



IE 516 Manufacturing Planning and Control Take Home Final Examination due January 8th, 2014 Fall 2013



Question Number One:

A company has received an order for four types of wallpapers: one (paper 1) has a Green background with blue and yellow patterns, another (paper 2) a red background and green, blue and yellow patterns, another (paper 3) has a yellow background with blue, green and red patterns and the last (paper 4) has a green background with red and blue patterns. Every paper type is produced as a continuous roll of paper that passes through several machines, each printing a different color. The order in which the papers are run through the machines depends on the design of the paper: for paper 1 first the green background and then the blue and then yellow patterns are printed. After the red background for paper 2, first the green, then the blue and then the yellow patterns are printed. The printing of paper 3 starts with the yellow background, followed by the blue and then the green and then the red patterns. For paper 4 the red and then the blue patterns are printed after printing green background.

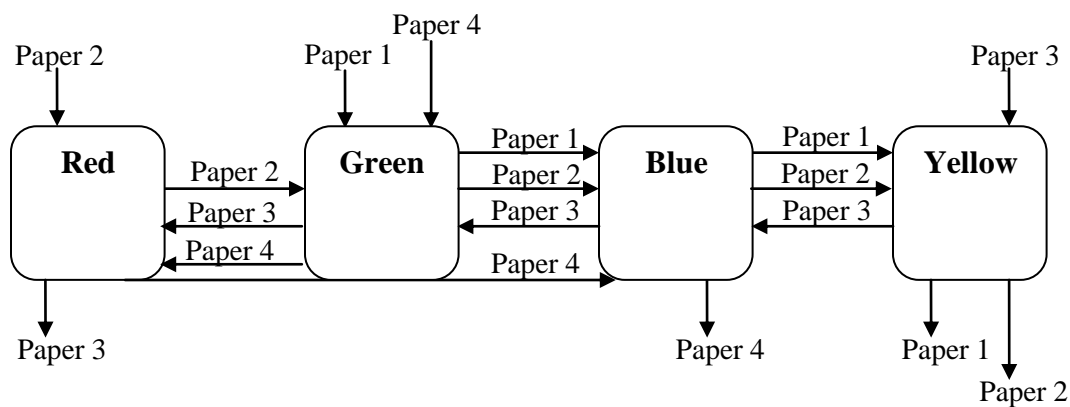


Figure: Production flows through printing machines



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The production shop consists of one machine for printing red, blue and yellow colors each and two machines for printing green color. The processing times differ depending on the surface that needs to be printed. The times (in minutes) for applying every color of the four paper types are given in the following table.

Table: Times required for applying every color

Machine	Color	Paper 1	Paper 2	Paper 3	Paper 4
1	Red	---	3.5	2.5	2
2 & 3	Green	4	2.9	3.2	4.5
4	Blue	3.2	2.5	2.2	2.1
5	Yellow	2.4	2	3.6	---
Order Size		250	180	200	280

Every machine can only process one wallpaper at a time and that a paper cannot be processed by several machines simultaneously, how should the paper printing be scheduled on the machines in order to finish the order as early as possible?



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Question Number Two:

The company Line Production decides to plan the production of its products on its five production Lines (L1 to L5). The processing times differ depending on the line that products is processed. Table below lists the processing time in hours necessary for the production of one unit of every product on every production line.

Table: Times required for products to process on different line

Products	Lines					Due Date (hrs)	Penalty/hour late (SR)
	L1	L2	L3	L4	L5		
P1	86	19	84	43	57	189	79
P2	60	69	87	22	53	156	21
P3	40	97	21	54	83	163	79
P4	36	18	66	35	21	215	47
P5	13	48	33	65	70	186	15
P6	93	94	19	53	12	197	20
P7	17	91	37	88	29	187	43
P8	59	54	42	62	76	140	19
P9	98	58	27	91	77	178	10
P10	22	84	73	71	57	144	38
P11	32	45	50	48	63	174	71
P12	95	21	21	18	24	152	60
P13	54	76	18	84	46	202	99
P14	65	81	22	43	74	209	39
P15	16	88	24	79	25	207	33
P16	57	24	35	50	66	144	28
P17	87	58	79	61	44	175	20
P18	75	29	68	51	41	216	49
P19	34	16	87	17	13	237	99
P20	31	14	66	17	91	214	80

Only one product can be processed on every production line at a time and that a product cannot be processed by several lines simultaneously, how should the products be scheduled on the machines in order to finish all the products with minimum total penalty?



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Question Number Three:

Transformers Crop has been manufacturing custom designed power transformers. Transformer Crop company has following order for next month.

Transformer Type	Power Range	Order Quantity (Nos.)
Generation	200 MVA	1
	100 MVA	2
	50 MVA	2
System	50 MVA	1
	20 MVA	2
Distribution	10 MVA	3
	5 MVA	3
	2 MVA	3

All types of transformers are manufactured and follow the sequence of operations as represented in the following flow Diagram:



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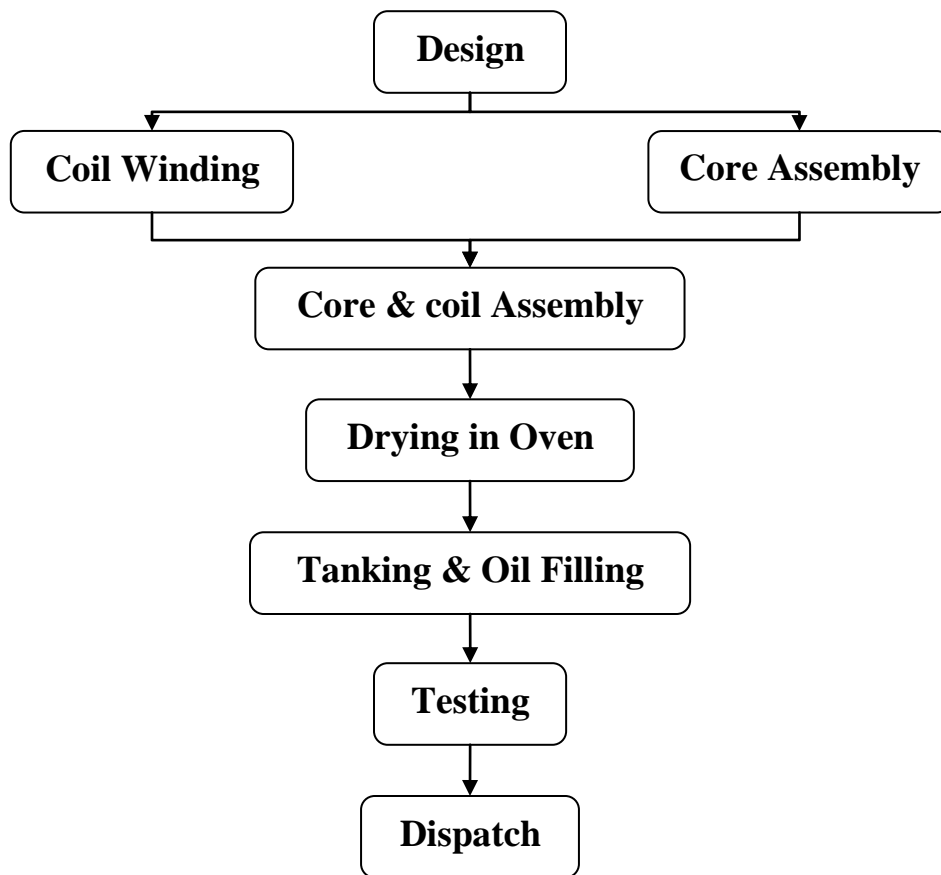


Figure: Production flow for a transformer

The manufacturing process of transformers starts with designing transformer as specified by the customer. Then these designs are provided to different department for the fabrication of transformers. Coil assembly and core build are done parallel in different department. After that core and coil assembly is done and then assembly kept in oven for drying. Once assembly is completely dried is sent for the tanking and oil filling. The completed transformers are then sent to the testing department. After passing the entire testing transformer are prepared for the dispatch.

Consider sufficient manpower is available for performing the entire task in each process. Most of the raw material is commonly used for all type of transformers, so company



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maintains sufficient stock for every process. Production never stops or postponed due to manpower or raw material.

Design:

Transformer Corp is supported by a team of well-trained design engineers. All engineers are equipped with a variety of special purpose software such as Optimized core and coil design, no-load and load-loss optimization, Impulse Voltage calculation, Short circuit calculation and magnetic field calculation. Thermal calculations include overloads, hot-spot temperature calculation for windings and core, clamping force and structure strength calculation, etc.. Transformer Corp has only three design engineers in design department. A time required for designing a transformer by any one engineer is given in following table.

Transformer Type	Generation			System		Distribution		
	Power Range (MVA)	200	100	50	50	20	10	5
Design Time in Hrs.	48	40	32	24	24	16	16	16

Winding:

Both High Voltage (HV) and Low Voltage (LV) windings are done using Coil Winding Machines. The Copper or Aluminium strips/wires used in winding are meticulously selected for its quality to give the best output. The Copper or Aluminium strips/wires are paper covered and acts as insulators. This helps to increase short-circuit strength, thermal strength and higher efficiency. Winding Department has 4 Nos. of winding Machines and the time taken for winding of coils required of particular type of transformer are given below.

Transformer Type	Generation			System		Distribution		
	Power Range (MVA)	200	100	50	50	20	10	5
Winding Time in Hrs.	56	40	24	24	24	8	8	8



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Core Bulid:

The Cold Rolled Grain Oriented (CRGO) laminations used in transformers are of high quality. They are in the form of thin sheets and they are cut as per the design varying for different capacities of transformers. Highly skilled people assemble the laminations on a core channel to form CORE. These are perfectly assembled without any gaps to avoid energy loss. This Department has 4 Nos. of core building platform where core can be build. At a time one core is built on one platform once core assembly start is not possible to remove the core assembly until is completed. Time consume for building a particular type of core is given below.

Transformer Type	Generation			System		Distribution		
	200	100	50	50	20	10	5	2
Power Range (MVA)	200	100	50	50	20	10	5	2
Core Building Time in Hrs.	40	32	24	16	16	8	8	8

Core & Coil Assembly:

The wound coils are placed carefully in the assembled core. Insulations are given wherever required using materials like press board. The core bolt and tie rods are fixed in position. The Primary and Secondary windings are connected as per the requirement. The assembly department is having only three assembly station and once assembly of any transformer start it can't be removed from the station unless it completes. Times for assembly of different transformers are given in table below.

Transformer Type	Generation			System		Distribution		
	200	100	50	50	20	10	5	2
Power Range (MVA)	200	100	50	50	20	10	5	2
Assembly Time in Hrs.	32	24	20	12	12	6	6	4

Drying:

The complete assembly is kept in the Hot Air Chamber and a high temperature is maintained to prevent any moisture in the core & coil assembly. Transformer Crop is having 2 ovens for the drying core & coil assembly. Once assembly is kept in oven and



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oven is closed it cannot be opened till process completes. Time for drying is given in following table.

Transformer Type	Generation			System		Distribution		
	200	100	50	50	20	10	5	2
Drying Time in Hrs.	24	24	16	16	16	12	12	12

Tanking & Oil filling:

The tank is fabricated with high quality MS plates. The assembled job is placed carefully inside the tank. The bushings, tap switch drives and lug sockets are fitted on the tank. The oil is filled and the cover is placed on the tank frame and bolted. 2 coats of anticorrosive paint and 2 coats of enamel paint are painted on the outside of the tank. The inner portion of the tank is painted with varnish. Times for tanking and oil filling is given following table and tanking department having total 4 stations for working and one oil filling Machines. Once a transformer is put on station it is removed only after complete process;

Transformer Type	Generation			System		Distribution		
	200	100	50	50	20	10	5	2
Tanking Time in Hrs.	50	42	40	40	32	20	16	16
Oil filling Time in Hrs.	14	10	8	8	5	3	2	2

Testing:

The transformers are individually tested and the following routines tests are conducted in our lab:

No Load Loss, Full Load Loss, Double Frequency Double Voltage Test, High Voltage Test, Insulation Test, Measurement of Resistance, Heat Run Test, Pressure Test on Tank, Break Down Voltage - BDV and Acidity Test on Transformer Oil. Testing department has constrained due to testing procedure and Safety that, if they are conducting a test on one transformer they cannot do testing with another. Testing time mostly depend on



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which type of test is required by the client. Using past experience average times for testing different transformers is given in table below;

Transformer Type	Generation			System		Distribution		
	Power Range (MVA)	200	100	50	50	20	10	5
Testing Time in Hrs.	24	20	20	25	20	15	12	12

Dispatch:

Depending on transportation considerations, Power Systems transformers may be shipped either with or without bushings, radiators, fans, conservator and oil. Accordingly packing and loading is done in the company. Company has a large space for packing and loading transformers, so there no limitation, dispatch department can work on as many as possible transformers simultaneously without any constraints. Times for packing and dispatch of each transformer are given below;

Transformer Type	Generation			System		Distribution		
	Power Range (MVA)	200	100	50	50	20	10	5
Packing & loading Time in Hrs.	24	20	16	16	12	6	4	4

Question:

How should the Transformers be scheduled in the different departments in order to finish the complete order as early as possible?