill pliers body	4500.00	
7	● ⇨ □ D ▽	Mill pliers base	1800.00	
8	○ ➡ □ D ▽	Move to manual lathe	0.13	8
9	● ⇨ □ D ▽	Lathe work	300.00	
10	○ ➡ □ D ▽	Move to assembly	0.27	15
11	● ⇨ □ D ▽	Assemble	550.00	
12	○ ⇨ ■ D ▽	testing	450.00	
13	○ ➡ □ D ▽	Move to polishing dept	0.47	27
14	● ⇨ □ D ▽	Polishing	300.00	
15	○ ➡ □ D ▽	Move to QC	0.45	26
16	○ ⇨ ■ D ▽	QC	50.00	
17	○ ➡ □ D ▽	Move to storage	0.98	57
		Total	8108.47	201

Table 10A - Process Flowchart for Spine Cage, batch of 20

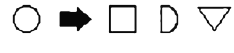
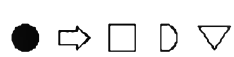
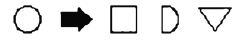
Step		Description	Time [min]	Distance [m]
1		Move from stock to manual lathe	0.97	56
2		Lathe setup (once per batch)	30.00	
3		Lathe work	160.00	
4		Move to manual milling centre	0.13	8
5		Machine setup (once per batch)	35.00	
6		Milling work	3500.00	
7		Move to sand blaster	0.38	22
8		Sand blast	40.00	
9		Move to polishing dept	0.28	16
10		Cleaning (batch)	15.00	
11		Move to QC	0.45	26
12		QC	120.00	
13		Move to storage	0.55	32
		Total	3902.77	160

Table 11A - Process Flowchart for Inner Hex Holder (part 1of 2 – Shaft), batch of 10

Step		Description	Time [min]	Distance [m]
1		Move from stock to manual lathe	0.47	56
2		Latch setup (once per batch)	35.00	
3		Lathe work	135.00	
4		Move to outward storage	1.07	62
5		Wait for outgoing transport	1.5days	
6		Send to hardener and wait	3days	
7		move from office to polishing dept	0.78	45
8		Polish	8.00	
9		Move to manual milling centre	0.58	34
10		machine setup (once per batch)	30.00	
11		Milling work	170.00	
12		Move to outbound storage	1.00	58
8		Wait for transport	1.5days	
13		Send to wire-cutter and wait	8days	
14		move from office to assembly	0.95	55
15		Assemble	60.00	
16		Move to QC	0.62	36
17		QC	40.00	
18		Move to storage	0.55	32
		Total	484.02	378

Table 12A - Process Flowchart for Inner Hex Holder (part 2 of 2 – handle), batch of 10

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	Move from stock to manual lathe	0.97	56
2	○ ⇨ □ ◗ ▽	Latch setup (once per batch)	35.00	
3	● ⇨ □ D ▽	Lathe work	300.00	
4	○ ➡ □ D ▽	Move to manual milling centre	0.10	6
5	○ ⇨ □ ◗ ▽	Machine setup (once per batch)	30.00	
6	● ⇨ □ D ▽	Milling work	220.00	
7	○ ➡ □ D ▽	Move to outbound storage	1.12	65
8	○ ⇨ □ D ▼	Wait for outgoing transport	1.5days	
9	○ ⇨ □ ◗ ▽	Send to anodiser and wait	6days	
10	○ ➡ □ D ▽	move from office to assembly	0.95	55
11	● ⇨ □ D ▽	Assemble - see sheet 1/2		
		Total	588.13	182

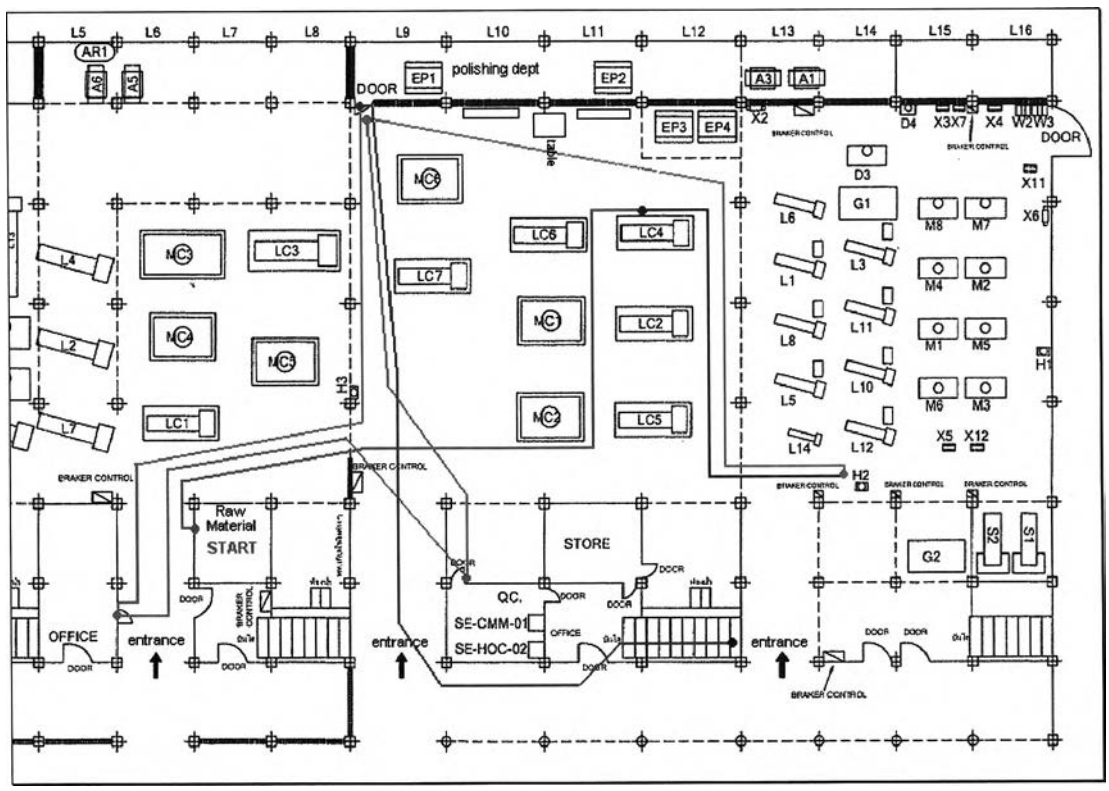


Figure 1B – Compression screw string diagram for the original design

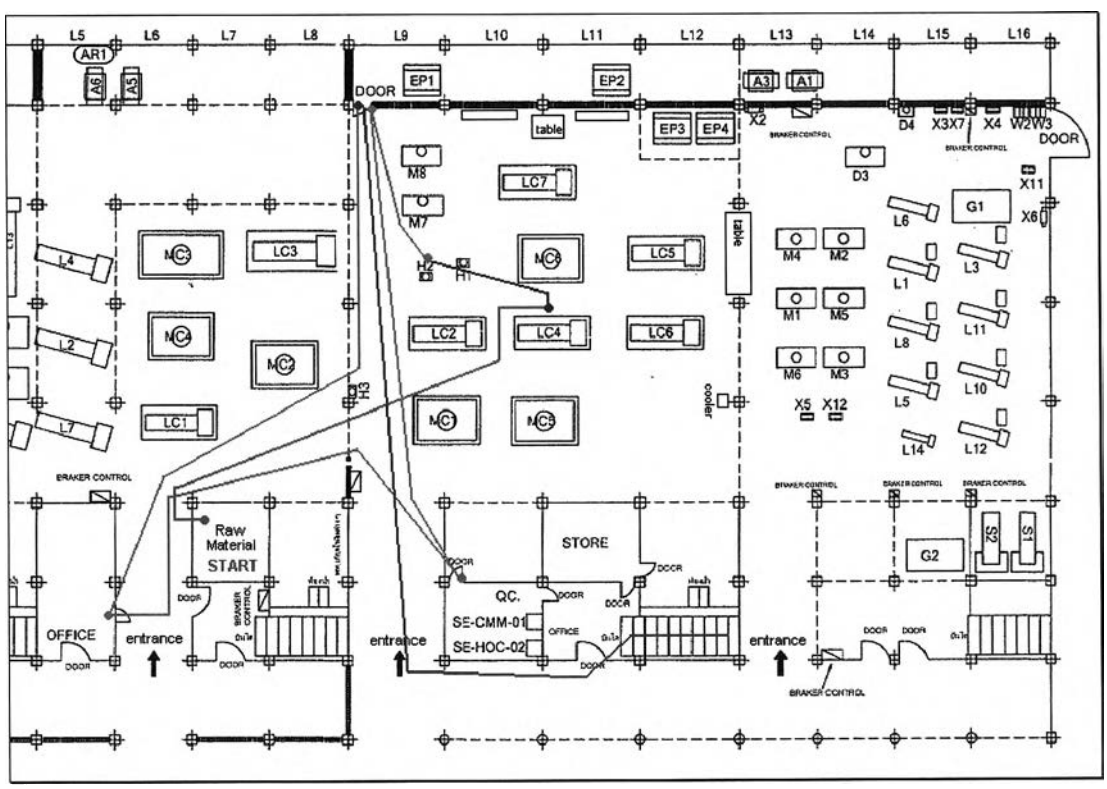


Figure 2B - Compression screw string diagram for design #1

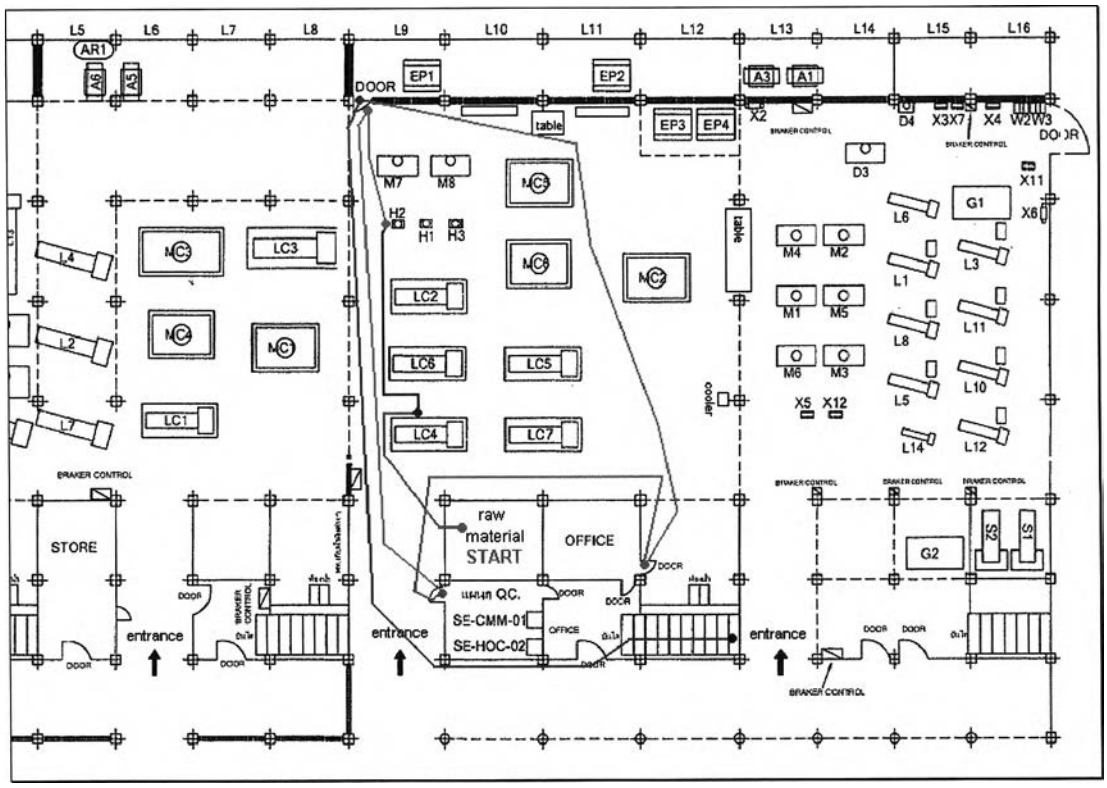


Figure 3B - Compression screw string diagram for design #2

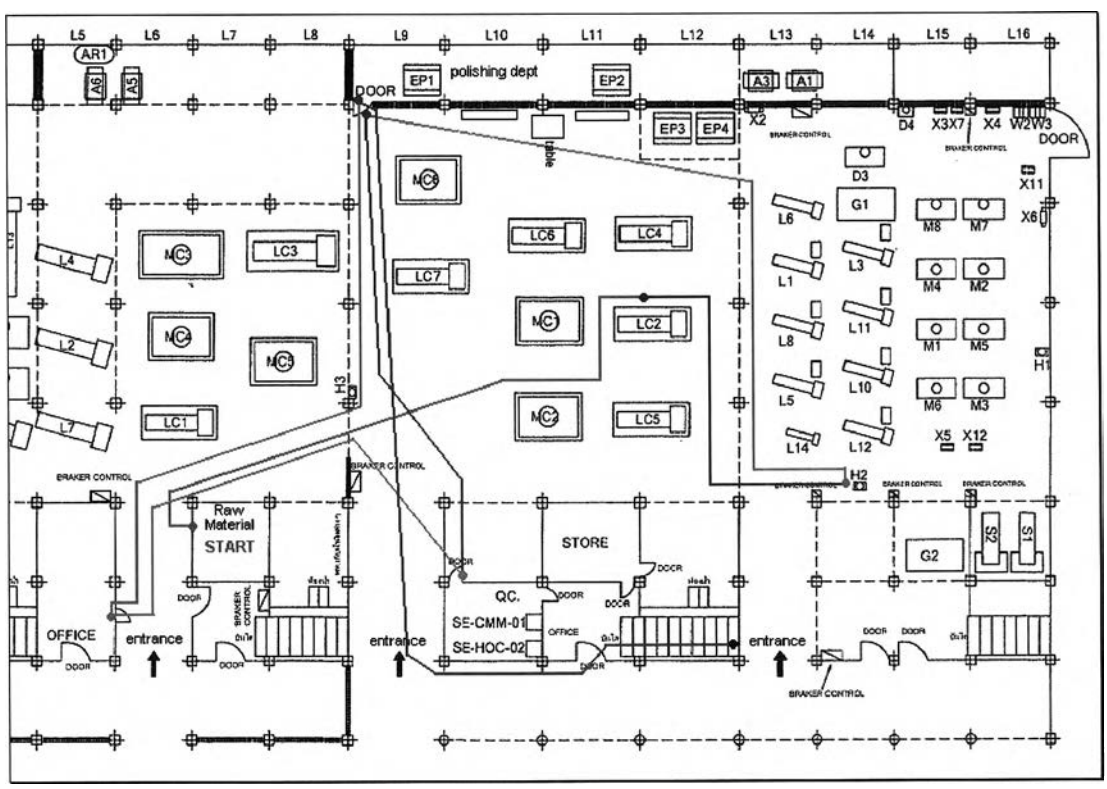


Figure 4B – Cortical screw string diagram for the original design

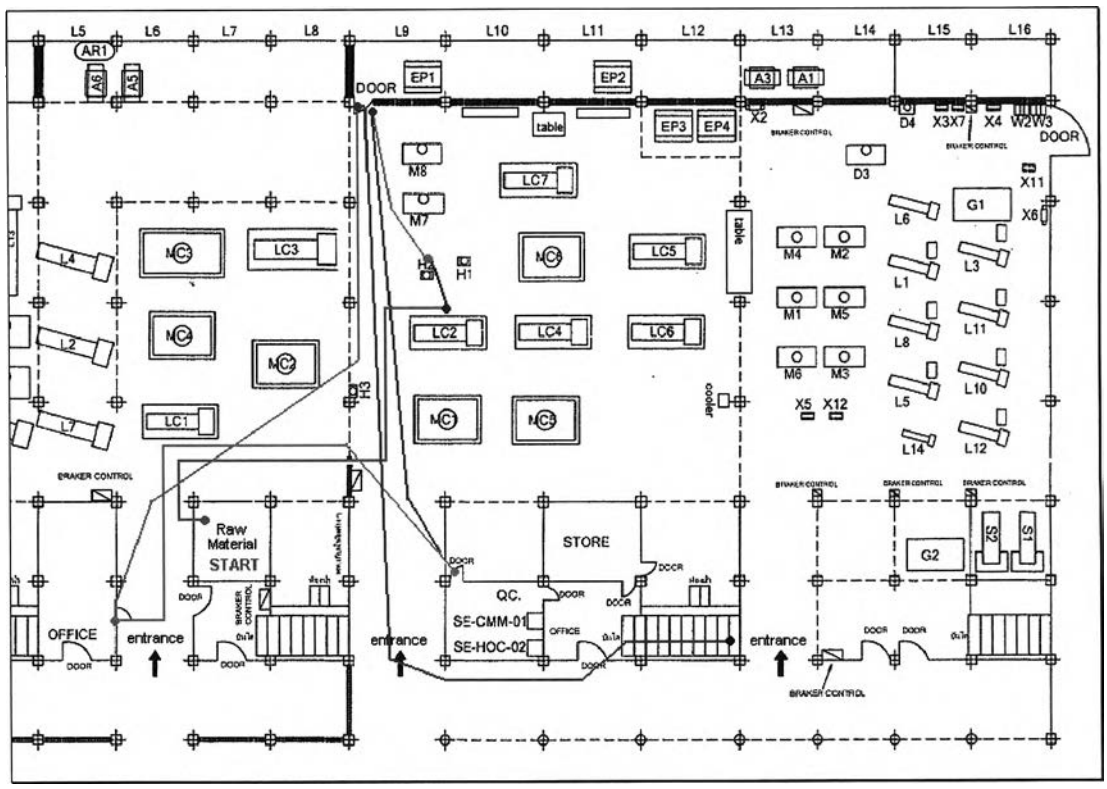


Figure 5B - Cortical screw string diagram for design #1

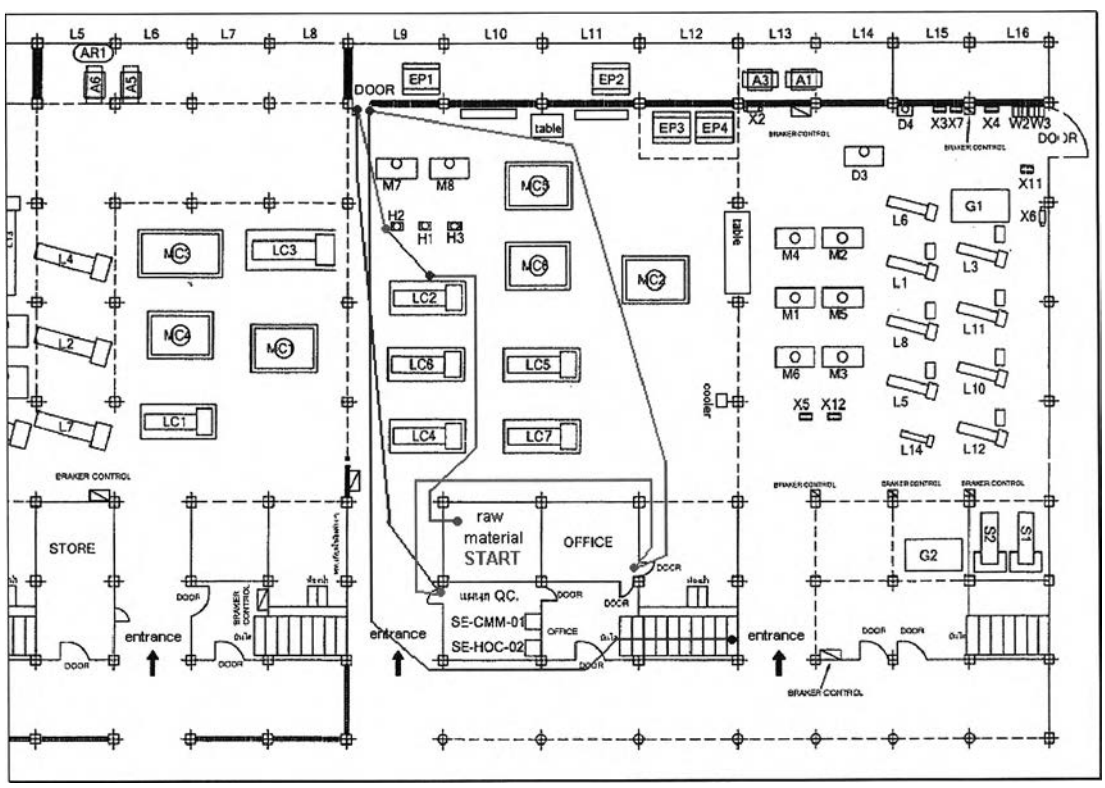


Figure 6B - Cortical screw string diagram for design #2

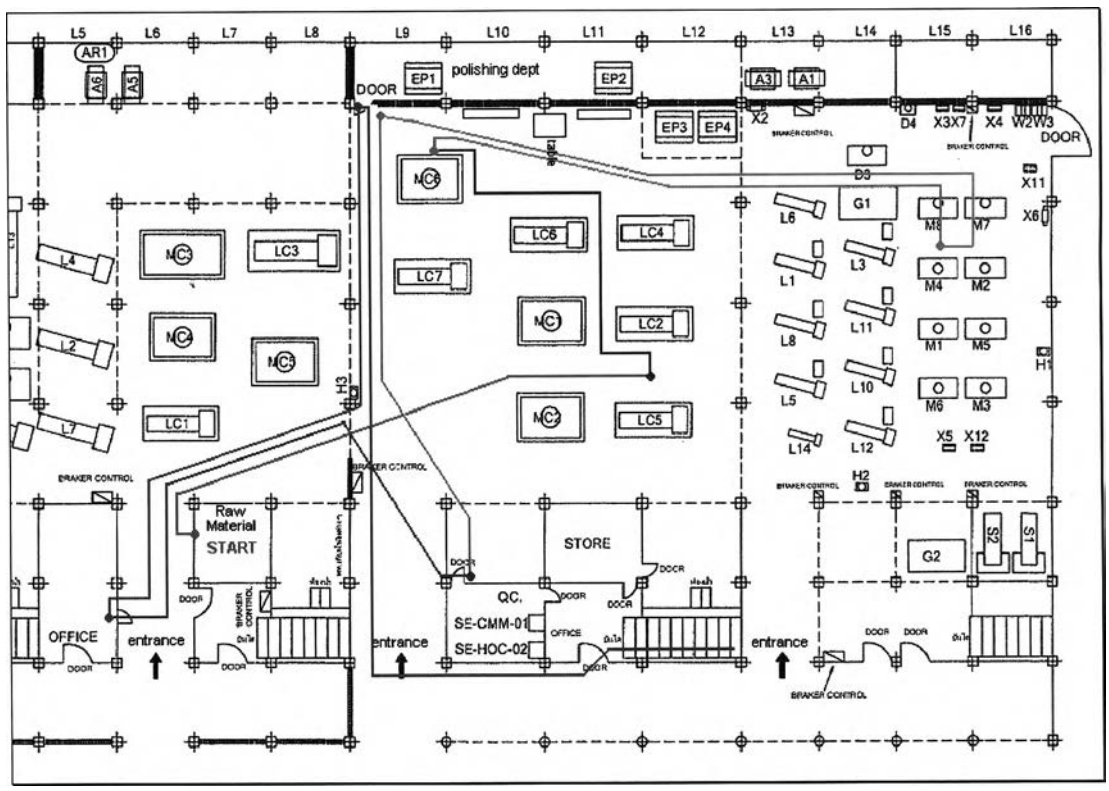


Figure 7B – Pedicle screw string diagram (part 1 of 2, screw body) for the original design

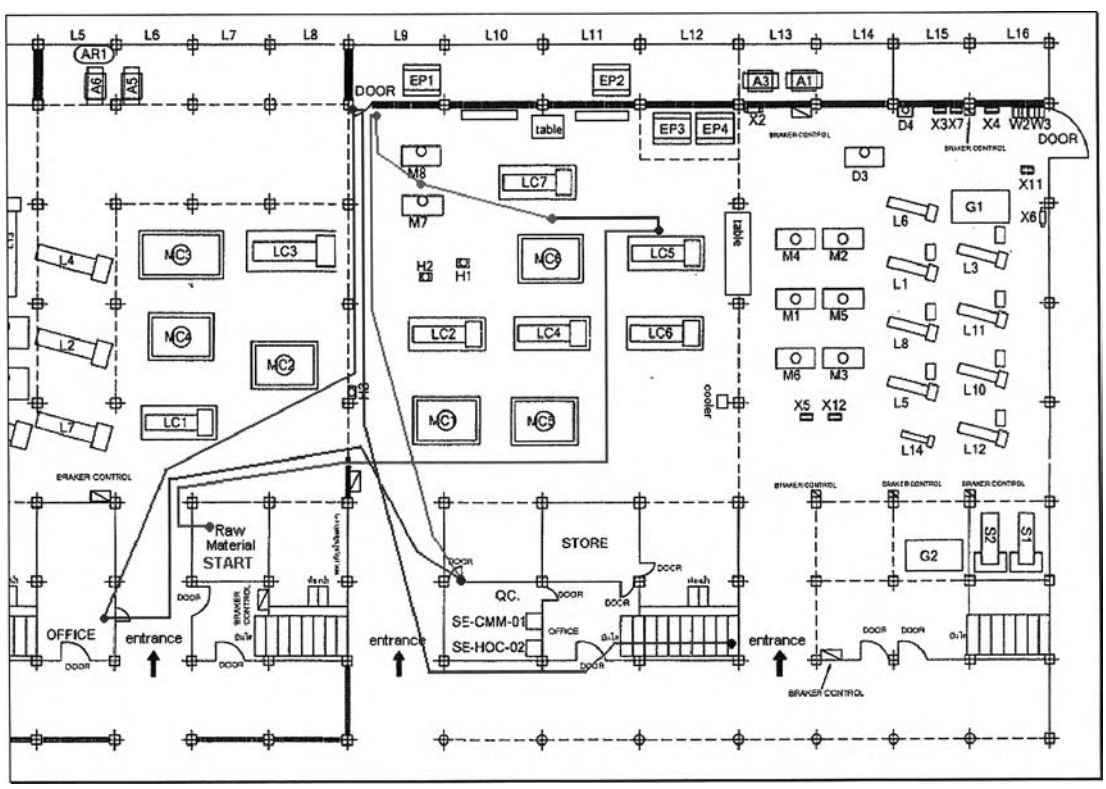


Figure 8B – Pedicle screw string diagram (part 1 of 2, screw body) for design #1

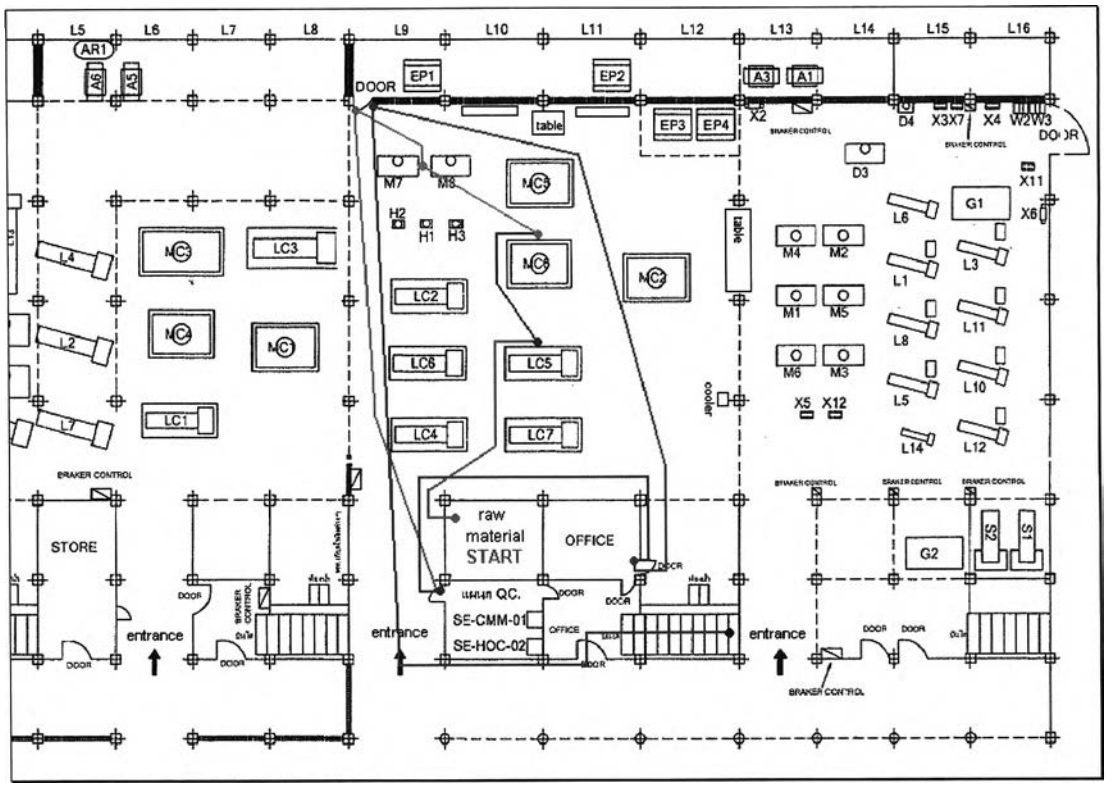


Figure 9B - Pedicle screw string diagram (part 1 of 2, screw body) for design #2

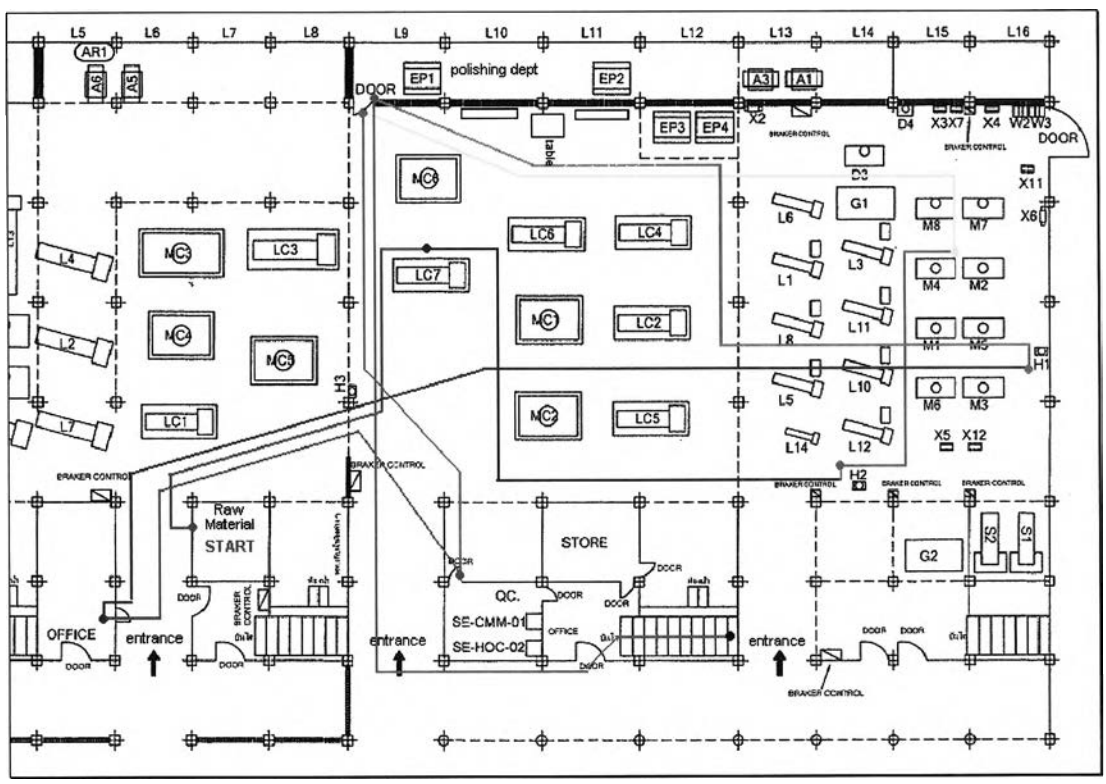


Figure 10B – Poly screw string diagram (part 1 of 3, screw body) for the original design

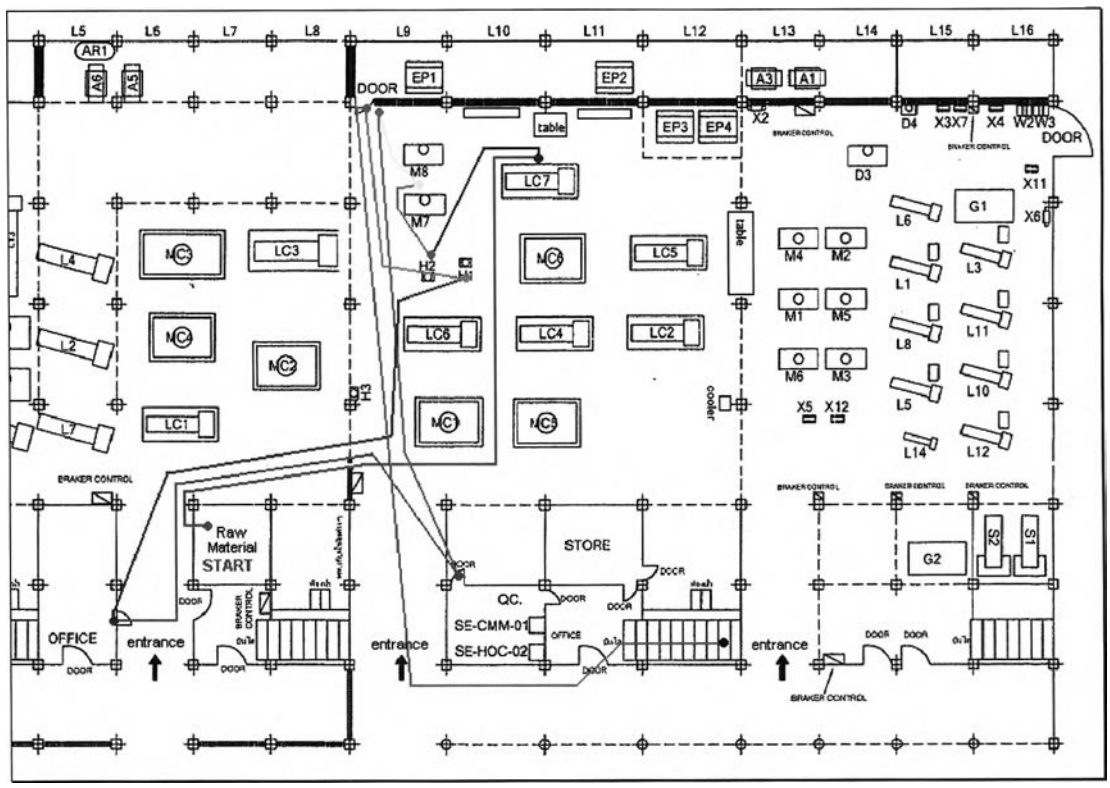


Figure 11B - Poly screw string diagram (part 1 of 3, screw body) for design #1

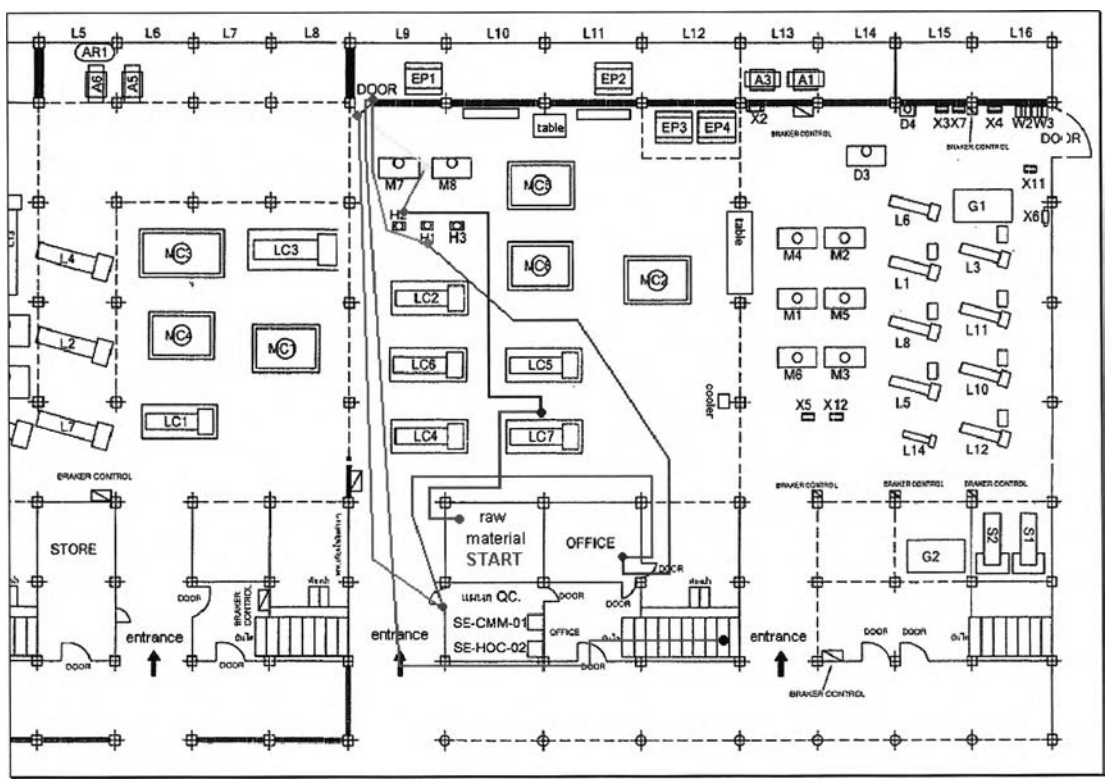


Figure 12B - Poly screw string diagram (part 1 of 3, screw body) for design #2

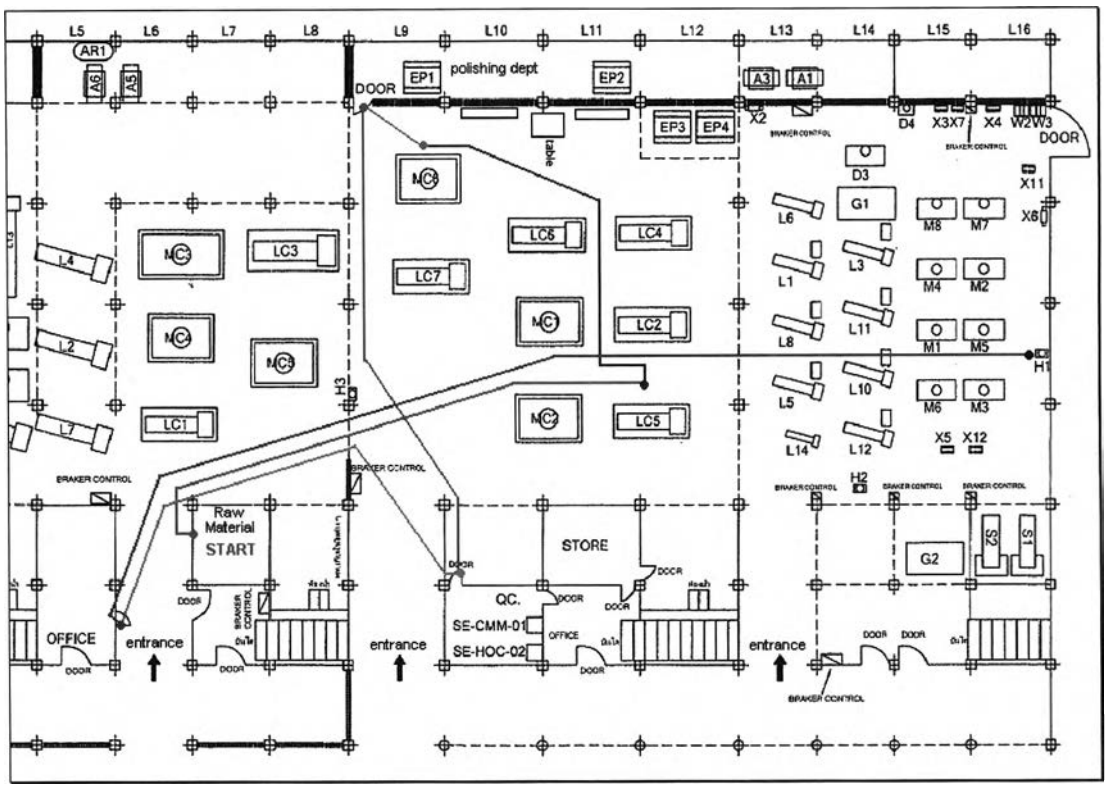


Figure 13B – Poly screw string diagram (part 2 of 3, Screw U head) for the original design

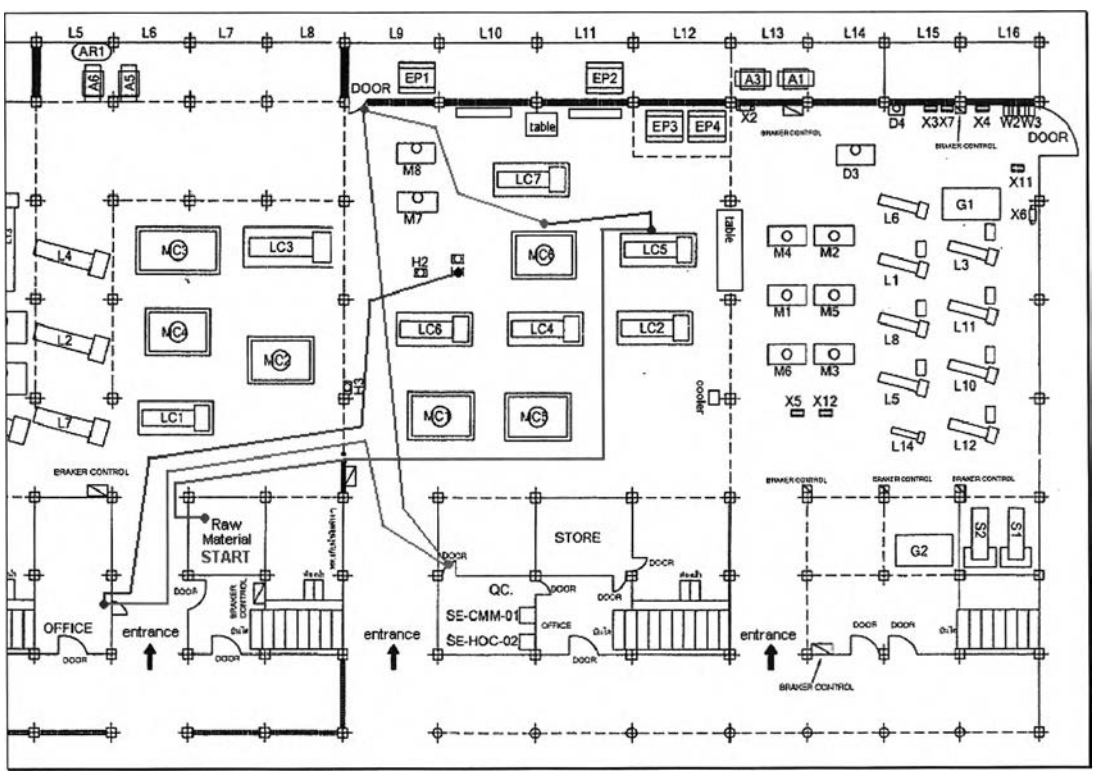


Figure 14B - Poly screw string diagram (part 2 of 3, Screw U head) for design #1

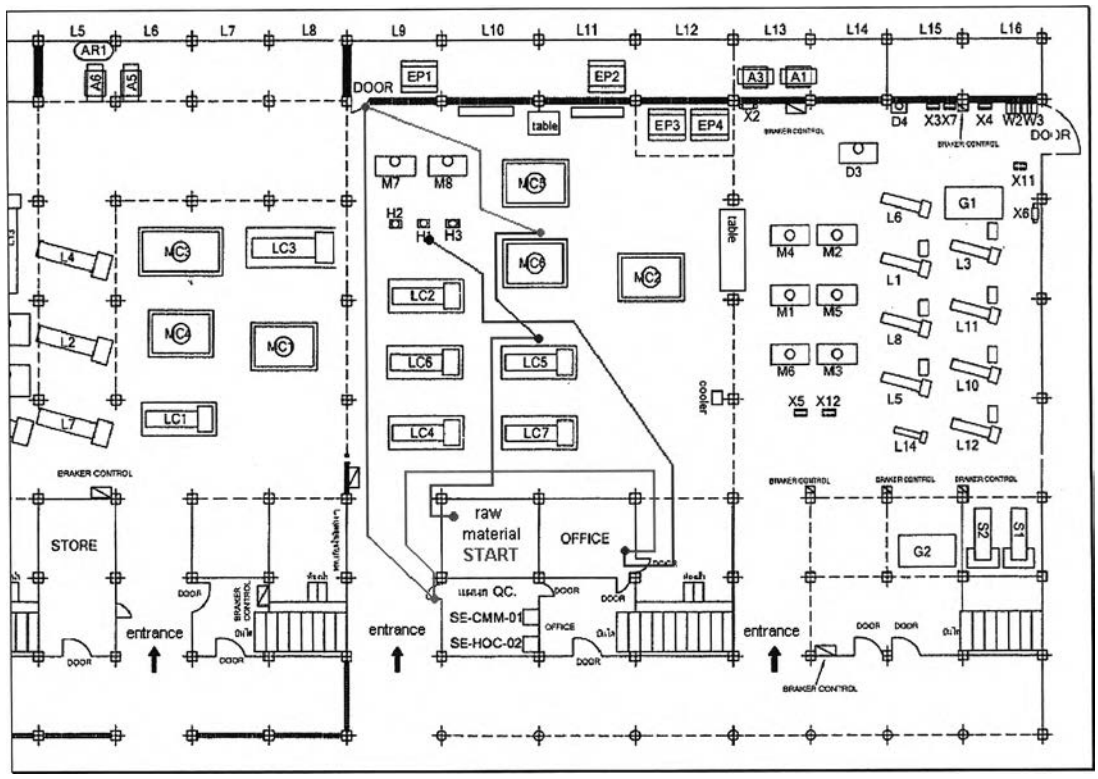


Figure 15B - Poly screw string diagram (part 2 of 3, Screw U head) for design #2

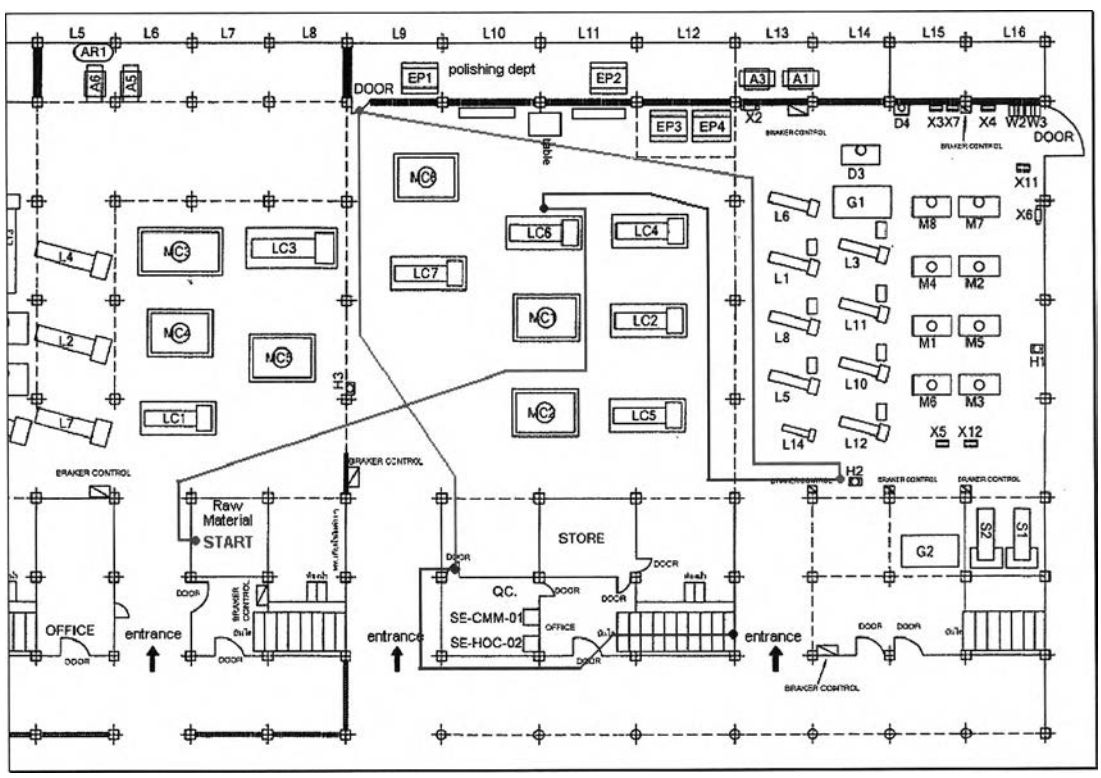


Figure 16B – Set screw string diagram (part 2of 2 for pedicle screw and part 3 of 3 for poly screw) for the original design

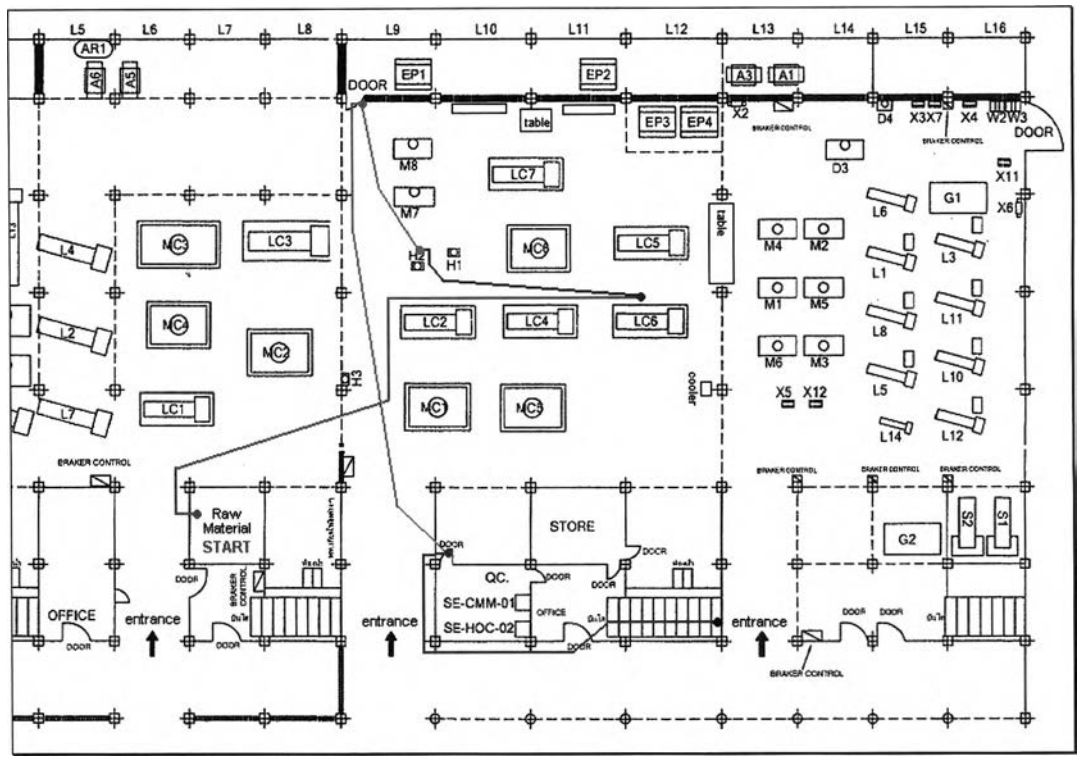


Figure 17B – Set screw string diagram (part 2of 2 for pedicle screw and part 3 of 3 for poly screw) for design #1

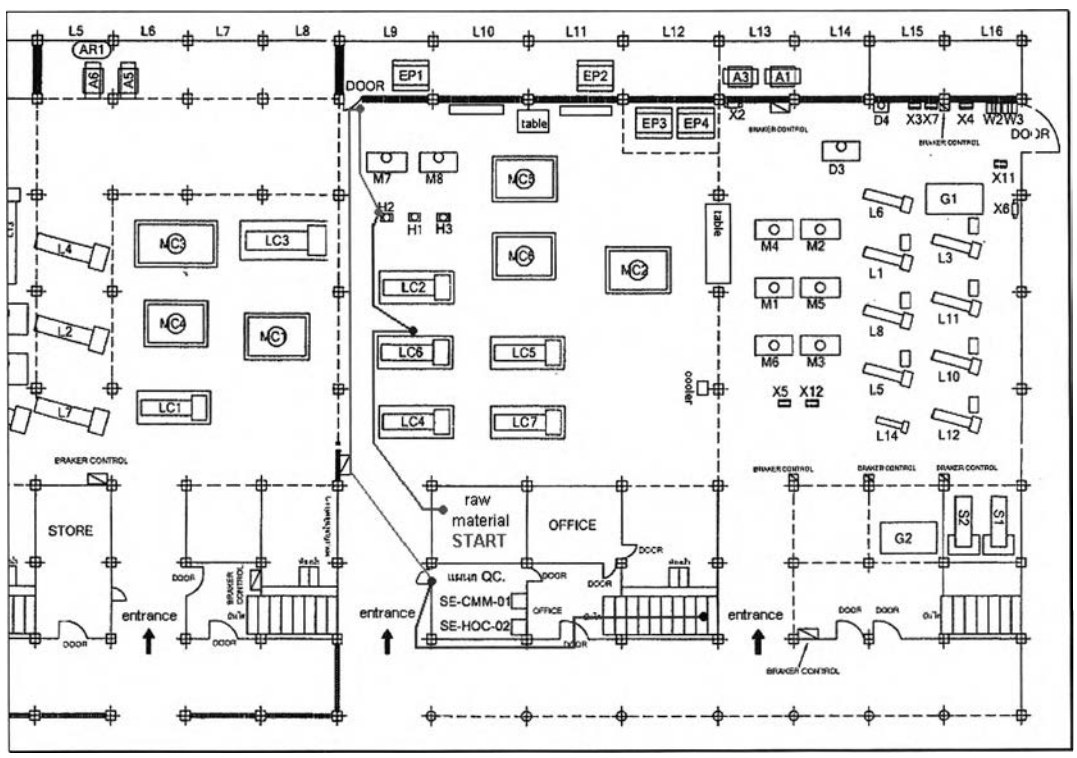


Figure 18B – Set screw string diagram (part 2of 2 for pedicle screw and part 3 of 3 for poly screw) for design #2

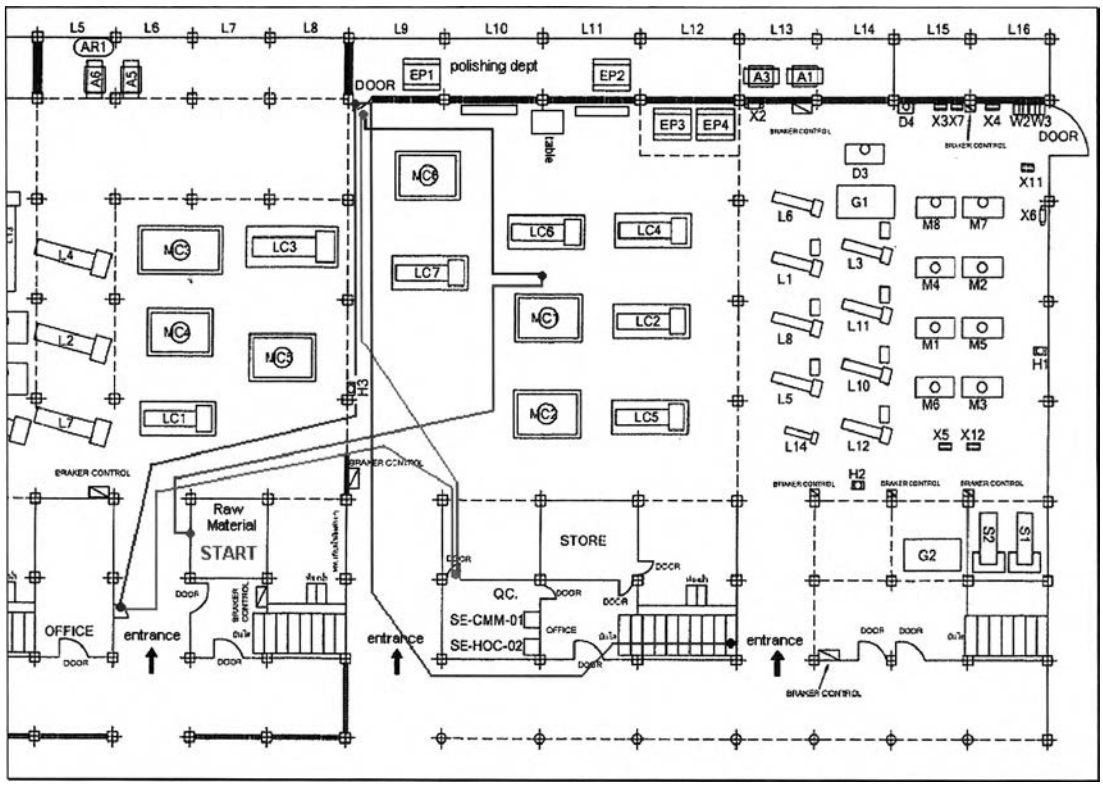


Figure 19B – Bone plate 8H string diagram for the original design

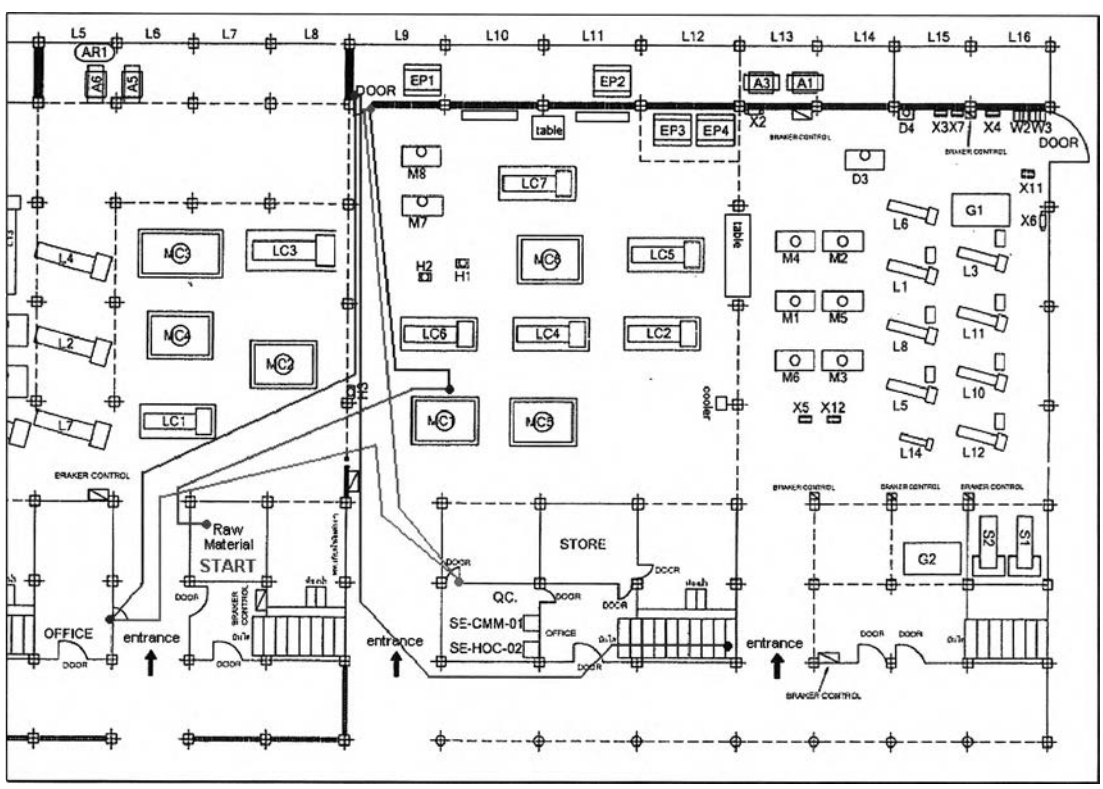


Figure 20B – Bone plate 8H string diagram for design #1

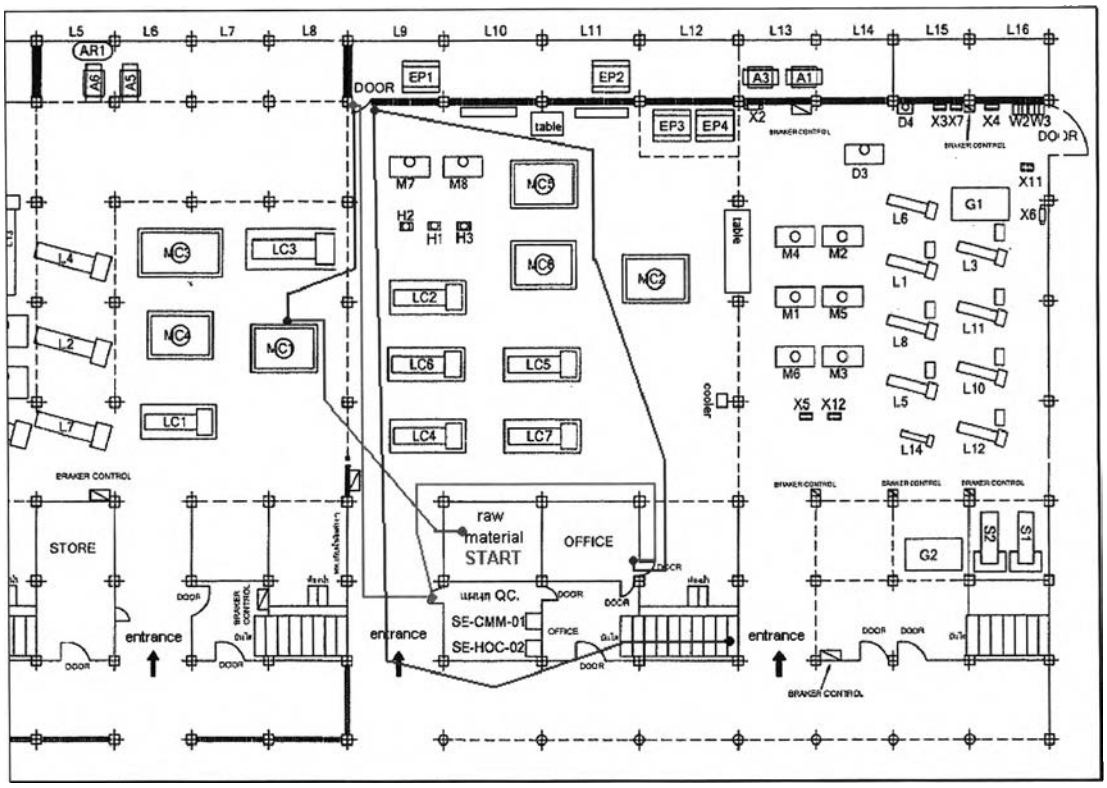


Figure 21B – Bone plate 8H string diagram for design #2

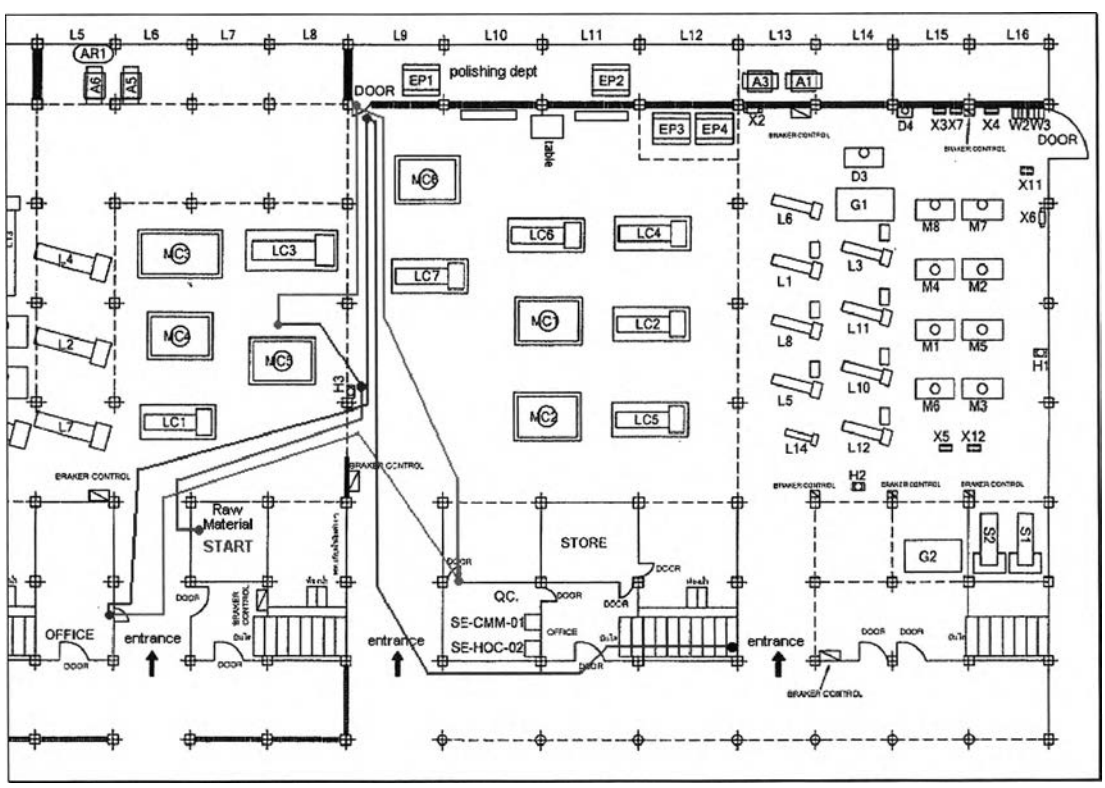


Figure 22B – Y plates string diagram for the original design

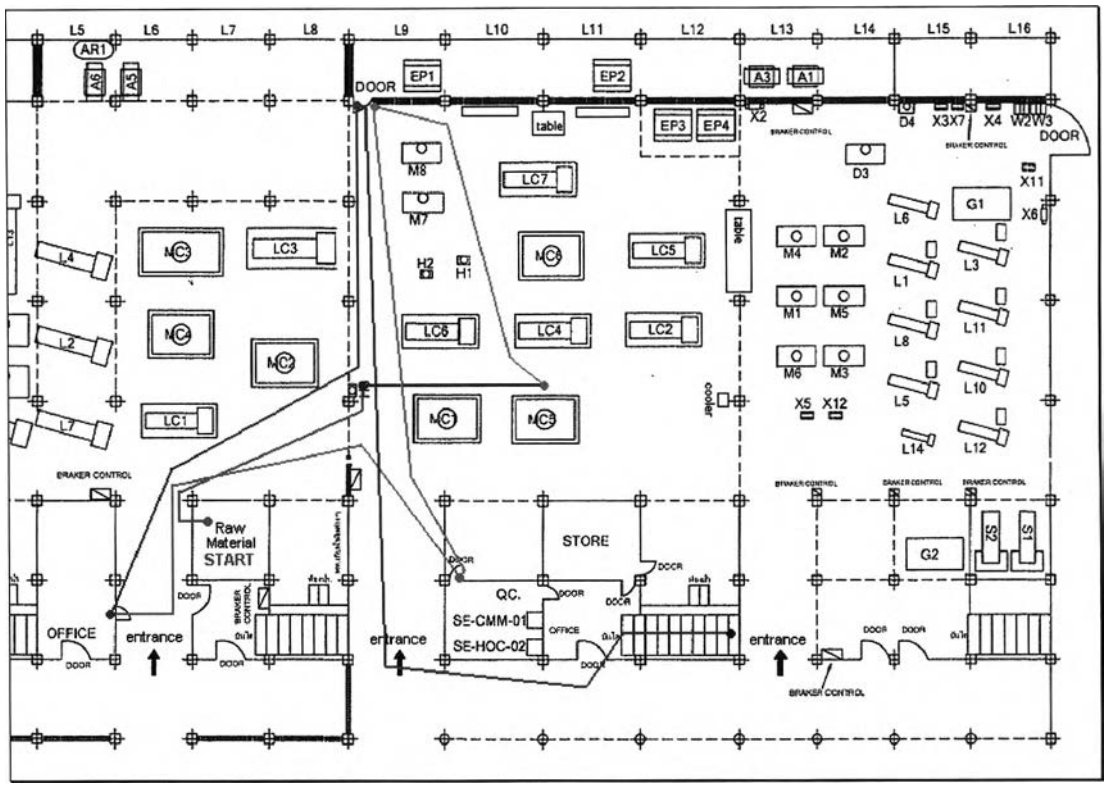


Figure 23B – Y plates string diagram for design #1

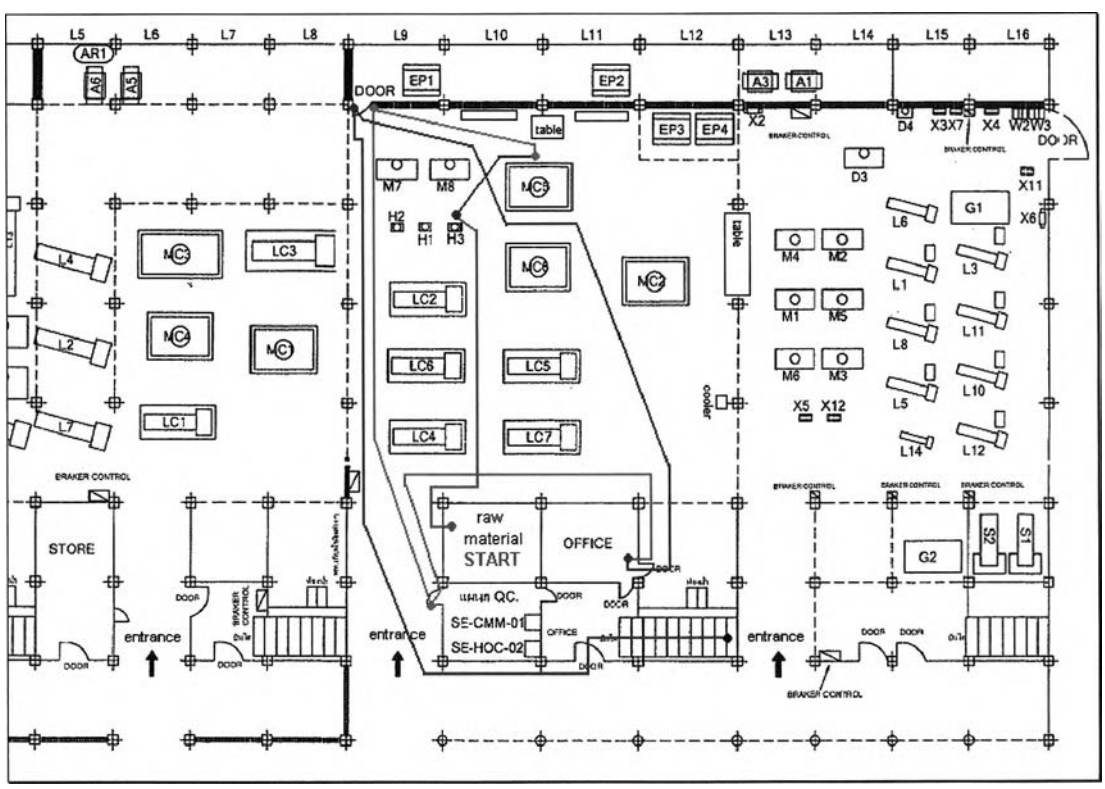


Figure 24B – Y plates string diagram for design #2

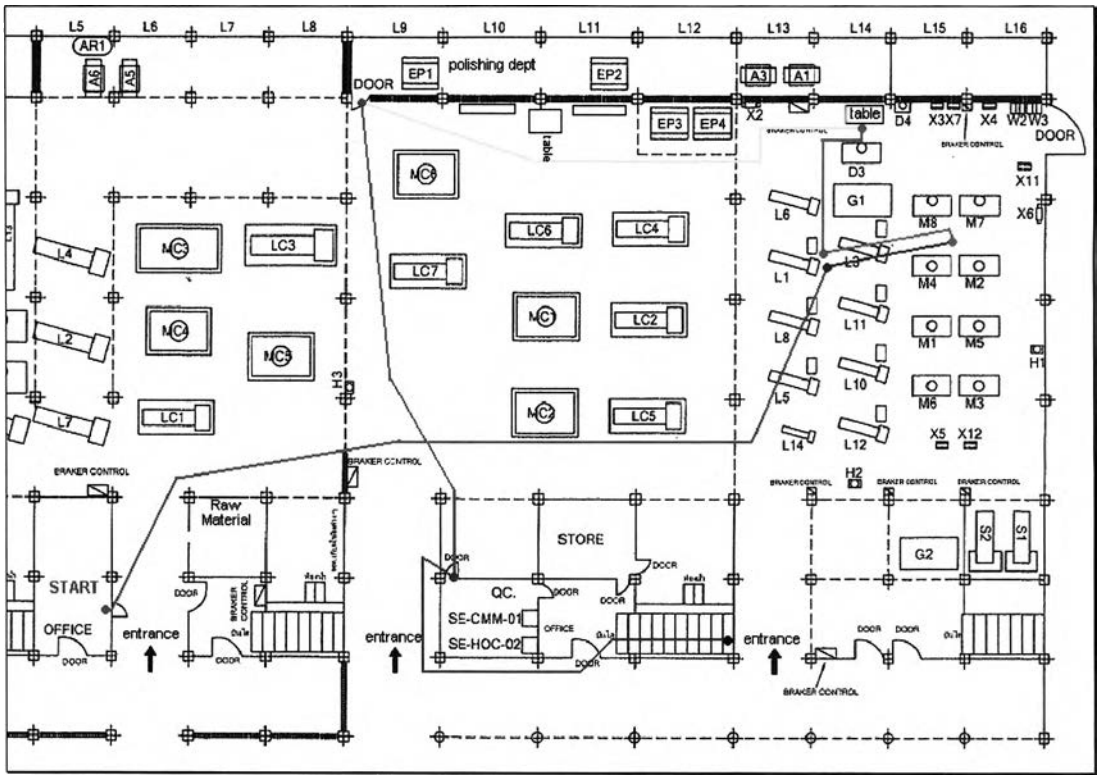


Figure 25B – Compression pliers string diagram for the original design

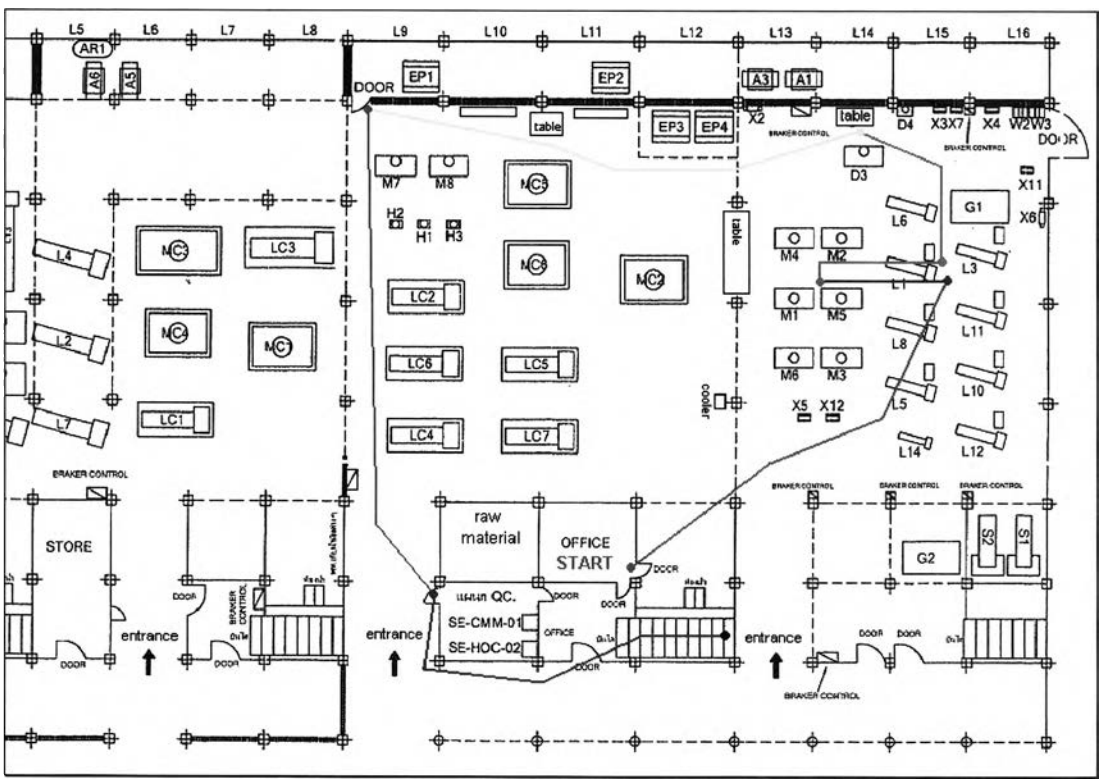


Figure 26B – Compression pliers string diagram for design #1

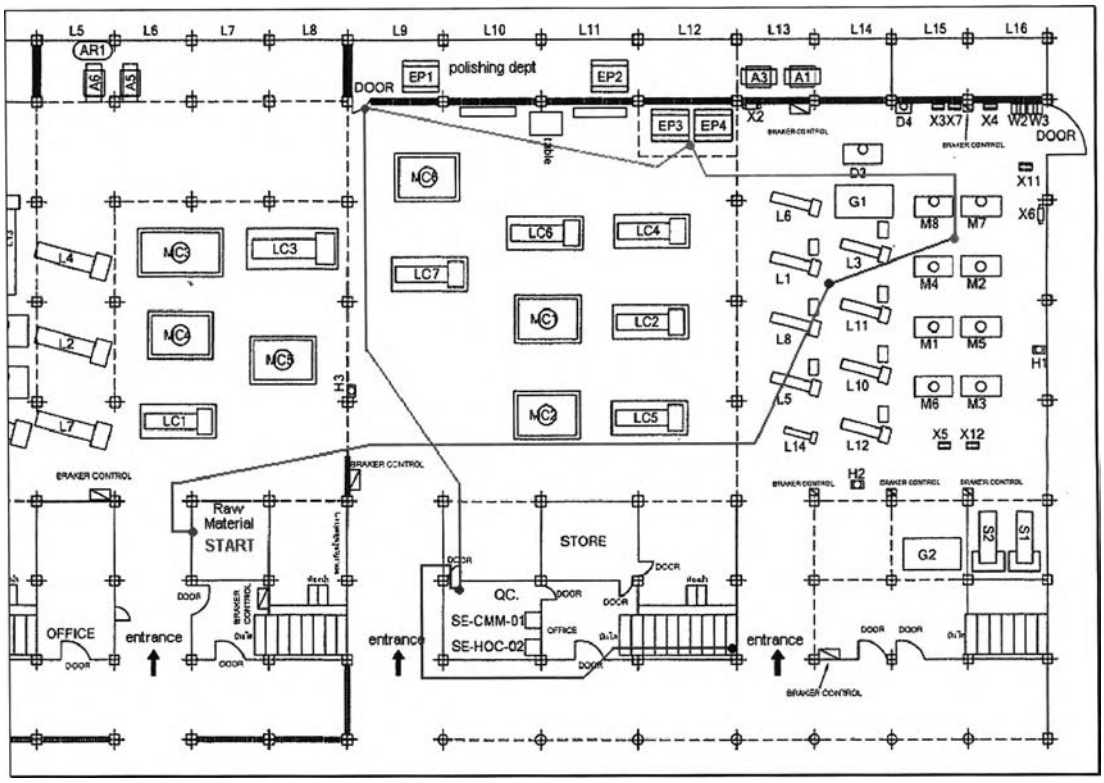


Figure 27B – Spine cage string diagram for the original design

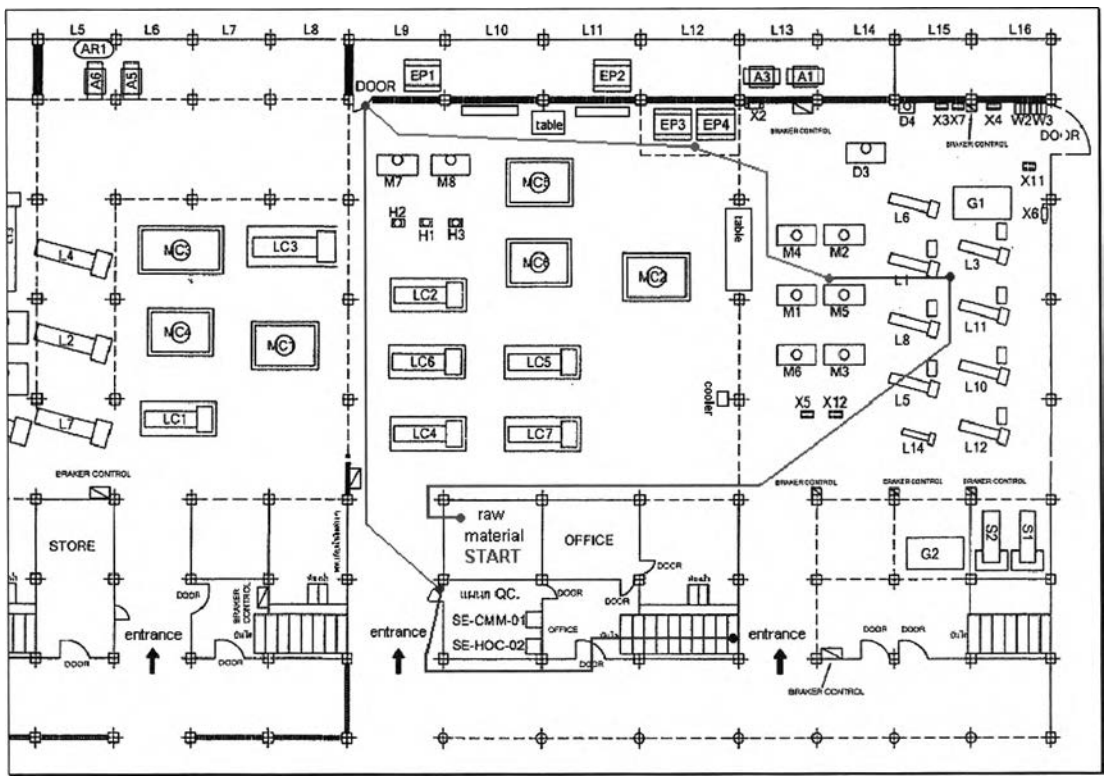


Figure 28B – Spine cage string diagram for design #2

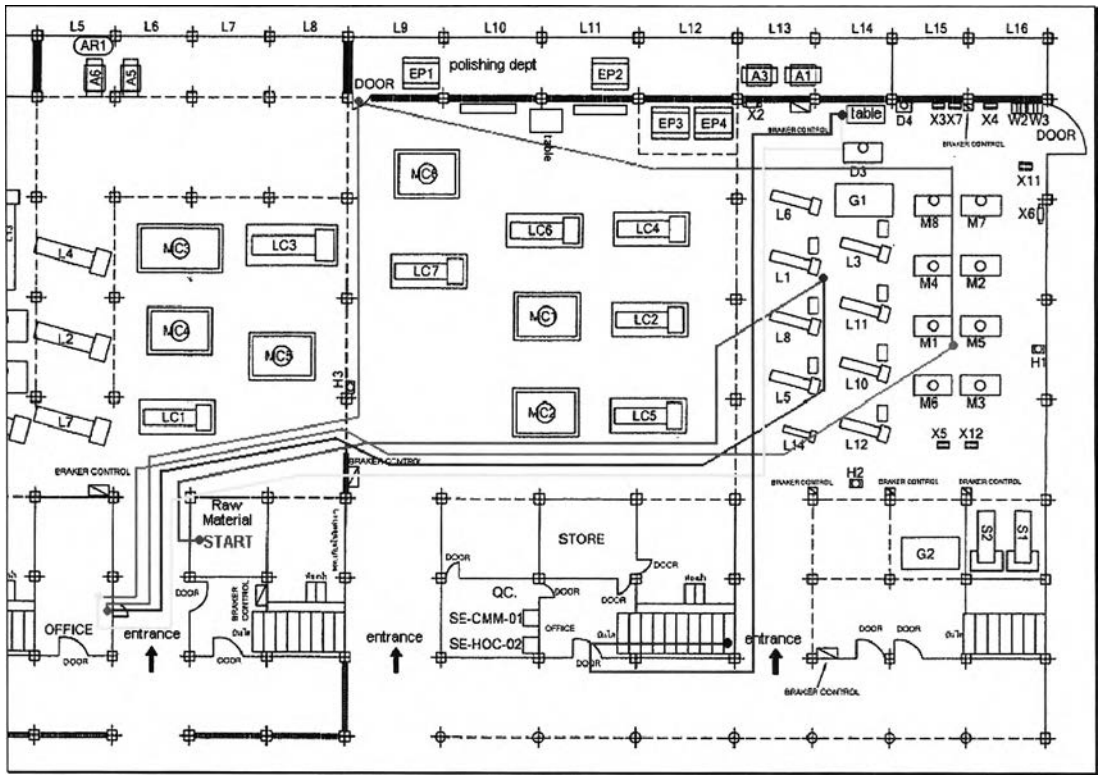


Figure 29B – Inner hex holder string diagram (part 1 of 2, shaft) for the original design

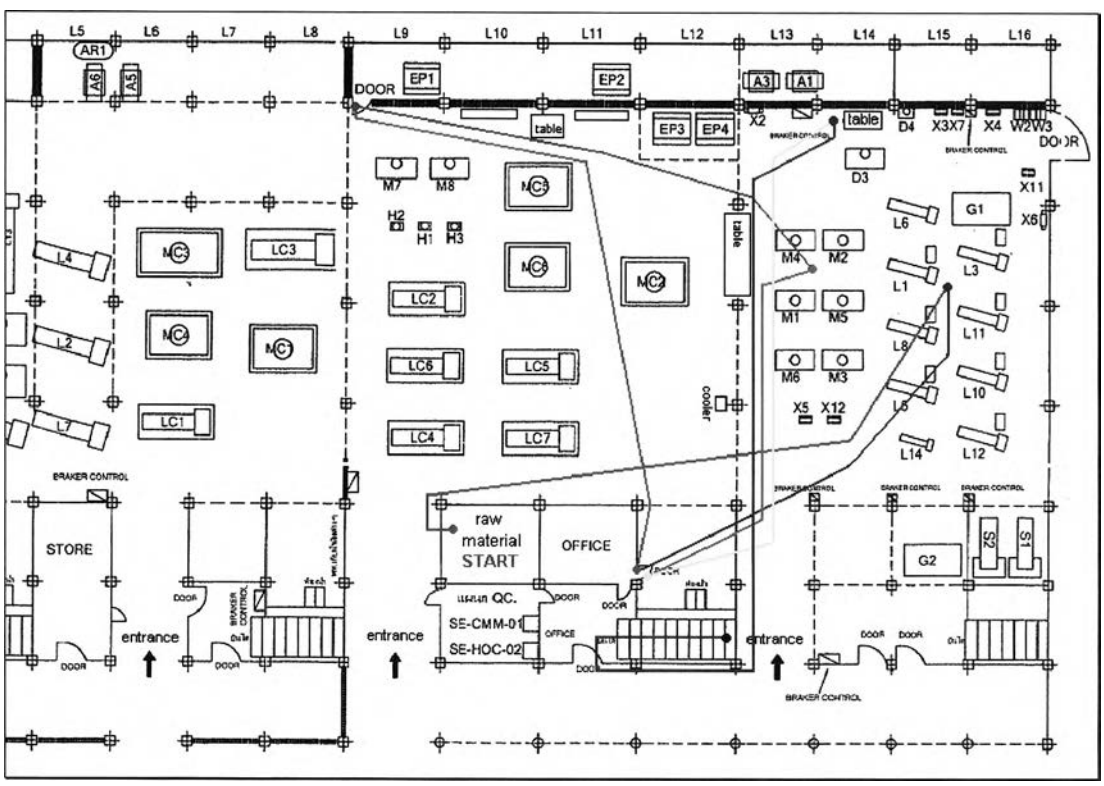


Figure 30B – Inner hex holder string diagram (part 1 of 2, shaft) for design #2

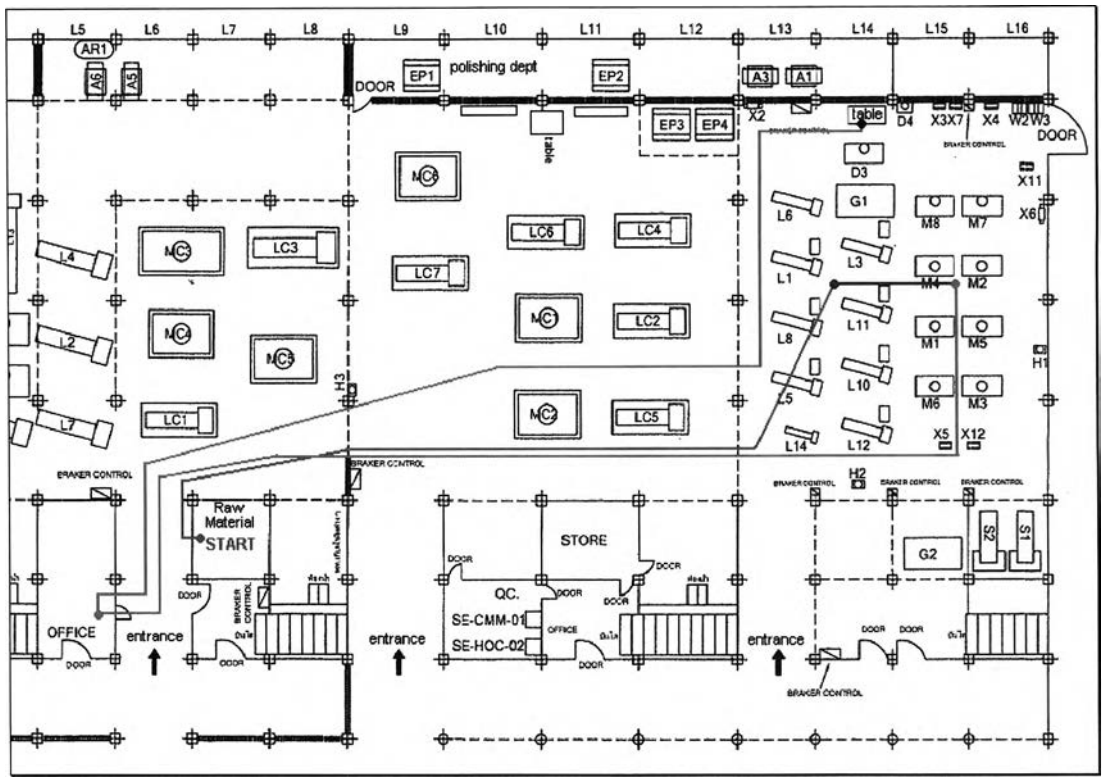


Figure 31B – Inner hex holder string diagram (part 2 of 2, handle) for the original design

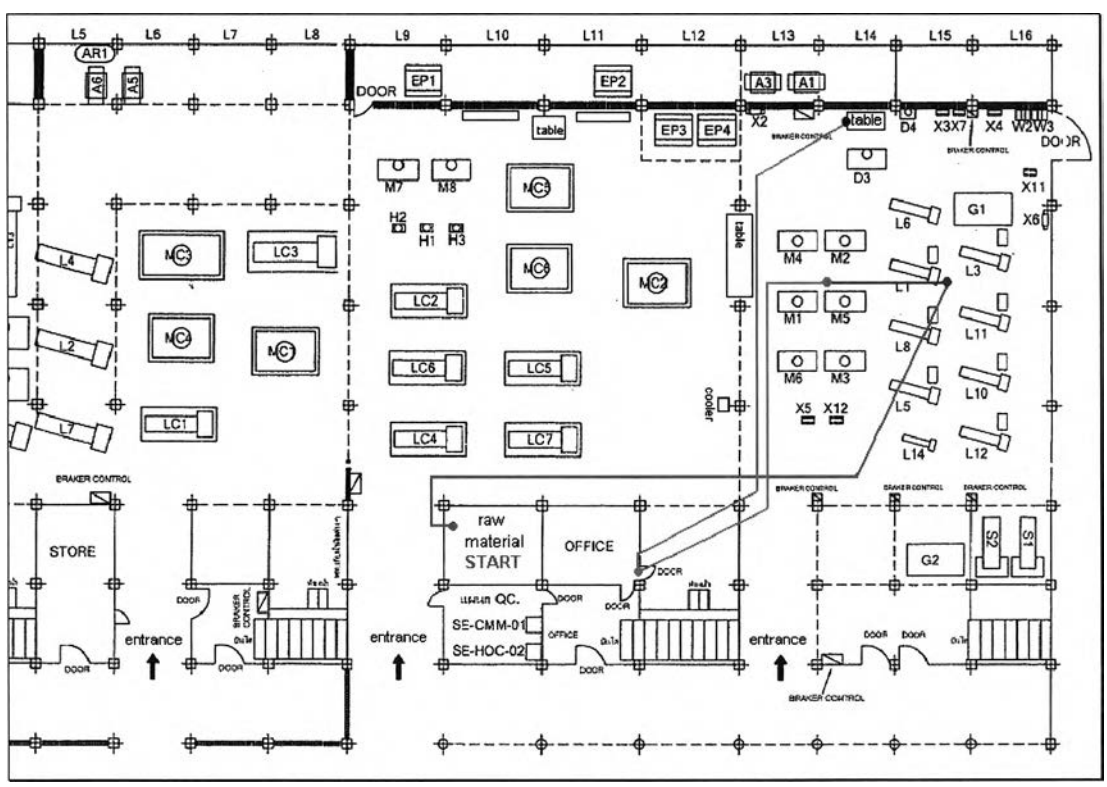


Figure 32B – Inner hex holder string diagram (part 2 of 2, handle) for design #2

Appendix B

Calculations

B.1 Setup Time Calculation

Table B.1 – Setup Frequency

	2006 production volume	Average batch size	setup frequency
Screws			
Poly	9820	100	98
Pedicle	7875	100	79
Compression	18997	100	190
Cortical	22135	100	221
Set screw	23087	100	231
Plates			
Curved	8279	65	127
Flat	7620	65	117
Instruments			
Pliers	414	10	41
Small parts	821	20	41
Screw drivers	1789	10	179

Table B.1 above shows the setup frequency required by each product. The batch sizes are averaged values. The setup frequency was simply calculated by dividing the volume by the batch size.

The next step is to find the setup time required by each machine for each product. This information can be found in the process flow charts of each product (see details of process flowchart in appendix A). Table B.2 summarises the setup times.

Table B.2 – Setup time of each machine for the different products

	Screws					Plates		Instruments		
	poly screw	pedicle screw	compression screw	cortical screw	set screw	Curved plates	Flat plates	Pliers type	Small type	Screw driver type
MC1							65			
MC5						70				
H3						negligible				
MC6	70	70								
LC2				70						
LC4			70							
LC5	70	70								
LC6					55					
LC7	70									
H1	negligible									
H2	negligible		negligible	negligible	negligible					
Manual Milling	30	30						90	30	30
Manual Lathe								30	35	30

With this information, the total setup time requirement by each product can be calculated by multiplying the setup frequency in table B.1 by the setup time in table B.2. The result is summarised in table B.3 in the next page.

Table B.3 – Total setup time of each product

	Screws					Plates		Instruments		
	poly screw	pedicle screw	compression screw	cortical screw	set screw	Curved plates	Flat plates	Pliers type	Small type	Screw driver type
MC1							7620			
MC5						8916				
H3										
MC6	6874	5513								
LC2				15495						
LC4			13298							
LC5	6874	5513								
LC6					12698					
LC7	6874									
H1										
H2										
Manual Milling	2946	2363						1242	1437	10734
Manual Lathe								3726	1232	12523

B.2 Machining time requirement of each product

Knowing the production volume (table B.1 earlier) and the process time requirement in the process flowcharts (appendix A), the machine time requirement of each product can be calculated. For example, if the volume of product Screw A is 1000 and the threading time on the CNC lathe take 5 minutes per piece, then the total Lathe time requirement for Screw A is 5000 minutes. Table C.2 below show the machine requirement of each product.

Table B.2 – machining time requirement of each product.

	poly screw	pedicle screw	compression screw	cortical screw	set screw	Curved plates	Flat plates	Pliers type	Small type	Screw driver type
CNC milling	108020	78750				140743	68580			
CNC Lathe	166940	173250	132979	132810	138522					
Manual Milling	58920	39375						260820	143675	69771
Manual Lathe								13869	6568	77821.5
Hydraulic Pump	58920		28495.5	33202.5	23087	24837				

Bibliography

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