



**AIMS/ERP** <sup>tm</sup>

**Integrated Production & Material  
Scheduling**

**Functional Specifications**

*AIMS Software, Inc.*

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## **Overview**

The Schedule function performs the following:

- Calculates valid schedule start and complete dates for each operation on all work orders including planned status work orders.
- Generates lower level demand for each manufactured part number.
- Uses a compression scheduling logic to “fit” dates between the current date and the demand date for the work order/operation, removing planned buffer times.
- Generates purchased material requirements, with the requirement dates equaling the start dates of the operation on which the purchased part number is required. Additional buffer days may be added.
- If a work order cannot be scheduled to fit between the demand date for its last operation, and the current date, it is forward scheduled from the first uncompleted operation. If it has next higher assembly demand part number(s), these work orders are also forward scheduled, all the way up the product structure.
- Dates and pegging information are maintained in each work order record for each uncompleted operation for scheduled start date, scheduled completion date, and the demand dates for each as well. This information generates a projected dates late for work orders having future dates, where the scheduled completion date is after the demand date for the work order.
- Overall Summary – the Scheduler performs all normal MRP and CRP functions, plus pegging all lower level demand to the operation, not just the part number, also utilizing the compression algorithm, and forward scheduling up the product structure, so as to maintain schedule date validity for all work orders at all times.
- The Multiple Products Option allows scheduling of a family of very similar products as a though they were a single product. Material movement transactions prompt for the correct finished part number, so inventory is correct. This simplifies shop floor paperwork where the family of products is actually made at the same time.

### **Running Scheduler - Preparatory Steps & Assumptions**

These steps must be performed prior to running the scheduling program. Its operation depends on the validity of these data.

1. Low Level Code calculation program must have been run before scheduling.
2. Manufacturing Calendar should be up to date, including both holidays and extra work dates that fall within the planning horizon period.
3. Review MPS, make sure all entries desired have been made, and any period changes needed have been applied.
4. Review possible routing changes needed, especially alternate work centers that may have been identified to solve delays, or changes in scheduling data for OP status work orders that would affect how critical work orders will be scheduled.
5. WIP updating - make sure all WO Operation movements that have occurred have been entered, especially for off-site manufacturing and movement of material between outside work centers, such as leaving a O/M vendor, onto a ship or truck.
6. WIP WO Completions - any subassembly or other lower level work orders that complete without going to inventory must be completed with the NHA Link transaction, completing the lower level work order and issuing the completed items to the appropriate next higher assembly work order(s).

Performed as part of the Scheduler Process - Update Schedule Days/Hours record in Work Center records - This program reads the manufacturing calendar record and work center master records then generates a new Schedule Days/Hours record for each Work Center. This record contains a list of all valid work days, the hours schedulable, assigns an consecutive hour number for each schedulable, and identifies work centers that are not schedulable for those hours because they are identified as closed on the days corresponding to those hour numbers. The program functions include the following:

Retrieve the Manufacturing Calendar record and current system date.

Calculate the Planning Horizon End Date:

Current System Date  
+ Planning Horizon M-Days from calendar record  
= Planning Horizon End Date

Clear the Schedule Days/Hours table record.

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Starting at the current system date and using the Default Operation Start Time value as the first hour on that day, create the first line in the Schedule Days/Hours record, consisting of the following:

Manufacturing Day Number = next working day in calendar or Extra Work Day, whichever is earlier.

Day Number Schedule Hours = Standard day hours or extra work day hours, if the date is in Extra Work Day list.

Day Start Hour Number = 0.0

Exception Work Center ID's = list (sub-values) of Work Center ID that have this Manufacturing Day listed as a non-working day for this work center only.

Increment each successive day, using the calendar calculation sub-program to calculate working days and convert to system internal day numbers.

For each successive Manufacturing Day Number line, store the schedule hours value for that day, using either the Standard Day Hours or Extra Work Day Hours of this day number is in the Extra Work Day List in the Calendar record.

Add the Day Number Schedule Hours to the preceding line's Day Start Hour Number to obtain the Day Start Hour Number value for this line.

Store the ID's of Work Centers that have this manufacturing day listed as a non-working day for this work center only.

Continues until the number of lines in the table equals the Planning Horizon M-Days value, which is the most future date into which work may be scheduled.

### **Scheduling Program Major Functions - Summary**

General Scheduling Rules - General sequence of scheduling logic is that the Schedule Demand table contains all demand for part numbers to be scheduled. The program translates this data, using various scheduling options and/or Order Rules, into work order records that equal or exceed these demands. In the process of scheduling, demand for lower level items is identified and added to the Scheduled Demand table, which continues as the demand source when that part number's turn to be schedule comes. The results of this process include:

Planned Completion Quantities that are equal or greater (depending on the Routing Type Code and/or Order Rule) than the demand quantity.

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Last Operation Scheduled Completion Dates are equal to or earlier than the demand dates/times.

Demand quantities are defined as data that are in the Scheduling Demand Work table. Initially, this is the MPS record data for the part number, plus any safety stock quantities. During scheduling, the table is updated, as dependent demand required manufactured part numbers and quantities are identified.

Manually entered work orders will be automatically rescheduled to synchronize with management's decisions as reflected in the MPS data and product configuration, which defines dependent demand.

Routing Type Code and Order Rules will determine the relationship between the number of demand lines in the Scheduling Demand Work Table for a given part number and the number of work order records, due to how the Demand Quantities are converted into Planned Completion Quantities in the related Open Work Order records.

Type W (regular work order) work orders with status RNP & OP are:

Rescheduled to have their resulting schedule dates (Operation Scheduled Completion & Start Dates & Times) match the Scheduling Demand Work Table data as far as is possible, before creating or updating any PLND status work orders

Neither the Planned Completion Quantity nor Work Order Effectivity Dates will not be changed by the scheduling program, but may be changed via manual work order change. The scheduling program will always set the last Operation's Scheduled Quantity equal to the Planned Completion Quantity at the beginning of its scheduling process for each work order. So if it has been changed manually, the scheduling program will update Operation Scheduled Quantities, starting with the last operation. When rescheduling and RNP or OP work order, the extended work load (run times) for each operation use the quantities remaining at each operation.

If the Part Number's Route Type Code changes from one to the other, RNP or OP work order records will not be altered, but will continue to be scheduled as originally created, i.e., as regular work order or flow/repetitive scheduled work order records. Any PLND type work orders will be deleted and re-created with the new scheduling rules.

If the Part Number Route Type Code is W, and the Order Rule for the part number has changed since the RNP or OP work order was created, it is not modified.

## **Scheduling Processing Steps**

The following steps constitute the main logic of the scheduling program. It is essentially a series of small sub-programs that are called by the main program. The numbers in the following structure correspond to the numbering scheme used to identify the corresponding sub-processes in this program description.

1. Preliminary Processing Steps:
  - 1a. Load Independent Demand & Part Number Data
  - 1b. Organize Open Work Orders for Scheduling
2. Schedule Each Part Number
  - 2a. Satisfy Dependent Demand with Available Inventory
  - 2b. Retrieve Routing Data
  - 2c. Retrieve Work Order records for the Part Number
  - 2d. Select Scheduling Method for Part Number
3. Flow/Repetitive Routing Type Code Scheduling Algorithm - Planned Development
  - 3a. Calculate the Maximum Hourly Rate
  - 3b. Calculate Cycle Time
  - 3c. Set Scheduling Periods
  - 3d. Summarize Demand for each Schedule Period
  - 3e. Calculate the Hourly Rate for each Period
  - 3f. Calculate Required Workstations
  - 3g. Update Work Order records
4. Regular Work Order Scheduling
  - 4a. Order Rule Processing
    - 4a1. Order Rule 1 - Order Exact Requirements

- 4a2. Order Rule 2 - Order Exact with minimum quantity
- 4a3. Order Rule 3 - Order Exact Requirements with maximum Quantity
- 4a4. Order Rule 4 - Order Exact Requirements between minimum and maximum quantity
- 4a5. Order Rule 5 - Order Fixed Order Quantity
- 4a6. Order Rule 6 - Order Monthly Requirements
- 4a7. Order Rule 7 - Order Weekly Requirements
- 4b. Work Order Update & Create
- 4c. Operation Backscheduling Algorithm
- 4d. Forward Schedule Adjustments
  - 4d1. Work Order Forward Scheduling Algorithm
  - 4d2. NHA Forward Schedule Linking
- 5. Lower Assembly Level Demand Identification

The scheduling program calls each of these sub-programs in turn in order to complete the scheduling process for all part numbers in the system, and to carryout the scheduling process for each part number.

### **Detailed Program Functions**

Each of the following sections describe in detail the functions of each sub-program that form the scheduling program overall.

#### **1. Preliminary Processing Steps:**

These steps must be performed prior to the actual scheduling process.

1.a Clear Demand Work Table - Make sure the Scheduling Demand Work Table is empty at the start of the scheduling process.



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1b. Load Independent Demand & Part Number Data - Load the MPS table into the Scheduling Demand Work Table, omitting any multi-value demand line with an MPS date earlier than the current system date. Read the Part Master table for each part number in the table to retrieve each part number's Low Level Code, Route Name, Order Rule, Safety Stock, and if present, Minimum Order quantity, Maximum Order Quantity, and Fixed Order Quantity Data, adding this data to the MPS data in the record for the part number. This process eliminates redundant accesses to the Part Master table for each part number in the demand table.

The Part Master is re-read before each low level code's scheduling begins to retrieve data for new part numbers that have been added to the Scheduling Demand Work Table as dependent demand identified during the scheduling process. Only those part numbers which are to be processed as part of that low level code group need to have their part master data retrieved at that point.

Order Rule data is retrieved from the Part Master for each part number by scanning fields 22 to 26, and XX and XX (new fields) in the Part Master record, selecting the only one with a Y value. Default; if either no fields or more than one fields have a Y in them, use Order Rule 1, order exact requirements.

1d. Organize Open Work Orders for Scheduling - Sort Open Work Order table by ascending LL Code, Route Name, Parent Part Number, then ascending first Operation Scheduled Start Date, omitting work orders with a status code = "C" (closed).

## **2. Schedule Each Part Number**

2a. Satisfy Dependent Demand with Available Inventory - is performed prior to scheduling any production of a dependent demand source.

Non-MPS demand is identified, then satisfied with available inventory. Remaining demand is then submitted to the scheduling processes. MPS identified demand sources result in scheduled production regardless of inventory quantities. This is accomplished by calculating available, non-safety stock inventory quantities, then subtracting it from the non-MPS demand data.

The following steps adjust the demand data:

From the Inventory record for the part number being scheduled, retrieve the total quantity on hand (not including Receiving Inspection or DMR/MRB quantities) for all locations. Do include WH Transfer quantities.

Subtract the Safety Stock Quantity shown in the Part Master record for the part number.

Total Inventory

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minus Safety Stock Quantity  
= Available Inventory

Calculate Adjusted Demand Quantity for each demand date from:

Non-MPS Demand Quantity for date  
minus Available Inventory  
= Adjusted Demand Quantity for each demand date

If the resulting Adjusted Demand Quantity for each demand date in ascending date sequence is greater than zero and a positive value, continue this process iteratively, satisfying each demand date's quantity with available inventory until a negative Adjusted Demand Quantity value is obtained for a demand date.

The resulting Adjusted Demand data is then processed by the appropriate scheduling methods, depending on Routing Type Code and Order Rule.

2b. Retrieve Work Order records for the Part Number - Retrieve all Open Work Order records (in the sequence previously sorted) where the parent part number equals the part number being scheduled.

2c. Create and Process Planning Array for the Part Number - match demand from Demand Table with supply from Work Order data, modifying as needed according to scheduling rules to insure supply matches demand.

3. Continuous Flow Scheduling Algorithm - Planned Development

#### 4. Regular Work Order Scheduling

These processes are used for part numbers having a routing type of W, for regular work order.

There are several steps to this process:

- 4a. Order Rule Processing - plan work order quantities and completion dates according to which Order Rule is indicated in the Part Master record for this part number. The major process flows include:
- 4b. Work Order Update & Creation - translates results of order rule processing into specific work orders to be submitted for scheduling.
- 4c. Operation Backscheduling - schedule each work order's operations using a primarily backscheduling type of algorithm.

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- 4d. Forward Schedule Adjustments - Used for work orders for which backscheduling resulted in an invalid (dates in the past) schedule; also to modify schedules for higher assembly level work orders having lower level work orders that were forward scheduled.

From this point the scheduler branches to the appropriate Order Rule processing sub-program.

- 4a. Order Rule Processing is used to group demand into individual work order quantities that are then scheduled by operation.

The source for this process is the Schedule Demand table data for the part number being scheduled. Demand data for each part number with an Routing Type of W or associated with a work order with a type of W and a status of RNP or OP, is processed into a Regular Work Order Scheduling Array in RAM to group it from "raw" demand data into preliminary planned completion quantities. This technique is also termed "lot sizing".

The Regular Work Order Scheduling Array columns/fields, one row/line for each work order:

Multiple planning lines, one for each work order:

Planned Quantity (key to planning lines)  
Work Order No. (for RNP & OP work orders only)  
End Day  
End Time  
Start Day  
Start Time  
Over/Under Scheduled Quantity

Order rule processing involves the following steps for the part number being scheduled:

Clear the scheduling array.

Copy Open Work Order records with a status of RNP or OP into the Scheduling Array, as follows:

Planned Completion Quantity (work order) = Planned Quantity (array)  
Work Order No. (from work order record) = Work Order No. (array)

Calculate Over/Under Scheduled Quantities to account for currently open work order quantities, for which the Planned Completion Quantities are not changed. Differences between demand dates and quantities and current work in process are calculated and

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added to subsequently planned quantities. Over/under scheduled conditions are calculated by performing the following steps:

If a planning line has a non-null/blank Work Order No. in its line, then the quantity is not changed.

Calculate Over/Under Scheduled Quantity for this line from:

Demand Quantity  
minus Planned Quantity  
= Over/Under Scheduled Quantity

Add or subtract this quantity to the next demand line's quantity.

If there are Planning Lines that have Work Order Number values, but no corresponding Demand Data line with any dates or quantities, then use the Planning Horizon End Date value as the End Day for that line, and proceed to the Operation Backscheduling Algorithm. No Order Rule processing is needed, since there is no demand for this part number, although there are currently quantities in work in process.

Select the appropriate Order Rule algorithm according to the Order Rule value for the part number as copied into the Scheduling Demand table for the part number.

#### 4a1. Order Rule 1 - Order Exact Requirements

In this algorithm, work order quantities are grouped to match demand data exactly as to dates and quantities. The following steps are performed.

Scheduling line dates match demand data dates exactly. For Planning Lines not flagged as Open Work Order = Y, set the Planning Line dates and quantities equal to the demand line dates and quantities as shown in the table below.

#### Scheduling Demand Data

#### Planning Lines Data

Demand Quantity	= Planned Quantity
Demand Date	= End Day
Demand Time	= End Time

Use the Operation Scheduling algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

#### 4a2. Order Rule 2 - Order Exact with minimum quantity

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In this algorithm, Demand data is processed to produce Planned Quantities that are equal or greater than the Minimum Order Quantity shown for the part number in its Part Master record. The steps include:

Retrieve the Minimum Order Quantity from the Demand table record for the part number.

Process the demand data line against the Minimum Order Quantity value as follows:

Demand Quantity  
minus Minimum Order Quantity  
= Over/Under Scheduled Quantity for this demand line

If the Over/Under Scheduled Quantity value is zero or a positive value, then a Planning Line is written to the Scheduling Array where:

<u>Scheduling Demand Data</u>	<u>Planning Lines Data</u>
Demand Quantity	= Planned quantity
Demand Date	= End Day
Zero	= Over/Under Scheduled Quantity

If the Over/Under Scheduled is negative, the Demand Quantity for this demand line is added to the next Demand line and the Over/Under Scheduled Quantity is calculated again. The process may be repeated with subsequent demand lines until the cumulative Demand Quantity is equal or greater than the Minimum Order Quantity. These demand lines are satisfied by a single Planning Line where:

<u>Scheduling Demand Data</u>	<u>Planning Lines Data</u>
Cumulative Demand Quantity (from demand multiple lines)	= Planned quantity
Demand Date from (first line in the accumulation process)	= End Day
Zero	= Over/Under Scheduled Quantity

The effect of this process is that a planning data line is created that satisfies multiple demand dates and associated quantities, but with a single planning data line having a completion date early enough to satisfy the first demand quantity in this summed group.

Use the Operation Scheduling Algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

#### 4a3. Order Rule 3 - Order Exact Requirements with Maximum Quantity

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In this algorithm, Demand data is processed to produce planned quantities that are equal or greater than the Maximum Order Quantity shown for the part number in its Part Master record. The steps include:

Retrieve the Maximum Order Quantity from the Demand table record for the part number.

Process the Demand line data against the Maximum Order Quantity value as follows:

Demand Quantity  
minus Maximum Order Quantity  
= Over/Under Scheduled Quantity for this Demand Line

If the Over/Under Scheduled Quantity value is zero or a negative value, then a Planning Line is generated where:

<u>Scheduling Demand Data</u>	<u>Planning Lines Data</u>
Demand Quantity	= Planned Quantity
Demand Date	= End Day
Zero	= Over/Under Scheduled Quantity

If it is greater than zero, and positive, then a Planning Line is generated where:

<u>Scheduling Demand Data</u>	<u>Planning Lines Data</u>
Demand Quantity	= Planned Quantity
Demand Date	= End Day
Calculated value	= Over/Under Scheduled Quantity

And the Over/Under Scheduled is added to the next Demand line's Demand Quantity before continuing processing. Generate an additional Planning Line for each iteration of this process, repeating it for successive demand lines until the resulting Over/Under Scheduled Quantity becomes zero or negative. The Demand Date from the initial demand line that generated the Over/Under Scheduled Quantity is the End Day value for each successive Planning Line.

This process compensates for the fact that the quantity needed was greater than the maximum order quantity, so multiple orders due at the same time are planned to satisfy this total demand, each Planning Line representing a separate work order that will be updated or created.

Use the Operation Scheduling Algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

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4a4. Order Rule 4 - Order Exact Requirements between minimum and maximum quantity

In this algorithm, Demand data is processed to produce planned quantities that are equal or greater than the Minimum Order Quantity and equal or less than the Maximum Order Quantity shown for the part number in its Part Master record. The steps include:

Retrieve the Minimum and Maximum Order Quantity values from the demand table record for the part number.

Process the Demand line data against the Minimum and Maximum Order Quantity values as follows:

If the demand line's Demand Quantity is equal or greater than the Minimum Order Quantity and equal or less than the Maximum Order Quantity, then the Planning line data matches the demand line dates and quantities exactly:

Scheduling Demand Data

Planning Lines Data

Demand Quantity

= Planned Quantity

Demand Date

= End Day

Zero

= Over/Under Scheduled Quantity

If the Demand line's Demand Quantity is less than the Minimum Order Quantity, then the Demand Quantity for this demand line is added to subsequent demand lines until the cumulative sum is equal or greater than the Minimum Order Quantity. These demand lines are satisfied by a single Planning Line where the End Day is equal to the first Demand Date that was less than the Minimum Order Quantity value. The corresponding Planned Quantity therefore is the sum of multiple smaller demands.

If the demand line's Demand Quantity is greater than the Maximum Order Quantity, then calculate the Over/Under Scheduled Quantity for this Demand Line as follows:

Demand Quantity

minus Maximum Order Quantity

= Over/Under Scheduled Quantity

A Planning Line is generated where:

Scheduling Demand Data

Planning Lines Data

Demand Quantity

= Planned Quantity

Demand Date

= End Day

Calculated value

= Over/Under Scheduled Quantity

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The Over/Under Scheduled is added to the next Demand line's Demand Quantity before continuing processing. Generate an additional Planning Line for each iteration of this process, repeating it for successive demand lines until the resulting Over/Under Scheduled Quantity becomes zero or negative. The Demand Date from the initial demand line that generated the Over/Under Scheduled Quantity is the End Day value for each successive Planning Line.

Use the Operation Scheduling Algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

4a5. Order Rule 5 - Order Fixed Order Quantity

In this algorithm, Demand data is processed to produce planned quantities that are equal to the Fixed Order Quantity shown for the part number in its Part Master record. The steps include:

Retrieve the Fixed Order Quantity value from the Demand table record for the part number.

Process the demand line data against the Fixed Order Quantity value as follows:

Demand Quantity  
minus Fixed Order Quantity  
= Over/Under Scheduled Quantity for this demand line

If the Unscheduled value is zero (demand quantity equals fixed order quantity), then a Planning line is generated matches the Demand line data exactly:

<u>Scheduling Demand Data</u>	<u>Planning Lines Data</u>
Demand Quantity	= Planned Quantity
Demand Date	= End Day
Zero	= Over/Under Scheduled Quantity

If the Over/Under Scheduled Quantity is a negative value (demand quantity is less than the fixed order quantity), the Demand Quantity for this demand line is added to the next Demand line and the Over/Under Scheduled Quantity is calculated again. The process may be repeated with subsequent demand lines until the cumulative Demand Quantity is equal or greater than the Minimum Order Quantity. These demand lines are satisfied by a single Planning Line where:

<u>Scheduling Demand Data</u>	<u>Planning Lines Data</u>
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Cumulative Demand Quantity  
(from demand multiple lines) = Planned quantity

Demand Date from (first line in  
the accumulation process) = End Day  
Zero = Over/Under Scheduled Quantity

The effect of this process is that a planning data line is created that satisfies multiple demand dates and associated quantities, but with a single planning data line having a completion date early enough to satisfy the first demand quantity in this summed group.

If the Over/Under Scheduled Quantity is greater than zero, and positive, then a Planning Line is generated where:

Planned Quantity	= Demand Quantity
End Day	= Demand Date
Over/Under Scheduled Quantity	= Calculated value

And the Over/Under Scheduled is added to the next Demand line's Demand Quantity before continuing processing. Generate an additional Planning Line for each iteration of this process, repeating it for successive demand lines until the resulting Over/Under Scheduled Quantity becomes zero or negative. The Demand Date from the initial demand line that generated the Over/Under Scheduled Quantity is the End Day value for each successive Planning Line.

This process compensates for the fact that the quantity needed was greater than the maximum order quantity, so multiple orders due at the same time are planned to satisfy this total demand, each Planning Line representing a separate work order that will be updated or created.

Use the Operation Backscheduling Algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

#### 4a6. Order Rule 6 - Order Monthly Requirements

In this algorithm, Demand data is processed to produce planned quantities that are equal to the total demand falling between the first and last calendar days within a calendar month. The steps include:

Read the Demand lines, identifying the first Demand Date's calendar month.

For each successive Demand Date having the same calendar month as the line used to start the accumulation process, add each successive Demand line's Demand Quantity to the

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previously accumulated value until a Demand Date is reached that is the next Calendar month. At this point, a Planning line is generated where:

#### Scheduling Demand Data

#### Planning Lines Data

Cumulative Demand Quantity  
(from demand multiple lines) = Planned quantity

Demand Date from (first line in  
the accumulation process) = End Day  
Zero = Over/Under Scheduled Quantity

Use the Operation Backscheduling Algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

#### 4a7. Order Rule 7 - Order Weekly Requirements

In this algorithm, Demand data is processed to produce planned quantities that are equal to the total demand falling between the first and last calendar days within a calendar week. The steps include:

Read the Demand lines, identifying the first Demand Date's calendar week.

For each successive Demand Date having the same calendar week as the line used to start the accumulation process, add each successive Demand line's Demand Quantity to the previously accumulated value until a Demand Date is reached that is the next Calendar week. At this point, a Planning line is generated where:

#### Scheduling Demand Data

#### Planning Lines Data

Cumulative Demand Quantity  
(from demand multiple lines) = Planned quantity

Demand Date from (first line in  
the accumulation process) = End Day  
Zero = Over/Under Scheduled Quantity

Use the Operation Scheduling Algorithm to calculate operation line data for each work order, both RNP or OP status, and to generate or update PLND status work orders.

#### 4b. Work Order Updating & Creation

This algorithm translates Schedule Array Planning Line data into work orders. When Order Rule processing for each part number is completed, the resulting Scheduling Array

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will contain one Planning Line for each work order to be updated or created. Each Planning Line is read to a corresponding Open Work Order table record, scheduled with this algorithm, then written before reading the next Planning Line in the Scheduling Array. The data for each work order is obtained as follows:

### Scheduling Array

### Work Order record

Each Planning Line = one Work Order record

Work Order No.

(if present; if not,  
next record ID)

= Work Order Number

Demand Part Number

= Parent Part Number

Planned Quantity

= Planned Completion Quantity

End Day

= Last Operation Scheduled Completion Date

Non-RNP/OP lines:

End Day

= Planned Completion Date

### Demand Table

For all Demand Dates  
associated with a given  
Planning Line copy Demand  
data lines into work order  
demand fields:

NHA Work Order No.

= NHA Work Order No.

NHA Operation No.

= NHA Operation No.

Demand line Quantity

= NHA Quantity

Select earliest Demand Date's  
associated

Demand Time

= Last Operation Scheduled Completion Time

(if not blank/null)

Data for the Operation Lines associated with each work order are generated from the Operation Scheduling algorithm, then the Work Order is written to the table and the next Planning Line in the Scheduling Array is read and the process repeated until all Planning Lines have been processed into work orders.

#### 4c. Operation Backscheduling Algorithm

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This algorithm is used to update and create schedules for each work order record. Only work orders with a type of W, regular work order, can be scheduled by this algorithm. If a work order is retrieved where the Parent Part Number on the Work Order matches the part number being scheduled, and its status is RNP or OP, and its type is F (flow/repetitive work order type), it is scheduled with the flow/repetitive scheduling algorithm. If its status is PLND and its type is F, it is deleted. The scheduler then returns to this algorithm to schedule remaining work orders and/or create new PLND status work orders to supply the demanded quantities.

NOTES: All scheduling uses only the Operation Lines on Work Order records, except that new work order records (status = PLND), the Planned Start and Completion Dates are updated to match the first and last operation dates.

Scheduling is initially backwards from the last operation's Scheduled Completion Date and Time. However, if these calculations result in start or completion dates earlier than the next working day that is available for scheduling (i.e., it would be in the past), then the scheduler will first re-perform the backscheduling calculations, this time using Buffer Compression values from each work center record. If this process does not produce dates earlier than the first schedule date, then the process completes at this point. If the process still produces dates earlier than the first schedule date, then the work order then forward scheduled starting at the first operation where there is a Quantity Remaining. If there is next higher assembly demand from work orders, they are listed for forward scheduling after all backscheduling is completed.

Work Center capacity is not considered in any of these algorithms.

Each operation line is scheduled individually.

All scheduling calculations are in decimal hour values.

The schedules for individual work orders having the same parent part number may overlap, since they are calculated individually. This means that the start dates of one may be earlier than the completion date of another. However, related subassembly schedules are dynamically updated to maintain schedule synchronization between demand and supply for manufactured part numbers.

For each primary operation (decimal value = .00; alternates, those with decimal values are skipped) number's line in the work order or retrieved from the Routing Master, perform the following:

Calculate each Operation line's Scheduled Operation Quantity and Load Quantity  
(before calculating start and completion dates & times from the following:

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Scheduled Setup Time and Loaded Unit Run Time are retrieved for each operation from the Scheduling Demand Work record.

Operation Quantity Scheduled is obtained from:

Previous Scheduled Operation Quantity (Planned Completion Quantity if the last operation)  
X Operation Attrition  
= Scheduled Operation Quantity

Operation Load Quantity is obtained from:

Scheduled Operation Quantity  
minus Operation Quantity Completed  
= Operation Load Quantity

Loaded Extended Unit Run Times are calculated for each operation by:

Operation Load Quantity  
X Loaded Unit Run Time

Perform backscheduling using the following steps, using either the Uncompressed Fixed Schedule Interval time or the Compressed Fixed Schedule Interval Time if it is the second attempt to backschedule the same work order number.

Start with the last (largest value) operation's Scheduled Completion Date already present in the Work Order record, and the Scheduled Completion Time.

If the last operation's Scheduled Completion Time is blank, the Default Operation Completion Time from the Calendar record is used.

If the operation number is not the last operation, the Operation Scheduled Completion Date and Time values equal the previous operation's Scheduled Start Date and Time values.

Find the Operation Completion Hour Number In the Schedule Days/Hours record to convert the Scheduled Completion Date and Time as follows:

Locate the Manufacturing Day Number that equals the Operation Scheduled Completion Date.

Retrieve the corresponding Day Start Hour Number.

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Add the Operation Start Time (in hours) to the Day Start Hour Number to obtain the Hour Number that corresponds to the combined Day and Time represented by the Operation Completion Date and Time, equals the Operation Completion Hour Number.

Adjust the Operation Completion Hour Number for Parallel Operation Factor as follows:

If one or more of the Demand lines that this work order is supplying is MPS or SS, skip the parallel operation factor adjustment entirely for the last operation number.

If none of the Demand lines is MPS or SS, or the operation number is not the last operation, then adjust the Operation Completion Hour Number by:

Operation Completion Hour Number  
+ Parallel Operation Factor

Calculate Schedule Interval Hours for each operation:

1st pass schedule calculation (uncompressed buffer times) -

Loaded Extended Unit Run Time (each operation)  
+ Uncompressed Fixed Schedule Interval Hours each operation)  
= Schedule Interval Hours (each operation)

2d pass schedule calculation (compressed buffer times) -

Loaded Extended Unit Run Time (each operation)  
+ Compressed Fixed Schedule Interval Hours each operation)  
= Schedule Interval Hours (each operation)

Calculate Operation Scheduled Start Hour Number =

Operation Completion Hour Number  
minus Schedule Interval Hours

If the resulting Operation Scheduled Start Hour Number is a negative value, then stop the back scheduling at this point, return to the last operation and restart the process, this time using the Compressed Fixed Schedule Interval Time values for each operation line during the back scheduling.

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If this is the second pass (previous failure) and an Operation Scheduled Start Hour Number is still negative, then perform the Forward Scheduling Adjustment process for this work order.

Otherwise, continue the backscheduling process.

Find the Operation Start Date and Time in the Schedule Days/Hours record as follows:

Locate the Day Start Hour Number that is closest to the Operation Scheduled Start Hour Number

Calculate the Operation Scheduled Start Time from:

Operation Scheduled Start Hour Number  
minus Day Start Hour Number

The Operation Scheduled Start Date equals the corresponding Manufacturing Day Number in the Schedule Days/Hours table.

Continue scheduling each operation line in the work order in succession until either all operations in the routing are scheduled, or an operation is reached where the Operation Load Quantity is zero. This indicates that this and all previous operations in the routing have been completed, leaving only the remaining ones to schedule.

NOTE: Parallel Operation Factor - Number of hours that the Schedule Interval of this operation can overlap the next primary operation number. If this value is greater than zero, the scheduling program adds this value, in decimal hours, to the Operation Completion Hour for the operation line with a work center where parallel operation factor value is present. This moves the Operation Completion Date/Time forward in time.

This causes an overlap in the operation start of an operation and the completion dates and times of the preceding operation, resulting in a degree of parallel operation. The operation carrying the Parallel Operation Factor can continue for this number of hours while the next successive operation in the flow can be starting up. This is useful in situations where parts are produced in batches, but can have the same batch being processed on two (or more) machines at two different work centers, at the same time.

Once the predecessor operation is underway, parts are moved to the successor (overlapped) operation and processing begun. Meanwhile, the batch is continued to be processed at the successor operation until all are completed.

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If appropriate Parallel Operation Factor values are added to each work center record in the flow, a very high degree of parallel operation can be generated during scheduling and actual operations, in effect, "daisy-chaining" a series of operations together.

If the Parallel Operation Factor is present at the last operation in a routing, its effects will vary. If the Demand source data for the work order is MPS or SS, then this function is skipped entirely. If the Demand source data for the work order indicates that this is a lower level (dependent demand item) work order, then the Parallel Operation Factor is used, offsetting the last operation to the Next Higher Assembly Work Order's Operation Scheduled Start Date & Time.

4d. Forward Scheduling Adjustments - this algorithm is used if the scheduler has backscheduled operations on a work order twice, once with buffer times not compressed, and an additional pass with work center buffer compression values used, which shortens the schedule interval times. If this occurs, it is because the required completion date for the work order as a whole is too close to the current date being scheduled, i.e., it cannot be completed as originally scheduled, or was initiated inside the actual time required to complete it.

At the completion of backscheduling, i.e., when all work orders have been processed by the backscheduler, the scheduler calls this process, and begins by reading the Forward Scheduling Work Table, processing each work order listed in it, deleting each as it is scheduled, adding to it if NHA demand sources are identified, and continuing iteratively until the Forward Scheduling Work Table is finally empty.

To accomplish the forward scheduling process, the scheduler performs two separate, but related processes:

Starting with the first operation with and positive value for Operation Load Quantity, it calculates operation start and completion dates and times forward through the last operation. Forward scheduling always uses Compressed Before and After Buffer Time values only to schedule the completion of the work order in the shortest possible time and to minimize Next Higher Assembly level forward schedule impact.

Examines the NHA Demand Source data in the work order and, if there are NHA work orders as the source of demand, places these work orders in the Forward Scheduling Work Table to be forward scheduled also.

4d1. Work Order Forward Scheduling Algorithm



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This algorithm is used to calculate operation start and completion dates and times. It starts either with the first operation having a positive Operation Load Quantity, or the Operation Number retrieved from the Forward Schedule Work table, or if this operation number has Operation Load Quantities that are positive at an earlier operation, will backschedule those operations backwards in time from the operation number where the NHA linking occurs, i.e., the point where schedule synchronization must occur. It uses the following steps:

Identify the first operation (smallest primary operation number) where the Operation Load Quantity is greater than zero, or that is equal to the Operation Number retrieved from the Forward Schedule Work Table for the work order.

Set this operation's Scheduled Operation Start Date to either:

Date currently being scheduled (next working day), or

Start Date in the Forward Scheduling Work Table for the Work Order (if retrieved from this table).

Set this operation's Scheduled Operation Start Time to either:

Default Operation Start Time, calculated from the Default Operation Completion Time (calendar) minus the working hours for the first day in the Schedule Days/Hours table, or

Start Time in the Forward Scheduling Work Table for the Work Order (if retrieved from this table).

Find the Operation Start Hour Number in the Schedule Days/Hours record to convert the Scheduled Start Date and Time as follows:

Locate the Manufacturing Day Number that equals the Operation Start Date.

Retrieve the corresponding Day Start Hour Number

Add the Operation Start Time (if obtained from the Forward Scheduling Work Table; otherwise skip this step) to the Day Start Hour Number to obtain the Hour Number that corresponds to the combined Day and Time represented by the Operation Start Date and Time. This equals the Operation Start Hour Number.

Adjust the Operation Start Hour Number for Parallel Operation Factor as follows:

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If one or more of the Demand lines that this work order is supplying is MPS or SS, skip the parallel operation factor adjustment entirely for the last operation number.

If none of the Demand lines is MPS or SS, or the operation number is not the last operation, then adjust the Operation Start Hour Number by:

Operation Start Hour Number  
+ Parallel Operation Factor

Calculate Schedule Interval Hours for each operation:

Loaded Extended Unit Run Time  
+ Compressed Fixed Schedule Interval Time

Calculate the Operation Completion Hour Number from:

Operation Start Hour Number  
+ Schedule Interval Hours this operation  
= Operation Completion Hour Number

Find the Operation Completion Date and Time in the Schedule Days/Hours record as follows:

Locate the Day Start Hour Number that is the closest to the Operation Completion Hour Number

Calculate the Operation Scheduled Completion Time from:

Operation Scheduled Completion hour Number  
minus Day Start Hour Number  
- Operation Scheduled Completion Time

Operation Scheduled Completion Date equals the corresponding Manufacturing Day Number in the Schedule Day's Hours table.

Each operation line in the work order is scheduled in succession, from smaller operation number values through the last until all operations remaining are scheduled.

When the last operation is reached, the scheduler reads the operation line that precedes the operation number (value smaller) where the forward scheduling process began).

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If this operation does not have an Operation Load Quantity that is greater than zero, then the scheduler continues to the NHA Forward Schedule Linking algorithm.

If the Operation Load Quantity is a positive number (indicating that scheduling action is required), then the Backscheduling algorithm is called to calculate the Scheduled Operation Completion and Start Dates and Times, working backwards from the operation number where the forward scheduling began.

At the beginning of the backscheduling process, the Operation Completion Date and Time for the next preceding operation are set equal to the Scheduled Operation Start Date and Time for the operation where the forward scheduling began.

When this backscheduling process is completed for the work order, the scheduler continues to the NHA Forward Schedule Linking algorithm.

4d2. NHA Forward Schedule Linking

This algorithm is used when forward scheduling of a work order is completed, and is used to determine if there is a need to synchronize any next higher assembly level work order's schedule. It examines the NHA Demand Source data in the work order record for Work Order Numbers, and if present, writes these to the Forward Scheduling Work Table. The steps performed include:

Read the NHA Work Order Number field multi-value lines for the work order.

If there all lines have either an MPS Date value or the term "SS", then all demand sources are independent demand and there is no forward schedule linking to be performed. The scheduler then continues to the Lower Assembly Level Demand algorithm.

If there are lines that carry a Work Order Number, indicating that this demand source is dependent demand, and forward scheduling is to be performed.

For each demand source line having a Work Order Number, write these data to the Forward Schedule Work Table:

Work Order data

Forward Schedule Work Table data

Next Higher Assembly  
Work Order No.

= Work Order Number

Next High Assembly  
Operation No.

= Operation No.

Last Operation Completion

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Date = Start Date  
Last Operation Completion Time = Start Time

When all demand source lines in the work order have been processed, the scheduler continues to the Lower Assembly Level Demand algorithm.

#### 5. Lower Assembly Level Demand

This function identifies and creates the demand data for lower assembly level manufactured part numbers that are required to make the part number being scheduled. This demand data includes schedule synchronization data enabling the resulting lower level schedules to support the higher level assembly schedules.

The relationships between parent and component/required part numbers, plus associated data, are carried in the Scheduling Demand Work table for each part number. The parent part number is the record ID for each record, and the Required Part Numbers are the manufactured component part numbers needed to manufacture the parent.

This process also passes NHA demand data, and with this addition, Independent Demand data originally generated from the MPS or SS quantities, passing through the Demand table to Open Work Order table records processed by the schedule through each Level.

The dependent demand data (dates, quantities, etc) for these required part numbers are written to the Scheduling Demand Work record for that part number, to indicate a demand for it. In this way, when the required part numbers turn to be scheduled arrives, all demand for it will have been stored in the demand fields for that part number and it can be scheduled to satisfy those demands.

This process also requires checking for appropriate Engineering Effectivity In and Out Dates to insure that configuration changes are properly scheduled. This is accomplished by performing the following:

Read the Required Part Number data in the Scheduling Demand Work table where its Part Number equals the Parent Part Number of the work order just scheduled. If,

1st Opn Start Date is equal to or between Effectivity In and Out Dates

then generate a Demand line to the Scheduling Demand Work Table record for the required part number as follows, otherwise continue scheduling processing:

(Demand line data)  
Operation Scheduled Start Date = Demand Date

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Required Part Number = Part Number (record ID)

Quantity Per Required  
X Operation Quantity  
Scheduled  
X (1+ Opn/Exception Attrition %)  
X (1 + Planned Attrition %) = Demand Quantity

Operation Scheduled Start  
Time = Demand Time

Work Order Number = NHA Work Order No.

Work Order Type (F or W) = NHA Work Order Type

Operation Used In = NHA Operation No.

Schedule Period = Demand Period (blank if regular work order)

Independent Demand Part No.  
associated with WO No. = Independent Demand Part No.

Independent Demand Date  
associated with WO. = Independent Demand Date

Independent Demand Quantity  
associated with WO. = Independent Demand Quantity

When all manufactured parts required by this work order at all operations have been identified, and the demand for them reflected in the Scheduling Demand Work Table, the same data are written to the work order's Supply fields as follows:

Scheduling Demand record    Work Order record

Required Part Number = Supply Part Number

Operation Used In = Supply Operation No.

Quantity Per Required  
X Operation Quantity Scheduled  
X (1+Opn/Exception Attrition %)  
X (1 + Planned Attrition %) = Subassembly Work Order Quantity

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When all required manufactured part numbers for all operations on this work order have been added to the Supply fields, processing of the work order is complete and it is written to the Open Work Orders table. After each work order the scheduler returns to the Work Order Updating and Creation algorithm where the next Planning line in the Schedule Array is read and processed into a work order.

When all work orders for the same part number have been processed and written to the Open Work Orders table, the scheduler returns to Schedule Each Part Number algorithm selects the next part number to be scheduled.

### **Scheduler Work Order Routing Data Modifications**

The logic applying to and defining routing information as it is used in work orders has been modified. Scheduler is changed to support these concepts. Other programming changes to the work order routing maintenance are implemented to provide these additional logical controls to support the following rules concerning routing data:

- Only primary operation numbers will have their Operation Start and Complete Dates & Times calculated by Scheduler. Alternate operation numbers are for parallel movement of material, and will assume that there is a corresponding primary operation number for scheduling purposes that defines the regular flow of material. In order to provide non-blank date fields, Scheduler will "plug in" the same Operation Start and Complete Dates/Times for an alternate as calculated for its related Primary Operation Number. If there is no operation with the same numbers to the left of the decimal as an alternate, the Operation Start & Complete Dates/ Times of the next preceding operation are plugged into the alternate's data fields.
- If the flow of a route is to be altered, entries are made directly to the operation lines that are to be changed, i.e., different work center, additional or fewer operation steps (add/delete steps), to redefine its normal flow. There are editing restrictions on work orders where movement transactions have been processed.
- Freezing the routing (setting the "frozen" flag) for PLND & RNP orders will cause scheduler to use only operation line data and scheduling values in the work order, and not refresh the work order data from the routing, essentially causing Scheduler to treat the work order as an OP order, for scheduling purposes. Unfreezing the routing will cause scheduler to refresh the complete routing for PLND orders (as at present), and refresh scheduling parameters for RNP orders. OP orders will be processed the same as Frozen PLND or RNP orders. Once an order is an OP status order, the Frozen flag has no effect, either way. Any routing retrievals will always search for Part Exception schedule data.
- Once the work order has been released (status = RNP or OP), changing the route name in the work order header information will only affect how the Route-based shortage reports are organized, but will have no other effect.

Changes to Scheduler must support the following:

If the Frozen? flag = Y, or the status = OP, Scheduler will skip the routing master refresh steps, instead using the work order's operation number sequence and associated scheduling variables to calculate operation start and complete dates & times.

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If the Frozen? flag = N, and the status is PLND, Scheduler will retrieve the current routing data from the Routing Master table, using the Route Name in the Part Master table for the part number being scheduled, then retrieving routing primary operation lines, including Part Exception data.

If the Frozen? flag = N and the status is RNP, Scheduler will not alter the current routing operation line structure

Alternative A:

RNP + Frozen = N are also re-blown from route master like PLND orders.

Alternative B:

RNP - operation line data is looked up in routing master from work order operation numbers. If there is a match, Routing scheduling variables are used; if there is no match, work order data is used.



## **Multiple Products/Power Supply Mix Capability Summary**

The Multiple Products/Power Supply Mix capability includes the following functions:

- Multiple Products list in Part Master table screen to allow part numbers to be designated as allowing multiple produced part numbers, assign valid power supply codes, to allow abbreviated reporting, assign valid associated part numbers for material movement/tracking purposes, and to enter a default product mix table to be used for scheduling purposes. These multiple part numbers in effect give the "root" part number the characteristic of allowing multiple parent part numbers.
- Work Order record fields - Alteration to the Open Work Order record to add data fields for Power Supply Codes, associated P/N's and product mix.
- Ability to change mix - Addition of fields to the Open Work Order maintenance screen to maintain these data, allowing changes to RNP and OP work orders.
- Reorientation of production schedule information - A new inquiry and reports display the primary part number, which is the Parent Part Number identified as the product configuration parent part number retrieved and used to generate work order material record data.
- Impact on BOM's - No change is required to the Product Configuration record or maintenance logic. Parent Part Numbers identify "generic" products to be manufactured, each of which, when completed, must be reported as complete by selecting from one of the valid associated part numbers in the Multiple Products list, defined in the Part Master record.
- Purchase Parts only in Mix - the list of parts associated with each of the multiple products should contain only part numbers coded as purchased. The scheduling system and work order generation processes will skip required part numbers designated as manufactured parts. The purpose of the multiple products capability is to provide a flexible management tool for products that are essentially the same, but with minor variations. It is not a substitute for a configure to order methodology.
- Scheduler Changes - The Scheduling Program is changed to copy this multiple produced part number and associated default power supply mix into the Planned Open work Order records that are generated and/or updated. No change to the MPS record or the use of its data as the independent demand source to Scheduler is planned. The MPS will be stated in terms of the product itself, regardless of mix. Mix data is maintained in the resulting Open Work Order records that Scheduler creates and reschedules.

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- Summary Manufacturing Report - A new Summary Manufacturing Plan report is added which retrieves those work orders with these types of parent part numbers and displays their planned volume, planning period, and planned product mix data.
- Work Order Completion & Move to Stock Transaction Changes - This program will call a different sub-program whenever a MPA? = Y part number is detected. This program will run instead of the normal WO Completion & MTS program, collecting and validating work order, part number and inventory location data. Once the work order number is entered and validated, the program then prompts for entry of and validates selections for product mix. Completed quantities of each power supply designated are also posted to the work order record.
- Receipt to Dock, Outside Manufacturing PO Types - Whenever a MPA? = Y part number is detected, via selection of the PO Line Item, a different sub-program will perform the work order validation, prompt for power supply code, and update the Receiving Lot record with the selected part number and associated PO Line Item & WO Parent Part Number for cross reference. Completed quantities of each power supply designated are also posted to the work order record.

### **Scheduler Functions for Multiple Products**

The Scheduling program is enhanced to add the following functions for part numbers that have been flagged as Multiple Products Allowed? = Yes (MPA flag):

Open Work Order record has a set of multi-value fields added, termed the multiple product data list:

- Power Supply Codes (stack "key")
- Related Part Numbers
- Related Mix Quantities
- Related Mix Quantities Completed

Scheduler Added Logic:

If the Part Number being scheduled has the MPA? flag = Yes in the Part Master record, then as part of the creating or update of a planned work order, the Scheduler retrieves the current Multiple Product data list for the part number and copies the Power Supply Codes, and Related Part Numbers into the Open Work Order record.

The Planned Completion Quantity for the work order is for the work order's parent part number. This value is multiplied times the Default Production Mix values for each Power Supply Code to obtain the Related Mix Quantity for each power supply code.

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This additional logic includes additional steps to retrieve multiple product oriented configuration data and add it to the Work Order material record. These steps follow the creation of the Open Work Order Multiple Product List as described above. For each of the Part Numbers in the multiple product list, the following steps are performed:

- Read each Part Number.
- Using the operation numbers in the Operation list for the Open Work Order
- Each of the Part Numbers in the multiple product list is used to attempt to retrieve a product configuration record for each Power Supply part number.
- Scan the Product Configuration record's Required Part Number list. For any manufactured part number in the list, skip the part number and continue scanning the list. In particular the program must skip situations where a manufactured part number is shown as required that is equal to the product part number being scheduled. This would create a self-referring loop for scheduler, a fatal condition.
- For each configuration record retrieved, extend the quantities required by the Product Mix Quantity for that part numbers.
- Add the extended quantities for each required part number to the existing Work Order Material record already generated for the scheduled part number.
- Repeat until all part numbers in the Multiple Product List have been processed. The Scheduled Part Number's Work Order Material record may now be written.

No other changes are required for the Scheduler to implement the Multiple Products capability.