Improving inventory management policies and establishing raw material stock levels

by

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Executive Summary

An extensive component of Wispeco Aluminium's expenses consists of buying raw materials and consumables used in the production process. Currently, the company does not have a scientifically-based system for inventory management of consumables and raw material stock levels.

After completion of this project, a flexible system will be in place which will assist Wispeco to correctly manage their inventory levels. This system will be derived by making use of a thorough literature study, studying best practices found in the industry and other operations management techniques. The system will determine the economic order quantity, reorder points and safety stock levels for all the products, which will in turn minimize the total costs associated with inventory management.

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Chapter 1

1.1 Introduction and Background

WISPECO (PTY) LTD began operations as a nail supplier during the First World War and has since then become one of the leading manufacturers and distributors of aluminium extrusions in South Africa. Wispeco consists of four main distinguishable operating units, namely: Die manufacturing, Aluminium extrusions, Finishing and Aluminium systems.

The Die manufacturing unit uses CAD designs and state of the art CAD CAM machining facilities, CNC milling machines and lathes in order to deliver a high quality product.
A variety of products can be extruded in the Aluminium extrusion section. These products include: Irrigation tubing, curtain railing, skirtings, ladders, architectural systems, partitioning, engineering sections, electrical bus bars and scaffolding.
The company specialises in both Powder Coating and Anodising finishes which are SABS approved and come in a variety of colours.

Raw materials contribute to an average of 77% of the monthly expenses at the Wispeco plant in Alrode, Gauteng. Similarly, the consumables in the production process also have a relatively large contribution factor towards the monthly expenses. It is therefore desirable to have an optimal solution in establishing raw material stock levels and to improve the inventory management policies and systems in order to save costs.

1.2 Project Aim

The aim of the project is to create and implement an improved inventory management policy for consumables and establishing raw material stock levels in order to save money.

1.3 Project Scope

The scope of the project is to improve the inventory management policies by establishing economic order quantities, reorder points and safety stock levels for both the raw materials and consumables used in the production process at Wispeco Aluminium. Factors such as the cost of consumables and raw materials, holding cost, ordering cost, the demand and lead times of products, etc., should be considered in developing an optimal solution for the project.

With the intention of narrowing the project scope, the project will not include the management of maintenance and/or administrative consumables and materials. Only individual ordering policies will be considered.

Chapter 2

Literature Review

Inventory

A distinction must be made between inventory and an inventory system. Inventory is the stock used in an organisation, business, service, or in a production process. An inventory system controls the inventory. These controls consist of different policies which determine the optimal stock levels, order quantities, frequency of orders etc.

2.1 Purpose of Inventory

There exist various reasons why it is favourable for a business or organisation to have inventory available. On the contrary, if inventory is not properly managed, it can cost a business a lot of money and/or the business can loose a great deal of its customers.

All firms, including firms using JIT (Just In Time) operations, must keep a supply of inventory for one or more of the following reasons as explained by Jacobs, Chase & Aquilano (2009):

2.1.1 Maintaining independence of operations

A flexible operations centre can be achieved by a good supply of materials. This supply will act as a cushion between independent workstations on an assembly line with different performance times. This cushion will reduce the number of setups, and therefore the total setup cost.

2.1.2 Meeting variation in product demand

Since it is impossible to completely know the demand for a product, a level of stock must be maintained to absorb the variation. This type of stock is known as safety stock or buffer stock.

2.1.3 Allowing flexibility in production scheduling

After the setup has been made, larger number of units favours high setup costs. Sufficient inventory levels lessen the strain on the production system to get the goods out.

2.1.4 Providing a safeguard for variation in raw material delivery time

A lost order, faulty material, wrong material, a normal variation in shipping time, an unforeseen strike at the vendor's stand or at one of the shipping companies, or a shortage of material at the vendor's plant causing backlogs are all reasons why delays can occur when stock is ordered from a vendor.

2.1.5 Taking advantage of economic purchase order size

Since there exist of various costs for making an order, larger-, less frequent orders are usually more economical than smaller-, more frequent orders. These costs include, but are not limited to: phone calls, postage, and labour. Similarly, larger shipments reduce the per-unit costs.

It must be noted however, that lengthy cycle times require large amounts of inventory, which leads to large holding costs.

Other objectives of inventory are to decrease the difference between the supply and the demand for a product and to improve customer service.

2.2 Types of Inventory

Inventory can be grouped into different types of inventory. It is important to note that some of these inventory types are also identified by other names. Inventory types are strongly related and decisions regarding inventory management should never be made by isolating one type of inventory. The most important types of inventories and their purposes are discussed below:

2.2.1 Raw Materials

In a manufacturing organisation, raw material inventory are those materials which have not yet received any form of transformation within the company, and act as an input to the production process. Raw material inventory is kept with the intention of separating production functions from purchasing functions and to minimize production delays which may occur as a result of defective material, shipment problems, etc.

2.2.2 Work In Progress

Work-in-progress (WIP) inventory are materials that have unfinished work done on them, but are in storage, waiting to be processed by the next task. Longer and more complex production processes have larger WIP investments. WIP inventory is used to separate various production processes in order to avoid a stoppage of the entire production process caused by work stoppages or machine malfunctions.

2.2.3 Anticipation Inventory

Anticipation inventory is excess inventory which is kept for when an unknown future event should occur. Examples of possible events include, but are not limited to seasonal demands, price increases, and strikes. Some organisations which produce products with seasonal demands will build up their anticipation inventories during low demand seasons and then use this excess stock during peak seasons.

2.2.4 Buffer Inventory

Buffer inventory or safety stocks are used as a cushion to guard a company from the variations found in supply and demand. Buffer inventory are used to improve an organisations customer service by increasing availability and reducing backorders.

2.2.5 Finished Goods

Finished goods inventory is products which completed the entire production process cycle. If necessary, these goods have already passed the inspected stage and are awaiting sales. Finished goods are kept in inventory with the intention of separating the production functions from the sales functions in order to meet the demand and to eliminate lost of sales.

2.3 Inventory Costs

Inventory management is all about controlling an organisation's inventory in the most economical manner possible and minimizing the total costs associated with the inventory. For calculating the most economical inventory model, the inventory system needs to be broken up into different kinds of inventory costs:

2.3.1 Unit Purchasing Cost

The unit purchasing cost is the expenditure associated with purchasing one unit. The unit purchasing cost includes all the variable costs associated with producing a single unit and shipping the unit from an external vendor.

2.3.2 Holding or Carrying Cost

The holding or carrying cost is the cost of carrying one unit of inventory for one period of time. The carrying cost is made up of a variety of components which include:

- Interest lost on invested capital tied up in inventories
- Taxes on inventories
- Obsolescence
- Handling cost
- Insurance of inventories
- Storage facilities cost
- Pilferage cost
- Risk of spoilage
- Depreciation and/or deterioration of inventories

It is important to note that high carrying costs have a tendency to favour small inventory levels and regular replacement.

2.3.3 Ordering Cost

Ordering cost is independent of the quantity of items and amount of each item ordered. Ordering cost can be sub divided into the following categories:

- Writing and processing of the order
- Tracking orders
- Inspecting and storing of inventory received
- Handling the stock at receiving
- Invoice processing for payment

2.3.4 Setup Cost

Setup cost occurs within manufacturing organisations. Jacobs, Chase & Aquilano (2009) explains that manufacturing different products involves obtaining the necessary material, arranging specific equipment setups, filling out the required papers, appropriately charging time and materials, and moving out the previous stock of material. All of the above actions contribute to the total setup cost. They go further by saying that if no costs or loss of time in changing from one product to another occur, many small lots would be produced. This would reduce inventory levels, with a resulting savings in cost.

2.3.5 Stockout, Shortage or Depletion Cost

Stockout cost, shortage cost and depletion cost are all synonyms for the costs involved in failing to meet a demand on time. WL Winston (2004) explains that demands may be back-ordered if customers will accept delivery at a later date. Backlogged demand is often used in cases in which back-ordering is endorsed. The lost sales case occurs if customers will not accept late delivery. A vague estimate of the optimal inventory policy can be determined by calculating the optimal inventory policies of these two extremes cases. Back-orders generally results in extra costs. Lost of sales and lost of goodwill are usually the results of stockouts.

Of all the costs involve in inventory management, the costs of stockouts are generally the hardest to calculate. Providentially, stockout cost is often very insensitive to errors in estimating the total cost of the inventory system.

2.4 Inventory Policies

An inventory policy describes inventory management issues in a company like when to place an order, how much to order, etc. The inventory policy reveals a company's approach to inventory management. There exist various inventory policies of which the most important and most frequently used policies are described in the following text.

2.4.1 The (s, S) Inventory Policy

In this inventory policy an organisation has a certain quantity of inventory on hand. As soon as the inventory level on hand become less than, or equal to s, a new order will immediately be placed which will fill the inventory level up to a quantity of S units. The (s, S) inventory policy is a continuous review policy.

2.4.2 The (S-1, S) Inventory Policy

The (S-1, S) inventory policy is also known as the base stock policy. One usually comes across this policy within companies who deal with very expensive products and products with long lead times. This policy requires that an order is placed as soon as one of the products in inventory have been used. A continuous review is essential for the (S-1, S) inventory policy.

2.4.3 The (r, q) Inventory Policy

The (r, q) inventory policy is a continuous review policy where q amount of inventory is ordered as soon as the inventory level on hand reaches the reorder point r. The (r, q) inventory policy is the most commonly used policy. As opposed to r, some organisations use the safety stock level s for this inventory policy.

2.4.4 The (R, S) Inventory Policy

The (R, S) inventory policy is an periodically reviewed policy where an order is placed every R units of time to bring the inventory level on hand up to S units. WL Winston (2004) explains that one can foresee when an order is going to be placed and that the (R, S) inventory model is much easier to govern than any other continuous review policy. A drawback of the (R, S) inventory policy is that it usually has a very high holding cost.

2.5 ABC Inventory Analysis

Coyle, Bardi & Langley (2003) explains that the ABC analysis is ingrained in Pareto's law. Pareto's law, which is also known as the 80-20 principle, separates the vital few from the trivial many. This analysis is used to classify items according to different characteristic which includes, but are not limited to: stockout costs, lead times and sales volumes.

In performing an ABC analysis, we separate the items into three different groups relative to the impact or value which these items hold. The items with the greatest value or impact contribute to group A. Group B and C consist of items which have a less significant value or impact.

In terms of inventory management, the ABC analysis suggests that a relatively small quantity of units contribute to a relative large total of sales and income. As an example, Figure 1 illustrates a company of which 80% of its total sales are made up from only 20% of its products. Here the 20% of products makes up group A, while approximately 50% of the products make up group B (about 15% of the total sales). Group C is made up of the remaining 30% with a 5% contribution to the sales.

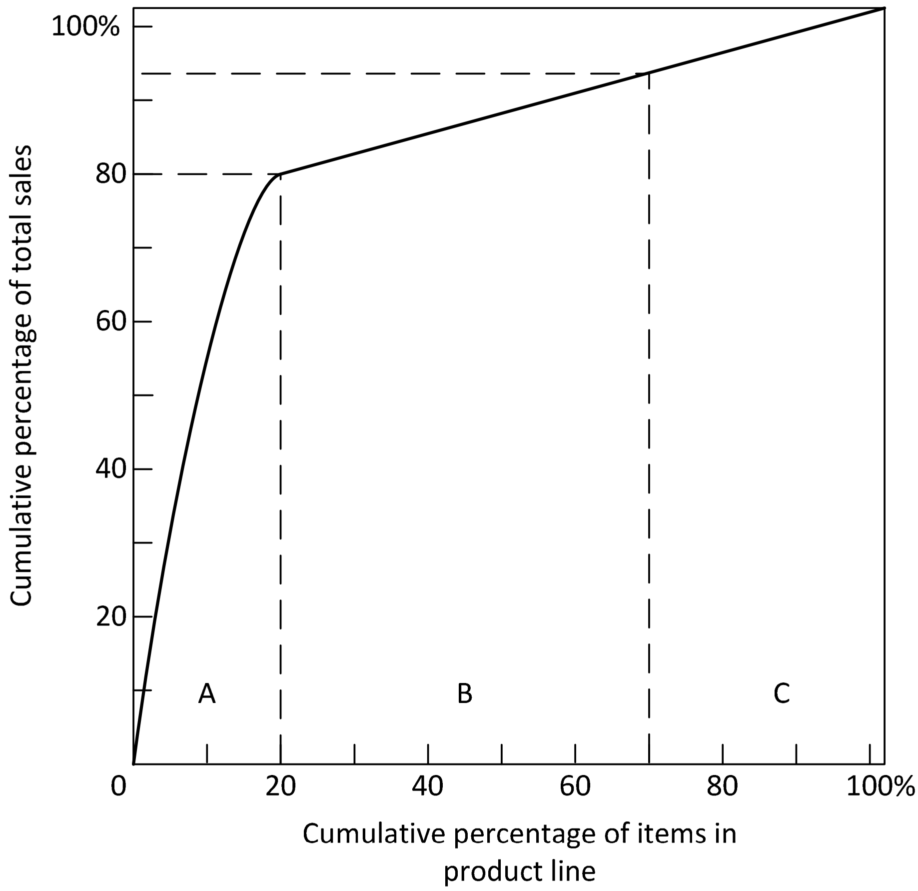

Figure 1: ABC inventory analysis. Coyle, Bardi & Langley (2003, p.209)

This analysis gives a clear indication of which products a company should always have available (Group A's products), and which product is not as important to always have on hand (Group B and C). It is important to note that the products of group B or C should always be on hand if it compliments the products from group A.

There are three steps for performing an ABC inventory analysis. The first step is to decide on a decisive factor for developing the ranking. An example of such a decisive factor is sales revenue. The second step is to rank the items according to the criterion in a descending order of importance. Finally, subjectively assign the items into group A, B or C. Coyle, Bardi & Langley (2003).

2.6 Inventory Models

Inventory models are used in organisations to determine the most economical inventory management policies for meeting the customers demand. According to WL Winston (2004), inventory models should be divided into two groups, namely:

1) Deterministic EOQ (Economic Order Quantity) Inventory models
2) Probabilistic Inventory models

Deterministic EOQ models are used for inventory decisions when the demand is known in advance. Probabilistic inventory models are those models used when the demand over a certain time period is random, or unknown.

2.6.1 Purpose of Inventory Models

WL Winston (2004) point out that the purpose of inventory models is to minimize the costs associated with maintaining inventory and meeting the customers demand. Inventory models present an organisation with a structure for controlling and preserving goods to be stocked. An inventory model is responsible for the timing of order placement, quantity of products ordered and from which vendor to order.

2.6.2 Inventory Models Decisions

According to WL Winston (2004), inventory models are used to answer the following questions:

1) How frequently should an order for a product be placed?
2) How many should be ordered?

2.7 Deterministic EOQ Inventory Models

As described earlier, deterministic EOQ inventory models are those models used when the demand is known in advance. There are various different types of deterministic EOQ inventory models in existence which can be used for different circumstances. The most important models will be discussed.

2.7.1 Assumptions of EOQ Models

According to WL Winston (2004), various assumptions should be considered when using EOQ models. These assumptions are:

2.7.1.1 Repetitive Ordering

The ordering decision is a continuously repeated process. In other words, an organisation will place an order; wait until the inventory is depleted and than start the process all over again.

In contrast with a repetitive order, an one-time order is an order which is only placed once and refer to single-period inventory models.

2.7.1.2 Constant Demand

WL Winston (2004) explains that the demand is said to occur at a known, constant rate. This implies, for example, that if the demand occurs at an annual rate of 500 units, the demand during any t-month period will be $\frac{500t}{12}$.

2.7.1.3 Constant Lead Time

The lead time can be defined as the length of time it takes for an order to arrive after the order has been placed. The lead time for each order is assumed to be a known constant.

2.7.1.4 Continuous Ordering

Continuous review models are models where an order may be placed at any time. We are dealing with a periodic review model if orders may only be placed periodically, i.e. the amount of on-hand inventory is reviewed periodically. For example, if an organisation examines its inventory, say only once a week, and then makes a decision on whether or not to place a new order accordingly.

2.7.2 EOQ Variables and Notation

The natation which will be used throughout different types of EOQ inventory models is given as:

b	=	Point of price break
c	=	Unit cost
D	=	Demand per time unit
h	=	Holding cost for one unit in inventory for one unit of time
I	=	Inventory level
K	=	Setup or ordering cost
L	=	Lead time
n	=	Number of orders per time unit
p	=	Purchasing cost
q	=	Order quantity
r	=	Rate of production per time unit ($r > D$)
s	=	Shortage cost of one unit for one unit of time
t	=	Time between orders

2.7.3 The Basic EOQ Model

2.7.3.1 Assumptions of the Basic EOQ Model

For the basic EOQ model to hold, WL Winston (2004) has identified various assumptions. These assumptions are:

- One year is equal to one unit of time
- The demand is constant and deterministic
- Shortages are not allowed
- Each order's lead time is zero
- The purchasing cost and the order size is independent

The first two assumptions imply that the demand will always be *Dt*.

2.7.3.2 Derivation of the Basic EOQ Model

The following derivation of the basic EOQ model is based on the derivation found in WL Winston (2004). If *q* units are ordered every time the inventory level, *I*, equals zero, then the total annual cost will be *TC(q)*. That is,

TC(q) = annual ordering cost + annual purchasing cost + annual holding cost.

The annual ordering cost is given by

$$Ordering\ Cost\ per\ Year = \left(\frac{Ordering\ cost}{Order}\right)\left(\frac{Orders}{Year}\right) = \frac{KD}{q}$$

The annual purchasing cost is given by

$$Purchasing\ Cost\ per\ Year = \left(\frac{Purchasing\ cost}{Unit}\right)\left(\frac{Units\ purchased}{Year}\right) = pD$$

In order to compute the annual holding cost, let us consider the behaviour of inventory levels over time. Figure 2 illustrates this inventory level behaviour. Since the annual demand is equal to *D*, it will take $\frac{q}{D}$ years for the inventory level to be exhausted, given that an order size of *q* is received at time zero. The declining straight line between any two time intervals, *t*, will have a slope which is equal to negative the annual demand (-*D*). Every time the inventory level is exhausted, a new order will be placed. The inventory level will immediately rise the order quantity, *q*. The entire cycle will repeat itself after each time interval. The horizontal dotted line in Figure 2 represents the average inventory level and can be computed by calculating half of the maximum inventory level.

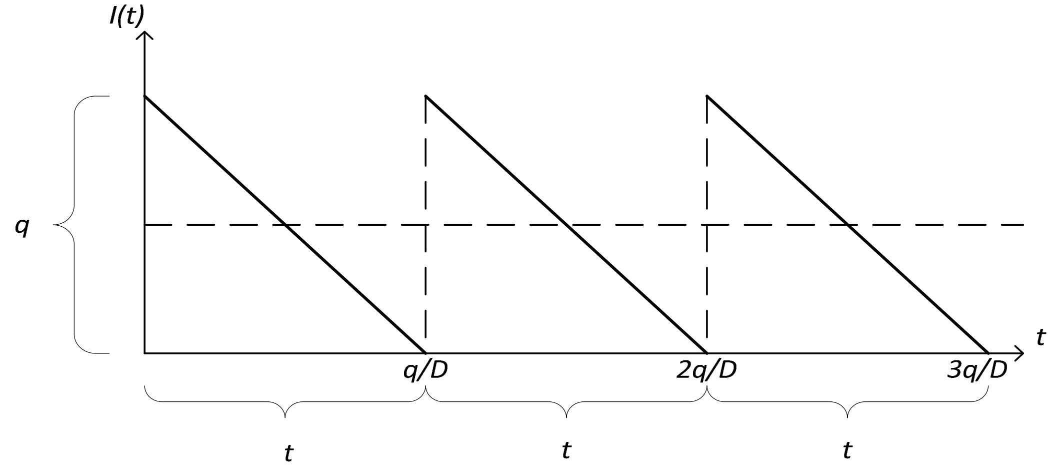

Figure 2: Behaviour of inventory level over time in the Basic EOQ Model. WL Winston (2004, p.107)

The annual holding cost can now be calculated as follow:

$$Holding\ Cost\ per\ Year = \left(\frac{Holding\ cost}{Cycle}\right)\left(\frac{Cycles}{Year}\right) = \left(\frac{q}{2}\right)\left(\frac{q}{D}\right)(h)\left(\frac{D}{q}\right) = \frac{hq}{2}$$

This means that the total annual cost can now be written as

$$TC(q) = \frac{KD}{q} + pD + \frac{hq}{2}$$

To find the optimal order quantity, we need to find a value for *q* which minimizes the total annual cost. In order to find this, we take the derivative of *TC(q)* and set it equal to zero.

$$TC' = -\frac{KD}{q^2} + \frac{h}{2} = 0 = \pm\sqrt{\frac{2KD}{h}}$$

If we take the second derivative of the total annual cost, *TC(q)''*, we see that *q* will minimize the total cost if $q > 0$. We can thus say that the economic order quantity q^* is

$$q^* = \sqrt{\frac{2KD}{h}}$$

Figure 3 illustrates that the annual holding cost will be equal to the annual ordering cost if q^* is ordered.

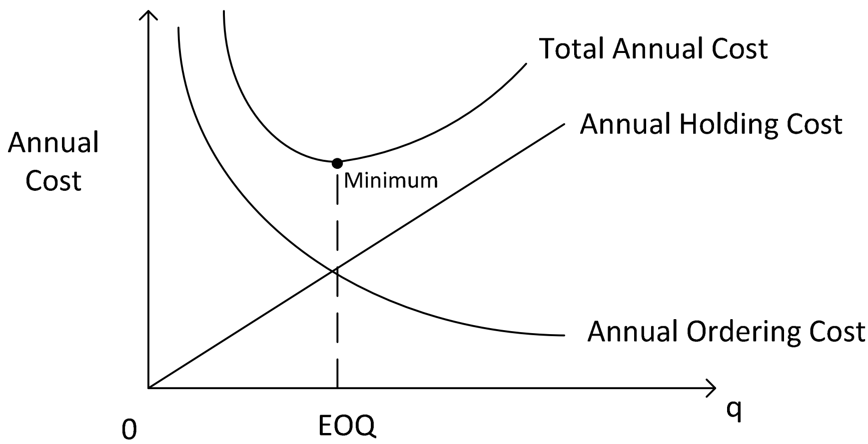

Figure 3: Min cost if annual holding cost equals annual ordering cost. WL Winston (2004, p.109)

2.7.4 EOQ Model with Nonzero Lead Times

Let's assume that the nonzero lead time assumption is invalid and that we allow lead times. The lead times would not change the annual holding cost, nor will it change the annual ordering cost. This implies that the EOQ stays the same as derived for the basic EOQ model. With the aim of minimizing annual holding cost by preventing shortages, the reorder point should now take place at an earlier stage. To determine this reorder point, WL Winston (2004) considers two distinct cases.

In the first case we assume that the lead time is smaller than the EOQ ($LD \leq EOQ$). In this case, the reorder point should take place when the product of the lead time and demand is equal to the inventory level. This will ensure that the order will arrive just as the inventory level is equal to zero.

In the second case, we assume that the lead time is greater than the EOQ ($LD > EOQ$). Here we divide *LD* by the EOQ. The remainder of $\frac{LD}{EOQ}$ will be equal to the reorder point. Again, this lead time will ensure that the order will arrive in time to prevent shortages.

2.7.5 EOQ when Quantity Discounts are Allowed

For models where discounts are allowed, it is important to note that the annual purchasing cost depends on the order size. This occurs when you buy in bulk quantities and it is known as quantity discounts. To calculate the EOQ in this situation, WL Winston (2004) analysed it as follows. Let q be the quantity ordered, and b_k be the price break points. For this model, we assume

- $TC_i(q)$ to be the total annual cost where p_i is the purchasing price
- EOQ_i is the optimal quantity for p_i
- EOQ_i is allowed if $b_{i-1} \leq EOQ_i < b_i$
- $TC(q)$ is the actual cost per year and is determined by using p_i as the purchasing price if $b_{i-1} \leq b_i$

The value of q which minimizes $TC(q)$, are usually found at some EOQ_i or at a break point b_k. This means that $TC_k(q) < TC_{k-1}(q) < \ldots < TC_2(q) < TC_1(q)$ for all values of q.

According to WL Winston (2004), the following steps are used to solve the EOQ where price breaks are present:

Start with calculating the order quantity which minimizes the total annual costs for $b_{i-1} \leq q < b_i$, beginning with the lowest price and call it q_i^*. Determine all the $q_k^*, q_{k-1}^*, \ldots$ until a q_i^* is reached which is admissible. This will result in $q_i^* = EOQ_i$. The quantity with the smallest *TC(q)* value from $\{q_k^*, q_{k-1}^*, \ldots, q_i^*\}$ will be the optimal EOQ.

2.7.6 Continuous Rate EOQ Model

The continuous rate EOQ model is used when an organisation produces its own products with the intention of meeting the demand. For the continuous rate EOQ model, WL Winston (2004) assumes that no shortages are allowed and that the demand is at a constant rate and deterministic. Let *r* be the number of units the company produce per time unit, *t* (we select *t* to be one year). For this model, WL Winston (2004) define the following variables

D = The products annual demand

h = Annual holding cost for one inventory unit per

K = Setup cost per production run

q = Quantity of units produced for the period of one production run

Figure 4 illustrates the behaviour of the inventory over time. At time zero, we produce at an annual rate of *r* units, while the annual demand is *D* units. This implies that if *r* ≥ *D,* the inventory rise at a rate of *r-D* units per year, until *q* units are reached. Shortages would occur if *r* ≤ *D*. If *q* units have been produced (at time $\frac{q}{r}$), the production run is stopped and the inventory level diminishes at a rate equal to the annual demand, until no inventory is left. This will occur at time $\frac{q}{D}$ and the cycle will repeat itself.

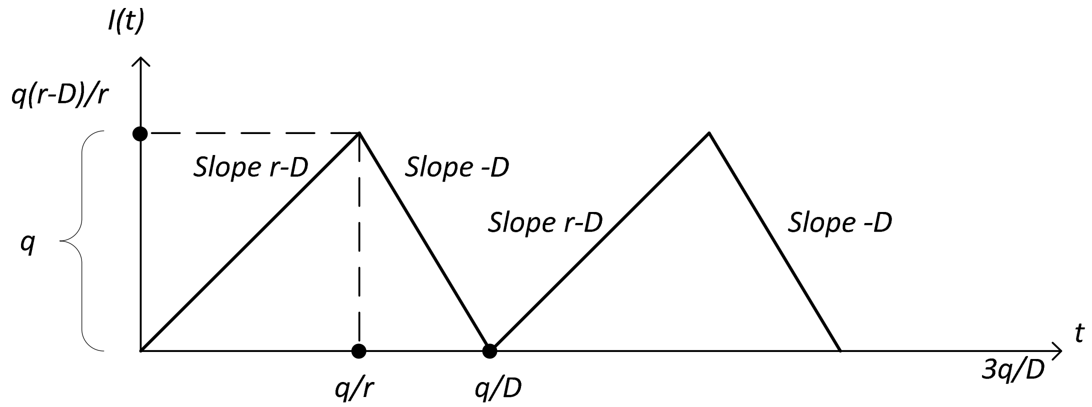

Figure 4: Behaviour of inventory for Continuous Rate EOQ model. WL Winston (2004, p.123)

According to WL Winston (2004) we need to find a value for q which will minimize

$$\frac{Holding\ cost}{Year} + \frac{Setup\ cost}{Year}$$

Since the demand has a constant rate, the average inventory level will be half the maximum inventory level. Thus,

$$Avarage\ Inventory\ Level = \left(\frac{1}{2}\right)\left(\frac{q}{r}\right)(r - D)$$

This gives us

$$Holding\ Cost\ per\ Year = h(Average\ Anventory)(One\ Year) = \frac{h(r-D)q}{2r}$$

$$Ordering\ Cost\ per\ Year = \left(\frac{Ordering\ cost}{Cycle}\right)\left(\frac{Cycles}{Year}\right) = \frac{KD}{q}$$

This implies that

$$Holding\ Cost\ per\ Year + Ordering\ Cost\ per\ Year = \frac{hq(r-D)}{2r} + \frac{KD}{q}$$

Substituting this into the basic EOQ model, we get

$$Optimal\ Run\ Size = \sqrt{\frac{2KD}{\frac{h(r-D)}{r}}} = \sqrt{\frac{2KDr}{h(r-D)}}$$

If r has a tendency towards infinity, the continuous rate model's optimal run size approaches $EOQ = \sqrt{\frac{2KD}{h}}$.

2.7.7 EOQ Model where Back Orders are Allowed

In the case where shortages are allowed, companies lose money as more costs are involved. These costs include future lost of goodwill, placing special orders and loss of clients and business. WL Winston (2004) explains that when shortages are possible, we need to define the cost of being short by one unit for one year (*s*). He also assumes that no sales are lost and that all the demand is backlogged. Let q - M be the maximum shortage that takes place within an ordering policy. This implies that every time an order is placed, the company will experience a shortage of q - M units, assuming a lead time of zero. From Figure 5 we can see that the maximum inventory level will always be $M - q + q = M$. Seeing that the pattern on Figure 5 repeats itself between *O* and *A*, and *B* and *D*, we can call *OB* and *BD* cycles.

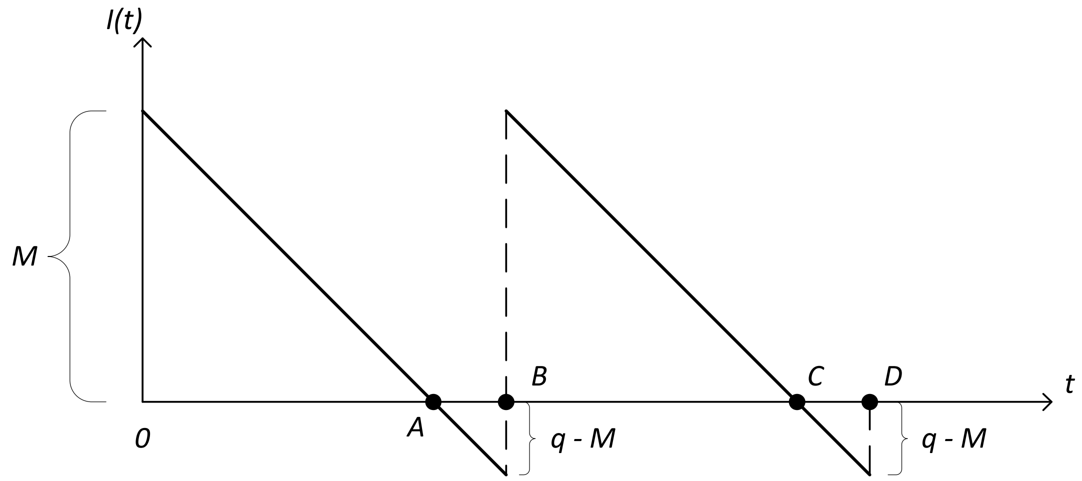

Figure 5: Behaviour of inventory over time for EOQ model where Back Orders are allowed. WL Winston (2004, p. 126)

WL Winston (2004) explains further that since the purchasing costs is independent on both *M* and *q*, the annual costs can be minimized by finding values for *M* and *q* which minimize

$$Holding\ Cost\ per\ Year + Storage\ Cost\ per\ Year + Ordering\ Cost\ per\ Year$$

The inventory level is depleted when the demand is *M* units. Therefore, the length of interval *OA* is equal to $\frac{M}{D}$. Similarly, OB = $\frac{q}{D}$ since every cycle ends when after *q* units have been demanded. Now

$$Length\ of\ AB = (length\ of\ OB) - \ (length\ of\ OA) = \frac{q-M}{D}$$

The holding cost per cycle is equal to the holding cost from time *O* up to time *A*. From Figure 5 we see that the average level of inventory between *O* and *A* is half of *M*. This gives us,

$$Holding\ Cost\ per\ Cycle = \left(\frac{M}{2}\right)\left(\frac{M}{D}\right)h = \frac{M^2h}{2D}$$

With $\frac{D}{q}$ cycles per year, we get,

$$Holding\ Cost\ per\ Year = \left(\frac{M^2h}{2D}\right)\left(\frac{D}{q}\right) = \frac{M^2h}{2q}$$

Similarly, the average shortage level is the same as half the maximum shortage, and the length of segment $AB = \frac{q-M}{2}$ with $\frac{D}{q}$ cycles per year, we find

$$Shortage\ Cost\ per\ Year = \left(\frac{(q-M)^2s}{2D}\right)\left(\frac{D}{q}\right) = \frac{(q-M)^2s}{2q}$$

In order to find the optimal *q* value, we need to find the appropriate values for *q* and *M* which will minimize the total cost. That is, minimize

$$TC(q, M) = \frac{M^2 h}{2q} + \frac{(q - M)^2 s}{2q} + \frac{KD}{q}$$

Making use of further algebraic manipulation we find that q^* and M^* can be written as

$$q^* = \sqrt{\frac{2KD(h + s)}{hs}}$$

$$M^* = \sqrt{\frac{2KDs}{h(h + s)}}$$

The optimal maximum shortage which should be allowed is q^* - M^*.

2.7.8 Continuous Rate EOQ Model when Back Orders are Allowed

For this EOQ model we assume that a company produces its own products at a continuous rate and that back orders are allowed. WL Winston (2004) shows that in this case, the optimal EOQ is

$$q^* = \sqrt{\frac{2KDr(h + s)}{h(r - D)s}}$$

The maximum inventory level is

$$M^* = \frac{q^*(r - D)}{r} - \sqrt{\frac{2KD(r - D)h}{sr(h + s)}}$$

Finally, the maximum shortage (S^*) which will occur in this case is

$$S^* = \sqrt{\frac{2KD(r - D)h}{sr(h + s)}}$$

2.8 Probabilistic Inventory Models

As described earlier, probabilistic inventory models are those models used when the demand over a certain time period is random, or unknown. The most important probabilistic inventory models and other techniques used to solve inventory models will be discussed.

2.8.1 The News Vendor Problem: Discrete Demand

From time to time it happens that companies are faced with the following set of events:

- Let *q* be the quantity of units a firm chooses to order
- Let *d* be a nonnegative demand of units which occur with a probability of *p(d)*. Then *D* is the random variable which symbolize the demand
- The cost, *c(d,q)*, incurred is a function of *d* and *q*

WL Winston (2004) calls this the news vendor problem with discrete demand. He argues that a newspaper vender needs to make a daily decision of how many newspapers should be ordered. If he orders too few papers he will loose money and if he orders too many papers he would have also spend more money than what was necessary.

If we let c_o be the overstocking cost per unit and c_u the under stocking cost per unit, we can determine that

$$c(d,q) = c_o q + (terms\ not\ involving\ q), for\ (d \leq q, i.e. overstock)$$

and

$$c(d,q) = -c_u q + (terms\ not\ involving\ q), for\ (d \geq q+1, i.e. understock)$$

We use marginal analysis to minimize the expected cost, *E(q)*, for placing *q* units. This means that the smallest value of *q* should be found for which $E(q+1) - E(q) \geq 0$. For this we consider two different cases.

In the first case we assume that the demand is smaller than, or equal to, *q*. For every unit we order extra, we amplify the cost by c_o.

In the second case we assume that the demand is greater than, or equal to, *q+1*. This means that for every *q+1* unit we place an orders for, instead of *q* units, we are reducing the cost by c_u.

The probability for the first case to occur is $P(D \leq q)$ and for the second case its $P(D \geq q+1) = 1 - P(D \leq q)$. This means that the average cost for ordering *q+1* units will be

$$c_o P(D \leq q) - c_u[1 - P(D \leq q)]$$

more than for ordering only *q* units.

This means that

$$E(q+1) - E(q) = c_o P(D \leq q) - c_u[1 - P(D \leq q)]$$

But $E(q+1) - E(q)$ will only be greater or equal to zero if

$$(c_o + c_u)P(D \leq q) - c_u \geq 0$$

or when

$$P(D \leq q) \geq \frac{c_u}{c_o + c_u}$$

This indicates that *E(q)* will be a minimum if we use the smallest *q*. Let's call this *q*-value q^* and define the demand distribution function as $F(q) = P(D \leq q)$. We can now conclude that $F(q^*) \geq \frac{c_u}{c_o c_u}$. WL Winston (2004).

2.8.2 The News Vendor Problem: Continuous Demand

Consider the same news vendor model as developed in the previous section, but this time the demand is a continuous random variable with a density function of *f(d)*. WL Winston (2004) explains that if we use Leibniz's rule, we can transform the expected cost of the decision maker to be a minimum by ordering q^* units. q^* is the smallest amount of units that satisfy

$$P(D \leq q^*) \geq \frac{c_u}{c_o + c_u}$$

For the q^* value to be optimal it must satisfy the following equations

$$P(D \leq q^*) = \frac{c_u}{c_o + c_u} \quad or \quad P(D \geq q^*) = \frac{c_o}{c_o + c_u}$$

It can be seen from above that the optimal quantity of units to order exists at the point where there is a chance of $\frac{c_0}{c_o + c_u}$ that the last unit will be sold.

2.8.3 Uncertain Demand EOQ Models

For these EOQ models with uncertain demand WL Winston (2004) assume that

- The there exist a nonzero lead time
- The demand is random
- Backlogs are allowed
- The review model is continuous

WL Winston (2004) defines *D* to be the annual demand with a standard deviation of σ_D, a variance of var *D*, and a mean of *E(D).* c_B is defined as the cost associated with every unit short and is independent on the duration of the stockout. The inventory on hand at time *t* is written as *OHI(t). I(t)* is the level of net inventory at time *t* and *r* is known as the reorder point. *B(t)* is the quantity of back orders outstanding at time *t*.

As an example, consider the reorder point model in Figure 6. Here we see that we place an order of *q* units whenever the inventory level drops to *r*. If an order is placed at time O_1, the order will only be received at time $O_1 + L$ as a result of the lead time of 2 time units.

Assume X is a continuous random variable which represents the demand during the lead time with a variance of var X, standard deviation of σ_X, mean of *E(X)* and a density function of *f(x).* The random lead time (***L***) demand *X* satisfies

$$E(X) = LE(D), \qquad var\ X = L(var\ D), \qquad \sigma_X = \sigma_D\sqrt{L}$$

If the demand per unit time during the lead time is not dependent on the lead time length, then

$$E(X) = E(\boldsymbol{L})E(D), \qquad var\ X = E(\boldsymbol{L})(var\ D) + E(D)^2(var\ \boldsymbol{L})$$

Returning to the example in Figure 6, we see that during the first cycle there are no shortages present because the demand during the lead time is less than *r*. In contrast, stockouts are present during the second cycle because the lead time demand is more that *r*. By analysing these situations, it is clear that we need optimal values for both *q* and *r* which will minimize the sum of the stockout costs and the holding costs. WL Winston (2004).

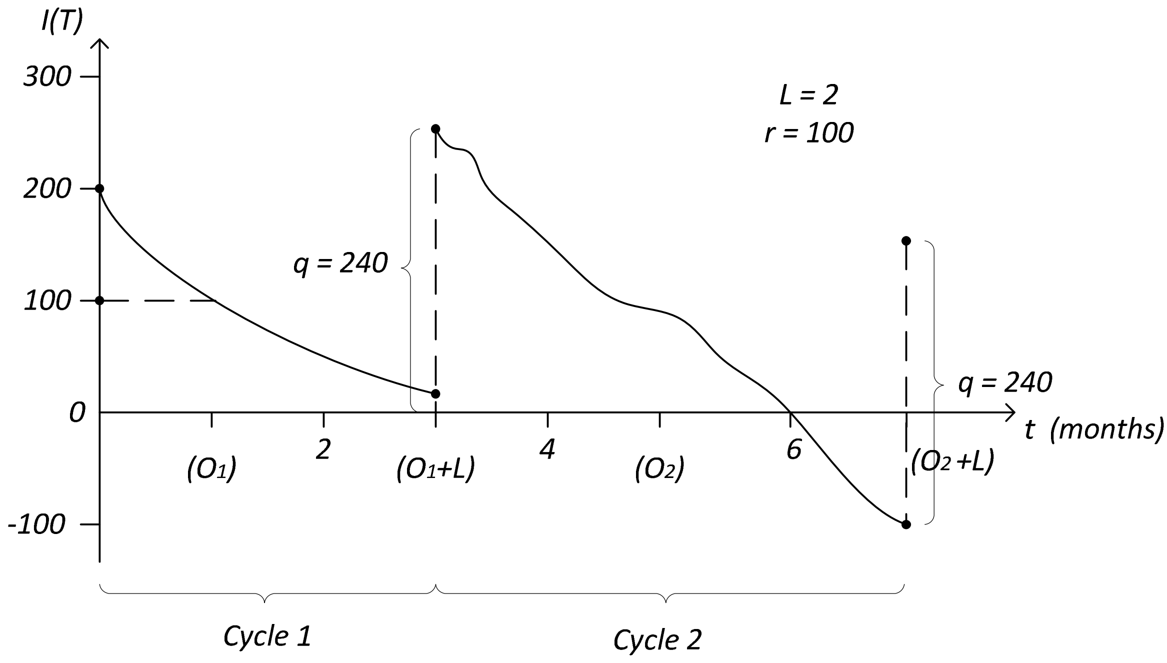

Figure 6: Behaviour of inventory over time in a reorder point model. WL Winston (2004, p147)

2.8.3.1 The Reorder Point for the Back-Ordered Case

In this case we are not allowed to lose any sales and all the demands must eventually be met. We want to minimize the total annual cost which is the sum of the holding cost per year, ordering cost per year, and the shortages cost per year.

Since the expected value of *I(t)* is very close to the expected value of the inventory on hand during *t*, we can calculate (WL Winston (2004)) the expected annual holding cost to be

$$Expected\ Holding\ Cost\ per\ Year\ \cong h(\frac{q}{2} + r - E(X))$$

If we define $\boldsymbol{B}_r$ to be a random number of stockouts during a cycle, with *r* the reorder point, it can be shown that the expected annual shortage cost is

$$Expected\ Shortage\ Cost\ per\ Year = \frac{c_B E(\boldsymbol{B}_r)E(D)}{q}$$

Finally, the expected annual order cost is

$$Expected\ Order\ Cost\ per\ Year = \frac{KE(D)}{q}$$

Thus, the total annual cost is

$$TC(q,r) = h\left(\frac{q}{2} + r - E(X)\right) + \frac{c_B E(\boldsymbol{B}_r)E(D)}{q} + \frac{KE(D)}{q}$$

Using further algebraic manipulation, we see that q^* is very close to the EOQ if the EOQ is less than or equal to σ_X. Thus

$$q^* = \sqrt{\frac{2KE(D)}{h}}$$

and

$$P(X \geq r^*) = \frac{hq^*}{c_B E(D)}, \qquad if \ \frac{hq^*}{c_B E(D)} > 1$$

2.8.3.2 The Reorder Point for the Lost Sales Case

Here we assume that no backorders are allowed and that all the stockouts will result in lost sales at a cost of c_{LS} per lost sale. Similar to the backorder model, WL Winston (2004) derives the following formulas for q^* and for r^*

$$q^* = \sqrt{\frac{2KE(D)}{h}}$$

and

$$P(X \geq r^*) = \frac{hq^*}{hq^* + c_{LS}E(D)}$$

2.8.4 Uncertain Demand EOQ: Service Level Approach

It is generally extremely complicated to determine an accurate cost for being one unit short. WL Winston (2004) describes two measures of service level to control shortages.

The first measure is known as Service Level Measure 1 (SLM_1) and represents the percentage part of all the demand that is met on time. The second measure is the expected number of annual cycles during which a shortage occurs and is known as Service Level Measure 2 (SLM_2).

If an organisation currently has a particular SLM_1 level and wishes to improve it, a feasibility study must be carried out to ensure that the new SLM_1 level will reduce the total costs or increase the net profit. It must be noted that increasing the SLM_1 level will reduce the shortage cost, but at the same time increases the holding cost. Hence, an economical balance should be established for optimal inventory management. An economical analysis should also be conducted for improving the SLM_2 level. With the intention of calculating the reorder point and safety stock level for these measurements, it is assumed that all the shortages are backlogged.

2.9 Tools and Methods Selection

The demand for the consumables used in the production line is unknown. Thus, in order to calculate the economic order quantity, reorder point and safety stock level for the consumables, the Probabilistic Uncertain Demand EOQ model will be used. A continuously reviewed (r, q) inventory policy is used for the consumables inventory management.

Similarly, a continuous reviewed (r, q) inventory policy is used for managing the raw materials inventory. Since the raw material's demand is uncertain, a Probabilistic Uncertain Demand EOQ model will be used to improve the current inventory system.

Chapter 3

Solution

3.1 ABC Analysis and Service Level Measurement

Wispeco Aluminium's income and profit is directly related to the amount of time the production line is running and the capacity it is running at. Should there be a shortage with some of the consumables and especially raw materials, the entire production line will come to a complete standstill. Other consumables and materials will have a less significant impact on the production, while others will hardly have any impact at all.

The decisive factor which will be used for the ABC analysis is the Service Level Measurement (SLM), which is indicated by the impact the consumable or material will have on the production process progress. All of the products used in the production process are divided into three classes namely A, B or C which indicates the importance of the product. Class A represents the critical products which the production process cannot operate without. The production process can continue without class B products, but at a lower capacity. Finally, class C products will have nearly no impact on the production process. Wispeco strives to meet 99% of the demand for class A, 80% for class B, and 70% for class C. Please refer to Appendix A for the complete list of products and class classification, and Table 1 for a summary of the product classification and SLM analysis.

Product Class	SLM	Number of Products in Class	Percentage of Stock List in Each Class
A	99%	46	82.14%
B	80%	7	12.50%
C	70%	3	5.36%
Total:		56	100%

Table 1: Product Class and SLM Summary

From the above it is clear that product class A is the most important and should meet the demand as much as possible. It is also be advised to first implement the new inventory policy to product class A, then B and finally to product class C.

3.2 Determining Inventory Costs and Values

Historical data, consultation meetings, financial records, inventory records, and interviews are the main methods used to gather all the relevant data needed for developing a new and improved inventory management system. The unit purchasing costs, holding costs, ordering costs, stockout cost, demands and lead times for both the raw materials and consumables which will be used in finding the optimal solutions in terms of the inventory decisions where collected and discussed below.

3.2.1 Unit Purchasing Cost

The unit purchasing cost is the total cost which Wispeco is currently paying for one unit of the consumables and raw material. This cost includes the shipping and transportation cost from the external vendor to Wispeco's premises. See Appendix A for the complete list of unit purchase costs for every product.

3.2.2 Holding Cost

Holding cost is the cost of carrying one unit of inventory for one period of time. The time period in this case is one year. Holding cost is made up of a variety of components which will be discussed below. It is important to note that some of the holding cost components are not applicable in Wispeco's case because of various reasons. These components include, but are not limited to:

- Depreciation and/or deterioration of inventories: All products are fast moving consumables of relatively low value and does therefore not depreciate or deteriorate.
- Insurance costs: Wispeco pays a constant monthly payment for insurance purposes, regardless of the amount of consumables and raw materials in storage. The insurance costs will therefore have no influence on the inventory policy followed.

- Risk of spoilage: The items in storage have either a very long useful life or are unperishable.

The different components used to calculate the holding cost consists of handling cost, interest lost on invested capital, and storage facility cost, each of which are determined here after. Please refer to Appendix A for the complete product list and each ones holding cost.

3.2.2.1 Handling Cost

The following calculation is performed to calculate the cost of handling one unit of inventory for one month:

$$\frac{\sum[(Monthly\ Salary\ of\ Handling\ Operator)(\%\ Time\ Spend\ Handling\ Material\ per\ Month)]}{Average\ Number\ of\ Units\ in\ Inventory}$$

$$= \frac{1750}{22226} \approx 0.08$$

This implies that the fraction of all the material handlers' salaries spent on physically handling and picking the consumables and raw materials are divided by the average number of units in inventory to determine the cost to handle one unit of inventory for one time period. To determine the handling cost per year, the monthly handling cost is simply multiplied by 12 to give R0.96 per inventory unit.

3.2.2.2 Interest Lost on Invested Capital

Since the consumables and raw materials in inventory do not gain any value over time, there exists an opportunity cost for interest lost on invested capital. In order to calculate the monthly opportunity cost per unit, one takes the value of each product and multiplies it with the monthly prime interest rate. The current annual prime interest rate is 10.0% as determined by the South African Reserve Bank. The yearly opportunity cost per unit is twelve times that of the monthly equivalent. Please refer to Appendix A for the complete list of products and each opportunity lost on interest.

3.2.2.3 Storage Cost

Since all the consumables and raw material are stored inside a warehouse, one needs to determine the potential loss of storage income. This means that if Wispeco is able to have fewer items in storage, they can rent the extra warehouse space for additional income. Wispeco currently use a total warehouse space of 100m^2 to store their consumables and raw material and pays an average of R5.80/m^2 per month for the warehouse space. The following calculation is performed to calculate the monthly potential loss of storage income per inventory unit:

$$\frac{(Total\ Warehouse\ Space)(Cost\ of\ Monthly\ Warehouse\ Rent/m^2)}{Average\ Number\ of\ Units\ in\ Inventory}$$

$$= \frac{(100m^2)(5.80/m^2)}{(22226)} \approx 0.03$$

This means that the yearly potential lost of storage will be R0.36 per inventory unit.

3.2.3 Ordering Cost

Most of the ordering costs are included in the product's purchase price. This includes the freight costs, cost for tracking the orders, etc. However, Wispeco employ some of its employees to place the orders and make the purchases. This monthly purchasing cost per inventory unit can be calculated by taking the purchasing department's monthly salary and multiply it by the percentage of time they spend doing the actual purchases of consumables and raw materials.

$$\frac{\sum[(Monthly\ Salary\ of\ Purchasing\ Operator)(\%\ Time\ Spend\ Ordering\ per\ Month)]}{Average\ Number\ of\ Units\ in\ Inventory}$$

$$= \frac{28000}{22226} \approx 1.26$$

This implies that if Wispeco is able to place fewer orders per month, the purchasing employees will be able to spend more time elsewhere and the total ordering cost will be reduced. However, fewer orders will tend to raise the storage costs and the minimum cost balance should be found. To convert the monthly ordering cost to yearly ordering cost, the value per month is multiplied by 12. Please refer to Appendix A for the complete ordering cost list.

3.2.4 Stockout Cost

In order to calculate a monetary value for the cost of having a shortage in stock, one must consider three distinct cases:

- Case I: In this case Wispeco is unable to supply a customer's demand immediately, but the customer is prepared to wait until Wispeco can meet the customer's demand with no additional costs or charges.

- Case II: Again, Wispeco is unable to meet the customer's demands, but a special arrangement between Wispeco and the customer is made, which usually costs Wispeco more to comply to.
- Case III: In this case the customer opts to make use of an alternative supplier because Wispeco is unable to meet their demands on time. This means that Wispeco will loose the revenue of that specific order due to opportunity profit lost.

The total shortage cost are summarised in the following table:

Case	**Probability**	**Penalty Cost (R)**	**Shortage Cost (R)**
Case I	0.55	0.00	0.00
Case II	0.40	1.00	0.40
Case III	0.05	2.73	0.14
Total Shortage Cost (R):	1.00		0.54

Table 2: Shortage Cost Calculation

The probabilities were determined making use of historical data and the help of an experienced Operations Manager. This means that Wispeco loses on average R0.54 for every kilogram of the final product which they cannot supply to.

3.2.5 Demand

In order to compute the EOQ, the expected demand for each product needs to be divided into two parts namely: the average demand, and the demand's standard deviation.

3.2.5.1 Average Demand

The average monthly demand for each product was firstly calculated. By simply multiplying the average monthly demand by twelve, the average demand per year is determined. The annual average demand for every product can be seen in Appendix A.

3.2.5.2 Standard Deviation Demand

The monthly standard deviation of each of the product's demands where multiplied by the square root of twelve to give an accurate indication of the standard deviation of the demand per year. Appendix A shows the complete product list and their demand standard deviation.

3.2.6 Lead Time

The lead time is directly dependent on the location of the supplier. The majority of Wispeco's suppliers are located in China. The rest of the suppliers are situated in South Africa and mostly in and around the Gauteng area which is relatively close to the Wispeco factory. In order to compute the EOQ, one needs the average and the standard deviation of the lead times per year for each product.

3.2.6.1 Average Lead Time

The lead time for each product is different because of the diversity of the suppliers. The products which are ordered from China has an average lead time of 8 weeks, whereas the products ordered from within South Africa usually has a lead time of only a few days before the products arrive at Wispeco. Appendix A gives the complete list of products with each of their average lead times in years.

3.2.6.2 Standard Deviation Lead Time

All the products ordered from China have a standard deviation of 10 days, while the products ordered from within South Africa have a standard deviation of 2 days. Please refer to Appendix A for all the consumables and raw materials lead times in years.

3.2.6.3 Standard Deviation in Lead Time Demand

In order to compute the EOQ, reorder points and safety stock levels, one need to determine the standard deviation in lead time demands. As described earlier in section 2.8.3, WL Winston (2004) explains that the random lead time demand X satisfies $\sigma_X = \sigma_D\sqrt{L}$, if one assumes that the demands at different points in time are independent, where:

- σ_X is the random variable which represents the demand during the lead time
- σ_D is the standard deviation of the demand
- σ_L is the annual standard deviation in lead time, and
- L is the lead time

Appendix A shows the standard deviation in lead time and the standard deviation in lead time demand for all the products.

3.3 Program Modelling

In this section, the actual programming and solving of the EOQ, reorder point and safety stock level will be described and executed.

3.3.1 Programming Software

An operations research program from LINDO Systems, call LINGO will be used with the intention of calculating the EOQ, reorder point and safety stock level for all the consumables and raw material. LINGO is a capable, fast and easy program designed to solve various types of optimization models.

3.3.2 Programming Constraints

A LINGO code for each one of the consumables and raw materials were written to calculate the most economical EOQ, reorder point and safety stock level. Like all good operations research programs, the problem needs to comply to some constraints in order to keep the solution realistic and within certain bounds. See Appendix B for all the product's LINGO codes.

3.3.2.1 Cost Constraints

The purpose of the program is to minimise the total annual inventory cost. As explained in section 2.8.3, the total cost is the sum of the holding cost, ordering cost and the stockout cost, where:

$$Holding\ Cost\ per\ Year = h(\frac{q}{2} + r - (L.D))$$

$$Ordering\ Cost\ per\ Year = \frac{(k)(D)}{q}$$

$$Stockout\ Cost\ per\ Year = \frac{(Shortages)(Shortage\ Cost)(D)}{q}$$

All of the above costs and values are as determined in section 10, with the exception of the shortages which are part of the stockout cost. WL Winston (2004) explains that the expected number of shortages occurring can be determined by considering the normal loss function. LINGO has a built in function called @PSL which is used to compute the normal loss function value.

3.3.2.2 Other Constraints

The "Q + SafetyStock > RoP" constraint ensures that the solution is feasible by guaranteeing that the total of the EOQ and safety stock is always larger than the reorder points.

The "Q>MLD" constraint ensures that the demand is met by making sure the EOQ is larger than the expected mean lead time demand.

Chapter 4

4.1 Solution: Economic Order Quantities, Reorder Points and Safety Stock Levels

Appendix C shows the summary report as obtained from LINGO for all the consumables and raw materials (refer to Appendix B for the program codes). These reports show all the relevant values and costs, including the optimal economic order quantity (Q), reorder points (RoP) and safety stock levels which minimises the total cost, i.e. minimises the objective value.

Table 3 gives a summary of every product's economic order quantity, reorder point, safety stock level, various costs and also the total cost. As an example, take the first item in the table called Cover Flux 7R. Wispeco should make an order of 456 kg whenever the inventory level reaches 176 kg in stock. The safety stock level should be 47 kg. If Wispeco follow this inventory management policy, they would pay an estimated annual ordering cost of R397.48, annual holding cost of R520.14 and an annual shortage cost of R38.46. This computes to a total annual cost of R956.08.

	Product Description	**EOQ (Q)**	**Reorder Point (RoP)**	**Safety Stock Level**	**Ordering Cost (R)**	**Holding Cost (R)**	**Shortage Cost (R)**	**Total Cost (R)**
1	Cover Flux 7R	456.48	176.08	46.79	397.48	520.14	38.46	956.08
2	Degasser Tablets 17	49.80	2.64	0.32	72.87	73.70	0.83	147.40
3	Plastic Mindural	97.89	16.50	1.99	231.69	248.15	16.46	496.30
4	Magnesium Crystals	495.36	519.59	132.96	1 098.83	2 197.96	367.45	3 664.24
5	Silicon Metal SS4	428.98	259.33	66.08	634.44	954.32	107.70	1 696.46
6	Mould Paint PVA	162.30	26.19	4.24	201.23	220.66	13.01	434.90
7	Titanium Boron Coil	297.19	162.41	35.54	610.52	869.98	111.65	1 592.15
8	Titanium Boron Rod	144.60	38.72	5.39	351.34	406.56	45.58	803.49
9	Density Stopper (Big Cone)	132.54	132.54	4.29	98.57	187.54	15.09	301.20
10	Hullets Foil	79.15	79.15	2.56	98.57	173.74	9.01	281.32
11	Talc Powder Remelt	67.71	66.00	0.80	133.98	137.79	3.81	275.58
12	Transition Ring N-17 7"	20.73	18.41	0.60	87.51	89.37	1.86	178.73
13	Transition Ring N-17 6"	22.29	18.41	0.60	81.40	83.14	1.73	166.27
14	Silicone Water Seals 127L 5"	35.69	18.41	0.60	50.84	51.92	1.08	103.85

15	Silicone Water Seals 127S 5"	36.19	18.41	0.60	50.14	51.21	1.07	102.41
16	Silicone Water Seals 152L 6"	33.82	18.41	0.60	53.65	54.79	1.14	109.58
17	Silicone Water Seals 152S 6"	34.69	18.41	0.60	52.31	53.42	1.11	106.84
18	Silicone Water Seal 177.8L 7"	32.59	18.41	0.60	55.68	56.86	1.18	113.73
19	Silicone Water Seal 177.8S 7"	33.82	18.41	0.60	53.65	54.79	1.14	109.58
20	Silicone Seals 203L 8"	31.15	18.41	0.60	58.25	59.49	1.24	118.98
21	Silicone Seals 203S 8"	32.59	18.41	0.60	55.68	56.86	1.18	113.73
22	Back Launder	4.61	4.61	0.15	98.57	171.63	0.52	270.72
23	Small Cone Plug	109.64	92.04	2.98	82.75	91.55	8.80	183.09
24	Front Launder	4.60	4.60	0.15	98.57	198.30	0.52	297.39
25	Graphite Ring 127 5"	3.08	0.31	0.01	10.00	10.01	0.00	20.01
26	Graphite Ring 6"	2.48	0.31	0.01	12.44	12.44	0.00	24.88
27	Graphite Ring 177.8 7"	2.15	0.31	0.01	14.34	14.35	0.01	28.69
28	Graphite Ring 8"	2.03	0.31	0.01	15.21	15.21	0.01	30.42
29	Cast Iron Plug	14.58	7.36	0.24	49.79	50.21	0.42	100.43
30	Mould 127 Dia 5"	11.04	11.04	0.36	98.57	521.65	1.26	621.47
31	Complete Mould 6"	11.04	11.04	0.36	98.57	661.80	1.26	761.63
32	Mould 177.8 Dia 7"	11.04	11.04	0.36	98.57	823.33	1.26	923.16
33	Complete Mould 8"	11.04	11.04	0.36	98.57	969.62	1.26	1 069.45
34	O-Rings 127 Dia 5"	24.03	11.04	0.36	45.31	45.89	0.58	91.78
35	Black Seal O-Ring 7"	24.85	11.04	0.36	43.80	44.36	0.56	88.72
36	Black Seal O-Ring 6"	25.73	11.04	0.36	42.31	42.84	0.54	85.69
37	Black Seals 8"	23.51	11.04	0.36	46.31	46.90	0.59	93.80
38	Patching Compound	17.72	9.20	0.30	51.20	51.74	0.54	103.48
39	Spoons	6.82	0.92	0.01	106.45	106.77	0.32	213.54
40	Starting Head 5"	9.20	9.20	0.30	98.57	151.41	1.05	251.02
41	Starting Head 6"	9.20	9.20	0.30	98.57	160.43	1.05	260.04
42	Starting Head 7"	9.20	9.20	0.30	98.57	206.26	1.05	305.88
43	Starting Head 8"	9.20	9.20	0.30	98.57	198.53	1.05	298.14
44	Thimble 177.8 Dia	40.34	36.82	1.19	89.96	93.79	3.83	187.57
45	Thimble .9	18.72	9.20	0.30	48.45	48.96	0.51	97.93
46	Transition Plate 5"	24.08	18.41	0.60	75.34	76.94	1.60	153.89
47	Transition Plate 8"	19.63	18.41	0.60	92.44	94.41	1.97	188.82
48	Nozzle Cleaner	45.34	29.45	0.95	64.02	66.20	2.18	132.40
49	Exit Insert	6.85	3.68	0.12	53.00	53.23	0.23	106.46
50	Flex Hose	9.20	9.20	0.30	98.57	211.78	1.05	311.40
51	Ceramic Foam Filter	331.34	331.34	10.72	98.57	3 810.46	37.73	3 946.75
52	Nozzle Insert	20.02	18.41	0.60	90.65	92.57	1.93	185.15
53	Degasser Nozzle	64.43	64.43	2.08	98.57	467.75	7.34	573.65
54	Bone Ash	190.44	76.08	10.90	285.82	344.35	35.08	665.25
55	Fibre Blanket	17.50	2.64	0.32	207.41	209.77	2.36	419.54
56	Filter Cloth	0.30	0.00	0.00	75.09	75.10	0.01	150.20

Table 3: Summary of calculated solutions

4.2 Sensitivity Analysis

The mathematical model was designed to make it as flexible as possible. Should any changes occur in any one of the raw materials or consumables' demand, lead time or any one of the associated costs, the program can be updated by simply changing the relevant input data with the new data in the program code.

As an example, let us consider the first item in the products table called Cover Flux 7R.
The current values for the Cover Flux 7R is as follow (also see Appendix A):

Variable	Value
Annual Demand	12000
Annual Standard Deviation in Demand	381.05
Annual Lead Time	0.011
Annual Standard Deviation	0.0055
Standard Deviation in Lead Time Demand	39.89
Annual Holding Cost	1.91
Annual Shortage Cost	0.54
Annual Ordering Cost	15.12

Table 4: Current Values for Cover Flux 7R

These values give the following optimal solution (from Section 12):

EOQ (Q)	456.48
Reorder Point (RoP)	176.08
Safety Stock Level	46.79
Annual Ordering Cost (R)	397.48
Annual Holding Cost (R)	520.14
Annual Shortage Cost (R)	38.46
Total Annual Cost (R)	956.08

Table 5: Current Optimal Solution for Cover Flux 7R

Let us now consider a hypothetical change in the annual demand to 800 kg of Cover Flux 7R. This means that the input data will change to the following:

Variable	Value
Annual Demand	800
Annual Standard Deviation in Demand	25.40
Annual Lead Time	0.011
Annual Standard Deviation	0.0055
Standard Deviation in Lead Time Demand	2.66
Annual Holding Cost	1.91
Annual Shortage Cost	0.54
Annual Ordering Cost	15.12

Table 6: Cover Flux 7R values with change in the annual demand

With this demand and other values, the optimal solution has change as follow:

EOQ (Q)	114.66
Reorder Point (RoP)	8.8
Safety Stock Level	1.06
Annual Ordering Cost (R)	105.50
Annual Holding Cost (R)	109.50
Annual Shortage Cost (R)	3.99
Total Annual Cost (R)	218.99

Table 7: Optimal solution for Cover Flux 7R with a change in the annual demand

As seen above, any changes in the inventory management system can be calculated for by changing the input data in the mathematical model program code. Any change in the lead time, holding cost, shortage cost, ordering cost, unit purchase price, etc. can be accounted for in a similar approach.

4.3 Conclusion

Currently Wispeco Aluminium spends large amounts of money on buying raw materials, spares and consumables used in the production process. Regardless of the huge amount of money involved, the company does not have a scientifically based system for managing their inventory. The aim of this project is therefore to create and implement a flexible and improved inventory management policy for the consumables and raw materials in order to save money.

A literature review was conducted to examine and identify the appropriate methods and tools to solve the problem. Since the demand for the products are unknown, a probabilistic inventory model with a continuous review inventory policy was used.

The relevant data, costs and applicable values for all the products were gathered and calculated. This data was introduced into a flexible LINGO program code which was developed with the main purpose of calculating the optimal economic order quantity, reorder point and safety stock level which will minimise the total cost.

It is suggested that Wispeco Aluminium conduct further research and development into joint ordering policies from their suppliers, as the scope for this project was limited to individual ordering policies only.

Wispeco Aluminium will gain an immense advantage by implementing the proposed inventory management solution, not only by means of saving money, but also by improving the productivity of the production process and their overall customer service.

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Appendixes

Appendix A

Complete product list of consumables and raw materials used in the production process and their relevant values used to calculate the EOQ, reorder point and safety stock level:

	Product Description	SLM Product Class	Unit Purchase Cost per Qty (R)	Annual Handling Cost per Unit (R)	Annual Opportunity Interest per Unit (R)	Annual Storage Cost per Unit (R)	Annual Holding Cost per Unit (R)	Annual Ordering Cost per Unit (R)	Shortage Cost per Unit (R)
1	Cover Flux 7R	A	5.90	0.96	0.59	0.36	1.91	15.12	0.54
2	Degasser Tablets 17	C	16.41	0.96	1.64	0.36	2.96	15.12	0.54
3	Plastic Mindural	B	37.50	0.96	3.75	0.36	5.07	15.12	0.54
4	Magnesium Crystals	A	46.00	0.96	4.60	0.36	5.92	15.12	0.54
5	Silicon Metal SS4	B	21.40	0.96	2.14	0.36	3.46	15.12	0.54
6	Mould Paint PVA	A	13.20	0.96	1.32	0.36	2.64	15.12	0.54
7	Titanium Boron Coil	A	35.39	0.96	3.54	0.36	4.86	15.12	0.54
8	Titanium Boron Rod	A	41.70	0.96	4.17	0.36	5.49	15.12	0.54
9	Density Stopper (Big Cone)	A	15.14	0.96	1.51	0.36	2.83	15.12	0.54
10	Hullets Foil	A	30.70	0.96	3.07	0.36	4.39	15.12	0.54
11	Talc Powder Remelt	A	27.50	0.96	2.75	0.36	4.07	15.12	0.54
12	Transition Ring N-17 7"	A	73.03	0.96	7.30	0.36	8.62	15.12	0.54
13	Transition Ring N-17 6"	A	61.44	0.96	6.14	0.36	7.46	15.12	0.54

14	Silicone Water Seals 127L 5"	A	15.92	0.96	1.59	0.36	2.91	15.12	0.54
15	Silicone Water Seals 127S 5"	A	15.09	0.96	1.51	0.36	2.83	15.12	0.54
16	Silicone Water Seals 152L 6"	A	19.23	0.96	1.92	0.36	3.24	15.12	0.54
17	Silicone Water Seals 152S 6"	A	17.57	0.96	1.76	0.36	3.08	15.12	0.54
18	Silicone Water Seal 177.8L 7"	A	21.71	0.96	2.17	0.36	3.49	15.12	0.54
19	Silicone Water Seal 177.8S 7"	A	19.23	0.96	1.92	0.36	3.24	15.12	0.54
20	Silicone Seals 203L 8"	A	25.02	0.96	2.50	0.36	3.82	15.12	0.54
21	Silicone Seals 203S 8"	A	21.71	0.96	2.17	0.36	3.49	15.12	0.54
22	Back Launder	A	732.74	0.96	73.27	0.36	74.59	15.12	0.54
23	Small Cone Plug	B	3.53	0.96	0.35	0.36	1.67	15.12	0.54
24	Front Launder	A	848.62	0.96	84.86	0.36	86.18	15.12	0.54
25	Graphite Ring 127 5"	A	51.70	0.96	5.17	0.36	6.49	15.12	0.54
26	Graphite Ring 6"	A	87.10	0.96	8.71	0.36	10.03	15.12	0.54
27	Graphite Ring 177.8 7"	A	120.21	0.96	12.02	0.36	13.34	15.12	0.54
28	Graphite Ring 8"	A	136.77	0.96	13.68	0.36	15.00	15.12	0.54
29	Cast Iron Plug	A	55.65	0.96	5.57	0.36	6.89	15.12	0.54
30	Mould 127 Dia 5"	A	931.39	0.96	93.14	0.36	94.46	15.12	0.54
31	Complete Mould 6"	A	1 185.21	0.96	118.52	0.36	119.84	15.12	0.54
32	Mould 177.8 Dia 7"	A	1 477.70	0.96	147.77	0.36	149.09	15.12	0.54
33	Complete Mould 8"	A	1 742.57	0.96	174.26	0.36	175.58	15.12	0.54
34	O-Rings 127 Dia 5"	A	25.01	0.96	2.50	0.36	3.82	15.12	0.54
35	Black Seal O-Ring 7"	A	22.54	0.96	2.25	0.36	3.57	15.12	0.54
36	Black Seal O-Ring 6"	A	20.06	0.96	2.01	0.36	3.33	15.12	0.54
37	Black Seals 8"	A	26.68	0.96	2.67	0.36	3.99	15.12	0.54
38	Patching Compound	B	45.20	0.96	4.52	0.36	5.84	15.12	0.54
39	Spoons	C	300.00	0.96	30.00	0.36	31.32	15.12	0.54
40	Starting Head 5"	A	315.79	0.96	31.58	0.36	32.90	15.12	0.54

41	Starting Head 6"	A	335.42	0.96	33.54	0.36	34.86	15.12	0.54
42	Starting Head 7"	A	435.04	0.96	43.50	0.36	44.82	15.12	0.54
43	Starting Head 8"	A	418.20	0.96	41.82	0.36	43.14	15.12	0.54
44	Thimble 177.8 Dia	A	33.30	0.96	3.33	0.36	4.65	15.12	0.54
45	Thimble .9	A	39.09	0.96	3.91	0.36	5.23	15.12	0.54
46	Transition Plate 5"	A	50.68	0.96	5.07	0.36	6.39	15.12	0.54
47	Transition Plate 8"	A	82.96	0.96	8.30	0.36	9.62	15.12	0.54
48	Nozzle Cleaner	C	16.00	0.96	1.60	0.36	2.92	15.12	0.54
49	Exit Insert	A	142.28	0.96	14.23	0.36	15.55	15.12	0.54
50	Flex Hose	A	446.95	0.96	44.70	0.36	46.02	15.12	0.54
51	Ceramic Foam Filter	B	216.82	0.96	21.68	0.36	23.00	15.12	0.54
52	Nozzle Insert	A	79.30	0.96	7.93	0.36	9.25	15.12	0.54
53	Degasser Nozzle	A	132.00	0.96	13.20	0.36	14.52	15.12	0.54
54	Bone Ash	B	20.50	0.96	2.05	0.36	3.37	15.12	0.54
55	Fibre Blanket	A	226.64	0.96	22.66	0.36	23.98	15.12	0.54
56	Filter Cloth	B	4 960.00	0.96	496.00	0.36	497.32	15.12	0.54

	Product Description	Average Annual Demand	Standard Deviation Annual Demand	Demand Unit	Average Lead Time (Years)	Standard Deviation Lead Time (Years)	Standard Deviation in Lead Time Demand
1	Cover Flux 7R	12000	381.05	kg	0.0110	0.0055	39.890
2	Degasser Tablets 17	240	7.62	kg	0.0110	0.0055	0.798
3	Plastic Mindural	1500	47.63	kg	0.0110	0.0055	4.986
4	Magnesium Crystals	36000	1 143.15	kg	0.0110	0.0055	119.671
5	Silicon Metal SS4	18000	571.58	kg	0.0110	0.0055	59.835
6	Mould Paint PVA	2160	68.59	kg	0.0110	0.0055	7.180
7	Titanium Boron Coil	12000	381.05	kg	0.0110	0.0055	39.890
8	Titanium Boron Rod	3360	106.69	kg	0.0110	0.0055	11.169
9	Density Stopper (Big Cone)	864	27.44	each	0.1534	0.0274	10.746
10	Hullets Foil	516	16.39	kg	0.1534	0.0274	6.418
11	Talc Powder Remelt	600	19.05	kg	0.0110	0.0055	1.995
12	Transition Ring N-17 7"	120	3.81	each	0.1534	0.0274	1.493
13	Transition Ring N-17 6"	120	3.81	each	0.1534	0.0274	1.493
14	Silicone Water Seals 127L 5"	120	3.81	each	0.1534	0.0274	1.493
15	Silicone Water Seals 127S 5"	120	3.81	each	0.1534	0.0274	1.493
16	Silicone Water Seals 152L 6"	120	3.81	each	0.1534	0.0274	1.493
17	Silicone Water Seals 152S 6"	120	3.81	each	0.1534	0.0274	1.493
18	Silicone Water Seal 177.8L 7"	120	3.81	each	0.1534	0.0274	1.493
19	Silicone Water Seal 177.8S 7"	120	3.81	each	0.1534	0.0274	1.493
20	Silicone Seals 203L 8"	120	3.81	each	0.1534	0.0274	1.493
21	Silicone Seals 203S 8"	120	3.81	each	0.1534	0.0274	1.493
22	Back Launder	30	0.95	each	0.1534	0.0274	0.373
23	Small Cone Plug	600	19.05	each	0.1534	0.0274	7.463

24	Front Launder	30	0.95	each	0.1534	0.0274	0.373
25	Graphite Ring 127 5"	2.04	0.06	each	0.1534	0.0274	0.025
26	Graphite Ring 6"	2.04	0.06	each	0.1534	0.0274	0.025
27	Graphite Ring 177.8 7"	2.04	0.06	each	0.1534	0.0274	0.025
28	Graphite Ring 8"	2.04	0.06	each	0.1534	0.0274	0.025
29	Cast Iron Plug	48	1.52	each	0.1534	0.0274	0.597
30	Mould 127 Dia 5"	72	2.29	each	0.1534	0.0274	0.896
31	Complete Mould 6"	72	2.29	each	0.1534	0.0274	0.896
32	Mould 177.8 Dia 7"	72	2.29	each	0.1534	0.0274	0.896
33	Complete Mould 8"	72	2.29	each	0.1534	0.0274	0.896
34	O-Rings 127 Dia 5"	72	2.29	each	0.1534	0.0274	0.896
35	Black Seal O-Ring 7"	72	2.29	each	0.1534	0.0274	0.896
36	Black Seal O-Ring 6"	72	2.29	each	0.1534	0.0274	0.896
37	Black Seals 8"	72	2.29	each	0.1534	0.0274	0.896
38	Patching Compound	60	1.91	kg	0.1534	0.0274	0.746
39	Spoons	48	1.52	each	0.0192	0.0055	0.211
40	Starting Head 5"	60	1.91	each	0.1534	0.0274	0.746
41	Starting Head 6"	60	1.91	each	0.1534	0.0274	0.746
42	Starting Head 7"	60	1.91	each	0.1534	0.0274	0.746
43	Starting Head 8"	60	1.91	each	0.1534	0.0274	0.746
44	Thimble 177.8 Dia	240	7.62	each	0.1534	0.0274	2.985
45	Thimble .9	60	1.91	each	0.1534	0.0274	0.746
46	Transition Plate 5"	120	3.81	each	0.1534	0.0274	1.493
47	Transition Plate 8"	120	3.81	each	0.1534	0.0274	1.493
48	Nozzle Cleaner	192	6.10	each	0.1534	0.0274	2.388
49	Exit Insert	24	0.76	each	0.1534	0.0274	0.299
50	Flex Hose	60	1.91	each	0.1534	0.0274	0.746
51	Ceramic Foam Filter	2160	68.59	each	0.1534	0.0274	26.866
52	Nozzle Insert	120	3.81	each	0.1534	0.0274	1.493

53	Degasser Nozzle	420	13.34	each	0.1534	0.0274	5.224
54	Bone Ash	3600	114.32	kg	0.0192	0.0055	15.831
55	Fibre Blanket	240	7.62	each	0.0110	0.0055	0.798
56	Filter Cloth	1.5	0.05	each	0.0110	0.0055	0.005

Appendix B

LINGO programming code for every consumable and raw material used to solve the EOQ, reorder point and safety stock level:

EOQ Model: Item 1 - Cover Flux 7R

```
!EOQ model: Item 1 - Cover Flux 7R;
Data:
D = 12000 ;!Annual Mean Demand;
SDD = 381.05 ;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 39.89 ;!Standard Deviation in Lead Time Demand;
h = 1.91 ;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ Model: Item 2 - Degasser Tablets 17

```
!EOQ model: Item 2 - Degasser Tablets 17;
Data:
D = 240 ;!Annual Mean Demand;
SDD = 7.62;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 0.798 ;!Standard Deviation in Lead Time Demand;
h = 2.96;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ Model: Item 3 - Plastic Mindural

```
!EOQ model: Item 3 - Plastic Mindural;
Data:
D = 1500 ;!Annual Mean Demand;
SDD = 47.63;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 4.986 ;!Standard Deviation in Lead Time Demand;
h = 5.07;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 4 - Magnesium Crystals

```
!EOQ model: Item 4 – Magnesium Crystals;
Data:
D = 36000 ;!Annual Mean Demand;
SDD = 1143.15;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 119.671;!Standard Deviation in Lead Time Demand;
h = 5.92;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 5 - Silicon Metal SS4

```
!EOQ model: Item 5 – Silicon Metal SS4;
Data:
D = 18000 ;!Annual Mean Demand;
SDD = 571.58;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 59.835;!Standard Deviation in Lead Time Demand;
h = 3.46;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 6 - Mould Paint PVA

```
!EOQ model: Item 6 - Mould Paint PVA;
Data:
D = 2160 ;!Annual Mean Demand;
SDD = 68.59;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 7.180;!Standard Deviation in Lead Time Demand;
h = 2.64;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 7 - Titanium Boron Coil

```
!EOQ model: Item 7 - Titanium Boron Coil;
Data:
D = 12000 ;!Annual Mean Demand;
SDD = 381.05;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 39.89;!Standard Deviation in Lead Time Demand;
h = 4.86;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 8 - Titanium Boron Rod

```
!EOQ model: Item 8 – Titanium Boron Rod;
Data:
D = 3360 ;!Annual Mean Demand;
SDD = 106.69;!Annual Standard Deviation in Demand;
L = 0.011 ;!Annual Lead Time;
SDL = 0.0055 ;!Annual Standard Deviation in Lead Time;
SDLD = 11.169;!Standard Deviation in Lead Time Demand;
h = 5.49;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 9 - Density Stopper (Big Cone)

```
!EOQ model: Item 9 – Density Stopper (Big Cone);
Data:
D = 864 ;!Annual Mean Demand;
SDD = 27.44;!Annual Standard Deviation in Demand;
L = .1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 10.746;!Standard Deviation in Lead Time Demand;
h = 2.83;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 10 - Hullets Foil

```
!EOQ model: Item 10 - Hullets Foil;
Data:
D = 516 ;!Annual Mean Demand;
SDD = 16.39;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 6.418;!Standard Deviation in Lead Time Demand;
h = 4.39;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 11 - Talc Powder Remelt

```
!EOQ model: Item 11 - Talc Powder Remelt;
Data:
D = 600 ;!Annual Mean Demand;
SDD = 19.05;!Annual Standard Deviation in Demand;
L = 0.11;!Annual Lead Time;
SDL = 0.0055;!Annual Standard Deviation in Lead Time;
SDLD = 1.995;!Standard Deviation in Lead Time Demand;
h = 4.07;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 12 - Transition Ring N-17 7"

```
!EOQ model: Item 12 – Transition Ring N-17 7";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 8.62;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 13 - Transition Ring N-17 6"

```
!EOQ model: Item 13 – Transition Ring N-17 6";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 7.46;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 14 - Silicone Water Seals 127L 5"

```
!EOQ model: Item 14 - Silicone Water Seals 127L 5";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 2.91;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 15 - Silicone Water Seals 127S 5"

```
!EOQ model: Item 15 - Silicone Water Seals 127S 5";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 2.83;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 16 - Silicone Water Seals 152L 6"

```
!EOQ model: Item 16 - Silicone Water Seals 152L 6";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 3.24;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 17 - Silicone Water Seals 152S 6"

```
!EOQ model: Item 17 - Silicone Water Seals 152S 6";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 3.08;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 18 - Silicone Water Seal 177.8L 7"

```
!EOQ model: Item 18 - Silicone Water Seal 177.8L 7";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 3.49;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 19 - Silicone Water Seal 177.8S 7"

```
!EOQ model: Item 19 - Silicone Water Seal 177.8S 7";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 3.24;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 20 - Silicone Seals 203L 8"

```
!EOQ model: Item 20 - Silicone Seals 203L 8";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 3.82;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 21 - Silicone Seals 203S 8"

```
!EOQ model: Item 21 - Silicone Seals 203S 8";
Data:
D = 120 ;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 3.49;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 22 - Back Launder

```
!EOQ model: Item 22 - Back Launder;
Data:
D = 30 ;!Annual Mean Demand;
SDD = 0.95;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.373;!Standard Deviation in Lead Time Demand;
h = 74.59;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 23 - Small Cone Plug

```
!EOQ model: Item 23 - Small Cone Plug;
Data:
D = 600 ;!Annual Mean Demand;
SDD = 19.05;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 7.463;!Standard Deviation in Lead Time Demand;
h = 1.67;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 24 - Front Launder

```
!EOQ model: Item 24 - Front Launder;
Data:
D = 30 ;!Annual Mean Demand;
SDD = 0.95;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.373;!Standard Deviation in Lead Time Demand;
h = 86.18;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 25 - Graphite Ring 127 5"

```
!EOQ model: Item 25 - Graphite Ring 127 5";
Data:
D = 2.04 ;!Annual Mean Demand;
SDD = 0.06;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.025;!Standard Deviation in Lead Time Demand;
h = 6.49;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 26 - Graphite Ring 6"

```
!EOQ model: Item 26 - Graphite Ring 6";
Data:
D = 2.04 ;!Annual Mean Demand;
SDD = 0.06;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.025;!Standard Deviation in Lead Time Demand;
h = 10.03;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 27 - Graphite Ring 177.8 7"

```
!EOQ model: Item 27 - Graphite Ring 177.8 7";
Data:
D = 2.04 ;!Annual Mean Demand;
SDD = 0.06;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.025;!Standard Deviation in Lead Time Demand;
h = 13.34;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 28 - Graphite Ring 8"

```
!EOQ model: Item 28 - Graphite Ring 8";
Data:
D = 2.04 ;!Annual Mean Demand;
SDD = 0.06;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.025;!Standard Deviation in Lead Time Demand;
h = 15.00;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 29 - Cast Iron Plug

```
!EOQ model: Item 29 - Cast Iron Plug;
Data:
D = 48;!Annual Mean Demand;
SDD = 1.52;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.597;!Standard Deviation in Lead Time Demand;
h = 6.89;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 30 - Mould 127 Dia 5"

```
!EOQ model: Item 30 - Mould 127 Dia 5";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 94.46;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 31 - Complete Mould 6"

```
!EOQ model: Item 31 - Complete Mould 6";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 119.84;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 32 - Mould 177.8 Dia 7"

```
!EOQ model: Item 32 - Mould 177.8 Dia 7";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 149.09;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 33 - Complete Mould 8"

```
!EOQ model: Item 33 - Complete Mould 8";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 175.58;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 34 - O-Rings 127 Dia 5"

```
!EOQ model: Item 34 - O-Rings 127 Dia 5";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 3.82;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 35 - Black Seal O-Ring 7"

```
!EOQ model: Item 35 - Black Seal O-Ring 7";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 3.57;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 36 - Black Seal O-Ring 6"

```
!EOQ model: Item 36 - Black Seal O-Ring 6";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 3.33;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 37 - Black Seals 8"

```
!EOQ model: Item 37 - Black Seals 8";
Data:
D = 72;!Annual Mean Demand;
SDD = 2.29;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.896;!Standard Deviation in Lead Time Demand;
h = 3.99;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 38 - Patching Compound

```
!EOQ model: Item 38 - Patching Compound;
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 5.84;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 39 - Spoons

```
!EOQ model: Item 39 - Spoons;
Data:
D = 48;!Annual Mean Demand;
SDD = 1.52;!Annual Standard Deviation in Demand;
L = 0.0192;!Annual Lead Time;
SDL = 0.0055;!Annual Standard Deviation in Lead Time;
SDLD = 0.211;!Standard Deviation in Lead Time Demand;
h = 31.32;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 40 - Starting Head 5"

```
!EOQ model: Item 40 - Starting Head 5";
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 32.90;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 41 - Starting Head 6"

```
!EOQ model: Item 41 - Starting Head 6";
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 34.86;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 42 - Starting Head 7"

```
!EOQ model: Item 42 - Starting Head 7";
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 44.82;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 43 - Starting Head 8"

```
!EOQ model: Item 43 - Starting Head 8";
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 43.14;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 44 - Thimble 177.8 Dia

```
!EOQ model: Item 44 - Thimble 177.8 Dia;
Data:
D = 240;!Annual Mean Demand;
SDD = 7.62;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 2.985;!Standard Deviation in Lead Time Demand;
h = 4.65;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 45 - Thimble .9

```
!EOQ model: Item 45 - Thimble .9;
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 5.23;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 46 - Transition Plate 5"

```
!EOQ model: Item 46 - Transition Plate 5";
Data:
D = 120;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 6.39;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 47 - Transition Plate 8"

```
!EOQ model: Item 47 - Transition Plate 8";
Data:
D = 120;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 9.62;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 48 - Nozzle Cleaner

```
!EOQ model: Item 48 – Nozzle Cleaner;
Data:
D = 192;!Annual Mean Demand;
SDD = 6.10;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 2.388;!Standard Deviation in Lead Time Demand;
h = 2.92;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 49 - Exit Insert

```
!EOQ model: Item 49 – Exit Insert;
Data:
D = 24;!Annual Mean Demand;
SDD = 0.76;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.299;!Standard Deviation in Lead Time Demand;
h = 15.55;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 50 - Flex Hose

```
!EOQ model: Item 50 - Flex Hose;
Data:
D = 60;!Annual Mean Demand;
SDD = 1.91;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 0.746;!Standard Deviation in Lead Time Demand;
h = 46.02;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 51 - Ceramic Foam Filter

```
!EOQ model: Item 51 - Ceramic Foam Filter;
Data:
D = 2160;!Annual Mean Demand;
SDD = 68.59;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 26.866;!Standard Deviation in Lead Time Demand;
h = 23.00;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 52 - Nozzle Insert

```
!EOQ model: Item 52 - Nozzle Insert;
Data:
D = 120;!Annual Mean Demand;
SDD = 3.81;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 1.493;!Standard Deviation in Lead Time Demand;
h = 9.25;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 53 - Degasser Nozzle

```
!EOQ model: Item 53 - Degasser Nozzle;
Data:
D = 420;!Annual Mean Demand;
SDD = 13.34;!Annual Standard Deviation in Demand;
L = 0.1534;!Annual Lead Time;
SDL = 0.0274;!Annual Standard Deviation in Lead Time;
SDLD = 5.224;!Standard Deviation in Lead Time Demand;
h = 14.52;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 54 - Bone Ash

```
!EOQ model: Item 54 - Bone Ash;
Data:
D = 3600;!Annual Mean Demand;
SDD = 114.32;!Annual Standard Deviation in Demand;
L = 0.0192;!Annual Lead Time;
SDL = 0.0055;!Annual Standard Deviation in Lead Time;
SDLD = 15.831;!Standard Deviation in Lead Time Demand;
h = 3.37;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 55 - Fibre Blanket

```
!EOQ model: Item 55 - Fibre Blanket;
Data:
D = 240;!Annual Mean Demand;
SDD = 7.62;!Annual Standard Deviation in Demand;
L = 0.011;!Annual Lead Time;
SDL = 0.0055;!Annual Standard Deviation in Lead Time;
SDLD = 0.798;!Standard Deviation in Lead Time Demand;
h = 23.98;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

EOQ model: Item 56 - Filter Cloth

```
!EOQ model: Item 56 - Filter Cloth;
Data:
D = 1.5;!Annual Mean Demand;
SDD = 0.05;!Annual Standard Deviation in Demand;
L = 0.011;!Annual Lead Time;
SDL = 0.0055;!Annual Standard Deviation in Lead Time;
SDLD = 0.005;!Standard Deviation in Lead Time Demand;
h = 497.32;!Annual Holding Cost per Unit;
SC = 0.54 ;!Annual Shortage Cost;
K = 15.12 ;!Annual Ordering Cost;
END DATA
!THE Q, RoP, Safety Stock EOQ Inventory Model;
MLD = L*D; !Mean Lead Time Demand;
MIN = TotalCost; !Objective Function;
TotalCost = OrderingCost + HoldingCost + ShortageCost;
OrderingCost = (K * D/Q);
HoldingCost = h*(Q/2+RoP-MLD);
ShortageCost = Shortages * SC*D/Q;
SafetyStock = (RoP-MLD+Shortages);
@PSL((RoP-MLD)/SDLD) = ((Q*(1-SLM))/SDLD);
Z = (RoP-MLD)/SDLD;
!Expected Amount of Shortage Cost per Cycle. @PSL() = Standard Normal
Loss Function;
Shortages = SDLD*@PSL(Z);
Q+SafetyStock>RoP;
Q+SafetyStock>MLD;
Q>MLD;
```

Appendix C

LINGO programming code solution report for every consumable and raw material:

Solution: Item 1 - Cover Flux 7R

```
Local optimal solution found at step:            43
 Objective value:                             956.0786

                       Variable           Value        Reduced Cost
                              D        12000.00           0.0000000
                            SDD        381.0500           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        39.89000           0.0000000
                              H        1.910000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        132.0000           0.0000000
                      TOTALCOST        956.0786           0.0000000
                   ORDERINGCOST        397.4760           0.0000000
                    HOLDINGCOST        520.1396           0.0000000
                   SHORTAGECOST        38.46304           0.0000000
                              Q        456.4804           0.0000000
                            ROP        176.0842           0.0000000
                      SHORTAGES        2.709510           0.4500311E-07
                    SAFETYSTOCK        46.79368           0.0000000
                            SLM       0.9940643           0.0000000
                              Z      1.105143         0.0000000
```

Solution: Item 2 - Degasser Tablets 17

```
Local optimal solution found at step:            32
 Objective value:                             147.4000

                       Variable           Value        Reduced Cost
                              D        240.0000           0.0000000
                            SDD        7.620000           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD       0.7980000           0.0000000
                              H        2.960000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        2.640000           0.0000000
                      TOTALCOST        147.4000           0.0000000
                   ORDERINGCOST        72.87146           0.0000000
                    HOLDINGCOST        73.69996           0.0000000
                   SHORTAGECOST       0.8285380           0.0000000
                              Q        49.79727           0.0000000
                            ROP        2.640000           0.0000000
                      SHORTAGES       0.3183559           0.0000000
                    SAFETYSTOCK       0.3183559           0.0000000
                            SLM       0.9936070           0.0000000
                              Z     0.0000000         1.323662
```

Solution: Item 3 - Plastic Mindural

```
Local optimal solution found at step:            34
 Objective value:                              496.2990

                       Variable           Value        Reduced Cost
                              D        1500.000            0.0000000
                            SDD        47.63000            0.0000000
                              L       0.1100000E-01        0.0000000
                            SDL       0.5500000E-02        0.0000000
                           SDLD        4.986000            0.0000000
                              H        5.070000            0.0000000
                             SC       0.5400000            0.0000000
                              K        15.12000            0.0000000
                            MLD        16.50000            0.0000000
                      TOTALCOST        496.2990            0.0000000
                   ORDERINGCOST        231.6902          -0.9148786E-07
                    HOLDINGCOST        248.1494            0.0000000
                   SHORTAGECOST        16.45932            0.0000000
                              Q        97.88933            0.0000000
                            ROP        16.50000            0.0000000
                      SHORTAGES        1.989126            0.0000000
                    SAFETYSTOCK        1.989126            0.0000000
                            SLM       0.9796798            0.0000000
                            Z      0.0000000         4.650316
```

Solution: Item 4 - Magnesium Crystals

```
Local optimal solution found at step:            41
 Objective value:                              3664.239

                       Variable           Value        Reduced Cost
                              D        36000.00            0.0000000
                            SDD        1143.150            0.0000000
                              L       0.1100000E-01        0.0000000
                            SDL       0.5500000E-02        0.0000000
                           SDLD        119.6710            0.0000000
                              H        5.920000            0.0000000
                             SC       0.5400000            0.0000000
                              K        15.12000            0.0000000
                            MLD        396.0000            0.0000000
                      TOTALCOST        3664.239            0.0000000
                   ORDERINGCOST        1098.828            0.0000000
                    HOLDINGCOST        2197.960            0.0000000
                   SHORTAGECOST        367.4517            0.0000000
                              Q        495.3644            0.0000000
                            ROP        519.5949            0.0000000
                      SHORTAGES        9.363296            0.0000000
                    SAFETYSTOCK        132.9582            0.0000000
                            SLM       0.9810982            0.0000000
                              Z        1.032789            0.3723324E-07
```

Solution: Item 5 - Silicon Metal SS4

```
Local optimal solution found at step:            43
 Objective value:                              1696.456

                       Variable           Value        Reduced Cost
                              D        18000.00           0.0000000
                            SDD        571.5800           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        59.83500           0.0000000
                              H        3.460000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        198.0000           0.0000000
                      TOTALCOST        1696.456           0.0000000
                   ORDERINGCOST        634.4361           0.0000000
                    HOLDINGCOST        954.3211           0.0000000
                   SHORTAGECOST        107.6986           0.0000000
                              Q        428.9794           0.0000000
                            ROP        259.3256           0.0000000
                      SHORTAGES        4.753137           0.0000000
                    SAFETYSTOCK        66.07879           0.0000000
                            SLM       0.9889199           0.0000000
                            Z      1.024913          0.1529787E-06
```

Solution: Item 6 - Mould Paint PVA

```
Local optimal solution found at step:            38
 Objective value:                              434.9002

                       Variable           Value        Reduced Cost
                              D        2160.000           0.0000000
                            SDD        68.59000           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        7.180000           0.0000000
                              H        2.640000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        23.76000           0.0000000
                      TOTALCOST        434.9002           0.0000000
                   ORDERINGCOST        201.2253           0.0000000
                    HOLDINGCOST        220.6618           0.0000000
                   SHORTAGECOST        13.01309           0.0000000
                              Q        162.3017           0.0000000
                            ROP        26.19317           0.0000000
                      SHORTAGES        1.810740           0.0000000
                    SAFETYSTOCK        4.243909           0.0000000
                            SLM       0.9888434           0.0000000
                              Z       0.3388814           0.0000000
```

Solution: Item 7 - Titanium Boron Coil

```
Local optimal solution found at step:            43
 Objective value:                              1592.154

                       Variable           Value        Reduced Cost
                              D        12000.00           0.0000000
                            SDD        381.0500           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        39.89000           0.0000000
                              H        4.860000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        132.0000           0.0000000
                      TOTALCOST        1592.154           0.0000000
                   ORDERINGCOST        610.5205           0.0000000
                    HOLDINGCOST        869.9846           0.0000000
                   SHORTAGECOST        111.6492           0.0000000
                              Q        297.1890           0.0000000
                            ROP        162.4147           0.0000000
                      SHORTAGES        5.120511           0.0000000
                    SAFETYSTOCK        35.53517           0.0000000
                            SLM       0.9827702           0.0000000
                              Z     0.7624632          0.7313969E-07
```

Solution: Item 8 - Titanium Boron Rod

```
Local optimal solution found at step:            38
 Objective value:                              803.4862

                       Variable           Value        Reduced Cost
                              D        3360.000           0.0000000
                            SDD        106.6900           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        11.16900           0.0000000
                              H        5.490000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        36.96000           0.0000000
                      TOTALCOST        803.4862           0.0000000
                   ORDERINGCOST        351.3406           0.0000000
                    HOLDINGCOST        406.5641           0.0000000
                   SHORTAGECOST        45.58145           0.0000000
                              Q        144.5981           0.0000000
                            ROP        38.71632           0.0000000
                      SHORTAGES        3.632602           0.0000000
                    SAFETYSTOCK        5.388924           0.0000000
                            SLM       0.9748779           0.0000000
                              Z       0.1572497          -0.1528705E-06
```

Solution: Item 9 - Density Stopper (Big Cone)

```
Local optimal solution found at step:            41
 Objective value:                           301.1978

                       Variable           Value        Reduced Cost
                              D        864.0000           0.0000000
                            SDD        27.44000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        10.74600           0.0000000
                              H        2.830000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        132.5376           0.0000000
                      TOTALCOST        301.1978           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        187.5407           0.0000000
                   SHORTAGECOST        15.09125           0.0000000
                              Q        132.5376           0.0000000
                            ROP        132.5376           0.0000000
                      SHORTAGES        4.287034           0.0000000
                    SAFETYSTOCK        4.287034           0.0000000
                            SLM       0.9676548           0.0000000
                              Z       0.0000000            11.49710
```

Solution: Item 10 - Hullets Foil

```
Local optimal solution found at step:            42
 Objective value:                           281.3229

                       Variable           Value        Reduced Cost
                              D        516.0000           0.0000000
                            SDD        16.39000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        6.418000           0.0000000
                              H        4.390000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        79.15440           0.0000000
                      TOTALCOST        281.3229           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        173.7439           0.0000000
                   SHORTAGECOST        9.013183           0.0000000
                              Q        79.15440           0.0000000
                            ROP        79.15440           0.0000000
                      SHORTAGES        2.560412           0.0000000
                    SAFETYSTOCK        2.560412           0.0000000
                            SLM       0.9676533           0.0000000
                              Z       0.0000000            16.87867
```

Solution: Item 11 - Talc Powder Remelt

```
Local optimal solution found at step:            42
 Objective value:                            275.5814

                       Variable           Value        Reduced Cost
                              D        600.0000           0.0000000
                            SDD        19.05000           0.0000000
                              L       0.1100000           0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        1.995000           0.0000000
                              H        4.070000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        66.00000           0.0000000
                      TOTALCOST        275.5814           0.0000000
                   ORDERINGCOST        133.9824           0.0000000
                    HOLDINGCOST        137.7907           0.0000000
                   SHORTAGECOST        3.808400           0.0000000
                              Q        67.71041           0.0000000
                            ROP        66.00000           0.0000000
                      SHORTAGES       0.7958898           0.0000000
                    SAFETYSTOCK       0.7958898           0.0000000
                            SLM       0.9882457           0.0000000
                              Z       0.0000000            3.346529
```

Solution: Item 12 - Transition Ring N-17 7"

```
Local optimal solution found at step:            25
 Objective value:                            178.7335

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        8.620000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        178.7335           0.0000000
                   ORDERINGCOST        87.50533           0.0000000
                    HOLDINGCOST        89.36672           0.0000000
                   SHORTAGECOST        1.861428           0.0000000
                              Q        20.73474           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9712743           0.0000000
                              Z       0.0000000            10.53671
```

Solution: Item 13 - Transition Ring N-17 6"

```
Local optimal solution found at step:            26
 Objective value:                          166.2730

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        7.460000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        166.2730           0.0000000
                   ORDERINGCOST        81.40485           0.0000000
                    HOLDINGCOST        83.13647           0.0000000
                   SHORTAGECOST        1.731658           0.0000000
                              Q        22.28860           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9732769           0.0000000
                              Z       0.0000000            8.967469
```

Solution: Item 14 - Silicone Water Seals 127L 5"

```
Local optimal solution found at step:            24
 Objective value:                          103.8481

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        2.910000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        103.8481           0.0000000
                   ORDERINGCOST        50.84256           0.0000000
                    HOLDINGCOST        51.92406           0.0000000
                   SHORTAGECOST        1.081532           0.0000000
                              Q        35.68664           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9833097           0.0000000
                              Z       0.0000000            2.989131
```

Solution: Item 15 - Silicone Water Seals 127S 5"

```
Local optimal solution found at step:            42
 Objective value:                              102.4107

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        2.830000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        102.4107           0.0000000
                   ORDERINGCOST        50.13882           0.0000000
                    HOLDINGCOST        51.20535           0.0000000
                   SHORTAGECOST        1.066562           0.0000000
                              Q        36.18753           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9835407           0.1843554E-06
                              Z       0.0000000            2.888453
```

Solution: Item 16 - Silicone Water Seals 152L 6"

```
Local optimal solution found at step:            24
 Objective value:                              109.5784

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        3.240000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        109.5784           0.0000000
                   ORDERINGCOST        53.64798           0.0000000
                    HOLDINGCOST        54.78916           0.5996785E-08
                   SHORTAGECOST        1.141209           0.0000000
                              Q        33.82047           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9823887           0.0000000
                              Z       0.0000000            3.407027
```

Solution: Item 17 - Silicone Water Seals 152S 6"

```
Local optimal solution found at step:           25
 Objective value:                           106.8385

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        3.080000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        106.8385           0.0000000
                   ORDERINGCOST        52.30657           0.0000000
                    HOLDINGCOST        53.41922           0.2351611E-08
                   SHORTAGECOST        1.112674           0.0000000
                              Q        34.68780           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9828291           0.0000000
                              Z       0.0000000            3.203910
```

Solution: Item 18 - Silicone Water Seal 177.8L 7"

```
Local optimal solution found at step:           24
 Objective value:                           113.7274

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        3.490000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        113.7274           0.0000000
                   ORDERINGCOST        55.67928           0.0000000
                    HOLDINGCOST        56.86367           0.0000000
                   SHORTAGECOST        1.184419           0.0000000
                              Q        32.58663           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9817219           0.0000000
                              Z       0.0000000            3.726121
```

Solution: Item 19 - Silicone Water Seal 177.8S 7"

```
Local optimal solution found at step:            24
 Objective value:                            109.5784

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        3.240000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        109.5784           0.0000000
                   ORDERINGCOST        53.64798           0.0000000
                    HOLDINGCOST        54.78916           0.5996785E-08
                   SHORTAGECOST        1.141209           0.0000000
                              Q        33.82047           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9823887           0.0000000
                              Z       0.0000000            3.407027
```

Solution: Item 20 - Silicone Seals 203L 8"

```
Local optimal solution found at step:            23
 Objective value:                            118.9827

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        3.820000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        118.9827           0.0000000
                   ORDERINGCOST        58.25223          -0.2937638E-07
                    HOLDINGCOST        59.49135           0.0000000
                   SHORTAGECOST        1.239151           0.0000000
                              Q        31.14731           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9808773           0.0000000
                              Z       0.0000000            4.150214
```

Solution: Item 21 - Silicone Seals 203S 8"

```
Local optimal solution found at step:           24
 Objective value:                         113.7274

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        3.490000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        113.7274           0.0000000
                   ORDERINGCOST        55.67928           0.0000000
                    HOLDINGCOST        56.86367           0.0000000
                   SHORTAGECOST        1.184419           0.0000000
                              Q        32.58663           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9817219           0.0000000
                              Z       0.0000000            3.726121
```

Solution: Item 22 - Back Launder

```
Local optimal solution found at step:           19
 Objective value:                         270.7213

                       Variable           Value        Reduced Cost
                              D        30.00000           0.0000000
                            SDD       0.9500000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.3730000           0.0000000
                              H        74.59000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        4.602000           0.0000000
                      TOTALCOST        270.7213           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        171.6316           0.0000000
                   SHORTAGECOST       0.5238263           0.0000000
                              Q        4.602000           0.0000000
                            ROP        4.602000           0.0000000
                      SHORTAGES       0.1488055           0.0000000
                    SAFETYSTOCK       0.1488055           0.0000000
                            SLM       0.9676654           0.0000000
                              Z       0.0000000            27.16555
```

Solution: Item 23 - Small Cone Plug

```
Local optimal solution found at step:          46
 Objective value:                         183.0912

                       Variable           Value        Reduced Cost
                              D        600.0000           0.0000000
                            SDD        19.05000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        7.463000           0.0000000
                              H        1.670000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        92.04000           0.0000000
                      TOTALCOST        183.0912           0.0000000
                   ORDERINGCOST        82.74696           0.0000000
                    HOLDINGCOST        91.54560           0.0000000
                   SHORTAGECOST        8.798680           0.0000000
                              Q        109.6354         -0.2511431E-07
                            ROP        92.04000           0.0000000
                      SHORTAGES        2.977306           0.0000000
                    SAFETYSTOCK        2.977306           0.0000000
                            SLM       0.9728436           0.0000000
                              Z       0.0000000            1.435700
```

Solution: Item 24 - Front Launder

```
Local optimal solution found at step:          19
 Objective value:                         297.3898

                       Variable           Value        Reduced Cost
                              D        30.00000           0.0000000
                            SDD       0.9500000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.3730000           0.0000000
                              H        86.18000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        4.602000           0.0000000
                      TOTALCOST        297.3898           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        198.3002           0.0000000
                   SHORTAGECOST       0.5238263           0.0000000
                              Q        4.602000           0.0000000
                            ROP        4.602000           0.0000000
                      SHORTAGES       0.1488055           0.0000000
                    SAFETYSTOCK       0.1488055           0.0000000
                            SLM       0.9676654           0.0000000
                              Z       0.0000000            31.48862
```

Solution: Item 25 - Graphite Ring 127 5"

```
Local optimal solution found at step:            25
 Objective value:                          20.01270

                       Variable           Value        Reduced Cost
                              D        2.040000           0.0000000
                            SDD       0.6000000E-01       0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.2500000E-01       0.0000000
                              H        6.490000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD       0.3129360           0.0000000
                      TOTALCOST        20.01270           0.0000000
                   ORDERINGCOST        10.00279           0.0000000
                    HOLDINGCOST        10.00635           0.0000000
                   SHORTAGECOST       0.3562978E-02       0.0000000
                              Q        3.083620           0.0000000
                            ROP       0.3129360           0.0000000
                      SHORTAGES       0.9973557E-02       0.0000000
                    SAFETYSTOCK       0.9973557E-02       0.0000000
                            SLM       0.9967656           0.0000000
                              Z       0.0000000           0.1577845
```

Solution: Item 26 - Graphite Ring 6"

```
Local optimal solution found at step:            26
 Objective value:                          24.87905

                       Variable           Value        Reduced Cost
                              D        2.040000           0.0000000
                            SDD       0.6000000E-01       0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.2500000E-01       0.0000000
                              H        10.03000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD       0.3129360           0.0000000
                      TOTALCOST        24.87905           0.0000000
                   ORDERINGCOST        12.43510           0.0000000
                    HOLDINGCOST        12.43952           0.0000000
                   SHORTAGECOST       0.4429363E-02       0.0000000
                              Q        2.480463           0.0000000
                            ROP       0.3129360           0.0000000
                      SHORTAGES       0.9973557E-02       0.0000000
                    SAFETYSTOCK       0.9973557E-02       0.0000000
                            SLM       0.9959792           0.0000000
                              Z       0.0000000           0.2451986
```

Solution: Item 27 - Graphite Ring 177.8 7"

Local optimal solution found at step: 26
Objective value: 28.69203

Variable	Value	Reduced Cost
D	2.040000	0.0000000
SDD	0.6000000E-01	0.0000000
L	0.1534000	0.0000000
SDL	0.2740000E-01	0.0000000
SDLD	0.2500000E-01	0.0000000
H	13.34000	0.0000000
SC	0.5400000	0.0000000
K	15.12000	0.0000000
MLD	0.3129360	0.0000000
TOTALCOST	28.69203	0.0000000
ORDERINGCOST	14.34091	0.0000000
HOLDINGCOST	14.34601	0.0000000
SHORTAGECOST	0.5108210E-02	0.0000000
Q	2.150826	0.0000000
ROP	0.3129360	0.0000000
SHORTAGES	0.9973557E-02	0.0000000
SAFETYSTOCK	0.9973557E-02	0.0000000
SLM	0.9953629	0.0000000
Z	0.0000000	0.3270978

Solution: Item 28 - Graphite Ring 8"

Local optimal solution found at step: 26
Objective value: 30.42488

Variable	Value	Reduced Cost
D	2.040000	0.0000000
SDD	0.6000000E-01	0.0000000
L	0.1534000	0.0000000
SDL	0.2740000E-01	0.0000000
SDLD	0.2500000E-01	0.0000000
H	15.00000	0.0000000
SC	0.5400000	0.0000000
K	15.12000	0.0000000
MLD	0.3129360	0.0000000
TOTALCOST	30.42488	0.0000000
ORDERINGCOST	15.20703	0.0000000
HOLDINGCOST	15.21244	0.0000000
SHORTAGECOST	0.5416721E-02	0.0000000
Q	2.028325	0.0000000
ROP	0.3129360	0.0000000
SHORTAGES	0.9973557E-02	0.0000000
SAFETYSTOCK	0.9973557E-02	0.0000000
SLM	0.9950829	0.0000000
Z	0.0000000	0.3682111

Solution: Item 29 - Cast Iron Plug

```
Local optimal solution found at step:            44
 Objective value:                              100.4293

                       Variable           Value        Reduced Cost
                              D        48.00000           0.0000000
                            SDD        1.520000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.5970000           0.0000000
                              H        6.890000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        7.363200           0.0000000
                      TOTALCOST        100.4293           0.0000000
                   ORDERINGCOST        49.79113           0.0000000
                    HOLDINGCOST        50.21463           0.0000000
                   SHORTAGECOST       0.4235243           0.4396783E-07
                              Q        14.57609           0.0000000
                            ROP        7.363200           0.0000000
                      SHORTAGES       0.2381685           0.0000000
                    SAFETYSTOCK       0.2381685           0.0000000
                            SLM       0.9836603           0.0000000
                              Z       0.0000000            3.582521
```

Solution: Item 30 - Mould 127 Dia 5"

```
Local optimal solution found at step:            19
 Objective value:                              621.4701

                       Variable           Value        Reduced Cost
                              D        72.00000           0.0000000
                            SDD        2.290000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.8960000           0.0000000
                              H        94.46000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        11.04480           0.0000000
                      TOTALCOST        621.4701           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        521.6459           0.0000000
                   SHORTAGECOST        1.258307           0.0000000
                              Q        11.04480           0.0000000
                            ROP        11.04480           0.0000000
                      SHORTAGES       0.3574523           0.0000000
                    SAFETYSTOCK       0.3574523           0.0000000
                            SLM       0.9676363           0.0000000
                              Z       0.0000000            83.05911
```

Solution: Item 31 - Complete Mould 6"

Local optimal solution found at step: 19
Objective value: 761.6286

Variable	Value	Reduced Cost
D	72.00000	0.0000000
SDD	2.290000	0.0000000
L	0.1534000	0.0000000
SDL	0.2740000E-01	0.0000000
SDLD	0.8960000	0.0000000
H	119.8400	0.0000000
SC	0.5400000	0.0000000
K	15.12000	0.0000000
MLD	11.04480	0.0000000
TOTALCOST	761.6286	0.0000000
ORDERINGCOST	98.56584	0.0000000
HOLDINGCOST	661.8044	0.0000000
SHORTAGECOST	1.258307	0.0000000
Q	11.04480	0.0000000
ROP	11.04480	0.0000000
SHORTAGES	0.3574523	0.0000000
SAFETYSTOCK	0.3574523	0.0000000
SLM	0.9676363	0.0000000
Z	0.0000000	105.7996

Solution: Item 32 - Mould 177.8 Dia 7"

Local optimal solution found at step: 19
Objective value: 923.1588

Variable	Value	Reduced Cost
D	72.00000	0.0000000
SDD	2.290000	0.0000000
L	0.1534000	0.0000000
SDL	0.2740000E-01	0.0000000
SDLD	0.8960000	0.0000000
H	149.0900	0.0000000
SC	0.5400000	0.0000000
K	15.12000	0.0000000
MLD	11.04480	0.0000000
TOTALCOST	923.1588	0.0000000
ORDERINGCOST	98.56584	0.0000000
HOLDINGCOST	823.3346	0.0000000
SHORTAGECOST	1.258307	0.0000000
Q	11.04480	0.0000000
ROP	11.04480	0.0000000
SHORTAGES	0.3574523	0.0000000
SAFETYSTOCK	0.3574523	0.0000000
SLM	0.9676363	0.0000000
Z	0.0000000	132.0076

Solution: Item 33 - Complete Mould 8"

Local optimal solution found at step: 19
Objective value: 1069.447

Variable	Value	Reduced Cost
D	72.00000	0.0000000
SDD	2.290000	0.0000000
L	0.1534000	0.0000000
SDL	0.2740000E-01	0.0000000
SDLD	0.8960000	0.0000000
H	175.5800	0.0000000
SC	0.5400000	0.0000000
K	15.12000	0.0000000
MLD	11.04480	0.0000000
TOTALCOST	1069.447	0.0000000
ORDERINGCOST	98.56584	0.0000000
HOLDINGCOST	969.6230	0.0000000
SHORTAGECOST	1.258307	0.0000000
Q	11.04480	0.0000000
ROP	11.04480	0.0000000
SHORTAGES	0.3574523	0.0000000
SAFETYSTOCK	0.3574523	0.0000000
SLM	0.9676363	0.0000000
Z	0.0000000	155.7426

Solution: Item 34 - O-Rings 127 Dia 5"

Local optimal solution found at step: 44
Objective value: 91.77902

Variable	Value	Reduced Cost
D	72.00000	0.0000000
SDD	2.290000	0.0000000
L	0.1534000	0.0000000
SDL	0.2740000E-01	0.0000000
SDLD	0.8960000	0.0000000
H	3.820000	0.0000000
SC	0.5400000	0.0000000
K	15.12000	0.0000000
MLD	11.04480	0.0000000
TOTALCOST	91.77902	0.0000000
ORDERINGCOST	45.31107	0.0000000
HOLDINGCOST	45.88950	0.0000000
SHORTAGECOST	0.5784481	0.3244102E-07
Q	24.02592	0.0000000
ROP	11.04480	0.0000000
SHORTAGES	0.3574523	0.0000000
SAFETYSTOCK	0.3574523	0.0000000
SLM	0.9851222	0.0000000
Z	0.0000000	2.697743

Solution: Item 35 - Black Seal O-Ring 7"

```
Local optimal solution found at step:            43
 Objective value:                          88.72497

                       Variable           Value        Reduced Cost
                              D        72.00000           0.0000000
                            SDD        2.290000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.8960000           0.0000000
                              H        3.570000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        11.04480           0.0000000
                      TOTALCOST        88.72497           0.0000000
                   ORDERINGCOST        43.80329           0.0000000
                    HOLDINGCOST        44.36247           0.0000000
                   SHORTAGECOST       0.5591996           0.1108658E-07
                              Q        24.85293           0.0000000
                            ROP        11.04480           0.0000000
                      SHORTAGES       0.3574523           0.0000000
                    SAFETYSTOCK       0.3574523           0.0000000
                            SLM       0.9856173           0.0000000
                              Z       0.0000000            2.497867
```

Solution: Item 36 - Black Seal O-Ring 6"

```
Local optimal solution found at step:            44
 Objective value:                          85.69073

                       Variable           Value        Reduced Cost
                              D        72.00000           0.0000000
                            SDD        2.290000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.8960000           0.0000000
                              H        3.330000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        11.04480           0.0000000
                      TOTALCOST        85.69073           0.0000000
                   ORDERINGCOST        42.30530           0.0000000
                    HOLDINGCOST        42.84535           0.0000000
                   SHORTAGECOST       0.5400759          -0.7690992E-07
                              Q        25.73295           0.0000000
                            ROP        11.04480           0.0000000
                      SHORTAGES       0.3574523           0.0000000
                    SAFETYSTOCK       0.3574523           0.0000000
                            SLM       0.9861092           0.0000000
                              Z       0.0000000            2.306795
```

Solution: Item 37 - Black Seals 8"

```
Local optimal solution found at step:            46
 Objective value:                           93.79899

                       Variable           Value        Reduced Cost
                              D        72.00000           0.0000000
                            SDD        2.290000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.8960000           0.0000000
                              H        3.990000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        11.04480           0.0000000
                      TOTALCOST        93.79899           0.0000000
                   ORDERINGCOST        46.30833           0.0000000
                    HOLDINGCOST        46.89949           0.0000000
                   SHORTAGECOST       0.5911792           0.0000000
                              Q        23.50851           0.0000000
                            ROP        11.04480           0.0000000
                      SHORTAGES       0.3574523           0.0000000
                    SAFETYSTOCK       0.3574523           0.0000000
                            SLM       0.9847948           0.0000000
                              Z       0.0000000            2.834107
```

Solution: Item 38 - Patching Compound

```
Local optimal solution found at step:            42
 Objective value:                           103.4830

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        5.840000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        103.4830           0.0000000
                   ORDERINGCOST        51.19731           0.0000000
                    HOLDINGCOST        51.74146           0.2882876E-08
                   SHORTAGECOST       0.5441743           0.0000000
                              Q        17.71968           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9832045           0.0000000
                              Z       0.0000000            3.674619
```

Solution: Item 39 - Spoons

```
Local optimal solution found at step:            23
 Objective value:                             213.5375

                       Variable           Value        Reduced Cost
                              D        48.00000           0.0000000
                            SDD        1.520000           0.0000000
                              L       0.1920000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD       0.2110000           0.0000000
                              H        31.32000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD       0.9216000           0.0000000
                      TOTALCOST        213.5375           0.0000000
                   ORDERINGCOST        106.4488           0.0000000
                    HOLDINGCOST        106.7687           0.0000000
                   SHORTAGECOST       0.3200186         -0.1988837E-06
                              Q        6.817927           0.0000000
                            ROP       0.9216000           0.0000000
                      SHORTAGES       0.8417682E-01       0.0000000
                    SAFETYSTOCK       0.8417682E-01       0.0000000
                            SLM       0.9876536           0.0000000
                              Z       0.0000000            6.207436
```

Solution: Item 40 - Starting Head 5"

```
Local optimal solution found at step:            19
 Objective value:                             251.0193

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        32.90000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        251.0193           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        151.4058           0.0000000
                   SHORTAGECOST        1.047653           0.0000000
                              Q        9.204000           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9676653           0.0000000
                              Z       0.0000000            23.23036
```

Solution: Item 41 - Starting Head 6"

```
Local optimal solution found at step:             19
 Objective value:                               260.0392

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        34.86000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        260.0392           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        160.4257           0.0000000
                   SHORTAGECOST        1.047653           0.0000000
                              Q        9.204000           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9676653           0.0000000
                              Z       0.0000000            24.69252
```

Solution: Item 42 - Starting Head 7"

```
Local optimal solution found at step:             19
 Objective value:                               305.8751

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        44.82000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        305.8751           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        206.2616           0.0000000
                   SHORTAGECOST        1.047653           0.0000000
                              Q        9.204000           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9676653           0.0000000
                              Z       0.0000000            32.12268
```

Solution: Item 43 - Starting Head 8"

```
Local optimal solution found at step:            19
 Objective value:                            298.1438

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        43.14000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        298.1438           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        198.5303           0.0000000
                   SHORTAGECOST        1.047653           0.0000000
                              Q        9.204000           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9676653           0.0000000
                              Z       0.0000000            30.86940
```

Solution: Item 44 - Thimble 177.8 Dia

```
Local optimal solution found at step:            45
 Objective value:                            187.5717

                       Variable           Value        Reduced Cost
                              D        240.0000           0.0000000
                            SDD        7.620000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        2.985000           0.0000000
                              H        4.650000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        36.81600           0.0000000
                      TOTALCOST        187.5717           0.0000000
                   ORDERINGCOST        89.95987           0.0000000
                    HOLDINGCOST        93.78582           0.0000000
                   SHORTAGECOST        3.826002           0.0000000
                              Q        40.33799           0.0000000
                            ROP        36.81600           0.0000000
                      SHORTAGES        1.190843           0.0000000
                    SAFETYSTOCK        1.190843           0.0000000
                            SLM       0.9704784           0.0000000
                              Z       0.0000000            9.085068
```

Solution: Item 45 - Thimble .9

```
Local optimal solution found at step:            40
 Objective value:                             97.92943

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        5.230000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        97.92943           0.0000000
                   ORDERINGCOST        48.44976           0.0000000
                    HOLDINGCOST        48.96470           0.0000000
                   SHORTAGECOST       0.5149706           0.4722874E-08
                              Q        18.72455           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9841058           0.0000000
                              Z       0.0000000            3.256160
```

Solution: Item 46 - Transition Plate 5"

```
Local optimal solution found at step:            25
 Objective value:                             153.8873

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        6.390000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        153.8873           0.0000000
                   ORDERINGCOST        75.34099           0.0000000
                    HOLDINGCOST        76.94362           0.0000000
                   SHORTAGECOST        1.602666           0.0000000
                              Q        24.08251           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9752675           0.0000000
                              Z       0.0000000            7.531625
```

Solution: Item 47 - Transition Plate 8"

```
Local optimal solution found at step:            24
 Objective value:                             188.8164

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        9.620000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        188.8164           0.0000000
                   ORDERINGCOST        92.44180           0.0000000
                    HOLDINGCOST        94.40820           0.0000000
                   SHORTAGECOST        1.966438           0.0000000
                              Q        19.62748           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9696537           0.0000000
                              Z       0.0000000            11.89810
```

Solution: Item 48 - Nozzle Cleaner

```
Local optimal solution found at step:            44
 Objective value:                             132.4031

                       Variable           Value        Reduced Cost
                              D        192.0000           0.0000000
                            SDD        6.100000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        2.388000           0.0000000
                              H        2.920000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        29.45280           0.0000000
                      TOTALCOST        132.4031           0.0000000
                   ORDERINGCOST        64.02325           0.0000000
                    HOLDINGCOST        66.20155           0.0000000
                   SHORTAGECOST        2.178332           0.0000000
                              Q        45.34353           0.0000000
                            ROP        29.45280           0.0000000
                      SHORTAGES       0.9526742           0.0000000
                    SAFETYSTOCK       0.9526742           0.0000000
                            SLM       0.9789899           0.0000000
                              Z       0.0000000            4.242826
```

Solution: Item 49 - Exit Insert

```
Local optimal solution found at step:            30
 Objective value:                            106.4596

                       Variable           Value        Reduced Cost
                              D        24.00000           0.0000000
                            SDD       0.7600000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.2990000           0.0000000
                              H        15.55000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        3.681600           0.0000000
                      TOTALCOST        106.4596           0.0000000
                   ORDERINGCOST        53.00401           0.0000000
                    HOLDINGCOST        53.22979           0.0000000
                   SHORTAGECOST       0.2258042           0.4353386E-07
                              Q        6.846275           0.0000000
                            ROP        3.681600           0.0000000
                      SHORTAGES       0.1192837           0.0000000
                    SAFETYSTOCK       0.1192837           0.0000000
                            SLM       0.9825768           0.0000000
                              Z       0.0000000            4.366446
```

Solution: Item 50 - Flex Hose

```
Local optimal solution found at step:            19
 Objective value:                            311.3975

                       Variable           Value        Reduced Cost
                              D        60.00000           0.0000000
                            SDD        1.910000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD       0.7460000           0.0000000
                              H        46.02000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        9.204000           0.0000000
                      TOTALCOST        311.3975           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        211.7840           0.0000000
                   SHORTAGECOST        1.047653           0.0000000
                              Q        9.204000           0.0000000
                            ROP        9.204000           0.0000000
                      SHORTAGES       0.2976109           0.0000000
                    SAFETYSTOCK       0.2976109           0.0000000
                            SLM       0.9676653           0.0000000
                              Z       0.0000000            33.01788
```

Solution: Item 51 - Ceramic Foam Filter

```
Local optimal solution found at step:            43
 Objective value:                          3946.751

                       Variable           Value        Reduced Cost
                              D        2160.000           0.0000000
                            SDD        68.59000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        26.86600           0.0000000
                              H        23.00000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        331.3440           0.0000000
                      TOTALCOST        3946.751           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        3810.456           0.0000000
                   SHORTAGECOST        37.72954           0.0000000
                              Q        331.3440           0.0000000
                            ROP        331.3440           0.0000000
                      SHORTAGES        10.71798           0.0000000
                    SAFETYSTOCK        10.71798           0.0000000
                            SLM       0.9676534           0.0000000
                              Z       0.0000000            570.6310
```

Solution: Item 52 - Nozzle Insert

```
Local optimal solution found at step:            25
 Objective value:                          185.1498

                       Variable           Value        Reduced Cost
                              D        120.0000           0.0000000
                            SDD        3.810000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        1.493000           0.0000000
                              H        9.250000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        18.40800           0.0000000
                      TOTALCOST        185.1498           0.0000000
                   ORDERINGCOST        90.64665           0.0000000
                    HOLDINGCOST        92.57485           0.0000000
                   SHORTAGECOST        1.928251           0.0000000
                              Q        20.01618           0.0000000
                            ROP        18.40800           0.0000000
                      SHORTAGES       0.5956208           0.0000000
                    SAFETYSTOCK       0.5956208           0.0000000
                            SLM       0.9702430           0.0000000
                              Z       0.0000000            11.39355
```

Solution: Item 53 - Degasser Nozzle

```
Local optimal solution found at step:            42
 Objective value:                             573.6495

                       Variable           Value        Reduced Cost
                              D        420.0000           0.0000000
                            SDD        13.34000           0.0000000
                              L       0.1534000           0.0000000
                            SDL       0.2740000E-01       0.0000000
                           SDLD        5.224000           0.0000000
                              H        14.52000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        64.42800           0.0000000
                      TOTALCOST        573.6495           0.0000000
                   ORDERINGCOST        98.56584           0.0000000
                    HOLDINGCOST        467.7473           0.0000000
                   SHORTAGECOST        7.336377           0.0000000
                              Q        64.42800           0.0000000
                            ROP        64.42800           0.0000000
                      SHORTAGES        2.084074           0.0000000
                    SAFETYSTOCK        2.084074           0.0000000
                            SLM       0.9676531           0.0000000
                              Z       0.0000000            66.65770
```

Solution: Item 54 - Bone Ash

```
Local optimal solution found at step:            35
 Objective value:                             665.2472

                       Variable           Value        Reduced Cost
                              D        3600.000           0.0000000
                            SDD        114.3200           0.0000000
                              L       0.1920000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD        15.83100           0.0000000
                              H        3.370000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        69.12000           0.0000000
                      TOTALCOST        665.2472           0.0000000
                   ORDERINGCOST        285.8153           0.0000000
                    HOLDINGCOST        344.3477           0.0000000
                   SHORTAGECOST        35.08423           0.0000000
                              Q        190.4447           0.0000000
                            ROP        76.07799           0.0000000
                      SHORTAGES        3.437040           0.0000000
                    SAFETYSTOCK        10.39503           0.0000000
                            SLM       0.9819526           0.0000000
                              Z       0.4395167          -0.5650764E-07
```

Solution: Item 55 - Fibre Blanket

```
Local optimal solution found at step:            33
 Objective value:                           419.5426

                       Variable           Value        Reduced Cost
                              D        240.0000           0.0000000
                            SDD        7.620000           0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD       0.7980000           0.0000000
                              H        23.98000           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD        2.640000           0.0000000
                      TOTALCOST        419.5426           0.0000000
                   ORDERINGCOST        207.4131           0.4571357E-08
                    HOLDINGCOST        209.7713           0.0000000
                   SHORTAGECOST        2.358257           0.0000000
                              Q        17.49552           0.0000000
                            ROP        2.640000           0.0000000
                      SHORTAGES       0.3183559           0.0000000
                    SAFETYSTOCK       0.3183559           0.0000000
                            SLM       0.9818036           0.0000000
                              Z       0.0000000            16.18040
```

Solution: Item 56 - Filter Cloth

```
Local optimal solution found at step:            46
 Objective value:                           150.2000

                       Variable           Value        Reduced Cost
                              D        1.500000           0.0000000
                            SDD       0.5000000E-01       0.0000000
                              L       0.1100000E-01       0.0000000
                            SDL       0.5500000E-02       0.0000000
                           SDLD       0.5000000E-02       0.0000000
                              H        497.3200           0.0000000
                             SC       0.5400000           0.0000000
                              K        15.12000           0.0000000
                            MLD       0.1650000E-01       0.0000000
                      TOTALCOST        150.2000           0.0000000
                   ORDERINGCOST        75.09467           0.0000000
                    HOLDINGCOST        75.09998           0.0000000
                   SHORTAGECOST       0.5349721E-02       0.0000000
                              Q       0.3020188           0.0000000
                            ROP       0.1650000E-01       0.0000000
                      SHORTAGES       0.1994711E-02       0.0000000
                    SAFETYSTOCK       0.1994711E-02       0.0000000
                            SLM       0.9933954           0.0000000
                              Z       0.0000000            2.479895
```