MET 2 P1 2009

## Examiners General Remarks

The paper offered a range of questions that were varied in their technical content. The majority of the students tended to focus on those questions that required general discussions on technology rather than specific technical aspects of manufacturing. This is in line with previous years and shows little sign of change. Manufacturing design and sustainability questions (3,4) were answered very well and the students demonstrated high levels of understanding across the cohort in this respect. All in all the cohort exhibited a good level of general knowledge on the technical aspects of manufacturing and were worthy of the class average of 66..

## Question ONE Cribs

1a) The phenomenon of increasing logic density on integrated circuits was observed and commented on by Gordon Moore, co-founder of Intel, in 1965.

The observation was that the logic density of silicon integrated circuits has closely followed the curve (bits per square inch) = 2^(t-1962) where t is the time in years: that is the amount of information stored on a given amount of silicon has roughly doubled every year since the technology was invented. This relation held until the late 1970s at which point the doubling period slowed to 18 months. The doubling period remains around that value – although some sources now quote 2 years.

Provide graph of Moore's law

1b)

(i) The principal stages of ASIC manufacture:

There are two main sections: 'front end' or wafer fabrication, and 'back end' or test, assembly and packaging of the IC.

See Figure 2 from NXP, showing individual stages, or process steps, within these sections.

(ii) The principal consequence of Moore's law is the decreasing line width that is fundamental to the IC design. This line width is the separation distance of features on the circuit, and hence determines the density of transistors on the silicon. This progressive reduction of feature size over the last 45 years has had the following consequences for manufacturing processes:

- greater purity requirements for the semi-conducting materials
- cleaner manufacturing facilities and larger wafer diameters
- challenges to the optics for mask making and photolithography – leads to use of shorter wavelength light and diffraction effects
- doping technology moves from diffusion to ion implantation to reduce migration

- handling techniques require greater mechanical precision and avoidance of damage
- inspection and testing becomes lengthier and more automated. Testing is carried out as early as possible in order to avoid expensive scrap later in the process

If cleanliness and wafer diameter had not been increased, the decreasing line width would have greatly reduced process yields. The overall yield is made up of four individual key process step yields. The steps apply to all ICs, but the yield will vary depending on the complexity and volume of the chip. For a well established, high volume TV ASIC, the following figures could apply:

- wafer processing, 98%
- wafer probe, 87%
- assembly, 98%
- final test, 97%

This gives an overall yield of 80%, and hence the importance of improving yield at every stage can be seen, particularly wafer probe, which is where contamination defects become apparent.

1c)

The limitations to Moore's law relate to the physical limits of line width reduction that is achievable. This is predicted by the International Technology Roadmap for Semiconductors (ITRS) to reach 14 nm by 2020, although there are many manufacturing and design problems to be solved before that is achieved. Decreasing feature size leads to many problems of noise (electrical interference), heat dissipation and optical and handling precision. However history shows that these have been collectively solved by the industry so far over the last 20 years based on increasing investment, and the signs are that this will continue for the foreseeable future. Ultimately as line widths reduce further, there will be limits as the atomic scale is approached, due to quantum effects.

Organic semiconductors are at a much earlier stage of development, and an equivalent to Moore's law has not yet been articulated. They are not a replacement for silicon based semiconductors in most applications, but are useful in large area, low resolution circuits, for example displays and photovoltaic devices. In time, as the technology matures, an empirical law describing increasing circuit density may be proposed.

**Examiners Comments:**

This was a very popular, with 90% of the candidates answering this question, achieving an average of 65 and many high scoring answers.

About 25% of the candidates gave comprehensive answers to part a), with detailed description of the law, including the background to Moore's position in the industry (Intel), and a graph showing the rise in transistor density. Some students lost a number of marks by merely stating the law, without providing the relation as detailed by Moore and a graph showing the rise in circuit density.

Most candidates were able to give a good answer to part b)i, top marks were given to those candidates that detailed the process steps as shown in figure.2, marks lost by those that failed to describe the back end processing steps.

Often only general answers were given in part b)ii. Marks were often lost through the provision of limited discussions of the impact the law would have on yield, often cited without specific details described in the crib. High marks were awarded to those that detailed the critical yield increase or loss associated with each process step, and full marks were awarded to those candidates that could offer typical yield % values of the four major manufacturing steps listed in the cribs.

Answers to part c) were not very comprehensive, with candidates running out of information, often repeating the answers of previous sections. Few gave detailed discussions of the limits of heat loss, line widths, quantum effects, and cross talk. Although all candidates were able to indentify the limits of the applications of organic semiconductors. These were cited from knowledge of CDT and Plastic Logic manufacturing process steps given by industrial speakers.

**<u>Question TWO Crib.</u>**

Answer

(a) Produced by injection moulding to achieve high volume at low cost. Materials likely to be 'engineering' thermoplastics (e.g. ABS, PBT, PC, PET, PEEK, ...) rather than commodity (e.g. PE, PP, PVC, PS...) as these show undesirable dimensional changes over time, leading to poor tolerances. Choice will depend on properties required (eg modulus, strength, optical properties, gas permeability etc). High material specification – eg at least food grade, maybe pharmaceutical grade (US FDA approval may be required). Component is safety critical as failure can lead to failure to deliver adequate dose, or lead to over-delivery of dose – either can have serious, conceivably fatal consequences for the user. In injection moulding the manufacture of the mould with exactly correct dimensions is critical to achieving correct dimensions and properties of final part – so modelling of the moulding process is essential to avoid costly and wasteful trial and error approach. Model needs to take account of polymer injection process and heat transfer, so that final shape takes account of local variation of polymer properties, residual stresses etc. Tolerances in product need to be very close to achieve precise dosing and reliable performance so as well as model for moulding process, modelling of response of components to loads in use is valuable to ensure correct device function.

(b) Cylindrical steel rim formed from sheet by cutting to length, rolling profile shape to form circle and welding ends. Wheel disc formed from steel sheet by blanking to shape, press forming, piercing or drilling holes. Rim assembled to rim either by welding or in case of dismountable rims, by bolting. Component is safety-critical as failure of wheel would cause accident, involving damage to property, possibly injury, even fatality. Wheels are designed against plastic failure; fatigue failure is the critical mode. Rim failure is more desirable than disc failure, as it leads to tyre deflation rather than potential loss of wheel. Modelling of stress distribution in wheel under various service loads is used to optimise design and ensure that wheel always operates safely away from fatigue limits. Modelling can also be used to analyse internal stresses induced by forming and assembly processes, ensuring that distortion and internal stresses are acceptable.

(c) Two competing processes used to form wide-chord hollow fan blades. Titanium alloy is the material in both cases. First generation used hollow honeycomb structure as spacer bonded by diffusion bonding between the two outer sheets – disadvantage of stress concentration in service at the points of contact between the core and the skin. Second generation uses thin Ti alloy sheet diffusion bonded between the two skins, with a mask printed on to them to prevent bonding in selected areas. This structure is then subjected to superplastic forming with internal gas pressure which 'inflates' and separates the two skins and produces a zigzag continuous spacer, which gives lower stress concentration than the 1st generation honeycomb spacer. Fan blade is safety critical as failure can lead to complete engine failure, and potentially loss of the aircraft. Fatigue failure is most critical. Modelling of in-service stresses and temperature profiles as well is essential to provide optimal design (minimum weight consistent with required performance and acceptable life). Modelling of the diffusion bonding and superplastic forming processes would also be very useful in optimising the manufacturing process and achieving high yield.

**Examiners Comments**

57% of the candidates answered this question. Most candidates gave a good account of the safety critical aspects of manufactured components and good answers provided a detailed discussion of the links between design requirements, optimised production processes, and the means by which process modeling could be used to deliver information important to manufacturing process selection and general overall decision making.

Candidates lost marks in section i) through not providing sufficient information on the types of plastics that one could use, some merely stated "pharmaceutical plastics" rather than a list of the principle materials. Good answers detailed the material properties that would be desirable in such a device.

Candidates lost marks in section ii) by providing a very brief details of the manufacturing process steps for wheel production. This often lead to a limited discussion of the opportunities for process modeling, since they were unable to link the production steps with modeling outputs.

A number of candidates described the process of single crystal turbine blade production, rather than wide-chord fan blade production. Those that did answer correctly were able to provide a good account. Although marks were often lost by giving accounts that were too brief, or mentioning the use of "air" inflation rather than "Ar" inflation techniques, or simply stating "diffusion bonding and forming" without a detailed description of the SPFDB process steps and the tooling required for it.

In general the students knowledge of simulation and modelling techniques was rather poor. Cursory mention of Computer Aided Engineering was often provided, when one would like to have seen specific information on fluid, stress, thermal, or other characteristic modelling techniques, including their limitations, AND their benefits to the particular application in question.

**<u>Question THREE Crib</u>**

a) Briefly outline the origins and purpose of Value Analysis/Value Engineering (VA/VE), indicating the difference between Value Analysis and Value Engineering/

VA/VE was first introduced in the 1940s by General Electric, who produced consumer goods, as a tool to reduce costs and improve perceived 'value' to customers. Originally, VA was applied to goods that were currently in production. Later, the same tool was applied to goods that were at the design stage, only this time called VE. VE is therefore preferable, as it enables a focus on improving the design before production. VA is also however a valuable and useful tool in many companies.

b) Describe the main stages of VA/VE, and analyse the toothbrush design, to highlight opportunities for improving its value to customers.

Value is a relationship between function and cost. The value can be improved in one of the following ways.

$$\frac{F \rightarrow}{C \downarrow} \qquad \frac{F \uparrow}{C \rightarrow} \qquad \frac{F \uparrow}{C \downarrow} \qquad \frac{F \uparrow \uparrow}{C \uparrow} \qquad \frac{F \downarrow}{C \downarrow \downarrow}$$

The first step is to determine the primary functions of the device, preferably arranged as a tree structure. There are of course many possible functions, and different students will choose differently:

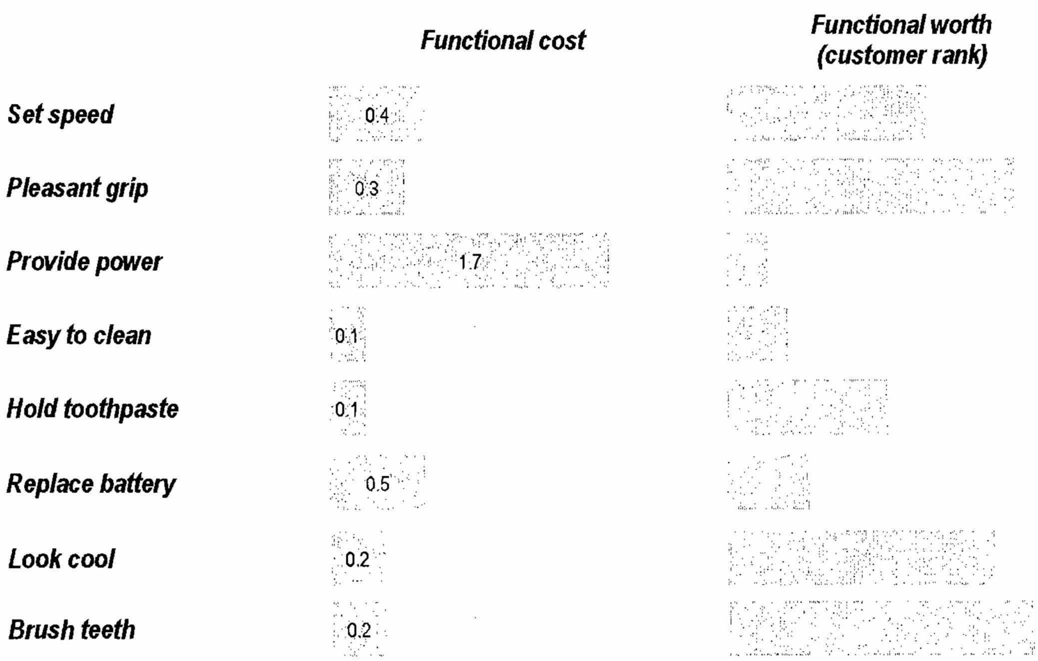
Functions:

- Clean teeth
    - Move bristles
        - Switch on/off
        - Activate motor
        - Provide power
    - Hold toothpaste
    - Appeal to customer
        - Look cool
    - Enable battery replacement
    - Be easy to clean
    - Comfortable grip

It is then necessary to select the functions that are viewed to be critical, and build the value matrix, combining the cost estimates with the functions. The student should be able to construct a sensible matrix.

| | Cost | Set Speed | Pleasant Grip | Provide Power | Easy to clean | Hold Toothpaste | Replace Battery | Look Cool | Brush teeth |
|---|---|---|---|---|---|---|---|---|---|
| Housing | 0.8 | | 0.3 | | 0.1 | | 0.2 | 0.2 | |
| Motor | 0.5 | 0.1 | | 0.4 | | | | | |
| Gearbox | 0.3 | 0.2 | | 0.1 | | | | | |
| Drive shaft | 0.2 | | | 0.2 | | | | | |
| Bristle-shaft | 0.2 | | | 0.2 | | | | | |
| Bristles | 0.3 | | | | | 0.1 | | | 0.2 |
| Switch | 0.2 | 0.1 | | 0.1 | | | | | |
| Batteries | 1.0 | | | 0.7 | | | 0.3 | | |
| **Cost of Function** | | **0.4** | **0.3** | **1.7** | **0.1** | **0.1** | **0.5** | **0.2** | **0.2** |
| | **100%** | | | | | | | | |

Next need to look for opportunities for improving value. First, the importance of the functions can be assessed using a paired comparison technique (Not done in this crib). Ideally this should be done by customers. The functional cost can then be compared with the functional worth:



This analysis suggests little cost is being applied to the most important functions, and that too much cost is being allocated to providing power, which customers might not view as essential. Opportunities for reducing the cost of this function should be explored.

More effort could also be made to make it look cool, and to improve the grip.

A good answer will include some sketches of product ideas.

c) Discuss the effectiveness of Value Analysis/Value Engineering as a design tool

Like all design tools, VA/VE is most effective at bringing together different functional perspectives. To be done well, it needs detailed costing information from production engineering, market insights from marketing and technical insights from engineering. This is its primary strength. Its weakness is that it might be viewed as producing a 'right answer'. It is very simple to bias the results to confirm already held prejudices.

**Examiners Comments**

In general, this was a well answered question with over 95% of the candidates answering. Most candidates gave good comprehensive answers. In general they were able to present a detailed VA/VE analysis and were able to identify the principle shortcomings of the design, i.e too much being spent on the power systems. Candidates often lost marks by not providing detailed discussions of the primary functions of the device, or by choosing functions that were not related to the parts list. This made a comprehensive assessment of the design quite difficult. Higher marks were achieved when candidates offered sketches of design improvements, in addition to detailed discussions of the aspects of re-design that would increase the value and reduce costs.

## <u>Question FOUR crib</u>

*(a) A* ***carbon footprint*** *is a measure of the amount of greenhouse gases produced (e.g. by burning fossil fuels for electricity, heating and transportation etc. It has units of tonnes (or kg) of carbon dioxide equivalent.*

*(b) The environmental impact can be assessed very differently by including or excluding components. This is dangerous: it means that selective use of data can be used to support any environmental impact argument (including Life Cycle Analysis, which does at least have an agreed methodology for what should be included).*

*Examples: A company whose core business is plastics injection-moulding might define its boundary narrowly as manufacturing operations from the receipt of* *polymer granules into the factory until the product leaves the shop floor. A very different answer would be obtained if the manufacture of the polymer itself were included, or its end-of-life impact. Similarly, it might be reasonable to include aspects of the factory infrastructure, such as the machinery or building.*

*(c) Panels will be made from aluminium or steel, protected using paints and lacquers. Reference should be made to specific manufacturing processes. Sheet metal should be assumed to be delivered to the factory; it will then be cut, pressed to shape and welded. Painting may be included.*

*Relevant factors which should be mentioned include:*

| | *Factors* | *How can impact be minimised?* |
|---|---|---|
| *Manufacturing operations:* | *Energy to power equipment* | *Turn off when not required.*<br><br>*Assess operations to see if energy requirements can be reduced (e.g. heat exchangers; different manufacturing processes).* |
| | *Maintenance of machinery* | *Renovate equipment, rather than disposing of it* |
| | *Out-of-specification parts* | *Improve quality control to avoid re-manufacturing costs.* |
| | *Materials* | *Avoid unnecessary waste: tailored blanks; cutting sequences. Design for manufacturability. Recycle waste as possible.*<br><br>*Minimise material usage by lightweighting parts.* |
| *Infrastructure* | *Lighting, heating / air conditioning of shop floor and offices.* | *Turn off when not needed. Insulate building.*<br><br>*Use green energy sources for heating.* |
| | *Office operations: photocopiers, computers, paper etc* | *Turn off when not needed; avoid waste of energy or materials; recycle.* |
| *Goods out* | *Packaging for panels* | *Use minimum material to adequately protect panels. Re-usable packaging as far as* |

| | | |
|---|---|---|
| | | *possible. Provision for recycling other materials.* |
| | *Transport* | *Minimise distance.*<br><br>*Use low-impact transport e.g. sea better than rail better than road better than air* |

*(d) Water is not covered explicitly (avoid wastage; install recirculating plant).*

*Lubricants: avoid where possible in machining operations (reduce recyclability); use low-impact lubricants for pressing and forging.*

*Paints: Use water-based rather than solvent-based. Avoid toxic chemicals in preparing for painting.*

**Examiners Comments**

This was a popular and generally well answered question. 75% of Candidates answered this question. In answers for part a) candidates often referred only to the emission of CO2 and did not offer further details such as units of measure or the means by which it is measured for various output sources, such as the Kaya identity. In part b) most candidates were able to give very comprehensive discussions concerning system boundaries with good examples from a range of sectors. Marks were lost largely due to lack of practical examples or limited discussions. Part c) was answered very well by all candidates, it is clear that current MET students have a good grasp of the environmental impact of manufacturing operations and there were some excellent examples of detailed outputs.

**Question FIVE Crib**

a) Process Intensification (PI) is a term used to describe the strategy of making dramatic reductions in the size of a manufacturing plant in order to reach a given production objective. The concept was pioneered in ICI during the late 1970s for chemical operations, when the primary goal was to reduce the capital cost of a production system.

i) The virtue of the PI approach can be realised when the main plant items involved in the process (i.e. reactors, heat exchangers, separators etc.) only contribute around 20% of the cost of a given plant. The balance is incurred by installation costs which involve pipework, structural support, civil engineering and so on. A major reduction of equipment size, coupled preferably with a degree of "telescoping" of equipment function - for example reactor/heat exchangers or combined condenser/distillation/re-boilers - could generate very significant cost savings by eliminating support structure, expensive column foundations and long pipe runs. In addition to the installation costs, current process plant is large and the use of high volume chemistry leads to physical limits, i.e. limited rates of mixing, diffusion, reactions and heat flow. Hence large scale infrastructure is required to deliver the required production volumes. (PI) is a highly innovative concept in the design of process plant. The aim of intensification is to optimise capital, energy, environmental and safety benefits. Process intensification can be an important means in reducing the costs of process integration, and process performance.

ii) Power Generation is able to provide technologies for distributed generation, an example here would be wind farms, fuel cells, local wind-turbines, solar collectors etc. A brief discussion of these technologies would be appropriate. An alternative and very radical solution is the distribution of nuclear power stations that are set to populate the globe. The system woks on sealed reactor that sits in the ground for 20 years and supplies around 20,000 homes with power.

a) <u>The benefits of may be summarised as:-</u>

*Intrinsic safety:* If equipment volumes are reduced by a factor Of 100-1000, then dangerous/toxix inventories will present much less of a threat to the environment/population.

*Environmental impact:* Conventional process plant is dominated by pipework, tall columns and cooling towers which spoil landscapes and affect the quality of life of local communities. Intensified plant can be hidden by trees at the boundary fence so plant can be harmonised better with its surroundings. There is also the opportunity for Lower waste levels reduce downstream purification costs and are conducive to "Green" manufacture economic distributed.

*Energy efficiency:* The improved transfer coefficients on supply lines which may be achieved in intensified equipment may reduce the system losses represented by

- Power line resistance
- Distribution management and control

*Better product quality:* More efficient controls over generation rates and operating conditions lead to improved and reliability and quality of supply.

*Just-in-time manufacture* becomes feasible local production of power.

*Distributed (rather than centralised) manufacture* may become economic allowing point-of-use or point-of-sale process technologies. There is also the opportunity for cost savings by avoiding transport of the product through lossy lines.

PI can help companies and others meet all of these demands, in the process industries and in other sectors

<u>The problems of exploitation of may be summarised as:-</u>

Step changes in equipment design/operation are involved. This creates problems when there is already an established process investment costing hundreds of millions of pounds, as it will be exceedingly difficult to justify a "scrap and start again" policy.

For PI to be fully effective, a very wide range of technology must be developed covering all of the main unit operations, and the ability to supply the demand

Most plant managers "rush to be second" and require full scale evidence of successful operation before they are prepared to take a any risk.

Design codes are needed for new equipment, these are not fully developed as the science and engineering of localised power generation is still in its infancy.

There is a need to distinguish between slow (>30s) and fast (<30s) response rates. Different PI technology will be needed for each regime.

The culture shock in batch dominated industries will be difficult to overcome.

**Examiners Comments**

This question was well answered although not popular, with only 30% of candidates choosing to answer. In answers for part a) parts i and ii, good answers provided a critical assessment of the benefits of PI, those candidates that used their engineering knowledge to offer technical justifications for the use of PI, i.e. increased diffusion rates, reaction rates, energy efficiencies etc, brought out by a reduction in scale gained the highest marks. Lower marks were given for offering generalized discussions. Some high scoring candidates provided in depth analysis of the benefits of local supply of power, using their knowledge of the renewable sector to highlight the possibilities of local provision (domestic) and the technologies and business practices that would be required to effect these solutions.

Low scoring candidates often limited their discussions in part b with generalized accounts. There are many positive and negative points to raise in the power generation sector, and around 30% of the candidates were able to cover all of the points raised in the cribs.

## Question SIX crib

a) Considerations in linking the automated assembly process.
   - it has to be able to present the components in such a way that the automation can perform the material handling and fastening operations required to secure the lid
   - it has to perform these operations within a suitable time frame to synchronise with the initial manual assembly process. (Within a 15 second cycle time).
   - it has to recognise and deal with error conditions

Several approaches could be used. It is unlikely that one robot would be able to do all the material handling and screwing within the cycle time, hence 2 pieces of automation are suggested. See fig.

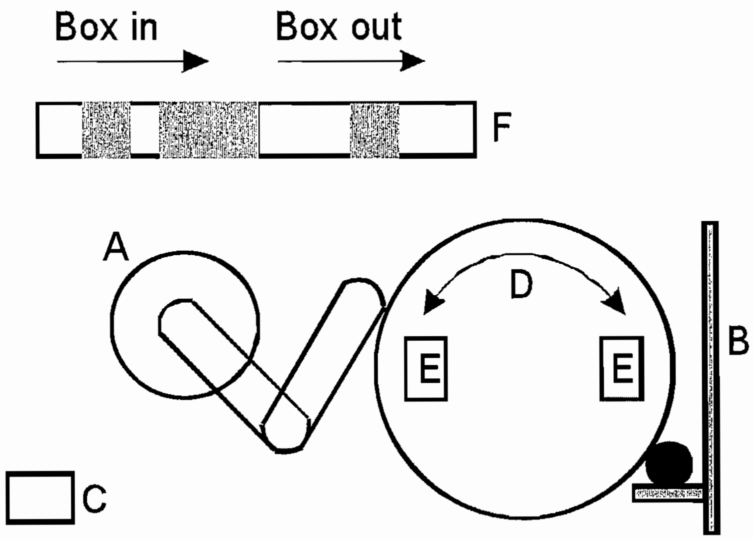
Boxes with the attached electronics board would be placed on a belt conveyor by the operator of the manual processes. They would enter the automated system via this conveyor system (f). This would provide an operational buffer capability between the two processes. There would be a gating system to roughly position the fixtures ready for pick-up. The positioning would be accurate enough to allow the box to be placed in the assembly fixture within the limits of travel of the pneumatic clamps, which would do the final accurate positioning.

The automated system would consist of a SCARA type robot, with vacuum end gripper (a), an automated screwdriver (b), gravity part feeder for box lids (c) and a rotary table (d) that can be rotated through 180 degrees into 2 fixed locations. Note each side of the rotary table would be fitted with an assembly fixture (e).

The SCARA robot would service one side of the rotary table loading a box from the conveyor system into a fixture on the rotary table. The fixture would clamp, accurately positioning the box. The SCARA would take a lid from the lids part feeder and place it accurately in position on the box. The table would rotate. The SCARA would unload a finished box onto the outgoing conveyor system.

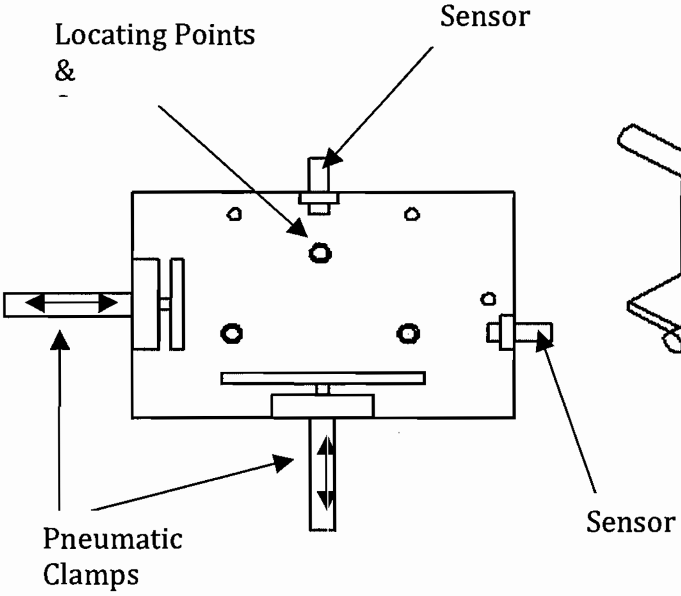
The opposite side of the rotary table would be serviced by the automated screw driver using dedicated automation, probably based on simple x,y,z coordinate slides, to fasten the lid of the box onto the lower box with four screws. (Purchase as self contained system)

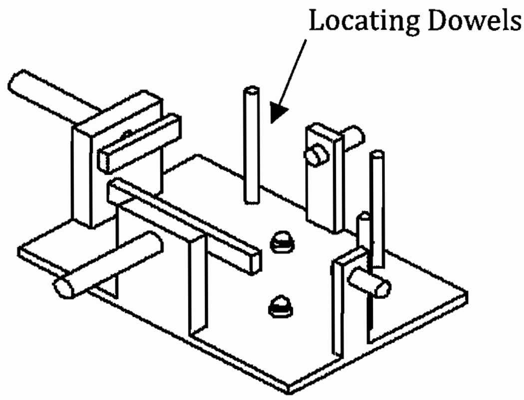
The rotary table would be used to rotate components between the two processes. It should be noted that by using the rotary table the fastening operation and the robot load / unload operation can be perform simultaneously. If rotate time of the turntable is 1s., that leaves 13 seconds to complete (loading / unloading) and 13 seconds to complete the fastening operation. Good practice would be to specify equipment that could perform slightly faster than this, allowing it to operate below its rated maximum ( ie 70% - 80% of max operating speed being 13 seconds.) This ensures robust operation, stability in performance and longer working life of equipment.




b) The fixture used for the automated assembly would be duplicated on either side of the rotary table. Its primary function is to locate components that need to be assembled and hold them in place during the fastening process.

To ensure that the components are located accurately and repeatedly it is important to make use of kinematic principles. This specifies that six points of contact are required to locate the box correctly in 3D. To ensure tolerances of components and their placement are catered for pneumatic pistons would be used locate parts against the fixed points. The stroke of the pneumatic pistons has to be long enough to ensure that the pistons can be redrawn far enough to ensure that the box components can be placed in the jig without fouling. (Below can be seen a top view of the fixture required)
The fixture would be fitted with sensors to ensure that the parts are correctly located in all three dimensions.




c) The most suitable types of sensors for this application would be none contact, such as optical diffused, or capacitive. These types of sensors work well with plastic components and can be purchased in a thread barrel type package that allows them to be easily positioned in the fixture for optimal operation. Due to their non-contact operation they have a much better operating life than typical contact devices.

| **Sensor Required** | **Location** |
|---|---|
| Robot (Vacuum sensor for gripper) | Gripper (Pneumatic system) |
| Robot (Lid in position) | Robot end effector (z axis) |
| Turn Table (Location of 180 Degree stop locations) | Turn Table (Bed) |
| Screw Driver (Screw at correct insertion level – Down) | Screw Driver (z Slide way) |
| Screw Driver (Screw at the correct torque setting – Tight) | Screw Driver (Motor mechanism) |
| Screw Driver (Replenishment of screws required) | Screw Driver |
| Gravity Lid Feeder (Lid in position and ready to be picked) | Gravity Lid Feeder (Bottom) |
| Gravity Lid Feeder (Replenishment of lids required) | Gravity Lid Feeder (Mid Point) |
| Fixture (Part Located in position) | As shown on fixture above |

| **Error Condition** | **Sensor Type** |
|---|---|

| | |
|---|---|
| Lid not in position | High accuracy optical diffused |
| Robot fails to pick up part | Vacuum Sensor on gripper |
| Part not clamped correctly | Fixture sensor optical diffused |
| Screw driver out of screws / miss feed | Screw driver Inductive sensor |
| Screw not fastened correctly (X thread) | Screw level inductive / torque |
| Screw thread damaged (Run the threads) | Screw Level inductive / torque |

**Examiners Comments**

This is the most technical question on paper, and as such attracted only 52% of candidates. Unlike the other questions, it requires the candidate to think of a new solution to a technical problem. MET students spend some considerable time in the Robot lab and as such should be well versed in problem solving of this kind. Despite this, the range of answers was quite considerable. For those that are comfortable with this type of problem, it is relatively straightforward and some excellent answers were given. In contrast, may students failed to provide a clear solution to the problem. Some were unable to offer more than cursory descriptions of the proposed solutions, and very few solved the problem efficiently. Many relying on a single robot with an indexing end effecter and screw driver. No candidate offered a solution with the level efficiency proposed in the crib, the rotational table allowing for two actions at once (plate fixing/removing and screwing of the lid)

Few candidates spotted the time constraints, and the consequent timing limits of the automated assembly requirements. Most candidates had rather limited ideas regarding the sensors and error conditions, and the answers to this section were rather disappointing. In general, this type of question offers rich pickings for candidates confident in the technical description of automated production systems, although they appear to be few and far between on the current MET course.

Examiner: W. O'Neill, 2009 June