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WEIRTON STEEL CORPORATION
LOGISTICS AND INTEGRATED SCHEDULING

Final Report

Project Director:
William J. Murphy

Compiled and Edited by:
Mary Beth Guzzetta

June 1996

Work Performed Under Contract DE-FC07-92ID13162

For
U.S. Department of Energy
Office of Industrial Technologies
Washington, D.C.

By
Weirton Steel Corporation
Weirton, WV

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1.0 ABSTRACT

In order to remain competitive in the changing steel market, US steel producers restructured by taking on foreign and domestic partners, closing facilities and/or trimming work forces, and modernizing their steel making facilities. However, very little was done to develop production management technology to complement these changes.

The Logistics and Integrated Scheduling program (LIS) was undertaken to address this issue. LIS is an information management system that delivers better customer service, better quality materials, and a just-in-time delivery system.

The program involves three major components:

1. Material Marking and Sensing: Advanced research and development applied to determining cost effective, feasible solutions to passive inventory (passive inventory meaning the collection of inventory movement/location information without the current, industry-standard levels of human involvement).
2. Material Inventory and Tracking: Advanced technology applied to the management of inventory movement.
3. Planning and Scheduling: Beginning with annual production plans, order management, and operational constraints, the ability to build integrated schedules capable of pull through and push through scheduling for various plant capability levels and location configurations with rapid turn-around capability.

LIS provides accurate, automated tracking of material flows throughout the mill, the collection and analysis of production data and automated schedule optimization.

2.0 INTRODUCTION

2.1 BACKGROUND

Excess worldwide steel capacity and the desire of foreign countries to capture a share of the US market has forced a climate of change in the domestic steel industry. When, during the 70's and 80's, excess steel was dumped in the US, American steel producers faced staggering losses. They were forced to restructure or perish, and a recovery ensued after changes were made:

- Foreign and domestic partners were taken on
- Facilities were closed
- Work forces were trimmed
- Billions of dollars were spent on modernization programs

These changes have helped to bring about a turn around in the domestic steel market and have made US steel producers competitive again. However, to date, very little has been done to develop new production management technology to correspond with and compliment these initial changes. In order to retain their current market share, US steel manufacturers must find a way to provide better customer service, better quality materials, and just-in-time delivery systems. A near-term, cost-effective program to deal with information management is needed to deliver these benefits and enable domestic steel producers to remain competitive in the world market. Weirton Steel Corp., Miles Burke Assoc., West Virginia University, and Westinghouse Science and Technology Center have joined forces to produce such a program--the Logistics and Integrated Scheduling System (LIS).

LIS enables the steel industry to fully exploit the benefits of the equipment upgrades which dominated capital investment programs in the 1970's and 80's. It allows existing industries to achieve viability and global competitiveness through the integration of business and manufacturing processes.

The LIS program consists of three subprograms:

- Material Marking and Sensing System (MMSS)
- Material Tracking System (MTS)
- Planning and Scheduling System (PSS)

2.2 OBJECTIVES

Principal Objective:

Research and develop a Logistics and Integrated Scheduling System (LIS) that improves competitiveness by improving customer service and reducing costs that are often lumped into the category of overhead.

LIS allows accurate, automated tracking of material flows throughout the mill, the collection and analysis of quality production data, and automated schedule optimization.

Projected Benefits

- Improved on-time delivery
- Improved customer service
- Improved data reliability and availability for better strategic planning
- Lead time reduction
- Finished inventory reduction
- Work-in-process inventory reduction
- Reduced energy usage
- Increased throughput

These objectives were met through the successful research into and development of the three subprograms: MMSS, MTS, and PSS.

2.2.1 MATERIAL MARKING AND SENSING SYSTEM (MMSS)

PROBLEM:

Maintaining the often changing identity of steel throughout its various stages of processing is a universal problem in the steel industry. Each piece is unique in respect to its chemistry, quality, physical dimensions, temper, coating, etc. Identification is critical, however, since the end-use of steel is dictated by its characteristics.

Normal processing operations destroy or occlude stamps, paints, and other conventional markings, making material tracking difficult. So, alternatively, most companies rely on hand written tags, stickers, tickets or brands. However, problems arise when these markers are lost. Costly analytical processes are required to reestablish the material's metallurgical "identity." In addition, these markings are most commonly recorded by hand and are dependent on human accuracy to manually transpose identification numbers from each item to either paper or a computer terminal. In some cases, misidentified material is discovered only after a customer experiences problems with the delivered steel product.

In recent years, bar coding material has become widely used to remedy these problems. This technology has presented a vast improvement over the previously noted manual methods. A bar code label can be used as an index to an information database, allowing for the automatic encoding of product information. However, bar codes can only be used for labeling "cool" products. Additionally, since most material handling is done manually, updated location information must be manually entered into the computer system whenever an item is moved. Virtually all process information must be manually entered as well.

SOLUTION:

A fully automated Material Marking and Sensing System.

Most steel companies already use bar code IDs or appliqués to identify "cool" steel product, and in some processing stages these methods are probably reasonable.

What is really needed, however, is a system for indelibly marking metal, most likely at the slab stage, with an identifier that will not be destroyed throughout the various processing stages. The identifier must be electronically legible, visibly legible if possible, and must not degrade the product from the customer's viewpoint.

2.2.2 MATERIAL TRACKING SYSTEM (MTS)

PROBLEM:

Currently at Weirton Steel, the identity and location of each slab are read visually from tags and hand painted identification markers. Then the locations and IDs of these slabs are typed into a computer manually. The same is true of bar code labels on finished coils--they are manually scanned using a bar code scanner, and then the location of each coil is manually entered into the system. These locations are not tracked in real-time, but rather on a batch update basis--usually no more than once per turn.

In addition, the information that is available is only a general indication of where the material is located, making it difficult to accurately locate a piece of material when it is needed.

Added to this problem is the fact that the present tracking system is paperwork intensive, making errors in recording and tracking material locations far more likely than they would be with an automated system. This causes corrective moves of work-in-process (WIP) inventory, which in turn often results in damaged WIP pieces.

SOLUTION:

A fully automated Material Tracking System.

MTS involves the automation of both the tracking/material identification process and the operator data entry process. It provides a real-time picture of the location of every WIP item and communicates material movement and handling instructions (pick-up schedules, put-down schedules, special schedules and intermill movement) to the operators of the material handling equipment.

2.2.3 PLANNING AND SCHEDULING SYSTEM (PSS)

PROBLEM:

In the steel industry, the process planning and scheduling functions are highly interdependent and extremely data intensive. The function of the planning department is to plan and schedule all phases of production, including: determining unit operating and load requirements; scheduling the exact number of turns and days per week that each unit will operate; maintaining production and inventory records by unit, product, and process; and adjusting production and operating plans to account for planned and unplanned outages, inventory shortages and production backlogs. A tremendous amount of paperwork is generated in both the mill and office settings, and data errors are quite common.

Process planning and scheduling are further complicated by the fact that most steel mills operate around the clock: there is no time to correct errors or to catch up on paperwork if it falls behind.

As a result of its complexity, process planning and scheduling suffer from a lack of integrated system information, untimely data and unresponsiveness to events. All cause and effect scenarios must be derived manually, often resulting in non-optimal operation solutions to difficult production problems.

SOLUTION:

A Planning and Scheduling System (PSS)

The PSS modernizes the planning and scheduling process, employing computers to integrate and assimilate information, reduce the amount of manual computation and paperwork, and provide simulation programs that can quickly evaluate scheduling alternatives and trade-offs.

A major component of the PSS is a computerized scheduling system that assists planners in preparing and analyzing production schedules based upon production goals, inventory position, order status, and unit operating status. It allows for short term scheduling models to be created that will enable schedulers to reschedule and react in response to dynamic plant conditions. Moreover, its incorporation into the overall process planning and scheduling system provides integration of plant information and will permit integrated plant scheduling down to the individual unit level. In addition to Integrated Scheduling, the major components of planning and scheduling that are addressed are as follows:

- Forecasting and Planning -- This component addresses supplying information about the capability of the company to accept new orders.
- Order Management -- This component addresses the information quality and quantity for production needs at the order level.
- Plant Floor Preparation -- This component addresses the gathering of requirements for man-machine interfaces, the development of scheduling conformance rules and codes, and operator training.

2.3 RESULTS

2.3.1 MATERIAL MARKING AND SENSING SYSTEM (MMSS)

After analyzing the marking and sensing requirements of WSC and completing preparatory tasks such as measuring the environment and documenting the functional specifications for the project, the Weirton Steel Corporation (WSC) team identified potential contractors to develop the needed technology.

Three contractors were selected to test and further develop their technologies in order to evaluate their ability to comply with the established functional specifications. Each candidate performed proof-of-concept demonstrations of their technologies and submitted final reports. WSC concluded from these demonstrations and reports that two of the three proved to have viable technologies with a good chance for commercial success:

1. West Virginia University (WVU): Optical Character Recognition (OCR) + Bar Code Recognition for slabs
2. Westinghouse Science and Technology Center (WSTC): Local Global Positioning System for all other with the exception of hot bands.

The technology supplied by the third contractor, Pyrometer Instrument Co., was found to have several fundamental weaknesses that rendered it unworkable as an industrial strength solution to the marking and sensing requirements in a primary metals production facility. Therefore, the Weirton review team determined that the Pyro technology would not be pursued to an in-plant level based on the extremely low likelihood that a commercially feasible product could result.

2.3.1.1 WEST VIRGINIA UNIVERSITY

WVU was selected to develop video camera bar code sensing system for the Weirton Steel slab area. The technology utilizes a video camera and image processing software to read both bar codes and alphanumeric characters from a minimum distance of thirty feet and wide varieties of light levels.

The technology works in the following manner:

Starting with a wide angle view of the slabs, the systems can pinpoint the location of the tags on the slabs. The computer can distinguish identification tags from other bright objects in the scene and control a pan/tilt head to point the camera at each tag in turn. The system then corrects the close-up image for distortions due to variations in camera-tag distance, viewing angle, tag rotation, and light level. It finds both alpha-numeric and bar code label portions and reads each of them independently. The two readings (OCR and bar code) are compared for accuracy verification, and can then be stored in computer memory and downloaded to WSC's database.

A field demonstration of this technology was conducted in the slab yard for representatives of the Department of Energy (DOE) and WSC. The following functions were demonstrated in the slab yard:

1. **Straight Pick and Move:** The operator was directed to pick the top two slabs from a pile marked "A" and take them to pile "C." The operator completed the move and acknowledged it by pressing the "DONE" button ton the touch screen. The database was updated showing the move was completed.

2. **Sort and Move:** The operator was directed to pick two slabs from pile "B" that were not on the top. The operator completed the sort and placed the two designated coils on top of pile "C." The database was updated and showed the new slabs in pile "C."

3. **Field Scan Feature:** The operator was directed to back onto a pile of existing slabs and initiate the Field Scan feature. The tags on the slabs were all scanned and read, and, once the pile number was entered, the slab identifications were updated in the WSC database.

4. **Hot Slab Demo:** The primary concern in reading hot slabs was whether or not the intense infra-red present would cause the camera to bloom and impair tag identification. The hot slab test was performed successfully and videotaped prior to the DOE demo.

In conclusion, the testing program and demonstration of the prototype system proved successful. The capability of the video camera sensing technology was illustrated, but additional development will be required to refine and harden the system before it can be utilized on a full time basis in a slab yard environment. WVU and the DOE are jointly exploring ways of creating interest among commercial suppliers to fund the additional development required.

2.3.1.2 WESTINGHOUSE SCIENCE AND TECHNOLOGY CENTER

WSTC was selected to develop a Local Global Positioning System (Local GPS) to track coil moving devices inside the mill areas. The term "Local GPS" is meant to indicate that the system is functionally similar and produces the same kind of real-time location information as the conventional satellite based GPS.

The local GPS technology uses a video camera based system that measures the position of a coil hauler in three dimensional space. The four cameras mounted at the corners of a designated warehouse space locate the coil haulers by the use of strobe lights mounted on the haulers. After the lights are strobed, the camera transmits its raster back to the frame grabber that converts the video signal to a digitized representation of the image. The four digitized images are then analyzed to determine the 3D position of the placed coil.

A field demonstration of this technology was conducted in the Finished Product Warehouse (FPW) for representatives of the Department of Energy (DOE) and WSC.

The demonstration consisted of dispatching the coil hauler operator to pick coils up from known positions and deliver them to various locations in the FPW warehouse, and then verifying the position measurement accuracy. The tests were performed over a region that enables evaluation of the effect of ambient light variations. In all of the coil movements the position accuracy was well within the specified spatial accuracy requirements of 12 to 18 inches. Hundreds of tests performed at the FPW prior to the DOE demo confirmed that the spatial accuracy requirements were met on over 95% of the tests.

In conclusion, the in-plant trials successfully demonstrated that the local GPS system developed by WSTC can effectively track the movement of materials in real time and provide local databases the accurate position of coils in the FPW warehouse. Additional development will be required to make the system applicable in a routine twenty-four hour operational basis. WSTC and WSC are currently exploring ways to justify funding the additional development.

2.3.2 MATERIAL TRACKING SYSTEM (MTS)

2.3.2.1 PHASE I

Phase I of the Material and Inventory Tracking System resulted in the implementation of the new three-dimensional corporate location definition (CLD) schema via Radio Frequency (RF) scanning devices. This phase allowed for the tracking of both work-in-process and finished material movements via RF scanners after the movement has occurred and default locations as pieces are produced. The following results were delivered to the Tin Mill, Sheet Mill, Strip Steel and FPW:

- A new corporate location schema based on functionality was provided.

  Prior to implementation, the location schema did not take into account the function performed on each coil based on its sub-area location. The new schema includes code that differentiates between sub-area functions; i.e., a coil with the location code of SMAB.METHLD.0005 indicates that the sub-area for the coil is METHLD-- the Metalurgic Hold Area of the Sheet Mill. In addition, the new schema incorporates an x-y-z (x=row, y=column, z=height) code to pinpoint exact coil location within an area and subarea.
- Location codes are bar coded and printed on labels to identify plant floor areas and IPMs, then scanned via RF scanning devices. Prior to MTS, the location codes were hand keyed or written on paper and recorded via the 3270.
- Material movements are recorded accurately and in real-time. This supports the Scheduling System requirement that each piece of material must be in its expected location or will be moved to its expected location.
- Engineering maps of various locations throughout the plant, based on the new CLD schema, were provided.
- Accurate and real-time coil locations were provided as a prerequisite of the Scheduling System. This in turn contributes to increased on-time delivery to customers.
- An organized system for coil placement was provided which led to the elimination of multiple moves and lost coils, and to reduced coil damage.
- Supporting screens and reports for coil and product identification were provided, giving workers on the plant floor immediate access to coil information from their RF scanner screens and reports.
- The RF scanning communication system installed is dynamic, so that as the technology advances, so will the RF scanning system. It will allow for the ability to implement technology so that a mover can record material movements as they occur.

In terms of area-by-area results, implementation of MTS produced the following:

<u>TIN MILL</u>

An RF based, bar-coded location system was installed throughout the WSC Tin Mill. Update functions were created from data obtained from the RF inputs which provide a real-time location determination scheme. This system was installed with interface switches that enabled previous location schemes to co-exist with the new location schemes until the full plant was encompassed in the new schema.

The tracking of work-in-process material is periodically updated via floor scans by Tin Mill personnel. In contrast, the movement of finished material out of the Tin Mill Warehouse is reported via Lift Truck RF intervention (refer to Phase II Intermill Transfer System--Railcar).

FINISHED PRODUCT WAREHOUSE

The Material Tracking System provides the FPW personnel with real-time inventories and accurate locations. This is accomplished by providing the Lift Truck Operators and Shippers with RF technology to record intermill coils and all coil movements as they occur.

SHEET MILL

The RF technology was implemented in the Sheet Mill. Both Lift Truck scanners and hand scanners were used to track in-process coil movements, and they were used in conjunction with each other when handling finished material (refer to Appendix C for detailed standard operating procedures for tracking material in this way).

Following implementation, audit reports were run for management personnel to determine the completeness of scanning activity and the accuracy of area inventories.

STRIP STEEL

The location tracking and RF scanning technology was successfully installed in the Strip Steel environment, providing coil tracking abilities and Cross Systems Product (CSP) and RF screens to summarize coil inventory by: commodity, index number, next operation, and location.

In addition, six lift trucks in the Strip Steel area were equipped with voice activated RF terminals which allow for voice activated data entry.

2.3.2.2 PHASE II

Phase II of the Material and Inventory Tracking System resulted in the ability to track moves as they occurred and, in some areas, the ability to show movement schedules for exit end movements and intermill transfers.

This was achieved through the development of first generation pick-up and put-down schedules for Operations based on the Integrated Scheduling System's output. Numerous material view screens and reports were developed to allow management personnel to view their inventory on a real-time basis and note precise locations. These developments enable the scheduling program to schedule material with the assurance that the steel will be found and moved into position in a timely manner. Using input based on the RF bar-code scanning technology while utilizing real-time location tracking capabilities, a real-time intermill shipment program was developed. This program, to a large extent, automates intermill transfer to the Finished Products Warehouse.

The following results were realized due to the implementation of the Intermill Transfer System and the Crane System and their interface with the Scheduling System for demands:

INTERMILL TRANSFER SYSTEM-- RAIL CAR

The Intermill Transfer system serves the area between the Tin Mill and the FPW. Prior to the RF system being implemented, the shipper would fill out by hand a transfer sheet. He would fill in customer, base weight/gauge, coating, index, IPM (quantity to transfer field), age, base box, weight, carrier, and lineal feet for coils that were loaded on a box car. The transfer sheet would then be faxed to various locations.

The new system enables the buggy driver to automatically record the above information by scanning the location , destination, rail car number and each IPM he loads onto the car. A rail shipper's report is be printed out once a turn, which eliminates the need for transfer papers to be faxed to the locations.

The implementation of this system resulted in the following:

- The replacement of the former, manual method of recording intermill loading with a quicker and more accurate automated method.
- An on-line method of viewing and correcting the identification of rail cars and/or loaded IPMs.
- A report more readable than the reports previously faxed to the locations.
- The increased elimination of the loading of distressed pieces to the FPW.
- The combination of the shippers and buggy drivers positions into one job.

INTERMILL TRANSFER SYSTEM -- #57 CRANE

The Crane Intermill Transfer System serves the #57 Crane in the Strip Steel. It provides the crane operator with an ordered list of material to be moved in a Designated Service Area. A Designated Service Area is the entry or exit of a facility, receiving area, or shipping area within a mill area.

Note: A "proof of concept" RF system was installed at the Tin Mill cleaning lines to test the crane tracking equipment for locations accurate to an x,y grid, and to test voice and touch applications for pick-up schedules and intermill receipts via RF communication.

The implementation of this system:

- **Minimizes manual effort required to move material throughout Weirton Steel.**
  - Provides a movement schedule, which indicates required moves for a designated area, with less manual effort.
  - Provides accurate material locations to support movement schedules, facility schedules and intermill transfers.
  - Supports facility schedules with minimal manual effort.
- **Provides Intermill Transfer schedules to support downstream Scheduling System requirements.**
  - Provides Intermill Transfer schedules dependent on facility schedules.
  - Provides optimal rail car loading schedules to the crane operator.
- **Provides accurate locations and lead time for the Scheduling System.**
  - Integrates facility schedules with material movement to ensure accurate locations and the scheduled date and time material is required at a producing unit.

- **Provides real-time material tracking with minimum operator intervention.**
  - -- Implement crane technology to automatically track a vehicle's location.
  - -- Display Move Schedules to support unit production, facility schedules, and rail car loading to give the operator a list of prioritized moves required.
  - -- Dynamic tracking of a material's location as movements occur, with minimum operator intervention.
  - -- Record all Scheduled and unscheduled material movements.
- **Reduces the number of times material is moved, thereby reducing the volume of damaged material.**
  - -- Provides operator with pertinent material information to choose the best "put down" location.
- **Provides the Tin Mill Operations Planning group maintenance capabilities on intermill transfer schedules.**
  - -- Gives TM Operations Planning the ability to change priority, adjust the intermill transfer schedules, or add rush orders.
- **Provides Tin Mill Operators with an enhanced RF Rail-Car unloading capability.**
- **Provides Operations with appropriate backup procedures and/or applications.**
- **Provides the Operations, Operations Planning, and Accounting Departments with appropriate auxiliary reports.**
  - -- Intermill Reports - Car Tally reports.
  - -- Accounting Summary reports - reports showing all material moved over a period of time.
  - -- In-Process reports - these reports are generated from schedules produced by the scheduling group. These reports show material scheduled for downstream units that is currently in the Strip Steel.
- **Provides potential manpower reductions.**

2.3.3 PLANNING AND SCHEDULING SYSTEM (PSS)

2.3.3.1 FORECASTING AND PLANNING

This subprogram satisfied the need for accurate and timely production planning information. Two on-line booking control reports were created to display the current production capabilities of the company.

The first report, Order Acceptance, is based on planned production rates by product type. It compares the target booking quantity of a specific product type to the current quantity booked. This information is then used by Operations Planning to determine when a potential customer order should be promised based on the plant's projected ability to achieve on-time delivery of the order.

The second report, Unit Load, determines the week in which an order must be processed at each unit in its routing in order to meet its customer promise date. The processing week is determined by taking into consideration the order's product type, date promised and quantity promised, and the lead time and yield for each unit in the order's routing.

This information is used by Operations Planning to determine mill position and obligation off of individually operating units. It reflects whether the units are operating ahead or behind projected production and aids in controlling bookings on future orders.

2.3.3.2 ORDER MANAGEMENT

In preparation for the implementation of integrated scheduling, the Unit Specific Process Codes System was developed. Process codes are used by Order Entry to define the string of operations required to produce a customer order. Prior to IMIS™*, the process codes were generic, meaning that the code would define the type of unit on which an order should be ordered, but it would not suggest which specific unit was most capable of handling the order. For example, the process code GD would translate to "Temper Mill," but it would not specify *which* Temper Mill--#4 line or #5 line.

The Unit Specific Process Code System converts the generic order entry process codes into a unit specific string of operations. It determines the preferred unit and offers alternate units (if there are any) to accommodate material swings for each operation in the process code. It also shows the operation to be performed by each of the specific units. This information is downloaded to the plant floor interface and also feeds the Integrated Scheduling System. The Integrated Scheduling System then uses this information to schedule an order to a specific string of units.

* Note that IMIS™ (Integrated Manufacturing Information System) will be referenced throughout this report.. IMIS™ was a system implemented prior to LIS at WSC. It is the collection of business applications that gather, edit and manage inventory descriptions and locations. Included within the business application portfolio is function that manages inventory relative to its position in the order cycle--a real-time order status or debiting and crediting of order requirements and delivery expectation fulfillment. These applications include Inventory Capture, Distressed Material, Material Reapplication, Material Movement, Order Status, Inventory Tracking, etc.

2.3.3.3 SCHEDULING

2.3.3.3.1 WATERFALL

An early component of the Scheduling System is the Waterfall project. Waterfalling ensures the placement of the most finished material on the most needed orders.

Its implementation prior to the development of the scheduling system resulted in the following:

- *Increased on-time delivery.* By systematically applying material to the oldest orders, those orders are fulfilled in a more timely manner.
- *Decreased overproduction.* The system recalculates needed tonnage during the waterfall process. This decreases overproduction by providing accurate required tonnage per order.
- *Provided data integrity for the success of the Integrated Scheduling System.* The integrated schedules require accurate tonnage requirements for each order.

2.3.3.3.2 INTEGRATED SCHEDULING SYSTEM

The overall program will continue to evolve and be refined for the next several years. As of this writing, we have demonstrated several capabilities that are very promising. Some of these results are natural products of the system's operating in its place, others occur only after special efforts are expended.

- Unit specific order development enables us to read actual obligation at any given operation unit at any time. This leads to better booking control. Our delivery rate has improved to 90% routinely, from 50% previously.
- Integrated scheduling now builds "loading schedules" for material transferred to the Tin Mill. It is essentially tomorrow's schedule driving what is to be delivered. This greatly smoothes the production environment in the Tin Mill, as needed material is what arrives.
- We now schedule operating units that were never scheduled before. This improves our warehouse/delivery performance, helps unit dependent activities, and turns inventory faster.
- We have reduced the manpower required to schedule.
- Operators are now behaving in accord with customer requirements. In previous practice, they made the best production run they could from available material. Now, that material is ordered according to customer delivery needs, a consideration they had no access to before.
- Three separate tests have shown that we can produce useful schedules for operations at approximately half the inventory previously desired for production in our Tin Mill.
- Production performance on Tin Mill platers has improved by 12% since enabling integrated scheduling. We feel that scheduling contributes to this, but is not the only factor.
- We have sustained the operation at a level of production higher than ever achieved before, without material outage disruption occurring.

- We no longer inadvertently produce portions of scheduled material for a customer--we know where all of the material is, and it is scheduled together. This saves on fragmentation costs, additional setups, etc.

- Material movement is driven by operating schedule needs. We can produce "spotter" schedules four hours before production is to begin, enabling accurate material retrieval and positioning for production.

2.3.3.4 PLANT FLOOR

PLANT FLOOR/SCHEDULING SYSTEM INTERFACE

The LIS Plant Floor System provides a method to display a production schedule to the operating personnel throughout Weirton Steel Corporation. This schedule is displayed to the operator on an existing DEC IMIS™ Plant Floor terminal.

The operator has the capability to view multiple run numbers for his/her processing unit. He/She can then select a run number to display a list of In-Process Material (IPMs). From this list of IPMs, the operator can build the unit's lineup, which is the order in which the unit will process the IPMs.

SCHEDULE CONFORMANCE SYSTEM

The Schedule Conformance System was developed to provide the operators with an on-line means of viewing schedule conformance percentages (i.e. a measure of how well the schedules being run are adhering to the schedules generated by the Integrated Scheduling System) and related information. This system eliminates the manual calculations which were formerly performed and provides users with a fast, automated method for receiving conformance information. This information is used as a tool to evaluate the performance of foremen on the plant floor, grading them according to the calculated conformance percentages.

3.0 WORK COMPLETED

3.1 MATERIAL MARKING AND SENSING SYSTEM (MMSS)

Final reports for MMSS were submitted to WSC by the sub-contractors responsible for the high-technology components of the program:

- West Virginia University
- Westinghouse Science and Technology Center

These reports are included in their entirety in Appendix A of this report.

3.2 MATERIAL TRACKING SYSTEM (MTS)

The primary goal of MTS is to provide accurate location definitions and the mechanism to provide real-time location tracking for the Tin Mill, Sheet Mill, Strip Steel and Finished Product Warehouse (FPW). The 28 byte Corporate Location Definition (CLD) Schema has been implemented in conjunction with the current Radio Frequency (RF) network configuration to meet this goal.

3.2.1 PHASE I

Phase I of MTS entailed the implementation of corporate location schema and the tracking of material movements after they have occurred via RF scanning.

3.2.1.1 ACCURATE LOCATION DEFINITIONS

28 BYTE CORPORATE LOCATION DEFINITION (CLD) SCHEMA

Weirton Steel's inventory locations were previously recorded in one of two formats.

One format was made up of 3 fields which contained a total of 6 bytes as shown below:

Building	Bay	Row	
2	3	1	= 6 bytes

The other format was made up of 4 fields which contain a total of 7 bytes as shown below:

Building	Bay	Row	Position	
2	3	1	1	= 7 bytes

These formats were not flexible nor specific enough to support the demands of the just-in-time delivery promised by the Scheduling System.

The new location schema is made up of 28 bytes over 5 fields as shown below:

Location ID	Sub Area	Row	Column	Height	
10	6	4	4	4	= 28 bytes

Not all 5 fields need be used. Location ID is the only required field. This flexibility enables the different mills within the plant to use the fields in a way that pertains to their individual needs. These fields are generally defined as follows:

Location ID	This field must contain a plant indicator. It may optionally include a sub-plant or sub-floor abbreviation.
Sub Area	This field could possibly be a further break down of the plant or sub-floor.
Row	This field is used to partition either a location ID or the combination of location ID and sub-area into rows.
Column	This field identifies the position within a row.
Height	This field quantifies the vertical position of an object.

CROSS REFERENCE OF 28 BYTE CLD SCHEMA TO 7 BYTE LOCATION CODES

Updates were made to tables to support the transition to the new CLD schema.

The Location Table was updated with the addition of a Roll Out Indicator to identify which locations (old 7 byte) had been converted to the new MTS location schema. If the location had been rolled out, any applications that maintained the location would use the 28 byte code, otherwise, the old 7 byte code was retained.

The Unit Table was also updated with the addition of a Roll Out Indicator to identify which units had been rolled out with the new location schema. Default exit and entry locations were also added to the table for each unit, and location records were updated with production and consumption times for the appropriate inventory.

3.2.1.2 RF TRACKING OF INVENTORY

RF INTERFACE

The Radio Frequency (RF) system employs Symbol RF Hand Held terminals as well as vehicle mounted terminals. These terminals communicate, via spread spectrum radio frequencies, with transceivers. These transceivers are connected to a network controller, which communicates to the DEC IMIS™ system. The existing IBM/DEC Interface is utilized for communications between the two platforms.

RF NETWORK CONFIGURATION

See Appendix B for a diagram of the general Logistics communication and technology architecture for Phase I and referenced descriptions of the components.

RF TRACKING--STANDARD OPERATING PROCEDURES (SOPs)

See Appendix C for the Standard Operating Procedures for RF tracking in the Sheet Mill, Strip Steel, and the FPW and for an example of an RF user manual.

RF TRACKING USER SCREENS

See Appendix D for screen prints and descriptions of the MTS user screens.

3.2.1.3 ROLL OUT

The Tin Mill was the first mill-area to roll out the Material and Inventory Tracking System. Hand-held bar-code scanners were programmed to transmit coil information over the Tin Mill's RF System. The programs which operate these scanners exist on the DEC mainframe. The data is then posted to or read from the IBM mainframe data tables where the information is stored.

Several CSP screens are available on the IMIS™ terminals. These screens allow inventory information to be viewed in a variety of ways, including by index, by location, by commodity, etc.

The work performed during the Tin Mill roll out was duplicated for the subsequent rollouts of the remaining mill areas, with functionality being enhanced as needed to accommodate the variances from area to area. The Tin Mill work detail and the variations to it for each rolled-out mill area are provided in the proceeding sections.

TIN MILL SYSTEM DESIGN METHODOLOGY

The following methodology was followed for the Tin Mill to design, develop and implement the Material Tracking System.

Determined Corporate Location Schema

- Researched all mill areas and gathered requirements for new location definitions
    - -- researched all physical requirements for location schema for all mill areas
    - -- in Tin Mill, conducted movement and path analysis
- Defined new schema
- Documented the location definitions with physical implementation
- Coded all application changes
    - -- Plant Floor
    - -- DEC (RF Applications)
    - -- CSP
    - -- Mainframe
- Presented new location schema to the users, by area, for sign-off approval

Determined the Physical System Deliverables

- Defined Tin Mill physical implementation
    - -- developed a plan to map the individual floors in the Tin Mill
    - -- developed rule definitions for mapping physical location names to the Logistics Table definition
    - -- determined physical requirements and changes
        - -- rework of rubber mats and wooden saddles
- Defined business policies and standard operating procedures (driven by scheduling requirements of accurate locations)
    - -- determined system requirements
    - -- captured user requirements
    - -- defined interfaces with IMIS™ plant floor systems, mainframe applications, and the Scheduling Systems

Defined System Functions and Objectives

- Determined the functions to be delivered
- Defined the processes to be implemented; created and diagrammed requirements
- Determined the data requirements and implementation time frames for:
    - -- new corporate location definitions
    - -- accurate location capturing
    - -- historical views of all movements for an IPM
    - -- movement transactions transmitted from the mill via RF devices
    - -- the translation of new location code to old IMIS™ location for existing systems (i.e. shipping)
    - -- the interface to the Scheduling System
    - -- the handling of new locations and old schema under IMIS™
    - -- assuring ad-hoc users proper data for reporting purposes
- Defined project plan and estimated work effort
- Defined data definitions for
    - -- logistics and IMIS™ on mainframe for DB2
    - -- for logistics and IMIS™ on plant floor DEC system for RDB.
- Defined application specifications and end-user requirements for
    - -- new application definitions.
    - -- maintenance to IMIS™ and scheduling applications
        - -- captured list of all existing applications requiring change

- -- for each application requiring change, we detailed the modifications required and the corresponding main IO routing (ZZ87) requirements.
  Note: ZZ87 is the main IO routine for handling all on-line and interface updates for logistics. It handles all updates to the logistics tables from the IMIS™ on-line software and from the Plant Floor Interface System routine. It handles coil movements and updates to the movement tracking and history tables.
- -- conversions to new location schema by add-hoc QMF (Query Management Facility) users (convert queries used by end-users accessing location data with their own query tools)
  - -- First obtained list of users accessing location data
  - -- Then compiled a detailed list, per user, of queries requiring change

Coded Applications
- RF applications on DEC
- IMIS™ applications on mainframe

Implemented Physical Changes in Plant
- Created maps of plant floor and areas in which coils are to be tagged
- Bar coded, created and physically installed signs on plant floor
- Installed rubber mats and wooden saddles

Tested System
- Conducted unit testing
- Conducted integrated testing
- Incorporated fixes for problems encountered in integrated testing
- Conducted integrated testing for fixes

Trained End-Users
- Documented operator's procedures for Red Tagging and RF scanning
- Trained operators on Red Tagging and RF scanning
- Trained QMF users on new tables and converted queries

Rolled Out
- Developed and executed plan for cutover of applications
- Scanned all IPMs in Tin Mill
- Implemented new QMF queries

SHEET MILL SYSTEM DESIGN METHODOLOGY

In addition to the functionality implemented in the Tin Mill, the Sheet Mill roll out included the design and implementation of queries that interface with the Conformance System. Also, an expert end-user manual was developed to allow Sheet Mill personnel to assume more authority over their system.

The following methodology was followed in the Sheet Mill to design, develop and implement the Material Tracking System.

Determined Corporate Location Schema
- Researched all mill areas and gathered requirements for new location definitions
  - -- researched all physical requirements for location schema for all mill areas
  - -- in Sheet Mill, conducted movement and path analysis
- Defined new schema
- Documented the location definitions with physical implementation

- Coded all application changes
  - -- Plant Floor
  - -- DEC (RF Applications)
  - -- CSP
  - -- Mainframe
- Presented new location schema to the users, by area, for sign-off approval

Determined the Physical System Deliverables

- Defined Sheet Mill physical implementation
  - -- developed a plan to map the individual floors in the Sheet Mill
  - -- developed rule definitions for mapping physical location names to the Logistics Table definition
  - -- Created data flow diagrams and decision tables
  - -- determined physical requirements and changes
    - -- rework of rubber mats and wooden saddles
- Developed expert end user manual
- Defined business policies and standard operating procedures (driven by scheduling requirements of accurate locations)
  - -- determined system requirements
  - -- captured user requirements
  - -- defined interfaces with IMIS™ plant floor systems, mainframe applications, and the Scheduling Systems

Defined System Functions and Objectives

- Determined the functions to be delivered
- Defined the processes to be implemented; created and diagrammed requirements
- Determined the data requirements and implementation time frames for:
  - -- new corporate location definitions
  - -- accurate location capturing
  - -- historical views of all movements for an IPM
  - -- movement transactions transmitted from the mill via RF devices
  - -- the translation of new location code to old IMIS™ location for existing systems (i.e. shipping)
  - -- the interface to the Scheduling System
  - -- the handling of new locations and old schema under IMIS™
  - -- assuring ad-hoc users proper data for reporting purposes
- Defined project plan and estimated work effort
- Defined data definitions for
  - -- logistics and IMIS™ on mainframe for DB2
  - -- for logistics and IMIS™ on plant floor DEC system for RDB.
- Defined application specifications and end-user requirements for
  - -- new application definitions
  - -- maintenance to IMIS™ and scheduling applications
    - -- captured list of all existing applications requiring change
    - -- for each application requiring change, we detailed the modifications required and the corresponding main IO routing (ZZ87) requirements.
      Note: ZZ87 is the main IO routine for handling all on-line and interface updates for logistics. It handles all updates to the logistics tables from the IMIS™ on-line software and from the Plant Floor Interface System routine. It handles coil movements and updates to the movement tracking and history tables.
  - -- conversions to new location schema by add-hoc QMF users (convert queries used by end-users accessing location data with their own query tools)
    - -- First obtained list of users accessing location data
    - -- Then compiled a detailed list, per user, of queries requiring change

- -- conformance queries

Coded Applications
- RF applications on DEC
- IMIS™ applications on mainframe

Implemented Physical Changes in Plant
- Created maps of plant floor and areas in which coils are to be tagged
- Bar coded, created and physically installed signs on plant floor
- Installed rubber mats and wooden saddles

Tested System
- Conducted unit testing
- Conducted integrated testing
- Incorporated fixes for problems encountered in integrated testing
- Conducted integrated testing for fixes

Trained End-Users
- Documented operator's procedures for Red Tagging and RF scanning
- Trained operators on Red Tagging and RF scanning
- Trained QMF users on new tables and converted queries

Rolled Out
- Developed and executed plan for cutover of applications
- Scanned all IPMs in Sheet Mill
- Implemented new QMF queries

STRIP STEEL SYSTEM DESIGN METHODOLOGY

The MTS was implemented in the Strip Steel environment in two phases.

In Phase 1, the RF technology implemented in the other areas of the plant were also implemented in the Strip Steel area.

In Phase 2, six lift trucks were equipped with the ability to track coil movement using voice activated data entry. The voice activated data entry system on each lift truck consists of a Symbol 3310 RF terminal, a headset, and a Verbex voice processing unit.

Lift truck operators speak coil movement commands into a microphone. The Verbex unit receives the voice commands and translates them to keyboard commands. Keyboard commands are sent from the Verbex unit to the 3310 RF terminal mounted on the buggy. The Strip Steel RF system connects the 3310 terminal with the Network Controller and the DEC Plant Floor IMIS™ computer.

The following methodology was followed for the Strip Steel to design, develop and implement the Material Tracking System.

Determined Corporate Location Schema
- Researched all mill areas and gathered requirements for new location definitions
  - -- researched all physical requirements for location schema for all mill areas
  - -- in Tin Mill, conducted movement and path analysis
- Defined new schema
- Documented the location definitions with physical implementation
- Coded all application changes
  - -- Plant Floor
  - -- DEC (RF Applications)
  - -- CSP
  - -- Mainframe

- Presented new location schema to the Strip Steel managers for sign-off approval
- Presented new location schema to the users

Determined the Physical System Deliverables

- Determined voice activation system requirements
  - -- voice activation units and software
  - -- mounting brackets for buggies
- Defined Tin Mill physical implementation
  - -- developed a plan to map the individual floors in the Tin Mill
  - -- developed rule definitions for mapping physical location names to the Logistics Table definition
  - -- determined physical requirements and changes
    - -- rework of wooden saddles
- Defined business policies and standard operating procedures (driven by scheduling requirements of accurate locations)
  - -- determined system requirements
  - -- captured user requirements
  - -- defined interfaces with IMIS™ plant floor systems, mainframe applications, and the Scheduling Systems

Defined System Functions and Objectives

- Determined the functions to be delivered
- Defined the processes to be implemented; created and diagrammed requirements
- Determined the data requirements and implementation time frames for:
  - -- new corporate location definitions
  - -- accurate location capturing
  - -- historical views of all movements for an IPM
  - -- movement transactions transmitted from the mill via RF devices
  - -- the translation of new location code to old IMIS™ location for existing systems (i.e. shipping)
  - -- the interface to the Scheduling System
  - -- the handling of new locations and old schema under IMIS™
  - -- assuring ad-hoc users proper data for reporting purposes
- Defined project plan and estimated work effort
- Defined data definitions for
  - -- logistics and IMIS™ on mainframe for DB2
  - -- for logistics and IMIS™ on plant floor DEC system for RDB.
- Defined application specifications and end-user requirements for
  - -- new application definitions.
  - -- maintenance to IMIS™ and scheduling applications
    - -- captured list of all existing applications requiring change
    - -- for each application requiring change, we detailed the modifications required and the corresponding main IO routing (ZZ87) requirements.
      Note: ZZ87 is the main IO routine for handling all on-line and interface updates for logistics. It handles all updates to the logistics tables from the IMIS™ on-line software and from the Plant Floor Interface System routine. It handles coil movements and updates to the movement tracking and history tables.
  - -- conversions to new location schema by add-hoc QMF users (convert queries used by end-users accessing location data with their own query tools)
    - -- First obtained list of users accessing location data
    - -- Then compiled a detailed list, per user, of queries requiring change

Coded Applications

- RF applications on DEC

- IMIS™ applications on mainframe

Implemented Physical Changes in Plant

- Created maps of plant floor and areas in which coils are to be tagged
- Bar coded, created and physically installed signs on plant floor
- Installed wooden saddles

Tested System

- Conducted unit testing
- Conducted integrated testing
- Incorporated fixes for problems encountered in integrated testing
- Conducted integrated testing for fixes

Trained End-Users

- Documented operator's procedures for White Tagging and RF scanning and voice activation
- Trained operators on White Tagging and RF scanning and coil ID marking
- Trained hookers and shippers on RF scanning
- Trained Strip Steel foremen as expert users
- Trained buggy drivers and move-up personnel on voice activation and the RF screen set
- Trained clerks responsible for coil movement on updating locations of coils not scanned.
- Trained QMF users on new tables and converted queries

Rolled Out

- Developed and executed plan for cutover of applications
- Scanned all IPMs in Tin Mill
- Implemented new QMF queries
- Provided 24 hour on-site coverage for 2 week post-roll out period.

FPW SYSTEM DESIGN METHODOLOGY

The following methodology was followed in the FPW to design, develop and implement the Material Tracking System.

Determined Corporate Location Schema

- Researched all mill areas and gathered requirements for new location definitions
- Defined new schema
- Coded all application changes
    - -- Plant Floor
    - -- DEC (RF Applications)
    - -- CSP
    - -- Mainframe
- Presented new location schema to the users, by area, for sign-off approval

Determined the Physical System Deliverables

- Defined FPW physical implementation
    - -- developed a plan to map the individual floors in the FPW
    - -- developed rule definitions for mapping physical location names to the Logistics Table definition
- Defined business policies and standard operating procedures (driven by scheduling requirements of accurate locations)
    - -- determined system requirements
    - -- captured user requirements
    - -- defined interfaces with IMIS™ plant floor systems, mainframe applications, and the Scheduling Systems

Defined System Functions and Objectives

- Determined the functions to be delivered
- Defined the processes to be implemented; created and diagrammed requirements
- Determined the data requirements and implementation time frames for:
  - -- new corporate location definitions
  - -- accurate location capturing
  - -- historical views of all movements for an IPM
  - -- movement transactions transmitted from the mill via RF devices
  - -- the translation of new location code to old IMIS™ location for existing systems (i.e. shipping)
  - -- the interface to the Scheduling System
  - -- the handling of new locations and old schema under IMIS™
  - -- assuring ad-hoc users proper data for reporting purposes.
- Defined project plan and estimated work effort.
- Defined data definitions for
  - -- logistics and IMIS™ on mainframe for DB2
  - -- for logistics and IMIS™ on plant floor DEC system for RDB.
- Defined application specifications and end-user requirements for
  - -- new application definitions.
  - -- maintenance to IMIS™ and scheduling applications
    - -- captured list of all existing applications requiring change
    - -- for each application requiring change, detailed the modifications required and the corresponding main IO routing (ZZ87) requirements.
  - -- conversions to new location schema by add-hoc QMF users (convert queries used by end-users accessing location data with their own query tools).
    - -- First obtained list of users accessing location data
    - -- Then compiled a detailed list, per user, of queries requiring change

Coded Applications

- RF applications on DEC
- IMIS™ applications on mainframe

Implemented Physical Changes in Plant

- Created maps of plant floor and areas in which coils are to be tagged
- Bar coded, created and physically installed signs on plant floor

Tested System

- Conducted unit testing
- Conducted integrated testing
- Incorporated fixes for problems encountered in integrated testing
- Conducted integrated testing for fixes

Trained End-Users

- Documented operator's procedures for RF scanning
- Trained operators on RF scanning
- Trained QMF users on new tables and converted queries

Rolled Out

- Developed and executed plan for cutover of applications
- Scanned all IPMs in FPW
- Implemented new QMF queries

3.2.2 PHASE II

Phase II of MTS built on the functionality implemented in Phase 1. It entailed the tracking of material movements as they occur and, in some areas, showing movement schedules for facility schedules, exit-end movements and intermill movements.

3.2.2.1 RF TRACKING OF INVENTORY

RF NETWORK CONFIGURATION

See Appendix B for a diagram of the general Logistics communication and technology architecture for Phase II and referenced descriptions of the components.

RF TRACKING USER SCREENS

See Appendix D for screen prints and descriptions of the MTS user screens implemented in Phase II.

3.2.2.2 INTERMILL TRANSFER SYSTEM--RAIL CARS

This segment of the Logistics project provides a real-time method of recording the loading of rail cars through RF scanners and viewing the recorded loads through on-line CSP applications. RF scanners are buggy mounted and/or hand held. The data received is processed by the current IMIS™ interface applications.

All intermill transfer loading can be viewed and/or corrected by re-scanning the erroneous data or by on-line CSP applications. The on-line CSP applications are intended for use only as a backup means of correcting data when the RF system is down.

The work flow is as follows:

The buggy driver enters the current turn and date. An RF scanner is used to scan the location of the cars to be loaded. For each car, the following occurs until all cars are loaded: the destination of the rail car and the rail car number are scanned; as each IPM is loaded onto the railcar, it is scanned.

The buggy driver can review the loaded IPM data by viewing the IL37M01 Intermill Carrier View Screen or by reviewing the Rails Shippers Report that is printed once per turn. If errors are found, the buggy driver can perform maintenance through any of the following screens:

IL38M01 -- Intermill Carrier IPM Detail Screen

IL39M01 -- Intermill Carrier Maintenance Screen

IL40M01 -- Intermill Carrier IPM Removal Screen

IL41M01 -- Intermill Carrier IPM Add Screen

If maintenance is performed before the Rail Shippers Report is printed, the report will show the corrections. However, if maintenance is performed after the report is printed, the buggy driver must call the FPW and Tin Mill Accounting to notify them of the change.

3.2.2.3 INTERMILL TRANSFER SYSTEM-- #57 CRANE

This segment of the Logistics project provides an on-line/real-time *Movement Schedule (Rail-Car Loading Schedule)* for the #57 Crane in the Strip Steel. This schedule provides the crane operator with an ordered list of material to be moved in a Designated Service Area.

A *Designated Service Area* is the entry or exit end of a facility, receiving area, or ship- out location within a mill area. The exit end of the #9 Tandem Mill and intermill transfers to the Tin Mill are supported. The operator of the crane indicates the area to be serviced which will limit the view of material to be moved from or to that designated location.

SYSTEM INTERACTION DIAGRAMS

The next two figures depict high-level Logistics System Interaction diagrams. Descriptions follow the figures.

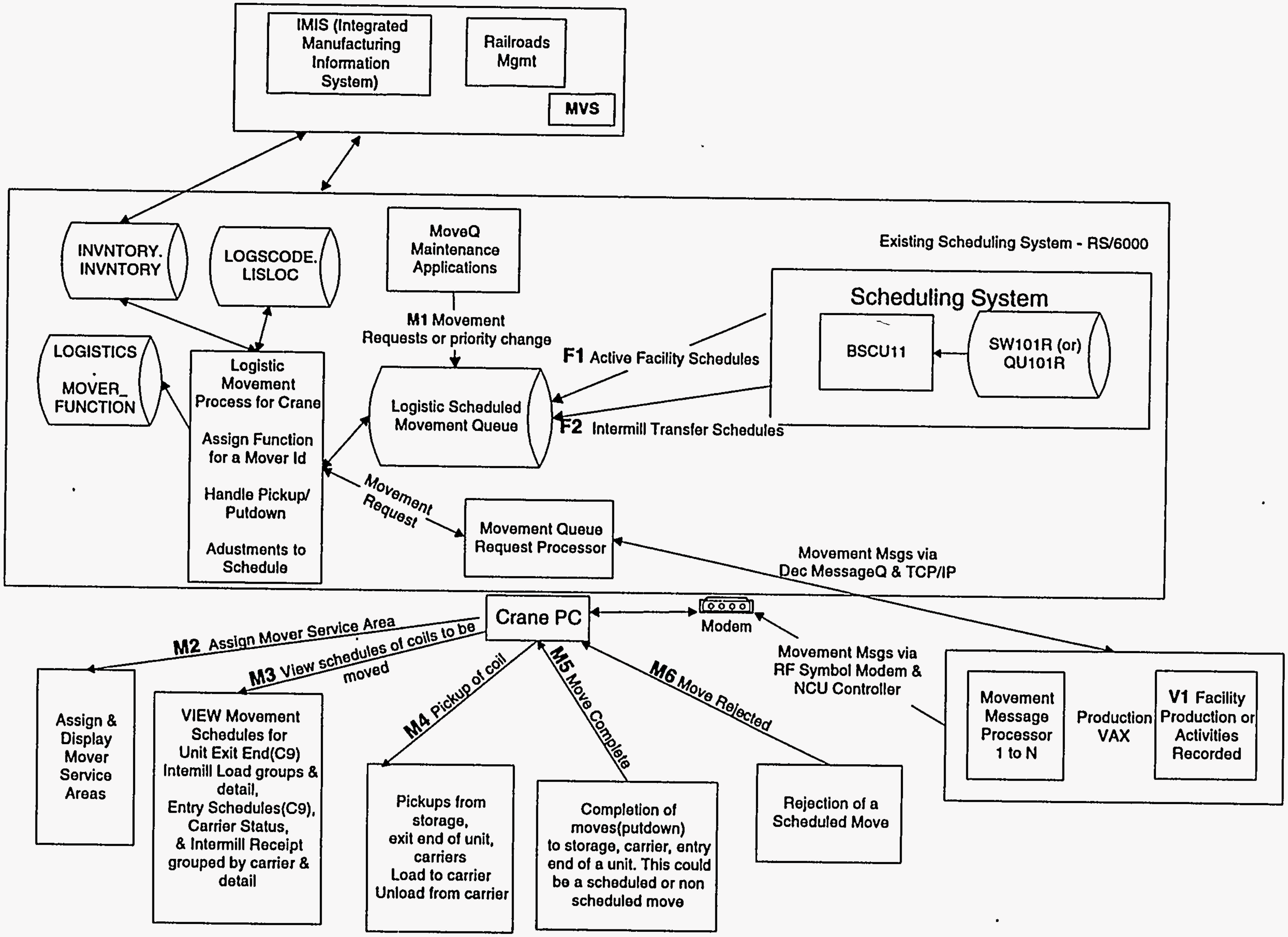
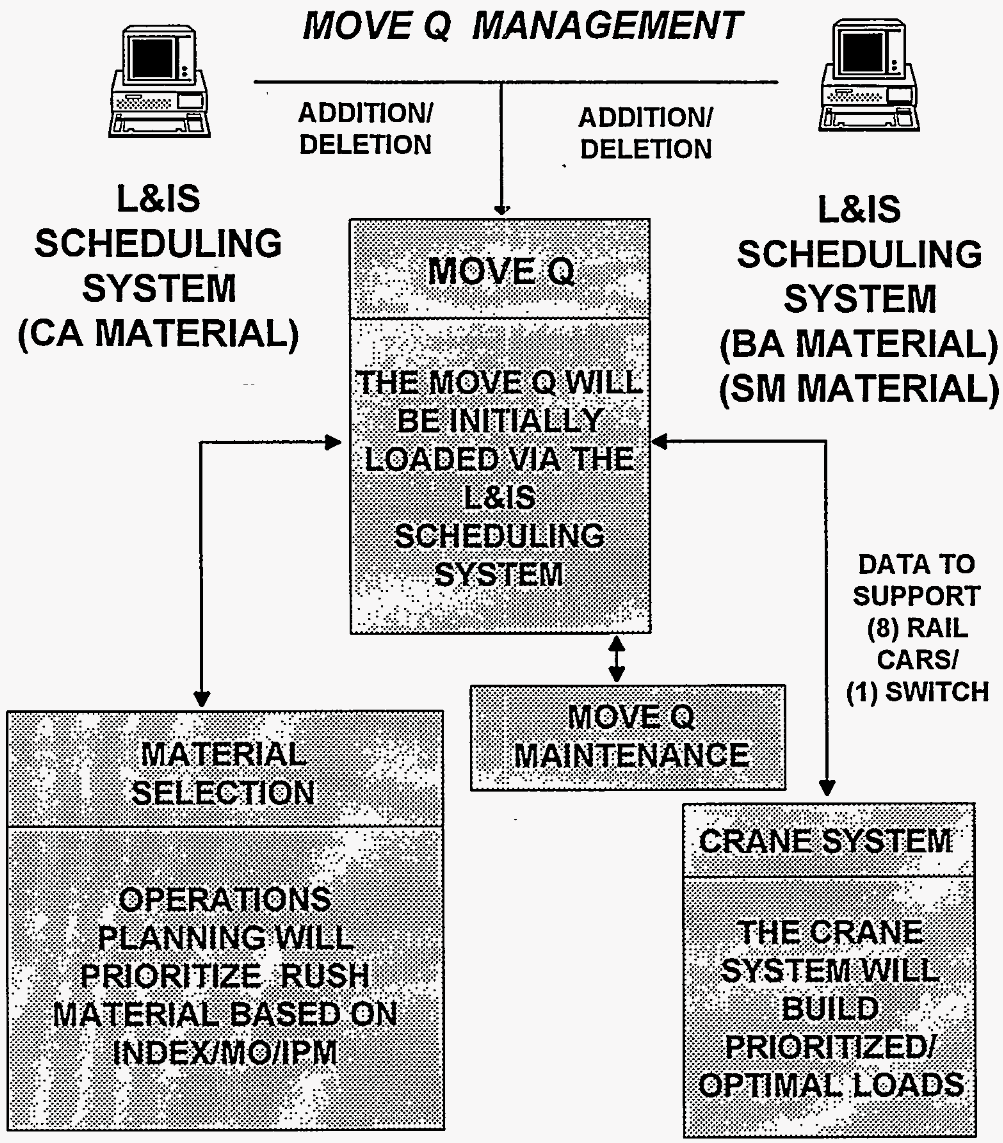


Figure 1 System Interaction Diagram

Figure 2 Move Queue Management Diagram



SYSTEM INTERACTION DIAGRAM DESCRIPTION

The Movement Schedule for cranes is displayed from the Movement Queue which is populated dynamically with requests from the following interfaces:

- **Facility Production and Activities Recorded from the Plant Floor VAX** (Figure 1, V1)

  When a production transaction or an activity is captured from the DEC plant floor system, the transaction is placed in the Movement Queue for the designated service area depending on the facility. We transmit the material identity as it is comes off the exit end of the producing unit or activity via queuing software from the VAX to RISC 6000. For this phase, we captured only the C9 (#9 Tandem Mill) production records.

  The purpose for this interface is to capture newly produced IPMs that reside on the exit end conveyor. Since the IPMs are now captured, hand scanning is not required.

  FUTURE ENHANCEMENT

  Active Facility Schedules (Figure 1, F1)

  Release of final schedules will place demands into the Movement Queue.

  These demands are the list of inventory required to run a unit for that scheduled run ID. The information required is the scheduled unit ID, inventory pieces (IPMs), run number, run sequence, date scheduled, and time scheduled.

- **In Process Intermill Transfer Schedules** (Figure 1, F2)

  The Scheduling System provides the Crane Intermill Transfer system a list of inventory to be transferred from the Strip Steel #57 crane No. 9 Tandem #14 track area to the Tin Mill's Cleaning Line and Continuous Anneal areas.

These Schedules are produced 24 hours in advance to automatically place these demands in a timely manner on the Movement schedule for the upstream facilities location. This coordination integrates the material flow to support scheduling needs between these plants.

The list of coils to be loaded for intermill transfers is placed on the Movement Queue in the order that scheduling requires them.

FUTURE ENHANCEMENTS

Finished Material Intermill

The user will transfer finished material from the Strip Steel, Tin Mill, or Sheet Mill to the Finished Product Warehouse (FPW) dependent on the Material

Release Process in the Distribution System.

The Order correspondents will determine the material that is to be staged for shipments or must be transferred to the FPW or other auxiliary finished storage areas. This will be determined by whether a customer holds the material, ships when ready, or releases an order.

In addition, there is a defined time period that material can sit per mill area. This will be dependent on storage capacity, production levels, and turnover. When the ship date exceeds this designated time or the material is held for release, the coils will then be moved to storage at the FPW. If the scheduled ship date is less than the specified time period, the material will be scheduled to ship from its current plant.

When the Order Correspondent select coils to be transferred, the move demands are sent to the Movement Queue in order to stage the load of the intermill transfer of material. Notification will also be sent to both the ship out and receiving points.

Distribution System - Shipping

When the new proposed Distribution/Shipping system is implemented, the release of material to be shipped outbound will place demands on the Movement Queue. This will require the movers to stage the material to ship at the proper designated location for that material type within the plant.

Manual Movement Request (Figure 1, M1) - Future

We will provide an application that will allow a user to enter a movement request for numerous reasons, i.e. relief of material for a specific storage area, staging of unscheduled material.

- **Assignment of Mover Service Areas and Functions** (Figure 1, M2)

  The Mover identifies his Vehicle ID when he initially logs into the MTS Logistic System. The Vehicle ID determines the list of primary areas and functions that will display on the Movement Schedule View Screen.

  For the Strip Steel #57 Crane, we default the mover ID on the Login screen.

- **View Movement Schedule** (Figure 1, M3)

  The mover selection determines the designated service area or function to be performed. This displays the list of coils in an ordered movement sequence for a specific area, areas, or function. The operator then performs the first move or chooses another depending on the vehicles current position or demands. The Movement Schedule View supports the following scenarios:

  - Service Areas that support *Unit Facility Schedules*; for example, the entry end of #2 Plater (K2). The queue displays a sequential list of IPMs in the order they are to be produced across that unit. The list contains the IPM, unit ID, current location of the piece, run ID, run sequence, distress category, index number and weight. The schedule run ID and run sequence indicate the order the material is to be loaded on a unit. This information is determined by the Facility Schedule System.
  - Service Areas that support *Unit Facility Production or Activities*; for example, the exit end of #2 Plater (K2) or the exit end #9 Tandem (C9). The queue displays a sequential list of IPMs in the order that they were produced off of the unit. The list contains the IPM, unit ID, current location of the piece off the exit end, distress category, number of total pieces grouped together, number of this piece within the group, index number, and next operation. This list indicates the order that material is to be serviced off a producing unit.
  - Service areas that support *Intermill Loads*; for example the Strip Steel #9 tandem mill area. The queue displays a list of material grouped by index for a switch order. The display shows summary information of the product mix for a switch order. Each grouping shows the number of pieces to be loaded, product type, and carriers if the loading for a rail car was underway (Figure 1, M3). The operator determines which group he wants to load. The operator is then shown the rail car detail view with specific IPMs and locations to be loaded.
  - Service areas that support *Intermill Receipts*; for example the Tin Mill Cleaning Line area. The queue displays a sequential list of carriers in the order were loaded that are in transit to this destination location. The operator visually identifies the incoming vehicle and selects the matching carrier. The view screen displays the list of coils for that incoming carrier in the order in which they were loaded. The operator then chooses the coil to be unloaded to storage. This was accomplished in the Tin Mill cleaning line #1 Crane pilot.
  - Other supported service areas are manual moves and ship out locations.

- **Pickup of Material** (Figure 1, M4)

  The crane operator picks material in two ways. The first is by selecting the IPM by default or by selecting a specific piece. This is done for the exit end of a producing unit and material off of a carrier (railcar, truck, or tractor) and is the link that ties the IPMs identity to a location. The second method of moving IPMs is from a storage location which uses the X and Y position. The crane technology automatically tracks the vehicles position to an X and Y position when the material is picked up and the operator invokes the load or "pick up" process. This transmits a location, and the logistic processor identifies the material ID that is being moved by searching the inventory via the location coordinates.

- **Put Down - Completion of a Scheduled or Non Scheduled Move** (Figure 1, M5)

  The crane technology automatically tracks the vehicles position to an X and Y position when the material is placed to storage, to the entry end of a unit, or on a carrier and when the operator invokes the unload or "put down" process. This transmits the vehicle's (mover's) location, and the logistic process updates the material with this new location. When material is placed on a carrier the operator must identify the carrier ID.

- **Rejection of a Scheduled Move** (Figure 1, M6)

  The operator must have the ability to reject a scheduled move for any number of reasons, i.e. IPM not found, piece is distressed or collapsed and should not be transferred or put in a scheduled line up for a unit, etc. This rejection will remove the movement from the queue.

- **Move Q Management** (Figure 2)

  The process of Adding, Deleting or Resequencing inventory that resides on the Move Q is called Move Q Management. The various ways that inventory can be added to the Move Q will be discussed in this section.

  Strictly from a scheduling perspective, the Move Q is a RS/6000 DB2 table that stores the Scheduled Material as requested by either of the following:

  1. LIS Scheduling System

  2. Move Q Maintenance (Add Rush)

  Strictly from the Crane System's perspective, the Move Q makes Scheduled inventory available to the Crane System in a prioritized sequence.

  The Rail-Car loading also results in an update to the Move Q.

  The LIS Scheduling system is the Primary vehicle to schedule both Continuous Anneal (CA) and Batch Anneal (BA) Material. As a direct result of scheduling the CA and Cleaning Lines via the LIS System, scheduled records are added to the Move Q in a TimeStamp sequence.

  These scheduled Move Q records are then used to build prioritized Rail-Car Loadings for #57 Crane at #9 Tandem Mill.

  The Operations Planning Department have been provided with screen applications that will allow for various types of scheduling maintenance functionality (i.e.; Rush).

  Currently, the LIS Scheduling System is looking at CA/BA inventory that is only on #9 Tandem's Delivery End floor.

  In the future, as the Tandem's are captured via the LIS Scheduling System, we may consider inventory to load that is ahead of #9 Tandem Mill.

#57 CRANE SYSTEM DESIGN METHODOLOGY

The following methodology was followed to design, develop and implement the #57 Crane Intermill Transfer System.

Evaluated Technologies

- Evaluate crane and buggy tracking technology
  - -- IBM
  - -- outside consultants
- Evaluate PC, communication, and application technology

Determined the Physical System Deliverables

- Defined business policies and standard operating procedures (driven by scheduling requirements of accurate locations)
  - -- designed interfaces with the Scheduling System and Plant Floor
  - -- captured user requirements for prototype for Tin Mill and Strip Steel
  - -- defined interfaces with IMIS™ plant floor systems, mainframe applications, and the Scheduling Systems
  - -- considered input from other applications areas:
    - -- Shipping
    - -- Material Release

Defined System Functions and Objectives

- Determined the functions to be delivered
- Defined the processes to be implemented; created and diagrammed requirements
- Determined the data requirements and implementation time frames for:
  - -- new corporate location definitions
  - -- accurate location capturing
  - -- historical views of all movements for an IPM
  - -- movement transactions transmitted from the mill via RF devices
  - -- the translation of new location code to old IMIS™ location for existing systems (i.e. shipping)
  - -- the interface to the Scheduling System
  - -- the handling of new locations and old schema under IMIS™
  - -- assuring ad-hoc users proper data for reporting purposes.
- Defined project plan and estimated work effort.
- Defined data definitions for
  - -- logistics and IMIS™ on mainframe for DB2
  - -- for logistics and IMIS™ on plant floor DEC system for RDB.
- Defined application specifications and end-user requirements for
  - -- new application definitions (See Appendix D for screen prints).
  - -- maintenance to IMIS™ and scheduling applications
    - -- captured list of all existing applications requiring change
    - -- for each application requiring change, detailed the modifications required and the corresponding main IO routing (ZZ87) requirements.
  - -- conversions to new location schema by add-hoc QMF users (convert queries used by end-users accessing location data with their own query tools)
    - -- first obtained list of users accessing location data
    - -- then compiled a detailed list, per user, of queries requiring change

Coded Applications

- RF applications on DEC
- IMIS™ applications on mainframe

Implemented Physical Changes in Plant

- Created maps of plant floor and areas in which coils are to be tagged
- Bar coded, created and physically installed signs on plant floor

Tested System

- Conducted unit testing
- Conducted integrated testing
- Incorporated fixes for problems encountered in integrated testing
- Conducted integrated testing for fixes

Trained End-Users

- Documented operator's procedures for RF scanning
- Trained operators on RF scanning
- Trained QMF users on new tables and converted queries

Rolled Out

- Developed and executed plan for cutover of applications
- Implemented new QMF queries

3. 3 PLANNING AND SCHEDULING SYSTEM (PSS)

3.3.1 FORECASTING AND PLANNING

ACCEPTANCE REPORT

Creation of the Acceptance Report begins with the collection of the following order entry data for each tentative and final order: promised date, promised quantity, and acceptance block (orders with processing and product characteristics in common are grouped into established "acceptance blocks.")

After this data is gathered, it is compiled in a report that presents the volume (in tons) of currently booked orders for each acceptance block, week by week, over a 26 week period.

The user is required to determine and enter into the report the weekly targeted production volume for each acceptance block. The report then subtracts the booked volume from the targeted volume and presents the result to the user. A result preceded by a negative sign (-) indicates that the target volume has not yet been reached. Otherwise, the result indicates by how much the acceptance block is overbooked.

See Appendix E for an example of the Acceptance Report.

UNIT LOAD REPORT

Creation of the Unit Load Report begins with the collection of the following order entry data for each tentative and final order: promised date, promised quantity, and product type.

The orders are grouped within each unit according to their product type, and then are further grouped according to the week in which they must be run to meet their promised date. The run weeks are calculated by factoring together the order's promised date and the lead times and yields for the order's product type at each unit it's routing.

See Appendix E for an example of the Unit Load Report.

3.3.2. ORDER MANAGEMENT

The Unit Specific Process Code System operates in the following manner:

1. The Unit Specific program reads a database that provides all of the tentative orders and their process strings. Note that a process string is the list of operations that must be performed on the order. At this point, the operations are identified by a generic code that indicates what type of unit will perform the operation (ex., BB = Pickler).
2. For every order, the program takes each operation in the process string and uses it as search criteria to determine which specific units are valid for each generic operation (ex., B3 and B5 are valid Pickling units for the operation BB).
3. The program then performs a series of edits for each operation in the process string, checking to see which specific units can best accommodate the order. The best fit becomes the "preferred unit" and the remaining fits are ranked from first to third alternate units. The scheduling system attempts to schedule each order on its string of preferred units, but will allow an order to be "swung" from the preferred unit to an alternate unit (if one exists) if necessary.

3.3.3 SCHEDULING

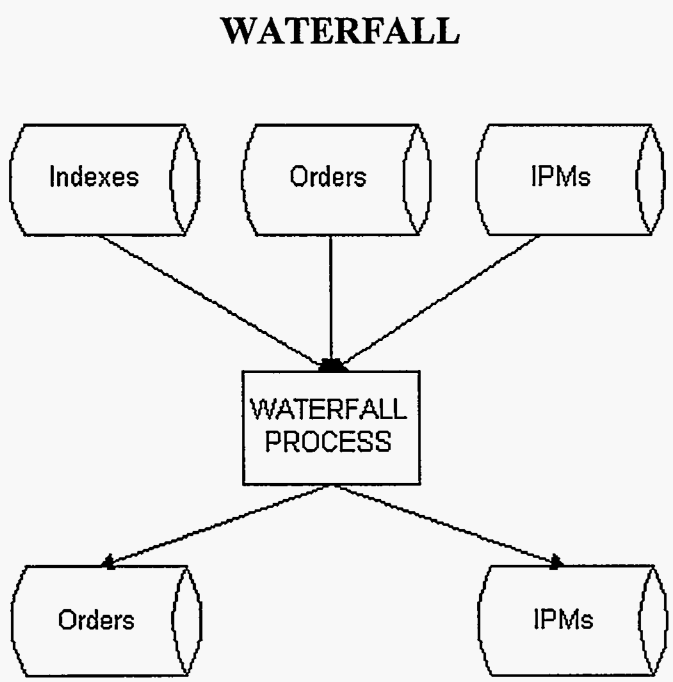
3.3.3.1 WATERFALL

The Waterfall System reapplies product to ensure the placement of the most finished material on the most needy orders within an index.

It accomplishes this through the execution of the following steps (see Figure 3 for a high level data flow diagram):

1. The active indexes are read.
2. The millorders for the active indexes are read.
3. The IPMs scheduled to be produced for the millorders are read.
4. The IPMs are sorted from most processed to least processed.
5. The millorders are sorted from most needed to least needed.
6. The IPMs are applied to the millorders using the most processed IPMs on the most needed millorders.

Figure 3 Waterfall Process Flow



3.3.3.2 INTEGRATED SCHEDULING SYSTEM

3.3.3.2.1 SCHEDULING CONCEPTS

Ideally, a schedule should adhere to facility operational constraints *and* direct production toward maximum customer promise performance. However, in real-world situations, these two goals often conflict. The LIS Scheduling System is based on the principle of achieving balance rather opposition between the two goals.

By scheduling all manufacturing units simultaneously, the Scheduling System balances each facility's operational constraints with downstream delivery requirements, across all facilities.

SCHEDULING METHODS

The Scheduling System supports three variations of the Push scheduling method.

The push scheduling method simply takes what is in front of a facility and sequences it into an operational schedule. This method is traditionally used with a bias towards efficient facility operation. Material starts on entry facilities are based on a normalized manufacturing lead time offset from the customer's product date.

During push scheduling, the system looks in specified inventory locations for material bound for the facility being scheduled. The system schedules material found at that facility and allots time in the schedule for material found upstream.

There are three push scheduling methods:

- Basic Push

  The basic push scheduling method produces a schedule from all work-in-process material in from of a facility. Where possible, the system attempts to look in downstream facility schedules for the timing requirements of the material to be scheduled.

- On-The-Come Push

  The Scheduling System looks in upstream inventory locations for work-in-process material yet to arrive. The system allocated time in each facility's schedule for the upstream material.

- On-The-Come Push --Downstream Disqual

  This method of scheduling closes the loop on integrating schedules between feeding operation units and their consuming counterparts. Downstream Disqual is based on a feature called Required Date\Time. Required Date\Time enables the system to view the moment in time that any order is due to start on any downstream operating unit, which in turn enables upstream units to schedule in time to meet that requirement.

  Downstream Disqual reviews the upstream units' schedules, and if material will not make it to the downstream unit in time for production , it is disqualified from the schedule, and the schedule is rebuilt.

SWINGS

Swings enable system operators to "move" large quantities of material within the Scheduling System in a way that creates a demand on alternative operating units. In this way, product mix can be maintained during the scheduling processes to optimize operation unit performance.

FACILITY MODELING

A facility schedule model is a description of a facility's cycle. The cycles, which are configured by production planners, are hierarchical and describe a sequenced breakdown of material into categories, based on a set of manufacturing characteristics. As the system considers the load on a facility, it collects material into these groups, while still considering the required downstream delivery time. The resulting schedule takes the form of multiple cycles of sequenced material. The scheduling system determines the length and product mix of each cycle.

A facility schedule model describes to the system the operating characteristics and constraints of one facility. These are expressed as rules and descriptions, in the form of tables, defined to the system by production planning and operations personnel. They describe the material groups, preferred material sequence, minimum material group run times, transition rules, and many other operational requirements of each facility.

Facility schedule models are built through an on-line screen set (see Appendix F for screen prints and descriptions). The Scheduling Program retrieves the rules for scheduling a facility by retrieving its model, which consists of three components:

- Schedule blocks
- Schedule block groups
- Processing cycles

Schedule Blocks

Schedule blocks are the atomic components of a processing cycle and are "buckets" to which orders of like characteristics are assigned during the batch scheduling process. The placement of schedule blocks, from left to right, indicates the sequence in which the material groups should be processed on the facility. For example, narrow/heavy sheet follows wide/heavy sheet on the cold mill.

Schedule blocks are assigned certain characteristics that the Scheduling Program uses to build and qualify a facility schedule. These characteristics include:

- Sort rule (which lists a sequence of sort parameters used to sequence items assigned to the same schedule block)
- Transition rule (which prescribes a list of techniques used to test violation conditions when transitioning from item to item in a schedule)
- Physical minimum run duration
- Preferred minimum run duration
- Maximum run duration

The same schedule block can occur more than once within one processing cycle. Such cases are referred to as different *occurrences* of the same schedule block.

Schedule block groups

The next higher level in the hierarchy consists of *schedule block groups*. A group of schedule blocks can have its own characteristics that dictate processing rules for the group. For example, the operators of the cold mill may not want to run any sheet product unless its *duration* (which is a sum of the durations of all sheet schedule blocks) meets or exceeds a minimum duration. The minimum run requirement is, therefore, set at the sheet schedule block group level.

The following characteristics can define each schedule block group:

- Physical minimum run duration
- Preferred minimum run duration
- Maximum run duration

Because a specific facility may require no schedule block groups, the schedule block group level is optional.

The schedule block group level can also be multi-level: that is, a schedule block group can belong to another schedule block group in the same processing cycle hierarchy.

Processing cycles

The next higher level in the hierarchy represents the ***processing cycle.***

Again, the processing cycle may have characteristics of its own that dictate rules for the collection of schedule blocks and schedule block groups underneath it in the hierarchy. For example, the **processing cycle's duration**, which is the sum of the durations of all components immediately below it in the hierarchy, can also be subject to a minimum run requirement.

Several rules for building the facility's processing cycle are also stored as characteristics of the cycle block. The following characteristics can define the processing cycle:

- Physical minimum run duration
- Preferred minimum run duration
- Minimum run resolution rule (which is invoked when a schedule block fails to meet specified minimum run-time, and prescribes action to take to resolve minimum run condition)
- Maximum run duration
- Minimum run block sequence rule (which lists schedule blocks and prescribes the sequence in which to analyze the model components for run-time thresholds)
- Block pattern identification rule (which specifies a pattern used to qualify a schedule by ensuring the sequence of the components of the processing cycle are valid)
- Startup material source rule (which prescribes material characteristics that cannot be scheduling in a unit and identifies specific piece of material scheduled or production)

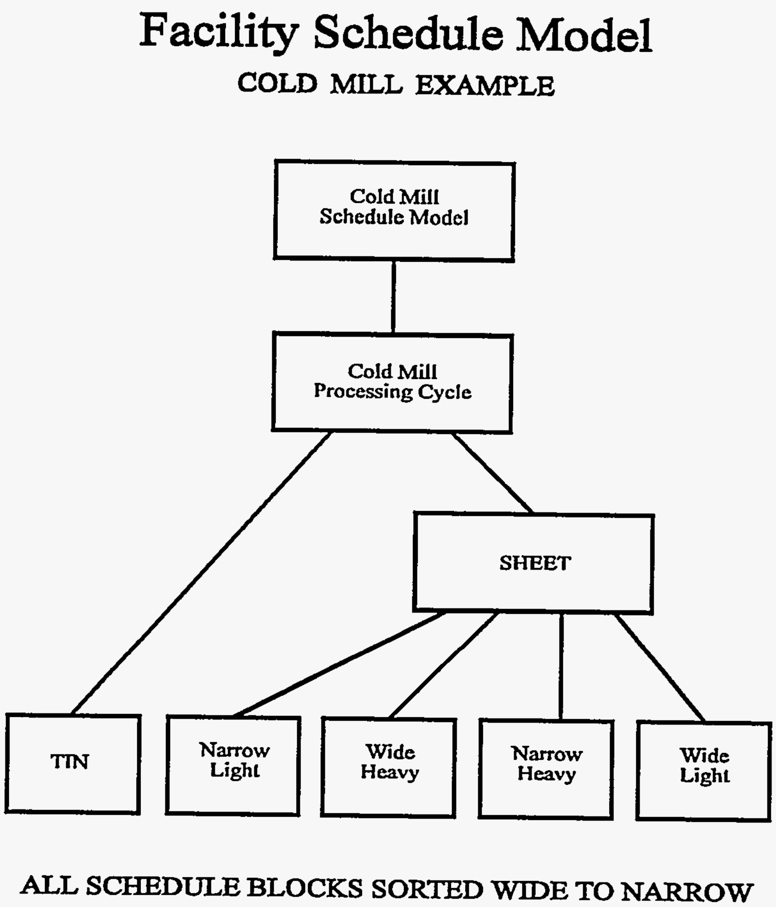
When the Scheduling Program executes, it builds each facility's schedule, one processing cycle at a time, up to the requested schedule horizon.

When business policy changes to meet market conditions, facility schedule models can be modified or replaced to meet the new conditions, without programming changes.

The scheduler can create more than one facility schedule model for a facility, and choose among them for schedule generation. In addition, the scheduler can test models for business policy compliance with live data, without affecting schedule execution on the plant floor.

See Figure 4 below for an example of a facility schedule model based on the Cold Mill.

Figure 4 Facility Schedule Model Example



SCHEDULE CONSTRUCTION

The Scheduling Engine builds a schedule for the facility based on its processing requirements and downstream delivery dates, striving for a balance between the two. It follows a step by step process as described below.

See Figures 5 and 6 for data flow diagrams that illustrate how data is loaded for scheduling and how the Scheduling Engine constructs a schedule.

STEP 1 *Select next period to construct.*

The Scheduling Program selects the next period for which to construct a schedule.

STEP 2 *Build next processing cycle network.*

The Scheduling Program builds the next processing cycle network, into which it will load orders and work-in-process material during scheduling. It also retrieves the processing cycle definition from the facility's schedule model.

STEP 3 *Consider next unscheduled item.*

The Scheduling Program considers the next unscheduled item in the source consideration work file. It builds the work file prior to schedule construction. The work file includes:

- Order book
- Production loads from downstream facilities
- Work-in-process material

The program reads the source consideration work file in the required delivery date and time sequence.

STEP 4 *Assign item to next matching schedule block.*

The Scheduling Program then assigns the item to the next occurrence of a matching schedule block in the processing cycle.

STEP 5 *Qualify item for schedule insertion.*

The Scheduling Program attempts to insert the item into the matching schedule block. Several conditions may disqualify an item's insertion:

- An item's duration may cause the number of turns for the period (its turn level) to exceed the limit set by the production planner.
- An item's characteristics may violate a material constraint qualification set by the scheduler.
- An item's duration may cause its block, group, or cycle duration to exceed its maximum, according to the facility's model.
- An item's insertion may jeopardize the on-time delivery of succeeding items already scheduled. See the Jeopardy qualification process section below.

STEP 6 *Declare full processing cycle.*

Jeopardy qualification process

An item's jeopardy is defined as its scheduled date/time minus its required date/time at a specific facility. A positive result means that the item will be delivered late.

The jeopardy qualification process considers the impact of "pushing" already scheduled items out (by the duration of the newly inserted item), and compares that to the impact of holding the item out for scheduling later.

Once an item is declared to be in jeopardy, the jeopardy qualification process begins. The process attempts to find the best balance between the importance of that item's delivery date versus the impact a schedule change will have on the facility's other scheduled items. The lesser of the two jeopardy quantities prevails. If the item is held out, the program restricts the maximum size of the current cycle (to no lower than the model's minimum size), to ensure that the non-inserted item is scheduled when needed.

When the facility is behind in meeting delivery dates, the program builds shorter cycles, each of which still meets the facility's minimum run requirements. When running shorter cycles, the facility processes its material groups more frequently, striving to improve its delivery performance.

SCHEDULE QUALIFICATION

After building each cycle in a facility's schedule, the Scheduling Program performs three analysis routines to identify and fix violations:

- Minimum run analysis
- Schedule block pattern analysis
- Transition analysis

Perform Minimum Run Analysis

First, the schedule qualification routine qualifies the completed processing cycle for minimum run requirements. Each processing cycle component can be assigned a physical minimum and preferred minimum run duration.

During qualification, the scheduling program analyzes the cycle's components in a sequence specified by the user. When a component fails either of the minimum run tests (physical or preferred), the Scheduling Program refers to a resolution rule to resolve the problem. Each rule is a series of resolution steps that the program executes one at a time until attaining success. The user defines the sequence of the steps in each rule.

- The *force fill resolution technique* attempts to bring the component's duration up to the violated minimum (physical or preferred). During force fill processing, the program does not perform jeopardy qualification on item insertion.
- The *steal technique* attempts to fill the current block with material from another block. The technique will steal from the other block down to its physical minimum or down to empty, as specified by the resolution rule.
- The *block cancellation technique* cancels the block and removes the block and its items from the processing cycle.
- The *soft block cancellation technique* cancels the block and removes it from the processing cycle, but reserves the block's items for later combination with another block.

Perform Schedule Block Pattern Analysis

After qualifying the cycle for minimum run requirements, the program analyzes the resulting cycle, looking for an invalid schedule block pattern. The user provides the pattern. On recognition of an invalid pattern, the Scheduling Program refers to a resolution rule for instructions on how to swap and/or combine the remaining blocks.

Perform Transition Analysis

After block pattern analysis, the Scheduling Program tests each schedule transition for violations such as width, gauge, and carbon jump. The Scheduling Program analyzes each transition and attempts to fix any violations by inserting other material in the gap, using one of these methods:

- The use scheduled item technique pulls a transition candidate from ahead or behind in the schedule.
- The use distressed material technique identifies transition candidates from secondary, excess prime, and dummy material.
- The use order book technique identifies transition candidates in the unscheduled order book.

After schedule qualification is complete, the program writes the schedule out to the database and repeats the construction and qualification process with another processing cycle. The process repeats, cycle after cycle, until it reaches the scheduling horizon or the program runs out of items to schedule.

Figure 5 Loading Data For Scheduling

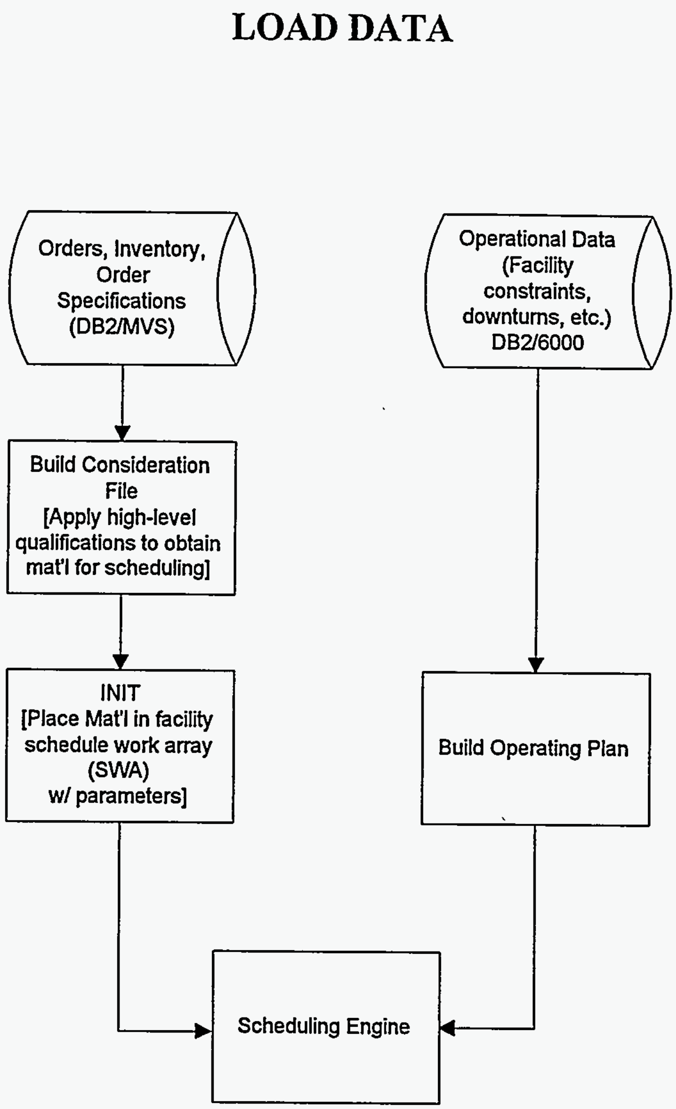
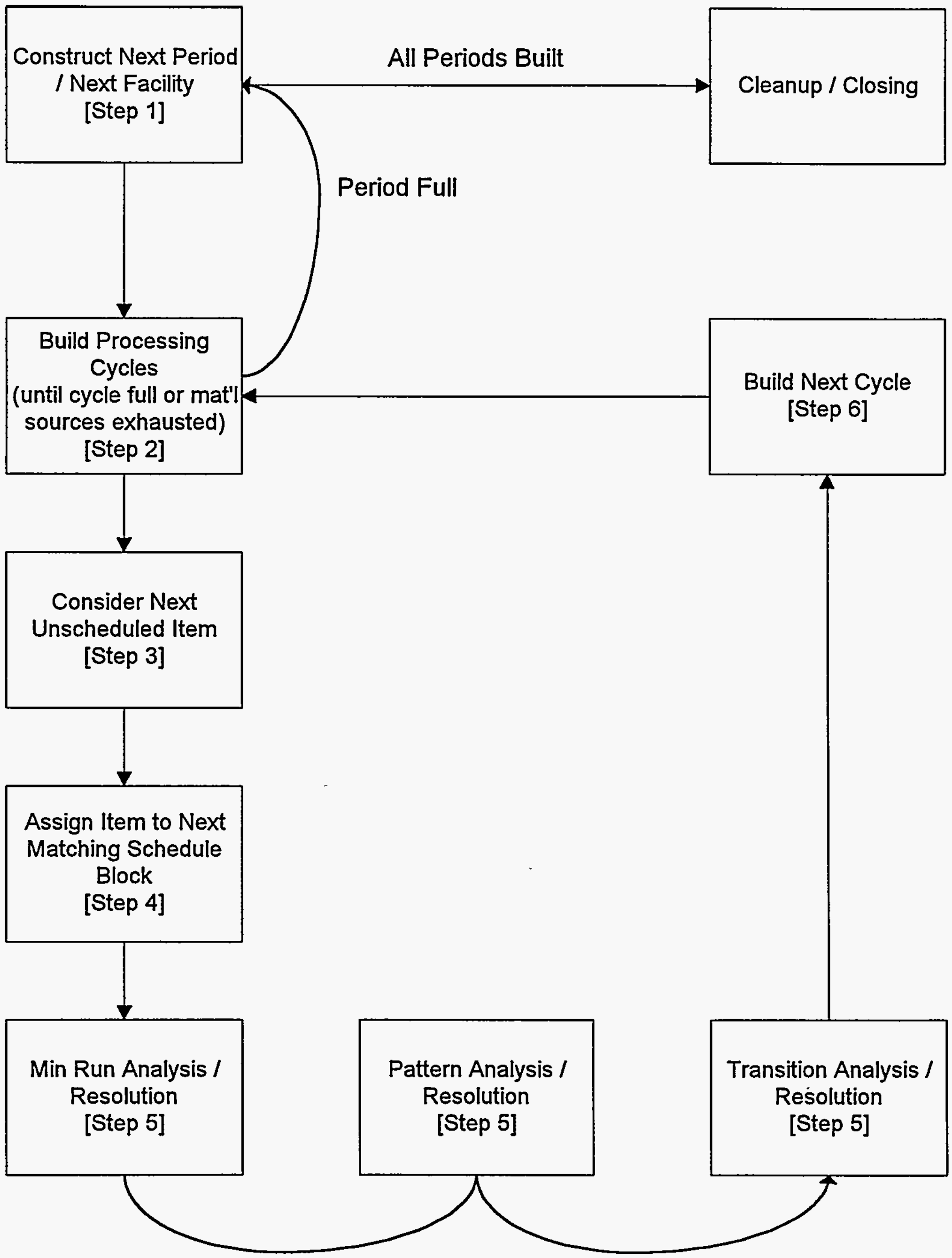


Figure 6 Scheduling Engine -- Schedule Construction



SCHEDULE BUILD AND RELEASE

Five major steps allow the production planner to build a new schedule for each facility and to "join" it with the schedule being processed on the plant floor. The result is that the facility's crew has on-line access to a seamless, perpetual schedule.

The steps are:

STEP 1 *Freeze active schedule*

A facility's *freeze point* marks the portion of the schedule that must stay unchanged during the upcoming scheduling process. A schedule is considered frozen through the freeze point. Its remainder is subject to rescheduling.

The main purpose of the freeze point is to allow the facility crew to continue processing the active schedule during the preparation of a new schedule. The production planner sets the freeze point for each facility through an on-line screen. If no freeze point is found, the Scheduling Program sets one automatically, choosing the greater of the facility's default freeze duration or the portion of the schedule already distributed to the crew.

STEP 2 *Open new mill schedule*

The production planner indicates that a new set of pending schedules is to be generated and requests submission of the Scheduling Program through an on-line screen.

STEP 3 *Schedule the mill*

The Scheduling Program produces a pending schedule for each facility in the set of facilities identified in step 2.

STEP 4 *Release mill schedule*

After on-line review, the production planner releases the pending schedule set. The release process appends each facility's pending schedule to its frozen schedule, and changes its status to active.

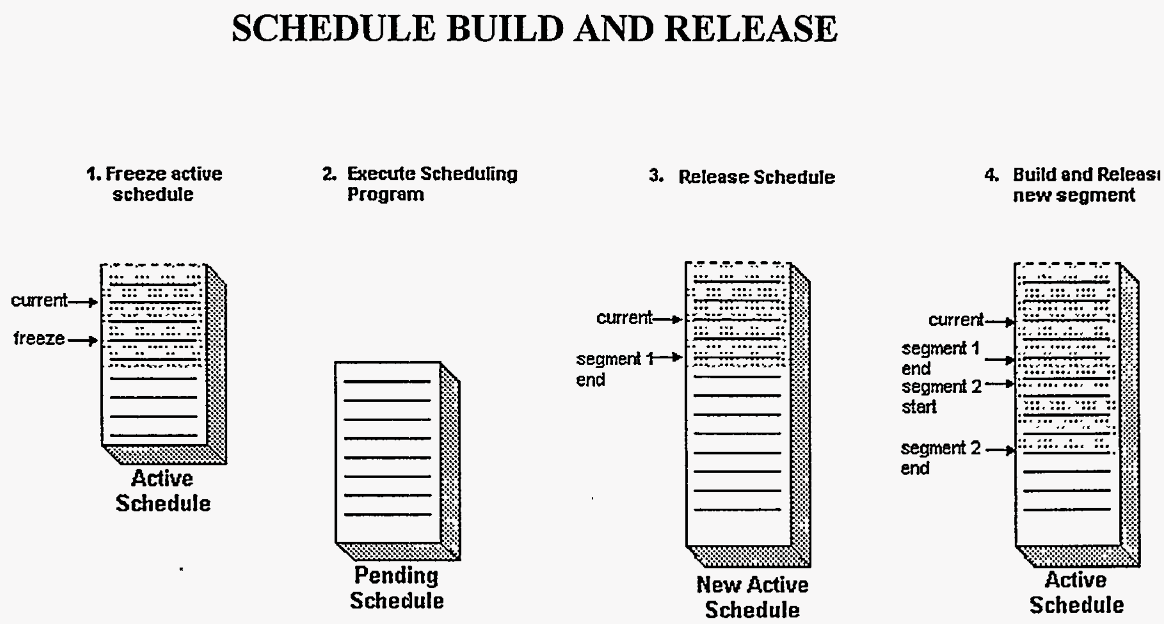
STEP 5 *Distribute facility schedules*

The *segment build* process is the final step in preparing a schedule for facility execution. The production planner, after review and/or modification of one facility's schedule, requests distribution of a specified schedule segment to the facility crew. The segment build process prepares cutting instructions for the segment and sends it to its facility (either through on-line screens or through a process control download).

As the crew processes the segment's material, the system keeps track of their current position. The *current pointer* indicates the last coil produced by the facility. In this way, the production planner always knows each facility's position and can decide when another scheduling run is necessary.

These steps are illustrated on the following page.

Figure 7   Schedule Build and Release



3.3.3.2.2 SCHEDULING SYSTEM USER SCREENS

The theories and concepts explained thus far are implemented through two categories of user screens: Modeling screens and Scheduling Screens. See Appendix F for prints and explanations of each Modeling and Scheduling screen.

Modeling Screens

Modeling screens are used by production planners to build facility schedule models. Extensive interviews were conducted with schedulers on the plant floor to document the operating characteristics and constraints of each processing unit (i.e. facility). Production planners then took the information gleaned from these interviews and translated it into processing rules and descriptions that define the material groups, preferred material sequences, run time-, transition-, sort- and block pattern requirements, and many other operational requirements for each facility. These processing rules and descriptions were then used to configure facility schedule models through the modeling screens. These facility schedule models can be updated as needed to accommodate changing business conditions, and by doing so through the modeling screens, the need to edit code is avoided.

Scheduling Screens

Scheduling screens are used by schedulers to build and fine tune schedules for release to the plant floor. The chart below illustrates the four major tasks involved in generating schedules. The charts on the following pages illustrate the screen-flow required to accomplish each of these four tasks.

Figure 8 Schedule Generation Task Flow

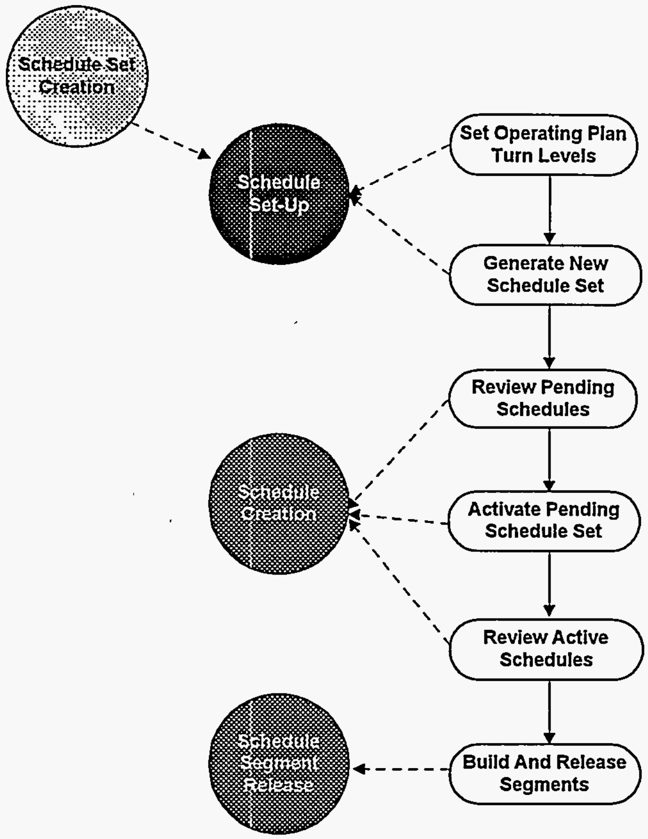


Figure 9 Schedule Set Creation Flow

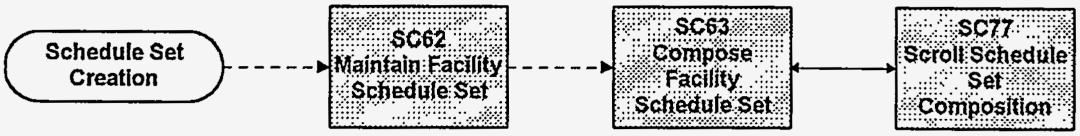


Figure 10 Schedule Set Up Flow

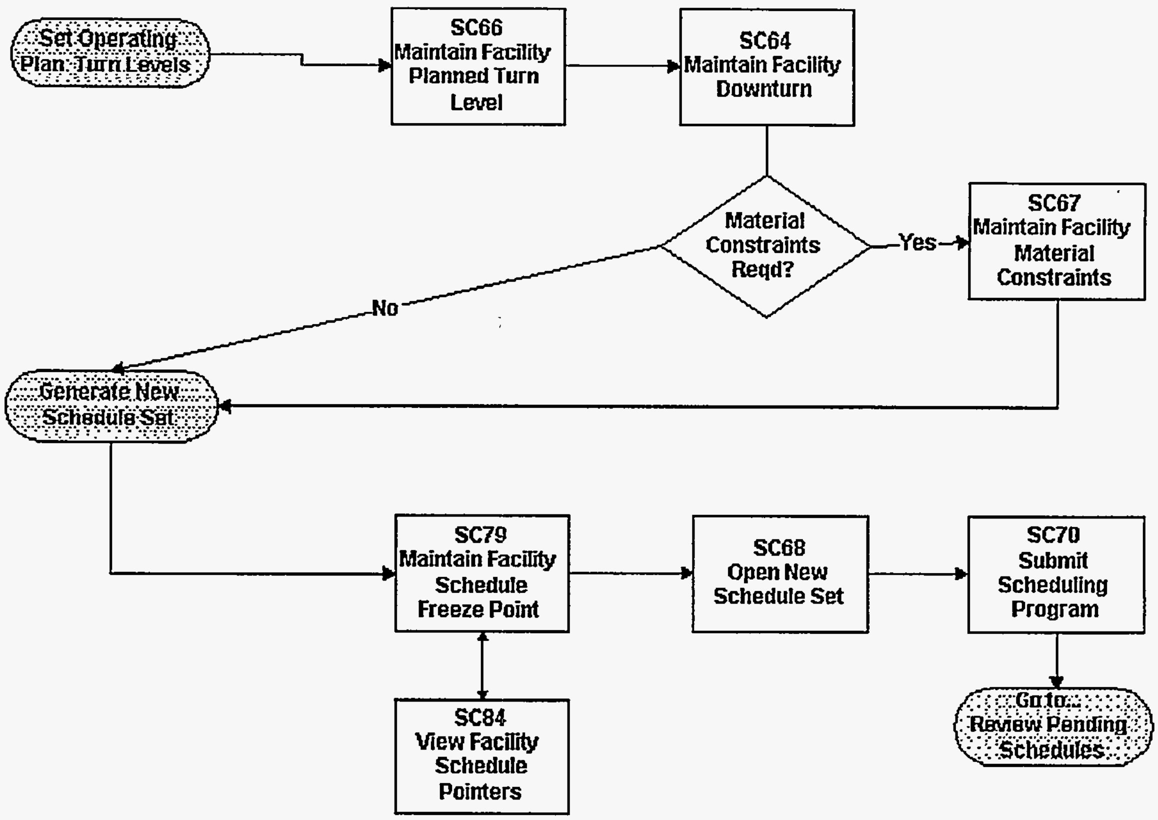


Figure 11 Schedule Creation Flow

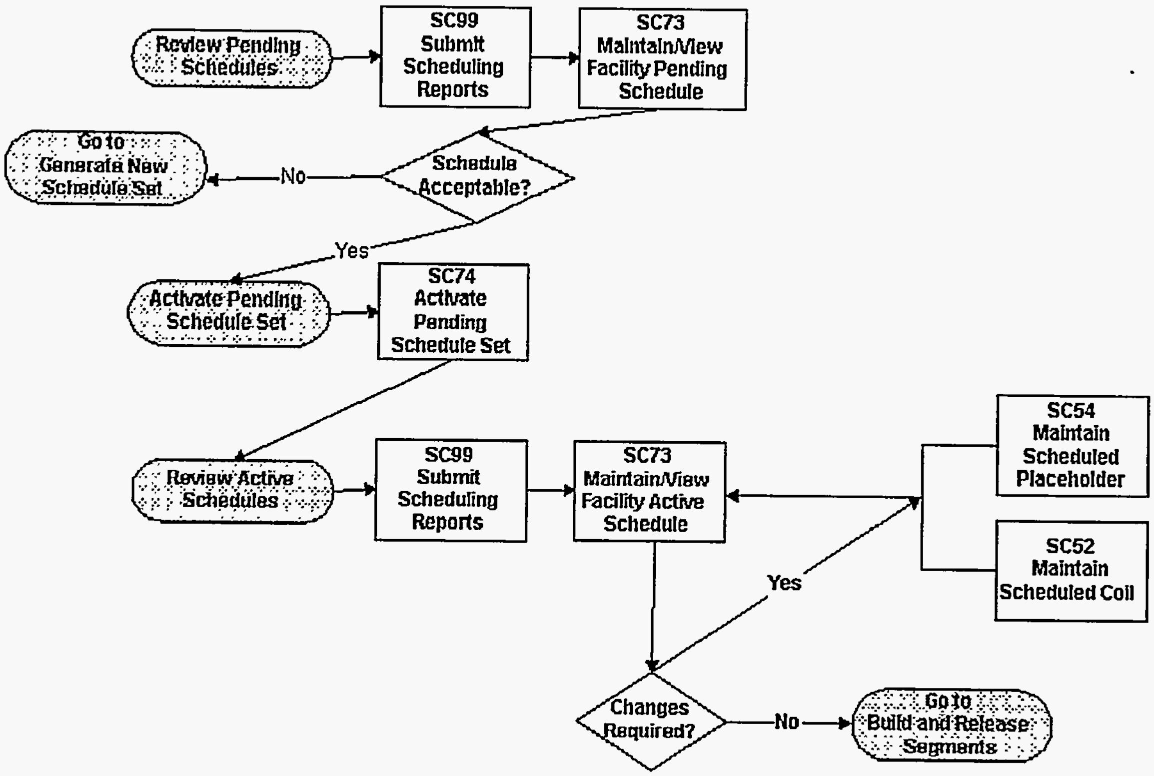
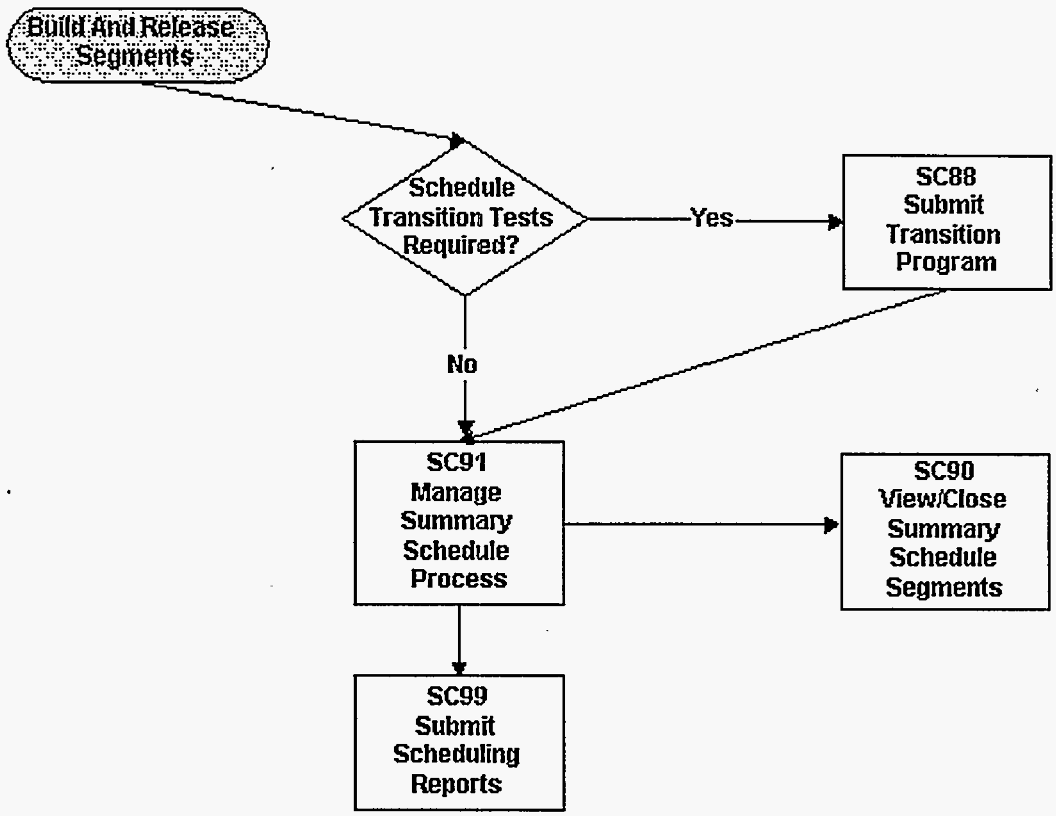


Figure 12 Schedule Segment Build Flow



3.3.3.4 PLANT FLOOR

3.3.3.4.1 INTERFACES

See Figure 13 for a data flow diagram of the Plant Floor/Scheduling System interface configuration.

SYSTEM INTERFACE

The production schedules will be sent from the IBM RISC computer to the IBM 3090 Mainframe, at which point they will be transmitted to the DEC IMIS™ computer. This transmission will use the current IBM to DEC interface (RECEIVE_DB2_UPDATE). The existing interface will also be used to receive updates for IPM locations, as well as updates to the LISLOC table (master location validation table).

The transmission of the location information from IMIS™ DEC to IBM will occur through the existing upside interface (SEND_DB2_UPDATE).

When an IPM is not found on the DEC IMIS™ RDB database, a retrieval request is made to the IBM 3090. This retrieval will not only fetch inventory information, but it will also retrieve location information. This retrieval of information will use the current interface retrieval program (REMOTE_DB2_RETRIEVE).

RECEIVE_DB2_UPDATE INTERFACE

Currently, the IBM 3090 and the DEC IMIS™ computer communicate via a detached background process that runs on the DEC IMIS™ system. This process, RECEIVE_DB2_UPDATE, receives records as PAMS messages containing EBCDIC data. The EBCDIC data is translated to character data, then the character data is converted into the format of the Interface Control Block (ICB).

When a valid record is received from the IBM, a database maintenance subroutine is called to add, update, or delete the record in the Relational Database (RDB). The correct action to be performed is determined by the Action field in the Header portion of the ICB record. The Record Type field of the ICB Header determines which database and/or table to modify. RECEIVE_DB2_UPDATE communicates with the process IH81 on the IBM 3090.

Schedule records received from the IBM 3090 will have a RECORD_TYPE of '25' and an ACTION of either 'A' or 'D'. Location records from the IBM will have a RECORD_TYPE of '23' and an ACTION of 'C'. Records for the LISLOC table (list of valid locations) will have a RECORD_TYPE of '28', with an ACTION of either 'A', 'C', or 'D'.

If the record received is a schedule record, the routine ASCII_TO_SCHED will be called to convert the ICB into the IMIS™ DEC format. After conversion, the ACTION field of the ICB Header will be used to determine whether the schedule record is to be added to the database (ADD_SCHED_TO_RDB), or it is to be deleted from the database (DEL_SCHED_FROM_RDB).

If the record received is a location record, the routine ASCII_TO_INVTLOC will be called to convert the ICB into the IMIS™ DEC format. After conversion, the routine UPD_INVTLOC_TO_RDB will be called to update the location of the IPM in the RDB database.

If the record received is a LISLOC record, the routine ASCII_TO_LISLOC will be called to convert the ICB into the IMIS™ DEC format. After conversion, the ACTION field of the ICB Header will be used to determine whether the record is to be added to the database (ADD_LISLOC_TO_RDB), updated to the database (UPD_LISLOC_TO_RDB), or deleted from the database (DEL_LISLOC_FROM_RDB).

PROTOCOL

IBM's proprietary LU6.2 SNA interface protocol provides the foundation for all transmissions to and from the DEC Plant Floor environment.

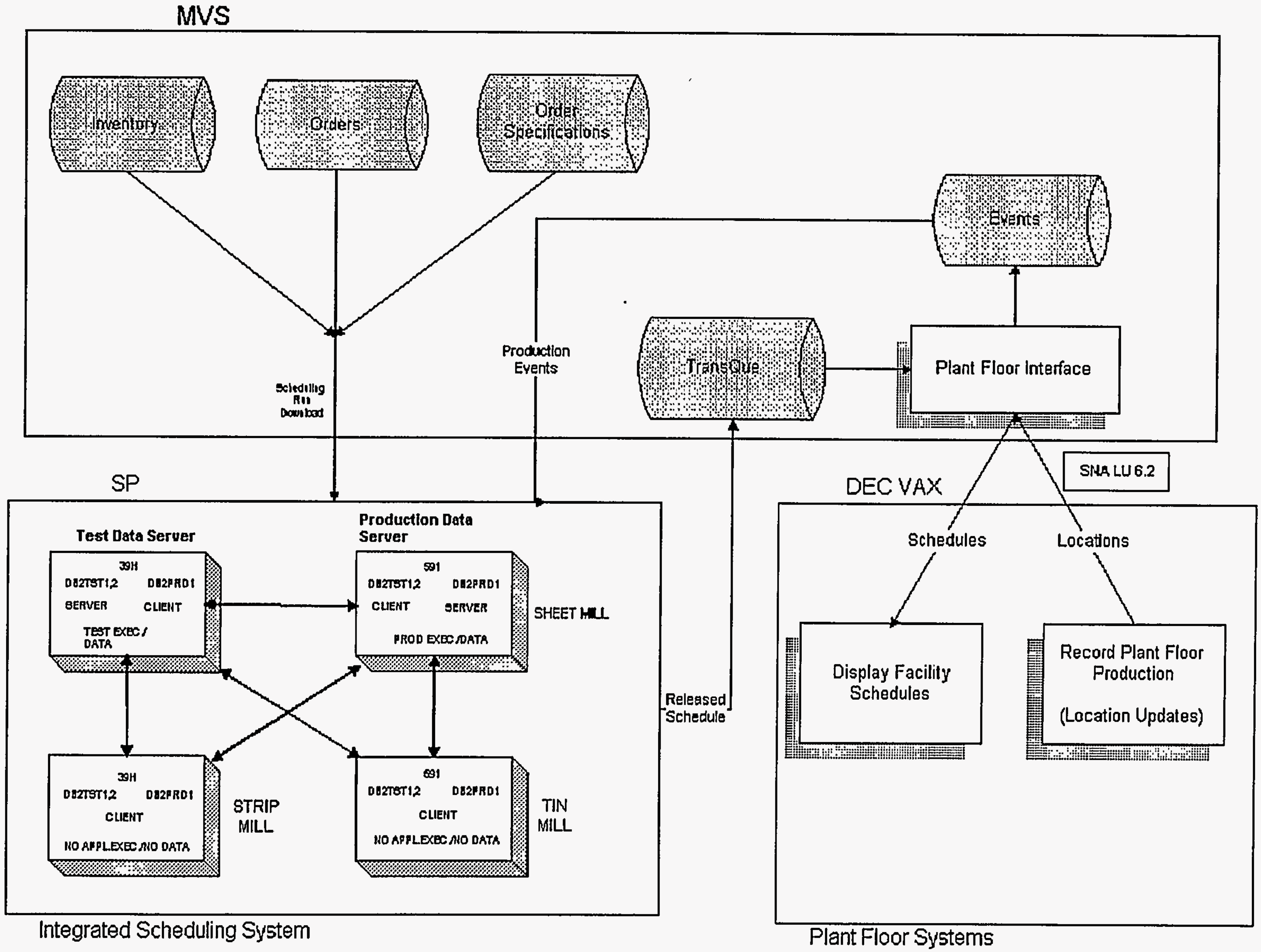


Figure 13 Plant Floor/Scheduling System Interface

USER INTERFACE

This process runs as a detached process and is connected logically to terminals in the Strip, Sheet, and Tin Mills. Within each mill, individual units may require one to five terminals. The position of the terminal on the line determines its function and process name. The terminals are related to specific user areas: Entry End, Operator, Delivery End, Inspector, and Reporter. Not all units require all of the functions. The functions that User Interface provides through operator interface screens include:

Turn Start End:	Entering and updating information for starting and ending a turn.
Entry End:	Entering, creating, and updating inventory to create a process lineup.
Material ID:	Viewing Run Numbers that are scheduled for the specific unit, as well as, creating a process lineup based upon the schedule. Viewing all inventory available for processing by a unit with the capability of viewing material with specific physical parameters.
Delivery End:	Processing material by updating IPM information and sending this information to the IBM 3090.
Turn Summary:	Viewing production for the current turn.
Material History:	Viewing an IPMs previous identification by physical and Mill Order parameters.
Process Parameters:	Viewing the physical and order parameters determined by the 99 byte record specified in the Mill Order.

See Appendix G for prints and explanations of each Conformance System screen.

3.3.3.4.2 CONFORMANCE

When a schedule is called "complete" on the plant floor (i.e. when the final scheduled piece has been run) the Conformance program, BSCU13, is automatically executed.

BSCU13 loads a table, SCHDRISC.CONFORM, with a detail row for each IPM associated with just completed schedule. This includes *scheduled* IPMs that were *not* run, *unscheduled* IPMs that *were* run, and IPMs that were run as scheduled.

Each IPM is marked with a non-conformance indicator (Y or N). Any scheduled IPM that is *not* run and any unscheduled IPM that *is* run will be marked with a "yes" indicator. Note that in order for a plant floor operator to add to the lineup an IPM that is not on the active schedule, he or she must also enter a reason code that indicates why the IPM does not conform to the current schedule. This information will be available for review on the Conformance user screens.

The Conformance user screens read from SCHDRISC.CONFORM and display all necessary detail and conformance information.

See Appendix G for prints and explanations of each Conformance System screen.

4.0 PROBLEMS ENCOUNTERED/RECOMMENDATIONS

4.1 MATERIAL MARKING AND SENSING SYSTEM (MMSS)

These areas are addressed in the final reports for MMSS submitted to WSC by West Virginia University.

Please refer to this report which is included in it's entirety in Appendix A of this report

4.2 MATERIAL TRACKING SYSTEM (MTS)

It is important to understand that before implementation of MTS, the only regularly scheduled inventory compliance activity was for finished inventory. This batch scanning process did not allow for the immediate relay of the location information back to the user as it was recorded. This resulted in a very cumbersome and inefficient way of resolving inventory errors.

In addition, due to the lack of robustness in the batch scanning process, inventory accuracy was constantly in question. Further, since work in process inventory was not included in the scope of work, unit scheduling rarely benefits from this inventory activity.

When transitioning from the batch mode to an on-line, dynamic inventory reporting system, several different issues had to be addressed that were not problematic under the batch conditions. The following issues pertain to both the real-time reporting of coil movements with hand scanning and voice activation units on selected coil handler buggies. It is recommended that they be taken into consideration during design and development of similar systems:

Data Integrity Problems

- Handling of non-active coils
- Procedures for unmarked inventory
- Development of extensive standard operation procedures to ensure proper error resolution and floor area tracking policies
- Detailed back-up procedures to address various levels of RF System/equipment outages.
- Development of performance tracking procedures to ensure proper system utilization.

Impact of Coil Movement By Crane

- Procedures to adjust floor inventory levels associated with external Mover/Handler activity (i.e. non-RF equipped cranes and buggies)

Modifications to Coil Identification Standards

- Reposition of bar-code label to facilitate safe and efficient hand scanning
- Implementation of marking practices on coil sidewalls to facilitate visual identification when utilizing voice activation.

Special Criteria Associated with Voice Recognition

- Proper identification and replication of background noise levels when implementing voice activation applications
- Establishment of an audio feedback for voice entry confirmation

4.3 PLANNING AND SCHEDULING SYSTEM (PSS)

The scheduling process at Weirton is still under refinement. With the core system in place, we find that delivering push schedules to all operating units is relatively straightforward. We still have problems running the whole plant with integrated scheduling, however.

When we developed the system, we implemented in areas which essentially proved the efficacy of the concept. Our most strenuous test, the Tin Mill, can still defeat our scheduling efforts, depending on operating conditions, inventory composition, and general schedule quality. The objective is to run schedules in an on-the-come mode, synchronizing with "upstream" schedules to provide material in time for the needy downstream operating units. This speeds the flow of material through the mill, reduces work in process, and emphasizes on time customer delivery. With annoying frequency, the schedules drop out of synchronization. This occurs because of myriad reasons, and one by one, we are improving the system to overcome those situations. Still, it is safe to say that we only synchronize schedules fully and without manual intervention about 35% of the time. This in itself pays large dividends. We have observed 10-15% production performance improvement across all of our plating production units--the main area of our emphasis as they cost the most in terms of processing per ton of steel. Plater area inventories run at 60% of previous average levels without material outages. We have been able to sustain a continuous annealing production level without interruption--something we were never able to do before. Overall customer delivery has increased to 90% on time (opposed to 50% when we began). The customer delivery number is not solely due to scheduling--booking management plays a crucial role in its improvement, and that was also done within this program.

When we cannot run integrated schedules, we are forced to run simple push schedules across units. This means that the schedule quality is diminished, because push can only recognize material on the floor destined for that operating unit. If we face long term push scheduling, we need to increase inventory levels back to previous levels, a costly proposition. Nonetheless, we have the ability to run in that mode, or employ manual schedule manipulation, until we refine the scheduling system sufficiently to improve the current "hands-off" 35%.

We feel that enhancements will be required in the operating unit model capability, and in material alignment.

The models we have constructed to represent each operating unit amount to sorting criteria which attempt to replicate the operators' thoughts when they used to line material up to run. Now we believe that for certain key areas, these models cannot provide the flexibility to make the adaptations common with human scheduling practices that are driven by environmental conditions. For instance, during low inventory conditions, we should run the models with lower minimum run times, allow orders to be split in production, and make several other "moves" that during ordinary inventory conditions you would wish to avoid. After an operating unit has not been running for 8 hours, the material it can run fits into a "start-up" mode--and is different than that which you might run on day two of a campaign. These and other environmental conditions are managed by system operators interpreting the circumstances, and then adjusting as well as they can. Our feeling is that this is too manually intense, and needs to be engineered with more thorough algorithms, perhaps including step-function logic driven by external variables. This is where the manual intervention takes place today, diminishing overall system effectiveness for "hands-off" to 35%. It should be noted that for only a few key places in our mill is this required. For all rolling, pickling, slitting, and annealing functions we feel that the original model process is sufficient.

The area of inventory alignment is another area that takes expertise and "handwork" that should be reduced. The problem: for each operating family of units, an order will have a primary production unit we schedule it for, and alternative units if there are any. Upstream production needs can result in material all stacked up in front of one operating unit of three in a family at a given point in time. The current cure is to manually "swing" material to available alternative units, so production can continue without unnecessary delay for the full unit, and starvation on the others. We will codify a partial solution for this, and build sophistication for full plant integration, further diminishing this effect.

These two areas are where the system does not perform as expected. We see what we have built as a major advancement in the industry, and an excellent foundation upon which to build. The shortcomings will be overcome during the next three to four months.

We set ourselves up for some of the problems outlined above, expecting system integration to be easily achieved. That is where our recommendation for how to avoid such disappointments comes to bear.

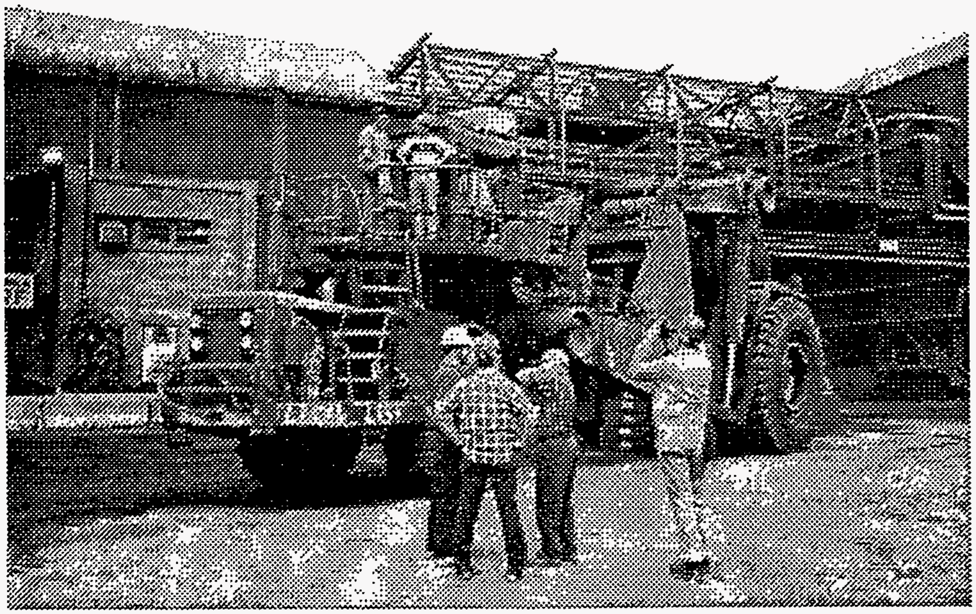
Had we analyzed the nature of integrating operating units thoroughly before beginning the program we might have been better prepared for the complexity and slowness of the transformation. I now see value in running manual simulation processes with team members and project sponsors, running through feasibility scripts, and demonstrating what will be most difficult to overcome. Better decisions about what is essential and what is of less value could have resulted from such an exercise. We charged in feeling that absolute control overall was the only answer. In some areas, the cost of that degree of control can be higher than the benefits provided. Had we recognized this early, we would have expended less effort trying to change business practices that yielded marginal results.

The adage "you cannot know too much" is important to large development projects. We worked with our user community for thousands of man-hours developing their requirements, then costing and building the system accordingly. Had we taken the user requirements and built an early, simple simulation of how it all fit together, we would have found that some aspects that sound good during analysis, do not work well when it is time to really utilize the system. Users will always tend to ask for the ultimate system. We could probably have done with more sophistication in model building capability and inventory management, and less is development technology, system modularity, and concepts of code re-use.

Appendix A

Final Reports--WVU and WSTC

Steel Slab Marking and Sensing
Phase II Final Report



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College of Engineering and Mineral Resources
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January 31, 1996

Executive Summary

This document is the final report for Phase II of a research and development project performed by West Virginia University (WVU) for the Weirton Steel Corporation. The objective of the overall project was to develop part of a system which would automate the process of tracking steel slabs from the caster through the slab yards and intermediate processes to the reheat furnace. Specifically, WVU was charged with the development of equipment which could automatically read the identification tags attached to the end of the slabs and then communicate the data via radio to the central inventory tracking system. The WVU system is a critical component of a real-time inventory control system, which is in turn necessary for efficient scheduling and management of the mill.

In Phase I, WVU researched potential solutions and determined that no existing commercial system was adequate for Weirton's needs. WVU then proposed a technical approach to solving the problem. Weirton accepted WVU's proposal and in September of 1994 WVU successfully demonstrated a laboratory scale system which could read both bar codes and alphanumeric codes at distances of up to thirty feet.

The objective of Phase II was to develop a mill-worthy version of this system. Analysis of the Weirton environment suggests that two types of systems will be required to afford complete inventory management capabilities. Some locations such as dekerfing and the reheat area will require wall-mounted stationary systems which scan piles of slabs and keep track of slab movements into and out of a specific storage area. It will also be necessary to have some mobile systems mounted on the slab hauler vehicles which can verify slab pick and place maneuvers in the outdoor slab yards. Following the logic that the mobile units represented the greater challenge, WVU was asked to develop a ruggedized slab identification system which could be mounted on a slab hauler and operated in the actual steel mill environment. To achieve this goal it was necessary to both redesign and expand the hardware and software systems that had been developed in Phase I. The following specific project objectives were identified:

- Enhance the software systems developed in Phase I;
- Develop hardware and software which could be installed on a slab hauler and operated by a slab hauler driver;
- Develop software for interfacing with Weirton's Logistics and Integrated Scheduling system, and with internal sensors and controls;
- Install and demonstrate the hardware and software systems at Weirton Steel.

All of the program objectives were accomplished, and the system was successfully demonstrated at Weirton Steel on November 7, 1995 before an audience of officials from the US Department of Energy, Weirton Steel, and the Westinghouse Science and Technology Center.

The system developed under this program is the only one in the world that has the capacity to automatically locate tags, point a code-reading device at them, read the codes, perform error checking and communicate with both an operator and dispatching/database functions in a steel mill environment. So far as we know, it is the only code reading device to achieve its level of integration and sophistication in any environment.

Additional development work is required to bring this technology to commercial status. The computing hardware must be miniaturized and a camera and lens system more suited to manufacturing and resale environments must be developed. Additional development on the

software will also be required, most notably the expansion of the barcode reader's vocabulary to include Code 128, Interleaf 2-of-5, UPC and other barcode standards. Additional work would also be required to solve problems with certain high-contrast lighting situations.

We believe that components of this system could be applied at Weirton Steel in the relatively near-term with positive results. A phased implementation of portions of the WVU system would result in immediate benefits in the area of inventory management, even before the scheduling and dispatching functions of Weirton's Logistics and Integrated Scheduling system are operational. Certainly a first step would be to change to the new tags which have both barcode and numerals. The cost of this change is insignificant and it makes possible the use of hand held scanners which could immediately improve the speed and accuracy of inventory data acquisition.

We would *not* deploy the slab hauler based systems first, but would begin by placing systems similar to the WVU prototype in fixed locations in the plant. By placing systems in certain strategic areas such as the dekerfing area, scarfing area and reheat furnace staging areas, the tasks of inventory control and material handling resource dispatching could be decentralized and handled by simple, local algorithms. Such a first step could eliminate the practice of painting the run sequence numbers on slabs in the reheat area, and should allow streamlining of the sorting/queuing processes in the most congested portions of the hot area of the plant. Ultimately, mobile units mounted on the slab haulers would allow complete elimination of the current system of painting run numbers on the ends of slabs and the optimization of slab hauler dispatching.

We believe that the basic technology demonstrated here has applications in other parts of the mill as well. With some additional development, the system could be used to read stenciled or painted numbers on hot bands or bar coded paper tags on finished products. We believe the system could easily be made compact enough to mount on lift trucks and could work nicely in conjunction with the lift truck locator system being developed by Westinghouse under the DOE contract.

Material handling represents a significant portion of the unit production cost, not only for Weirton Steel but for most integrated steel mills. By contrast, many minimills are much more streamlined in their material handling operations, creating a significant competitive advantage for their products. To remain competitive, Weirton and its peers must take steps to minimize all activities and costs which are not value-enhancing to the product. Material handling looms as a very lucrative opportunity in this regard. West Virginia University is proud to have made a contribution of significant potential in Weirton Steel's program for global competitiveness.

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1 Introduction

1.0 Background

This document is the final report for the research project "Steel Slab Marking and Sensing, Phase II". The project comprises a subcontract from Weirton Steel Corporation to West Virginia University under DOE contract #DE-FC07-92ID13162. The period of performance for Phase II is October 1, 1994 through January 31, 1996.

This project is part of a larger effort undertaken by the Weirton Steel Corporation to modernize their material handling operations through automated data acquisition, computerized inventory management and streamlined material movement operations. The overall program is known as the Logistics and Integrated Scheduling system (L&IS) at Weirton Steel. The West Virginia University (WVU) component focused on the development of a method for the automated detection and reading of identification codes on steel slabs.

As the title implies, WVU's effort has been divided into two phases. In Phase I, a functional specification for slab marking and tracking was developed which set forth the basic requirements for survivability, compatibility and functionality of the marking/tracking system. WVU then performed a "best practices" survey of other steel or similar industries, vendors and research organizations to determine what if any existing technologies were consistent with the requirements. It was determined that no off-the-shelf solutions existed, and furthermore that the most promising approach was one based on the use of video cameras and custom image processing software that would be developed by WVU.

Phase I of the project consisted of the development of a laboratory proof-of-concept demonstration. In September 1994, WVU successfully demonstrated a system which could automatically locate slab identification tags in a cluttered scene, point the camera at each tag for a closeup view, and read the alphanumeric and barcoded numbers on the tags from distances of up to thirty feet away. Following this demonstration, Weirton Steel awarded WVU a contract for Phase II of the project.

1.1 Phase II Project Objectives

The overall objective of the second phase of the project was to develop a ruggedized slab identification system which could be mounted on a steel slab hauler and operated in the actual steel mill environment. To achieve this goal it was necessary to both redesign and expand the hardware and software systems that had been developed in Phase I. The following specific project objectives were identified in the contract documents:

- enhance the software systems developed in Phase I;
- develop hardware and software which can be installed on a slab hauler and operated by a slab hauler driver;
- develop software for interfacing with the L&IS system, sensors and controls;
- install and demonstrate the hardware and software systems at Weirton Steel.

Each of these objectives will be described in more detail below.

1.1.1 Software Speed and Performance Enhancements

Although functional for laboratory demonstrations, the software developed under Phase I was not optimized for speed and was not adequately "ruggedized" against the severe challenges that the system will encounter in a working steel mill environment. The Phase I software required approximately 15 seconds per tag and worked with good reliability so long as the camera was viewing a tag from an angle of thirty degrees or less. The Phase II system was required to view tags from a much more acute angle and to process four slabs in fifteen seconds.

1.1.2 Mill-hardened Hardware and Software Development

The primary hardware development task was to design protective systems for the computer and vision systems which could survive the environmental and physical abuse of the mill: intense heat, bitter cold, rain, dust, shock and vibration. The image processing software can also handle greater variations in lighting levels and tag quality than the Phase I system.

1.1.3 Control and Interfacing Software and Hardware Development

New systems were necessary to provide computerized zoom control for the camera, information display and touch screen controls for operator interfaces, data formatting and flow control for the radio communications, improved and more flexible camera pointing systems, and database mockup and dispatch software for the demonstration.

1.1.4 Live Public Demonstration at WSC

The ultimate goal of the project was to perform a live demonstration of the fully functional system for Weirton Steel and Department of Energy officials in the Weirton Steel facility. This involved scripting a series of operations which demonstrated the capabilities of the system while allowing the spectators to view the procedures from a safe location.

1.2 Overview of Technical Approach

WVU chose a systems integration approach to the hardware design tasks wherever possible. This approach was chosen to minimize development costs, maximize reliability and simplify the path to the eventual commercialization of the system. To that end, commercially available hardware components were selected wherever possible. These included enclosures, displays, the computer, communications and video image processing components, power supplies and the pan/tilt head. At the same time, literally all of the control, interfacing and image processing software had to be developed in-house. Software was written in C++ and compiled using the Watcom 32-bit compiler running under DOS to minimize memory requirements.

1.3 Summary of Accomplishments

All of the program objectives were accomplished, and the project has been completed within budget. The system was successfully demonstrated at Weirton Steel on November 7, 1995 before an audience of officials from the US Department of Energy, Weirton Steel, and the Westinghouse Science and Technology Center.

The system developed under this program is the only one in the world with the capacity to automatically locate tags, point a camera at them, read the codes, perform error checking and communicate with both an operator and dispatching/database functions in a steel mill environment. It may be the only code reading device to achieve this level of integration in any environment. The research leading to this system has produced four Master of Science theses to date and will result in two more in the near future. Because of the proprietary nature of the work, publication in the open technical or trade literature has been delayed while Weirton Steel evaluates the desirability of seeking patent protection for the system.

2 Hardware Systems Development

The hardware consists of two major subsystems: the camera enclosure and the computer enclosure. The camera enclosure is an aluminum box mounted to the slab hauler catwalk which contains the camera mounted on a two-axis pan and tilt mechanism, a controller for the pan/tilt head and circuitry to allow computer control of the camera zoom position. The camera enclosure is shock mounted to the catwalk by viscoelastic vibration dampers, and the internal components are mounted on a seismic mass supported by foam rubber to further isolate the components from shock and vibration. The computer enclosure is a large NEMA box mounted on top of the slab hauler cab by viscoelastic dampers. Inside the enclosure on a subchassis are the computer, several terminal strips, circuitry for the camera zoom control and power supplies for the equipment. The radio modem is mounted to the lid of the box. Figure 2.1 shows the locations of the two enclosures. The flat panel display and touch screen operator interface are located in the slab hauler cab.

2.1 Camera Enclosure

The camera enclosure is a custom aluminum box fabricated at WVU from aluminum sheet and angle. It is mounted through viscoelastic dampers to heavy steel "C" channel which is in turn bolted rigidly to the slab hauler catwalk. The enclosure hangs beneath the catwalk on the starboard side of the hauler and has a high strength glass window facing rearward to afford the camera a view of the slabs as the machine is backed onto a pile for transport. The rear side of the box is hinged for access during the development phase. Figure 2.2 shows the arrangement of the internal components and the inlet and outlet for the cooling air.

2.1.1 Video Camera and Optics

Several options were considered in the selection of the video camera and lens for the system. The three most seriously investigated were a) a two camera system using fixed-focus lenses; b) a small industrial CCD camera and power zoom lens; and c) a standard consumer camcorder modified to allow computer control of the zoom. At issue were several requirements, namely the necessity of taking both wide-angle and closeup images of the slab pile/slabs, the need for a light weight, compact system and the requirement for ruggedness. Analysis of the focal length requirements and image size constraints led to the rejection of the first option. It was determined that the range of possible distances of the tag from the camera was too great to allow the use of a single telephoto focal length for all tag positions.

Of the other two options, the standard consumer video camera was eventually chosen over the power zoom lens for reasons of convenience and cost. The power zoom option would have cost approximately three times as much as the commercial camera while resulting in a system that was inferior to the camcorder for development work. The camcorder offers not only power zoom but auto focus and auto iris functions as well. While surveillance type systems can deliver auto iris, the auto focus function is not available on any suitable lenses we were able to find. Finally, it was a definite advantage to have recording capability in the camera for the development work. It was extremely useful to be able to video tape scenes of slabs and tags for later analysis in the lab, and this would have been much more difficult using surveillance type equipment. Clearly, the use of a commercial camera which must be modified is not a viable design for the final system, however for the development work it was the best option.

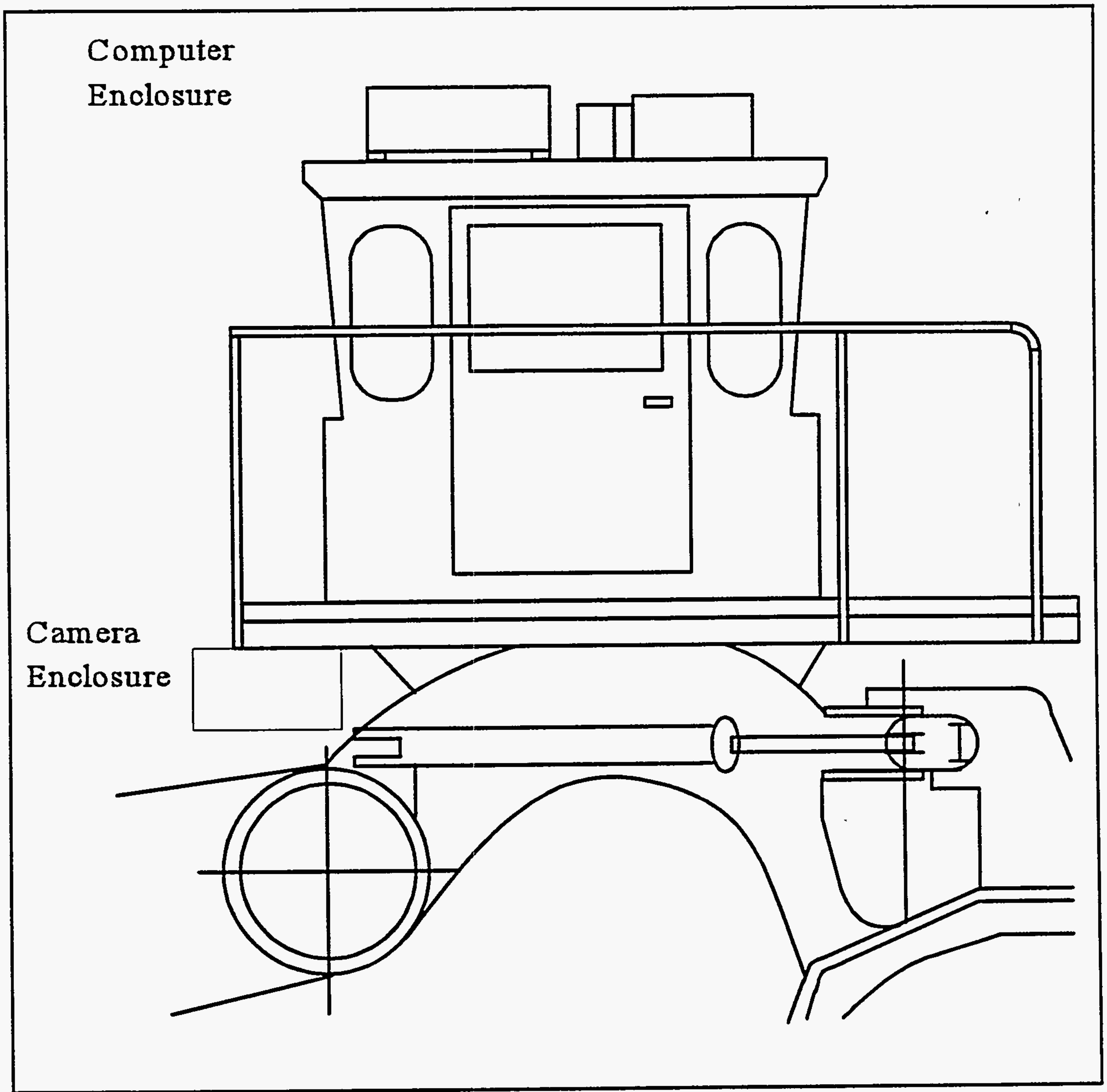

Figure 2.1: Locations of camera and computer enclosures on slab hauler

2.1.2 Pan/Tilt System Selection

Similar difficulties were encountered in finding commercially available equipment for the camera pointing task. The primary difficulty came in finding a system designed to be controlled by a computer. Most of the commercial hardware is set up for either security systems or for military radar applications. The former systems are designed to scan to preset points or to be controlled by an operator with a joystick. Setting up the system for computer control was either not possible or prohibitively bulky and expensive for this type of system. The military systems were in general designed for large payloads and were hence unacceptably slow and inaccurate. Where we desired a pointing accuracy of within one-tenth degree and slew rates of at least 100 degrees per second, the military systems were typically an order of magnitude worse in both categories and a factor of three higher in cost than our final solution.

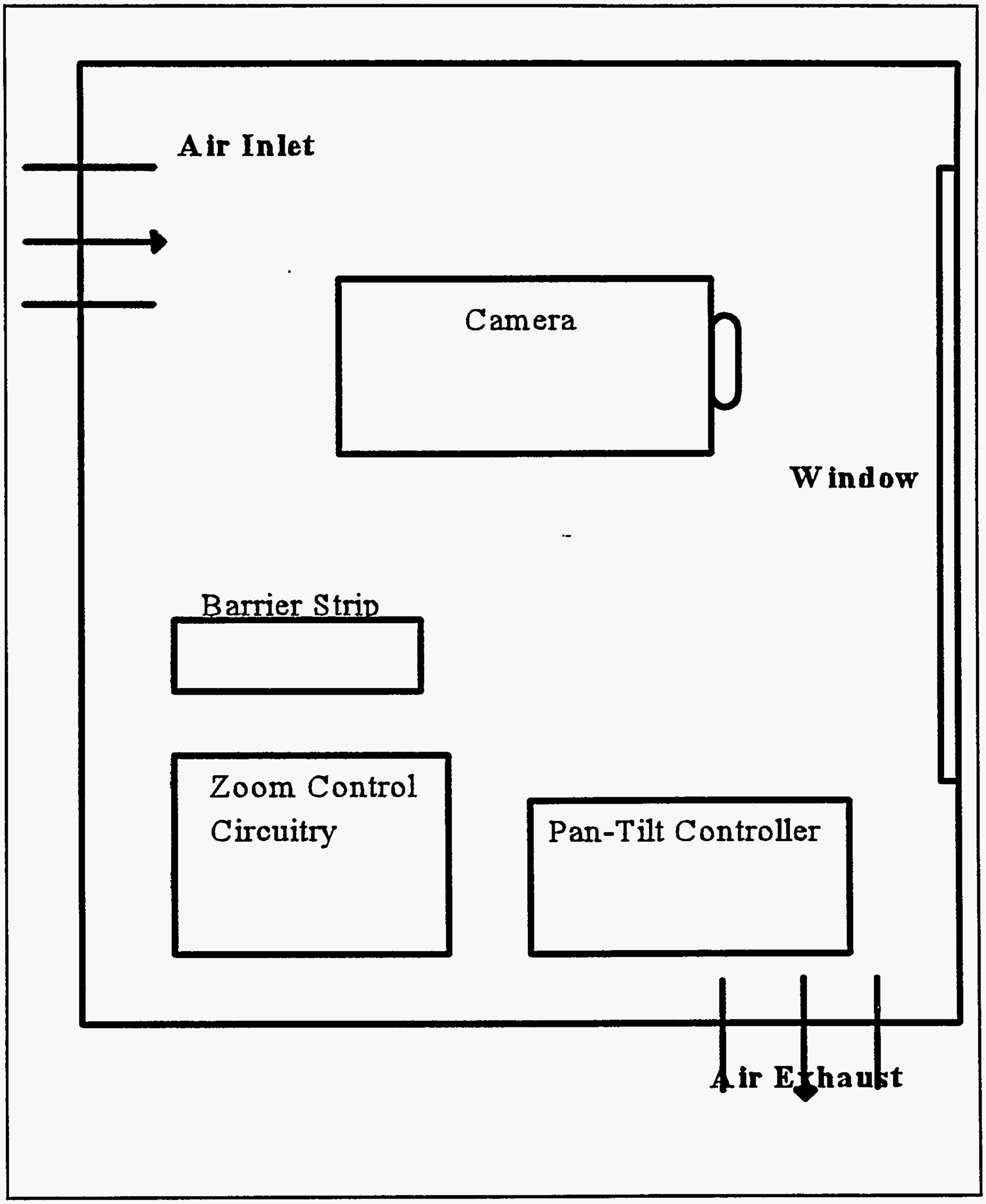

Figure 2.2: View of interior of the camera enclosure

In the end, only one vendor was found which could supply equipment appropriate for the task. Directed Perception, Inc. of Cupertino, CA offer two models of pan/tilt systems designed for robotics applications. The systems are designed for control by serial link to a computer, have high pointing accuracy, slew rates up to 300 degrees/ sec and a flexible control system designed for serial link input from a computer. We were initially concerned about the physical durability of the unit, which is designed only for a four-pound payload, however it has performed adequately in our testing to date. The unit costs $2000, which seems expensive but is still about half the cost of the surveillance equipment and one-third to one-fifth the cost of the military systems. Recently, a second vendor has emerged who offers a system designed for ten-pound payloads and computer control, however we have not evaluated the equipment first hand.

2.1.3 Temperature Control

The equipment in both the Camera Enclosure and the Computer Enclosure will be exposed to severe temperature extremes as a result of being outdoors and in proximity to extremely hot slabs. Since both enclosures contain electronics which can be damaged, especially by heat, it is necessary to provide conditioned air to the enclosures. In the prototype system this is accomplished by drawing conditioned air from the operator's cab through each enclosure. A plexiglass insert was fabricated for the sliding glass window of the hauler cab. The insert provides an attachment point for two flexible ducts which act as both air ducts and conduit for power and signal wiring. Muffin fans located in each enclosure draw conditioned air through the ductwork and exhaust air from the enclosures to the atmosphere.

In addition to the cooling air, the camera is protected from intense infrared exposure by slewing it to a "stow" position when it is not in use. The stow position turns the camera to face away from the window so the optics and CCD chip are not exposed to infrared radiation from hot slabs during transit. Our original design called for a reflective heat shield to be mounted on the side of the camera facing the window in stow position. This feature was never implemented since most of the development work was done with cold slabs, however the concept should be considered for commercial equipment.

The stow position has the added benefit of being located to minimize the gravitational loading of the camera on the tilt axis of the pan/tilt mechanism. Shock loading on both the pan and tilt-axis gear trains are also minimized by placing the camera center of mass directly above the tilt axis and as near to the pan axis as possible. These placements minimize the reaction torques applied about the pan and tilt axes when the slab hauler experiences accelerations in the vertical or longitudinal directions due to bumps, stop/start maneuvers or material handling operations.

2.2 Computer Enclosure

The computer enclosure is a water-tight, NEMA enclosure mounted on top of the slab hauler cab as was shown in Figure 2.1. The box is mounted via viscoelastic damping mounts to heavy steel C channel which is in turn bolted to tabs welded to the roof of the slab hauler. The computer enclosure contains power supplies for the entire system, the computer, modem and terminal strips for interconnection. Figure 2.3 shows the internal layout of the components.

2.2.1 Power Supplies

It was necessary to convert 24VDC power from the slab hauler charging and starting system to voltages that could be used by the computer, the camera, and the other peripheral devices. Commercial power supplies designed for this purpose were purchased from Industrial Computer Source. Two supplies were used in the design--one to provide power for the computer and its internal cards alone, and the second to provide power to all other equipment.

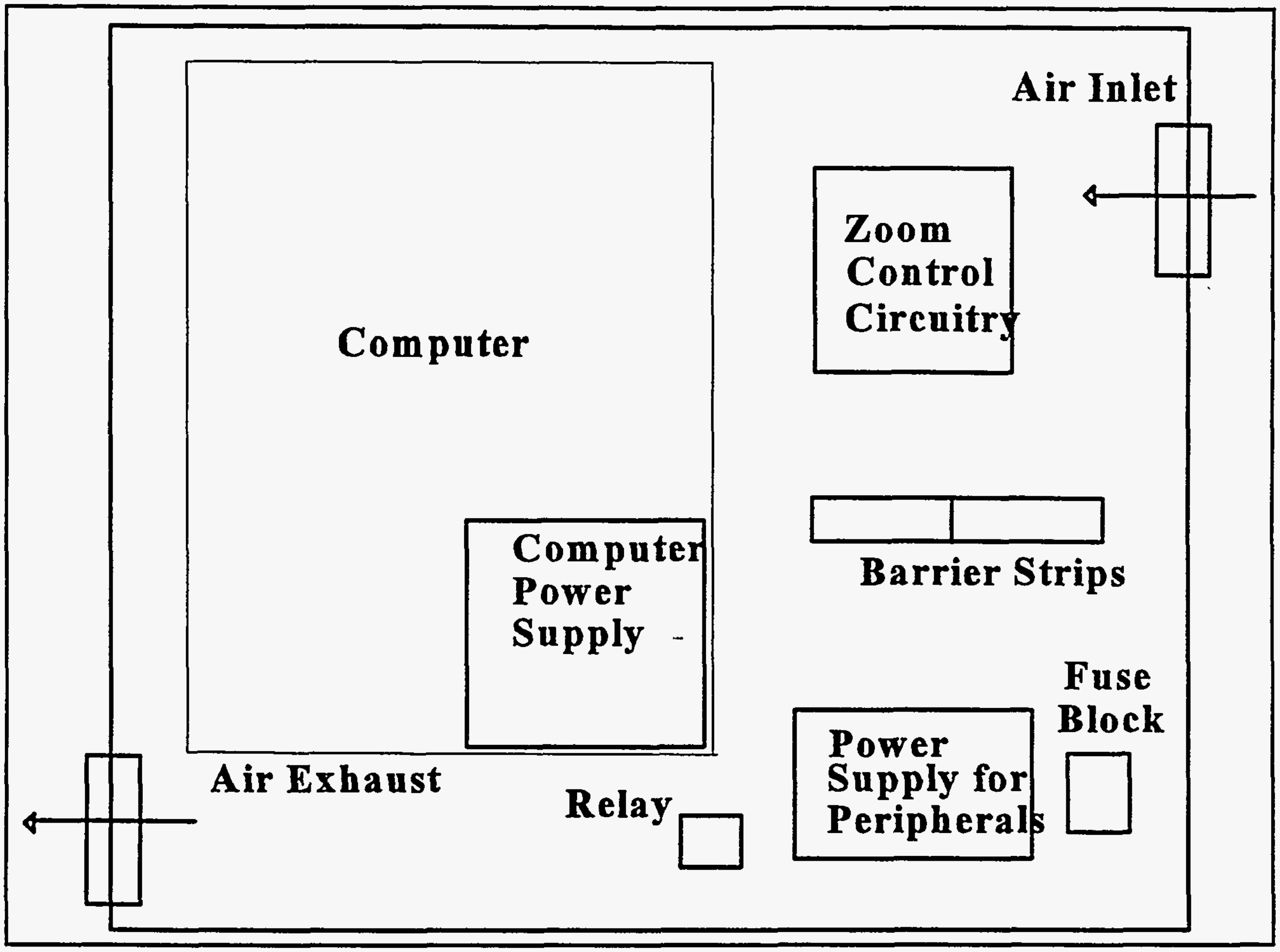

Figure 2.3: Component layout in Computer Enclosure

2.2.2 Computer and Interface Boards

Numerous vendors supply "industrial" PCS which are primarily sturdy enclosures with filtered cooling air and some shock/vibration mounting provisions. As nearly as we can tell, all other hardware is standard. We had difficulty in finding any such "ruggedized" systems which incorporated state of the art computing hardware, i.e. processors faster than 80486. We also found them unjustifiably expensive--typically $7,000-$10,000. We elected to purchase a ruggedized chassis and a standard Gateway 2000 120 MHZ Pentium computer and marry the two. We removed the motherboard from the Gateway and installed it in the ruggedized chassis along with a flash memory interface, the video frame grabber card, the touch screen interface and an analog/digital I/O card. Detailed information on the equipment and vendors from which it can be purchased is given in the Appendix.

2.2.3 Camera Zoom Interface Circuitry

The Sony video camera was modified to allow control of the zoom function by the computer. Two components of the modification were necessary. First, the manual zoom switch was opened up and bypassed, allowing the computer to zoom the lens in either direction. Second, it was necessary to obtain some kind of feedback on the lens focal length. This was done by tapping into the phases of the tiny stepping motor which positions the internal lens element controlling the focal length of the lens. The signals driving the stepper motor turn out to be pulse-width modulated, and so special filtering circuitry was designed to eliminate the high frequency noise caused by this drive mechanism. The filtered pulses were fed to a counter/timer on the A/D card, and software was developed to convert the pulse signals to incremental changes in the lens focal length. Because the camera is located some distance from the computer, custom line driver/receiver circuits were eventually also added to insure noise immunity in the counting process.

2.2.4 Radio Modem

Data are communicated between the slab hauler and the "base station"--a stationary computer which represents the main L&IS database system. The communications include dispatch orders, status information and database updates. The communications are handled by a pair of Proxim model PL-2 spread-spectrum radio modems operating at 2400 baud. The modems' range is nominally 1000 feet. We have tested them to distances of about 800 feet with good reliability, however the actual range in the steel mill environment would vary with location. The radio signals are high frequency (approximately 900 MHZ) and therefore susceptible to shadowing by metal structures or equipment, which are obviously in abundance in the mill. Receiving stations would need to be strategically placed to guarantee effective communications, however vantage points certainly exist which would make this possible.

2.3 Display and Operator Interface

The computer/system display and operator interface have been integrated into a single module by the use of a touch-screen overlay. The display is an active-matrix color LCD panel mounted in the slab hauler cab above the stern-facing windscreen. The mounting location places the panel out of the driver's way but well within his reach and at a convenient viewing angle. The panel is also shielded from direct sunlight, which makes it difficult to read. Overlaying the panel is a resistive type touch screen. The operator can read messages and information on the screen as on a normal computer video terminal display. He can also provide inputs to the system in the form of commands, responses to queries, etc. by physically touching virtual "buttons" on the screen, much as one would use a mouse. In this case, the pointing device is just the operator's finger. This system creates a very simple and intuitive interface which does not require keyboarding skills or even any particular manual dexterity as would be needed with a trackball or joystick. More detail on the interface will be given in the software section which will present examples of the operator screens and the logic of the program/control itself.

3 Software Systems Design

3.0 Overview

The overall flow of the program is controlled by the operator interface, since program function is determined by the timing of activities commanded by the operator. There are two closely interwoven issues that must be addressed in the development of a system such as this. Of primary concern for this project was the issue of *functionality*--that of creating a system with a specific set of capabilities. In this case, the system was required to find tags in a cluttered scene and to read them. The second issue is that of *application*. By application, we mean the way in which the available functions of the equipment are employed. For example, should every move in a sorting operation include scanning or only certain stages of the move? While we view the application issue as primarily a logistics decision which must be made by WSC management, the results of that decision also affect the requirements for system functionality. They profoundly affect the operator interface, including determining the choices available to the operator at each step of the processing and the sequences in which various functions occur.

In order to create a functional system, the WVU team has had to make some assumptions regarding applications which may not be appropriate for all customers or even for Weirton Steel itself as Weirton's needs and material handling strategies are refined. Thus what is presented here with regard to the program flow and the operator interface represents only one of many possibilities for systems which could be developed using the same basic functional modules. The following sections outline the strategies used by WVU to generate the functionality required by the particular application scenario we developed.

3.1 Operator Interface

The operator interface consists of 6 screens corresponding to different steps in the acquisition and processing of the tag information. Each of the screens and the choices provided to the operator by the screen will be described in terms of the high-level function modules called by the screen. During these descriptions, references to lower level modules (e.g. camera point and zoom or tag read) will be made. In order to maintain continuity, the lower level modules will be described only after all of the high level (screen level) modules are covered.

The scenarios described below assume that the slab hauler is dispatched from a central material handling scheduling center. In this scenario, a two-way data link between the slab hauler and the dispatcher is maintained by a radio data modem. Communications are initiated by the slab hauler in most cases.

3.1.1 DISPATCH Screen

When the operator brings the slab hauler into service at the beginning of a turn or following maintenance, he will see the DISPATCH screen shown in Figure 3.1. If he is ready to begin work, he alerts the material handling dispatcher to the availability of the unit by pressing the "Available" button on the touch screen display. The message is sent to the dispatcher, along with the slab hauler ID. The dispatcher consults the queue of move orders and, in our simple system would assign the next order to the slab hauler by radio signal. In a more complex system, the dispatcher might optimize matches between carrier type or size and the load size or task. If the hauler location were known, the dispatcher might choose an assignment to minimize unloaded travel distance. Irrespective of the assignment criteria, the dispatch order would contain at least the following information:

a) a list of the identification numbers of the slabs to be picked up (the *pick vector);*
b) the identification number of the pile where the slabs are currently located;
c) an ordered list of the slabs believed to be in the pile (the *pile vector*);
d) the destination for the slabs.

Upon receipt of this transmission, the screen would change to the START Screen, described below, and the data would be displayed on the screen.

Also available on the DISPATCH Screen is an option called "Field Scan". For one reason or another, an operator may wish to initiate a data collection action without being specifically dispatched to pick up any slabs. This might be done to upload the contents of a pile that the operator knows has been corrupted in the database. If the operator wishes to initiate a Field Scan, he presses the corresponding button on the startup screen. He will then be prompted to enter the number of the pile for which the scan will be performed and a keyboard display (Figure 3.6) will be provided through which he can key in the pile number. When the pile number has been entered it will be displayed on the START screen and the operator can initiate the scan procedure when the slab hauler is ready to back onto the pile.

3.1.2 START Screen

The START Screen (Figure 3.2) is a transition screen serving two purposes. The change from the DISPATCH Screen to the START Screen notifies the operator that communication has taken place between the slab hauler and dispatcher computers. The dispatch information is displayed on the screen advising the operator where to drive the slab hauler to pick up the next order or confirming the location of the field scan as the case may be. The second purpose is to prompt the operator to begin setting up for the scanning operation while backing onto the pile. This "head start" is necessary to conserve time. The camera is kept in a stowed position during transit to minimize the shock loading on the pan/tilt head and to point the optics and CCD sensor away from hot slabs. When the operator presses "Start" the camera is slewed to the proper position from which to take the first of two wide-angle views of the slab pile. Since the slewing process takes between one and two seconds, this procedure reduces the waiting time an operator must spend once he is in position to read the tags, speeding up the overall process. In addition to "Start", the operator can press "Back" which returns him to the DISPATCH Screen.

3.1.3 READ Screen

The READ Screen (Figure 3.3) is also a transition screen which contains two buttons: "Read" and "Back". Pressing the "Read" button initiates the entire read sequence which is described below. Pressing the "Back" button returns the program to the prior screen.

3.1.4 DATA Screen

Figure 3.4 shows the DATA Screen. The DATA screen keeps the operator abreast of the data acquisition process by displaying the results of various parts of the data acquisition process

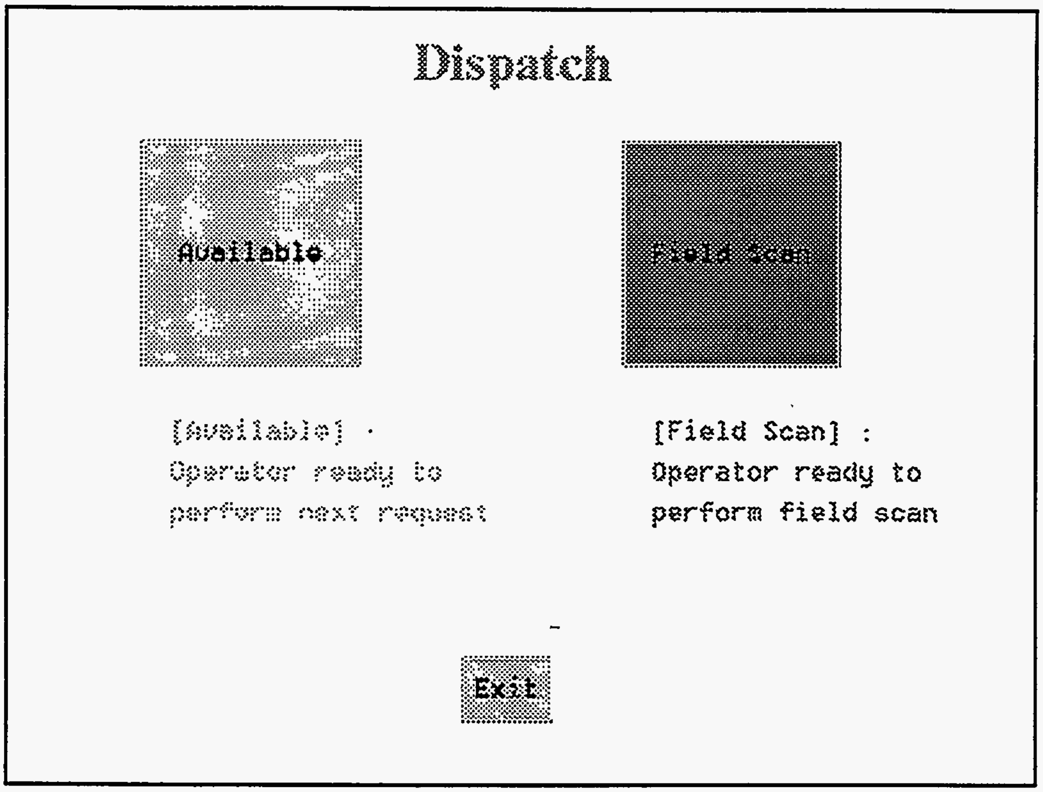

Figure 3.1 DISPATCH Screen

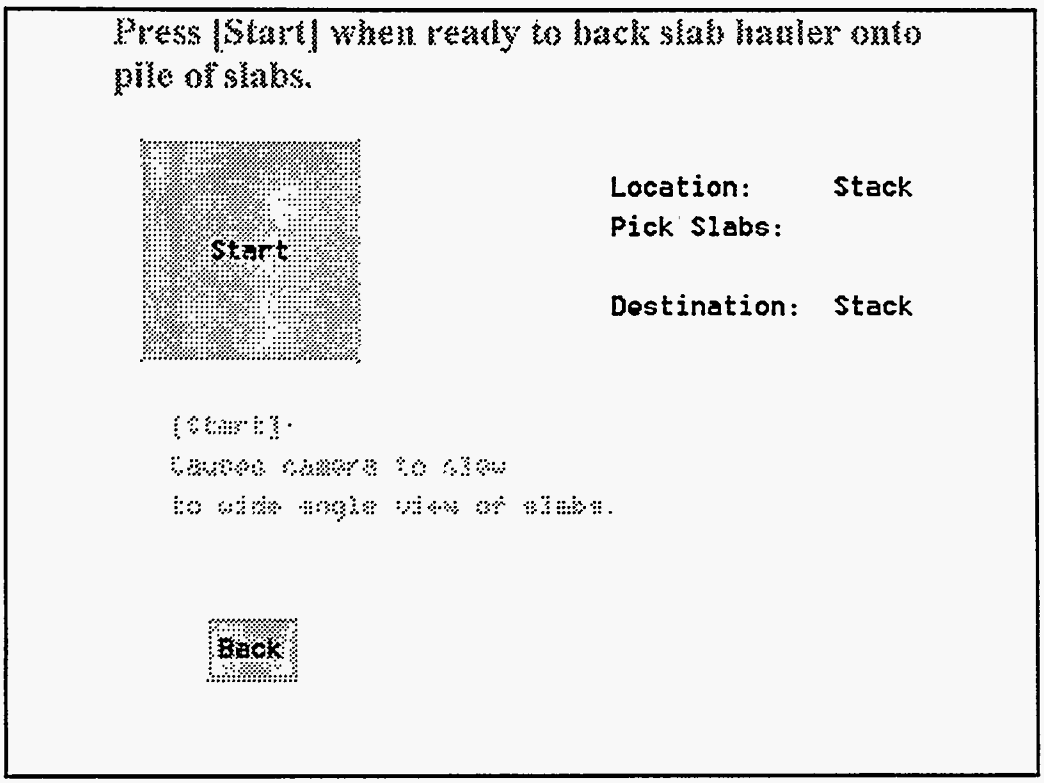

Figure 3.2 START Screen

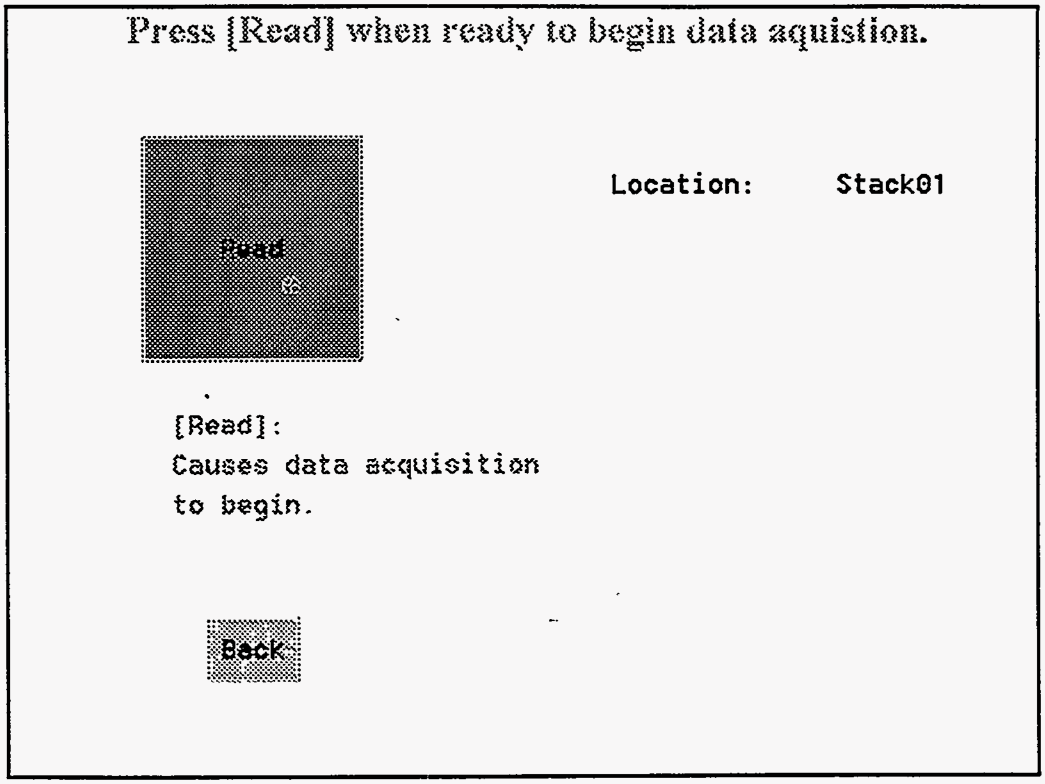

Figure 3.3 READ Screen

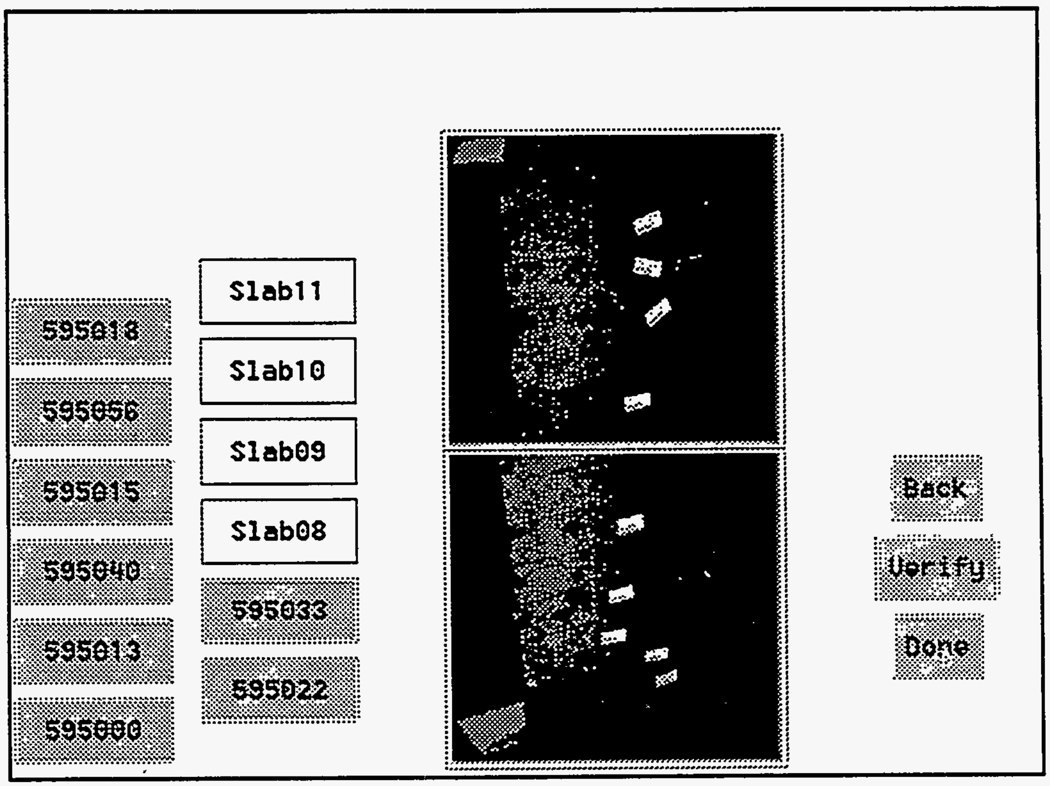

Figure 3.4 DATA Screen

as they occur. In the center of the screen are two windows which display the wide angle views of the bottom and top wide-angle views of the pile. To the left are twelve boxes marked "Slab 0" up to "Slab 11", one for each of up to twelve slabs which could be in the pile. As the camera is moved from tag to tag taking closeups and reading the identification numbers, the numbers are displayed in the corresponding boxes on the display, as shown in the figure. As each tag is read, it is compared with both the *pick vector* and with the *pile vector* mentioned earlier. If the slab number is a member of the pick vector, the corresponding box on the screen is turned green in color to assist the operator in locating the slab to be picked as part of the order. If the slab is not a member of the pick vector, the number is compared with the pile vector to confirm that the slab should indeed be in the pile. If the slab number is a member of the pile vector, the box is turned blue. If the slab is not a member of the pile vector, there is an error in the database and the display box is turned yellow to notify the operator .

Another possibility exists, which is that the tag is partially or completely illegible. When the tag is read, independent interpretations of the bar code and of the alphanumeric characters are made and compared. Any characters which cannot be read are assigned the value of questionmark, which does not appear in any of the tags used at Weirton Steel. The two readings are then compared on a character-by-character basis. If the two agree, the read is assumed valid and processed as outlined above. If the two do not agree, including the case in which one or more characters of either code is indecipherable, the read process is repeated. If after three tries the alpha- and bar codes do not agree, a "most likely" number is computed by comparing those portions (if any) of the two codes which do agree, and assigning the other characters based on confidence levels computed as part of the reading process for each character. In some cases, neither the bar code nor the alpha code will be decipherable, or perhaps the entire tag is missing from the slab. In these cases, the questionmarks will be displayed on the screen and the box will turn red to notify the operator of a "bad read". The program proceeds to read the remaining tags in the pile. If all of the tags are correctly read, or if the operator decides that correction of the bad reads is not necessary (i.e. none of the bad reads is a pick slab) he can press the “Done” button. At this point, the slabs in the pick vector are considered to be in transit, and he can back onto the pile, sort out the pick slabs if necessary, make his lift and proceed to the destination.

If one or more of the slabs from the pick vector is a red tag, the operator may wish to input the slab number manually. To do so, he presses the “Verify” button in the pile and he is then presented the VERIFY Screen, described below. As always, the “Back” button allows the operator to return to the previous screen if need be.

3.1.5 VERIFY Screen

As shown in Figure 3.5, the VERIFY Screen is a subset of the DATA Screen, except that the slab boxes are now buttons. If the operator wishes to change the data in one of the boxes, he need only to touch the appropriate box and then touch the “Key Pad” button. He will then be presented with the KEYPAD Screen via which he can enter the number he wishes to appear in the box he has selected. When he has finished entering the data he presses “Enter” and is returned to the VERIFY Screen. At this point he may select another box to modify or press “Done” at which point he is returned to the DATA Screen.

3.1.6 KEYPAD Screen

The KEYPAD Screen is used for manually entering data, either to correct slab reading errors or to enter pile numbers in the case of a field scan as described above. As shown in Figure 3.6, it has a standard layout for the numerals, backspace and "Clear" buttons on the pad itself. As numbers are keyed in, they appear in the box in the upper right hand corner of the screen. Once the correct number has been keyed in, the operator presses the "Enter" button to assign the new number to the corresponding slab. He is then returned to the VERIFY Screen to select another slab to modify or to terminate the editing session. "Quit" aborts the manual data entry process without changing slab number data.

3.2 Camera Control Software

Two principal hardware functions must be controlled by the computer: control of the pan/tilt head to point the camera appropriately, and control of the zoom lens to set the correct focal length for viewing the slabs/tags. Each of those functions will be described below.

3.2.1 Camera Pointing Control

The pointing control system for the video camera is a combination of two pointing modes. The camera stow position and the positions for the two wide angle views of the slab pile are merely memorized pre-set locations to which the pan/tilt head is moved at the appropriate times. However, since the tags may be located almost anywhere on the ends of the slabs, preset positions cannot be used to generate the closeup views required to read the tags. The wide angle views of the slab pile are analyzed, and the tags are separated from the background as described below. The centroid of each tag is computed and used as a reference point for calculating the movements required to center the tag in the closeup image.

Figure 3.7 is a schematic representation of the camera with a number of slabs in its field of view. The problem is to determine the location of the tags with respect to a coordinate frame centered on the focal point of the camera. If that can be done, and if the physical distances, angles and optical parameters are known or measured, then the theory of homogeneous coordinate transformations can be applied to predict the pan and tilt angles required to place each tag on the optical axis of the camera. In the figure, a ray of light is shown passing through the centroid of one of the tags and entering the camera. It is clear that if certain distances and the pan/tilt angles are known, the coordinates of the tag can easily be determined trigonometrically. Nominally, the height h of the camera above the ground is known, as is the horizontal distance d from the camera to the slabs. In practice, neither of these is known with great precision, although h is fairly reliable. The knowledge of d is clearly dependent on the accuracy with which the slab hauler driver can position the huge machine, and routinely varies by more than six inches from the nominal. If d is ambiguous, then so is the position of the slab in the pile, as shown in Figure 3.8.

We solve this problem imperfectly but adequately by making a couple of assumptions. We base the calculation on the location of the lowest tag in the wide angle image, and assume that the tag is approximately centered vertically on the slab. This places the centroid of the lowest tag about 4.5 inches above the ground and allows d to be calculated with reasonable accuracy, provided the lowest tag visible in the pile actually belongs to the bottom slab. Should the bottom tag be missing or for some reason undetected, our calculations would contain errors, although the tags could still be found. Should both the bottom two tags be missing, the error would be

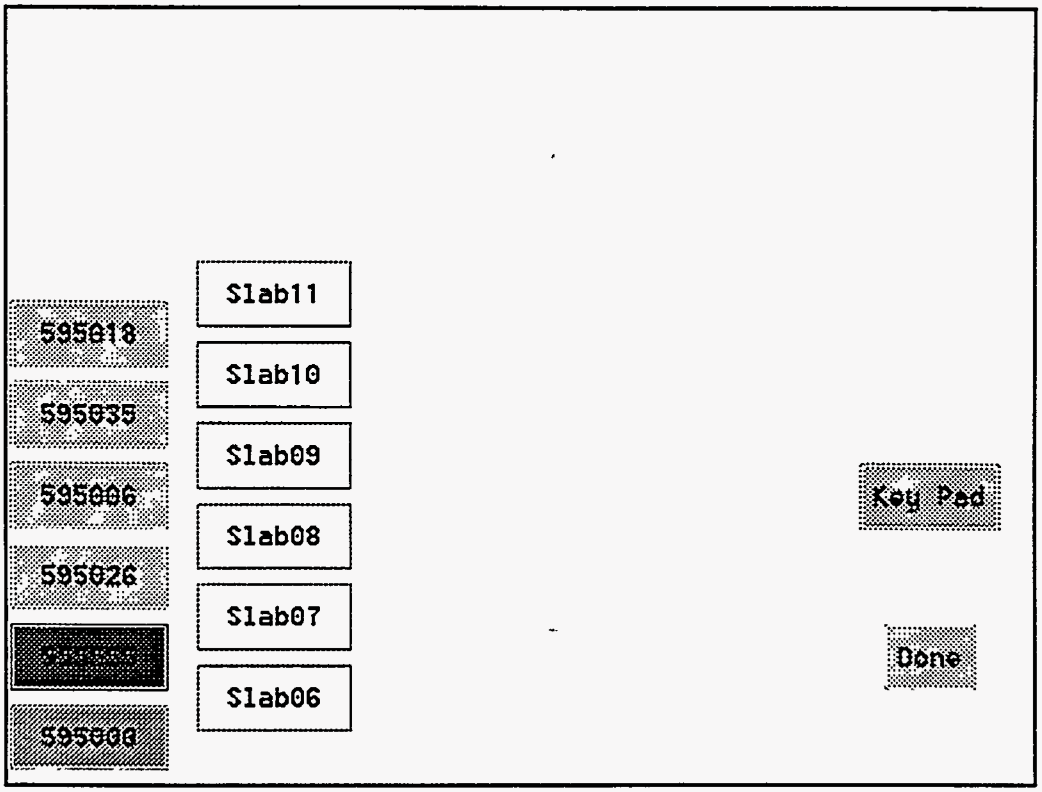

Figure 3.5 VERIFY Screen

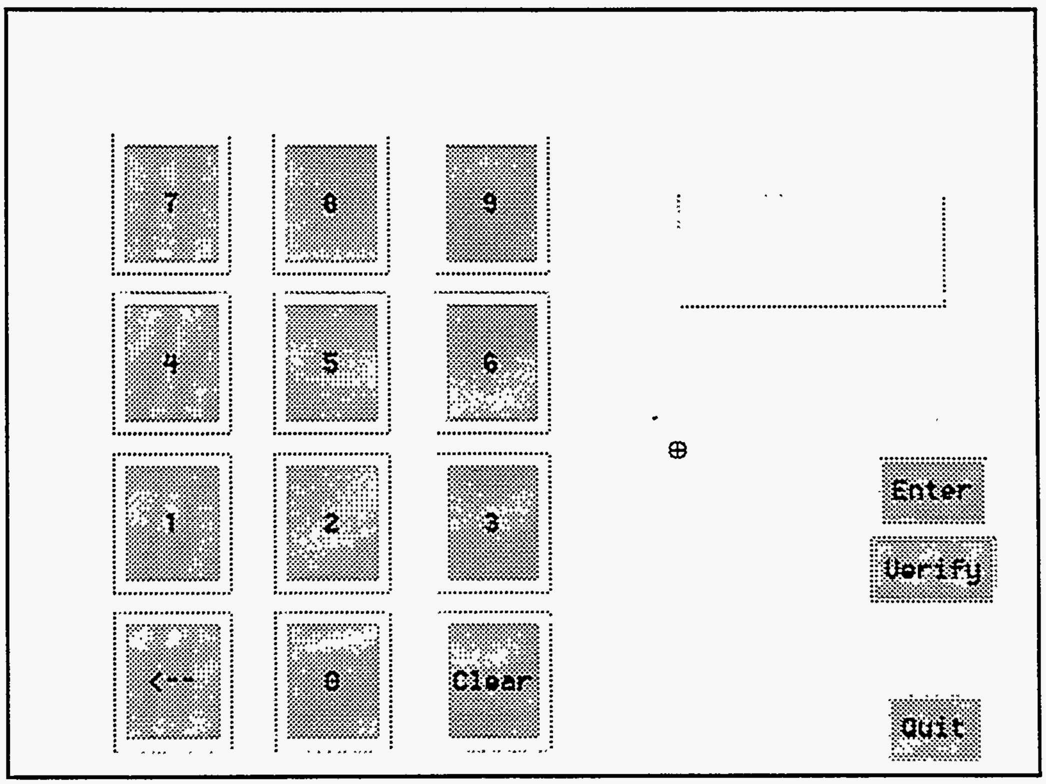

Figure 3.6 KEYPAD Screen

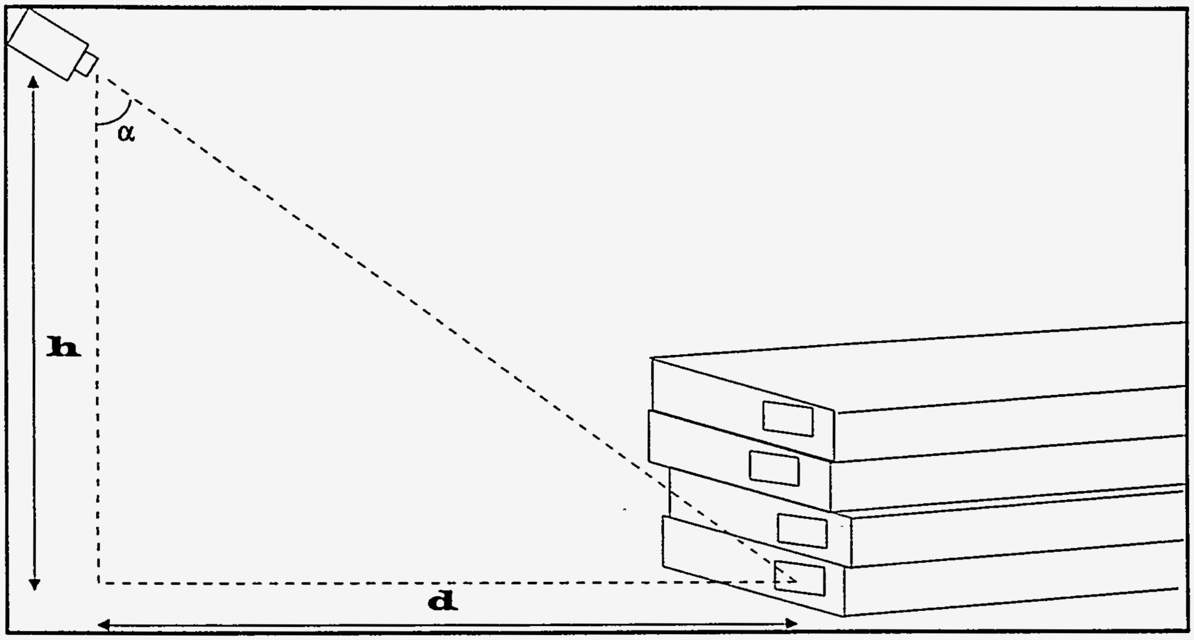

Figure 3.7 Triangulation method for finding slab position

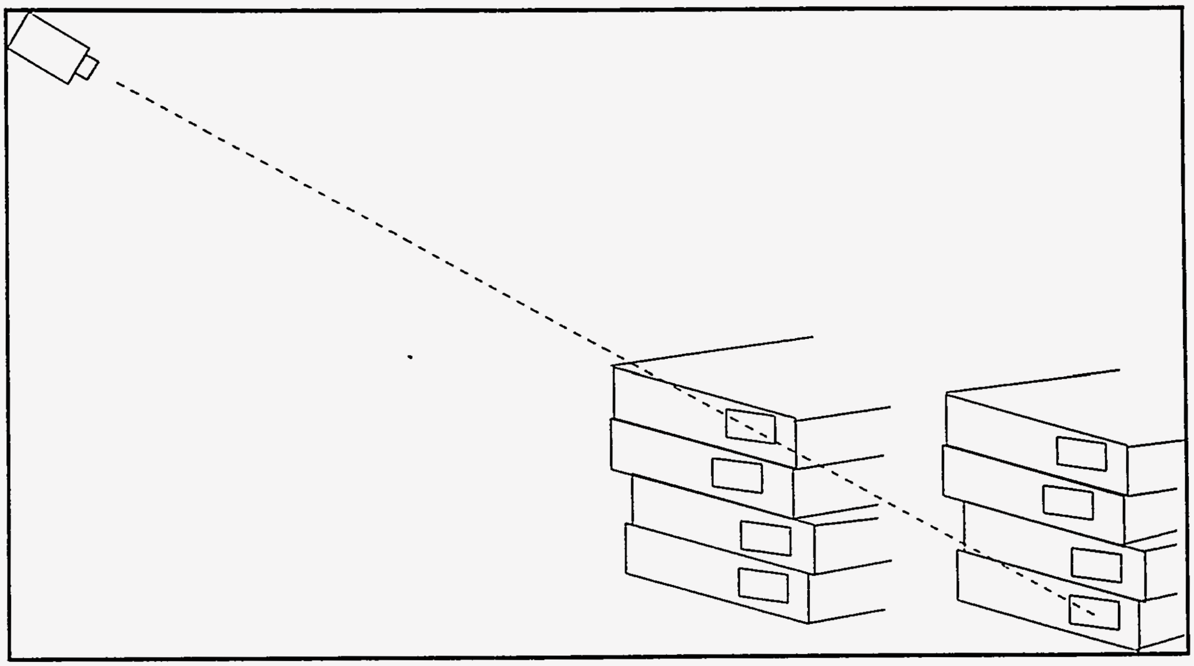
Figure 3.8 Ambiguity in the distance/hight relationship

sufficient to possibly cause complete misses in pointing the camera. Fortunately, it would be very rare to find both of the bottom tags missing in a single pile. To account for small pointing errors, the zoomed images are checked to make sure the tag is completely within the image boundaries, and the camera is repositioned if necessary. We have found through casual observation that the system is quite reliable and has not failed to find the tags in recent memory.

The second assumption required by this system is that all slabs are nine inches high, and are stacked with the front edges nearly aligned. Small deviations in alignment can be accommodated, but if slab height were to vary significantly, adjustments to the algorithm would be required. These assumptions are used to determine the position a particular tag/slab occupies in the pile. Essentially, we calculate the height of the tag above the ground and divide by nine inches to assign the slab number for the display. This method has the advantage of being robust to missing tags, except for the case of the bottom or top tag being missing.

3.2.2 Camera Zoom Control

Control of the camera lens focal length turned out to be far more difficult and time consuming than seems reasonable. As noted earlier in this report, we were unable to find off-the shelf hardware to make the task simple. We eventually elected to tap into the electronics of the camcorder itself to effect the control and to extract feedback. The Sony camera uses a tiny two-phase stepping motor to drive a lead screw which moves an internal lens element to effect the zoom function. The motor is driven by a pulse-width modulated signal generated by a microcontroller in the camera. Disconnecting the microcontroller from the motor seemed infeasible, so it was decided to control the zoom by tapping into the manual zoom switch and to obtain feedback by monitoring the voltage pulses sent to the motor phases. The phase signals were low-pass filtered to remove the digital modulation and then thresholded into a digital pulse train which was fed to an up/down counter on the I/O board in the computer. Since the camera and the computer are physically separated by several feet, a complementary line driver/receiver pair was used on each end of the cable to provide noise immunity. Figure 3.9 is a schematic of the circuitry on the camera end, showing the filtering and Schmidt trigger thresholding elements feeding the line driver.

The reference position is the extreme wide angle position of the lens. On startup, the camera self-calibrates by driving the lens to its wide angle extreme. When this happens, the counter is reset and maintains a count in terms of stepper rotations until it is reset again. To guard against lost pulses, we drive the lens to the wide angle limit at the end of each pile reading sequence and reset the counter. This system has proven extremely reliable. The counter establishes the position of the internal lens element on a linear scale. Optically, the zoom ratio is not a linea function of the lens position. An exponential curve was fit to experimental data to establish the relationship between the motor position and the optical zoom factor.

As the camera is pointed from one tag to another, the distance between the camera and the tags changes drastically. It is necessary to change the zoom level between tags to optimize the size of the tag in the image without making the closer tags too large to fit within the image boundaries. Progressively shorter focal lengths are used as the camera moves up the pile of slabs in the sequence. After the last slab is read, the camera is slewed to its stowed position facing away from the window and the zoom setting is returned to the wide angle extreme.

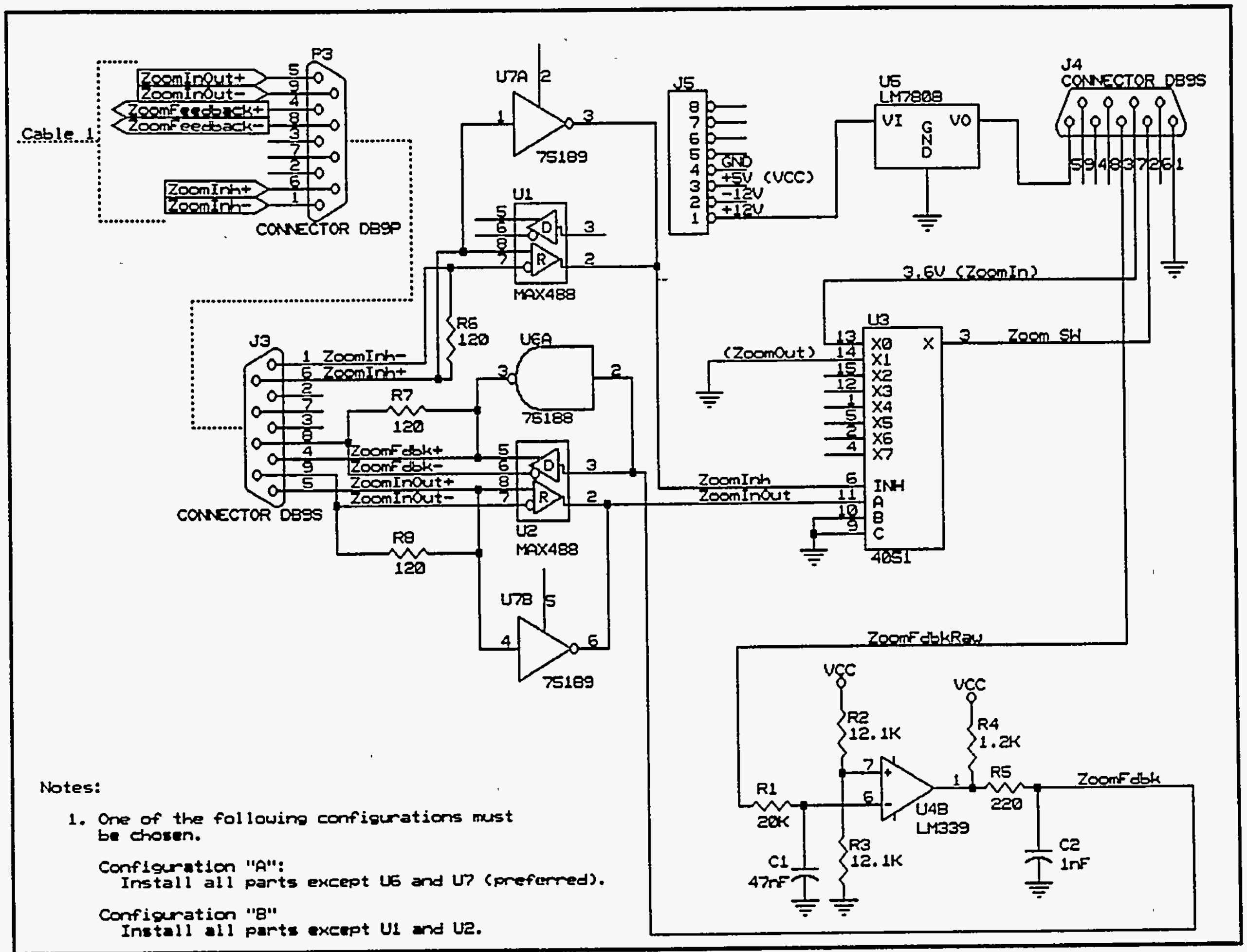

Figure 3.9a Schematic of the camera zoom control interface circutry in camera box

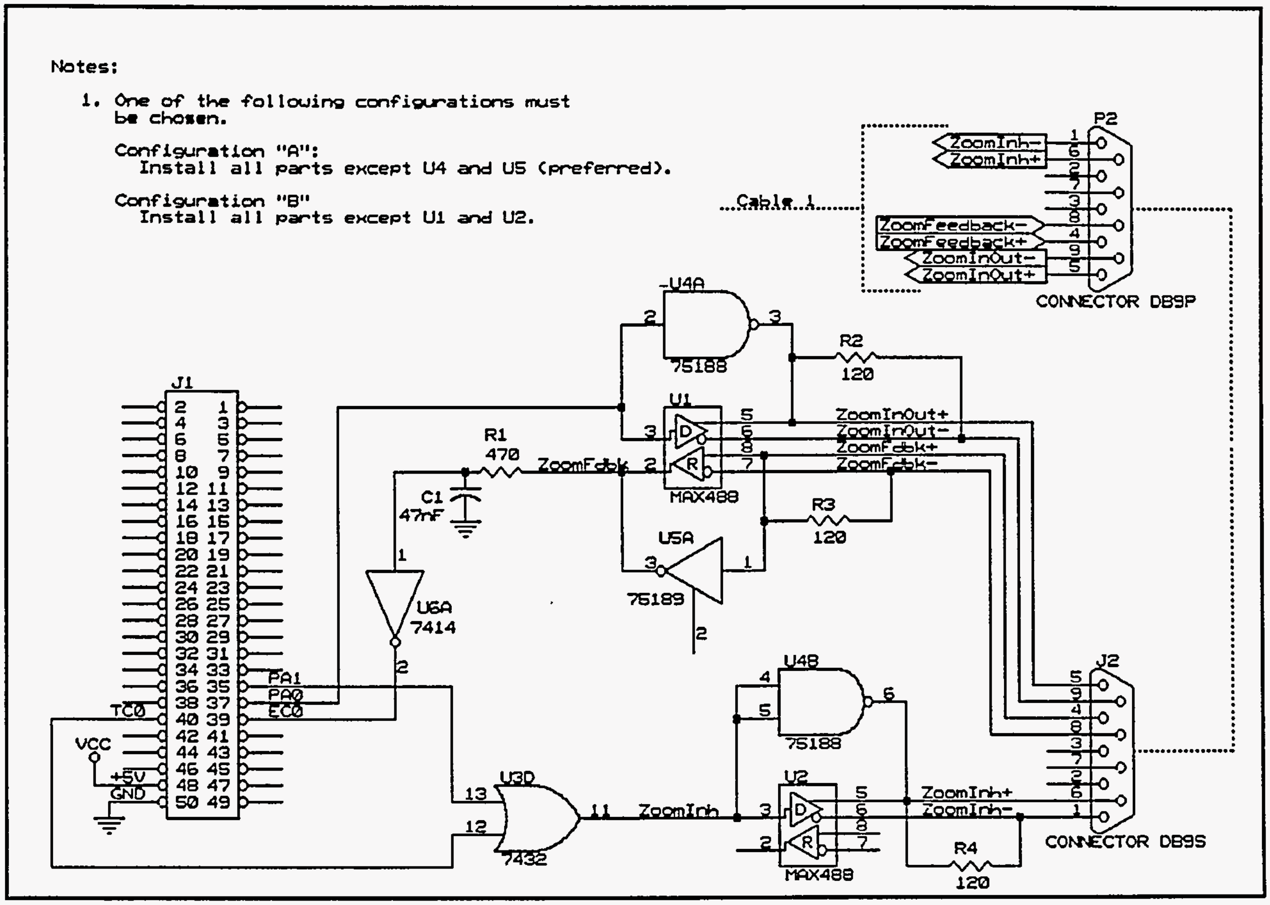

Figure 3.9b Schematic of camera zoom control interface circuitry in computer box

3.3 Image Processing Software

Finding the tags in a cluttered image and interpreting the codes imprinted on them involves a series of processes which make use of the modules described below. The descriptions in this report will be general in nature, outlining the approach and general strategies used to effect the pertinent functions. The shear volume of the software prohibits minute description in a document of manageable size--the source code for the system exceeds one million bytes of data. In addition, the exact workings of the system are considered proprietary by its inventors. Therefore, specific details of the processing will not be described here in the interest of the protection of intellectual property.

3.3.1 Tag Location

Figure 3.10 shows a typical wide-angle view of a pile of slabs. This image must be examined and the locations of the tags in the image determined. Over the course of the project numerous systems have been devised to accomplish this. The current and most successful version uses a gradient-based search algorithm to find the boundaries of the tags.

The primary key in searching for the tags in the image has always been the difference in color between the tags and the slabs. Initial processing systems used object brightness as the principal means of segmentation. Automatic thresholding algorithms were developed to overcome problems with variations in scene lighting. Ultimately, these methods proved incapable of coping with the tremendous dynamic range in illumination levels that can appear in an outdoor scene. In fact, reliable segmentation in the face of extreme lighting contrasts remains an issue for further research. While somewhat more computationally intensive, we have found the gradient based method more robust than the intensity threshold and hold it up as our best system to date.

The algorithm scans the image for regions of high intensity gradients. When it finds such regions, it clusters connected pixels into objects which are then further examined as candidate tags. The candidates are classified according to size, shape, and other parameters as either tags or not tags. For the tags, the centroid of each cluster is calculated and is used as a target for pointing the camera in the closeup image portion of the processing.

3.3.2 Closeup Image Distortion Correction

The tags as viewed in the closeup image contain significant distortion, mostly due to the oblique angle from which they are viewed. The viewing angle varies from tag to tag, and so distortion correction parameters must be calculated on an individual basis. This is done primarily from a geometric viewpoint by calculating an inverse transformation or mapping of the image coordinate frame to a new frame in which the tag image has been scaled and rotated to a standard size and shape. The details of this process have been addressed in earlier reports on this project, principally the Phase I final report. A summary will be given here for the reader's convenience and to present an update incorporated into the final software.

The basic idea behind the procedure is simple. The size and shape of the actual tag are known, and the size and shape of the tag image can be measured. We also know the principal components of distortion: scaling due to the variable distance of the tag from the camera, translation of the tag with respect to the optical axis of the camera, and rotation of the tag about all three major axes with respect to the camera. Perspective distortion is a minor effect in this case, since the distance from the camera to the tag is great in comparison with the focal length of the lens, even at maximum zoom. Perspective distortion is thus ignored in this procedure.

Figure 3.10: Typical wide angle view of pile of slabs

It is possible to calculate an inverse translation, scaling and rotation transformation if enough points on the camera image can be correlated with corresponding points on the target image. We use the "projected corners" of the tag as the reference points. By projected corners, we mean the points where the corners would occur if there were corners, since the tags actually have radiused "corners". These projected corners are computed by finding equations for the lines defined by the tag edges and extending the edges to their projected intersection points. The idea is illustrated in Figure 3.11.

The tag edges are located by using a gradient search technique similar to the one described in the preceding section. Regions of high intensity gradient are clustered into edge segments. The addresses of the pixels in each cluster are used in a Least Squares line-fit to define the tag edge lines, and then the corresponding equations are solved simultaneously to find the intersection points which serve as the tag's "corners". Once the corners are found, they must be correlated to the corners of the undistorted tag. Because the tags are much longer than they are high, the correlation to within 180 degrees is simple by matching long and short edges. To determine if the tag is upside down, a single scan is made across the area where the alphanumeric characters should be. The light/dark intensity transitions are counted across the scan. If the number is low, the scan has been made across the numerals and the tag is right side up. If the number of light/dark transitions is high, the scan has been made across the bar code, and the tag is upside down. Once this information is known, the corner correlations can be established. These coordinates of the distorted corners can be used with the theory of homogeneous coordinate transformations to find the inverse which corrects the geometric distortion.

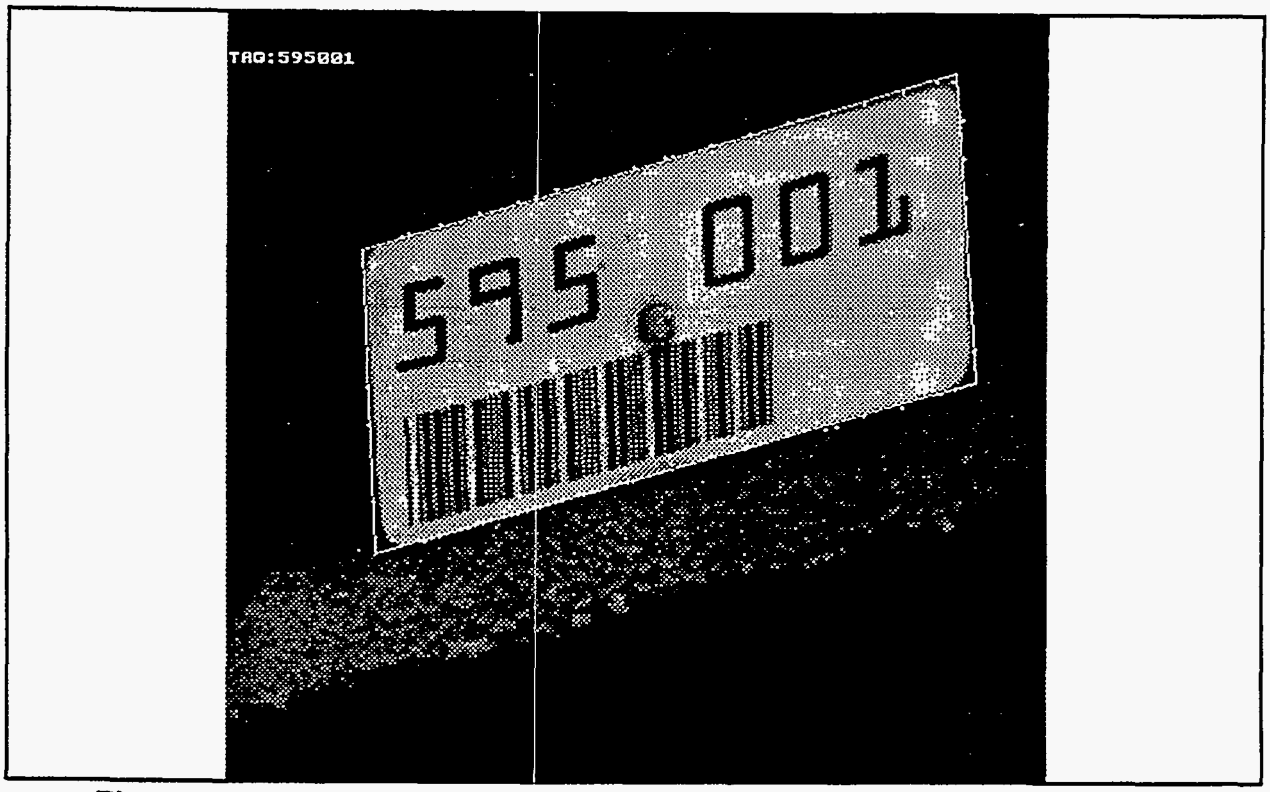

Figure 3.11: Tag image showing distortion, edge line fitting and projected corners

3.3.3 Optical Character Recognition

The Optical Character Recognition system (OCR) is the software which can "read" the numerals printed on the tag. The OCR system used in this work was developed completely by West Virginia University. While there are commercial OCR systems available, they are virtually all intended to read scanned documents in which the printing is on a page which has been input to a flatbed scanner and the image has been made under carefully controlled conditions. The scanner provides strictly controlled image quality by controlling illumination, focus, scaling, and all other image generation parameters.

By contrast, our system must cope with text located at random locations in an image, distorted geometrically as described above, and degraded by variable lighting levels and the presence of scratches or foreign substances on the tags. Figure 3.11 is actually a high quality image compared to some the system must process. No off-the shelf system was available at the time this research was initiated which could read tags such as these. It is doubtful that one currently exists which could be easily integrated into the overall software system required for this application.

The WVU system incorporates neural network processing to classify features extracted from the image into characters. A combination of geometric and image processing search methods is used to isolate individual characters in the six-number string on Weirton's tags. The region of the tag representing each character is then examined individually to extract features which distinguish one character from another. The neural network is given an input for each of the possible features. The input corresponds to the relative presence of the feature. The network then weighs the evidence supporting each possible classification and produces an output which is a measure of the "confidence" the net has in each of the ten possible assignments. That is, for any combination of feature inputs, each of the ten output neurodes will display a value between zero and one. The largest output value is taken as the most likely candidate and the character corresponding to that output is assigned to that space in the string. Ideally, all but one of the outputs will be small and the remaining one large. Imperfect distortion correction, poor character localization or degraded image quality can cause ambiguity in the detection of the features, however. If none of the possible character choices is clearly dominant, the question mark character is assigned to the space, and the program moves on.

The font used on the tags in the demonstration is an ANSI standard font called OCR-A. It is a font expressly designed for machine reading. Whereas other fonts sometimes contain characters that look quite similar, OCR-A has been specifically designed to make each character distinctive. However, the neural network technique developed in this research is not dependent on the use of the OCR-A font. Prior to discovering OCR-A, we successfully trained the network to read several other fonts, including Monospace and a dot-matrix font. Changing fonts would require retraining the network, and while this is a somewhat time consuming procedure it is not difficult.

3.3.4 Bar Code Reading

The bar code used on the demonstration tags is 3-of-9 code or Code 39. This is a standard code commonly used in industry. A code element can be either a black "bar" or a white "space", and can be one of two sizes, wide and narrow. The width of the narrow elements is called the "x dimension". In our tags, the wide elements have width 3x. Code 39 has a vocabulary of all 128 standard ASCII characters. Each character is made up of nine code elements, three of which are wide and the rest narrow--hence the name 3-of-9. The asterisk is used as the start and stop character. Figure 3.12 shows a sample tag and how the code elements correspond to the characters. The numbers above the bar code represent the position in units of x-dimension.

To correctly interpret the code on the tag, the system must find the code, which is done geometrically--that is, from a knowledge of where the tag edges are and where in the tag the barcode is printed. Five separate scans are made across the code, and each is processed separately. The results of each scan are stored and compared character by character at the completion of all of the scans. The number of consistent results constitutes a confidence level for each character. This confidence level is used by later processing to resolve conflicts.

For each scan, the system finds x-dimension, and determines the beginning and ending point for the code. The system uses proprietary methods to discriminate wide and narrow elements from each other, group the elements into sets of nine and translate the barcode into an identification number. The system has gone through significant evolution over the course of the project. The present system is both faster and more robust than methods reported in the Phase I documentation. We can currently read codes at much more oblique angles and with more severely degraded images than was previously possible. Figure 3.13 shows that our algorithm can successfully decode images that would be difficult or perhaps impossible to decode with the human eye.

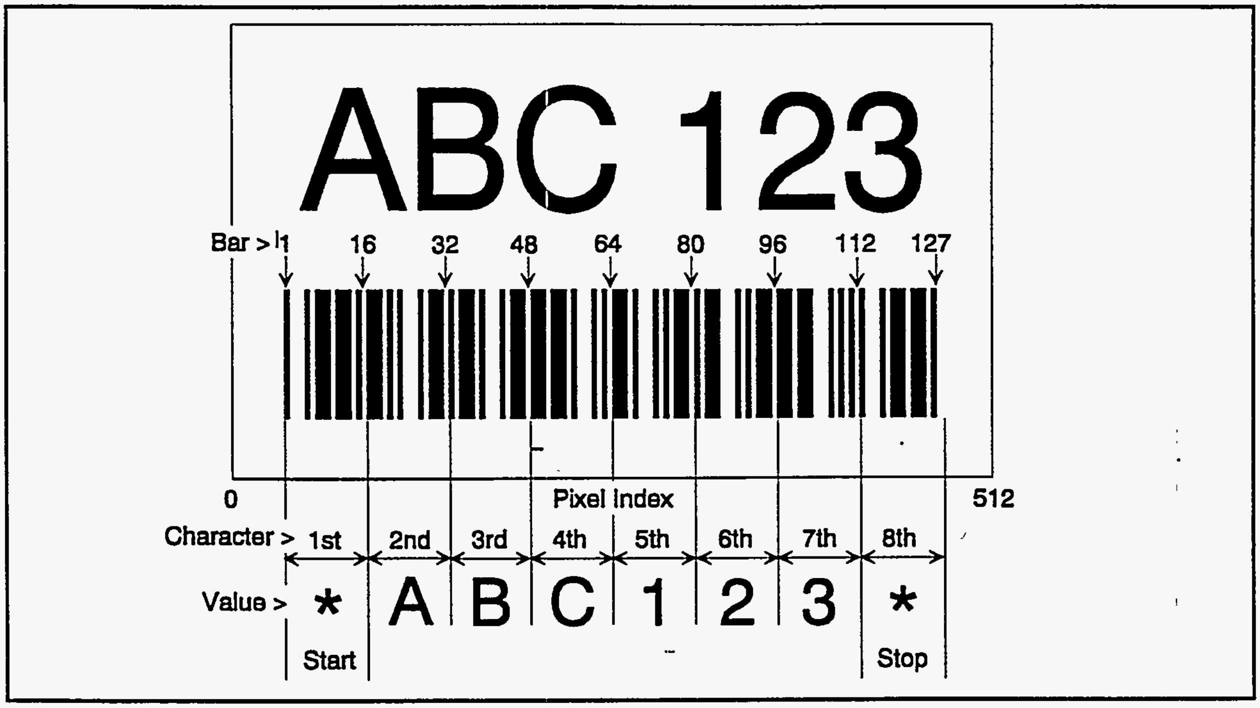

Figure 3.12: Sample tag showing bar code and character correlations

Figure 3.13: Even blurred barcodes such as this one can be read by the WVU algorithm

4 System Demonstration

On November 7, 1995 a "live" demonstration of the system was held at Weirton Steel for officials from WSC, the U.S. Department of Energy and other individuals. The equipment was installed on a slab hauler driven by a WSC employee. A mock slabyard was set up with three piles of slabs on which the "new" tags with bar code and OCR-A font had been installed. The tags were intentionally installed at random locations on the ends of the slabs. Tags were also placed at varying angles on the slabs, including at least one tag which was installed upside down.

A tent was set up to shelter the visitors from dust and inclement weather. In the tent were chairs and tables with several computers set up to emulate the dispatching and database functions of the L&IS system. Since these functions of L&IS have not yet been completed, WVU wrote a simulation program to allow the display of the three-pile database, entry of dispatching orders and control of the stationary communications link to the slab hauler. The database was initiated by manually entering the tag numbers for each pile.

The demonstration was planned as a scripted series of moves and field scans incorporating participation from the audience in choosing which slabs to move, etc. However at the outset a mysterious communications problem arose which disrupted the demo. The problem was repaired a short time later, but the classroom format had been lost as visitors climbed up on the slab hauler and asked questions while troubleshooting was being performed. Albeit in a less formal fashion than we had planned, the demonstration eventually was able to proceed with all of the following functions being performed.

4.1 Pick and Move

The first function was a basic move order to the slab hauler to illustrate the dispatching and database update functions. The hauler was told to proceed to one of the piles, retrieve the top two slabs and move them to an open pile. The order was originated in the tent and transmitted by radio modem to the slab hauler. The hauler acknowledged receipt of the order and proceeded to complete it. Upon completion, the information was transmitted back to the database and the database was updated showing the slabs moving from the original pile to the new one.

4.2 Sort and Move

A member of the audience was asked to choose two slabs for the operator to move which would require him to sort slabs. In the process of sorting, the slabs on top of the "target" slabs would be moved to an adjacent pile. The purpose was to intentionally corrupt the database to demonstrate the system's ability to detect and deal with the errors. Functionally, the steps performed by the system are the same as for the basic case: the order is transmitted, the hauler scans the pile and the pick slabs are highlighted. In this case, the operator removed some slabs from on top of the pick slabs and placed the "overburden" on an adjacent pile. He then removed the pick slabs and moved them to the assigned destination. Upon completion, the database was updated to show that the assigned move had taken place. However, the "overburden" slabs were still shown in their original pile and not in the new pile to which they were moved. This created a database error for the two piles for the purposes of demonstrating two additional functions described below.

4.3 Error Detection and Database Update

The slab hauler was dispatched back to the pile containing the "overburden" slabs from the sort procedure described above. When the slab hauler read the pile, it found two slabs that were not supposed to be in the pile. These slabs were flagged on the slab hauler operator's screen by turning them yellow. When the move complete message was sent back to the database following the move, the message contained an error message warning the L&IS system of a discrepancy between the database and the information gathered by the slab hauler.

4.4 Field Scan

The Field Scan function was demonstrated by having the slab hauler operator initiate the action by touching the Field Scan button on his display, as described earlier. A pile was selected and the field scan was performed, with the data successfully downloaded from the slab hauler to the database. The database was updated to reflect the new information.

4.5 Processing Time

One of the primary objectives in Phase II was to reduce the image processing time so as to limit the amount of "dead" time an operator would need to spend waiting for the data acquisition process to take place. The Phase I system required approximately fifteen seconds per tag once the zoomed in tag image was acquired. The goal for the Phase II system was to be able to read four slabs in fifteen seconds or less.

The exact processing time per tag depends on a number of factors. The actual image processing time for a zoomed in image of a tag has been reduced in the Phase II system to less than one second. To this time must be added the overhead of taking the wide angle views, slewing and zooming the camera and error checking. If the tags are all aligned above one another, the pile can be read faster because the relatively slow process of physically pointing the camera is simplified. If all of the tags read correctly on the first try, the processing is expedited, while if either the OCR or barcode readings fails, the system will retry the read up to three times and then branch to an error resolution routine. Thus the actual processing time for a pile of slabs may vary, but we expect the average to fall within the ranges shown below for various numbers of tags.

We believe that these times can be cut even further with improved hardware and software. Physically slewing the camera is one of the slowest processes in the entire chain. This is due in part to the fact that the camera is near the upper end of the design payload for the pan/tilt mechanism. We find it necessary to slew the camera at less than top speed to avoid damage to the pan/tilt system, and we must currently wait for approximately 0.30 seconds after a move before capturing an image to allow camera assembly vibrations to damp out. A faster and sturdier pan/tilt mechanism would allow more rapid slewing of the camera and would require less settling time once the move is complete. The zoom control on the camera lens is also fairly slow. Changing from full wide angle to full zoom requires nearly four seconds to complete. We are currently looking into ways to speed up or eliminate altogether the zooming process.

Finally, the image processing times themselves still can be lowered. Clearly, WVU has made huge strides in this area over the past year. Much of our effort has been focused on the development of the new functionality and assembly and troubleshooting the hardware. There is still room for streamlining of algorithms, and, of course, for the application of newer computing technology. Our system uses a 120 MHZ Pentium processor. New machines are about to emerge which will be fifty percent faster. We expect that by the time a commercial version of this device reaches marketability, the computing time will be insignificant in comparison with the physical pointing processes.

5 Conclusions and Recommendations

The viability of developing a video-based system for the automated identification and tracking of slabs in a steel mill has been demonstrated by this project. All of the program objectives laid out in the beginning of the project were met. The project was completed within budget. A one-month extension of the original contract duration was granted for completion of the final report. All other deliverables were completed and delivered on time.

The equipment demonstrated in this program is unique, and has more advanced data acquisition capabilities than any other system in the world of which we are aware. Weirton Steel is currently considering applying for patent protection on several of the innovations developed by WVU under this contract.

Additional development work is required to bring this technology to commercial status. The computing hardware must be miniaturized and a camera and lens system more suited to manufacturing and resale environments must be developed. Additional development on the software will also be required, most notably the expansion of the barcode reader's vocabulary to include Code 128, Interleaf 2-of-5, UPC and other barcode standards. Additional work would also be required to solve problems with certain high-contrast lighting situations.

We believe that components of this system could be applied at Weirton Steel in the relatively near-term with positive results. The maximum benefit of the system will not be realized until the full-blown scheduling and dispatching system is completed. However we believe that a phased implementation of portions of the WVU system would result in immediate benefits in the area of inventory management, even before the scheduling and dispatching functions are operational. Certainly a first step would be to change to the new tags which have both barcode and numerals. The cost of this change is insignificant and it makes possible the use of hand held scanners which could immediately improve the speed and accuracy of inventory data acquisition.

We would *not* deploy the slab hauler based systems first, but would begin by placing systems similar to the WVU prototype in fixed locations in the plant. This initial deployment would allow the control computer to be standard desktop PCS connected directly to the local area network. This strategy eliminates the requirement for computing hardware development and for the installation of a radio modem network for access to L&IS resources. One computer could handle several camera systems, each of which would scan piles of slabs and continually update the database. Some new software would be required, but hardware costs would be significantly less than for the mobile systems. By placing systems in certain strategic areas such as the dekerfing area, scarfing area and reheat furnace staging areas, the tasks of inventory control and material handling resource dispatching could be decentralized and handled by simple, local algorithms. Such a first step could eliminate the practice of painting the run sequence numbers on slabs in the reheat area, and should allow streamlining of the sorting/queuing processes in the most congested portions of the hot area of the plant. Ultimately, mobile units mounted on the slab haulers would allow complete elimination of the current system of painting run numbers on the ends of slabs and the optimization of slab hauler dispatching.

We believe that the basic technology demonstrated here has applications in other parts of the mill as well. With some additional development, the system could be used to read stenciled or painted numbers on hot bands or bar coded paper tags on finished products. We believe the system could easily be made compact enough to mount on lift trucks and could work nicely in conjunction with the lift truck locator system being developed by Westinghouse under the DOE contract.

Material handling represents a significant portion of the unit production cost, not only for Weirton Steel but for most integrated steel mills. By contrast, many mini-mills are much more streamlined in their material handling operations, creating a significant competitive advantage for their products. To remain competitive, Weirton and its peers must take steps to minimize all activities and costs which are not value enhancing to the product. Material handling looms as a very lucrative opportunity in this regard. West Virginia University is proud to have made what we see as a contribution of significant potential in Weirton Steel's program for global competitiveness.

7 Appendix

Vendor List: The following is a list of the model numbers, specifications and vendors of the equipment used in this project.

Camera:
Manufacturer: Sony
Model: CCD-TR400
Approx. price: $850
Image Device: CCD (Charge Coupled Device)
Lens: 12X, power zoom
Focal distance: 7/32 -- 2-5/8 inches (5.4 -- 64.8 mm)
Dimensions: 4.5" x 4.375" x 8.25"
Vendor: B & H Photo-Video, Inc.
119 West 17th Street
New York, NY 10011
800-947-9910

Radio Modems:
Model: PL2
Approx. price: $750
Serial interface maximum asynchronous speed: 19200 baud
RF maximum power output: 500mW; RF Frequency band: 902-928 MHz
Range (typical): up to 1000 feet
Vendor: Proxim
295 North Bernardo Ave.
Mountain View, CA 94043
415-960-1630

Pan-Tilt Unit:
Model: PTU-46-17.5
Approx. price: $2100
Load Capacity: 4 lbs. Maximum Speed: 300 deg./sec.
Vendor: Directed Perception, Inc.
1451 Cappuccino Avenue
Burlingame, CA 94010
415-342-9399

Computer and power supply Enclosure:
Manufacturer: Hoffman Engineering Model: A-36H30DLP
Approx. price: $400
NEMA rating: Type 12
Vendor: Newark Electronics
400 Allen Drive
Charleston, WV 25302-3947

304-345-3086

Computer Chassis:
Model: 7608-14H-DC24
Approx. price: $1500
Vendor: Industrial Computer Source
P.O. Box 910557
San Diego, CA 92191-0557
619-677-0877

Computer:
Manufacturer: Dell
Model: Dimension XPS P120c
Approx. price: $2500
Vendor: WVU Computing Services

Video Frame Grabber:
Model: IDEC 16
Approx. price: $400
Vendor: Catenary Systems
470 Belleview
St. Louis, MO 63119
314-962-7833

PCMCIA Card Drive:
Model: PCCIR-SU
Approx. price: $300
Vendor: Curtis, Inc.
418 West County Road D
St. Paul, MN 55112
612-631-9512

Industrial Control Board:
Model: ADA2110
Approx. price: $
Vendor: Real Time Devices, Inc.
P.O. Box 906
State College, PA 16804
814-234-8087

Flat Panel Display:
Model: PAC-SH13
Approx. price: $3000
Vendor: Computer Dynamics

7640 Pelham Rd.
Greenville, SC 29615
803-877-8700

95-9SN0-WIRTN-R5

WEIRTON STEEL MATERIAL TRACKING SYSTEM FINAL REPORT

L. E. Kline, K. M. Eichler, K. M. Bojarski,
C. M. Kirby, J. M. Mussler, J. M. Beatty
Electronic and Computer Systems

January 26, 1996

Weirton Steel Corporation
500 Three Springs Drive
MAB Department
Weirton, West Virginia 26062-5133
General Order: CR-12837-CE

Westinghouse STC
1310 Beulah Road
Pittsburgh, Pennsylvania 15235-5098

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1. EXECUTIVE SUMMARY

Tracking the physical locations of Work in Progress (WIP) and finished steel coils is a key element of the Logistics and Integrated Scheduling (L&IS) initiative at Weirton Steel. This report documents the design, development and testing of a pilot test system to test a new, video based, real time approach to tracking WIP and finished steel coils. The system uses video cameras to do real time tracking of WIP and finished coils. The pilot test system described here will be built and tested in the Weirton Steel Finished Products Warehouse (FPW) and in the Weirton Steel tin mill to verify the scaleability of the system and demonstrate the functionality of the system in real environments.

Requirements: The requirements for WIP and finished material tracking are:

- **Input:** Request for the location, in three dimensions, of a specific coil, by ID number.
- **Output:** The location, in three dimensional space, of the coil.
- **Accuracy:** Sufficient spatial accuracy to find the right coil. The corresponding spatial accuracy is 12 to 18 inches.
- **Response Time:** Real time response, i.e., coil location returned within a few seconds.

Approach: The system described here tracks coils by measuring lift truck location whenever the lift truck places a coil in new location. During the first part of this project we selected tracking of lift trucks and other material moving devices as the best approach to inventory tracking. We then made experimental measurements at the Weirton Steel tin mill to assess RF and ultrasonic ranging and video imaging for lift truck location measurement. Based on the experimental results, we concluded that the video approach is the best means of measuring lift truck location. We next designed, built and successfully tested a proof-of-concept laboratory demonstration system which locates lift truck by using video cameras to image two lights mounted on a lab "lift truck." The video location system processes video images of a scene to determine the x and y coordinates of both of the lift truck lights in image sensor pixel coordinates. The pixel coordinate values, along with the known camera parameters, define direction vectors in the 3D lab coordinate system. The direction vectors extend from the camera image sensor, through the optical center of the lens to the location of the lift truck-mounted lights. Two direction vectors are sufficient to measure the 3D location of a light. Additional direction vectors provide increased accuracy and redundancy to ensure reliable operation. In the proof of concept demo one light moved with the lift truck "lift" mechanism. This motion allows the video system to measure coil position in the vertical, or z, direction. The available vertical "headroom" in the FPW does not allow enough space for moving the light with the lift truck lift mechanism. Therefore, for the FPW pilot test, we instrumented lift mechanism on the lift truck in order to measure coil position in the z direction and used the video tracking system to measure coil position in the x and y directions. A complete measurement determines the lift truck orientation, the 3D location of the lift mechanism and the 3D location of a coil which is being placed with either approach to measurement the z position of the lift. The "all-video" approach used in the proof-of-concept demo will work in the Weirton Steel tin mill, the band wareroom, including the outdoor areas, and in most other mill areas at Weirton Steel

Pilot Test System Design: The pilot test system which we have designed includes a set of four video cameras for each rectangular area which is covered, "base stations" which control the cameras and lift truck lights in one or more areas, instrumentation for the lift truck and a "base server" which coordinates the operation of the system. The system components on the lift truck include an on-board computer for control, four independently controllable lights, a load sensor, a lift height sensor and an RF modem for two-way communications with the base station. The on-board computer is a ruggedized Ziatech STD bus system with an Intel 486 processor. The base station and base server hardware functions were implemented using a object oriented C++ software running on a single Pentium PC. The base station sends messages to control the lift truck lights, collects and processes video images from the video cameras, performs the 3D location calculations, saves and displays the 3D location measurement results, and performs periodic calibrations. A PCI bus frame grabber board in the base station PC collects the images. The PCI bus provides a high speed path to the PC memory thus allowing the PC processor to perform the required image processing functions. The base server base coordinates base stations and lift truck in adjacent areas, provides human interfaces and displays, and is set up to interface with the Weirton L&IS System..

We have designed and implemented the lift truck hardware and software. We have designed and implemented a protocol and message formats for the RF communications between the base station and the lift truck. We have tested two types of light sources: a) incandescent bulbs and b) infrared light emitting diodes (IR-LEDs). Both light sources can be detected at distances of up to 300 feet. We selected the incandescent light sources based on their light output intensity and angular coverage. We selected cameras and lenses which can provide wide area coverage in the complete FPW and the band wareroom, based on a camera coverage analysis for both locations. We have developed, implemented and tested new image processing code which runs on the Pentium processor in the base station.

Pilot Test System Component Tests at Weirton Steel: We performed component tests in the Weirton Steel environment, in advance of the pilot tests, in order to test a) incandescent lift truck light sources, b) the lift truck on-board computer and light control hardware and software, c) the RF communications hardware and software, d) the camera and lens combination and camera positioning, and e) the location measurement accuracy. The results of these tests verified our component designs, showed that we could meet out location measurement accuracy goals, and comprised a partial system integration test.

Pilot Test System Results: The system performance was quantitatively measured during the pilot tests in order to verify the system performance predictions which we had made. The pilot test results show that the system meets the position measurement accuracy goal of 12 to 18 inches. The results of the pilot tests also show that the combination of image transfer over the PCI bus and image processing on the Pentium will meet the "few second" response time performance requirement described above. Now that the system has been designed and the pilot tests are complete, the data needed to accurately study the costs and benefits of full scale system deployment in both the Weirton Steel FPW and in Weirton Steel mill environments is available.

2. INTRODUCTION

2.1 Background

This report the design and pilot testing pilot test of a new, video based, real time system for tracking Work in Progress (WIP) and finished steel coils in the Weirton Steel environment. The system is designed to track coils throughout the complete sequence of finished coil production processes and in the Finished Products Warehouse (FPW). Tracking of WIP steel is a key element of the overall Logistics and Integrated Scheduling (L&IS) initiative which is now underway at Weirton Steel. The expected payoffs from the L&IS initiative include: I) On-time delivery of WIP items to the correct location for each processing step and, ultimately, on time delivery to customers, ii) More efficient use of equipment and processes, iii) Reductions in the levels of WIP inventory and iv) Reductions in the numbers of damaged and lost coils, and elimination of the 6-8 week recycle time needed to replace them. These improvements in productivity are expected to reduce production costs and increase profitability.

New methods for tracking of WIP and finished steel items are needed because the current approaches to marking and tracking do not provide the information which is needed to support the L&IS initiative. The new tracking system must provide a real-time picture of the location of every WIP item. Real-time location information is a key requirement which enables integrated scheduling of the steel making processes. The WIP and finished products tracking needs at Weirton are typical of the needs of the U.S. steel industry. Therefore, the improved approach to materials tracking which is described here is expected to contribute to improved competitiveness for the U.S. steel industry and in other industries, such as the paper industry, which have similar material tracking requirements.

2.1.1 System Requirements

The required inputs, outputs, data requirements and system response time requirements for the material tracking system are as follows:

- **Input**: Request for the location, in three dimensions, of a specific WIP or finished products material item, e.g. a specific coil. The coil will be identified by its database ID number.
- **Output**: The location, in three dimensional space, of the WIP or finished product material item for which location data has been requested.
- **Accuracy Requirement**: Sufficient spatial accuracy to identify and locate the specific material item for which location data has been requested. The corresponding spatial accuracy is 12 to 18 inches.
- **Response Time Requirements**: The system response time should be fast enough to meet the needs of the L&IS scheduling system. A response time on the order of tens of seconds is expected to be adequate. The location data will be updated in real time. In other words, a new location will be stored as soon as the WIP or finished material item is placed in a new location. The system should not impose delays on lift truck drivers. To meet this requirement, location measurements must be performed in approximately one second.

2.2 Objective

The goal of this project was to demonstrate the video tracking system in the Weirton Steel environment and to show that the approach has sufficient accuracy and reliability to meet the needs of Weirton Steel. The tests which we performed were designed to investigate and quantify the factors which affect the 3D location measurement performance of the system, to obtain quantitative, statistical measures of performance, and to compare the measured performance with the goal of always picking or placing the desired coil to or form the correct location. Camera coverage is a key system parameter which strongly impacts on system practicality and cost. Therefore, we sized the coverage area in the pilot test to maximize camera coverage without compromising system performance.

2.3 Results

There were four major tasks performed during the 27 month period of performance for this project. The first task examined new approaches to marking and tracking WIP and finished steel coils. We identified tracking of lift trucks in order to track coil locations as the most promising new approach to coil tracking. The second task was a site evaluation which we performed in order to select the tracking lift truck tracking approach. Video tracking was selected based on the results of the site evaluation. We then designed and successfully demonstrated a laboratory proof-of-concept system. We used the results obtained from the proof-of-concept demonstration to design and build a full scale, pilot test system. The pilot the system was installed in the Weirton Steel Finished Products Warehouse. We equipped a lift truck and successfully demonstrated the ability to locate any one of 3,300 coils in a 200x300 square foot test area. The work performed and the results for each of these four tasks is described in more detail in the following sections.

2.3.1 Identification of New Marking and Tracking Approaches

We examined the Material Marking and Sensing Requirements developed by the Weirton Steel L&IS group and toured all of the Weirton Steel mill areas during this first part of the project. Then we held a joint Weirton Steel-Westinghouse brainstorming to identify and evaluate new approaches to marking and sensing. Altogether, we identified 45 possible approaches to marking and/or tracking slabs and coils at Weirton Steel. Eleven of these approaches were rated as promising with no major barriers to practical application for at least one area at Weirton Steel. Eleven additional approaches were rated as technically feasible but having possible shortcomings. The remaining 23 approaches were determined to be infeasible.

Tracking lift trucks in order to track the coil locations of was identified as the most promising new marking and sensing idea and was the focus of the rest of the project.

2.3.2 Selection of the Approach for Tracking Lift Trucks

We performed a series of site evaluation measurements at the Weirton Steel tin to evaluating RF ranging, ultrasonic ranging and video tracking as possible approaches to lift truck tracking. The major findings of this task were:

- The use of RF echo ranging (RADAR) within the mill is impractical because it lacks the high location measurement accuracy which is needed and it is extremely susceptible to the multipath reflections present within the mill.
- The use of ultrasonic echo ranging (SONAR) within the mill is impractical. Commercially available ultrasonic transducers are too weak to overcome the sound levels within the plant and the attenuation factors caused by temperature and humidity.
- Video cameras installed within the mill and hardwired to video signal processing equipment are the most practical means of gathering location information. Multiple monochrome video cameras with wide angle lenses are needed to cover each storage area. Resolution of the cameras is more than adequate to provide precise position location information. The completely passive nature of the sensing avoids concerns about meeting FCC, OSHA and similar regulations. Light levels at all locations are more than adequate, in fact camera apertures must be stopped down to overcome saturation effects.

2.3.3 Proof-of-Concept Demonstration

We designed and built a proof-of-concept demonstration based on the system concept which is shown in Figure 1. Our intent in developing the proof-of-concept demo design was to develop a laboratory demonstration design which would:

- Be useable in the Weirton Steel mill and warehouse environments with minimal modification and ruggedization.
- Scale from the pilot tests in the mill and warehouse environments to a full scale system which can track all work in progress and finished coils at Weirton Steel.

These goals have influenced many of our design choices as we developed the proof-of-concept demonstration system design.

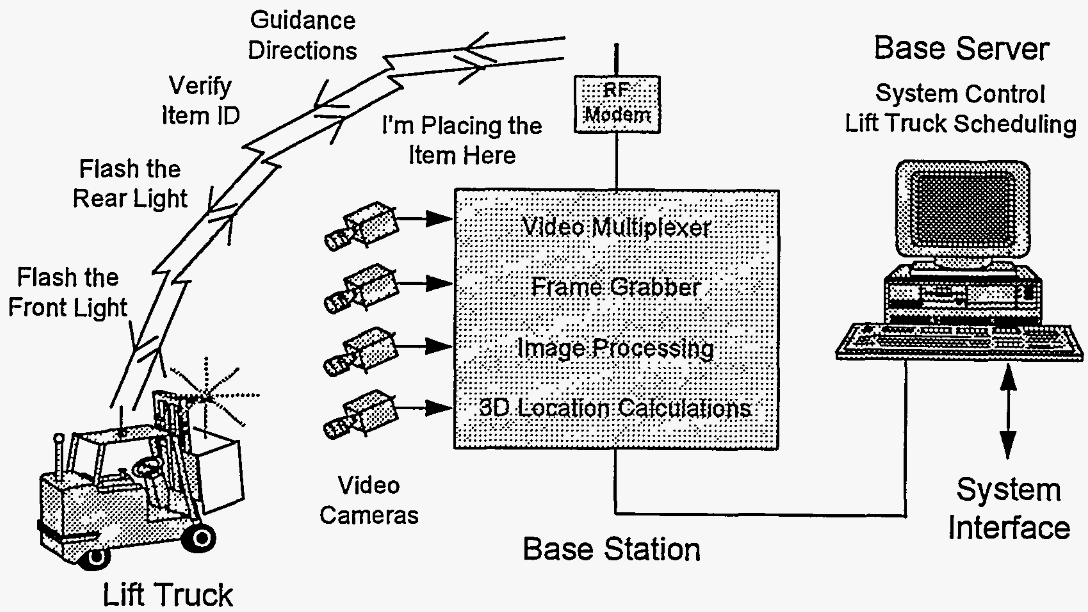

Figure 1. Video tracking system concept and system components.

We built a proof-of-concept system which included all of the components shown in Figure 1. The functions of both the Base Station and the Base Server were performed by a single PC in the proof-of-concept system. We used a lab cart with lights mounted a few inches above the floor to simulate a lift truck. The lab cart was equipped with an on-board computer and RF modems were used to communicate between the lab cart and the base station. The proof-of-concept system was set up in a 30x50 square foot lab area at Westinghouse STC. The actual camera coverage area was approximately 16x24 square feet. We measured the position of the front and rear lights on the lab "lift truck" at eight different lift truck positions. The average error for the entire group of 1,398 individual x, y and z measurements was 1.47 inches. These measured accuracy results showed that a full scale video tracking system would achieve the 12 - 18 inch position location accuracy which is needed to find the right coil at Weirton Steel. The proof-of-concept demo results clearly demonstrated the viability of the video location approach for lift truck location and coil tracking at Weirton Steel.

2.3.4 Finished Products Warehouse (FPW) Pilot Test

Based on the results of the proof-of-concept demonstration, we designed and built a full scale, pilot test system. The pilot test system incorporates a base server, one base station connected to four cameras, and two complete sets of lift truck on-board equipment. The pilot test system uses a single PC to perform both the base station and base server functions. Thus the system concept shown in Figure 1 was fully implemented for one area in the FPW. The four video cameras are selected and controlled by the base station, which is responsible for the image acquisition and processing, location measurement, and RF communications to and from the lift truck. The same RF modems were used for both the proof-of-concept and pilot test systems. As with the proof-of-concept system, the pilot test uses a Personal Computer (PC) as the hardware platform. We took advantage of the recently developed PCI computer bus in designing and building the pilot test system. This high speed bus can transfer images directly form the frame grabber board to the PC memory. As a result, we can use the PC processor to perform image processing. This design approach allows the PC hardware platform to perform high speed location measurements and achieve the system goal of minimal interference with the lift truck operator. The base server functions which we implemented included system setup and test functions as well as a complete coil location database for the pilot test area.

The pilot test system was set up in the Weirton Steel Finished Products Warehouse (FPW). We positioned four video cameras at the four corners of a 200x300 square foot area. The area covered is larger than a football field. . A diagram of the pilot test area is shown in Figure 2. The areas marked "Bay 1," etc. are the 20 foot wide aisles. The rectangular areas are 40x200 square foot coil storage areas. The locations of the four cameras, at the four corners of the area, are shown in the figure. This area can hold 3,360 coils in the coil locations designated in the L&IS coil location schema.

We performed preliminary tests in this area using a specially built cart which is the same size as an actual lift truck. These tests were performed to measure the location accuracy of the system. The average location accuracy for 1,963 individual x, y and z position measurements was better than one foot as shown in Figure 3. These results show that the system can meet the system performance goal of locating a specific coil in the 200x300 square foot test area.

The lift truck on-board system uses a ruggedized Ziatech computer to control four sets of lights, a coil height sensing system, a simulated coil presence sensor, a lift truck operator display

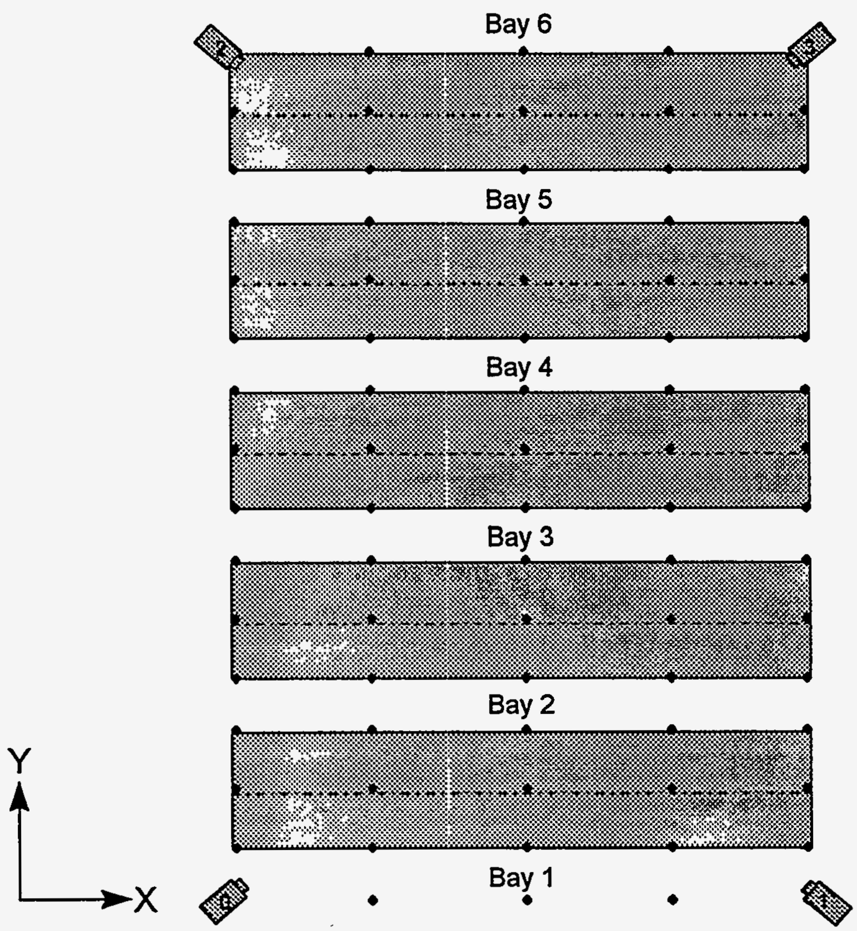

Figure 2. Pilot test area in the Finished Products Warehouse No. 1 warehouse.

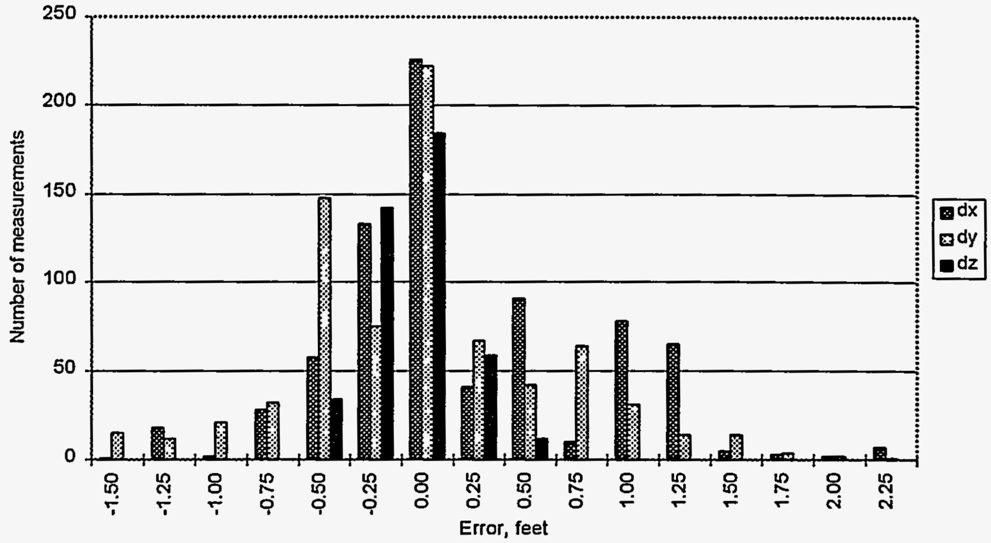

Figure 3. Measurement error histogram for the FPW pilot test location accuracy measurements.

Figure 4. Lift truck on-board equipment mounted on a lift truck in the FPW.

and the on-board RF modem. All of this equipment is powered from the lift truck battery. The on-board computer operates autonomously and does not have disk drives, a keyboard or a monitor. The lift truck system is shown mounted on top of the operator protective cage of an Elwell-Parker lift truck in Figure 4. Our system design uses a hydraulic pressure sensor to sense the presence of a coil by sensing the static pressure increase due to the presence of a coil. The system as tested uses an operator actuated toggle switch to simulate the pressure sensor signal.

We performed a large number of measurements to determine the location measurement accuracy using the on-board equipment mounted on the actual lift truck. We obtained results similar to those shown in Figure 3. The coil height measurement system was tested and accurately indicated whether the coil being picked or placed was at the top, middle or bottom position in the three high stacks of coils.

2.4 Video Tracking System Benefits

Materials are often stored in "free-form" 3D geometries. This is true, for example, on shop floors in many manufacturing environments, in warehouses and storage yards. Material tracking, placement, and retrieval management are challenging tasks in these "free form" 3D storage geometries. If the material with the highest priority for retrieval is at "the bottom of the pile," many excess material-handling actions will be required to retrieve that material, compared with the material handling required for retrieval from "the top of the pile."

The video tracking system uses video cameras to track material by tracking lift trucks or other material moving devices. The video tracking approach provides the following benefits:

- Automated, real-time updating of the material tracking database. The system eliminates the two manual barcode scans (item ID scan and location scan) which are needed for every pick and place with conventional RF barcode scanning systems. As a result, lift truck drivers are more productive and manual scan errors and are eliminated.
- Immediate savings of the time now required to find coils which are scheduled to be shipped to customers.
- Intelligent put down and pickup which provides additional time savings by keeping similar items together and eliminates coil put aways which "bury" coils which are already scheduled to be shipped to customers. An Intelligent put down and pickup system is feasible only after the video tracking system is installed.
- Optimal, real-time scheduling of lift truck moves to insures on-time material delivery and maximizes lift truck productivity. Real-time scheduling is also feasible only after the video tracking system is installed.
- Storage rack cost elimination - Material storage racks and location ID tags are not needed.
- Easy rearrangement of storage locations - the storage location map is defined in software. The storage location map can be changed by modifying the database which defines the map.
- Material ID tags are optional. The system works with Work-in-Process (WIP) items such as steel coils and slabs where the high temperatures prevent the use of paper bar code tags.
- Integration with manufacturing, warehouse and transportation scheduling systems. The system accepts material movement orders from any of these sources. The video tracking system provides real-time inventory location data for use by any of these external systems.

3. WORK ACCOMPLISHED

3.1 Brainstorming to Identify New Marking Techniques

A brainstorming session was held to generate new ideas for marking and tracking of WIP steel. The participants included both Weirton Steel and Westinghouse personnel. In order to facilitate the brainstorming session, Weirton Steel personnel briefed the group on the processing practices in the continuous caster, the hot strip mill, the sheet mill, and the tin mill. The group also toured these areas. In the spirit of brainstorming, limitations of the ideas proposed were ignored during the first part of the brainstorming session where the goal was the generation of as many new ideas as possible. These limitations were then considered in the second phase of the brainstorming session where the practicality of each new idea was evaluated.

Many possible new ideas for marking WIP steel were identified during this brainstorming session. Table 1 lists the promising ideas which were rated as promising with no major barriers to practical application for at least one area. In order to develop an approach to a complete marking and tracking system we defined one or more sensing approaches for each of these marking ideas. The sensing approach(es) are also listed in the table. Note that we have made a distinction between manual and automatic reading of the markings in some cases. The information coding approach(es) for each marking idea are listed in the table. The potential usefulness and practicality of each idea is coded with the following numeric ratings:

1 Promising idea with potential for improving current practice and no major barriers to use.

2 Promising idea with potential for improving current practice but with potential problems.

3 Idea with major barriers which prevent the idea from being used in practice.

The usefulness of each idea was evaluated separately for slabs, the strip mill and the finished products mills (tin mill and sheet mill). These areas are coded in the tables as follows:

S Slabs WIP marking.

H Hot mill and other strip mill WIP marking.

F Sheet mill and tin mill WIP marking.

A Ideas which are applicable in all three areas listed above.

The ideas in Table 1 are listed in approximate order from most promising to least promising. The ideas which we are proposing for investigation are highlighted by using larger, bold print. Optical character recognition (OCR) reading of the numbered tags now in use for slabs is being investigated by West Virginia University, as indicated in the table. We also proposed oxygen jet "dot matrix printing" for slab marking because it eliminates the recurring cost associated with the current numbered tags and the planned bar coded tags. Also, oxygen is readily available in the slab marking area. Automatic reading of a number or a barcode applied with an oxygen jet dot matrix printer should be possible by using a reading device mounted on the slab haulers, since the orientation of the slabs is normally well defined and is the same from slab to slab. However, this would probably require marking the sides of the slab which is inconsistent with current slab marking, stacking and reading practice. The use of WIP item marking in combination with a "Local GPS" system is included in Table 8, and was proposed for investigation, because we believed that a Local GPS system, as described below, is a key part of the optimal approach to a system which tracks all material at Weirton Steel.

Two additional groups of marking were identified. The second group of 11 approaches to marking was identified as technically feasible but having possible shortcomings, compared with the ideas in Table 1. A third group of 23 marking ideas was eliminated as impractical for all areas. These additional ideas are not described here.

Marking Technique	Sensing Technique	S	H	F	A	Comments
Numbered tags now in use on slabs	OCR of camera image	1				Work in progress at West Virginia University.
Oxygen jet, Write bar code and/or number on side/end of hot slab or coil	Bar code reader; Optical image processing, Laser, ultrasonic or optical ranging	1	2	3		Eliminates tags and associated recurring costs .
Oxygen jet, (same as above)	Reader, as above, mounted on material mover(s)	1	2	3		Allows automated WIP tracking in conjunction with tracking of movers.
Marking combined with a Local GPS system.	Local GPS system tracks all WIP material locations by recording the location each time a WIP item is placed	1	1	1	1	Local GPS, combined with WIP material marking and tracking, is a very robust system approach.
Self-orienting flag so barcode is readable (use rubber boot in the tin mill)	Hand held bar code reader	1	1	1	1	Guarantees readability (tag remains on top) Reading labor intensive.
Larger bar coded tags to enable long-distance bar code reading	Hand held bar code reader	1	1	1	1	Larger tags improve accuracy.
Self-orienting flag so barcode is readable (use rubber boot in the tin mill)	Bar code reader mounted on material mover(s)	1	1	1	1	Allows automated WIP tracking in conjunction with tracking of movers and automatic reading.
Full-length edge with marking a laser to produce a pattern like a bar code	Bar code reader; Optical image processing	2	1	1		Can read in any orientation if on side of coil. Complex marking process for coils.
Full-length edge marking with paint to produce a pattern like a bar code	Bar code reader; Optical image processing	2	1	1		Can read in any orientation if on side of coil. Complex marking process for coils.
Full-length edge marking - Punch	Optical reader or bar code reader	1	3	3	3	Complex marking process for coils. Survives multiple processing steps. Could damage rolls.
Full-length edge marking - Scoring / Nicking	Optical reader or bar code reader	1	3	3	3	Complex marking process for coils. Survives multiple processing steps. Could damage rolls.

Table 1. New Marking - sensing approaches identified as "good" ideas for one or more areas.

3.2 Site Evaluation Measurements

The site evaluation measurements which are described in this section were performed in order to assess and compare the RF ranging, ultrasonic ranging and video camera approaches to measuring the three dimensional locations of material moving devices in the indoor mill areas and in the finished products warehouse.

3.2.1 RF Measurements

3.2.1.1 Literature Search Results

RF ranging and communication within heavy industrial environments is strongly influenced by multipath problems, the same phenomena that cause "ghosts" on TV pictures and stereo signal breakup on automobile FM receivers. The time taken for a signal to travel from transmitter to receiver is dependent on the path it takes, i.e., direct line-of-sight or reflected one or more times. Reflected signals add to the direct line-of-sight signal. The resulting sum of time shifted signals causes distortion in phase and amplitude of both the carrier and modulation compared the original line-of-sight one. Since this 'noise' is the result of distortion, it is impossible to improve system signal-to-noise performance by the conventional means of increasing transmitted power. The magnitude of the problem increases with frequency of both the carrier and the modulation, and thus high speed data transmissions at microwave frequencies are much more susceptible than voice transmission at broadcast frequencies (~1MHz). As a result, it is best to avoid systems that require either wide bandwidth or microwave (GHz) carriers.

Rappaport[1] presents a very thorough and relevant treatment of the RF propagation problems that we could expect to encounter in the Weirton Steel mill and warehouse areas. His experimental results show that a highly cluttered environment will not reliably support an RF system involving high bandwidth (high data rate). More significantly, his results demonstrate that multipath problems prevent the successful use of echo ranging radar in the mill environment.

3.2.1.2 RF Frequencies in Use at Weirton Steel

In considering frequencies for an RF ranging system, it is important to know those allocations that are already in use and might conflict with our choices. Similarly, it is important to know those choices that have already been successfully employed in existing wireless networks. Conversations with Lou Carte, General Supervisor of Electronics at Weirton Steel reveals that the following frequencies in use at the mill:

- 460-470MHz communications (2W remotes, 40W base)
- 150MHz communications (2W remotes, 40W base)
- 900Mhz
- 460Mhz crane controller (0.25W)
- Railroad engine remote controls
- Data communications equipment is just being installed for finished inventory and work-in-process tracking. This system is a Symbol Technologies spread spectrum system.

In addition to the allocated RF sources, there are unusual EMI/RFI sources, such as arc welders (200-300VAC).

3.2.1.3 Measurement Locations in the Tin Mill

The RF & acoustic measurements are performed simultaneously at locations designated in Table 2. The intent is to gather information representative of the entire site, rather than the few locations which we might now consider appropriate for installation of the final system. Not only does this force the design to meet site wide application, but it avoids the possibility of the specifications being too restrictive by ignoring the interfering effects within adjacent areas.

Measurement Location	
1	Exit of #3 cleaning line, by office
2	Across roadway from entrance to #6 plater
3	Near to exit end of #6 plater
4	Closer to exit end of #6 plater
5	Near exits of #4 and #5 platers (#5 side of isle)
6	West of north & south shear floor
7	Near entrance end of CA1
8	Near CA exits & new Weirlite mill inputs
9	Near transfer car turntable
10	#3 loading dock area

Table 2. RF & Ultrasonic Measurement Sites in the Tin Mill.

3.2.1.4 Results and Conclusions

We made RF signal level measurements at all of the locations listed in Table 2. We observed RF signals at discrete frequencies. In most cases, these signals were identifiable. In general, it is not necessary to overcome the signal levels we observed, since these have been selected as the peak ambient levels and generally are produced by some narrowband communication channel. Such existing RF sources are overcome just by selecting a different operating frequency for any new service. The ambient RF noise measurements reveal that the mill environment is compatible with use of wireless RF communications, as is evidenced by the successful use of existing voice and data communications devices

On the other hand, because of the multitude of highly reflective steel surfaces within the mill, it is wise to avoid RF transmission systems that occupy large bandwidths (high data rates). In other words, avoid video transmissions and try to limit bandwidths to those involved in audio transmissions.

The use of RF echo ranging techniques should be avoided in the mill, mainly because of the unusually high resolution they require. In order to locate objects to within 1 ft, an echo ranging system (radar) must be able to resolve return pulses to a resolution of 1ns, requiring a bandwidth of 1GHz. A relatively high power transmitter is required to overcome the RF noise contained within a 1GHz passband. Moreover, to achieve good angular spatial resolution (beamwidths approaching 1ft at 50m distance), the carrier frequency must exceed 100 GHz to reduce antenna dimensions a practical size. At present, the cost and availability of 100 GHz microwave transmitters limits their use to state-of-the-art military and aerospace applications. In view of the need to keep RF emission levels within FCC tolerable levels and costs within reasonable bounds, radar is rejected as an approach to lift truck tracking.

3.2.2 Acoustic and Ultrasonic Measurements

3.2.2.1 Literature Search Results

Sound waves travel in a different media and at substantially lower velocity (344m/s) than electromagnetic waves such as radio and light (300,000,000m/s). As a result, sound is often used as a convenient alternative to RF media for communications or echo-ranging (sonar).

For some applications, such as the previous generation of TV remote controls, ultrasonic transmissions were used to convey the appropriate instructions from the hand-held controller to the TV receiver. The advantage was that all TV receivers could use the same operating frequency and codes without interfering with each other since the sound waves are easily contained within the room housing the TV receiver. Avoidance of RF emissions avoids interference with neighbors TV's as well as concerns about FCC regulations. Being ultrasonic (40kHz), the transmissions are not audible to people within the room and thus are not objectionable.

When used for echo-ranging, sonar systems are analogous to radars, except that they operate at substantially lower frequencies and bandwidths. Again, they do not involve RF transmissions, and pose no problem with normal communications devices or their FCC regulators.

One of the major obstacles to the use of ultrasonic devices in air is the presence of substantial background noise, which is generated by the same things that produce audible noise. In industrial environments, steam or compressed air discharges are particularly intense emitters of wideband ultrasonic noise. It is generally hopeless to attempt to overcome the power of such sources with a commercially available electronic transducer.

Another problem of ultrasonic devices, used in air, is that the attenuation of the sound waves increases rapidly with frequency. H. E. Bass, et.al.[2] presents a clear indication of the magnitude of this problem. The attenuation of sound increases with frequency, temperature and humidity, and is of the order of magnitude of 1dB/m at 40kHz, the operating frequency of most commercially available transducers. The measurements that we performed at the mill show that the background noise level at 40kHz reaches 50dB. In order to be able to do anything of significance, our transducer must be able to exceed 50dB at a distance of 50m. Commercially available ultrasonic transducers such as MuRata Erie's MA40E7R/S are limited in electrical drive power to 200mW and at a distance of 30cm. along the axis of their beam they produce an intensity of 106dB at 40kHz. Since the power density decreases as $1/\text{distance}^2$, the resulting acoustic power level will drop by a factor of 44.4 dB over a 50m path.

The absorption loss adds about another 50dB over the 50m distance and thus the net power level produced by the transducer at 50m will be 11.6 dB. This falls well below the anticipated 50dB noise level in the mill and therefore the signal could not be recovered from the background noise.

Use of frequencies at the high end of the audio range (15kHz) reduces the magnitude of absorption loss, but this is counteracted by the fact that ambient machinery noise increases.

3.2.2.2 Results and Conclusions

The acoustic levels were measured at Weirton Steel at the locations listed in Table 2. The 0dB level corresponds to the minimal threshold of human hearing. We found that the acoustic levels are most intense at low frequencies and roll off at ultrasonic frequencies. We also found that the integral of power over the entire frequency sweep, is essentially equal to the power level at the low end of the sweep. The high ambient noise levels at low frequencies indicate that any attempt to use acoustic transmissions at audio frequencies would require unreasonably high sound levels, especially if one allows a 20dB to 40dB margin to account for worst case conditions.

The ambient sound noise level within the plant is sufficiently high that the use of acoustic devices for communications links is impractical. The use of such devices in a sonar echo ranging system is much worse since the attenuation of the signal in dB/m is twice as large because it occurs in both the forward and reflected path. Acoustics techniques should definitely be avoided as a lift truck location measurement approach.

3.2.3 Optical Measurements

3.2.3.1 Still Camera Photographs

These are some of the most valuable records of the mill environment by virtue of the fact that they capture and retain many more details of the facility than our memories could. It is indeed very beneficial to peruse these photos to both refresh our view of the mill as well as to discover details which have escaped us.

In addition to the great detail made available in them, the photographs have the advantage of being mechanical records of the scenes without the accommodation added by human visual perception. In the system we propose, similar images will be processed electronically to extract the details needed to locate objects. At that time, the image analysis will have to function without human perception, and the photographs enable us to more clearly realize the difficulty which this entrails. For instance, overexposure and under-exposure, field of view, lack of contrast, inadequate resolution, overpowering background light sources, and highly reflective objects become obvious problems when seen in a photograph. On the other hand, our visual perception of the live scene generally fails to reveal such problems.

Exposure settings within any particular mill site were noted to be independent of the exact location or direction of the camera. The mill's lighting systems have obviously been designed to provide a standard level of illumination. The camera we used was a Nikon 6006 with AF zoom lens, 35-70 mm, f/3.5 - 4.5. The film used was Ektachrome 400. Some of the camera exposure measurements are presented in Table 3 [3]. The results shown in the table reveal that the light levels within the plant are more than adequate for most video cameras.

3.2.3.2 Video Camera Recordings

We made video camera recordings at a number of locations within the tin mill. The camcorder tapes revealed some variations form the response we expected of a video camera within the mill. Overall, however, the variations require relatively simple corrections and the concept of video location remains the most viable of all approaches considered. The video camera eventually used must have an exposure control which prevents the captured image from saturating the camera's dynamic luminance range. This avoids blooming effects which smear out the high resolution optical marker lights needed to designate locations to within a range of a few pixels. The various views from both the video and still camera indicate that a wide angle lens is needed to cover reasonable areas of the storage facility, and that this can be done with adequate resolution.

Location		View	Exposure		Lumen/m^2 (lux)
1	above WL #2	Downward on input area	1/30	f 4.5	320
2	Stairs at south wall of WL #2	Dependent on zoom	1/15	f 3.5	96
3	Finished products warehouse	General views	1/8	f 3.5	50
4	Shipping area at N side of TM	General views	1/30	f 3.5	190
5	Coil Catwalk storage area next to cleaning lines	General views	1/30	f 4.5	320
6	Receiving area by RR #1 track	General views	1/30	f 4.5	320

Table 3. Typical Still Camera Exposure Levels Within The Mill

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[1] ***Characterization of UHF Multipath Radio Channels in Factory Buildings;*** T. S. Rappaport, IEEE Transactions on Antennas and Propagation, Vol. 37, No. 8, August 1989, pp. 1058-1069.

[2] ***Absorption of Sound in Air: high Frequency Measurements;*** H. E. Bass, F. D. Shields, J. Acoust. Soc. Am., Vol. 62, No. 3, Sept. 1977, pp571-576.

[3] ***Kodak;*** phone call, 1-800-242-2424 extension 99, option 3, (values were read from an exposure chart) {400 ASA, 1/30 sec, f 4.0 ⇒ 250 lux}, {400 ASA, 1/30 sec, f 8.0 ⇒ 1000 lux}

3.3 Video Camera Tracking Approach

The goal of this project to develop and test a pilot system which provides accurate, real-time, three dimensional (3D) location information for WIP and finished product coils. The functional approach to meeting these requirements is to record the location and ID number of the coil which is being placed each time a coil is moved. Two requirements must be satisfied in order to record the new location whenever a coil is moved. First, the location of a material moving device, such as a lift truck, must be known whenever it places a coil in a new location. Second, the ID of the coil must be known when it is placed in the new location. The first requirement can be met by measuring the location of the material moving device when it "places" a coil in a new location. Tracking of the material moving devices at other times is not necessary to satisfy this requirement. The second requirement can be met by knowing the location of the material mover when it picks up the coil and retrieving the ID of the coil from the tracking database. Thus, the coil ID must be entered into the material tracking database only once, either when the item is first produced, or when it first enters a new area such as the FPW. Once the ID and initial position of a coil have been entered into the system, further tracking of the position of the coil in 3D space is automatic.

Figure 5 illustrates the principles of operation of the video camera based system which measures the position of a lift truck in three dimensional space. In the figure we show two video cameras looking down at the lift truck. The cameras are used as direction vector measuring devices. The direction vectors for each camera are defined by two points: the optical center and the image of a light on the camera image sensor. The direction vectors point to, and intersect at, the position of the light in 3D space. The cameras locate the lift truck by imaging lights which are mounted on the lift truck, as shown in the figure.

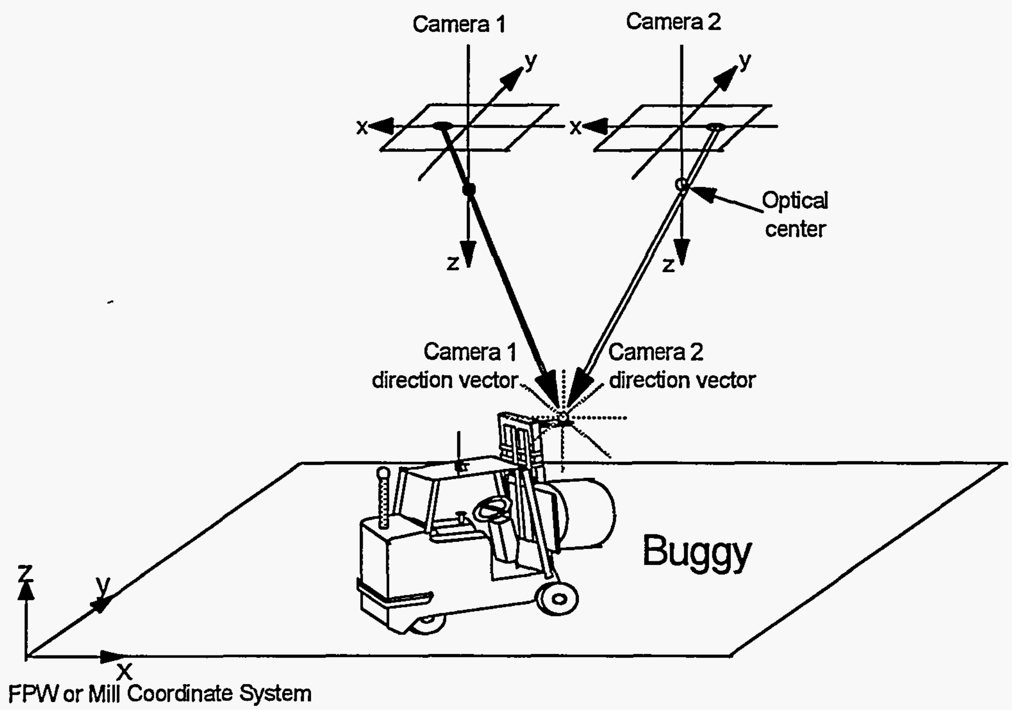


Figure 5. The direction vectors for each camera are defined by two points.

The lift truck shown in Figure 5 has 2 lights, a front light and a rear light. The front light moves with the coil lift mechanism and is mounted directly above the center of coil, at a fixed vertical offset. The position of this front light is an indicator of the vertical center of the coil, regardless of the direction from which the lift truck engages the coil's eye. The rear light on the lift truck is used only to determine the lift truck's physical orientation within the mill. This is needed to define the coil position and is also makes it possible to use the system to provide the driver with lift truck guidance information. The approach shown in Figure 5 will work in the Weirton Steel mills and outdoor storage areas where there is sufficient vertical "headroom" to allow the light mounted on the lift mechanism to move up and down as the lift mechanism moves up and down.

The approach shown in Figure 5 was modified for use in the Weirton Steel Finished Products Warehouse because the headroom in the FPW is severely limited. This limited headroom, and the geometry of the stacks of coils, would severely limit camera coverage if we positioned the cameras so that they are looking down from above as shown in Figure 5. On the other hand, cameras positioned to look horizontally can cover large areas. The camera positioning which we have chosen for the FPW pilot tests is shown schematically in Figure 2. Four cameras are positioned at the four corners of the test area. The size of the test area was chosen based on the results of the camera coverage calculations described in Section 3.6.2.2, preliminary experiments at Westinghouse STC, and preliminary experiments at the FPW.

The camera axes are approximately horizontal for the FPW pilot tests. With this camera arrangement, the minimum height of the lights must be greater than the height of the highest coil stacks. The wires shown in **Error! Reference source not found.** limit the maximum height of the lights to approximately 15 feet. Thus, the available range of vertical light travel is only about 2 to 3 feet. On the basis of these.considerations, we have chosen to measure coil height in the FPW pilot tests by instrumenting the lift truck lift mechanism and to use the cameras to measure the x-y location of the lift truck. The height of the lift truck lights is fixed at approximately 11 ft. This height provides the cameras with a clear view of the lights. Obstruction of the lift truck lights by the roof support poles and the bar code mounting plates was considered both in designing the arrangement of the lift truck lights and in determining the maximum area which can be covered by one set of four cameras. We chose to use four lift truck lights, rather than two, in order to minimize potential problems due to obstruction of the lights by the roof support poles.

An instrumented real lift truck, and a second simulated lift truck, were used in the FPW pilot tests. The real lift truck was equipped with an onboard computer, operator's console, lights and light control, lift height sensor and coil presence sensor. The second, simulated lift truck was a cart with an onboard computer, operator's console, lights and light control. The onboard computer will be used to simulate the lift height and coil presence signals on the second lift truck.

As shown in Figure 5, the x-y location of a pixel on the camera image defines a ray, i.e. a direction vector, extending from the camera image plane, through the focal point of the camera lens to the location of the light in 3D space. Two direction vectors are sufficient to measure a 3D location. Additional direction vectors, measured by additional cameras, provide redundancy to ensure reliable operation. Redundancy is needed to allow for both the possibility of a vector measuring device failing and for obstructions, such as a roof column or an overhead crane, which block the view of a light. The redundancy provided by the more than 2 cameras offers benefits beyond the ability to tolerate beam obstruction. In general, the direction measurement accuracy will not be sufficient to ensure that all beams precisely intersect at a point in 3D space. This is because there will always be some measurement error as well as the possibility of long-term drift in registration due to repair or replacement of cameras, physical impact to the camera mounts or building structure, building thermal expansion effects, and structural deformations caused by movement of the overhead cranes. The available direction vector information is combined by solving a least-squares estimation problem to find the point which minimizes the error in the position solution. The existence of extra direction vectors, i.e. more than two, improves the least squares solution. Periodic, automatic calibration will minimize the errors due to the various sources described above. Calibration was performed manually in the proof-of-concept demo and the FPW pilot test. The development of automatic calibration is underway in a separate Westinghouse funded project.

Figure 6 shows the various system components which are included in the pilot test system. The four video cameras are selected and controlled by the base station, which is responsible for the image processing and location measurement as well as the RF communications to and from the vehicles. The camera transmits images to a frame grabber which converts the video signal to a digitized representation of the image. Since we wish to locate the light in 3D space, the light is the desired signal, and all other features in the image are undesired background "noise." We eliminate most of the undesired background by synchronizing the light flashes with the video camera frame rate and capturing two successive images from each camera. Subtraction of two images remove all image features which have not changed in the time interval between the two successive frames. The resulting, differenced image contains "blobs" which are the images of the lights. The position of the center of the blobs is used to define the direction vectors.

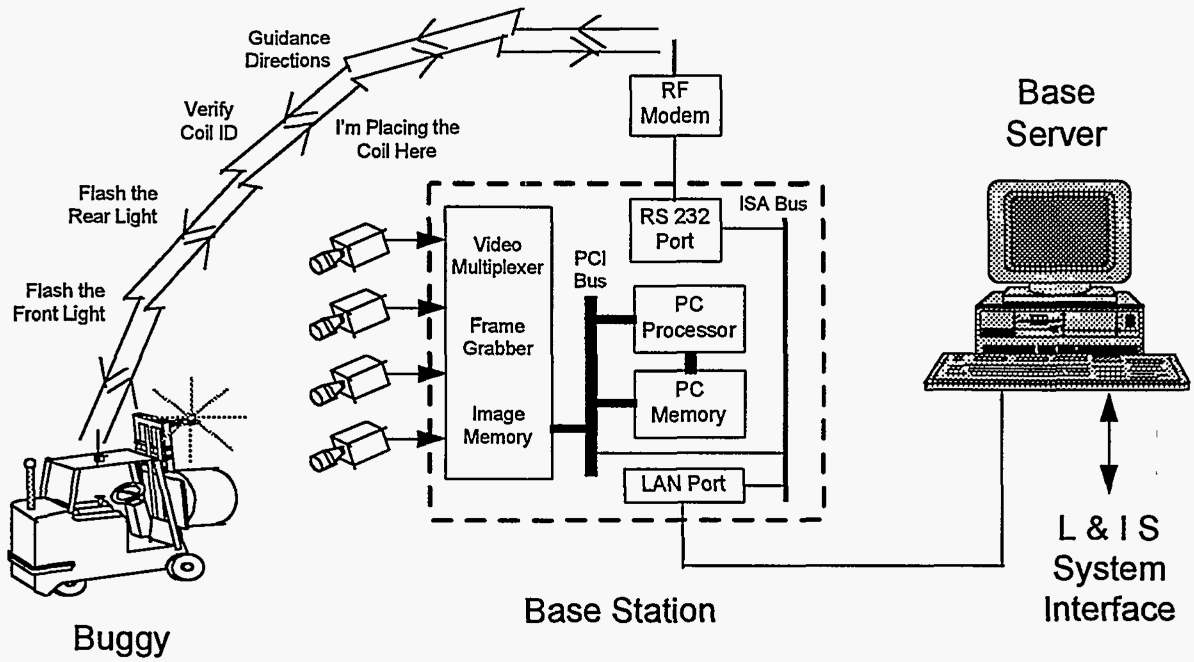


Figure 6. Schematic diagram of the pilot test system hardware.

The base station in the Pilot Test System is a Pentium PC. Video images are captured by the PCI bus frame grabber board and transferred to the PC memory over the high speed PCI bus. The image transfer rate is 30 to 50 Mbytes per second. As a result, the image transfer time is not a limiting factor in meeting the system goal of not delaying the lift truck operator. The Pentium processor performs the image processing functions. The time to process the images is also short enough that the image processing time does not delay the lift truck operator.

In the system as designed, the base station and its associated cameras communicate with a “base server” which coordinates the functioning of the base stations, contains a coil tracking database which maintains real-time 3D coil locations, and provides a single interface between the coil location measurement system and the L&IS materials tracking database. The base server translates coil position data to and from 3D x,y,z data and the L&IS coil location schema. The base server also acts to coordinate the firing of the lights on multiple lift truck when two or more lift truck pick up or place a coil at the same time. The base server sends a broadcast message to all base stations that a specific vehicle position location measurement sequence is commencing. The conceptual architecture of this base server and a group of base stations is shown schematically in Figure 7. In the FPW pilot tests, the base server functions just described were

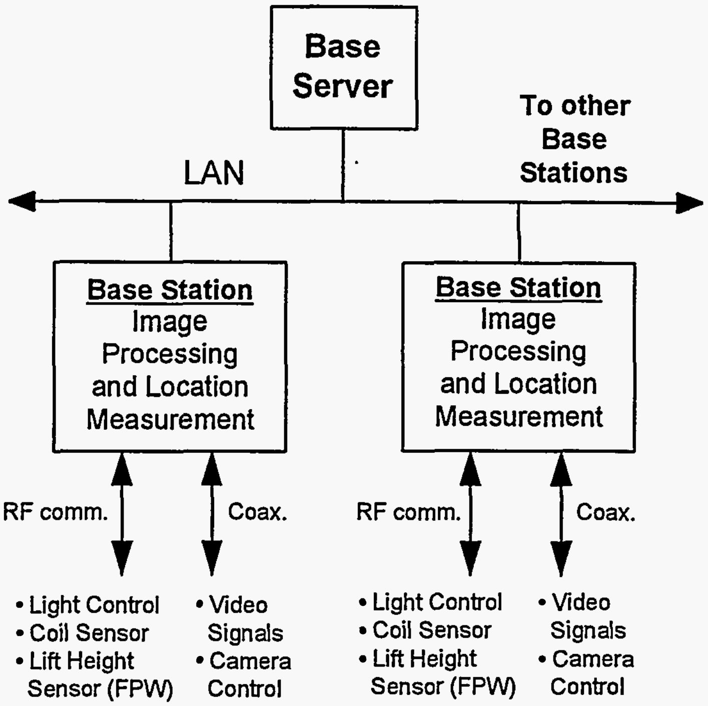


Figure 7. Architectural arrangement of base stations and the base server.

implemented on the same PC which implements the base station functions. The camera selection, image viewing and other interactive display functions which we implemented as a part of the proof-of-concept demo system were incorporated into the base server in the pilot test system. Additional base server functions to handle adjacent areas have been designed but were not implemented for the FPW pilot tests.

3.4 Finished Products Warehouse Pilot Test

The Weirton Steel FPW was selected as the location for the first pilot test of the video tracking system. The FPW environment is described in this section in order to provide the necessary background for the discussion of the pilot test results presented above in Section 2.3.4.

There are two ways of storing coils in the FPW. The more common storage arrangement is to store the coils in the "eye up" position, wrapped and on pallets. This arrangement is shown in Figure 8 where typical dimensions are given. The remaining coils are stored in rolling position. Coil weights and sizes vary over a wide range. We have observed coil weights between 6,000 and 25,000 pounds. The eye up coils are either a) wrapped in paper and banded to a pallet or b) wrapped in plastic and attached to the pallet using the plastic wrap. The plastic wrap method is a newer method being used at Weirton Steel. The eye up coils are stacked up to three high. The rolling position coils are not stacked on top of each other. There are both wrapped and unwrapped rolling position coils. The unwrapped rolling position coils which we observed were hot band coils with a black matte finish. Since the majority of coils in the warehouse are wrapped, or have a matte finish, reflections from coils should not be a problem for the video tracking system.

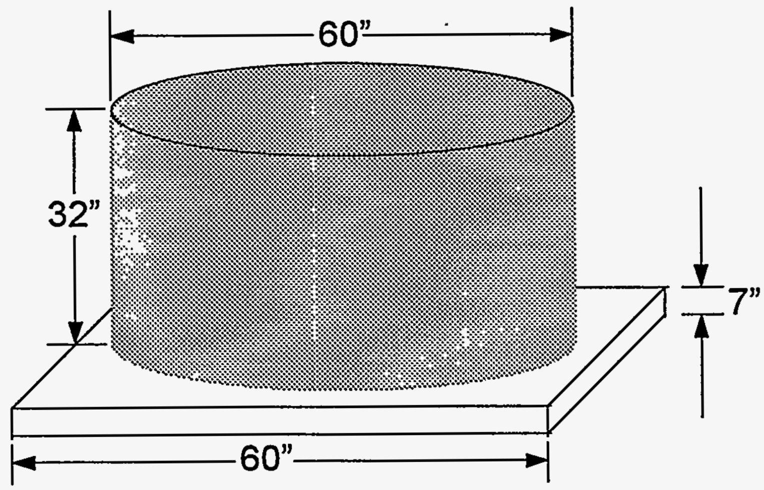


Figure 8. The stacked or "eye up" coil storage position with typical dimensions.

Both the eye up and rolling position coils are placed in rows. These rows may weave which must be taken into account when converting the XYZ coordinates used by the video tracking system to the L&IS nomenclature. The eye up coils are stacked close together with approximately 1 to 3 feet between the rows. Each row can be stacked 3 coils high and 8 coils deep. There are 7 rows in the new bays which have been defined by the L&IS group. A top view of the arrangement of coils in two adjacent bays is shown in The 20 foot dimension is defined by the 20 foot spacing of the foot support poles in the FPW. The 20 foot spacing of these poles also defines the width of the aisles between bays. The 50 foot dimension is also defined by the spacing of the roof support poles.

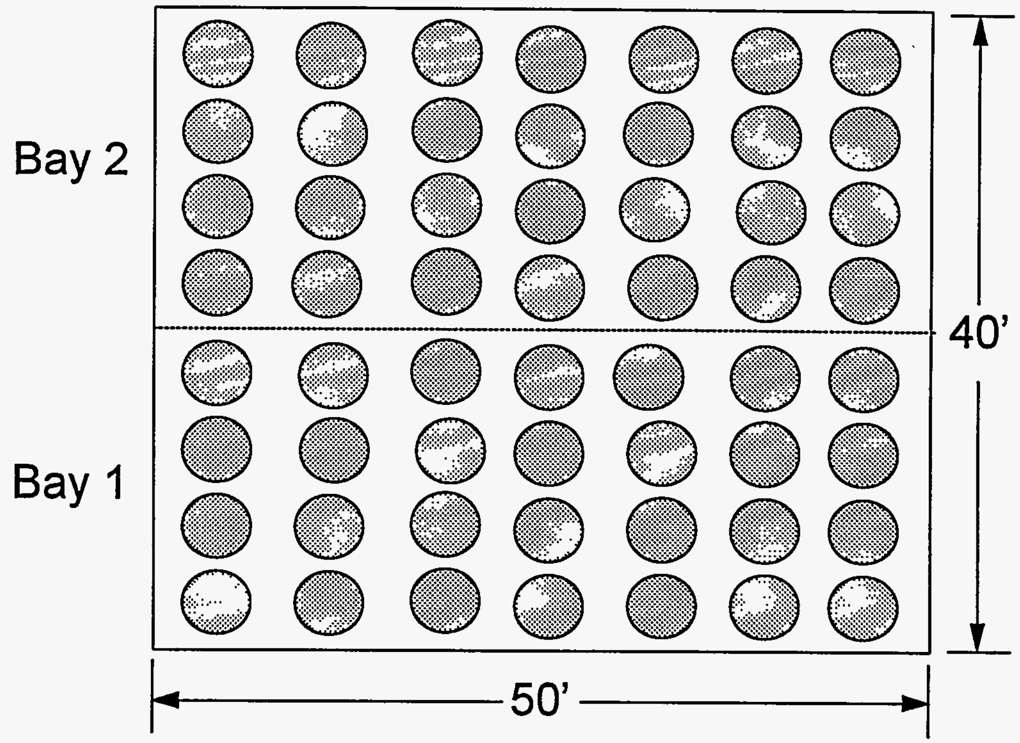


Figure 9. Arrangement of eye up coils on pallets in two adjacent FPW bays.

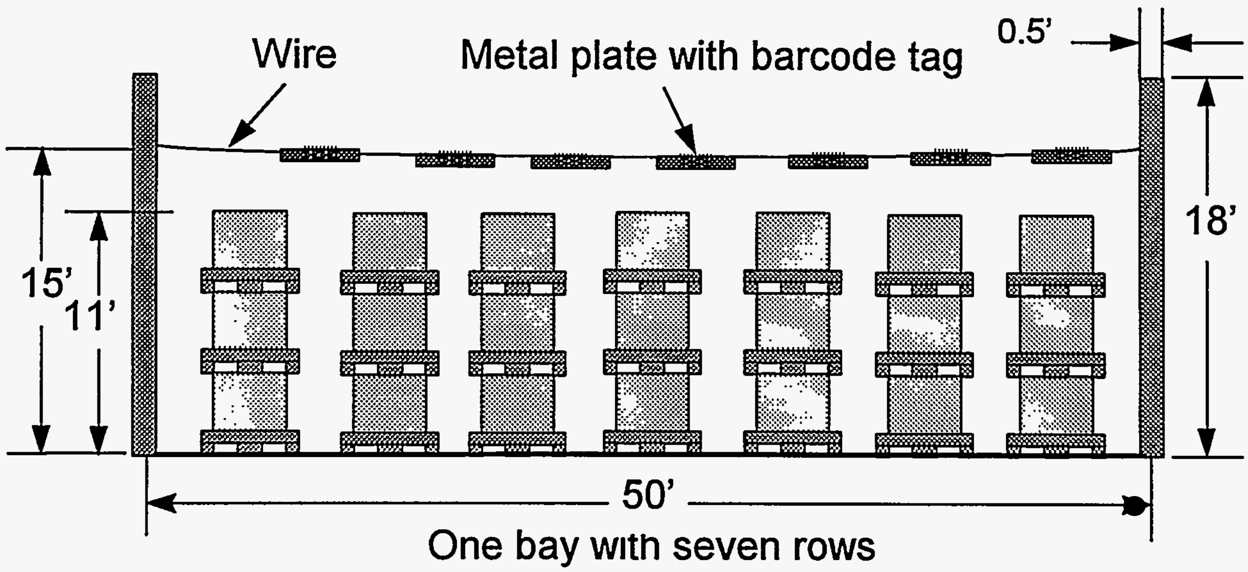


Figure 10. Side view of a typical bay showing the limited "headroom."

Figure 10 is a side view of a typical FPW bay which shows the vertical dimensions and the typical coil arrangement in the FPW. Figure 11 is a photograph taken near the front of the Number 8 Warehouse. The camera was approximately at the 12 foot level, approximately one foot above the tops of the coils. Figure 10 and Figure 11 clearly show the limited "headroom" between the tops of the coils and the warehouse roof. The available headroom is further limited by the wire supported metal plates which are being installed to mount barcode tags which label each warehouse bay. One of these wires, with the barcode tag mounting plates, is shown in Figure 10. There is only about four feet of vertical clearance between the bottom of these tags and the tops of typical three high stacks of coils which are 11 feet high. The lift truck lifts move through a maximum vertical distance of approximately eight feet in the FPW. As discussed below, it is impractical to measure vertical lift position in the FPW by having a light which moves up and down with the lift truck lift mechanism. Therefore, we instrumented the lift truck which was used in the pilot tests with instrumentation which measures the vertical position of the lift. This instrumentation is discussed further below. Since the lift height was measured by instrumentation on the lift truck, the video tracking system measured only the x and y position of the lift truck where x and y are the two horizontal coordinated in the FPW. The cameras were mounted so that they look horizontally. Since the warehouse is relatively open, as shown in Figure 11, a set of four cameras mounted at the four corners of a rectangular area will be able to cover a large area in the warehouse. Camera coverage and camera positioning are discussed in the next section.

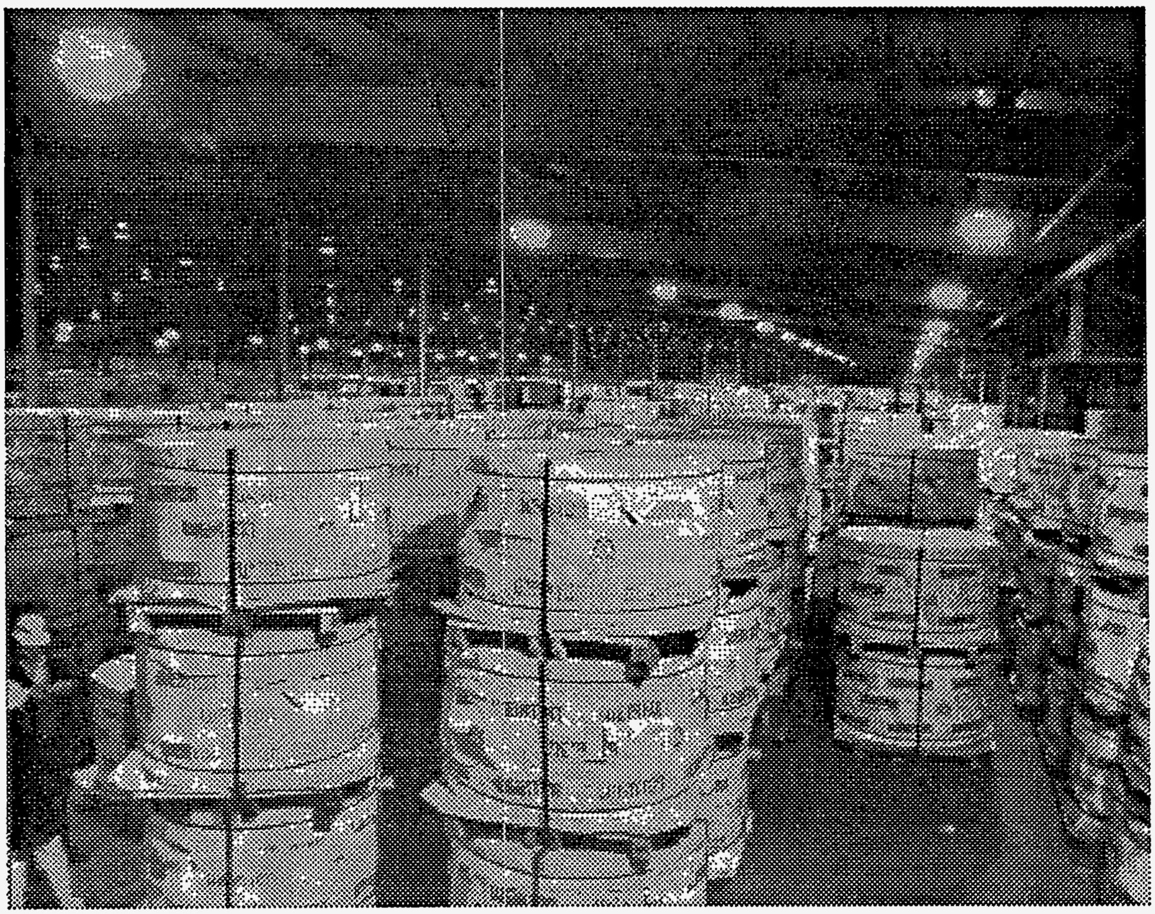


Figure 11. Photograph of a typical arrangement of coils taken in the No. 8 Warehouse.

3.5 Lift Truck System

3.5.1 Overview

The lift truck system consists of an assembly mounted on top of the lift truck driver protective cage along with a separate driver display, limit switches for coil height measurement, and a pressure sensor for sensing coil presence. A block diagram of the lift truck system is shown in Figure 12. Some of the key operational features are:

1. Communications interface to any Base Station via an RF modem
2. Control electronics for front and rear lamp assemblies
3. Pressure and height sensor interfacing for detecting coil presence and coil height
4. Driver display for alerting exception messages and providing driver log on/off

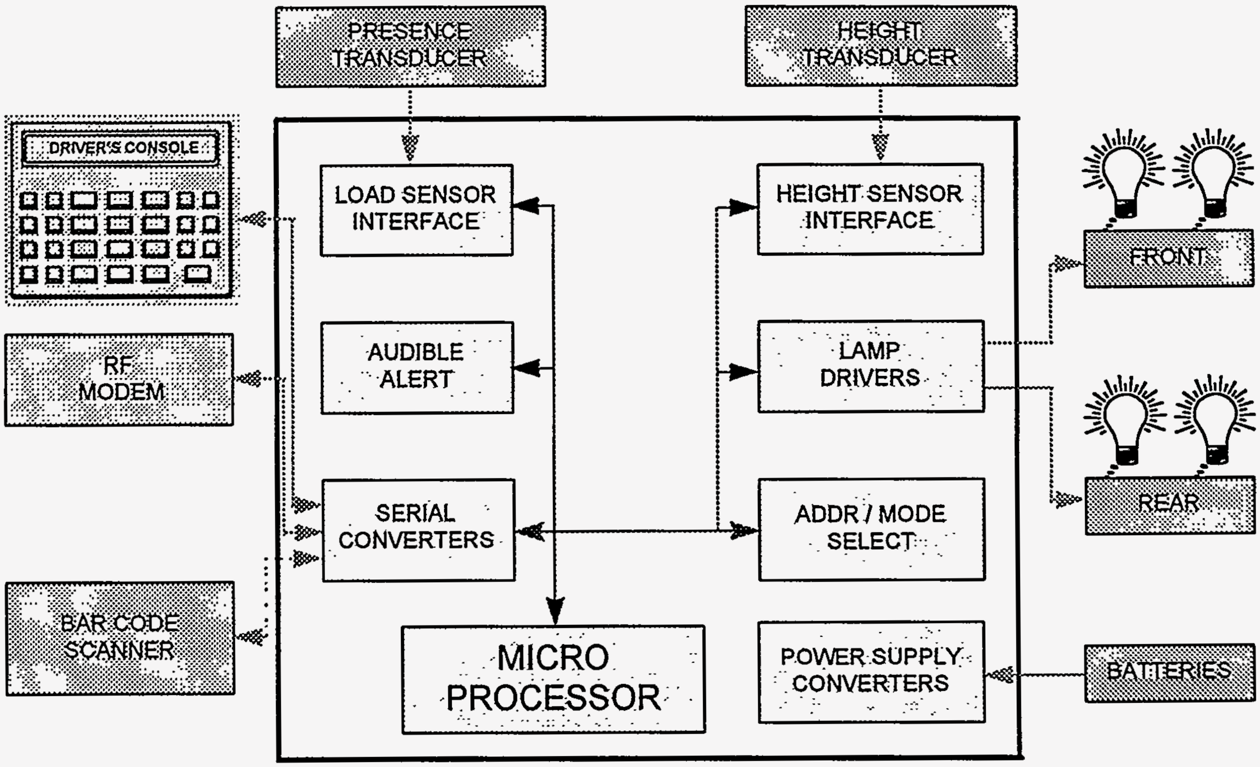


Figure 12. Lift Truck System block diagram

The Lift Truck System includes the following components which are described below:

1. Coil presence sensor
2. Coil height sensor
3. Display and audible alert for the driver
4. RF modem
5. Serial converters for interfacing to the display and the RF modem
6. Lamp drivers

7. Address and mode select
8. Power supply converters

3.5.2 Pilot Test Lift Truck System Assembly

The completed lift truck system is shown in Figure 13. The system is sized to fit on top of the protective cage on the Elwell-Parker lift trucks used in the FPW. The four light assemblies are mounted at the four top corners of the assembly. The micarta sheet at the bottom of the assembly holds the other components. The card cage which holds the on-board computer processor and interface cards can be seen at the center bottom of the assembly. The RF modem is to the right of the computer. This system is powered from the 36 V batteries on the lift truck. The lights are connected directly to the batteries and controlled by field effect transistors housed in the light assemblies. A single connector connects the system to the battery, height sensing limit switches, coil presence sensor, and driver display. Flash memory provides the permanent memory for the system; no hard disk is used. The assembly is shock mounted using four rubber shock mounts which can be seen at the bottom corners of the assembly. This system can be seen mounted on top of a lift truck in above.

Figure 13. Photograph of the lift truck system as tested.

3.5.3 Simulated lift truck

We built a "simulated lift truck" in order to perform location measurements in the FPW without taking an actual lift truck out of service. The simulated lift truck has all of the lift truck system components except for the coil presence and lift height sensors. The simulated lift truck was built using steel angle and was constructed to be approximately the same size as the Elwell-Parker lift trucks used in the FPW. The lights were located at the same height and arranged in the same x-y positions as on the actual lift trucks. This simulated lift truck system is AC powered. A photograph of the simulated lift truck is shown in Figure 14. The simulated lift truck was used for preliminary location measurement accuracy tests with two cameras installed in the FPW and for additional location measurement accuracy tests with four cameras installed.

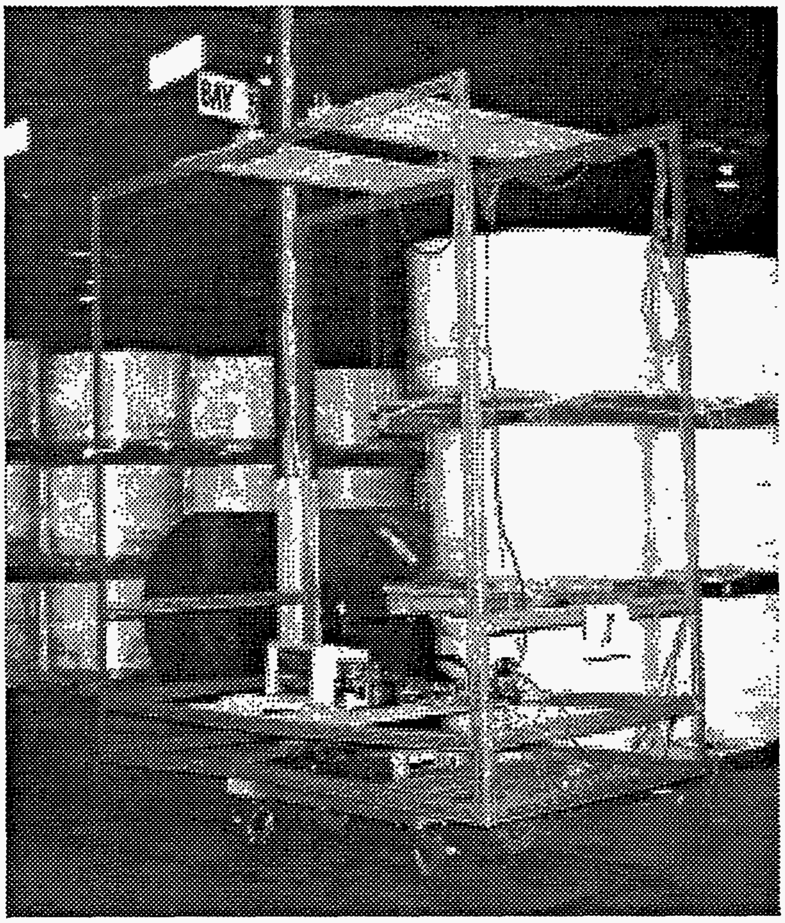


Figure 14. Simulated lift truck which was used for the initial location measurement accuracy tests.

3.5.4 Lift truck Components

The lift truck electronics provides the interface for all the peripheral components. The various major components will now be described.

3.5.4.1 On-board Computer

The on-board computer is a Ziatech STD bus based system with an Intel 486 processor card and additional cards for interfacing to the rest of the lift truck system components. The use of a card cage allows for maximum flexibility and ease of expandability. The system can be expanded simply by inserting a new board into a spare slot without having to redesign the existing hardware and allows software development on the actual system. The Ziatech ruggedized system is designed to withstand a shock and vibration environment which means the overall board dimensions are kept to a minimum. The STD bus, a proven standard since 1978, provides for a board form factor of 6.5" by 4.5." This bus is designed for industrial control as the boards are vibration and noise-resistant. Also, there are a multitude of vendors that manufacture I/O and controllers for this bus. A PC-based computer system offers the inherent advantage in that all the software development tools used in a normal PC type platform can also be used here. No special compilers and/or debuggers are needed. Also, much of the general-purpose, non I/O specific software can be written and tested on any PC-based platform. The video, disk drive, and keyboard interfaces used during development are removed when the electronics is installed on the lift truck. Also, an 110V AC power supply is used during development. The AC supply is replaced by a DC supply for system installation on the lift truck.

3.5.4.2 Coil Presence Sensor

An important function is determining that a coil is "on-board" the lift truck. The change in weight on the forks of the lift truck indicate that a coil has been picked up or unloaded. The location of the coil at this instant of time is the location that goes into the data base for future retrieval of the coil. A hydraulic pressure sensor used as a weight sensor is chosen as the most practical means of sensing that a coil is present on-board the lift truck. The coil presence sensor was simulated with a toggle switch during the FPW pilot tests. Proven commercial pressure sensors, e.g. the Square D 9012GCW-22 adjustable pressure sensor, are available to implement this function.

3.5.4.3 Height Sensor

The addition of a "lift-height" sensor on the lift truck allows the camera system to be optimized for the x,y location. The "lift-height" sensor provides the z or vertical dimension to indicate at what level the coil is stacked. The vertical location is not needed to the same degree of accuracy as the x,y dimensions since a coil stack only consists of up to three coils. The coarseness of the measurement is compatible with of the use of limit switches. Five limit switches were installed on the lift truck mast with equal spacings of 16 inches. This arrangement, together with a limit switch actuating bar 24 inches long, gives lift height steps of 8 inches. This resolution is adequate to determine whether the coil being picked or placed is in the top, middle or bottom coil height position for the full range of coil dimensions in the FPW. The height sensor function well during the pilot tests.

3.5.4.4 Audible Alert

A piezoelectric alarm is used to alert the driver that an exception condition has occurred and that he/she should pay attention to the display. This alarm can provide a 50db signal which will easily be heard over the existing mill and warehouse noises.

3.5.4.5 Serial Converters

There are three serial converters for interfacing to various lift truck components. The main channel is the RF link to the Base Station which is handled directly by the µP core internal communications interface. The two other converters, one for the driver's interface and the other for a bar code scanner, are interfaced to the on-board computer via two programmable communications interface devices.

3.5.4.6 Lamp Drivers

Two identical DC lamp driver circuits are provided to control the front and rear lift truck lamp assemblies. Additionally, current monitors in each circuit detect any assembly failure.

3.5.4.7 Address and Mode Select

An 8-position DIP switch is mounted on the edge of the board and is for setting the lift truck address. This allows any unit to be used on any lift truck by simply changing the lift truck address. A 4-position DIP switch, accessible like the other switch, provides the means for setting different operating modes. One such mode is a diagnostics check of the front and rear lamps.

3.5.4.8 Power Supply Converters

A Ziatech regulator module converts the 36VDC nominal battery voltage to the 5VDC required by the onboard electronics. Additionally, filtering eliminates the transients caused by the motor turn-on and turn-off.

3.5.5 Driver's Console

The driver's console is an off-the-shelf, ruggedized terminal which provides visual display and driver feedback capability. The display used in the pilot test system is a CP/2500 panel mount terminal from WPI Termiflex, Inc. This display has a large character 4x20 backlit display which is easily readable from 12 feet. A 25 character keypad provides the means for operator interaction such as daily log-ons and log-offs. This display is mount on the lift truck driver protective cage.

3.5.6 RF Modem

The ProxLink RF Modem is used as the wireless communications means between the Base Station any all lift truck. This device uses spread spectrum communications in the 902-928 MHz range and does not require an FCC site license. The operating range specified by Proxlinx is 500 feet.

3.5.7 Light Assemblies

Front and rear light assemblies are located on the lift truck and provide the necessary light source when the location process is in operation. The design requirements for the lamps and assembly used in this operating environment are:

1. Capability of withstanding a high number of on-off cycles
2. Two bulb "strings" per assembly so a single string failure will not disable operation
3. Bulb current monitoring to detect one or more bulb failures
4. Capability of withstanding the shock and vibration
5. Easy removal and replacement

6. Shatter and explosion proof
7. Maximum operating voltage of 36VDC (lift truck batteries)
8. Wide vs. narrow beam so multiple cameras can detect the light

We evaluated a variety of lamp types and selected automotive, incandescent lamps for use on the lift truck. These lamps can withstand a high degree of shock and vibration. The 1156 truck tail lamp was chosen because of its price, durability, and availability. The assemblies which we have tested consists of either four of these lamps arranged as two strings of two bulbs or six of these lamps arranged as two strings of three bulbs. The six bulb assemblies are used on the lift truck system. These arrangements provides very bright images with sufficient redundancy such that one of the strings can fail and the location process can still take place. We simulated a lamp failure by removing a bulb from one of the six light assemblies and were able to obtain accurate lift truck location measurements with only three lights.

3.6 Base Station

3.6.1 Overview

The Base Station for a fielded system would be a self contained electronics enclosure. The excellent price/performance available with PC hardware makes PCs an attractive choice for implementing the Base Stations in a fielded system. In addition, the flexibility in distributing the Base Station software which we have developed across physical hardware platforms allows one PC to perform the Base Station functions for two or possibly three areas covered by four cameras in each area. Thus we believe that PC hardware is a good choice for Base Station implementation. Consequently, we used a is a Gateway2000 P5-100XL PC to implement the Base Station functions for the pilot test. We used the same PC to perform the Base Server functions which were implemented for the pilot test. The Base Server is discussed below in Section 3.7. The Base Station provides the following general functionality:

1. Communications with any lift truck via an RF modem
    - Receives the lift truck coil placement message
    - Commands the lift truck to energize the front or rear lamp
    - Sends any driver update messages
2. Communications with the Base Server via a high speed LAN
    - Reports lift truck coil placement request
    - Receives command to initiate lift truck location sequence
    - Reports location of lift truck
    - System Diagnostics
    - Camera calibration
    - Video imaging
    - Software upgrade download from Base Server
3. Control of video cameras for frame capturing sequence

The assembly itself must be ruggedized and be able to withstand the harsh mill environmental characteristics including temperature variations and dirt.

The Base Station, shown in Figure 15, is designed as a system of modules that interact to provide the desired functionality. The **RF Communications** module hears when a lift truck announces a coil placement. It notifies **Camera Capture Control** which uses **Server Communication** to ask the Base Server if it should capture the location of the lift truck. Upon receiving confirmation, the **Camera Capture Control** lets **RF Communications** tell the lift truck to turn its front light on. After the lift truck sends confirmation, the **Camera Capture Control** tells the **Buffer Manager** to capture the front images. The **RF Communications** module then tells the lift truck to turn off its front light and turn on its rear one. Again after waiting for confirmation, the **Buffer Manager** captures the rear images.

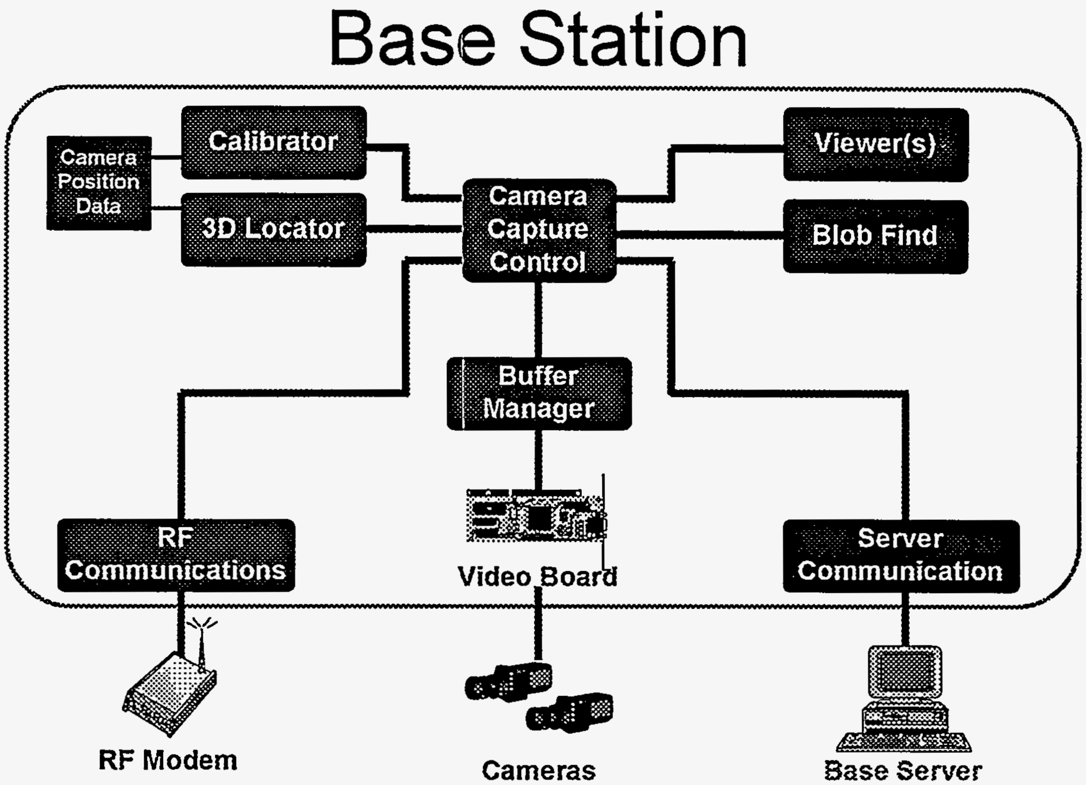


Figure 15. Base Station block diagram showing the hardware and software modules.

3.6.2 Optical Design

The cost and practicality of video materials tracking systems is a strong function of the size of the area which can be covered by a set of cameras. The camera coverage area is, in turn, a function of the camera resolution and the maximum distance at which the lift truck light sources can be reliably detected. The design calculations described in this section were performed to predict system performance as a function of the size of the area covered by one set of cameras. The results also allow us to estimate the size of the maximum area which can be covered by one set of cameras. The maximum distance at which the lift truck light sources can be reliably detected is determined by the combined performance of the camera and the light source.

3.6.2.1 Camera Resolution Calculations

The goal of the video tracking system is to measure the 3D position where coils are placed. In the FPW the vertical, or z position will be measured by instrumenting the lift truck lift mechanism. The video cameras will be used to measure x-y, or horizontal position in two dimensions. The resolution of the 2D position measurements depends on the resolution with which the cameras can measure the location of the lights sources on the lift truck. Camera resolution depends, in turn, on the characteristics of the camera/lens combination, including number and size of CCD elements, focal length, optical distortion, etc. The resolution per unit of width and depth can be controlled to optimize the camera coverage.

When the lens projects an image onto the CCD imaging array in the camera, the light impinging on each element is integrated over a fixed period of time. After the integration interval, on command, each element supplies a voltage proportional to the average light intensity over its surface over that period of time. Consequently, the position of an object cannot be resolved more accurately than the size of its virtual image projected on the sensor element. The resolution can be calculated by dividing the actual size of the field of view by the number of pixels in the CCD array.

We performed calculations for the three lenses which we have obtained in conjunction with a Panasonic WV-BL200 camera, which has a 1/2" nominal diagonal sensor utilizing 570 horizontal elements. The Computar H2Z4515CS lens focal length can be varied from 4.5 to 10 mm, with a corresponding angular field of view variation from 85.3 to 37.7 deg. The H3161FL lens has a focal length fixed at 3.6 mm with a 92.6 deg. angle of view, and the H26161FICS lens has a focal length of 2.6 mm with a 116.5 deg. field of view. The resolution for a range of angular fields of view tabulated vs. light to camera distance is in Table 4 and plotted in Figure 16.

The resolution required for adequate location accuracy is conservatively estimated as 1.5 feet. This falls well within the dimensions of a single coil. As can be seen from the graph, all focal lengths except the 2.6 mm focal length of the H26161FICS permit achievement of the accuracy goal at light to camera distances of 400 feet or less. The 2.6 mm lens would provide adequate resolution at 250 feet or less; however, it is a "fisheye" type lens which suffers from considerable distortion requiring substantial correction at the extremes of the field of view.

	Computar H2Z4515CS variable focal length lens				Computar H3161FI	Computar H26161FICS
focal length, mm	10	7	5.5	4	3.6 mm	2.6 mm
FOV, deg	37.7	61.5	73.4	85.3	92.6	116.5
Diag dist						
0	0	0	0	0	0	0
50	0.06	0.10	0.13	0.16	0.18	0.28
100	0.12	0.21	0.26	0.32	0.37	0.57
150	0.18	0.31	0.39	0.48	0.55	0.85
200	0.24	0.42	0.52	0.65	0.73	1.13
250	0.30	0.52	0.65	0.81	0.92	1.42
300	0.36	0.63	0.78	0.97	1.10	1.70
350	0.42	0.73	0.92	1.13	1.29	1.98
400	0.48	0.83	1.05	1.29	1.47	2.27
450	0.54	0.94	1.18	1.45	1.65	2.55
500	0.60	1.04	1.31	1.62	1.84	2.84

Table 4. Resolution in pixels per foot vs. distance from the camera for Computar Lenses

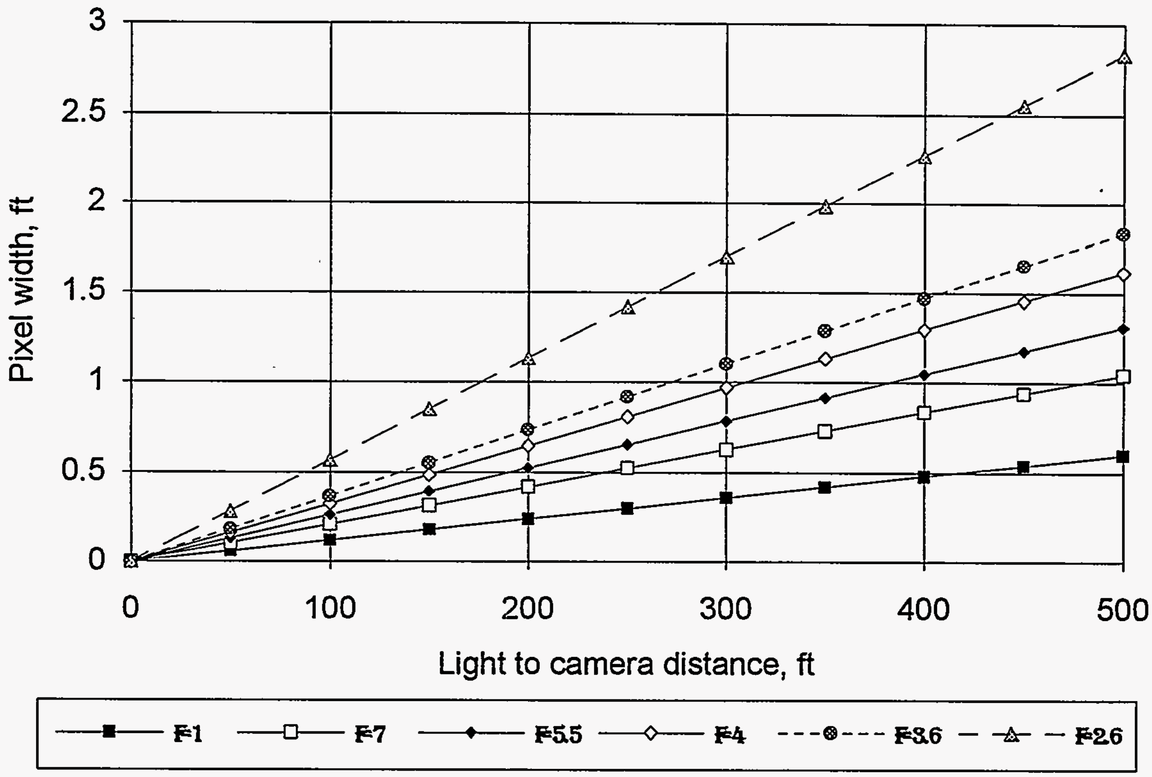


Figure 16. Graph of Computar Lens Resolution Calculations

3.6.2.2 Camera Coverage Calculations

For a lens with angular coverage near 90 deg., arranging the cameras in the corners of a rectangular space under surveillance offers the most efficient coverage of the space. Lenses in this range of focal lengths are reasonably well corrected for spherical distortion and are available at reasonable cost. We performed camera coverage calculations for rectangular areas in the FPW which are "M" bays wide by "N" bays deep.

From the these calculations and the layout of the warehouse we concluded that an array of 4 cameras arranged at the corners of the area covered can cover areas which are as large as 4 bays wide and 10 bays deep. This estimate is based on using the Computar H2Z4515CS with the lenses set at focal length = 4 mm (field of view = 85.3 degree). Preliminary tests verified the coverage calculation estimate. The resulting resolution for each camera at its extreme distance from the lift truck will be approximately 1.36 ft. per pixel, which meets the goal of 1.5 ft. per pixel worst case.

3.6.3 Hardware Modules

3.6.3.1 Base Station

The Base Station is a Gateway2000 P5-100XL PC. It contains 32 MB RAM, 1GB hard disk, 14.4 Kbps Fax Modem, LAN adapter card, and SVGA monitor. The operating system is Microsoft® Windows NT™ Server network operating system. This same PC was also used to implement the Base Server functions described below. The standard PC package provides a processor and memory, a high speed PCI bus interface for the image capture board as well as a software development environment including a keyboard and monitor. For a fielded system, the keyboard and monitor would not be needed and the Base Server would be a separate PC. The PC has more stringent environmental requirements than a ruggedized system, but this disadvantage tends to be offset by the low cost of PC hardware, peripheral boards, such as the image capture board, and cost effective software and software development tools.

3.6.3.2 Cameras

The cameras capture the images of the lift truck. Four Panasonic WV-BL200 cameras equipped with Computar H2Z4515CS variable focal length lens were used in the pilot test system. Images are sent using the RS-170 format with 520x480 pixels.

3.6.3.3 RF Modem

The Base Station uses the same Proxlinx RF Modem which is used on the simulated and actual lift trucks. The RF modem provides two-way communication between the Base Station and the lift trucks.

3.6.3.4 Image Capture Board

The MuTech PCI bus image capture board converts the image from the cameras into a digital form. In addition, it also handles camera selection.

3.6.4 Software Transfer Objects

3.6.4.1 3D Location

A 3D Location is the position (x,y,z) of a light source.

3.6.4.2 Blob

A Blob is a difference between the light source on and light source off images. The location (x,y) and size in the image is part of the blob object. In addition, a light/dark flag determines which image has the light source on.

3.6.4.3 Camera Position Data

The Camera Position Data holds the position of the camera (x,y,z), its angle of orientation, and coefficients used in calculating 3D Locations.

3.6.4.4 Image

An Image is a digitized version of the scene captured by a camera.

3.6.5 Software

The base station software consists of seven major software components: Base Station Control, Buffer Manager, Calibrator, 3D Locator, RF Communications, Viewer, and Server Communications. The functions and inter-process communications among these five components are shown in Figure 17. Additional details are provided in the following sections for each of the main components of Figure 17.

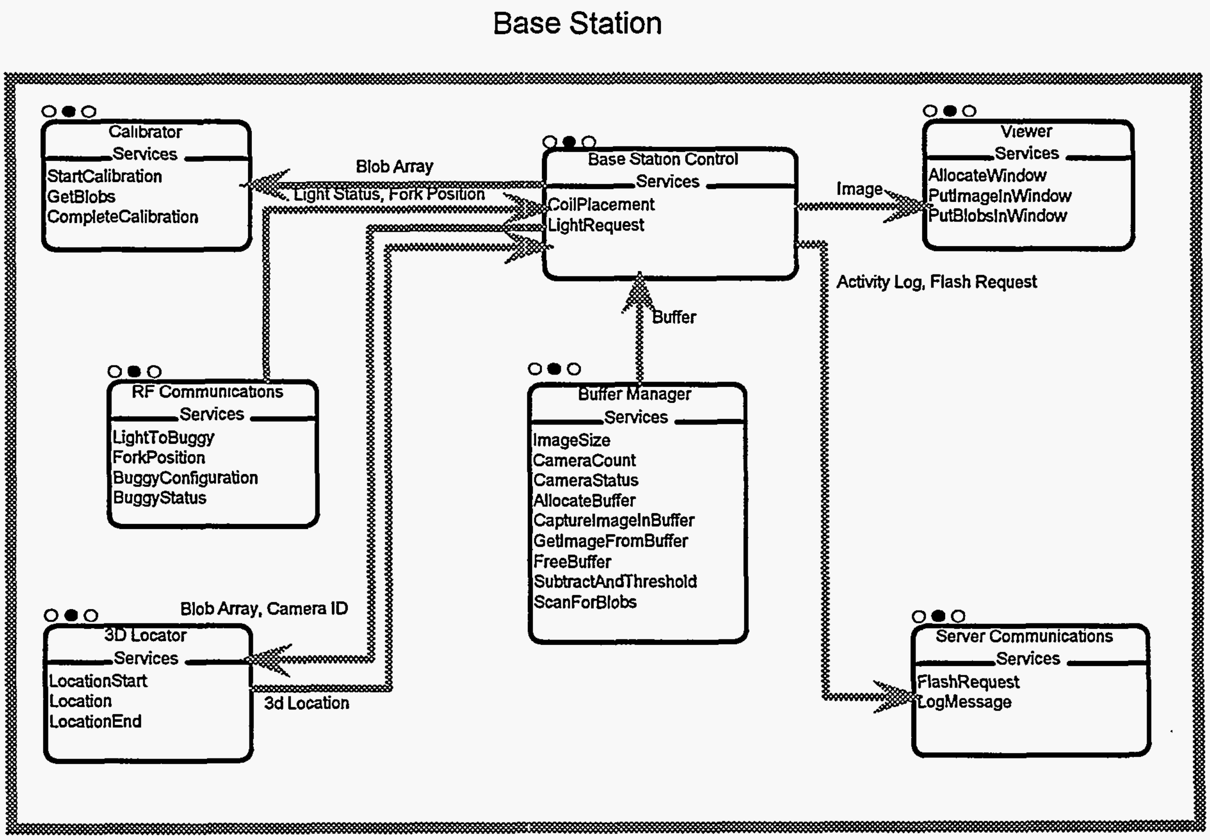


Figure 17. Base station software objects and messages.

3.6.5.1 Base Station Control

The Base Station Control handles the sequencing of the Real Time Materials Tracking System components. It determines which modules to call and in what order. For any particular action, there is a sequence of steps that do the necessary processing. A typical tracking sequence will start by turning the front light source on, capturing the front images, turning the rear light source on, and so on. By breaking the processing into individual *Steps*, each that do one simple action, we can then build any number of *Sequences* out of these *Steps*. This allows each step to be a simple object since it only needs to be concerned with its task rather than the complete sequence. In addition, since all of the *Sequences* are made from a common pool of *Steps*, testing one sequence will help test other similar sequences.

Steps map one for one to the set of functions available in each. Just as there are *CaptureImageInBuffer* and *ScanForBlobs* functions available in the Buffer Manager, the Base Station Control has a *CaptureImageInBufferStep* and a *ScanForBlobsStep*. These steps handle the processing required to interact with the Buffer Manager in a self contained manner.

Another feature of *Steps* is that they can loop through all of the desired cameras. This allows steps, such as the *CaptureImageInBufferStep*, to do their processing on each of the cameras stored in the *Sequence*. Using this feature, *Sequences* can be very short but provide a lot of functionality.

In addition, *Sequences* hold camera data which is accessed through the *Get/SetCameraData* functions. Steps can use these functions to retrieve information stored by previous steps without having to communicate directly with each other. This allows data transfer without requiring knowledge of other steps.

3.6.5.2 Buffer Manager

The Buffer Manager module takes the Camera ID and Buffer Type and returns the captured Image. The buffer manager first directs the video board to capture the image from the camera specified by Camera ID. Once this is completed, the buffer manager transfers the image from the video board into the PC's memory.

3.6.5.3 Blob Finder

The Blob Finder module takes paired Images from a Camera and generates Blobs for that Camera. The images are first subtracted and thresholded. Then the subtracted image is scanned for blobs. Once a new blob is detected, a sweep is made around the edge of the blob. The location of the blob is determined by averaging the location of the edge pixels.

3.6.5.4 Calibrator

Taking Blobs from each Camera and the location of each Camera from Camera Position Data, the Calibrator module will generate the rest of the information stored in the Camera Position Data. Using an algorithm similar to 3D Locator, the Calibrator takes blobs from light sources at known locations (x,y,z) and determines the correct constants to use in 3D Locator for each of the cameras.

3.6.5.5 3D Locator

The 3D Locator module takes Blobs from each Camera and Camera Position Data to determine the 3D Location of the Light Source. This is done using matrix arithmetic to combine the blob position (x,y) in the camera image and the Camera Position Data to generate a three dimensional vector. The intersections of vectors from different cameras are combined to generate potential light source locations (x,y,z). These potential locations are collapsed using heuristics until the location of the light source is determined.

3.6.5.6 RF Communications

The RF Communications module handles all communications with the RF Modem. It handles the transmission of information from the Base Station to the Lift truck. In addition, it listens for incoming messages from the lift truck. Information from incoming messages will be passed on to the Base Server Control.

The Viewer(s) module uses one or more of 3D Locations, Blobs, and/or Images to generate a display showing the inputs. It will have a zoomable graphical display to show the correspondence between Images and Blobs. In addition, it will have a text display which will show Blob coordinates as well as 3D Locations. In a fielded system, the viewer module probably would be accessed from the Base Server.

3.6.5.7 Server Communications

The Base Station Server Communications module handles all communications with the Base Server. It handles the transmission of information from the Base Station to the Base Server. In addition, it listens for incoming messages from the Base Server. Information from incoming messages will be passed on to the Base Station Control.

3.7 Base Server

3.7.1 Overview

The Base Server is a self contained PC that interacts with L&IS and the Base Stations. One server is located within a mill site (i. e. Finished Products Warehouse, Tin Mill). A base server provides the following general functionality:

1. Communications with L&IS
    - Receives lift truck dispatch messages
    - Reports location of lift truck
2. Communications with the Base Stations via a high speed LAN
    - Sends command to initiate lift truck location sequence
    - Receives location of lift truck
3. Data Storage
    - Holds the system configuration
    - Translates 3D coordinates to L&IS coordinates
    - Maintains a system activity log
4. User Interface
    - System Diagnostics Interface
        - Camera calibration
        - Video imaging
    - System Monitor

The assembly itself must be suitable for a standard Weirton office environment.

The Base Server description presented here is a preliminary description. A more complete description will be presented in a second design report to be issued at the end of June, 1995.

3.7.2 Hardware

As noted above, both the Base Station and Base Server functions are implemented in the pilot test system using a Gateway2000 P5-100XL PC. The server is database is implemented using a Watcom SQL database.

3.7.3 Software

The base server software consists of five major software components: Server Control, Base Station Communications, Server Viewer, L&IS Communications, and Data Storage. The Base Server objects and inter-process communications among these five objects are shown in Figure 18.

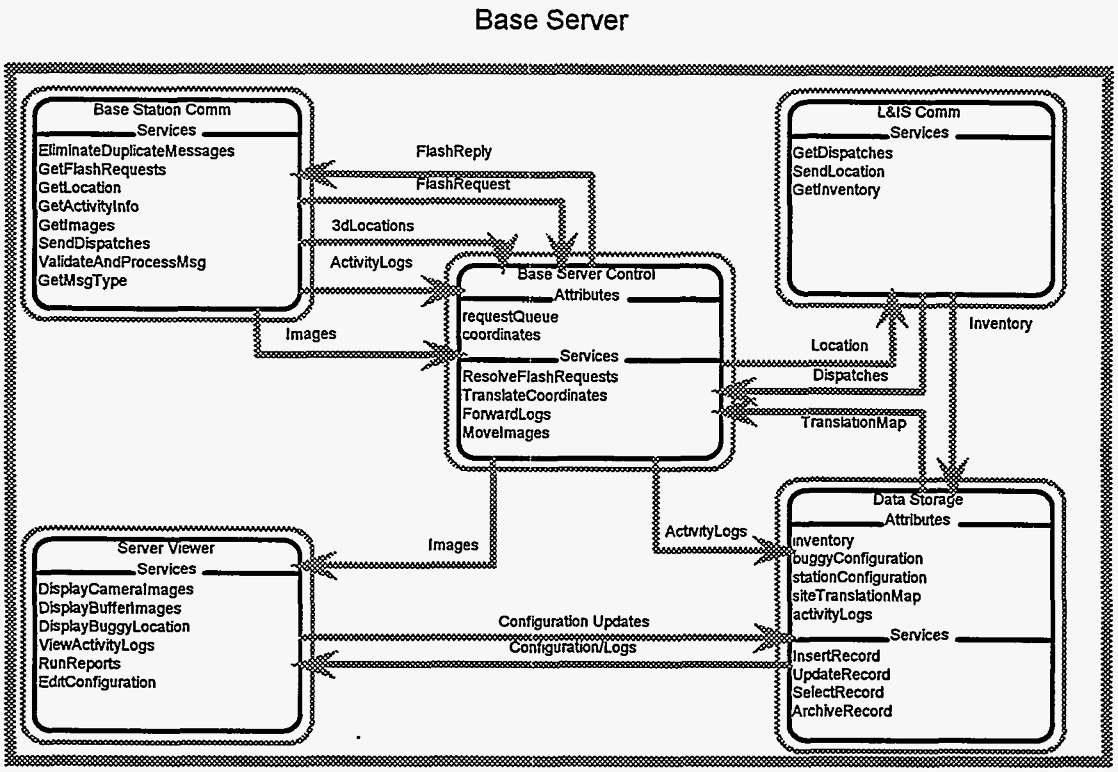


Figure 18. Base server software objects and messages.

3.7.3.1 Server Control

The Base Server Control handles the sequencing of the Real Time Materials Tracking System components. It determines which modules to call and in what order.

3.7.3.2 Base Station Communications

As discussed below, the Base Station and Base Server software has been designed and implemented using Sockets communications. This approach provides flexibility is the distribution of software modules across physical hardware platforms. In particular, this approach allowed us to use a single PC to implement both the Base Station and Server functions in the FPW pilot tests. In a fielded system a LAN would be established between the Base Server and the Base Stations which will allow the use of the existing TCP/IP and sockets communications software as implemented to communicate between multiple Base Stations and a Base Server on separate PCs. The Base Station will receive three different categories of message. The first is a request to initiate the lift truck light sequence and capture the camera images. The second message is the result produced by the 3D location algorithm. The last type of message includes all maintenance and error messages that originate either from the base station or from the lift truck. The primary function of the base server is to coordinate multiple requests to initiate the flash sequence from the base stations. The input to this function is the request to flash message. The output of this function is either a message to start the sequence or a message to wait. The wait would be followed by a retry or continue command. The coordinate request process will eliminate duplicate messages, then it will choose a base station and reply to start the flash sequence. Any other base stations will receive a wait response. Once the base station has completed its processing and returns a location result, then the base server releases the other stations from waiting and grants one of them the flash sequence.

3.7.3.3 Server Viewer

The server viewer allows an administrator or maintenance personnel to observe the system. The user has the ability to select a camera and view the camera sees. Primarily, this would be used to diagnose problems in the system. There is also an area on the screen which shows the pick or place location and displays the 3D coordinates and the L&IS location. This allows the user to watch the lift truck activity for the site. A third windowwhich was not implemented in the pilot test system, would notify the user of any alarm conditions in the system. This will consist of such things as a lift truck light failure, a base station camera failure, etc. In the future these alarms could also be logged to a dedicated printer.

3.7.3.4 L&IS Communications

L&IS communications was not implemented in the FPW pilot test. The link would be from the Base Server to the L&IS DEC host via TCP/IP. This link would provide access to the lift truck dispatch messages provided by L&IS. These messages inform the lift truck driver which coil to pick (or place), the location, and a due date and time to complete the move. This information would be incorporated into the 3D location algorithm when ranking the best solution. Once the location is determined, then it is proposed that it be transmitted to L&IS in the coordinate system it uses. The format of these two operations has yet to be determined. A third use of the communications link is to establish a metric which would compare a snapshot of the L&IS inventory with the pilot test inventory. If the server is down or the LAN is not operating properly, then the system is inoperable. In a production system, a redundant server would be added to the system.

3.7.3.5 Database

The Server Database acts as the main repository of information and configuration for the system. We used the commercially available Watcom SQL client-server database to implement the Server Database. A log of all incoming and outgoing messages is kept. This is also the location which stores the cross reference map between the 3D coordinate system and the L&IS locations. By using a database on the server, future enhancements such as a parts inventory or a preventative maintenance scheduler will be easier to implement.

3.8 Software Integration and Inter-Process Communications

3.8.1 Overview

The Real Time Materials Tracking System is composed of three major components: a base server responsible for overall system coordination, one or more base stations responsible for determining coil locations, and lift truck electronics responsible for determining when the lift truck load has been picked or placed. The software which we are using to implement this system has been designed for scalability. The software components are implemented as C++ objects, built upon the Microsoft Foundation Classes (MFC). Figure 19 shows a high level view of the Real Time Materials Tracking System software. Communication between the base station and the lift truck is via an RF link as discussed above. The protocol and messages which we are using for communication between the base station and the lift are based on the IEEE 802 standard and were developed as a part of this project. A conventional Ethernet Local Area Network (LAN) using the TCP/IP protocol is used for communication between the base station and the base server as discussed above. Sockets, which are described next, are used as the high level communication protocol for communication between the base station and the base server. Sockets are also used for communication between the software objects which are used to implement the base station and the base server. Sockets provide flexibility in distributing the software across several hardware platforms. For example, a single PC can serve as the hardware platform for one or several base stations.

Material Tracking System Software

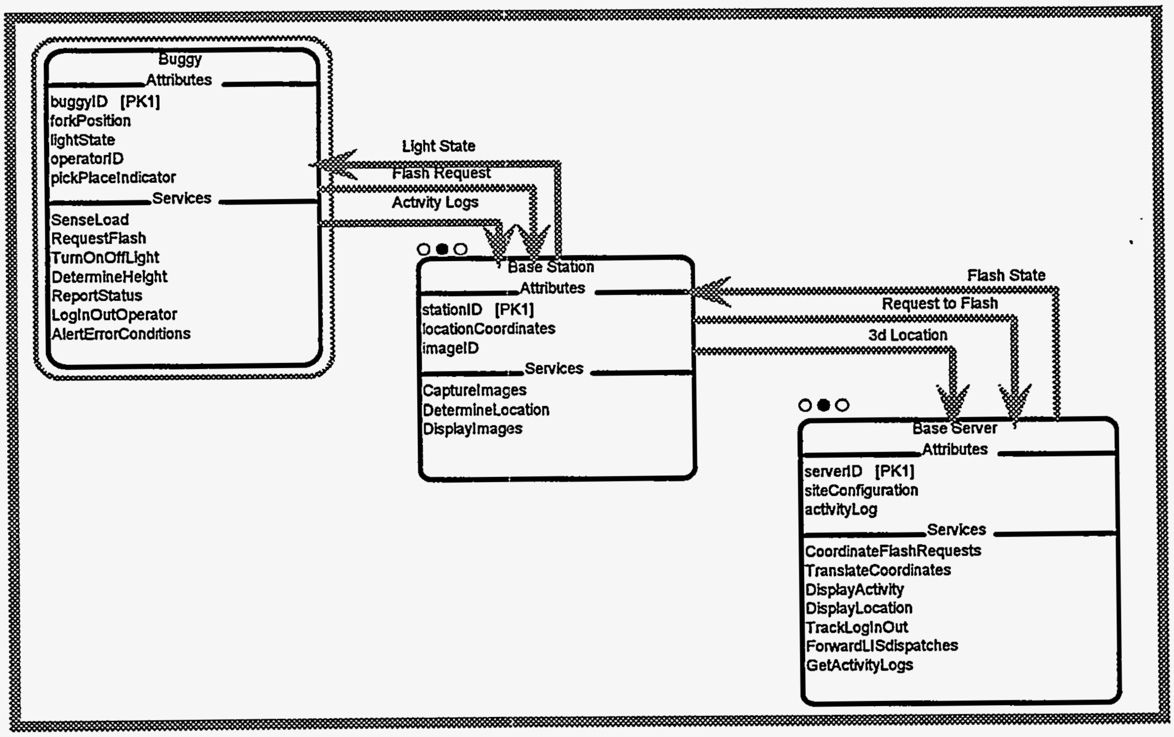


Figure 19. High level system software components for the pilot test system.

3.8.2 Software Operations

3.8.2.1 Initialization

A system initialization operation occurs whenever a system component, base server, base station, or lift truck electronics is powered up or resets. Since the various system components will power up asynchronously, initialization procedures must be structured to work with all possible initialization sequences. During initialization each system component will perform self-diagnostics to ensure that is functioning normally, then it will attempt to determine the status of other system components that it would normally communicate with. It will periodically attempt communications until the link is established with other system components. Once this link is established, normal operations can begin.

3.8.2.2 Normal Operations

Normal systems operations consist of performing three main functions:

1. Determining coil location whenever a coil is picked or placed.
2. Maintaining the operational status of system components.
3. Monitoring lift truck driver log on/log off activity.

3.8.2.3 Error Handling

Error handling consists of reporting any errors that occur during initialization procedures or normal operations and initiating the appropriate error reporting and recovery procedures.

3.8.3 Inter-Process Communications

3.8.3.1 Socket Description

The basic building block for communication between software objects in our implementation is the socket. A socket is an endpoint of communication to which a name may be bound. Each socket in use has a type and an associated process. Sockets exist within communication domains. A communication domain is an abstraction introduced to bundle common properties of threads communicating through sockets. Sockets normally exchange data only with sockets in the same domain (it may be possible to cross domain boundaries, but only if some translation process is performed). The Windows Sockets facilities support a single communication domain: the Internet domain, which is used by processes which communicate using the Internet Protocol Suite. (Future versions of this specification may include additional domains.)

3.8.3.2 Initialization

3.8.3.2.1 Base Server Initialization

The base server, as part of its initialization procedures, will attempt to communicate with each base station in the system. Once communications are established with a given base station, normal operations with that base station can begin. The base server will periodically attempt to communicate with base stations that have not yet responded. This will allow normal operations to automatically resume with base stations that are put back into service after maintenance without having to restart the base server.

3.8.3.2.2 Base Station Initialization

The base station, as part of its initialization procedures, will wait for the base server to communicate with it. Once communications are established with the base server, normal operations with that base station can begin.

3.8.3.2.3 Lift truck Electronics Initialization

The lift truck electronics, as part of its initialization procedures, will wait for a base station to communicate with it. Once communications are established with any base server, normal operations with the lift truck electronics can begin.

3.8.3.3 Normal Operations

This sections describes the general sequence of messages and the information they contain for each of the three operations, (coil location, status reporting , driver log on/log off), performed during normal system operations.

3.8.3.3.1 Base Server Normal Operations

Coil Location

1. Base server receives a message from one or more base stations that a pick or place operation has occurred. This message contains the lift truck ID and which type of operation (pick or place) has occurred.

2. Base server transmits to each base station that reported the lift truck pick or place message instructions to either determine the lift truck location or ignore this lift truck, i.e. the base server determines which base station should perform the lift truck location processing.

3. Base server receives a message from the base station that is determining the coil position. This message contains the coil X, Y, Z coordinates if successful and an error status if the location could not be determined.

Status Updates

1. Periodically, the base server will transmit requests for status to each base station in the system.

2. The base server will receive the status reply from each base station. Status information will include the status of the base station and the status of each lift truck electronics package that is in communications with that base station. Since more than one base station can be in contact with the same lift truck, the base server may receive duplicate status information on the lift truck electronics. Since the base station will time

stamp the lift truck status information, the base sever can determine which of the duplicate lift truck status information is the most current.

Driver Log on/Log off

1. The base server will receive a message from one or more base stations whenever a lift truck driver logs on or off. The message will include the lift truck ID and driver ID.

3.8.3.3.2 Base Station Normal Operation

Coil Location

1. Base station receives a message from the lift truck electronics that a pick or place operation has occurred. This message contains the lift truck ID and which type of operation (pick or place) has occurred.

2. Base station transmits that information to the base server.

3. Base station receives a message from the base server indicating if it should determine the lift truck location. If it should then this base stations proceeds with the following communications exchanges. If it should not, then no other communications occur during this operation.

4. Base station transmits to the lift truck electronics a sequence of messages to turn the lift truck lights on and off as required by the positioning algorithms. These messages contain information regarding which lights should be on and which should be off. The lift truck electronics acknowledges each message with status information indicating either success or an error status.

5. Base station transmits to the lift truck electronics a request for the lift height information.

6. Base station receives the lift height information or an error status.

7. Base station transmits the lift truck position or an error status to the base server.

Status Updates

1. Periodically, the base station will transmit requests for status to each lift truck electronics unit in the system.

2. The base station will receive the status reply from each lift truck electronics unit that is within its communications range. The status information will be time-stamped and stored in the base station and reported to the base server upon request.

3. Periodically, the base station will receive a request from the base server for status information.

4. The base station will respond by sending status information about itself and the most current status for each of the lift truck that are in communications with the base station. Since this status information is time-stamped, the base server can determine which base station has the most current lift truck status if more that one base station reports status for the same lift truck.

Driver Log on/Log off

1. The base station(s) will receive a message from the lift truck electronics whenever a lift truck driver logs on or off. This message will contain the driver ID.

3.8.3.3.3 Lift truck Electronics Normal Operations

Coil Location

1. Lift truck electronics transmits a message to all base stations that pick or place operation has occurred. This message contains the lift truck ID and which type of operation (pick or place) has occurred.

2. Lift truck electronics receives a sequence of messages from a base station to turn the lift truck lights on and off as required by the positioning algorithms. These messages contain information regarding which lights should be on and which should be off. The lift truck electronics acknowledges each message with status information indicating either success or an error status.

3. Lift truck electronics receives a message from the base station requesting the lift height position.

4. The lift truck electronics acknowledges this message by sending the lift height data or an error status

Status Updates

1. Periodically, the lift truck will receive a request for status from a base station.

2. The lift truck will transmit its current status to the requesting base station.

Driver Log on/Log off

1. The lift truck electronics will transmit to all base stations whenever a lift truck driver has logged on of off. The message will include the driver ID code used to log on.

3.8.3.4 Error Handling

3.8.3.4.1 Base Server Error Handling

1. The base server may receive error messages from the base station(s). Errors may include: hardware failures within the base station, failure to determine the lift truck position when requested, hardware failures within the lift truck electronics, or loss of communications between the base station and lift truck.

2. The base server will log all errors and notify the operator of the problem. Some errors, such as a loss of communications between lift truck and base station may only indicate that the lift truck has moved into an area covered by another base station. Status information from other base stations will allow the base server to determine if this has occurred.

3.8.3.4.2 Base Station Error Handling

1. The base station will determine the error status of the lift truck electronics by periodically polling the lift truck for their status as described above. Additionally, it will determine other error conditions through its own internal error checks.

2. The base station will transmit all error condition to the base server.

3.8.3.4.3 Lift truck Electronics Error Handling

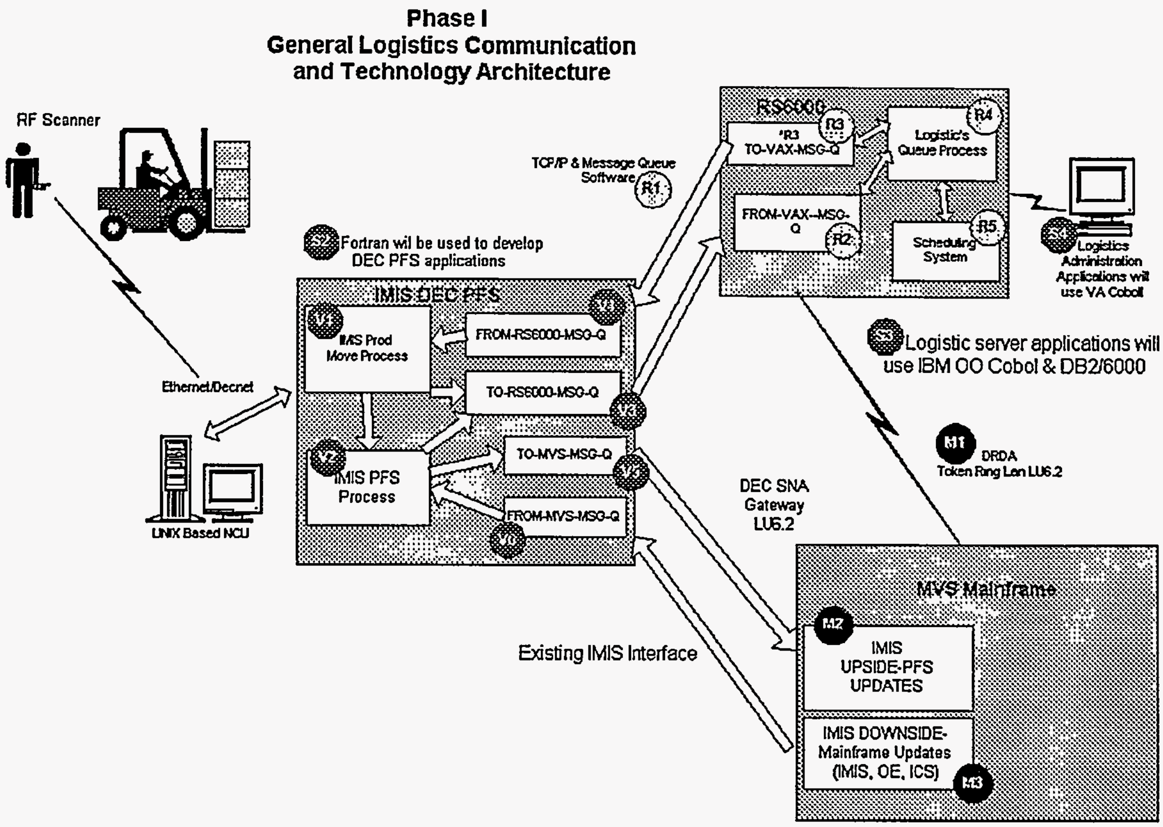
1. The lift truck electronics will maintain its operating status and the status of the lamp assemblies and other sensors.

2. The lift truck electronics will report any error conditions as part of the normal status polling messages to the base station as described above.

Appendix B

RF Network Configuration

PHASE 1 -- RF NETWORK CONFIGURATION



Phase 1 RF Network Configuration References

M1 Access to MVS DB2 databases from the RS6000 will be accomplished with the existing DRDA link. Additionally, in the future, message exchanges could be accomplished with IBM's MQ Series product.

M2 The IH80 CICS transaction receives messages from the VAX and invokes various CSP programs to process these messages.

M3 The IH83 CICS transaction is responsible for sending messages to the VAX.

R1 Message queuing software will be used for exchanging messages between the VAX and the RS6000 using TCP/IP as the transport protocol. DECmessageQ or IBM MQ Series software will be installed on both the VAX and the RS6000 to provide an easy way of exchanging messages with guaranteed message delivery.

R2 All messages transmitted from the VAX to the RS6000 are placed in FROM-VAX-MSG-Q.

R3 All messages transmitted from the RS6000 to the VAX are placed in TO-VAX-MSG-Q.

R4 The Logistics Q Processor program will read messages from FROM-VAX-MSG-Q and invoke the necessary program modules to process these messages. Messages to be sent back to the VAX will be placed in To-VAX-MSG-Q. Multiple instances of the Logistics Q Processor program can be started for processing messages in the From-VAX-MSG-Q; each instance of the program will be able to process messages for any Mover Computer. Each Logistics Q Processor instance will "hang" on a read to FROM-VAX-MSG-Q; this message will be deleted when the message has been successfully processed and a response message placed in TO-VAX-MSG-Q.

S2 The message handling application on the Vax will be developed in Fortran.

S3 The major portion of the Logistic System will be on the Risc environment and the applications will be written with IBM's OO Cobol. At this point we are moving forward with defining OO classes and implementation of them with this product. These applications will handle all messages from the crane operator for viewing requests, updates, and schedule interfaces.

S4 Logistic administration applications will be written with VA Cobol OS2 based. Some of these applications will be Movement Queue maintenance, i.e. adding rush orders, change the priority of the queue, etc.

V1 A separate process exists on the VAX for each Mover Computer to which it communicates. This process will be responsible for sending and receiving screens via the DecmessageQ and a message handling application to ship the mover message DecmessageQ defined for the RS6000. Therefore, the VAX is controlling the sending and receiving of messages to the Mover Computer via RF. Logistics back-end database processing - which will be performed on the RS6000 - will be invoked by this process by sending a message to the TO-RS6000-MSG-Q; responses from the RS6000 will be received in the FROM-RS6000-MSG-Q. In client/sever terms, the VAX acts as a terminal server & message handler for all of the Mover Computer clients, whereas the VAX is a client of the RS6000 Logistics database processes.

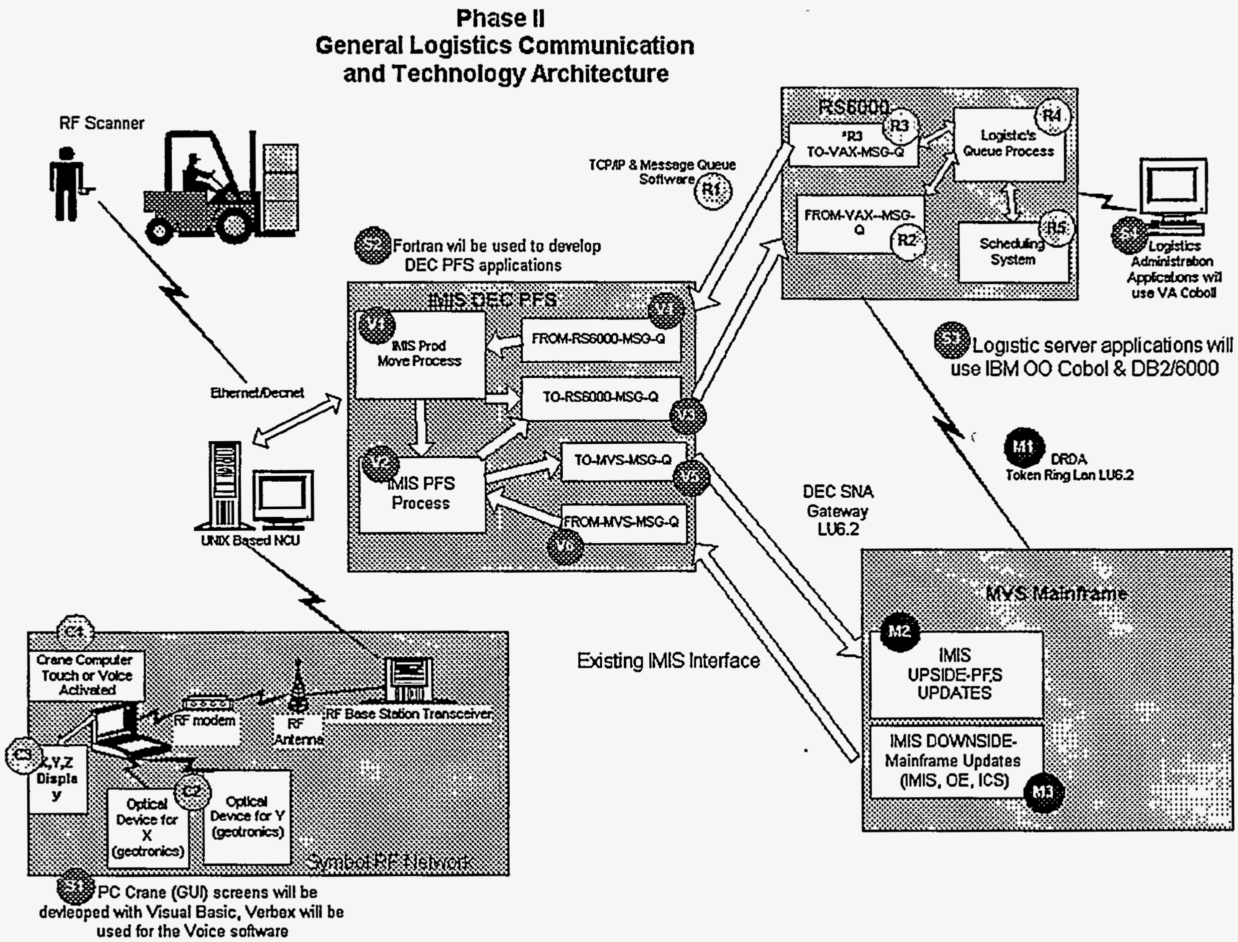
V2 The IMIS Plant Floor System process will send messages to TO-RS6000-MSG-Q (for production off of a unit) and to TO-MVS-MSG-Q (for various plant floor transactions); also, this process receives messages from MVS via FROM-MVS-MSG-Q and from the Move process for updates of locations and possible material moves rejected due to quality.

V3 All messages from the RS6000 are placed in the message queue FROM RS6000-MSG-Q.

V4 All messages to be sent to the RS6000 are placed in the message queue TO-RS6000-MSG-Q.

V5, V6 TO-MVS-MSG-Q and FROM-MVS-MSG-Q are used for exchanging messages with MVS.

PHASE 2 -- RF NETWORK CONFIGURATION



Phase 2 RF Network Configuration References

In addition to the components implemented in Phase 1, the following were implemented in Phase 2:

C1 The Mover Computer will communicate with the VAX (via RF modem) in the same way that an existing Symbol Terminal communicates with the VAX. Also, software written for the Mover Computer will enable access to the X, Y data values. Current plans are to use a PC based device with a 10-12" diagonal screen; both touch input and voice input will be supported. Voice commands will simulate a function key of the Visual Basic applications and will directly map to the commands that can be input via the touch interface.

C2, C3 Optical technology will be used for capturing the X and Y coordinates for the crane's position. For the #57 Crane they have decided on the geotronics devices.

S1 The crane operator screens will be developed with Visual Basic V4.0, this will be integrated with the voice interface which is Verbex for Windows. Visual Basic will also be used to format the messages to be transmitted via RF, poling the comports for X and Y values and translation of those value to their symbolic location.

Appendix C

MTS
Standard Operating Procedures
and RF User's Manual

TABLE OF CONTENTS

Page

SHEET MILL
Standard RF Operating Procedures

SECTION I--Standard RF Operating Procedures

I - Coils Enter The Sheet Mill Through The Black Coil Warehouse

1. The #23 Craneman will record the IPM number and locations of incoming coils by scanning railcar and truck tally sheets (faxed by the Strip Steel) and location bar codes (from a clipboard hung in the crane cab) with a LR hand scanner.

2. If the IPM cannot be scanned, the #23 Craneman will type the IPM number with the LR hand scanner.

3. If the IPM cannot be identified, the #23 Craneman will type an IPM number with seven zeroes with the LR hand scanner.

4. If the location cannot be scanned, the #23 Craneman will type in the location with the LR hand scanner.

5. When #23 Craneman retrieves a coil at the bottom of a double-stacked pile, the top coils should be placed within the same row or the #23 Craneman will type in the IPMs and their new locations.

6. The Junior Scheduler or another available SNE will maintain data integrity in the Black Coil Warehouse by recording numbers and locations of coils with ALR hand scanner as needed.

7. The charging unit, used to recharge the LR scanner, will be located at #5 Entry End Pulpit.

8. The #23 Craneman will be responsible for insuring that the LR scanner is properly charged.

9. When a coil is taken off the input conveyor (Backoffs), the #23 Craneman will type in the IPM and the IPMs new location).

II - Entry End Coils

1. The #23 Craneman will place a coil on the entry end of a Galvanize Line and The DEC Software will automatically record the default location of the coil as the input conveyor of that line.

III - Delivery End Coils

1. The DEC Software will automatically record the default location of the coil as the output conveyor that line.

2. The Operating Personnel on each line will continue to place a next operation sticker (e.g. Move to Packaging) on each coil. However, a Waster coil will be yellow-tagged by the Quality Operator.

3. The Operating Personnel on each line will apply a single large IPM bar code at the 12:00 position and the balance of the barcodes will be placed in a plastic bag on the coil.

4. The Lift Truck Operator will remove the coil from the line and move the coil to the next location where the coil will be scanned.

IV - Lift Truck Operator Scanning Prior to Packaging and/or Further Processing

1. The Lift Truck Operator will record the IPM number and new locations of coils by scanning the IPM barcode on the coil and location bar code signs with an XLR buggy scanner.

2. If the IPM cannot be scanned, the Lift Truck Operator will type the IPM number with the XLR buggy scanner.

3. If the location cannot be scanned, the Lift Truck Operator will type in the location with the XLR buggy scanner.

4. If the IPM cannot be identified, the Lift Truck Operator will type an IPM number with seven zeroes with the XLR scanner.

5. After a coil is removed from the Delivery End of the Galvanize Lines, the Lift Truck Operator will scan the new location based upon the following cases:

   A.) Prepackaged Coils
      a. Every coil placed in a Prepackaged Area (SMAB PREPKG) will be scanned by the Lift Truck Operator.
      b. Every coil placed in the Prepackaged Overflow Area (SMAB OVRFLW) will be scanned by the Lift Truck Operator.

   B.) Held Coils
      a. Every coil placed within the following Hold Locations will be scanned by the Lift Truck Operator:

Met Hold Area	(SMAB METHLD)
Process Control Hold Area	(SMAB PCHLD)
Slitter Hold Area	(SMBB SLTHLD)

   C.) Intermill Coils
      a. Every coil placed within the following intermill locations will be scanned by the Lift Truck Operator:

SMDB PAD	(D Building Intermill Pad Area)
SMDB IMSA1	(D Building Intermill Staging Area #1)
SMDB IMSA2	(D Building Intermill Staging Area #2)
SMDB IMSA3	(D Building Intermill Staging Area #3)
SMDB IMSA4	(D Building Intermill Staging Area #4)

6. After Slitter processing, coils in the SMBW BS4 (Beside #4 line) area will be moved by the Lift Truck Operator and will be either taken to Packaging , Prepackaging, Prepackaging Overflow, PC or MET Hold areas, or the D Building staging area (SMDB DBSA) if the coil is a Waster. The Lift Truck Operator will be responsible for scanning the new locations of these coils in all areas with the exception of Packaging.

V - Manual Scanning of Held & Further Processed Coils

1. Once a week, PC & QA departments will scan SMAB METHLD and SMAB PCHLD to insure integrity.
2. Any returned distressed material from customers will be assigned a location by the P.C. Department and/or the QA Department and will be scanned by the Lift Truck Operator.
3. Every Coil, within the hold areas, released as a Waster, will be yellow-tagged by the P.C. and/or Department.
4. Once a week, the Slitter Foreman will scan SMBB SLTHLD (Slitter Hold Area) to insure data integrity.

VI - Packaged Coil Procedures

1. The Packaging Checker will continue to place a move to location sticker (e.g. Move to C Building) on each coil. Additionally, the Packaging Checker will place a yellow-tag on every packaged coil tied on the shift.
2. Daily, at the end of the Packaging Checker's turn, the Packaging Checker will scan the unpackaged coils in the SMAB PKG area to insure data integrity.
3. The Packaging Checker will apply the large IPM barcode on the packaged coil at the 12:00 position and the two small IPM barcodes will be applied at the 10:00 and 2:00 positions.

VII - Scanning in the Staging Areas

1. Every Coil placed within the following staging areas will have a yellow-tag on the coil and the coil will be scanned by the Lift Truck Operator with the XLR buggy scanner:

B South Staging Area	SMBB SA1
B North Staging Area	SMBB SA2
C Staging Area #1	SMCB SA1
C Staging Area #2	SMCB SA2
D Staging Area	SMDB DBSA

2. Coils will be removed from their respective staging areas by crane and placed, with the yellow-tag in place to their final pre-shipped locations.

VIII - Manual Scanning by Warehouseman

1. The Warehouseman will record locations of yellow-tagged coils which have been backfilled from the various staging areas with an ALR hand held scanner.
2. If the IPM cannot be scanned, the warehouseman will type the IPM number with the LR hand scanner.
3. If the IPM cannot be identified, the Warehouseman will type an IPM number with seven zeroes with the LR hand scanner.

4. If the location cannot be scanned, the Warehouseman will type in the location with the XLR hand scanner.

5. After the yellow-tagged coils have been scanned with an ALR hand scanner, the warehouseman will remove and properly dispose the yellow-tags.

6. An additional duty in D-bldg will involve scanning intermill(Strip Steel-Tin Mill) weekly.

7. Every returned coil from the Strip Steel will be scanned with a Sheet Mill location.

8. An Additional duty in D-bldg will involve scanning Waster Area daily (yellow-tagged coils).

9. The warehouseman will continue to indicate, via the load bulletin sheet, which coils have been shipped.

10. An additional duty in B-bldg will involve scanning Sheets as the craneman places them SMBB NWSH (North Sheet Area) & SMBB SWSH (South Sheet Area).

11. The standard RF operating procedures, pertaining to the Warehouseman, will also apply to the Hookup and the Loader Checker as needed.

IX - Outbound Shipped Coils

1. The warehouseman will continue to indicate, via the load bulletin sheet, which coils have been shipped.

2. The Warehouseman will not scan outbound dock locations.

3. Craneman will not place a yellow-tagged coil on an outbound or intermill (Strip, Tin, FPW, River Docks) truck.

X - Slitter Operation Processing

1. The #23 Craneman will place a coil on the entry end of the Slitter and The DEC Software will automatically record the default location of the coil as the input conveyor of that line.

2. The DEC Software will automatically record the output conveyor as the default location of a coil processed by the Slitter.

3. The Slitter Hookup will continue to place a next operation sticker (e.g. Move to Packaging) on each coil. However, a Waster coil will be yellow-tagged by the Slitter Hookup.

4. The Slitterman Hookup will apply a single large IPM bar code at the 12:00 position and the balance of the barcodes will be placed in a plastic bag on the coil.

SECTION II--RF Backup Procedures

I - INOPERATIVE RF SYSTEM NOTIFICATION PROCEDURES

1. Lift Truck Operators and/or Warehouseman will notify the Sheet Mill's designated RF Expert User that the RF system is inoperative.

2. After inoperative RF system is verified, the Sheet Mill's designated RF Expert End User will implement the RF backup plan.

3. For further system outage verification and/or RF system repair the Sheet Mill's designated RF Expert End User will call Ext. 3405.

II - BACKUP LOCATION PROCEDURES WHILE RF SYSTEM IS INOPERATIVE

1. The #3 Line Quality Operator will place a yellow-tag on any Held (Met. or P.C.), Further Processed coil (Slitter, Strip Steel), or Waster produced on #3 Line.

2. The #4 Line Quality Operator will place a yellow-tag on any Held (Met. or P.C.), Further Processed coil (Slitter), or Waster produced on #4 Line.

3. The #5 Line Quality Operator will place a yellow-tag on any Held (Met. or P.C.), further processed coil (Slitter, Strip Steel, Tin Mill), or Waster produced on #5 Line.

4. The warehouseman will continue to indicate, via the load bulletin sheet, which coils have been shipped.

5. Cranemen will not place a yellow-tagged coil on an outbound or intermill (Strip, Tin, FPW, River Docks) vehicle.

6. The #23 Craneman will handwrite locations on the #22 Transfer Sheet and have the Galvanize Foreman deliver them to the Junior Scheduler.

7. The Junior Scheduler will enter coils entering Sheet Mill (Black Coil Warehouse) through IL30 Screen.

III - BACKUP LOCATION PROCEDURES WHEN RF SYSTEM IS BACK ON-LINE

1. The Sheet Mill's designated RF Expert End will notify lift truck operators, warehouseman, etc., that the RF system is functional.

2. The P.C. Department will scan any yellow-tagged coils in the P.C. Hold Areas.

3. The Met Department will scan any yellow-tagged coils in the Met Hold Areas.

4. The Slitter Foreman will scan any yellow-tagged coils in the Slitter Hold Areas.

5. The Warehouseman will hand scan the balance of yellow-tagged coils in their designated coil storage areas once the system is back on-line.

6. #3, #4, and #5 Lines will discontinue placing yellow-tags on coils (with the exception of Wasters).

7. Junior Scheduler will scan Black Coil Warehouse.

SECTION III--Jobs Utilizing New RF Technology And/Or Procedures

#23 Craneman

a. Record IPM number and locations of coils which enter the Sheet Mill via Railcar by scanning railcar tallies and location bar codes with LR hand held scanner.

b. Record IPM number and locations of coils which enter the Sheet Mill via Truck by scanning truck tallies and location bar codes with LR hand held scanner.

c. When #23 Craneman retrieves a coil at the bottom of a double-stacked pile, the top coils should be placed within the same row or the #23 Craneman will type in the IPMs and their new locations.

d. When RF system is down, #23 craneman will log the locations of incoming coils by hand and give the tally to the Junior Scheduler to input through the IL30 screen.

e. If the IPM cannot be scanned, the #23 Craneman will type the IPM number with the LR hand scanner.

f. If the IPM cannot be identified, the #23 Craneman will type an IPM number with seven zeroes with the LR hand scanner.

g. If the location cannot be scanned, the #23 Craneman will type in the location with the LR hand scanner.

h. The charging unit, used to recharge the LR scanner, will be located at #5 Entry End Pulpit.

i. The #23 Craneman will be responsible for insuring that the LR scanner is properly charged.

j. When a coil is taken off the input conveyor (Backoffs), the #23 Craneman will type in the IPM and the IPM's new location).

Junior Scheduler

a. The Junior Scheduler, or another available SNE, will maintain the data integrity in the Black Coil Warehouse by recording IPM numbers and locations of coils with ALR hand scanner as needed.

b. When RF system is down, Junior Scheduler will enter coils entering Sheet Mill through IL30 Screen.

c. When RF system is back on-line after an outage, the Junior Scheduler, or another available SNE, will scan the entire Black Warehouse with an ALR hand scanner.

Lift Truck Operators

a. Maintain data integrity of coils relocated within the Sheet Mill using XLR buggy scanners.

b. Lift Truck Operators should only scan coils within the following designated areas:
SMAB METHLD (Met Hold Area)

SMAB PCHLD	(PC Hold Area)
SMAB PREPKG	(Prepackaging Area)
SMAB OVRFLW	(Prepackaging Overflow Area)
SMCB SA1	(C Building #1 Staging Area)
SMCB SA2	(C Building #2 Staging Area)
SMBB SA1	(B Building South Staging Area)
SMBB SA2	(B Building North Staging Area)
SMDB SA1	(D Building Staging Area)
SMDB PAD	(D Building Intermill Pad Area)
SMDB IMSA1	(D Building Intermill Staging Area #1)
SMDB IMSA2	(D Building Intermill Staging Area #2)
SMDB IMSA3	(D Building Intermill Staging Area #3)
SMDB IMSA4	(D Building Intermill Staging Area #4)
SMBB SLTHLD	(B Building Slitter Hold Area)

c. The Lift Truck Operator will record the IPM number and new locations of coils by scanning IPM barcode on the coil and location bar code signs with an XLR buggy scanner.

d. If the IPM cannot be scanned, the Lift Truck Operator will type the IPM number with the XLR buggy scanner.

e. If the location cannot be scanned, the Lift Truck Operator will type in the location with the XLR buggy scanner.

f. If the IPM cannot be identified, the Lift Truck Operator will type an IPM number with seven zeroes with the XLR scanner.

g. After a coil is removed from the Delivery End of the Galvanize Lines, the Lift Truck Operator will scan the new location based upon the following cases:

1.) Prepackaged Coils
   a. Every coil placed in a Prepackaged Area (SMAB PREPKG) will be scanned by the Lift Truck Operator.
   b. Every coil placed in the Prepackaged Overflow Area (SMAB OVRFLW) will be scanned by the Lift Truck Operator.

2.) Held Coils
   a. Every coil placed within the following Hold Locations will be scanned by the Lift Truck Operator:

Met Hold Area	(SMAB METHLD)
Process Control Hold Area	(SMAB PCHLD)
Slitter Hold Area	(SMBB SLTHLD)

3.) Intermill Coils
   a. Every coil placed within the following intermill locations will be scanned by the Lift Truck Operator:

SMDB PAD	(D Building Intermill Pad Area)
SMDB IMSA1	(D Building Intermill Staging Area #1)
SMDB IMSA2	(D Building Intermill Staging Area #2)
SMDB IMSA3	(D Building Intermill Staging Area #3)
SMDB IMSA4	(D Building Intermill Staging Area #4)

h. After Slitter processing, coils in the SMBW BS4 (Beside #4 line) area will be moved by the Lift Truck Operator and will be either taken to Packaging , Prepackaging, Prepackaging Overflow, PC or MET Hold areas, or the D Building staging area (SMDB DBSA) if the coil is a Waster. The Lift Truck Operator will be responsible for scanning the new locations of these coils in all areas with the exception of Packaging.

#3, #4, & #5 LINE Quality Operators

a. The Quality Operator on each line will place a yellow-tag on every Waster coil produced on the line.

b. If the RF system is inoperative:

- The #3 Line Quality Operator will place a yellow-tag on any Held (Met. or P.C.), further processed coil (Slitter, Strip Steel), or Waster produced on #3 Line.
- The #4 Line Quality Operator will place a yellow-tag on any Held (Met. or P.C.), further processed coil(Slitter, or Waster produced on #4 Line.
- The #5 Line Quality Operator will place a yellow-tag on any Held (Met. or P.C.), further processed coil (Slitter, Strip Steel, Tin Mill), or Waster produced on #5 Line.

#3 LINE Piler

a. The #3 Line Piler will apply a single large IPM bar code at the 12:00 position and the balance of the barcodes will be placed in a plastic bag on the coil.

#4 LINE Quality Operator

a. The #4 Quality Operator will apply a single large IPM bar code at the 12:00 position and the balance of the barcodes will be placed in a plastic bag on the coil.

#5 LINE Delivery End Operator Helper

a. The #5 Delivery End Operator Helper will apply a single large IPM bar code at the 12:00 position and the balance of the barcodes will be placed in a plastic bag on the coil.

#15 Craneman

a. Do not place a yellow-tagged coil on an outbound or intermill (FPW, River Docks) truck.

b. Do not place a yellow-tagged coil on an outbound railcar or river railcar (River Docks).

#14 Craneman

a. Do not place a yellow-tagged coil on an outbound or intermill (FPW, River Docks) truck.

#8 Craneman

a. Do not place a yellow-tagged coil on an outbound or intermill (FPW, River Docks) truck.

#2 Craneman

a. Do not place a yellow-tagged coil on an outbound or intermill (Strip, Tin, FPW, River Docks) truck.

#3 Craneman

a. Do not place a yellow-tagged coil on an outbound or intermill (Strip, Tin, FPW, River Docks) truck.

Packaging Checker

a. The Packaging Checker will continue to place a move to location sticker (e.g. Move to C Building) on each coil. Additionally, the Packaging Checker will place a yellow-tag on every coil tied on the shift.

b. Daily, at the end of the Packaging Checker's turn, the Packaging Checker will scan the unpackaged coils in the SMAB PKG area to insure data integrity.

c. When the RF system is back on-line after an outage, the Packaging Checker will scan all yellow-tagged coils in SMAB PREPKG and SMAB OVRFLW areas.

d. The Packaging Checker will apply the large IPM barcode on the packaged coil at the 12:00 position
and the two small IPM barcodes will be applied at the 10:00 and 2:00 positions.

Warehouseman B-C-D-Bldg.

a. Record IPM number and locations of yellow-tagged coils which have been backfilled from the various staging areas with an ALR hand held scanner.

b. After the yellow-tagged coils have been scanned with an ALR hand scanner, the will remove and properly dispose the yellow-tags.

c. An Additional duty in D-bldg will involve scanning intermill(Strip Steel-Tin Mill) weekly.

d. Any returned coils from the Strip Steel will be scanned with a Sheet Mill location.

e. An Additional duty in D-bldg will involve scanning Waster Area daily.

f. If RF system went down, the warehouseman will hand scan the balance of yellow-tagged coils in their designated coil storage areas once the system is back on-line. (including staging areas).

g. The warehouseman will continue to indicate, via the load bulletin sheet, which coils have been shipped.

h. An additional duty in B-bldg. will involve scanning Sheets as the craneman places them in SMBB NWSH (North Sheet Area) & SMBB SWSH (South Sheet Area).

Hookups

a. The Hookups will have the same RF duties as the Warehouseman.

Loader Checker

a. The Loader Checker will be required to perform the same RF duties as the Warehouseman and Hookup as needed.

Slitter Operation

a. If the RF system went down, the Slitter Foreman will hand scan the balance of yellow-tagged coils in SMBB SLTHLD (Slitter Hold Area) once the system is back on-line.

b. Once a week, the Slitter Foreman will scan SMBB SLTHLD (Slitter Hold Area) to insure data integrity.

c. The Slitter Hookup will continue to place a move to location sticker on each coil. However, a Waster coil will be yellow-tagged by the Slitter Hookup.

d. The Slitterman Hookup will apply a single large IPM bar code at the 12:00 position and the balance of the barcodes will be placed in a plastic bag on the coil.

Process Control Department & QA Department

a. If the RF system went down, the PC & QA departments will hand scan the balance of yellow-tagged coils in SMAB PCHLD (PC Hold Area) and SMAB METHLD (Met Hold Area) once the system is back on-line.

b. Once a week, PC & QA departments will scan SMAB METHLD and SMAB PCHLD to insure data integrity

c. Any returned distressed material from customers will be assigned a location by the P.C. Department and/or QA Department and will be scanned by the Lift Truck Operator.

d. Every Coil, within the hold areas, released as a Waster, will be yellow-tagged by the P.C. and/or QA Department.

STRIP STEEL
Standard RF Operating Procedures

#7 TANDEM AREA

SECTION I--Standard RF Operating Procedures

I Coils Received into #7 Tandem Storage Area

1. All coils entering #7 Tandem Mill from other locations will have an IPM Sticker placed on the coils. The IPM number will be spray painted on the outside lap at the one (1) o'clock position. The letters will be large enough to be readable from the crane.

2. Coils received by means of Lift Trucks or Tractors will be updated by the Floating Expert End User using RF hand scanners.

3. Coils coming into this area from #33 Slitter will have a White Tag indicating that the coil needs scanned and the location updated in inventory.

II Frequency of Scanning

1. Scanning Locations - Coils will be scanned in the following areas:
   SSC7..0001 - 0021
   SSTRK14..0022 - 0160
   SSTRK14.REJ
   SSTRK14.SA
   SSTRK14.CANT
   SSB3.SAO1
   SSB3.SAO1

2. Scanning Frequency -

A. **White Tag Coils** - Coils will be scanned immediately

III Coils Returned to #7 Tandem Mill

1. Material returned to #7 Tandem from down stream units will be scanned into inventory by the Hook-Up.

IV Coils Removed from 7 Tandem Mill

1. Coils removed from the Entry End of the mill will have the IPM Number painted onto the outside lap at the one (1) o'clock position and scanned into the RF System by the hook -up.

V. Floating Expert End User

1. As determined by the supervisor the Floating Expert End User will use a hand held unit to check inventories.

2. The Floating Expert End user is responsible for insuring that the scanner is working properly.

3. Batteries for the hand held unit will be located in the Turn Supervisors Office.

VI. Supervisor Responsibilities

1. If the situation warrants or it is determined because of a time element the Turn Supervisor will

SECTION II--RF Back Up Procedures

I Inoperative RF System Notification Procedures

1. All operators of RF Equipment will notify the Strip Steel's designated RF Expert End User that the RF System is inoperative.

2. After inoperative system is verified, the Strip Steel's designated RF Expert End User will implement the RF backup plan.

3. For further system outage verification and/or RF system repair the Strip Steel's designated RF Expert End User will call Ext. *3405.*

II Back Up Location Procedures While RF System Is Inoperative

1. The hook up/bundler will place a white tag on any coils produced off of #8 Tandem for scanning after the system is backup on line.

2. If coils are moved by Buggy from one area to another area (other than row to row) the Buggy Operator will note rows in which coils are placed. These coils will be scanned at first opportunity.

III Back Up Location Procedures When RF System Is Back On Line

1. If the General Supervisor or Superintendent of Operations determines that the system has been down for a long enough period to adversely affect the integrity of inventories, additional people will be assigned to the areas to update inventories to an accurate level.

2. If the General Supervisor or Superintendent of Operations determines that the system was down but inventories where not adversely affected but needs only updated it is the responsibility of people in assigned areas to perform the scanning. Scanning by means of voice citation and/or hand scanners as defined by jobs and assigned equipment.

SECTION III - Jobs Utilizing RF Technology

Floating Expert End User

A. Record IPM Number and location of coils whose next" actual op." is 7 Tandem. Coils either at 7 Tandem or in other storage areas.

B. If IPM Number can not be scanned, the Floating Expert End User will type the IPM number with the hand scanner key pad.

C. If the location can not be scanned the Floating Expert End User will type the location with the scanner key pad.

D. If the IPM Number can not be identified the Floating Expert End User will type the IPM number with seven zeros using the hand scanner.

E. If the location cannot be identified the Floating Expert End User will type in seven zeros for the location of the coil using the hand scanner.

F. The Floating Expert End User will take a total floor inventory at least once a week.

G. The Floating Expert End User is responsible for insuring that the scanner is properly charged.

H. The charging unit will be located in the Turn Supervisor's office.

Turn Supervisor

A. Record IPM Number and location of coils whose next" actual op." is #8 Tandem. Coils either at #8 Tandem or in other storage areas.

B. If IPM Number can not be scanned, the Supervisor will type the IPM number with the hand scanner key pad.

C. If the location can not be scanned the Supervisor will type the location with the scanner key pad.

D. If the IPM Number can not be identified the Supervisor will type the IPM number with seven zeros using the hand scanner.

E. If the location cannot be identified the Supervisor will type in seven zeros for the location of the coil using the hand scanner.

F. The Supervisor is responsible for insuring that the scanner is properly charged.

G. The charging unit will be located in the Turn Supervisor's office.

#8 TANDEM AREA

SECTION I--Standard RF Operating Procedures

I Coils Received into #8 Tandem Storage Area

1. All coils entering #8 Tandem Mill from other locations will have an IPM Sticker placed on the coils. The IPM number will be spray painted on the outside lap at the one (1) o'clock position. The letters will be large enough to be readable from the crane.

2. Coils received by means of Lift Trucks or Tractors will be updated by the #8 Tandem Hookup using RF hand scanners.

3. Coils coming into this area from #33 Slitter will have a White Tag indicating that the coil needs scanned and the location updated in inventory.

II Frequency of Scanning

1. Scanning Locations - Coils will be scanned in the following areas:
   SSLEE..0001-0018
   SSC8..0001-0036
   SSC8.SAI
   SSC8.SAO1
   SSC8.SAO2
   SSB5.SAO1
   SSB5.SAO2
   SSB5.SAO3

2. Scanning Frequency - **To Be Determined**

   A. **White Tag Coils -** Coils will be scanned immediately

III Coils Returned to #8 Tandem Mill

1. Material returned to #8 Tandem from down stream units will be scanned into inventory by the Hook-Up.

IV Coils Removed from #8 Tandem Mill

1. Coils removed from the Entry End of the mill will have the IPM Number painted onto the outside lap at the one (1) o'clock position and scanned into the RF System by the hook -up.

V - Held Coils from #8 Tandem Mill

1. If Coils run across #8 Tandem are held and placed in a #8 Tandem location, the supervisor will scan these coils with a hand held unit.

VI Floating Expert End User

1. As determined by the supervisor, the Floating Expert End User will use a hand held unit to check inventories.

2. The Floating Expert End user is responsible for insuring that the scanner is working properly.

3. Batteries for the hand held unit will be located in the Turn Supervisors Office.

VII Supervisor Responsibilities

1. If the situation warrants or it is determined because of a time element the Turn Supervisor will assist the Hook -Up in scanning of the inventory.

SECTION II--RF Back Up Procedures

I Inoperative RF System Notification Procedures

1. All operators of RF Equipment will notify the Strip Steel's designated RF Expert End User that the RF System is inoperative.

2. After inoperative system is verified, the Strip Steel's designated RF Expert End User will implement the RF backup plan.

3. For further system outage verification and/or RF system repair the Strip Steel's designated RF Expert End User will call Ext. ***3405.***

II Back Up Location Procedures While RF System Is Inoperative

1. The hook up/bundler will place a white tag on any coils produced off of #8 Tandem for scanning after the system is backup on line.

2. If coils are moved by Buggy from one area to another area (other than row to row) the Buggy Operator will note rows in which coils are placed. These coils will be scanned at first opportunity.

III Back Up Location Procedures When RF System Is Back On Line

1. If the General Supervisor or Superintendent of Operations determines that the system has been down for a long enough period to adversely affect the integrity of inventories, additional people will be assigned to the areas to update inventories to an accurate level.

2. If the General Supervisor or Superintendent of Operations determines that the system was down but inventories where not adversely affected but needs only updated it is the responsibility of people in assigned areas to perform the scanning. Scanning by means of voice citation and/or hand scanners as defined by jobs and assigned equipment.

SECTION III--Jobs utilizing RF technology

Hook Up / Bundler

A. Record IPM Number and location of coils whose next" actual op." is #8 Tandem. Coils either at #8 Tandem or in other storage areas.

B. If IPM Number can not be scanned, the Hook-Up/Bundler will type the IPM number with the hand scanner key pad.

C. If the location can not be scanned the Hook-Up/Bundler will type the location with the scanner key pad.

D. If the IPM Number can not be identified the Hook Up-Bundler will type the IPM number with seven zeros using the hand scanner.

E. If the location cannot be identified the Hook-Up/Bundler will type in seven zeros for the location of the coil using the hand scanner.

F. The Hook-Up/ Bundler will take a total floor inventory at least once a week.

G. The Hook Up/Bundler is responsible for insuring that the scanner is properly charged.

H. The charging unit will be located in the Turn Supervisor's office.

Turn Supervisor

A. Record IPM Number and location of coils whose next" actual op." is #8 Tandem. Coils either at #8 Tandem or in other storage areas.

B. If IPM Number can not be scanned, the Supervisor will type the IPM number with the hand scanner key pad.

C. If the location can not be scanned the Supervisor will type the location with the scanner key pad.

D. If the IPM Number can not be identified the Supervisor will type the IPM number with seven zeros using the hand scanner.

E. If the location cannot be identified the Supervisor will type in seven zeros for the location of the coil using the hand scanner.

F. The Supervisor is responsible for insuring that the scanner is properly charged.

G. The charging unit will be located in the Turn Supervisor's office.

#9 TANDEM AREA

SECTION I--Standard RF Operating Procedures

I. Coils Received into #9 Tandem Storage Area

1. All coils entering #9 Tandem Mill from other locations will have an IPM Sticker placed on the coils. The IPM number will be spray painted on the outside lap at the one (1) o'clock position. The letters will be large enough to be readable from the crane.

2. Coils coming into this area from an out-of-line operation will have a white tag indicating that the coil needs scanned and the location updated in inventory. The Hookup/Bundler will use the RF Hand Scanner to update the inventory in this area.

3. When the coils are 'Backed-off' the entry end of the mill the Hookup/Bundler or Supervisor will:
   - paint the IPM number on the outside lap at 1 o'clock position
   - scan IPM and location

II. Scanning Frequency Summary

1. **White Tag Coils** - Coils will be scanned immediately after they are set on the floor.

2. No regular scanning will take place on the entry or delivery ends unless conditions are warranted.

III. Supervisor Responsibilities

1. As needed, the Turn Supervisor will assist the Hookup/Bundler in scanning of the #9 Tandem inventory. Ultimately, it is the Turn Supervisor's responsibility to insure accurate inventory and maintain all RF Equipment in his area.

SECTION II--RF Back Up Procedures

Inoperative RF System Notification Procedures

1. All operators of RF Equipment will notify the Strip Steel's designated RF Expert End User that the RF System is inoperative.

2. After inoperative system is verified, the Strip Steel's designated RF Expert End User will implement the RF backup plan.

3. For further system outage verification and/or RF system repair the Strip Steel's designated RF Expert End User will call Ext. *3405*

Back Up Location Procedures While RF System is Inoperative

1. No white tags should be removed from incoming coils.

Back Up Location Procedures When RF System is Back On-line

1. All white tagged coils should be scanned, and the white tags removed.

2. If the General Supervisor or Superintendent of Operations determines that the system has been down for a long enough period to adversely affect the integrity of inventories, additional people will be assigned to the areas to update inventories to an accurate level.

SECTION III - Jobs Utilizing RF Technology

I. Hookup/Bundler

1. Record the IPM Number and location of all white tagged coils. Coils will be either at #9 Tandem or in other storage areas. After scanning the coil, the white tag should be removed.

2. If IPM Number can not be scanned, the Hookup/Bundler will type the IPM number with the hand scanner key pad.

3. If the location can not be scanned the Hookup/Bundler will type the location with the scanner key pad.

4. If the IPM Number can not be identified the Hookup/Bundler will type the IPM number with seven zeros using the hand scanner.

5. If the location cannot be identified by the Hookup/Bundler, he should contact the Expert End User.

6. The Hookup/Bundler is responsible for insuring that the scanner is returned to the charging unit located in the Turn Supervisor's office.

II. Turn Supervisor

1. As needed, the Turn Supervisor will assist the Hookup/Bundler in scanning of the #9 Tandem inventory. Ultimately, it is the Turn Supervisor's responsibility to insure accurate inventory and maintain all RF Equipment in his area.

2. The Supervisor is responsible for insuring that the scanner is properly charged.

#8 SKIN MILL AREA

SECTION I--Standard RF Operating Procedures

I Coils Received into #8 Skin Mill Storage Area

1. The Turn Foreman will have the capability to scan coils for #8 Skin Mill as needed.

SECTION II--RF Back Up Procedures

I Inoperative RF System Notification Procedures

1. All operators of RF Equipment will notify the Strip Steel's designated RF Expert End User that the RF System is inoperative.

2. After inoperative system is verified, the Strip Steel's designated RF Expert End User will implement the RF backup plan.

3. For further system outage verification and/or RF system repair the Strip Steel's designated RF Expert End User will call Ext. ***3405.***

SLITTER AREA

SECTION I--STANDARD RF OPERATING PROCEDURES

I Coils Entering Wire Gang, Slitter, Combo and Warehouse Areas

1. All coils entering Wire Gang, Slitter, Combo and Warehouse areas from other locations will have a white tag attached.

2. The Buggy Driver will record the IPM number and locations of incoming coils by using voice activation, the IPM Sticker and Bar Code Location using Voice Activation Units.

3. If the IPM can not be voice activated the Buggy Driver will type in the IPM Number using the touch pad on the Voice Activation Unit.

4. If the IPM cannot be identified the Buggy Driver will type in IPM number with seven zeroes using the touch pad on the Voice Activation Unit.

5. If the location can not be voice activated the Buggy Driver will type the location with the touch pad on the Voice Activation Unit.

6. The Buggy Driver will be responsible for insuring that the Voice Activation Unit is properly charged.

7. The charging unit and spare batteries will be located in the Shipping Office at 2 Track.

8. The Yield and Scrap Expediter will scan all Hot Roll and Hold Coils entering the area with a white tag attached.

9. Once a week the Crew Chief along with the Yield and Scrap Expediter will take a total floor inventory.

10. Any material returned to area from customers will have a location assigned to it by the operator moving the material into storage.

II- Delivery End of Slitter

1. The DEC Software will automatically record the default location of the coil when the new M2 IPM Number is assigned and entered into IMIS.

2. The Hook -Up will remove the coil to the default location after the sticky back IMP Number has been placed on the coil .

3. The lift truck operator will input the M2 IPM Number and new location after placing the coil in the proper storage area.

4. If the IPM Number cannot be identified the lift truck operator will type in an IPM Number with seven zeros.

5. If the location can not be identified then the lift truck operator will type in the location with seven zeros.

SECTION II-RF Back Up Procedures

I - Inoperative RF System Notification Procedures

1. All operators of RF Equipment will notify the Strip Steel's designated RF Expert End User that the RF System is inoperative.

2. After inoperative system is verified, the Strip Steel's designated RF Expert End User will implement the RF backup plan.

3. For further system outage verification and/or RF system repair the Strip Steel's designated RF Expert End User will call Ext. 3405.

II Back Up Location Procedures While RF System Is Inoperative

1. The Slitter Delivery End Helper will place a white tag on any coils produced at the slitter for scanning after the system is backup on line.

2. If coils are moved by Buggy from one area to another area (other than row to row) the Buggy Operator will note rows in which coils are placed. These coils will be scanned at first opportunity.

3. The Shipper and/or the Loader will continue to indicate, via the load bulletin sheet and intermill loading forms, which coils have been shipped.

4. 54 Craneman will note coils moved from row to row to be entered into system when back on line.

SECTION III - JOBS UTILIZING RF TECHNOLOGY

Yield & Scrap Expediter

a. Record IPM number and location of coils entering Wire Gang, Combo, Slitter, and Warehouse areas by scanning bar codes with hand scanner.

b. If IPM number can not be scanned, the Yield & Scrap Expediter will type the IPM number with the hand scanner .

c. If the location can not be scanned the Yield & Scrap Expediter will type in the location using the hand scanner.

d. If the IPM number cannot be identified the Yield & Scrap Expediter will type in the IPM number with seven zeros using the hand scanner.

e. If the location cannot be identified the Yield & Scrap Expediter will type in seven zeros for the location of the coil using the hand scanner.

f. The Yield & Scrap Expediter will take a total floor inventory once a week.

g. The Yield & Scrap Expediter is responsible for insuring that the scanner is properly charged.

h. The charging unit will be located in the Yield & Scrap Expediter's office.

Crew Chief

a. Record IPM number and location of coils entering Wire Gang, Combo, Slitter, and Warehouse areas by scanning bar codes with hand scanner.

b. If IPM number can not be scanned, the Crew Chief will type the IPM number with the hand scanner.

c. If the location can not be scanned the Crew Chief will type in the location using the hand scanner.

d. If the IPM number can not be identified the Crew Chief will type in the IPM number with seven zeros using the hand scanner.

e. If the location can not be identified the Crew Chief will type in seven zeros for the location of the coil using the hand scanner.

f. The Crew Chief will take a total floor inventory once a week.

g. The Crew Chief is responsible for insuring that the scanner is properly charged.

h. The charging unit will be located in the Crew Chief's office.

Slitter Hook - Up

a. Record IPM numbers and location of coils entering Slitter building by scanning bar codes with hand scanner.

b. If IPM number can not be scanned, the Hook-Up will type in the IPM number using the hand scanner.

c. If the location can not be scanned, the Hook-Up will type in the location using the hand scanner.

d. If the IPM number can not be identified, the Hook-Up will type in seven zeros for the IPM number using the hand scanner.

e. If the Location can not be identified, the Hook-Up will type in seven zeros for the location of the coil using the hand scanner.

f. When a coil is backed off the slitter the Hook-Up will record the IPM number and location of the coil using the hand scanner when it is removed.

g. The Hook-Up is responsible for insuring that the scanner is fully charged.

h. The charging unit will be located at the Slitter.

Loader

a. Record IPM numbers and location of coils being shipped Intermill or Out Bound via load bulletin sheet or list supplied by Operation Planning.

b. If IPM number cannot be scanned, the Loader will type in the IPM number using the hand scanner.

c. If the location cannot be scanned the Loader will type in the location using the hand scanner.

d. The Loader is responsible for insuring the scanner is properly charged.

e. The charging unit will be located in the Shipper's office.

Lift Truck Operators

a. Record IPM numbers and Location of coils entering or inventory moved within Wire Gang, Combo, Slitter, and Warehouse areas using Voice Activated Units.

b. If the IPM number cannot be entered using voice activation, the buggy operator will enter the IPM number using the touch pad.

c. If the IPM number cannot be identified, the buggy operator will enter seven zeros for the IPM number using the touch pad.

d. If the location cannot be entered using the voice activation, the buggy operator will enter the location using the touch pad.

e. If the location cannot be identified, the buggy operator will enter seven zeros for the location using the touch pad.

f. The buggy operator is responsible for insuring that the Voice Activation Unit is properly charged.

g. The charging unit will be located in the Shipper's office.

Finished Product Warehouse
Standard RF Operating Procedures

SECTION I--Equipment Procedures

1. All spare RF equipment is to be stored in the RF Equipment Room located in the FPW office area.

2. Lift truck drivers are responsible for keeping their lift trucks equiped with a functioning RF unit. This could be a buggy mount or hand held unit.

3. RF operators (warehousemen -- lift truck operators) experiencing problems are to reference the "RF Trouble Shooting Guide" in an attempt to remedy a problem before returning a unit to the equipment room for a replacement.

4. Equipment in need of repair is to be returned to the RF Equipment Room by the user of the equipment with a note attaced describing the problem.

5. Buggie mounts are to be attached to the transformers located in the equipment when returned to the RF Equipment Room.

6. When changing the battery in a hand held unit, the battery is to placed into a charger and put on "Charge."

SECTION 2--Material Received Intermill

1. The warehousemen responsible for receiving intermill material will inspect each coil for proper bar coding.

2. Bar codes are to be attached at approximately the 10:00 and 2:00 areas on rolling posiiton coils and at approximately the 11:00 and 1:00 areas on skidded coils.

3. Warehousemen will attach proper bar coding to coils which do not meet standards. Bar codes will be produced by the warehouseman on the Monarch portable bar code printer.

4. Should the number of coils that need to be bar coded become excessive, the warehouseman will notify the crew chief or foreman on turn. They will make the decision to continue to receive this material or to return it to its origin.

5. In the event that a bar code cannot be scanned regardless of reason and the coil ID can be determined, the lift truck driver will type the number into the RF system.

6. If no indentification can be determined, the lift truck driver will scan the "0000000" bar code on the lift truck along with the location bar code.

7. Should there be reason to inventory a coil in a location where the location is not bar coded, the nearest bar coded location is to be used.

SECTION 3--Material Movement Within Warehouse (after initial location assigned)

1. Material that is changing location beyond the limits of a warehouse column or across an aisle must have the new location scanned.
2. If for any reason a bar code scan is not possible but the coil identification can be determined, the ID will be typed into the RF system by the lift truck driver.
3. If for any reason a bar code cannot be scanned and identification cannot be determined, the lift truck driver will scan the "0000000" bar code located on the lift truck along with the location.
4. Should there be reason to inventory a coil in a location where no bar code location exists, the nearest bar coded location is to be used.

SECTION 4--Error Correction Procedures

1. Error reports with the unidentifiable ("0000000") coils and the locations associated with each will be printed to the laser printer in the clerk's office area at 4:00 am, 12:00 pm and 8:00 pm each day. The individual reports will contain the errors for that given turn only. The reports will be distributed to the warehousemen by the crew chief.

2. Using the error report as a guide, each warehouseman is to scan the complete row of any location showing a coil ID of "0000000." If necessary, the coils are to be bar coded to standard. This will be done on a turn by turn basis.

SECTION 5--Recording When RF is Inoperative

1. Foreman or crew chief on turn is to be notified of RF problem. This person will verify with the trouble desk (ext. 3405) that the system is experiencing an outage.

2. All moves requiring a scan will be manually recorded by the lift truck drivers. Only the RF location needs to be recorded. No recording of coil ID will be necessary.

3. When the RF is back on line, the lists of locations are to be updated by scanning the locations and all the coils in these rows to ensure integrity of inventory.

4. Should the system remain down beyond any given turn, the manually recorded locations are to be passed to the next turn crew chief. When the RF is back on line, the accumulated lists will be distributed by the crew chief to the buggy drivers and warehouseman for updating. All the coils in any given row must be scanned to ensure integrity of inventory.

5. Completed lists are to be returned to the foreman's office.

Appendix D

MTS User Screens

TABLE OF CONTENTS

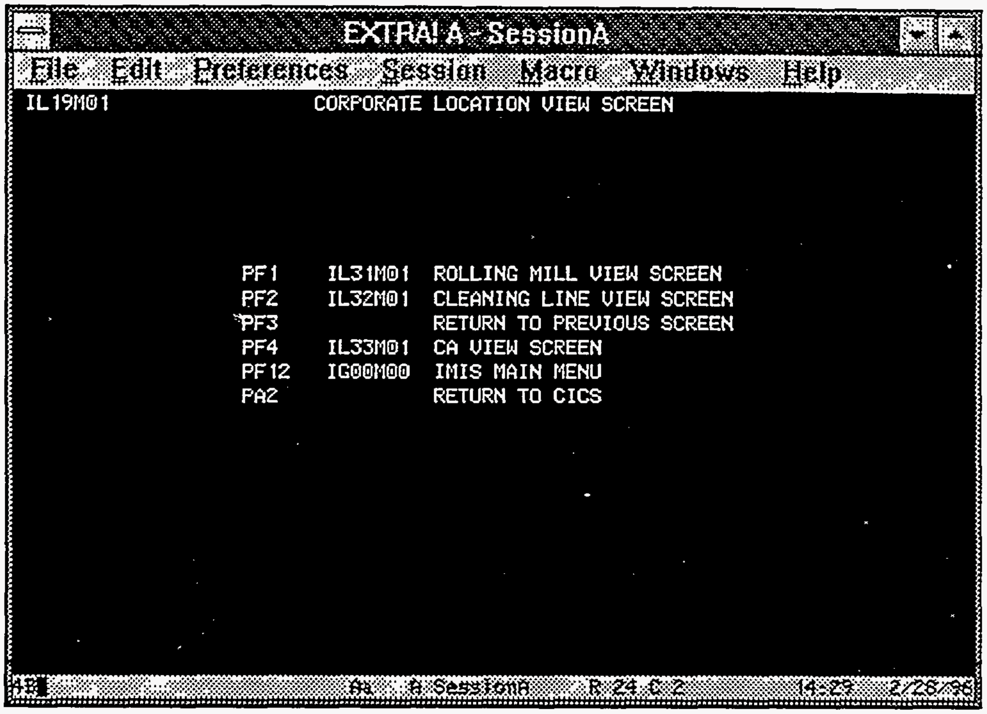
Page

MTS Phase I Screens

MTS Phase II Screens

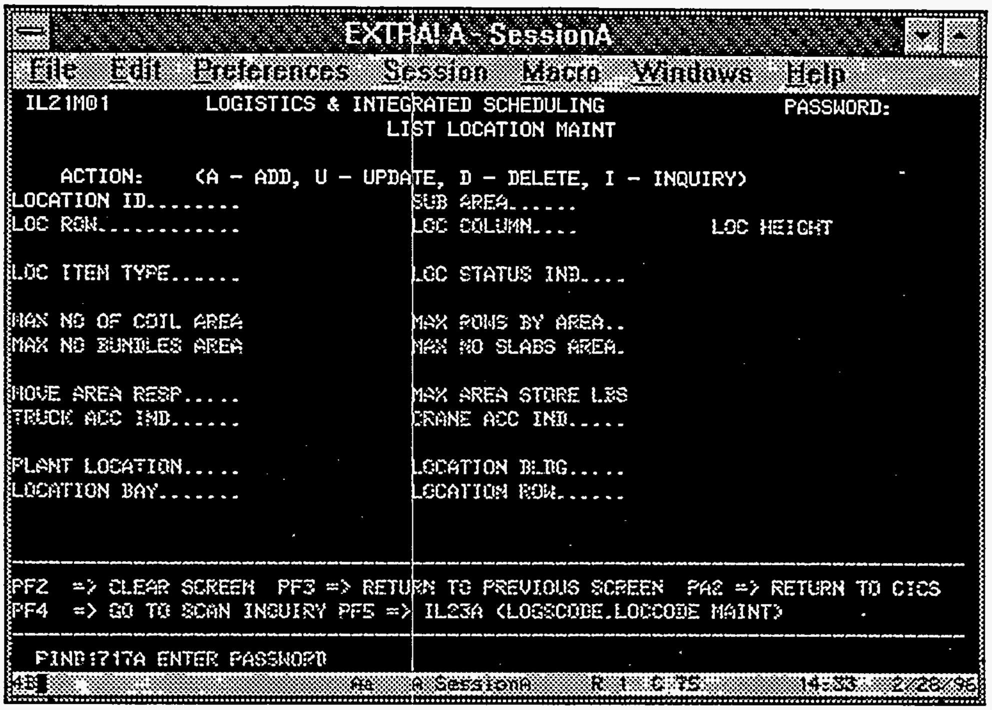
Intermill Transfer Crane Screens

(IL19M01) Corporate Location View Menu



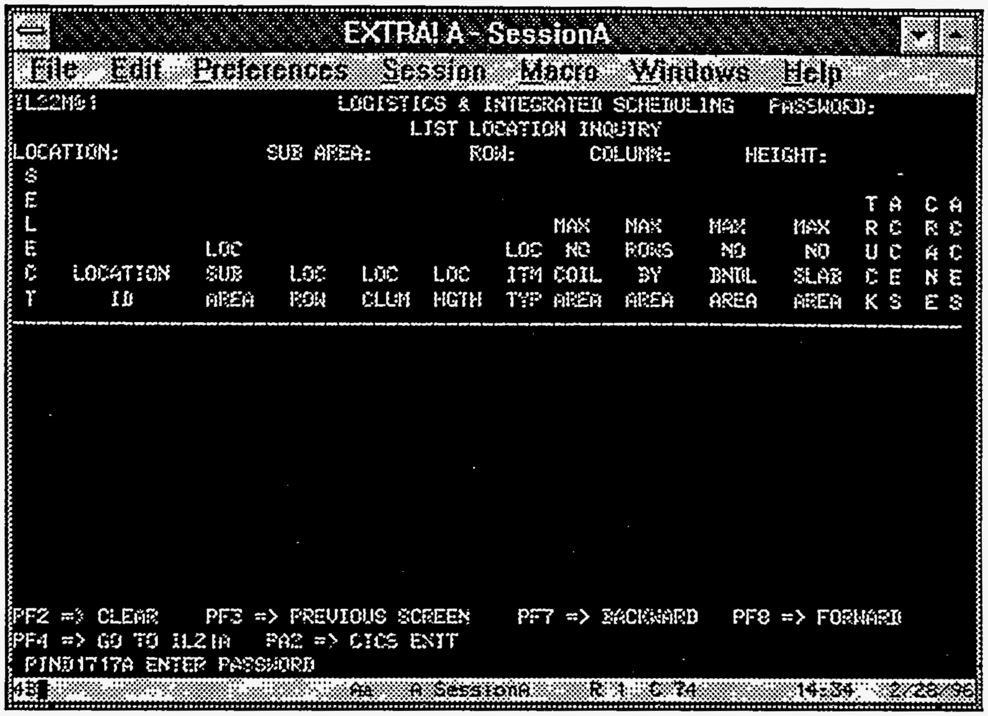
IL19M00 serves as the main menu for the Tin Mill Material Tracking System.

(IL21M01) List Location Maintenance Screen



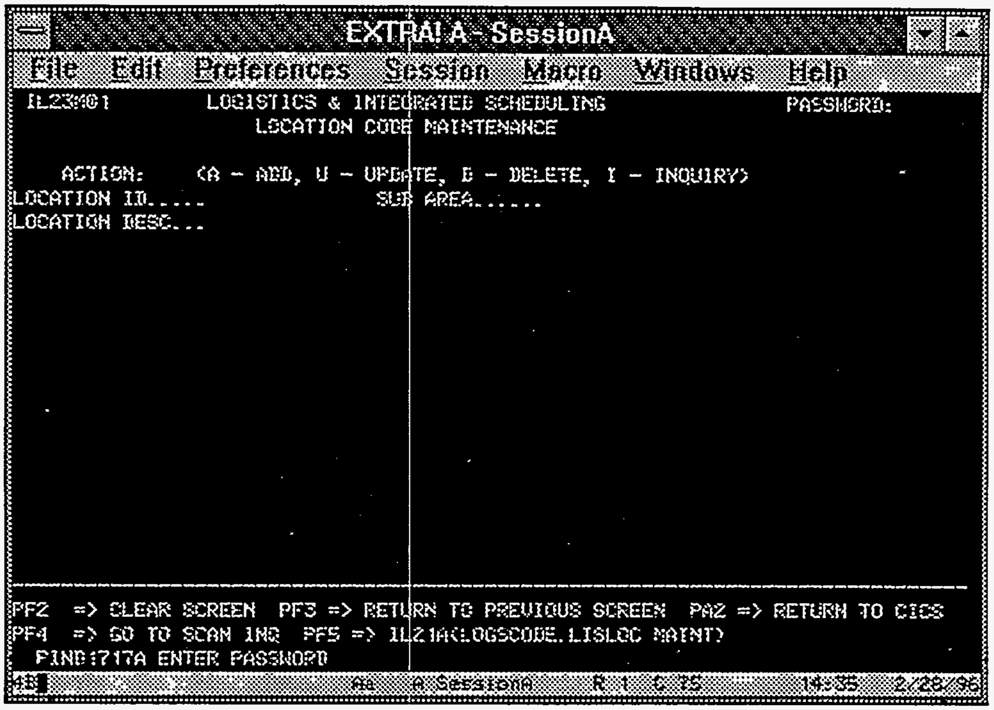
IL21M01 enables you to add, update, delete or inquire about the location of an IPM.

(IL22M01) List Location Inquiry Screen



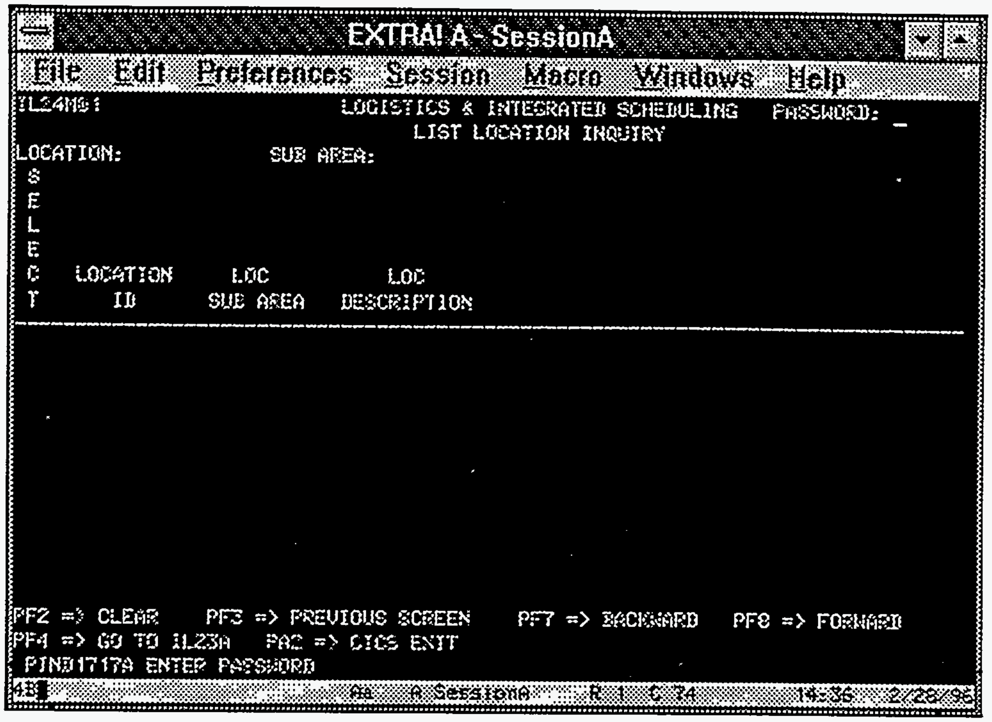
IL22M01 enables you to view all locations on the LOGSCODE.LISLOC table that match the search data entered at the top of the screen.

(IL23M01) Location Code Maintenance Screen



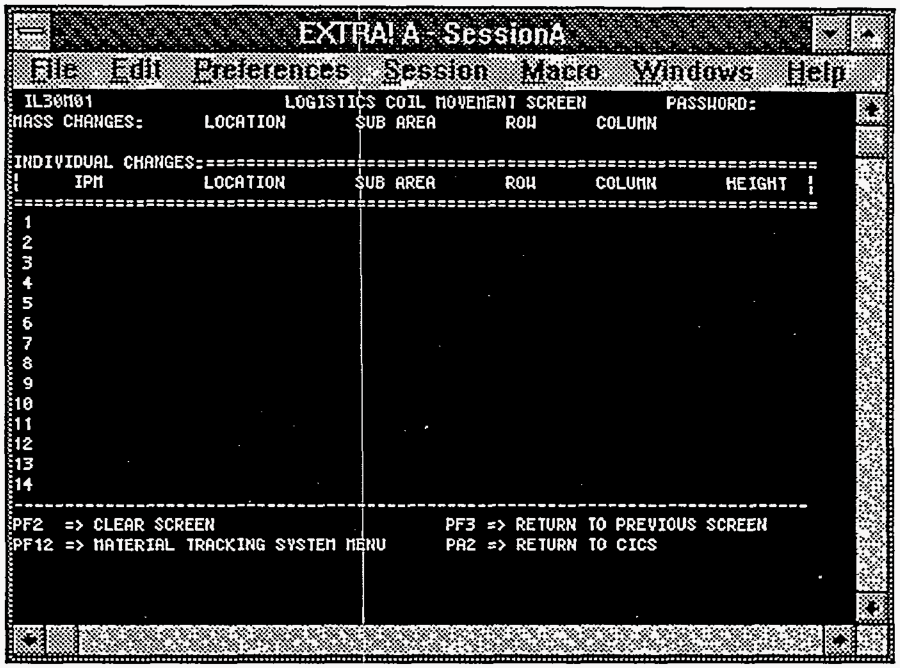
IL23M01 allows you to make corrections to the data recorded about a location code.

(IL24M01) List Location Inquiry Screen



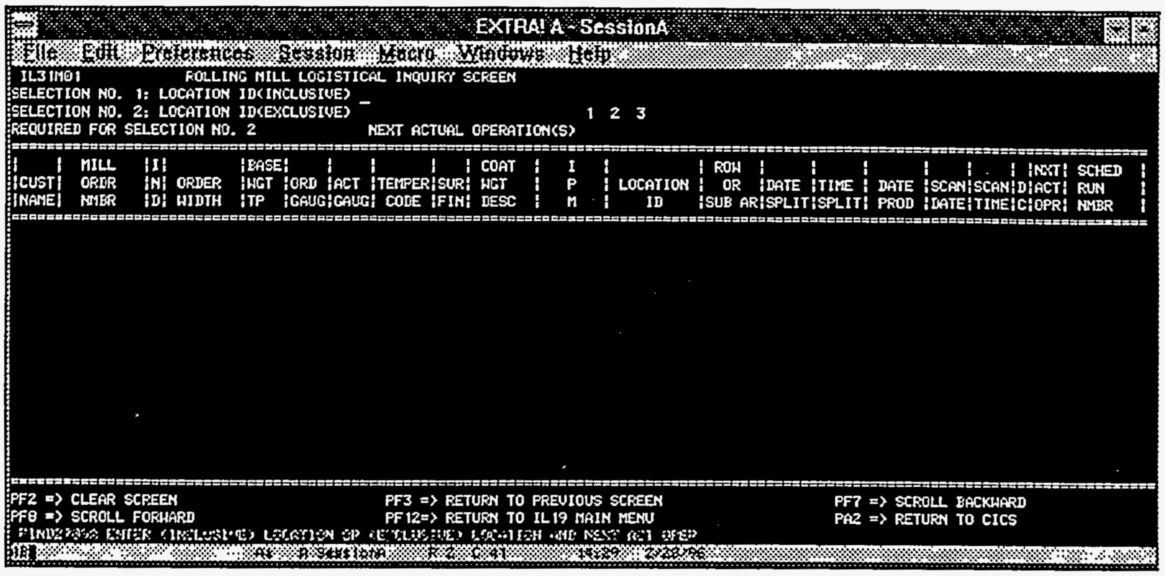
IL24M01 enables you to view location descriptions from the LOGSCODE.LOCCODE table.

(IL30M01) Logistics Coil Movement Screen



IL30M01 enables you to change the location of IPMs.

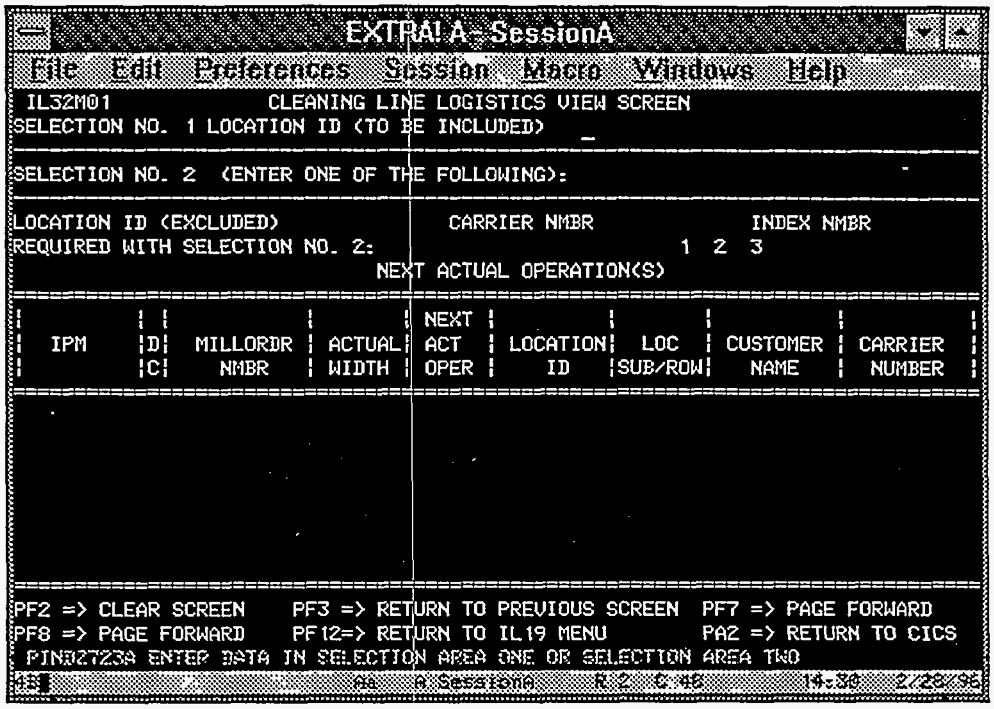
(IL31M01) Rolling Mill Logistics Inquiry Screen



IL31M01 displays a record associated with one of the following in the Rolling Mill inventory:

- Location ID
- Location ID and one or more "Next Actual Operations."

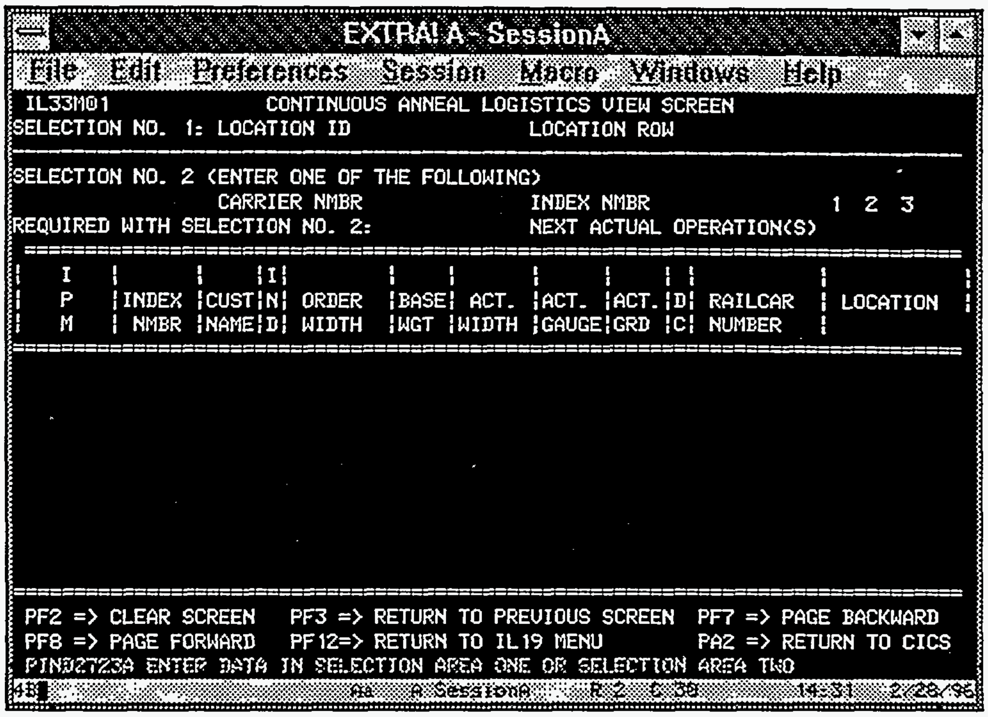
(IL32M01) Cleaning Line Logistics View Screen



IL32M01 displays a record associated with one of the following in the Cleaning Line inventory:

- Location ID
- Index Number and one or more Next Actual Operations
- Inter Mill Carrier and one or more Next Actual Operations
- Location ID and one or more Next Actual Operations

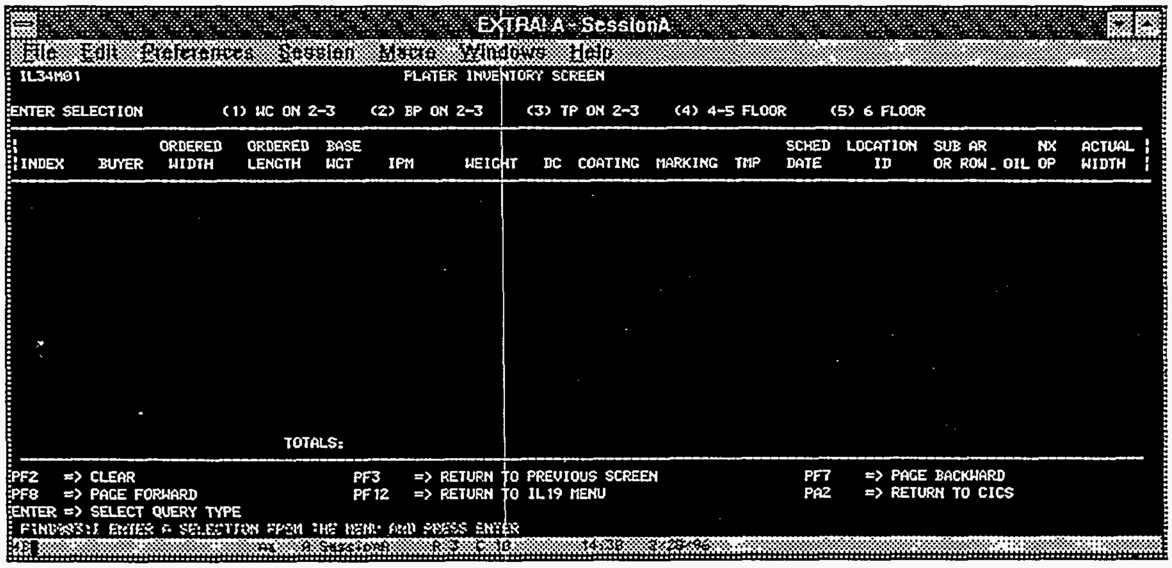
(IL33M01) Continuous Anneal Logistics View Screen



IL33M01 displays a record associated with one of the following in the Continuous Anneal inventory:

- Location ID
- Location Row
- Index Number and one or more Next Actual Operations
- Inter Mill Carrier and one or more Next Actual Operations

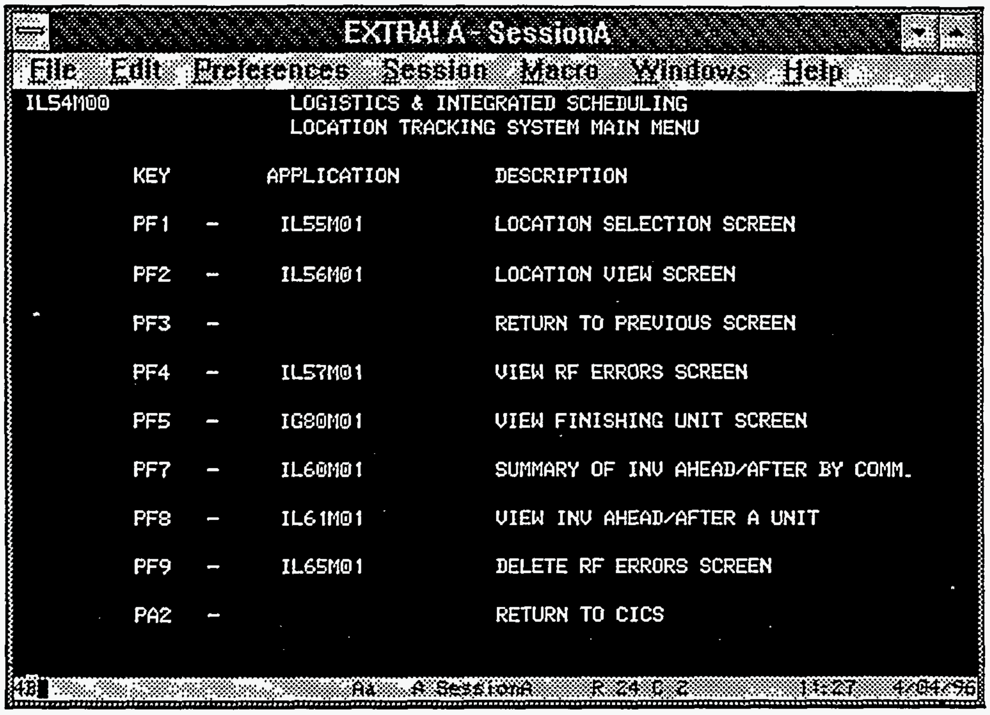
(IL34M01) Plater Inventory Screen



IL34M01 displays a record associated with one of the following in the Plater inventory:

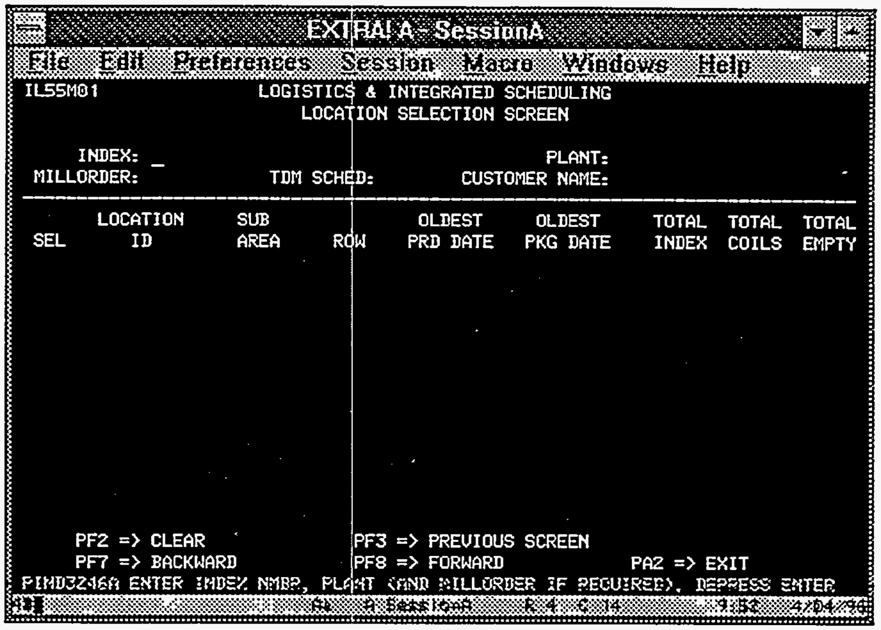
- Location ID
- Location Row

(IL54M01) Location Selection Screen



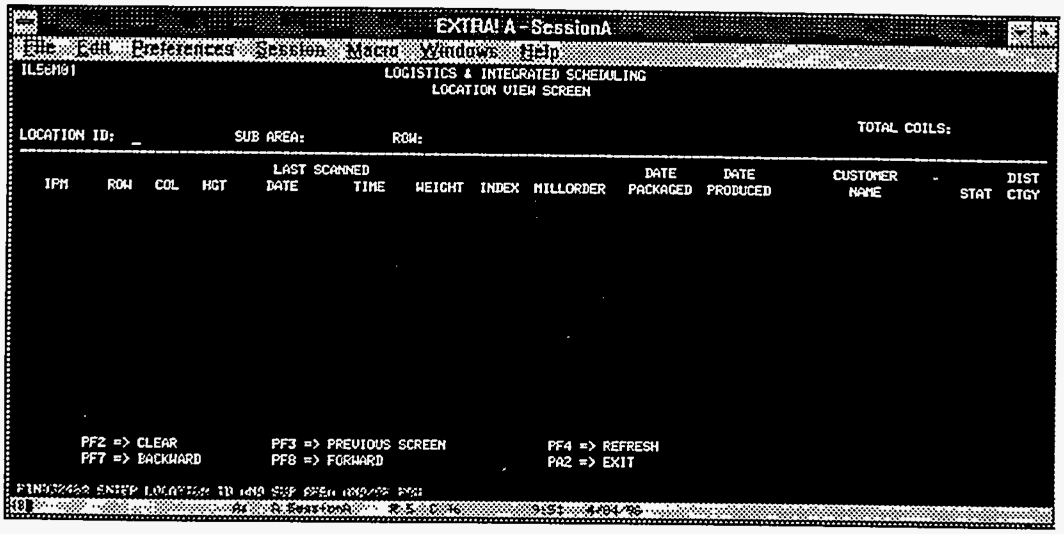
IL54M01 serves as the main menu for the Strip Steel, Sheet Mill and FPW Location Tracking Systems.

(IL55M01) Location Selection Screen



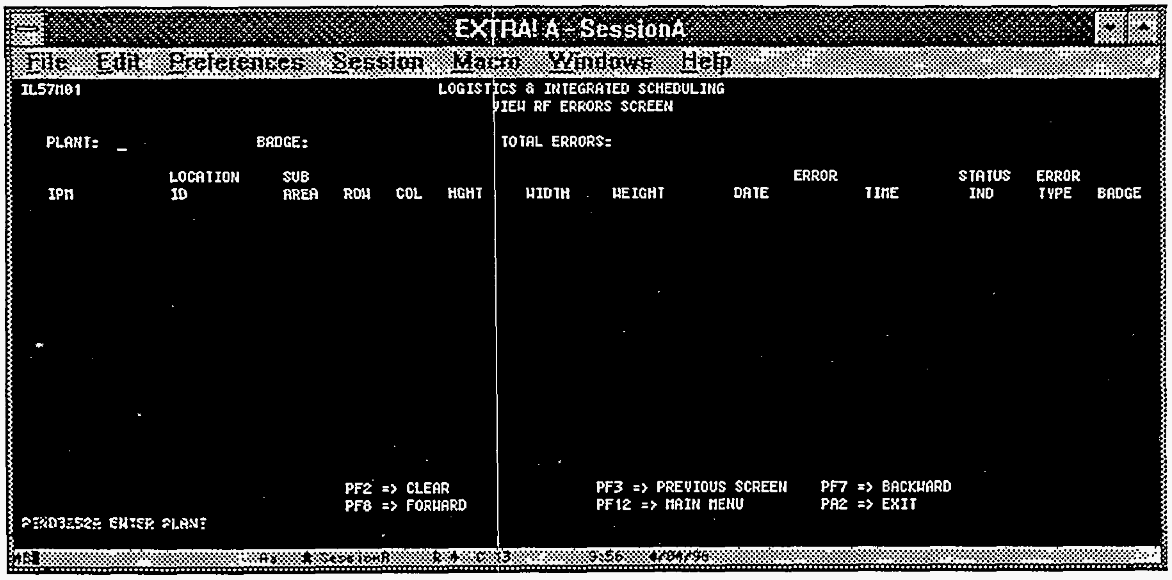
IL55M01 displays all locations at which a specified Index is held.

(IL56M01) Location View Screen



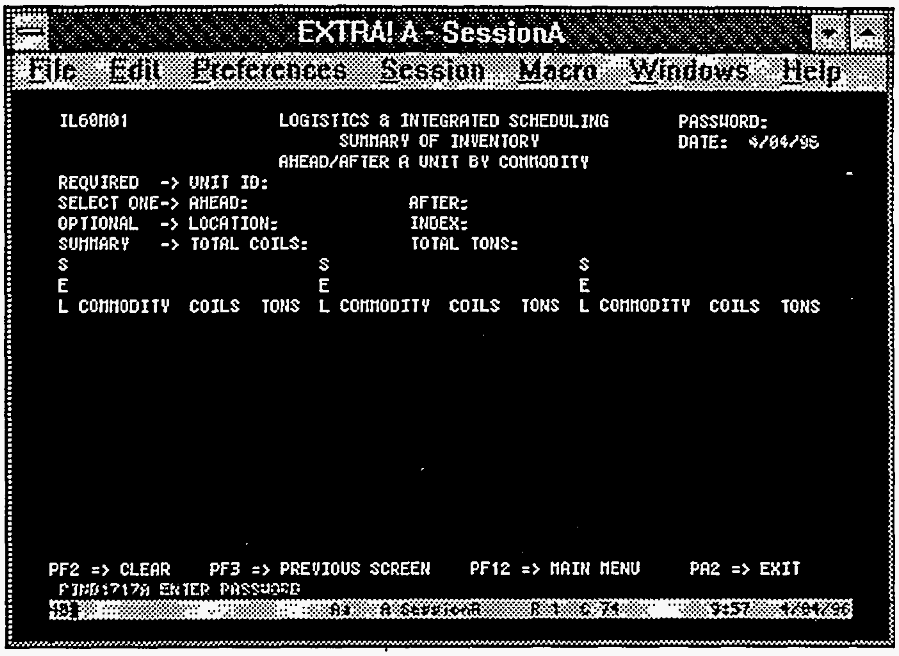
IL56M01 displays all coils held at a specified location.

(IL57M01) View of Errors Screen



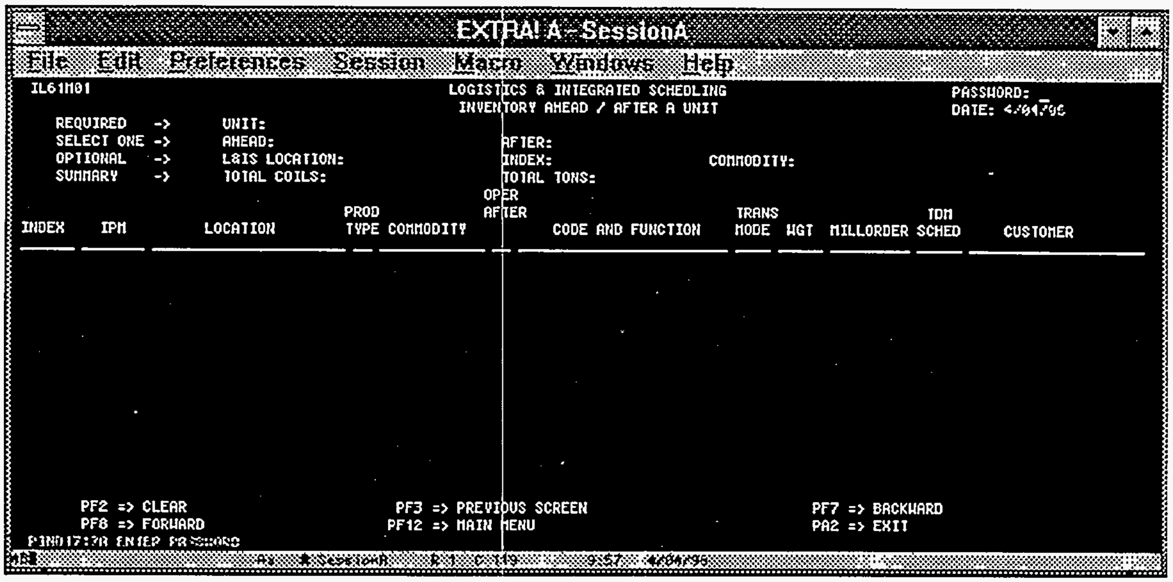
IL57M01 allows you to view all RF errors.

(IL60M01) Summary of Inventory Ahead/After a Unit by Commodity Screen



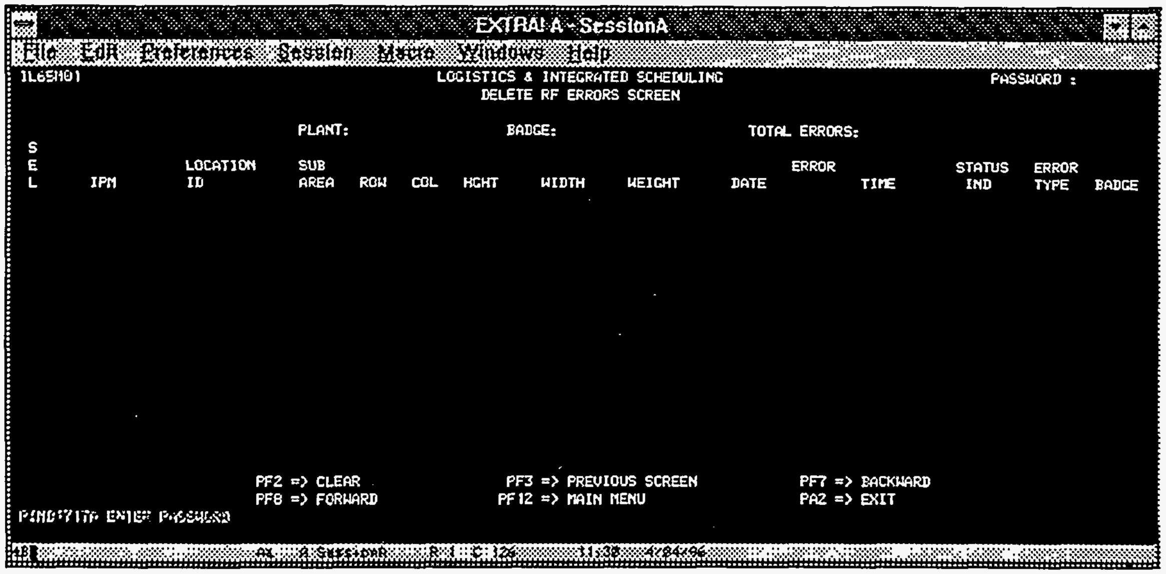
IL60M01 displays the list of commodities, tons and coil counts that are ahead of or after a specified unit.

(IL61M01) Location View Screen



IL61M01 displays the IPM, Index and Location for all coils ahead of or after a specified unit.

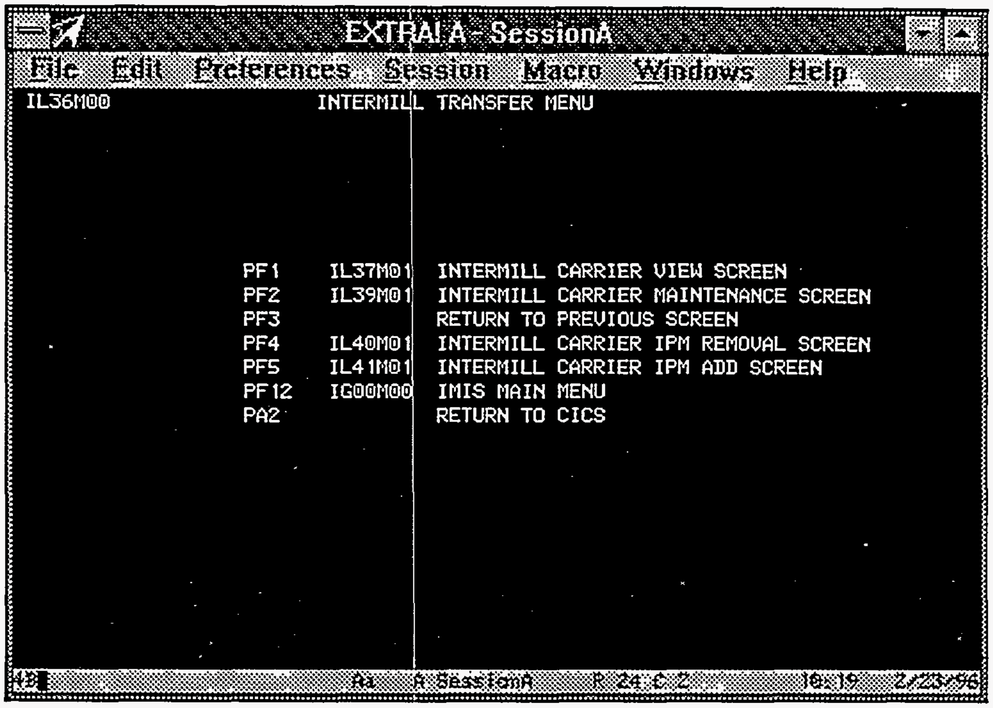
(IL65M01) Delete RF Error Screen



IL65M01 allows the user to delete RF errors.

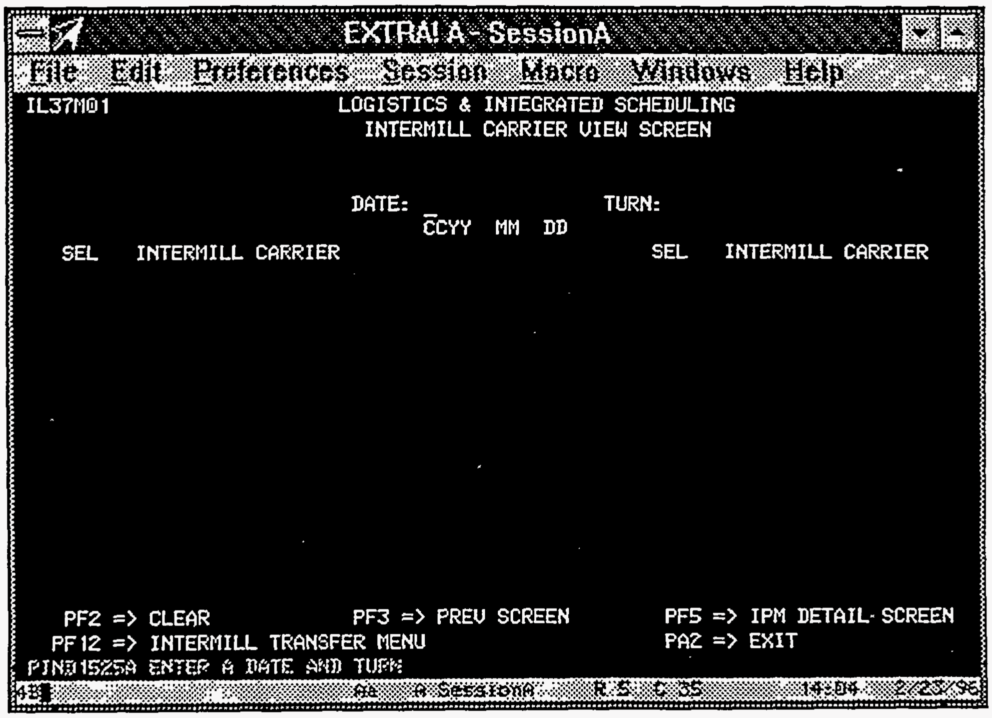
PHASE II INTERMILL TRANSFER SCREENS

(IL36M00) Intermill Transfer Menu



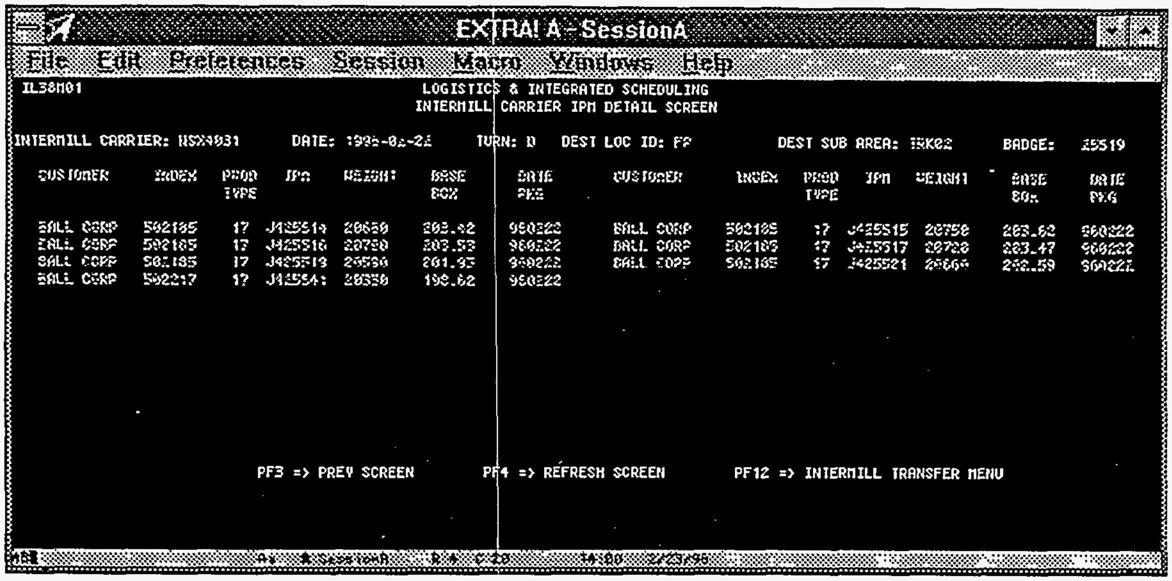
IL36M00 serves as the main menu for the Intermill Transfer System.

(IL37M01) Intermill Carrier View Screen



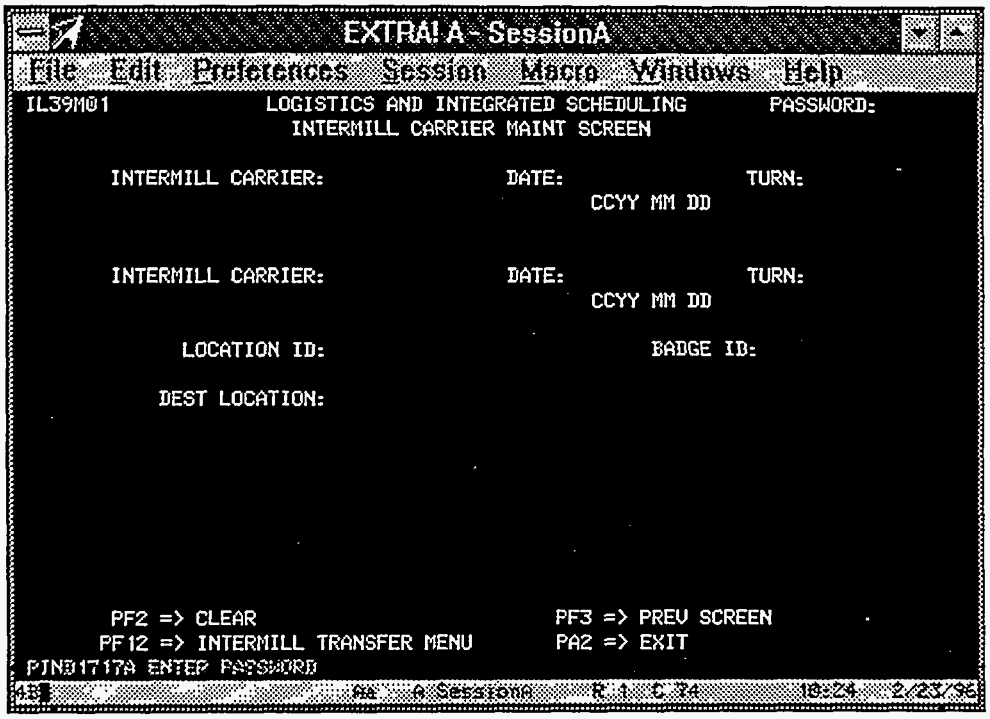
IL37M01 displays the list of carriers that were loaded for a specific date and turn. From this screen, you can go to IL38M01 to see detailed information about the IPMs loaded on this carrier.

(IL38M01) Intermill Carrier IPM Detail Screen



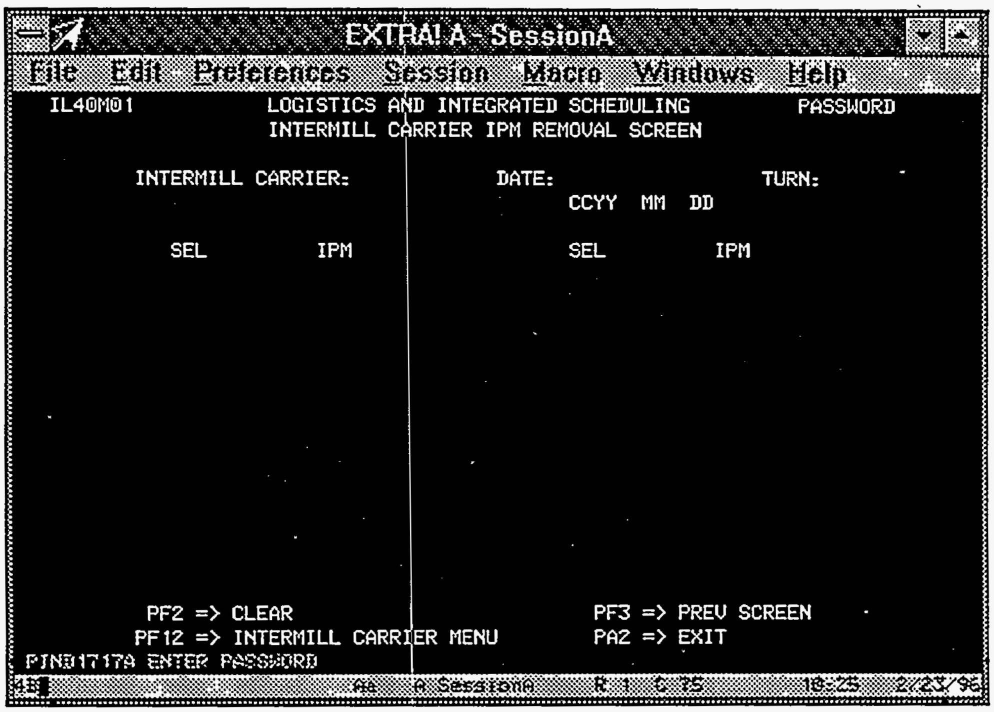
IL38M01 displays detailed information about the IPMs loaded on a carrier selected from the IL37M001 screen.

(IL39M01) Intermill Carrier Maintenance Screen



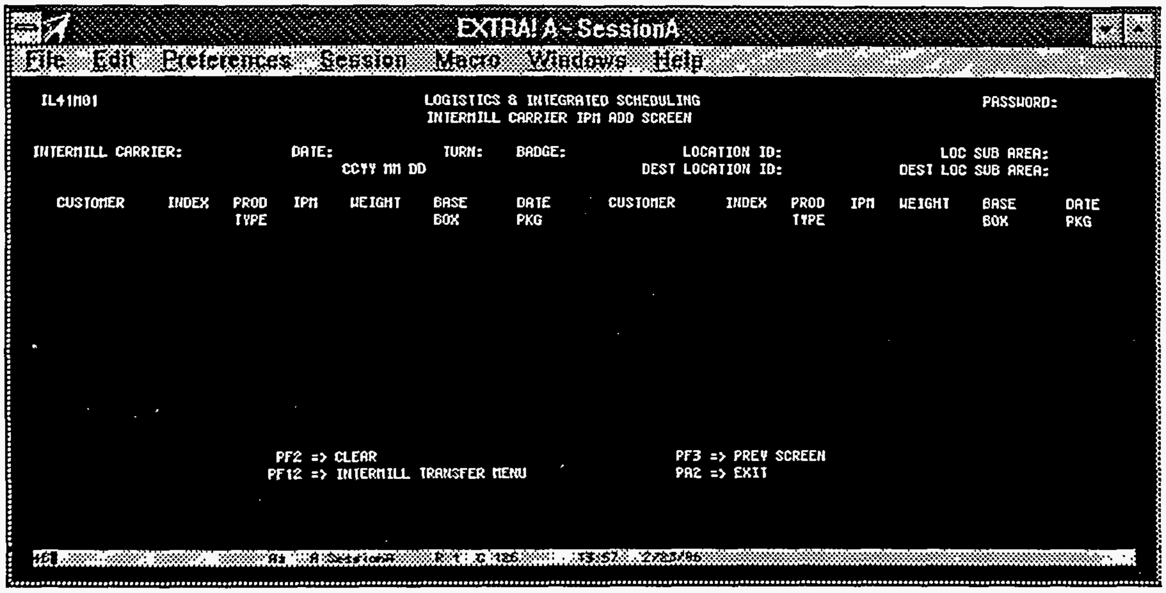
IL39M01 allows you to make corrections to the data recorded about a specified carrier.

(IL40M01) Intermill Carrier IPM Removal Screen



IL40M01 enables you to perform maintenance by making deletions from the list of IPMs that are recorded as "loaded" on a specified carrier.

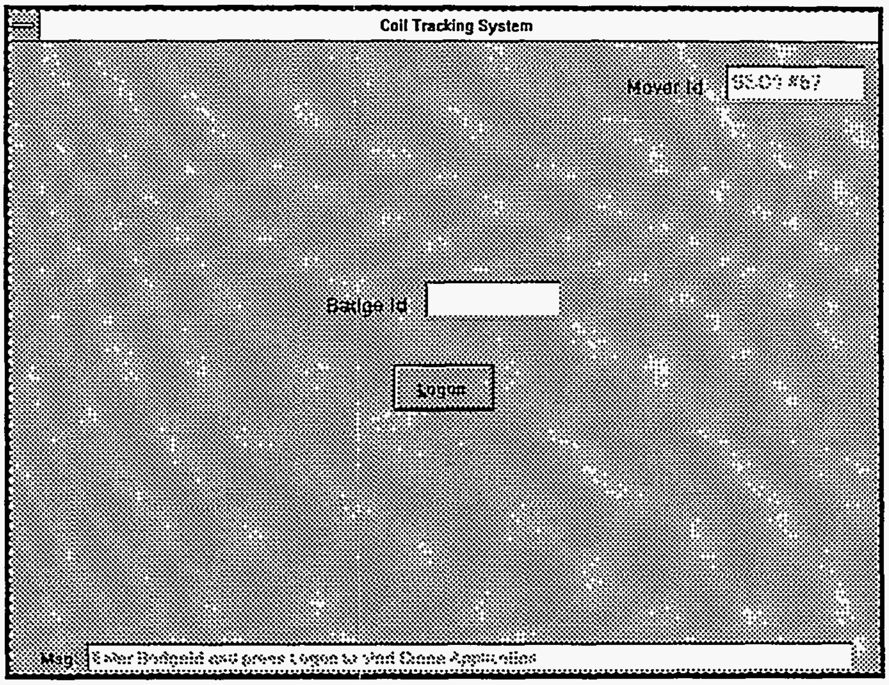
(IL41M01) Intermill Carrier IPM Add Screen



IL41M01 enables you to perform maintenance by adding to the list of IPMs recored as "loaded" on a specified carrier.

INTERMILL TRANSFER -- CRANE SCREENS

RF Crane Move Schedule Logon Screen



Description

The crane operator will logon to identify their employee ID as operating the #57 crane. This employee ID will be used to post any moves recorded for this crane. This will give the accounting and incentive departments direct reporting capabilities for any type of movement information; i.e., all moves by a crane operator for a specific time frame.

Basic Functions:

1. Capture which crane operator is working in the #57 crane. For this application we will default the Mover ID for the #57 Crane in the Strip Steel area.
2. Identify voice file by badge ID logging on.
3. Record all material moved from this application to the crane operators badge ID.

Process Detail

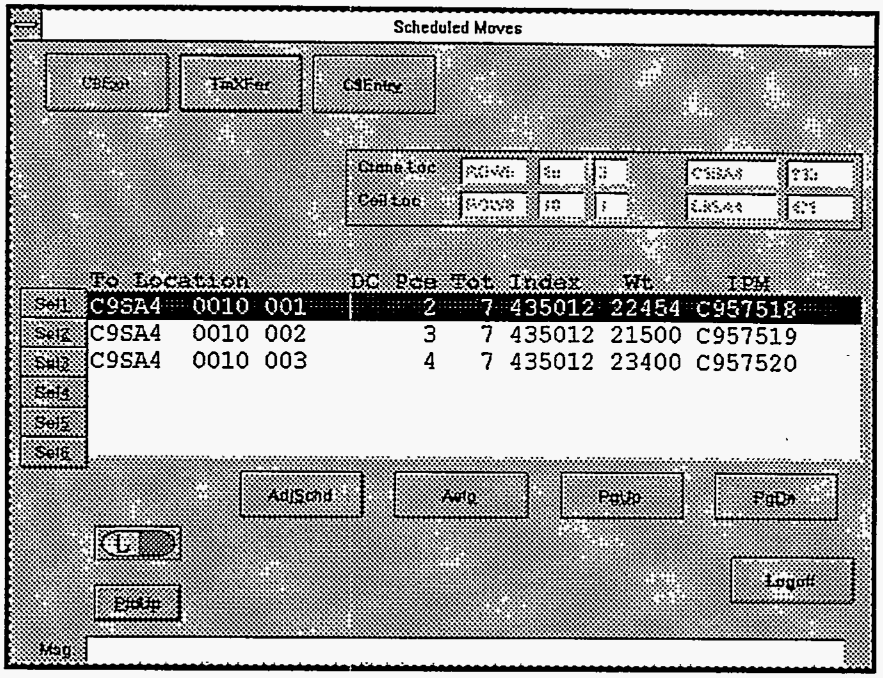
Operator must enter badge ID via touch screen input or numeric keyboard.
At startup time the mover ID will be passed in the message area.
Mover ID will be used to log all movements to a journal table.
Voice file will be activated for the crane operator by the badge ID entered. The service areas to be supported will be displayed dynamically in the proper sequence due to the mover ID identified.

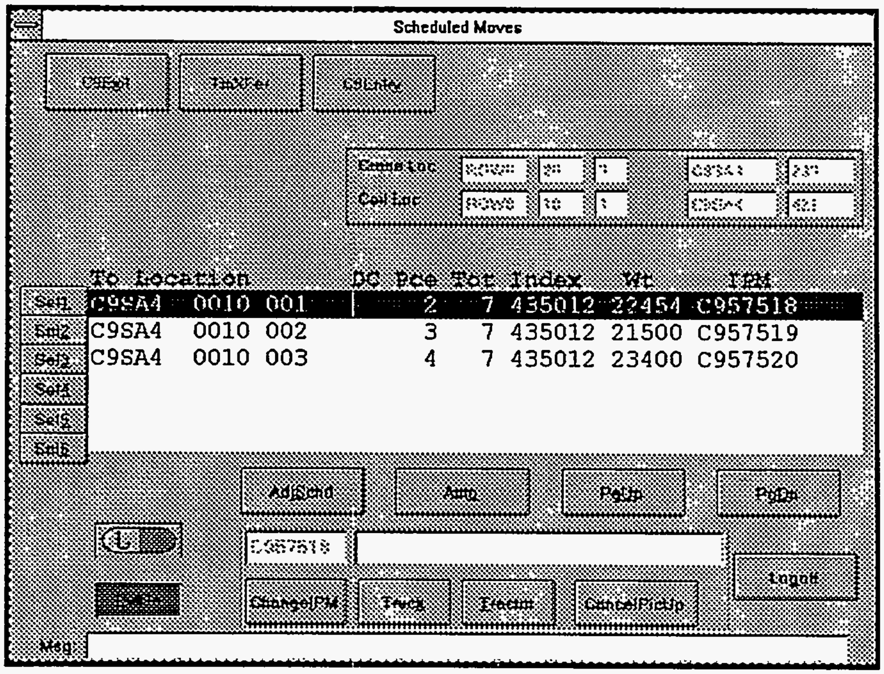
RF Crane Move Schedule Logon Notes:

1. Password not required

2. Date and time will be the system date and time recorded for each move. This will allow the Accounting Department to interpret turns correctly.
3. The crane operator must logoff at the end of his turn and the next crane operator must login at the start of a new turn to record moves properly.
   If an operator works a double, due to the rules we have implement, he will not have to logon again.

RF Crane Move Schedule Screen





Description:
Display the list of IPMs in the order they are produced off of the #9 Tandem mill and will be moved to storage, railcars, or auxiliary vehicles.

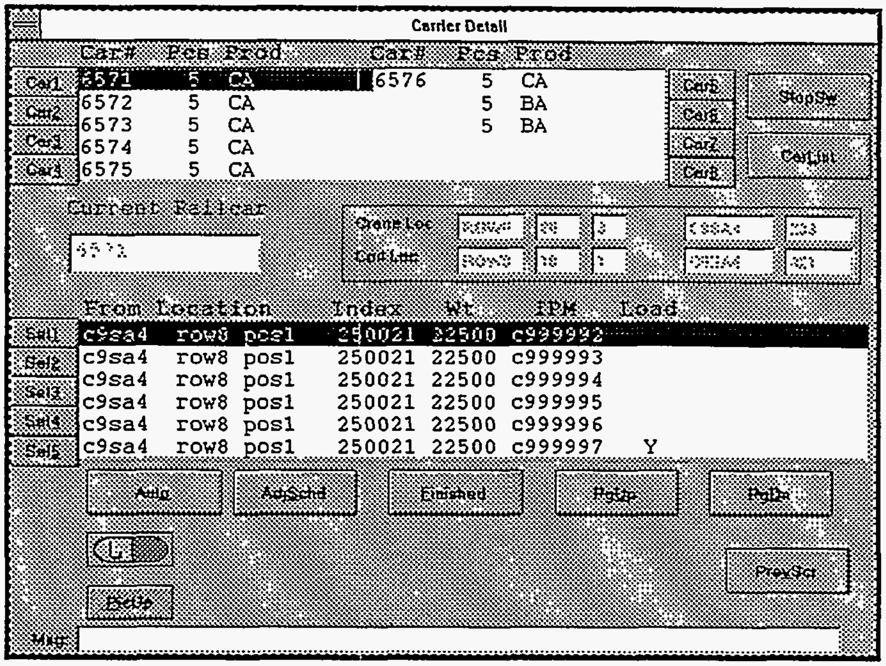
Basic Functions:

- Provide a Movement Schedule for material produced off of the C9 unit (located at the exit end conveyer) and which will be placed into:
  - Storage location
  - Railcar
  - Auxiliary carriers ... truck or tractor
- This requires a direct communication with the I.M.I.S. Plant Floor System for material produced off of the C9 unit. Display IPMs exiting C9 unit in order they were produced
- Allow selection of IPM to be picked up; the default will be the first ipm displayed in the Movement Schedule.
- If material is moved to a storage location, suggest an intelligent coil put down location, dependent on the number of coils to be grouped together.

Generic Functions - functions that can be performed from all screens except Logon Screen

- Identify Crane's location
  Current X, Y position and symbolic location translation
  Continuous display of crane's X, Y position translation symbolic location as crane is moving. Poling frequency should be 2 times per second.
- Detect Pickup load transaction
  Capture X, Y position and symbolic location translation.
  Format appropriate message for C9 Exit end pickup moves
- Allow the operator to adjust the schedule by removing the selected IPM from the list. Prompt for reason code as to why the piece could not be picked up.
- Display material information for pickup transaction and allow put down exceptions such as change IPM, load truck or tractor, and cancel pickup.
- Track put down location of material moved to storage location, railcar, or auxiliary carrier.
- Paging up and down for scheduled moves or displays.
- Allow the operator to temporarily invoke Auto mode to disable the tracking and sending of messages to make moves such as loading scrap, or maintenance moves (roll changes...).
- Logoff

RF Carrier Detail Screen



Description

Display the switch order grouped by car in the order the IPMs are scheduled to be moved to the Tin Mill, and display the list of IPMs that are to be loaded on the selected railcar.

Basic Functions:

- Provide Movement Schedule for Intermill Transfers to Tin Mill for a switch order grouped by car and prioritized by CA and cleaning line schedules.
  - This requires an interface between the L&IS Scheduling System and Movement Queue for the units listed above.
- Provide Movement Schedule for Intermill Transfers to Tin Mill for selected railcar loads to be moved to the Tin Mill CA or cleaning lines.
  - This requires an interface between the L&IS Scheduling system and Movement Queue for the units listed above.
- Allow selection of a car group to be loaded on a railcar; the default will be the first group displayed. If a railcar is partial loaded, that rail car ID will be displayed in the list.
- Identify the completion of a switch order.
- On a new load (no IPM loaded on this carrier), allow for operator to enter the railcar ID.
- Allow selection of an IPM to be picked up, the default will be the first IPM displayed in the Movement Schedule.
- Identify the finished action for a railcar and prompt operator for reason code if all coils have not been loaded for this railcar. If all coils have been loaded for this railcar, the finished action will be automatic, and this load group will be removed from the list of groups on the Tin Mill Intermill Move Schedule Screen.

Generic Functions - functions that can be performed from all screens except Logon Screen
Generic Functions listed above in RF Move Schedule Screen.
One exception: The PrevScr button replaces the Logoff button. This button will return the operator to the previous screen.

Function Buttons
Will be dynamically loaded via Mover ID. The function buttons will not appear on the Carrier Detail, but will be available with voice activation, or by using the PrevScr button.

Input Parameters
The activation of the pick up may require input:
- if the operator needs to change the IPM (input of ipm number)
- if the operator is going to put the coil down on a truck or tractor (input of truck or tractor ID).

If the railcar is empty, the operator will be prompted for the carrier ID to identify the railcar being loaded.

Process Detail
Display the list of material for a switch order, grouped by car, that is to be sent to the Tin Mill (*TinXFer*). This information will be captured when the Scheduling System schedules material located in the Strip Steel for the Tin Mill Cleaning Lines or Continuous Anneal. The groups will be in the order they are scheduled to run at the Tin Mill. The first group on the list will be the default selection on the screen, but the operator will have the ability to select any group shown on the list.

Display the list of IPMs to be loaded on the specific carrier. This information will be captured when the Scheduling System schedules material located in the Strip Steel for the Tin Mill Cleaning Lines or Continuous Anneal. The sequence of the IPMs will be in the order they are scheduled to run at the Tin Mill. The first IPM on the list will be the default selection on the screen, but the operator will have the ability to select any IPM shown on the list. If this is a new car load, the operator will be prompted to voice in the carrier ID.

Selection of the group to load: The first group will be selected by default. If the operator wants to pickup another group he must select that group by voice or touch.

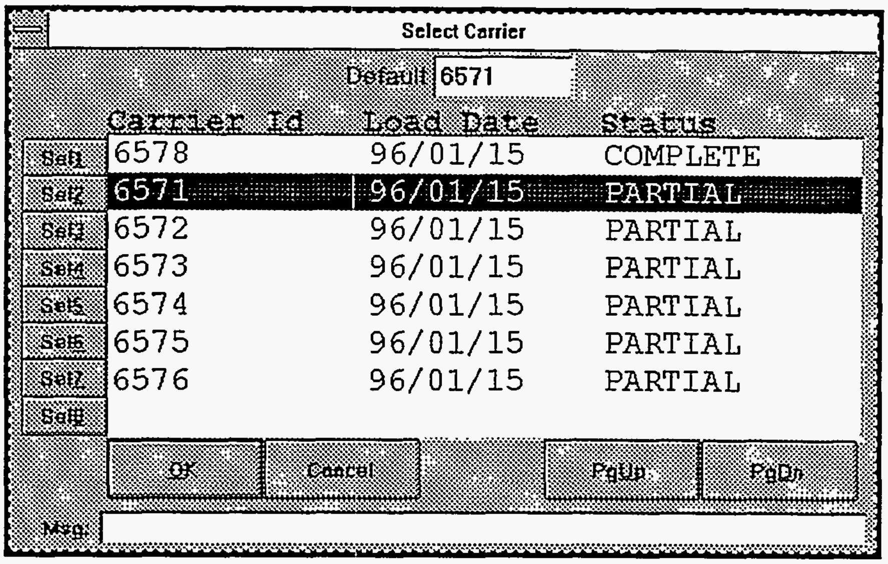
Selection of the IPM to load: The first IPM will be selected by default. If the operator wants to pickup another IPM he must select that ipm by voice or touch.
Pickup load will be invoked by voice activation or touching the PicUp button when the crane operator has positioned the hook in the coil.

A *switch order called complete* will be invoked by voice activation or touching the *StopSW*. This means all railcars have been loaded and the switch can be pulled from the Strip Steel #14 track. Load reports must be produced at this point for Production Planning and Operations.

Put-down locations for the coils placed on the railcar will be captured by the systems tracking device at the time the operator voices or presses the *PutDn* button.

Finished load will be invoked by voice activation or touching the Finished button.

RF Select Carrier Screen



Description

For the current switch order, display the list of railcars and status for each car that has been partially or completely loaded and allow the operator to view the detail for that carrier.

Basic Functions

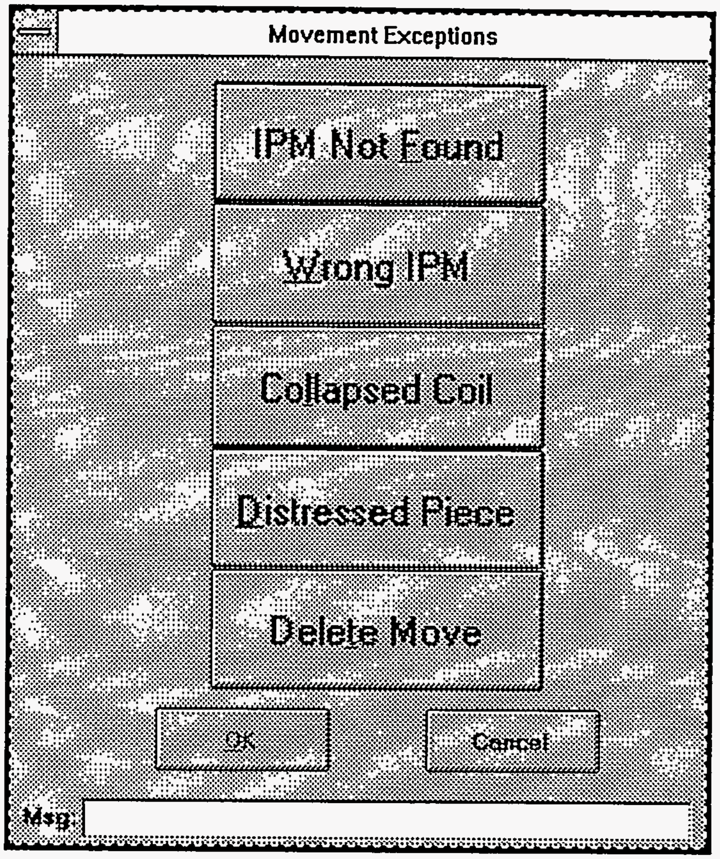
- Provide *Carrier Loaded list* for each railcar load to be moved to the Tin Mill CA or cleaning lines that has been partially or completely loaded.
- Allow selection of carrier to be picked up, the default will be the first carrier displayed in the list with a status of *PARTIAL*
- Selection of a carrier will bring up the *Tin Mill Intermill Move Schedule* for that particular carrier.
- *Paging* up and down for railcar list.
- *OK* button to return the operator to the previous screen, changing to the selected carrier.
- *Cancel* button to return the operator to the previous screen without changing the selected carrier.

Process Detail

Display the list of railcars and status for each car that has been partially or completely loaded for the current switch order. The first carrier on the list with a *PARTIAL* status will be the default selection on the screen, but the operator will have the ability to select any carrier shown on the list.

Selection of the carrier: The first carrier on the list with a *PARTIAL* status will be selected by default on the voice activation or touch of the *OK* button. If the operator wants to bring up the detail of another carrier, he must select that carrier by voice or touch. Selection of a carrier will bring up the *Tin Mill Intermill Move Schedule* for that particular carrier.

RF Crane Move Schedule for Movement Exceptions Requirements



Description

Allow the operator to remove a piece from his list by giving a valid reason as to why a coil can not be picked up by the crane.

Basic Functions:

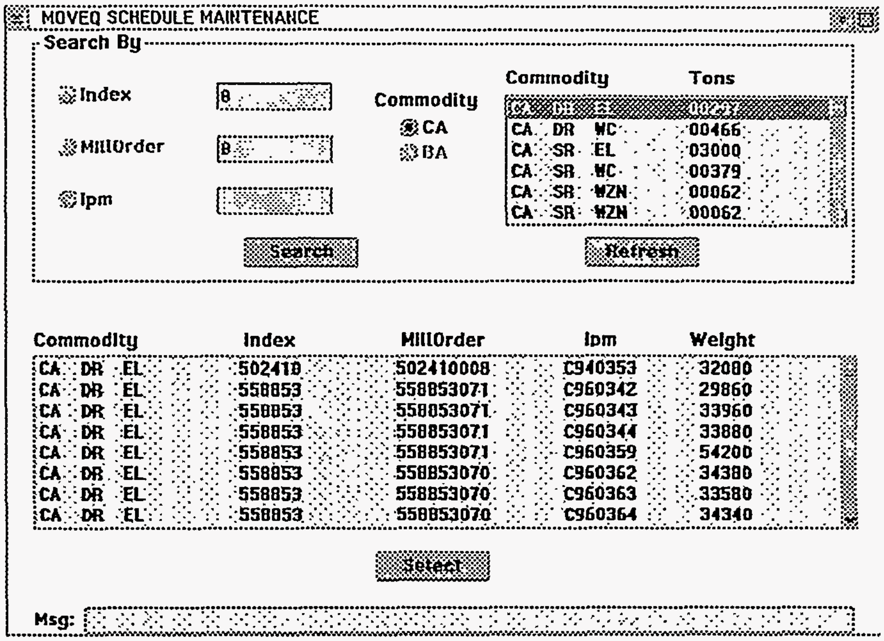
- Allow selection of exception reason.

Process Detail

Display possible reasons as to why a coil can not be picked up by the crane.
Selection of the exception reason: The operator must select the exception reason by voice or touch.

Allow user to cancel out of exception screen by voice activation or touch of *Cancel* button.

Move Q Maintenance Requirements



Description

This *GUI* application will give Operations Planning personnel the ability to add non-scheduled inventory to the Move Q. Examples would be items such as Rush/Start-up Material.

Inventory placed on the Move Q as a result of using this application will be given the highest priority and will be *Scheduled-To-Load* via the Crane Intermill Transfer System.

Basic Functions

The basic function of this application is to allow the user to Search and Select inventory in any of the following ways:

1) By Index
2) By MillOrder
3) By IPM
4) By CA/BA Commodity

Function Buttons

Index Radio Button :	Search and display inventory based on SQL query rules for the specified Index in the Entry Field.
MillOrder Radio Button:	Search and display inventory based on SQL query rules for the specified MillOrder in the Entry Field.
IPM Radio Button:	Search and display inventory based on SQL query rules for the specified IPM in the Entry Field.
CA/BA Radio Button:	Search and display Distinct Commodity Labels based on SQL query rules for either the CA/BA Radio Button.

The user can then Click on any of the returned Commodity Labels. After pressing the Search Button, a display of all associated inventory will appear in the Results List Box.

Appendix E

Forecasting and Planning Reports

Acceptance Report
Month of Sales

	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97
Product (Promise Front):						
Hot Roll (Bands 8/26, P&O 8/26)						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Cold Roll (8/5)						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Galvanize (#3 8/19, #4 9/9, #5 9/9, JP #3 9/23, JP #5 10/14)						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Galfan (9/30)						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Weirzin (BA 8/26, CA 8/12)						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Total Sheets						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Tin (BA 8/17, CA 8/17)						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Total Sheets and Tin						
Target	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Booked	0	0	0	0	0	0
Difference	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Acceptance Report
Promise Date Tons Booked by Month - Sheet

	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97
Hot Roll						
Bands	0	0	0	0	0	0
P&O	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Cold Roll						
BA SS	0	0	0	0	0	0
BA TM	0	0	0	0	0	0
CA TM	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Weirzin						
BA SS	0	0	0	0	0	0
BA TM	0	0	0	0	0	0
CA	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
3 Line Galvanize						
Galvanize-Regular	0	0	0	0	0	0
Galvanize-HS	0	0	0	0	0	0
JP-Regular	0	0	0	0	0	0
JP-HS	0	0	0	0	0	0
Galfan-Regular	0	0	0	0	0	0
Galfan-HS	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
4 Line Galvanize						
Regular Galvanize	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
5 Line Galvanize						
Regular Galvanize	0	0	0	0	0	0
JP	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Total Galvanize	**0**	**0**	**0**	**0**	**0**	**0**
Total Sheet	**0**	**0**	**0**	**0**	**0**	**0**

Acceptance Report

Totals:

Sheet Products

Promise Date

	Jan 06	Jan 13	Jan 20	Jan 27	Feb 03	Feb 10	Feb 17	Feb 24	Mar 03	Mar 10	Mar 17	Mar 24	Mar 31
Hot Roll													
Target													
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference													
Cold Roll													
Target													
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference													
Total Galvanize													
Target	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Weirzin													
Target													
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference													
Total Sheet Product													
Target	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######

5/24/96, 10:14 AM

Acceptance Report

Totals:

Sheet Products

Promise Date

	Apr 07	Apr 14	Apr 21	Apr 28	May 05	May 12	May 19	May 26	Jun 02	Jun 09	Jun 16	Jun 23	Jun 30
Hot Roll													
Target													
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference													
Cold Roll													
Target													
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference													
Total Galvanize													
Target	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Weirzin													
Target													
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference													
Total Sheet Product													
Target	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Booked	0	0	0	0	0	0	0	0	0	0	0	0	0
Difference	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######

E-4

Unit Load Report

Production Week Ending

Summary
Net Postions

	Apr 12	Apr 19	Apr 26	May 03	May 10	May 17	May 24	May 31	Jun 07	Jun 14	Jun 21	Jun 28	Jul 05
Caster-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
Hot Mill-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
Pickler-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
3 Galv-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
4 Galv-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
5 Galv-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
Tot Galv-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
TM BA-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
TM CA-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
SS BA-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----

Unit Load Report

Summary

Net Postions

Production Week Ending

	Apr 12	Apr 19	Apr 26	May 03	May 10	May 17	May 24	May 31	Jun 07	Jun 14	Jun 21	Jun 28	Jul 05
1 Plater-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
2 Plater-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
4 Plater-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
5 Plater-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
6 Plater-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	----	----	----	----	----	----	----	----	----	----	----	----	----
7 Tandem-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,000
8 Tandem-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500
9 Tandem-Net Position	----	----	----	----	----	----	----	----	----	----	----	----	----
-Remaining Prod	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000

Unit Load Report

Summary

Galvanize

Production Week Ending

	Apr 12	Apr 19	Apr 26	May 03	May 10	May 17	May 24	May 31	Jun 07	Jun 14	Jun 21	Jun 28	Jul 05
3 Galv													
Carryover													
Due													
Total Obligation													
Planned Production													
Net Position													
Remaining Production													
4 Galv													
Carryover													
Due													
Total Obligation													
Planned Production													
Net Position													
Remaining Production													
5 Galv													
Carryover													
Due													
Total Obligation													
Planned Production													
Net Position													
Remaining Production													
Total Galvanize													
Carryover													
Due													
Total Obligation													
Planned Production													
Net Position													
Remaining Production													

Galvanize

Production Week Ending

	CO+Due	Jan 18	Jan 25	Feb 01	Feb 08	Feb 15	Feb 22	Mar 01	Mar 08	Mar 15	Mar 22	Mar 29	Apr 05
3 Galvanize													
Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
JP	0	0	0	0	0	0	0	0	0	0	0	0	0
Galfan	0	0	0	0	0	0	0	0	0	0	0	0	0
HS Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
HS JP	0	0	0	0	0	0	0	0	0	0	0	0	0
HS Galfan	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 3 Galvanize	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
4 Galvanize													
Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 4 Galvanize	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5 Galvanize													
Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
JP	0	0	0	0	0	0	0	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 5 Galvanize	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Galvanize Due	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Unit Load Report

Galvanize

Production Week Ending

	Apr 12	Apr 19	Apr 26	May 03	May 10	May 17	May 24	May 31	Jun 07	Jun 14	Jun 21	Jun 28	Jul 05
3 Galvanize													
Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
JP	0	0	0	0	0	0	0	0	0	0	0	0	0
Galfan	0	0	0	0	0	0	0	0	0	0	0	0	0
HS Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
HS JP	0	0	0	0	0	0	0	0	0	0	0	0	0
HS Galfan	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 3 Galvanize	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
4 Galvanize													
Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 4 Galvanize	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5 Galvanize													
Regular	0	0	0	0	0	0	0	0	0	0	0	0	0
JP	0	0	0	0	0	0	0	0	0	0	0	0	0
Full Hard	0	0	0	0	0	0	0	0	0	0	0	0	0
Total 5 Galvanize	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Galvanize Due	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Appendix F

Scheduling System Screens

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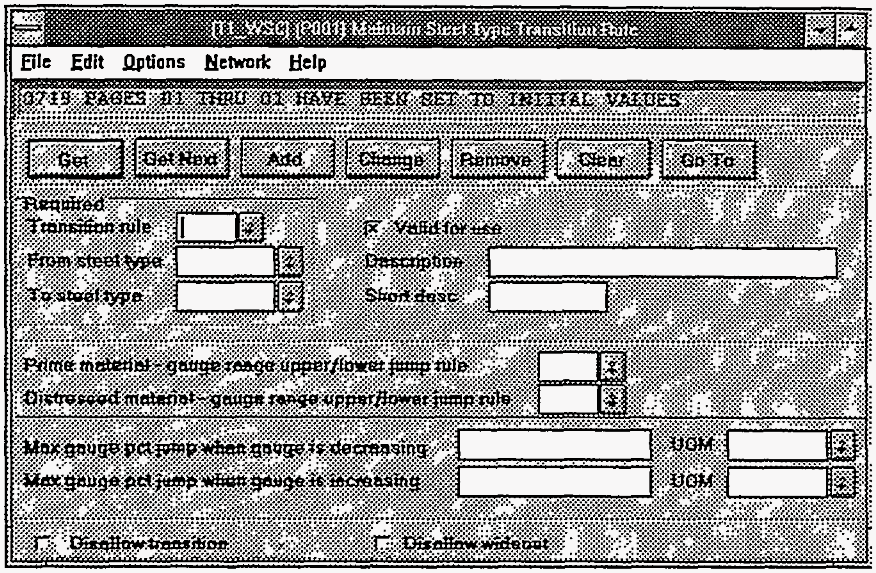
MODELING SCREENS

(P001) Maintain Steel Type Transition Rule



The Maintain Steel Type Transition Rule screen is used to create and maintain a rule that the system uses during transition qualification to determine steel type jump requirements for the items in a facility's schedule blocks.

Steel type jump requirements are used during transition qualification to set limits on the jumps that occur from one item to the next in the line-up.

When a transition is being made from one item (the From item) to another (the To item), the system uses Transition Rules to determine if the jump is valid. The Steel Type Transition Rule is such a rule. It defines the allowable width and gauge jumps that may be made for the steel type transitions you establish, and it also enables you to disallow transitions between specified steel types.

How this rule works:

A Steel Type Transition Rule is comprised of a series of steps. Each step in the rule defines a possible transition between two steel types. Jump limits are defined for each steel type transition. You can configure the rule to flag any of the following as violations:

- Gauge percent jumps when gauge is either increasing or decreasing.
- Gauge or width jumps that exceed the limits set by a Gauge Range Jump Rule that you specify.
- All transitions between the specified steel types.
- Transitions between the specified steel types when the items are widing out.

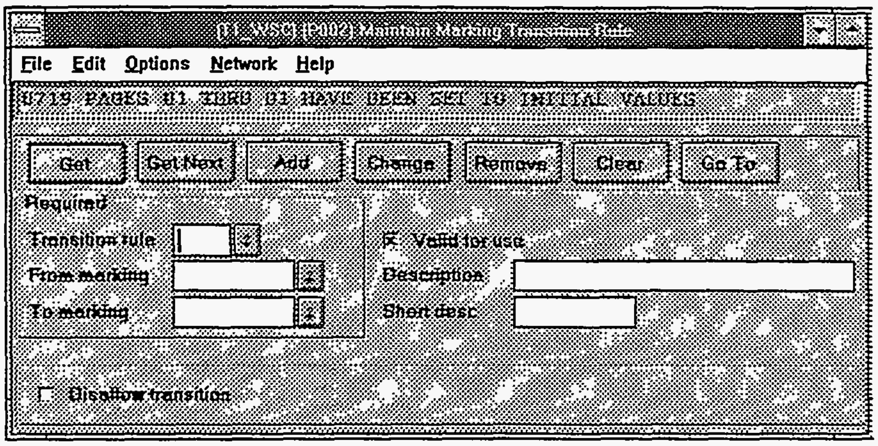
When a Steel Type Transition Rule is called during transition qualification, it is executed for each transition in the processing cycle.

For each transition, the system will determine the steel types of the From and To items and then execute the appropriate rule step. It will then use the jump limit specified in the step (or in the Gauge Jump Rule called by the step) to determine if the transition's jump causes a transition violation.

Where this rule is entered:

Steel Type Transition Rules are entered in the Steel Type Transition Rule field on the (P016) Maintain Demand Transition Qualification screen.

(P002) Maintain Marking Transition Rule



The Maintain Material Marking Transition Rule screen is used to create and maintain a rule that the system uses during transition qualification to determine if jumps between items with specified material markings are valid.

When a transition is being made from one item (the From item) to another (the To item) in a line-up, the system uses Transition Rules to determine if the jump is valid. The Material Marking Transition Rule is such a rule. It enables you to disallow transitions between items with specified material marking types.

How this rule works:

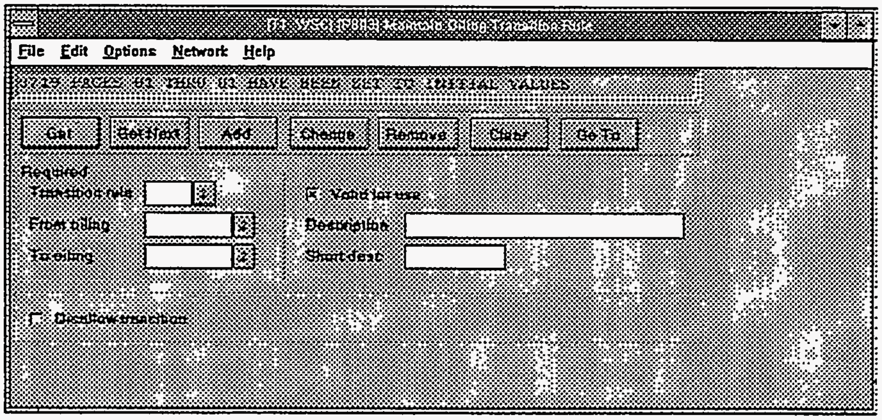
A Material Marking Transition Rule is comprised of a series of steps. Each step in the rule defines a possible transition between two material markings. When a Material Mark Transition Rule is called during transition qualification, it is executed for each transition in the processing cycle.

For each transition, the system will determine the material markings of the From and To items and then execute the appropriate rule step. If the step's Disallow Transition field is marked with an X, the system will flag the transition as a violation.

Where this rule is entered:

Material Marking Transition Rules are entered in the Material Mark Transition Rule field on the (P016) Maintain Demand Transition Qualification Rule screen.

(P003) Maintain Oiling Transition Rule



The Maintain Oiling Transition Rule screen is used to create and maintain a rule that is used by the system during transition qualification to determine if jumps between items with specified oiling types are valid.

When a transition is being made from one item (the From item) to another (the To item) in a line-up, the system uses Transition Rules to determine if the jump is valid. The Oiling Transition Rule is such a rule. It enables you to disallow transitions between items with specified oiling types.

How this rule works:

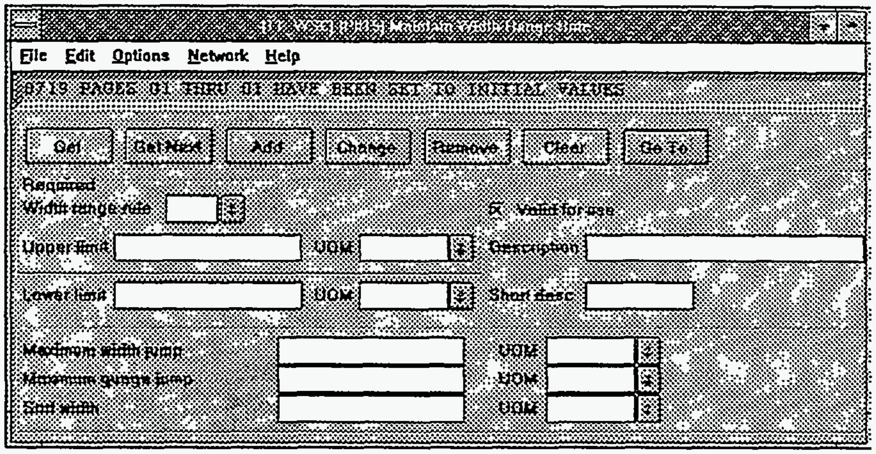
An Oiling Transition Rule is comprised of a series of steps. Each step in the rule defines a possible transition between two oiling types. When an Oiling Transition Rule is called during transition qualification, it is executed for each transition in the processing cycle.

For each transition, the system will determine the oiling types of the From and To items and then execute the appropriate rule step. If the step's Disallow Transition field is marked with an X, the system will flag the transition as a violation.

Where this rule is entered:

Oiling Transition Rules are entered in the Oiling Transition Rule field on the (P016) Maintain Demand Transition Qualification Rule screen.

(P015) Maintain Width Range Rule



The Maintain Width Range Rule screen is used to create and maintain a rule that will serve one of two purposes:

1) It can determine width range jump requirements.

   When the system is making a transition from one item (the From item) to another (the To item) in a line-up, it uses Transition Rules to determine if the jump is valid.

   The Width Range Jump Rule is such a rule. It defines the allowable width and gauge jumps that may be made for given width ranges.

2) It can determine a facility's sort width increments in the sorting process.

   This rule can be used to establish width increments within which a facility's items will be sorted. When the sorting process is executed, the facility's items will be sequenced according to the width increments within which they fall.

How this rule works:

A Width Range Rule is comprised of a series of steps. Each step in the rule defines a range of width measurements.

The upper limit of the step's range is set by the Upper Limit field and the lower limit of the step's range is automatically set equal to the maximum value of the previous step. If no previous step exists, the range will consist of all values less than or equal to the maximum value entered in the Upper Limit field.

If the rule is used to establish jump requirements, a jump limit (for example, a maximum gauge or width jump) is assigned to each width range. When the system performs transition analysis, it will first determine within which width range the transition's From item falls. It will then use the jump limit specified in the step to determine if the transition's jump exceeds the established limit.

If the rule is used to establish sort width increments, an exit or entry width will be specified for each width range. When the system attempts to add an item to the schedule, it will determine within which width range the item falls and then assign the appropriate exit or entry width to the item. The items will then be sorted according to their assigned exit or entry widths rather than their actual widths.

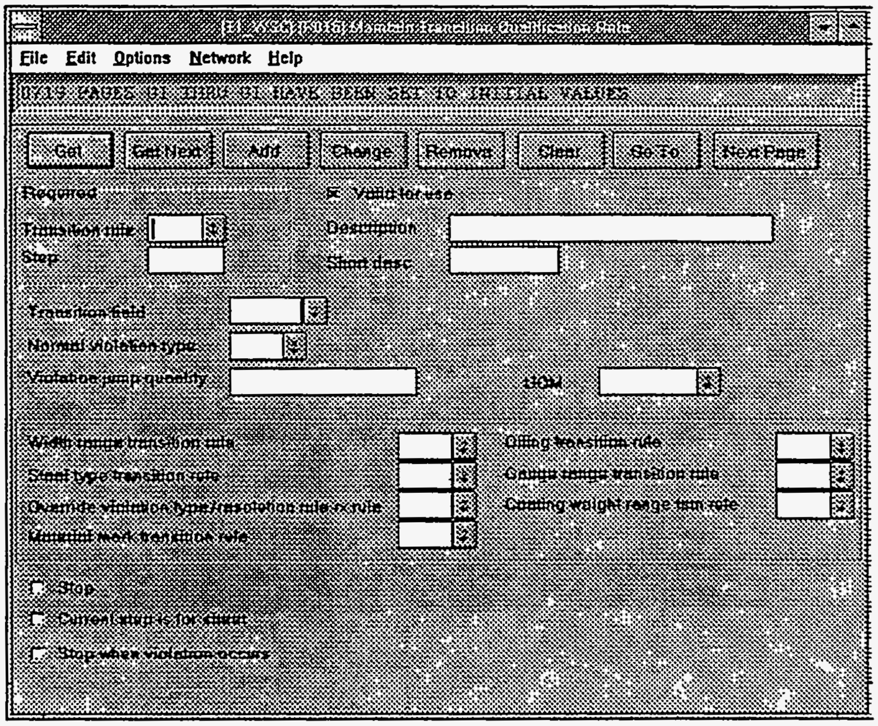
Where this rule is entered:

Width Range Rules used for defining width range jump requirements are entered in the Width Range Transition Rule field on the (P016) Maintain Transition Qualification Rule screen.

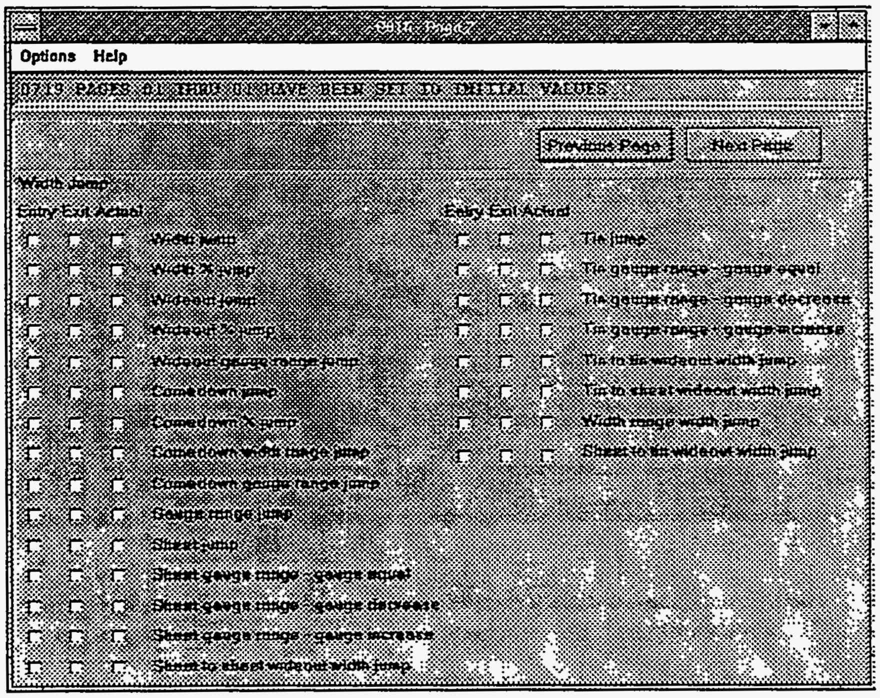
Width Range Rules used for defining a facility's sort width increments are entered in the Sort Width field on the (SC56) Maintain Facility screen.

(P016) Maintain Transition Qualification Rule

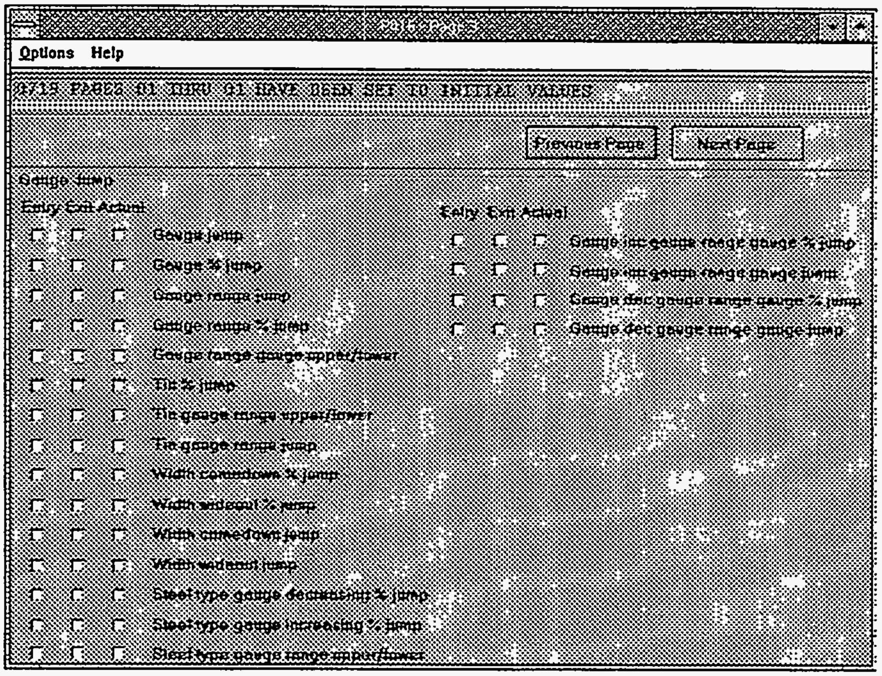
Page 1



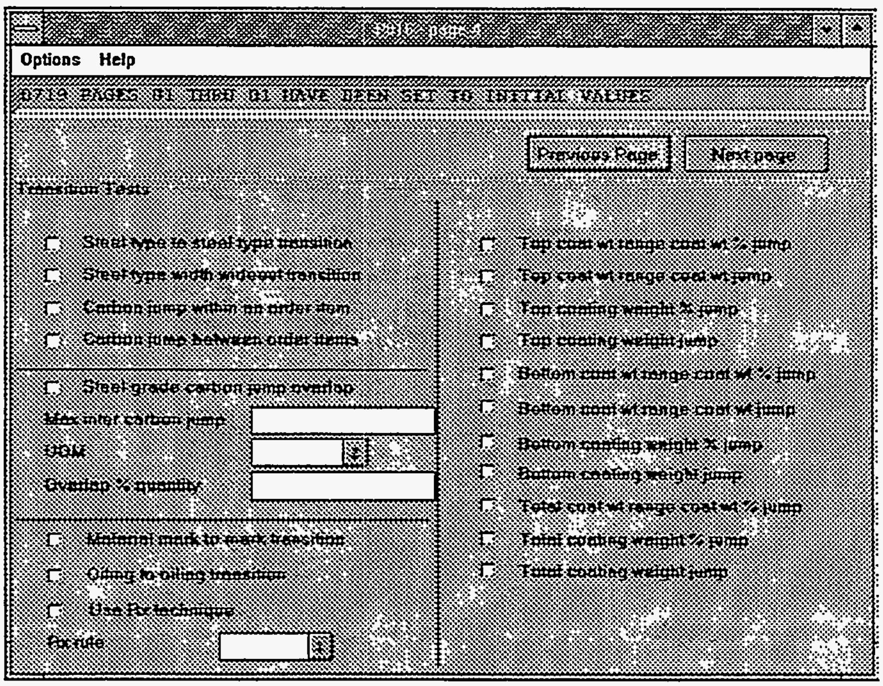
Page 2



Page 3



Page 4



The Maintain Demand Qualification Rule screen is used to specify the order in which the system will perform the qualification techniques it uses to check a schedule for transition violations.

The Scheduling System performs two main processes when it builds a facility's schedule:

1. The system builds a schedule based on the facility's schedule model and on the requirements of downstream facilities.
2. The system performs three analysis routines to identify and resolve violations in the schedule. The last of these routines performed is transition analysis, which looks for violations in each item-to-item transition.

The facility schedule model's Transition Qualification Rule initiates transition analysis by telling the system which qualifying techniques to use and in which order to use them.

To initiate transition analysis, the system will invoke the Transition Qualification Rule specified on the facility's (SC56) Maintain Facility screen.

How this screen works:

A Transition Qualification Rule consists of one or more steps. Each step in the rule has a numeric ID (step number) and defines one, and only one, technique for detecting violations of the facility's transition requirements.

In addition, depending on the technique being used, each step may also call on one of six other Transition Rules. These additional rules check for violations in transitions that fit specified descriptions.

- The six additional rules are:
- Width Range Jump Rules (P015)
- Gauge Range Jump Rules (P017)
- Coating Weight Range Jump Rules (P066)
- Steel Type Transition Rules (P001)
- Marking Transition Rules (P002)
- Oiling Transition Rules (P003)

Example: You may want to restrict the gauge jumps of all transitions that fit into a certain width range. In such a case, you would enter a P015 Maintain Width Range Rule within one of the steps of the Transition Qualification Rule.

When the system reaches the step, it will execute the P015 Rule to see if the transition being checked falls into the width range for which you want to restrict gauge jumps.

The system will execute the Transition Qualification Rule in the ascending order of its step numbers. If a violation is detected, the system will attempt to resolve it by executing either:

- the Transition Resolution Rule created on P025 and entered for the facility on SC56 or
- an Override Transition Resolution Rule created on RX9, entered on P016, and applied only to a particular type of violation.

The Transition Qualification Rule will continue executing until one of the steps instructs it to stop the qualification process.

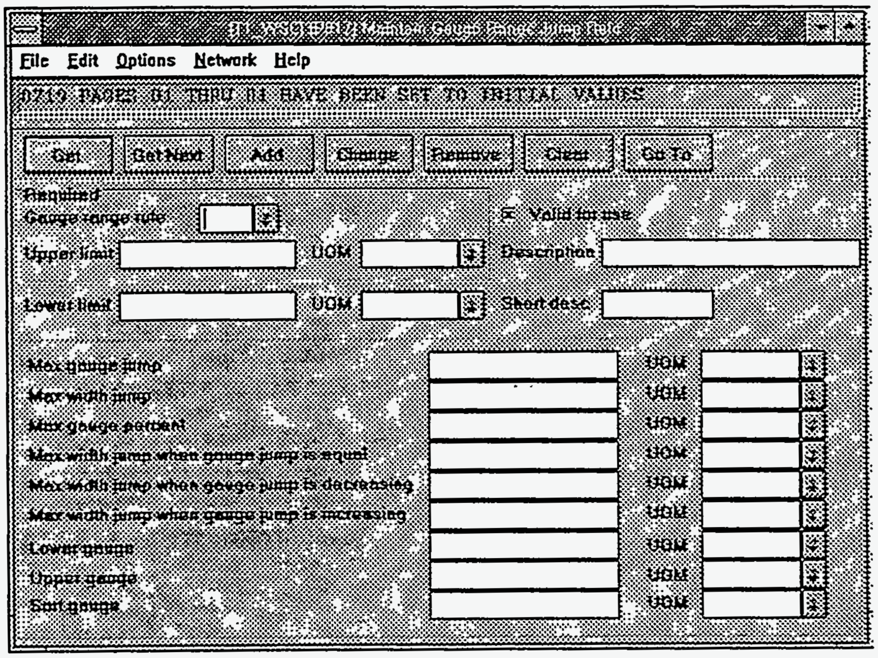
Where this rule is entered:

Transition Qualification Rules can be entered in any of the following fields:

- A Transition Qualification Rule that will be used as the default for a facility is entered in the Transition Qual Rule field on (SC56) Maintain Facility.

- A Transition Qualification Rule that will be used as an override to qualify resolution candidates is entered in the Resolution Override Qual Rule on (P025) Maintain Demand Transition Qualification Rule.
- A Transition Qualification Rule that will be used as an override for a specific schedule block is entered in the Resolution Override Qual Rule on (SC57) Maintain Schedule Block.

(P017) Maintain Gauge Range Jump Rule



This screen is used to create and maintain a rule that can serve two purposes:

1) Determine gauge range jump requirements.

   When the system is making a transition from one item (the From item) to another (the To item) in a line-up, it uses Transition Rules to determine if the jump is valid.

   The Gauge Jump Rule is such a rule. It can be used to define the allowable width and gauge jumps that may be made for given gauge ranges.

2) Determine a facility's sort gauge increments in the sorting process.

   This rule can be used to establish width increments within which a facility's items will be sorted. When the sorting process is executed, the facility's items will be sequenced according to the width increments within which they fall.

A Gauge Range Jump Rule is comprised of a series of steps. Each step in the rule defines a range of gauge measurements.

The upper limit of the step's range is set by the Upper Limit field and the lower limit of the step's range is automatically set equal to the maximum value of the previous step. If no previous step exists, the range will consist of all values less than or equal to the maximum value entered in the Upper Limit field.

If the rule is used to establish jump requirements, a jump limit (for example, a maximum gauge or width jump) is assigned to each gauge range. When the system performs transition analysis, it will first determine within which gauge range the transition's From item falls. It will then use the jump limit specified in the step to determine if the transition's jump exceeds the established limit.

If the rule is used to establish sort gauge increments, an exit or entry gauge will be specified for each gauge range. When the system attempts to add an item to the schedule, it will determine within which gauge range the item falls and then assign the appropriate exit or entry gauge to the item. The items will then be sorted according to their assigned exit or entry gauges rather than their actual gauges.

How this rule works:

A Gauge Range Jump Rule is comprised of a series of steps. Each step in the rule defines a range of gauge measurements.

The upper limit of the step's range is set by the Upper Limit field and the lower limit of the step's range is automatically set equal to the maximum value of the previous step. If no previous step exists, the range will consist of all values less than or equal to the maximum value entered in the Upper Limit field.

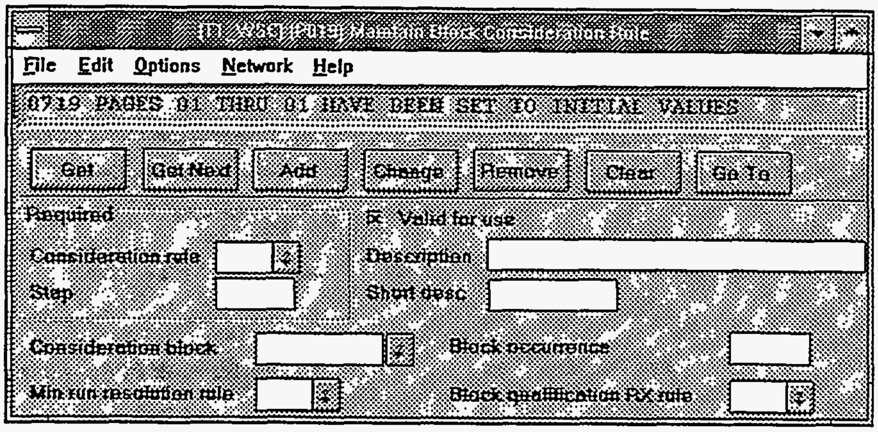
If the rule is used to establish jump requirements, a jump limit (for example, a maximum gauge or width jump) is assigned to each gauge range. When the system performs transition analysis, it will first determine within which gauge range the transition's From item falls. It will then use the jump limit specified in the step to determine if the transition's jump exceeds the established limit.

If the rule is used to establish sort gauge increments, an exit or entry gauge will be specified for each gauge range. When the system attempts to add an item to the schedule, it will determine within which gauge range the item falls and then assign the appropriate exit or entry gauge to the item. The items will then be sorted according to their assigned exit or entry gauges rather than their actual gauges.

Where this rule is entered:

- The Gauge Range Transition field on the (P016) Maintain Demand Qualification Rule screen.
- The Prime Material -- Gauge Range Upper/Lower Jump Rule field on the (P001) Maintain Steel Type Transition Rule screen.
- The Distressed Material -- Gauge Range Upper/Lower Jump Rule field on the (P001) Maintain Steel Type Transition Rule screen.
- Sort Gauge field on the (SC56) Maintain Facility screen.

(P019) Maintain Block Consideration Rule



The Maintain Block Consideration Rule screen is used to create and maintain a rule that can serve three purposes:

1) Identify the cycle's components (schedule blocks, schedule block groups, processing cycles) that must be checked for minimum run violations.
2) Indicate which schedule blocks can be used as sources for transition resolution.
3) Indicate which schedule blocks can be used as sources for start-up requirements.

How this rule works:

A Block Consideration Rule is comprised of a series of numbered steps. The system executes the rule in the ascending order of its step numbers. Depending on its purpose, the rule functions in one of the following ways:

1) When creating a Block Consideration Rule for minimum run analysis, you must include in each rule-step:

   - The name of the component to be analyzed.
   - The Minimum Run Resolution Rule (created on the (P020) Maintain Minimum Run Resolution Rule screen) that the system will execute if the component violates its minimum run requirements.

   After creating the Block Consideration Rule, attach it to a processing cycle using the (SC59) Maintain Processing Cycle screen.

   When the system conducts minimum run analysis on the current processing cycle, it will execute the cycle's Block Consideration Rule. The system will check for minimum run violations in each component included in the Block Consideration Rule.

   When a minimum run violation is detected, the system will attempt to resolve it by executing the specified Minimum Run Resolution Rule.

2) When creating a Transition Source Block Consideration Rule for a schedule block, you must include in each rule-step:

   - the ID of the block to be used as a source

When creating a Transition Source Block Consideration Rule for a specific schedule block occurrence, you must include in each rule-step:

- the ID of the block to be used as a source
- the occurrence number of the block

You may optionally include in either case:

- a Block Qualification RX Rule (created on RX9) that will test the source block's items to determine if they meet the requirements necessary to resolve transition violations.

After you create the Block Consideration Rule, you can assign it to:

- a schedule block on the (SC57) Maintain Facility Schedule Model Network screen

  or

- a schedule block occurrence on the (SC75) Maintain Facility Schedule Model Network screen.

If a transition violation occurs, the system will check to see in which block (or block occurrence) the violation has occurred.

The system will then execute the appropriate Block Consideration Rule, using the blocks included in it as sources for transition resolution candidates.

3) When creating a Block Consideration Rule to specify source blocks for start up materials, you must include the ID of a source block in each rule step.

   After you create the Block Consideration Rule, you can assign it to a processing cycle by entering it in the Start Up Pull Ahead Block Rule on the (SC59) Maintain Processing Cycle screen.

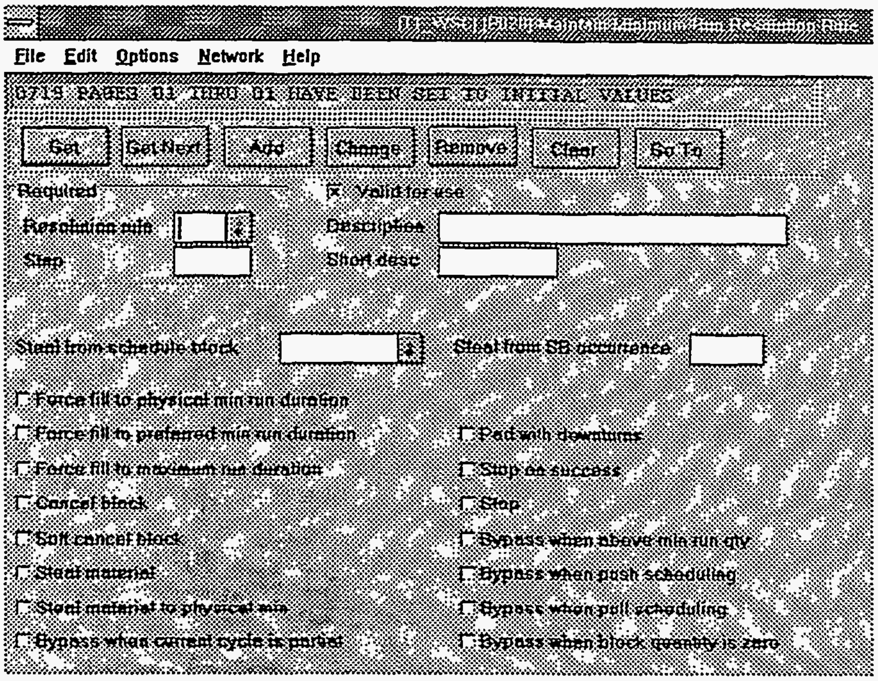
   When the system builds a schedule for a facility, it will check the facility's processing cycle(s) for start up requirements. If the facility has start up requirements, the system will execute the rule cycle's Start Up Pull Ahead Block Rule, using the blocks included in it as sources for the required start up material.

Where this rule is entered:

Block Consideration Rules can be entered on any of the following screens:

- If you are using the rule for minimum run analysis, enter it in the Minimum Run Block Consideration Rule field on the (SC59) Maintain Processing Cycle screen.
- If you are using the rule to find sources for transition resolution for a schedule block, enter it in the Transition Source Block Consideration Rule field on the (SC57) Maintain Schedule Block screen.
- If you are using the rule to find sources for transition resolution for a specific occurrence of a schedule block, enter it in the Transition Source Block Consideration Rule field on the (SC75) Maintain Facility Schedule Model Network screen.
- If you are using the rule to find start-up material, enter it in the Start Up Block Consideration Rule field on the (SC59) Maintain Processing Cycle screen.

(P020) Maintain Minimum Run Resolution Rule



The Maintain Minimum Run Resolution Rule screen is used to create and maintain a rule that tells the system what techniques it should use to resolve minimum run violations when they occur.

The system begins minimum run analysis by executing the current processing cycle's Block Consideration Rule (created on P019). The system tests each block included in the rule to see if the block's run duration requirements have been met.

If a block in the rule does not meet minimum run requirements, the system executes the Minimum Run Resolution Rule assigned to the block in the Block Consideration Rule.

How this rule works:

The Minimum Run Resolution Rule tells the system what steps to take to resolve the problem.

It does this through a series of steps. Each step has a numeric ID or step number. The system executes the Resolution Rule in the ascending order of its step numbers.

Each step in the rule instructs the system to perform one (and only one) resolution technique. The rule will continue to execute until the violation is resolved or until one of the steps instructs the system to stop. Usually, the steps for this rule are configured to first try to force fill the considered block to meet the preferred run quantity.

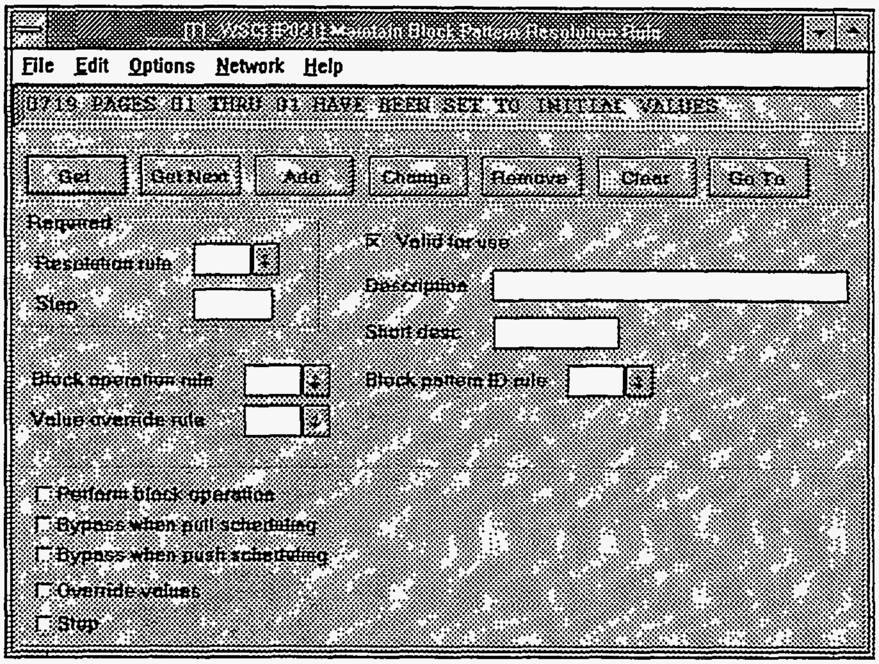
If the system cannot meet the preferred minimum run quantity, then the next steps should tell the system how to attempt to meet the physical minimum quantity.

Finally, if none of the suggested techniques succeed, the last step should indicate how if the block should be canceled or not.

Where this rule is entered:

Minimum Run Resolution Rules are entered in the Min Run Resolution Rule field of the (P019) Maintain Block Consideration Rule screen.

(P021) Maintain Block Pattern Resolution Rule



The Maintain Blk Pattern Resolution Rule screen is used to create and maintain a rule that will attempt to resolve block pattern violations detected during block pattern analysis.

This rule is the 'answer' to the invalid pattern identified through the P022 screen. In other words, it tells the system what steps to take to fix the block pattern problem that was found.

It defines and sequences the resolution techniques you want the system to attempt. Each step in the rule can initiate the execution of a Block Operation Rule or a Value Override Rule.

These rules re-organize the contents of the processing cycle in order to establish a new block pattern that is not invalid. After the pattern has been re-organized, you can qualify the outcome by executing another Block Pattern ID Rule.

How this rule works:

During block pattern analysis, the system executes a Block Pattern ID Rule to identify any invalid block patterns that may be present in the current processing cycle. If an invalid pattern is found, the system will attempt to resolve it by executing the Block Pattern Resolution Rule specified by the Block Pattern ID Rule.

A Block Pattern Resolution Rule consists of a series of steps. Each step can attempt to resolve the violation by initiating the execution of a Block Operation or Value Override rule. (A Block Operation Rule attempts to reorganize the pattern by swapping or combining blocks, by canceling blocks, or by rebuilding the cycle from scratch. A Value Override Rule attempts to reorganize the pattern by changing the contents of the blocks and then rebuilding the cycle from scratch.)

You can configure a Block Operation Rule so that after it is executed, a final step in the rule will initiate the execution of a Block Pattern ID Rule that will check the re-organized block pattern for additional pattern violations.

The system will execute the Block Pattern Resolution Rule in the ascending order of its step numbers until either a step succeeds (does not result in another invalid pattern) or there are no more steps.

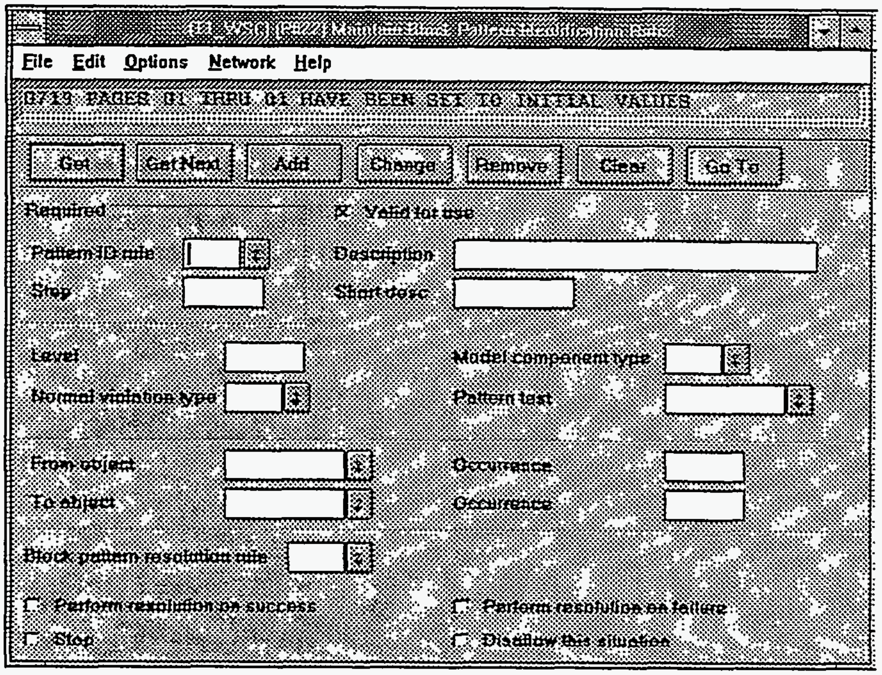
If the attempt at resolution is not successful and another Resolution Rule has been defined for this processing cycle, all changes made by the first Resolution Rule will be backed out by the system, and the next Resolution Rule will be executed.

If the attempt at resolution is not successful and the rule is the last possible Resolution Rule defined for this Processing Cycle, then the changes will not be backed out, but the entire processing cycle will be marked as having an unresolved block pattern violation.

Where this rule is entered:

Block Pattern Resolution Rules are entered in the Block Pattern Resolution Rule field on the (P022) Maintain Block Pattern Identification Rule screen.

(P022) Maintain Block Pattern Identification Rule



The Maintain Block Pattern Identification Rule screen is used to create and maintain a rule that will identify a processing cycle's invalid block patterns.

During minimum run analysis, the scheduling program may fail to resolve one or more minimum run violations (due to insufficient material, a full cycle, etc.) and may, depending on the resolution techniques used, cancel one or more blocks in the cycle.

The resulting pattern of blocks, however, may not meet the facility's block sequence requirements. The Block Pattern Identification Rule tests for invalid block patterns and specifies a rule the system will use to resolve any pattern violations that are detected.

How this screen works:

When the system performs block pattern analysis, it begins by retrieving the Normal Pattern ID Rule from the processing cycle.

The system will execute the rule in the ascending order of its step numbers to find out which block patterns to check for and which Pattern Resolution Rule it should execute to resolve any pattern violations.

As part of the resolution process, the system may have to make changes to the cycle's original block pattern. The changes may in turn create new pattern violations. You can qualify the new block pattern by specifying a second Pattern ID Rule on the Pattern Resolution Rule.

If no resolution can be found, the system will retain the changes made to the block pattern (i.e., all swaps, combines and cancels), retrieve the Fail Sit SB Pattern ID Rule from the processing cycle and again attempt to qualify the block pattern with the new rule.

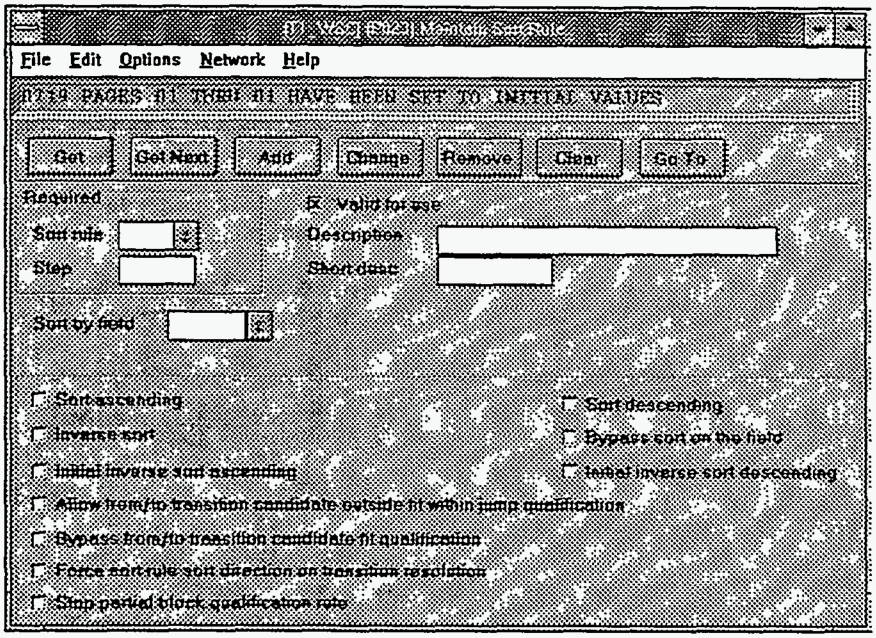
If, again, no resolution can be found, the system will stamp the violating block with the flag specified for it in the Normal Violation Type field of the Pattern ID Rule.

Where this rule is entered:

Block Pattern ID Rules are entered in the following fields:

- A Block Pattern ID Rule that will be used as the default rule for a processing cycle is entered in the Normal Pattern ID field on (SC59) Maintain Processing Cycle.
- A Block Pattern ID Rule that will be used should the default rule fail to resolve the pattern violation is entered in the Fail Sit SB Pattern ID field on (SC59) Maintain Processing Cycle.
- A Block Pattern ID Rule that will be used to qualify a new block pattern generated by the execution of a Block Pattern Resolution Rule is entered in the Blk Pattern ID Rule field on (P021) Maintain Blk Pattern Resolution Rule.

(P023) Maintain Sort Rule



The Maintain Sort Rule screen is used to create and maintain a Schedule Block Sort Rule.

A Schedule Block Sort Rule tells the system how to sequence a given group of schedule items (coils, slabs, etc.) within each of the model's schedule blocks.

There are three types of sort rules:

- A Normal Sort Rule acts as a default. It is applied to a model schedule block (rather than to a specific occurrence of the block) and defines the block's typical sort requirement.
- An Override Sort Rule is applied to a specific schedule block occurrence that has a unique sorting requirement OR to a schedule block that has been changed due to pattern block resolution.
- An Override Rule will allow you to invoke a special sort rule for a specific schedule block occurrence while maintaining the Normal Sort Rule for other occurrences of the same model schedule block.
- A WIP Sort Rule is applied to the transition resolution candidates collected in a facility's Work In Progress Queue.

While Override and WIP Sort Rules are optional, a Normal Sort Rule is required for each schedule block in the model.

How this rule works:

The scheduling system sequences the material in a schedule block according to a set of instructions or steps. Each step has a numeric ID or step number. The system will execute the Sort Rule in the ascending order of its step numbers.

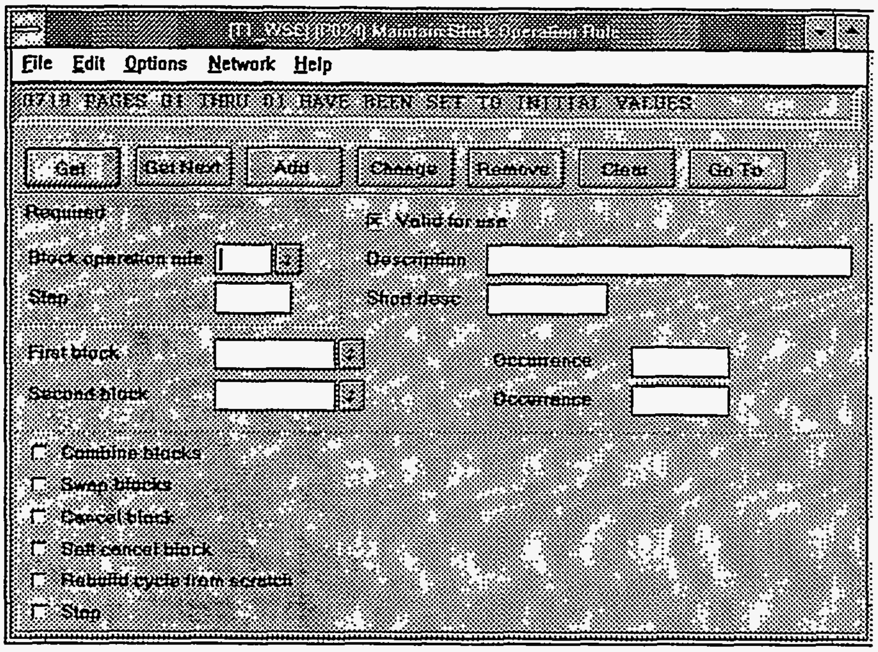
Each step instructs the system to sort the items by one attribute using one sort technique. Each step can also instruct the system to bypass or violate a sort requirement in order to resolve transition violations.

Where this screen is entered:

Schedule Block Sort Rules are entered in the following fields:

- Normal Sort Rules are entered in the Normal Sort Rule field on the (SC57) Maintain Schedule Block screen.
- Override Sort Rules used to sort a block occurrence with unique requirements are entered in the Schedule Block Sort Rule field on the (SC75) Maintain Facility Schedule Model Composition screen.
- Override Sort Rules used to sort a block during block pattern resolution are entered in the Override SB Sort Rule field on (P029) Maintain Value Override Rule screen.
- Override Sort Rules used to sort transition resolution candidates during transition resolution are entered in the From Pool Sort Rule and To Pool Sort Rule fields on (P025) Maintain Transition Resolution Rule screen.

(P024) Maintain Block Pattern Resolution



The Maintain Block Operation Rule screen is used to create and maintain a rule that will attempt to re-arrange a processing cycle's invalid block pattern through one or more block operations.

When the system identifies an invalid block pattern, it will attempt to resolve the violation by executing a Block Pattern Resolution Rule. The Block Pattern Resolution Rule tells the system how it should attempt to correct the invalid block pattern. One method is the execution of a Block Operation Rule.

A Block Operation Rule tells the system which operations it should perform to re-organize the blocks into a valid pattern. Possible block operations include the swapping, combining and canceling of blocks.

How this rule works:

When a step in a Block Pattern Resolution Rule calls a Block Operation Rule, the system executes the Block Operation Rule in the ascending order of its step numbers. Each step can instruct the system to perform one operation.

You can configure the Block Operation Rule to do one or more of the following operations:

- swap two or more blocks to change their positions in the schedule,
- combine the items in one block with those in another block
- cancel a block
- rebuild the entire processing cycle from scratch

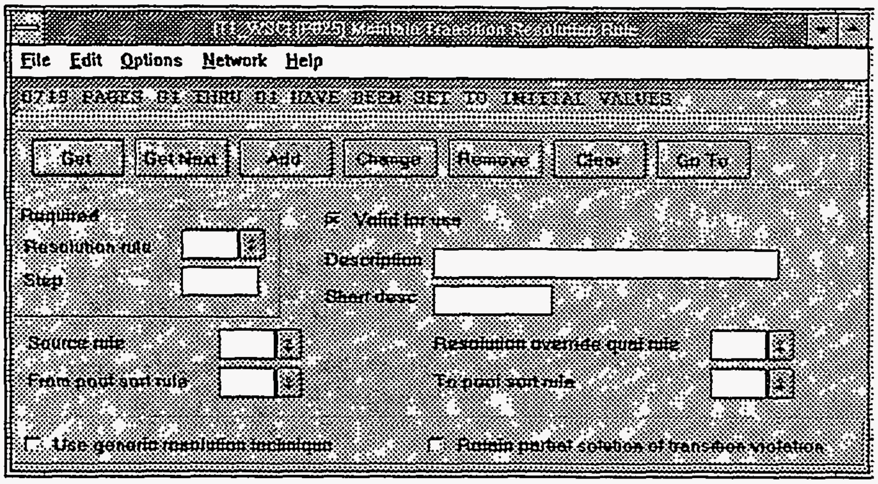
The system will continue executing the rule until one of the steps instructs the system to stop or until there are no more steps to execute.

When the rule is finished executing, the system will return to the next step in the Pattern Resolution Rule for further instructions on resolving the pattern violation.

Where this rule is entered:

Block Operation Rules can be entered in the Block Operation Rule field of the (P021) Maintain Block Pattern Resolution Rule screen.

(P025) Maintain Transition Resolution Rule



The Maintain Transition Resolution Rule screen is used to create and maintain a rule that will attempt to resolve transition violations detected during transition analysis.

During transition analysis, the system tests for violations by executing a Transition Qualification Rule for each transition in the processing cycle. Each time a transition violation is detected, the system will attempt to resolve the problem by executing the Transition Resolution Rule assigned to the facility

A Transition Resolution Rule tells the system what methods it should use to solve transition violations when they occur.

How this rule works:

Transition Resolution Rules consist of a series of steps. Each step has a numeric ID or step number. The system will execute the Resolution Rule in the ascending order of its step numbers.

Each step in the Transition Resolution Rule generally gives the system two instructions:

1) It tells the system which Resolution Source Rule it should use. Resolution Source Rules indicate where (i.e., at which source) the system can find items that can be inserted into the schedule to resolve a transition violation. These items are called resolution candidates.

2) It tells the system which resolution technique it should use. Currently, there is only one resolution technique the system is configured to use.

These two instructions are carried out in the following manner:

The system gathers the items it finds through the specified Resolution Source Rule and creates two pools of resolution candidates--a From pool and a To pool (for From and To resolution candidates). The system then taps these pools as it searches for items that can be inserted into the schedule to bridge the detected transition gap (i.e., the violation).

Each time an item from one of the pools is inserted into the schedule, the system qualifies the resolution candidate (see note below) to see if the new transition resolves the original violation or creates a new violation. If the violation is resolved, the system moves on to check the next transition in the schedule for violations.

If it is not resolved, the system continues its attempts at resolution until the violation is corrected or until the pools of candidates created during the current rule step are exhausted. In the case of the latter, the system will drop from the schedule all of the candidates inserted thus far, build a new pool of candidates according to the next rule step and again attempt to bridge the transition gap.

As a last resort, you may include a final rule step that tells the system to accept a partial resolution if the violation cannot be resolved. In this case, the system will allow the last set of resolution candidates to remain in the schedule, even though a violation still exists.

Otherwise, if the system executes the entire rule and is unable to resolve the violation, it will flag the violation and allow the production planner to determine how the problem should be handled.

Note:
By default, during transition resolution, the system uses the same Transition Qualification Rule it uses in the initial transition analysis. However, you can override the Default Rule by entering a different Transition Qualification Rule in the Resolution Candidate Qual Rule field.

Overriding the Default Rule enables you to "tweak" the resolution technique's results by relaxing the qualification requirements placed on the violating transition.

If the first step in the Transition Resolution Rule fails to resolve the violation, you might want the system to apply less constrictive qualification requirements in the succeeding step. Entering a relaxed Transition Qualification Rule accomplishes this.

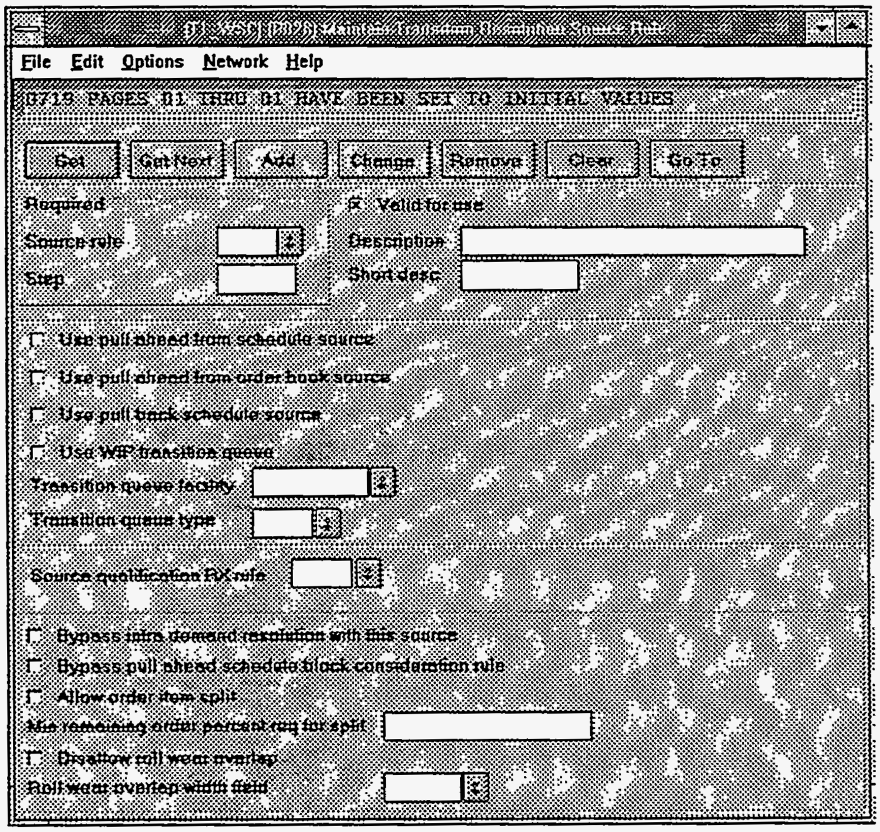
When the system executes a rule step with a Resolution Candidate Qual Rule, it will first, as usual, drop from the schedule all candidates previously inserted. It will then invoke the specified Resolution Source Rule, and then attempt to bridge the transition gap with the new pool of resolution candidates, this time checking for violations by using the less strict Transition Qualification Rule. The system will now have a greater chance of building a valid transition.

Where this rule is entered:

Transition Resolution Rules are entered in the following fields:

- A Transition Resolution Rule used during pull scheduling is entered in the Transition Resolution Rule field on the (SC56) Maintain Facility screen.
- A Transition Resolution Rule used during push scheduling is entered in the Push Transition Rsln Rule field on the (SC56) Maintain Facility screen.
- A Transition Resolution Rule used as an override for a specific schedule block is entered in the Override Transition Resolution Rule field on the (SC57) Maintain Schedule Block screen.

(P028) Maintain Transition Resolution Source Rule



The Maintain Transition Resolution Source Rule screen is used to create and maintain a rule that tells the system where (i.e., to what source) the system should look for items that can be inserted into the schedule to solve a transition violation.

How this rule works

When the system detects a transition violation, it is, in effect, detecting a gap between two successive items in a schedule. To resolve the violation, the system attempts to insert one or more items into the line-up to *bridge the gap*.

A Transition Resolution Source Rule tells the system where it might find candidates for this insertion process. It does this through a series of steps. Each step has a numeric ID or *step number*. The system will execute the Source Rule in the ascending order of its step numbers.

Each step instructs the system to search for and retrieve resolution candidates from one of the following sources:

- <u>Pull Ahead From Schedule Block Source</u> -- The system can use any item that is scheduled after the point at which the violation occurred.
- <u>Pull Back From Schedule Block Source</u> -- The system can use any item that is scheduled before the point at which the violation occurred.
- <u>Pull Ahead From Order Book Source</u> -- The system can use any item from the order book within the load horizon.

By default, the system will consider only those items assigned to schedule blocks with the same ID as the block currently being analyzed.

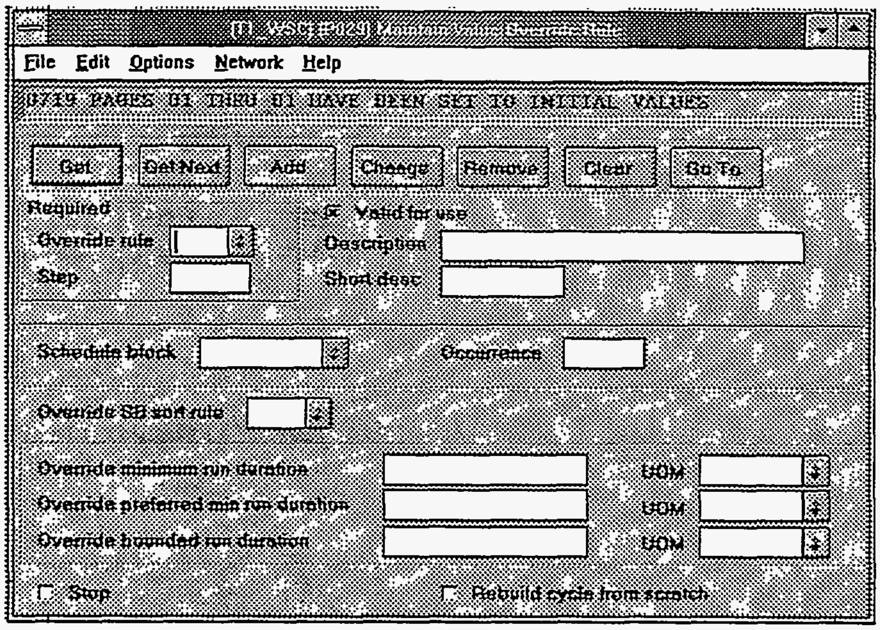
However, you can create a Block Consideration Rule (P019) to consider items assigned to alternate schedule block IDs. After creating the rule on P019, you can then apply it to the block being analyzed by entering its ID in one of the following fields:

- If you want to apply the rule to *all* occurrences of a schedule block, enter its ID in the Transition Source Block Consideration Rule field on the (SC57) Maintain Schedule Block screen.
- If you want to apply the rule to a specific occurrence of a schedule block, enter it in the Transition Source Block Consideration Rule field on the (SC75) Maintain Facility Schedule Model Network screen .

Where this rule is entered

Transition Resolution Source Rules are entered in the Source Rule field of the (P025) Maintain Demand Transition Resolution Rule screen.

(P029) Maintain Value Override Rule



The Maintain Value Override Rule screen is used to create and maintain a rule that will override a block's run duration requirements and/or override the block's Sort Rule during block pattern resolution.

When the system identifies an invalid block pattern, it will attempt to resolve the violation by executing a Block Pattern Resolution Rule.

The Block Pattern Resolution Rule tells the system how it should attempt to correct the invalid block pattern. One method is the execution of a **Value Override** Rule.

A Value Override Rule enables you to re-set the sort and/or run duration requirements for one or more blocks in the schedule model. Once the new requirements have been set, the system can rebuild the schedule from scratch.

Rebuilding the schedule with new run duration and sort requirements will most likely result in an item line-up that differs from the original. The rebuild process presents the system with another chance at generating a schedule that does not violate block pattern requirements.

How this rule works

A Value Override Rule usually comes into play when all other methods of resolution (i.e. swapping, combining and/or canceling blocks) have failed.

When a step in a Block Pattern Resolution Rule calls a Value Override Rule, the system executes the Value Override Rule in the ascending order of its step numbers. Each step can instruct the system to re-set the requirements of one block.

You can configure each step of the Value Override Rule to re-set one of the following requirements for each block in the model:

- Sort requirements (by assigning a new Schedule Block Sort Rule)
- Minimum physical run duration
- Minimum preferred run duration

- Maximum run duration

The system will re-sort a block using an override Schedule Block Sort Rule immediately after the Value Override Rule step instructs it to do so.

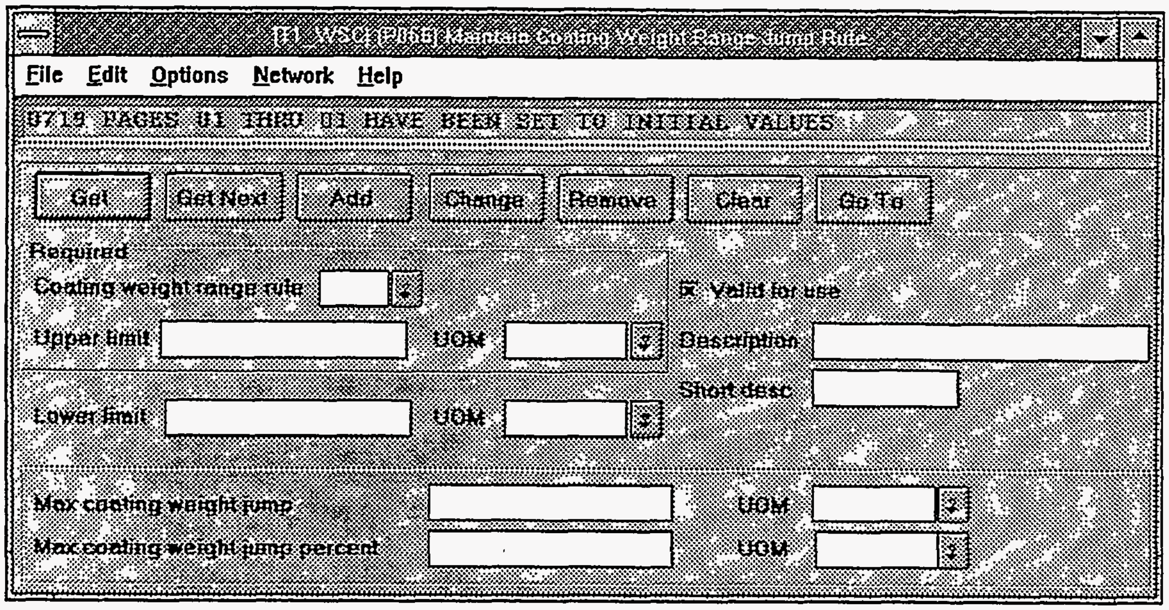
However, in order for the override run durations to take effect, you must tell the system to rebuild the schedule from scratch. The system will rebuild using the updated values and any swaps that occurred up to this point during the execution of the Block Pattern Resolution Rule.

Note, however, that any combines that occurred will be lost: since the combined items will still be stamped with their original schedule block ID, the system will assign them again to the original schedule block during the rebuild.

Where this rule is entered

Value Override Rules can be entered in the Block Override Rule field of the (P021) Maintain Block Pattern Resolution Rule screen:

(P066) Maintain Coating Weight Range Jump Rule



The Maintain Coating Weight Range Jump Rule screen is used to create and maintain a rule that will determine coating weight range jump requirements for the items in a facility's schedule blocks.

When the system is making a transition from one item (the *From* item) to another (the *To* item) in a line-up, it uses Transition Rules to determine if the jump is valid.

The Coating Weight Range Jump Rule is such a rule. It defines the allowable coating weight jumps that may be made for given coating weight ranges.

How this rule works

A Coating Weight Range Jump Rule is comprised of a series of steps. Each step in the rule defines a range of width measurements.

The upper limit of the step's range is set by the Upper Limit field, and the lower limit of the step's range is automatically set equal to the maximum value of the previous step.

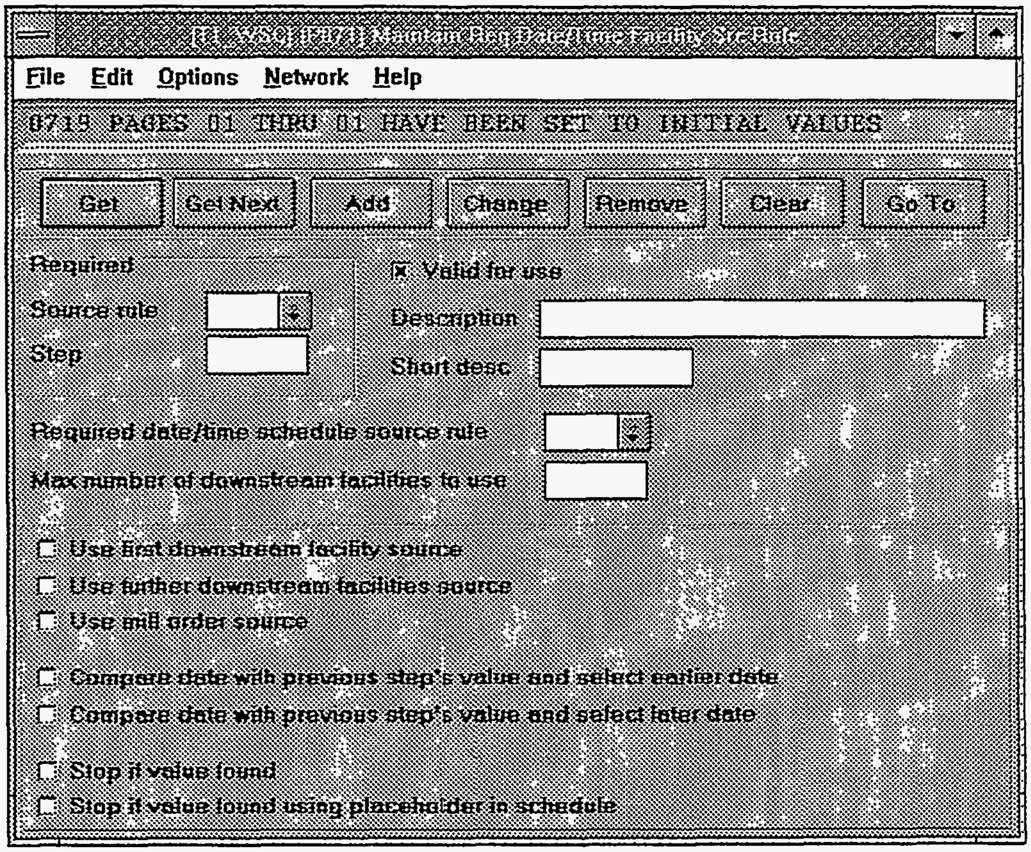
If no previous step exists, the range will consist of all values less than or equal to the maximum value entered in the Upper Limit field.

A maximum coating-weight jump limit is assigned to each coating weight range. When the system performs transition analysis, it will first determine within which coating weight range the transition's From item falls. It will then use the jump limit specified in the step to determine if the transition's jump exceeds the established limit.

Where this rule is entered

Coating Weight Range Jump Rules used for defining width range jump requirements are entered on the (P016) Maintain Transition Qualification Rule screen.

(P071) Maintain Required Date/Time Facility Source Rule



The Maintain Required Date/Time Facility Source Rule screen is used to create and maintain a Required Date/Time Facility Source Rule.

Required Date/Time Facility Source Rules tell the system to which source (i.e., facility or mill order) the system should look to determine an order item's required date/time.

Before the system places an item in the source consideration work file, it must stamp the item with it's required date/time. The system then uses the required date/time to qualify the item for schedule insertion during the Jeopardy qualification process.

The Required Date/Time Facility Source Rule tells the system at which facility it should look to determine an order item's required date/time.

How this rule works:

A Required Date/Time Facility Source Rule consists of a series of steps. Each step has a numeric ID or *step number*.

Each step in the Required Date/Time Facility Source Rule generally gives the system two basic instructions:

1) It tells the system at which facility to look. A Required Date/Time Facility Source Rule indicates where (i.e., at which source) the system should look to find an item's required date/time. It may instruct the system to look to downstream facilities or to the item's mill order.

2) It tells the system which Required Date/Time Schedule Source Rule to use. Once the system knows in which Facility to look, it executes a Required Date/Time Schedule Source Rule to determine at what point in the facility's schedule it should look.

The system will execute the Required Date/Time Facility Source Rule in the ascending order of its step numbers.

You can configure the rule so that each step looks for an item's required date/time at the next downstream facility, in several downstream facilities, or in the item's millorder. After the system knows in which facility to look, it will execute the Required Date/Time Schedule Source Rule (P072) specified for the step. The P072 rule will instruct the system where to look in the facility's schedule for the required date/time. P072 will execute until a required date/time is found or until all of the P072 steps have been executed.

You can further configure the Required Date/Time Facility Source Rule to compare the date/time retrieved in each step to the date/time retrieved in the previous step and to keep whichever date/time is either earlier or later.

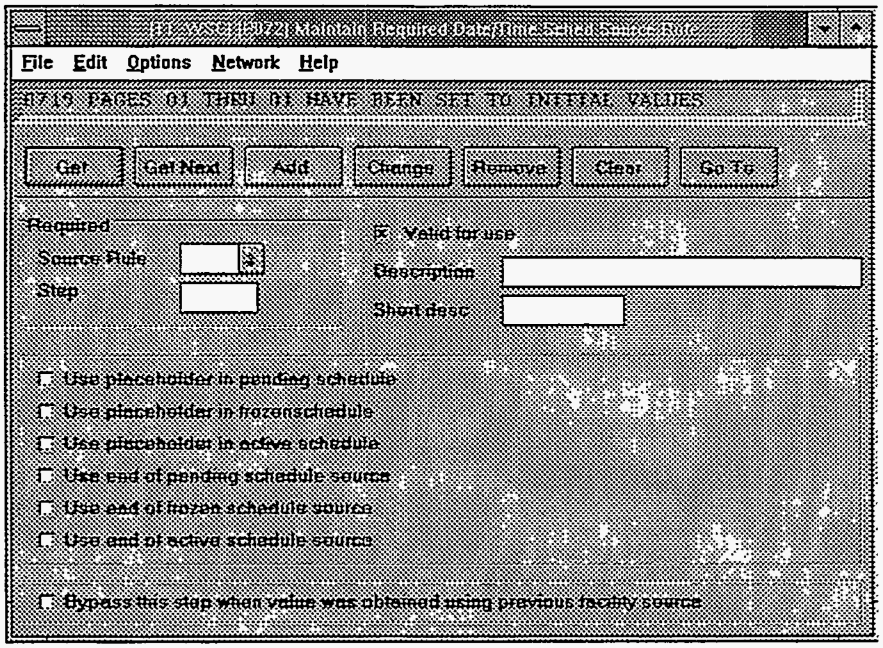
The Required Date/Time Facility Source Rule will continue to execute until one of the steps instructs it to stop or until all of its steps have been executed.

The required date/time held by the Required Date/Time Facility Source Rule when it has finished executing is stamped on the order item before it is added to the source consideration work.

Where this rule is entered

Required Date/Time Source Rules are entered in the Schedule Require Date Source Rule field on the (SC56) Maintain Facility screen.

(P072) Maintain Required Data/Time Schedule Source Rule



The Maintain Required Data/Time Schedule Source Rule screen is used to create and maintain a Required Data/Time Schedule Source Rule.

Required Data/Time Schedule Source Rules tell the system to what source (i.e., schedule) the system should look to determine an order item's required date/time.

Before the system places an item in the source consideration work file, it must stamp the item with it's required date/time. The system then uses the required date/time to qualify the item for schedule insertion during the Jeopardy qualification process.

To find out what an item's required date/time is, the system executes two rules:

1. Required Date/Time Facility Source Rule -- This rule tells the system at which facility it should look to determine an order item's required date/time. It also tells the system which Required Date/Time Schedule Source Rule to use.
2. Required Date/Time Schedule Source Rule -- This rule tells the system at what point in the facility's schedule it should look to find an item's required date time

How this rule works:

When the system attempts to locate a required date/time for an order item, it first executes a Required Date/Time Facility Source Rule (created on P071). This P071 rule tells the system in which facility locations it should look to find an order item's required date/time. It also tells the system which Required Date/Time Schedule Source Rule (P072) it should execute to find out at what point in the facility's schedule (active, pending or frozen) it should look.

Each step in the P072 rule instructs the system to look in one of the following places for an item's required date/time:

- The item's placeholder in the active schedule
- The item's placeholder in the frozen schedule

- The item's placeholder in pending the schedule
- The last item in the pending schedule
- The last item in the frozen portion of the schedule
- The last item in the active schedule

The system will execute the Required Date/Time Schedule Source Rule in the ascending order of its step numbers.

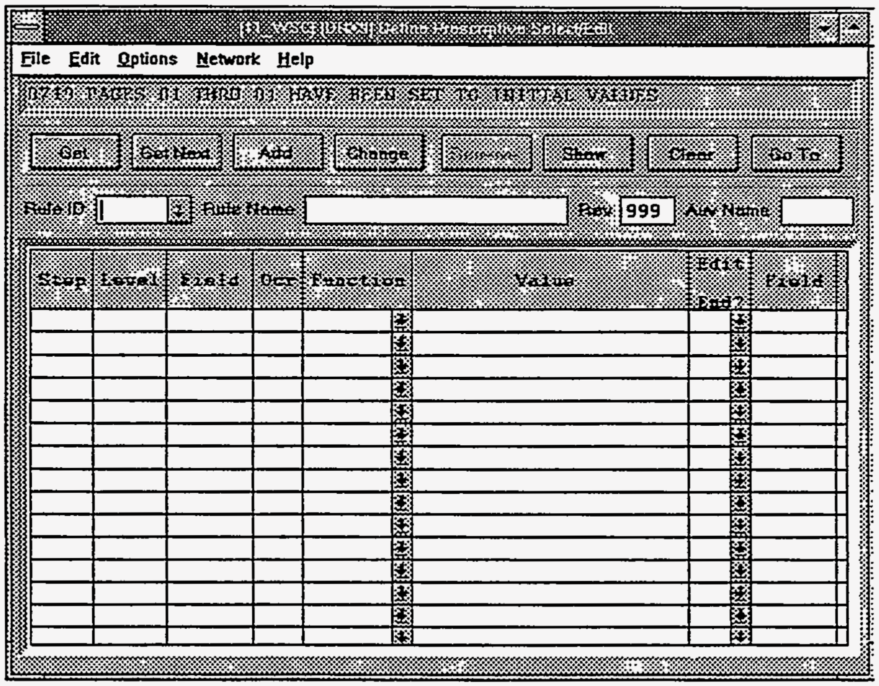
You can configure the rule so that each step looks for an item's required date/time at a different point in the facility's schedule.

The P072 rule will continue to execute until it finds a required date/time to return to the P071 rule or until all of its steps have been executed.

Where this rule is entered

Required Date/Time Schedule Source Rules are entered in the Required Date/Time Schedule Source Rule field on the (P071) Maintain Date/Time Facility Source Rule screen.

(DRX9) Define Prescriptive Select/Edit Rule



The Define Prescriptive Select/Edit Rule screen is used to create a customized rule that is driven by conditional statements.

You can use the DRX9 screen to create any of the following rules:

- Override Violation Type/Resolution Rule

  This rule is entered on P016. It overrides the facility's default Transition Resolution Rule that is created on P028 and entered on SC56.

  The Override Violation Type/Resolution Rule will instruct the system to execute an override Transition Resolution Rule when a specified combination of violations occurs.

- Transition Qualification RX Rule

  This rule is entered on P016. It overrides the default Transition Qualification Rule that is created on P025 and entered on P016.

  You can use the Transition Qualification RX Rule to filter out transition violations that cannot be detected by any of the qualification techniques available on P016. It can be configured to qualify transitions based on conditions that you specify.

- Override Transition Qualification Rule

  This rule is entered on P019 when the Block Consideration Rule is being used to designate source blocks for transition resolution.

  An Override Transition Qualification Rule can be assigned to each block included in the Block Consideration Rule. If a resolution candidate is found in a block to which an override Transition Qualification Rule was assigned, the system will qualify it by executing the Override Rule.

- Source Qualification RX Rule

This rule is entered on P028 when the Block Consideration Rule is being used to designate source blocks for transition resolution.

A Source Qualification RX Rule furthers qualifies resolution candidates found in any of the blocks included in the facility's Block Consideration Rule. It enable you to screen out undesirable candidates before the system tries to use them to resolve a violation.

- Schedule Block Assignment Rule

  This rule is entered on SC60. It serves as the default rule for the facility schedule model network.

  Schedule block Assignment Rules consist of a series of conditional statements that test items to determine their attributes. The system uses the results of the tests to assign the items to the appropriate schedule blocks when building a processing cycle.

- Roll Change Indicator Rule

  This rule is entered on SC56. Use it to mark the places in the facility's schedule at which roll changes will occur.

- Child Qualification RX Rule

  This rule is entered on SC75 and is assigned to a specific occurrence of a child block.

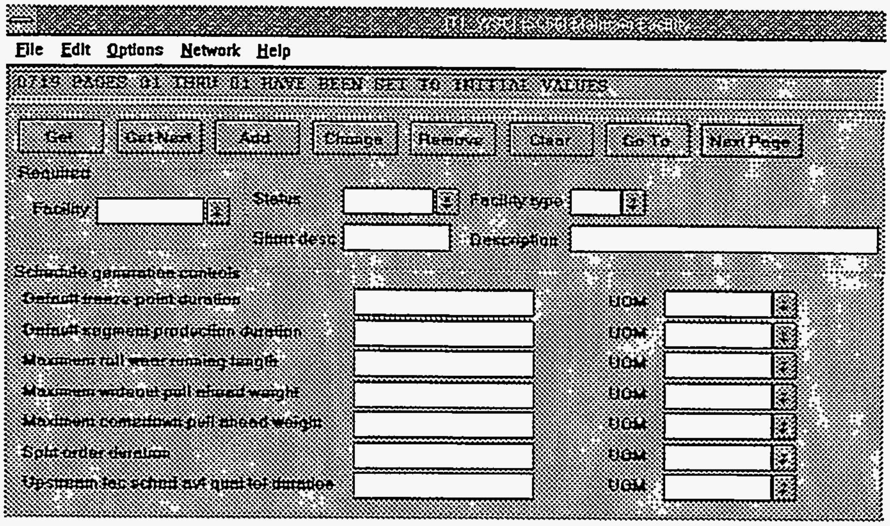
  During schedule block assignment, the system will use the Child Qualification RX Rule to disqualify specific items from being inserted into the child block occurrence.

- Material Constraint Rule

  This rule is entered on the SC67 screen to schedule a material constraint for a facility and on the SC83 screen to schedule a swing request.

  A Material Constraint Rule is used to prevent the system from running a select type of material for a specified duration or to tell the system what kind and how much of a material should be swung from one facility to another.

(SC56) Maintain Facility



The Maintain Facility screen enables you to create and maintain a facility by establishing:

A general description of the facility

You can define the facility by:

- giving the facility an ID
- giving the facility a brief description
- declaring the facility's current status

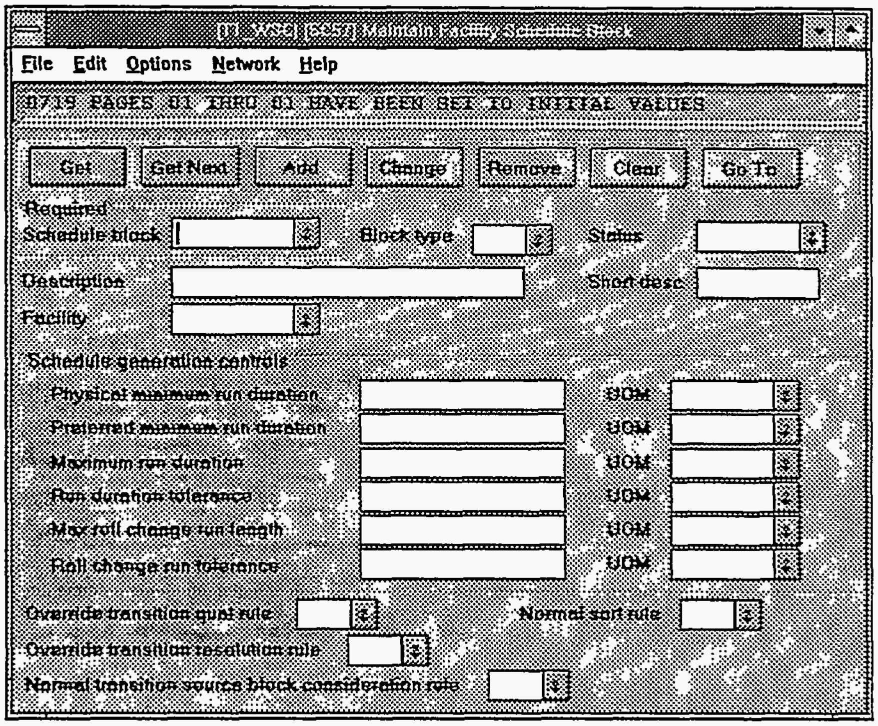
Schedule generation controls

Schedule generation controls enable you to place default requirements on all schedules built for a particular facility. These requirements set limits for things such as downturn and roll change frequency, the amount of material that can be pulled ahead during wideouts and comedowns, and other limits that pertain to all schedules run at a specific facility.

Schedule generation rules

The last group of fields on SC56, the Schedule Generation Rules, enable you to put rules and instructions into place that will act as defaults for all schedules built for a particular facility. The rules control things such as transition analysis, sorting, and schedule block assignment. The instructions tell the system to bypass, disallow or require the execution of certain functions.

(SC57) Maintain Facility Schedule Block



The Maintain Facility Schedule Block screen is used to create and maintain a schedule block by establishing:

A general description of the block

The first portion of the screen enables you to define the block by:

- giving the block an ID
- giving the block a brief description
- declaring the block's current status and block type
- assigning the block to a facility.

Run duration requirements

The second portion of the screen enables you to place minimum and maximum run duration requirements on the schedule block.

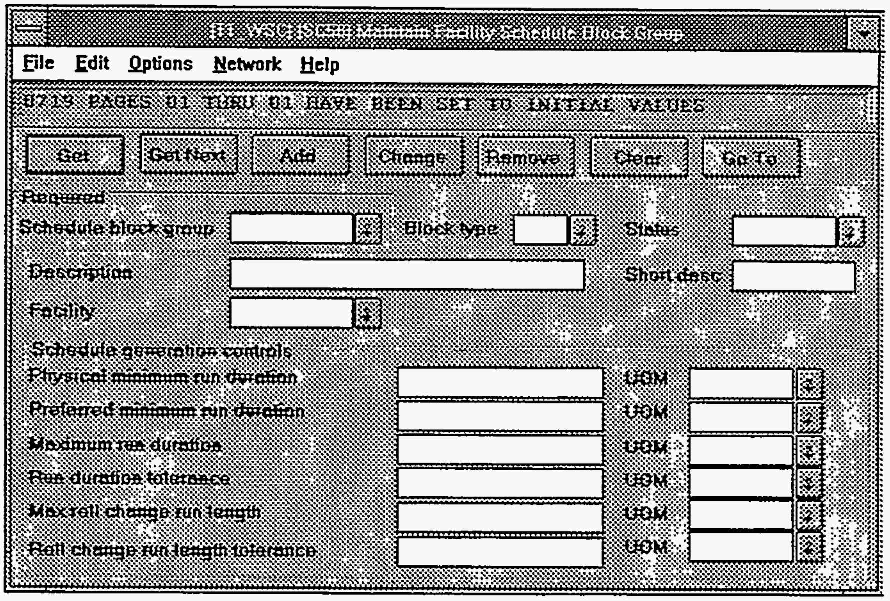
A facility's operators determine a schedule block's run requirements based on the facility's operating requirements and on the operators' preferred method of running the facility.

The system will use the requirements established on this screen to check for run duration violations. If violations are found, the system will attempt to resolve the problems.

Sort and transition rules

The final portion of the screen enables you to assign rules that will dictate the way the items are sequenced within the block.

(SC58) Maintain Facility Schedule Block Group



The Maintain Facility Schedule Block Group screen is used to create and maintain a schedule block group by establishing:

A general description of the group

The first portion of the screen enables you to define the group by:

- giving the group an ID
- giving the group a brief description
- declaring the group's current status and block type
- assigning the group to a facility

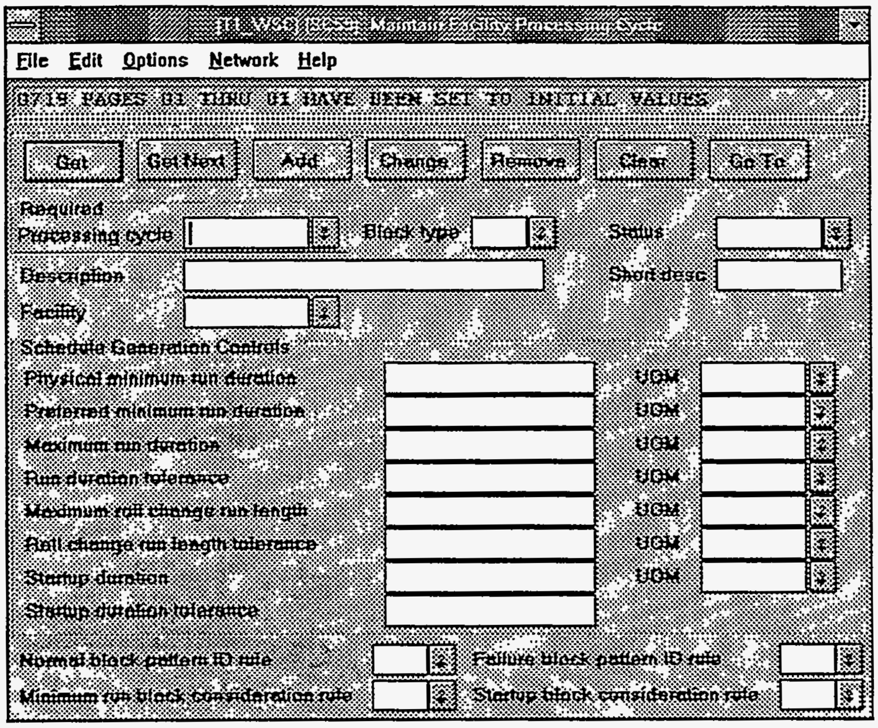
Run duration requirements

The second portion of the screen enables you to place several different minimum and maximum run duration requirements on the group.

A facility's operators determine a schedule block group's run requirements based on the facility's operating requirements and on the operators' preferred method of running the facility.

The system will use the requirements established on this screen to check for run duration violations. If violations are found, the system will attempt to resolve the problems.

(SC59) Maintain Facility Processing Cycle



The Maintain Facility Processing Cycle screen is used to create and maintain a processing cycle by establishing:

<u>A general description of the cycle</u>

The first portion of the screen enables you define the cycle by:

- giving the cycle an ID.
- giving the cycle a brief description.
- declaring the cycle current status and block type.
- assigning the cycle to a facility.

<u>Run duration requirements</u>

The second portion of the screen enables you to place several different minimum and maximum run duration requirements on the cycle.

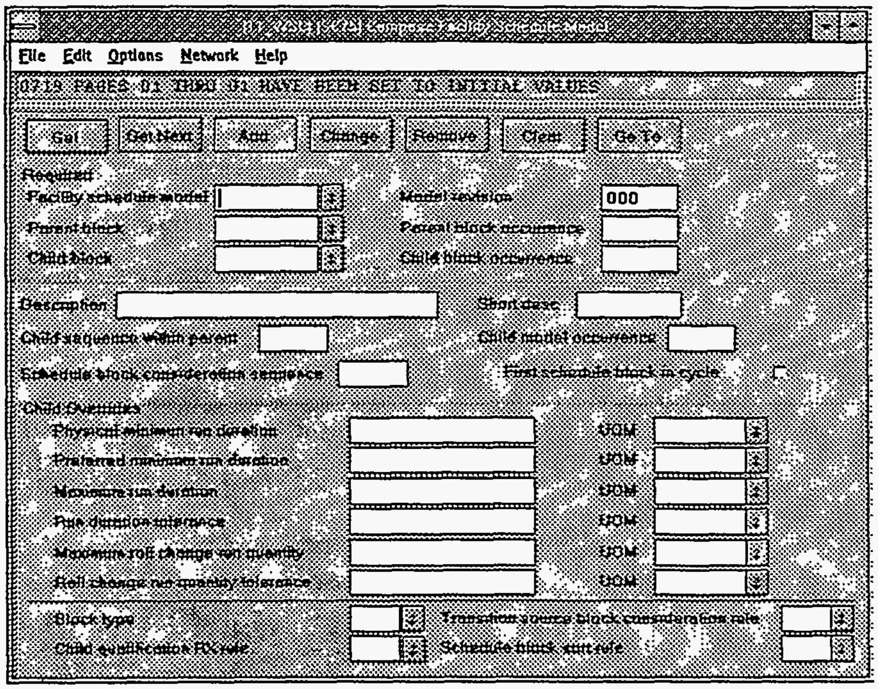
A facility's operators determine a processing cycle's run requirements based on the facility's operating requirements and on the operators' preferred method of running the facility.

The system will use the requirements established on this screen to check for run duration violations. If violations are found, the system will attempt to resolve the problems.

Sort and Transition Rules

The final portion of the screen enables you to assign rules that will control minimum run consideration, block pattern analysis, and start up requirements.

(SC75) Maintain Facility Schedule Model Network



The Maintain Facility Schedule Model Network screen is used to create and maintain a hierarchical network of linked blocks for a facility schedule model. The system uses the hierarchy to properly sequence blocks during schedule generation.

The SC75 screen enables you to see one parent-child network link at a time.

However, if you would like to see the links between a parent and all of its children, you may do sc through the (SC61) Scroll Facility Schedule Model screen.

Toggling between SC61 and SC75 gives you a detailed view of each individual parent-child link as well as an overview picture of each parent and all of it children.

How this screen works:

Establish each link in the network by:

1. Creating an identifying description of the link

   This distinguishes the link from other links by

   - assigning parent/child roles to the linked components.
   - tracking the number of times the components have occurred in the model in their current roles.
   - assigning a number to the child that determines its sequence within the parent.
   - giving the link a brief description.

2. Defining override run duration requirements

   The second portion of the screen enables you to place several override duration requirements on the child block.

These override values apply to the child only within the context of the link.

If no override values are entered, the child block's normal run duration requirements will take effect during schedule creation and qualification.

3. Assigning Override Sort and Transition Rules

   The final portion of the screen enables you to assign Override Sort, and Transition Rules to the child block.

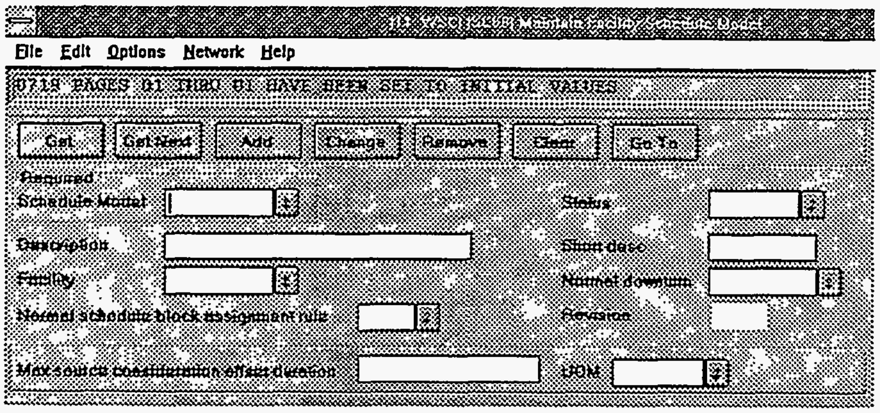
   These Override Rules apply to the child only within the context of the link.

   If no override values are entered, the child block's normal Sort and Transition Rules will take effect during schedule creation and qualification.

Build the network in a top-down manner by linking parent components to their child components in the following order:

1. Link the model to its processing cycles.
2. Link the cycles to their schedule block groups (if any).
3. Link the cycles and/or schedule block groups to their schedule blocks.

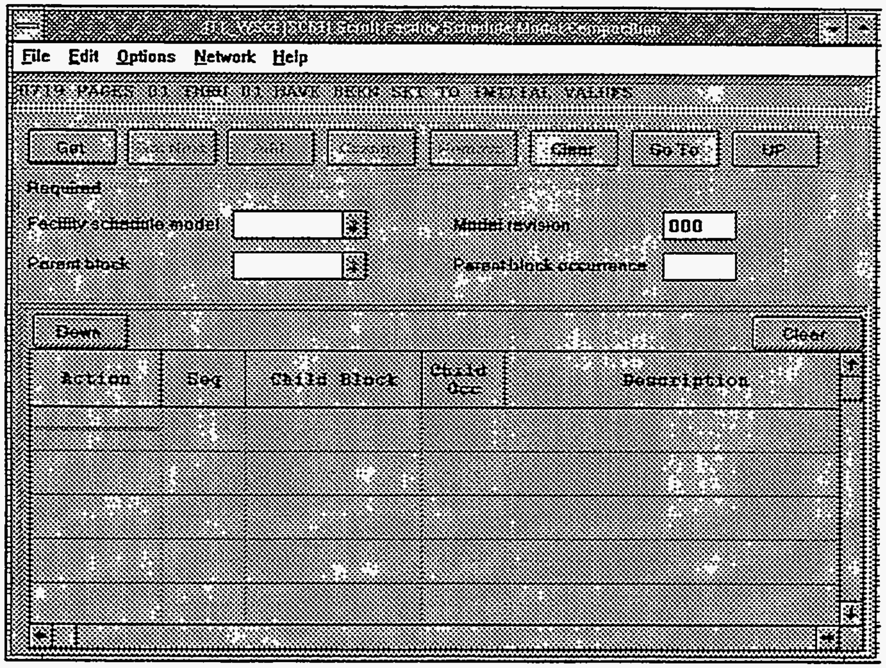
(SC60) Maintain Facility Schedule Model



The Maintain Facility Schedule Model screen is used to assign an ID to the facility schedule model network you will build through SC75, and it enables you to further define the network by establishing:

- A general description of the model.
- The model's normal downturn.
- The model's maximum source consideration offset.

(SC61) Scroll Facility Schedule Model Composition



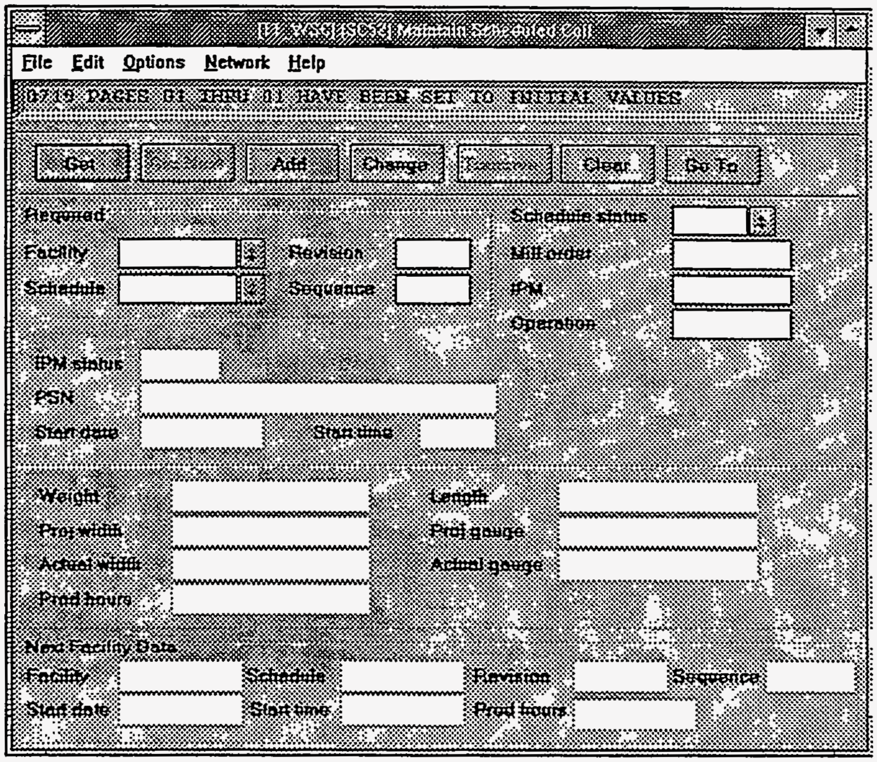
The Scroll Facility Schedule Model Composition screen is used along with the (SC75) Maintain Facility Schedule Model Network screen to create and maintain a network.

The SC61 screen enables you to scroll through a list of limited information about all of the children for any one parent.

The SC75 screen enables you to see one parent-child network link at a time. It includes detailed information about the child component, such as any Override Schedule Generation Rules or controls that will be applied to it.

Toggling between the two screens gives you a detailed view of each individual parent-child link as well as an overview picture of each parent and all of it children.

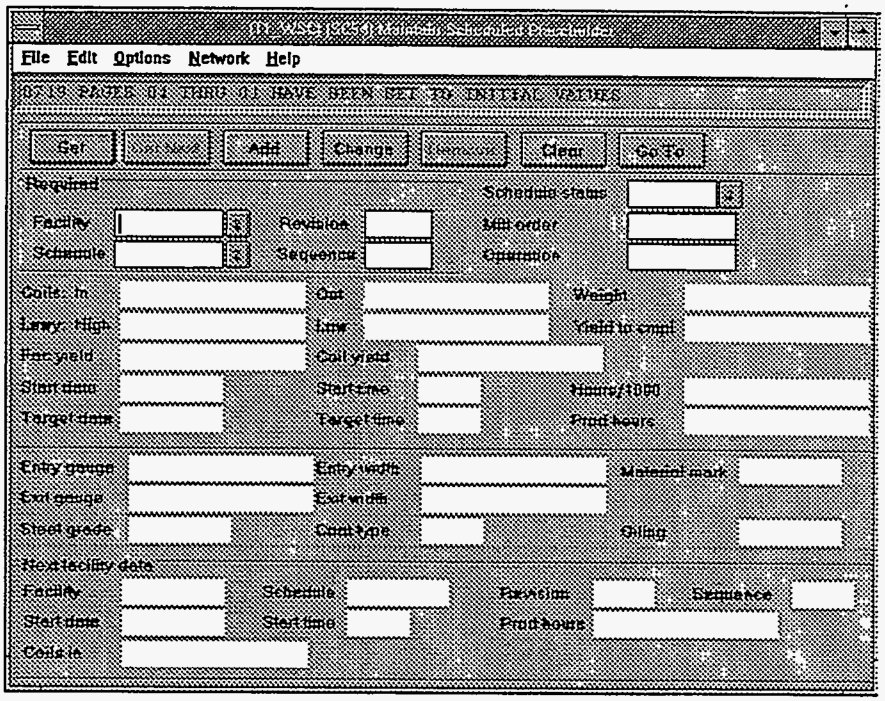
(SC52) Maintain Scheduled Coil



The Maintain Scheduled Coil screen is used to:

- Maintain an active schedule
- Change information about a coil
- Add a coil to the schedule
- Remove a coil from the schedule
- View information about a coil

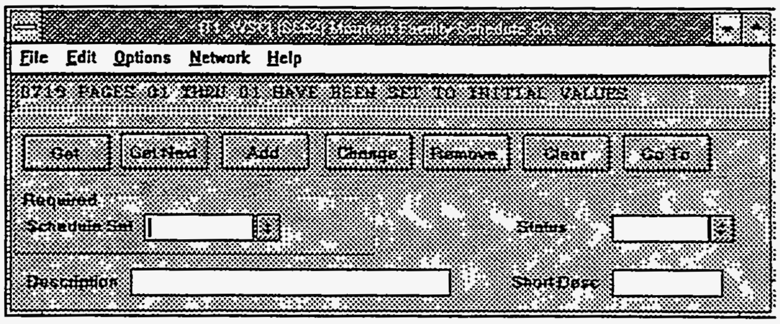
(SC54) Maintain Scheduled PlaceHolder



The Maintain Scheduled Placeholder screen is used to:

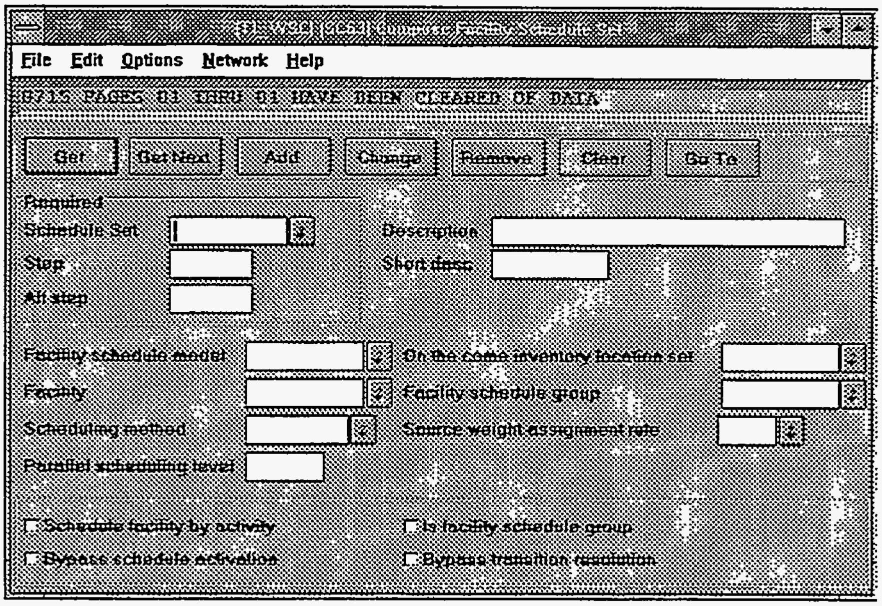
- Change information about a scheduled placeholder that is currently scheduled
- Insert a coil into a schedule
- Substitute a coil for a scheduled placeholder
- Delete a coil from a schedule

(SC62) Maintain Facility Schedule Set



The Maintain Facility Schedule Set screen is used to give a unique ID to a facility schedule set model that will be defined on (SC63) Compose Facility Schedule Set.

(SC63) Compose Facility Schedule Set



The Compose Facility Schedule Set screen is used to create and maintain a schedule set model.

A schedule set model is a sequenced list of facilities for which the system will build schedules. This screen enables you to define the list of facilities and to provide the system with instructions for scheduling them.

Schedule set models tell the system:

- which facilities to schedule
- in what sequence to schedule the facilities
- which scheduling methods to use (pull, push, push on the come, push-on-the-come downstream disqual) when scheduling the facilities.

When the scheduling program is executed, a schedule will be built for each schedule in the schedule set model according to the instructions provided.

How a schedule set model works

When the system begins the schedule building process, two of the first things it needs to know are which facilities to schedule and in which order to schedule them. The schedule set model provides this information through a series of steps.

Each step in the model has a numeric ID or *step number* and instructs the system how to schedule one facility. The system builds schedules by "stepping through" the schedule set model in the ascending order of its step numbers, creating each facility's schedule according to the instructions specified in the step.

In addition, when a swing-demand is included in a step, the step may be further defined by an alternate step.

When a step in the schedule set model is being configured to accommodate a swing-demand, all of the facilities that are participating in the swing are given the same step number. The Alt Step field enables you to differentiate between multiple units with the same step number.

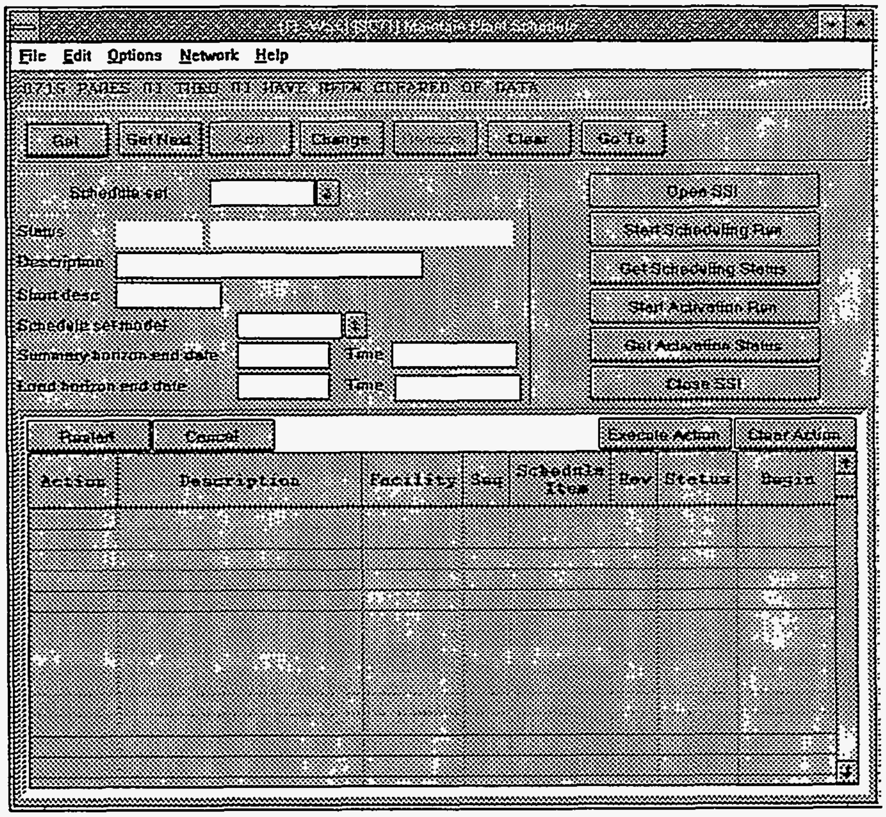
Another option available to you is parallel scheduling.

Parallel scheduling enables you to schedule up to five facilities at one time. You do this by assigning parallel schedule levels to the facilities. The system will then build the schedules in level sequence, scheduling all of the facilities of the same level together.

Where schedule set model IDs are entered

Once the schedule set models are created, they are available for production planners to select and enter on the (SC71) Maintain Plant Schedule screen.

(SC71) Maintain Plant Schedule



The Maintain Plant Schedule screen is used to complete the three tasks necessary to produce an active schedule:

1. <u>Open a plant schedule by generating a schedule set instance (SSI)</u>

   To open plant schedule, you must create a schedule set instance by:

   - selecting the schedule set model for which you want to create schedules
   - specifying the schedule's summary horizon
   - specifying the schedule's load horizon

   Once you have created a schedule set instance, you can generate a set of schedules for it by starting a scheduling run.

2. Execute and monitor a scheduling run

   You can use this screen to start the scheduling program and/or to terminate the scheduling program should you need to immediately stop its execution.

   When the system executes the scheduling program, it will generate a pending schedule for each of the facilities included in the schedule set that you specify in the Schedule Set field.

   As the program runs, you can watch its progress in the scroll area. The scroll area will display the scheduling status of each facility as the program steps through the schedule set.

The scroll area also enables you to restart or cancel a specific step of the schedule build if the status field shows that the program has abended.

When the program has finished executing, a pending schedule for each facility in the schedule set will have been created.

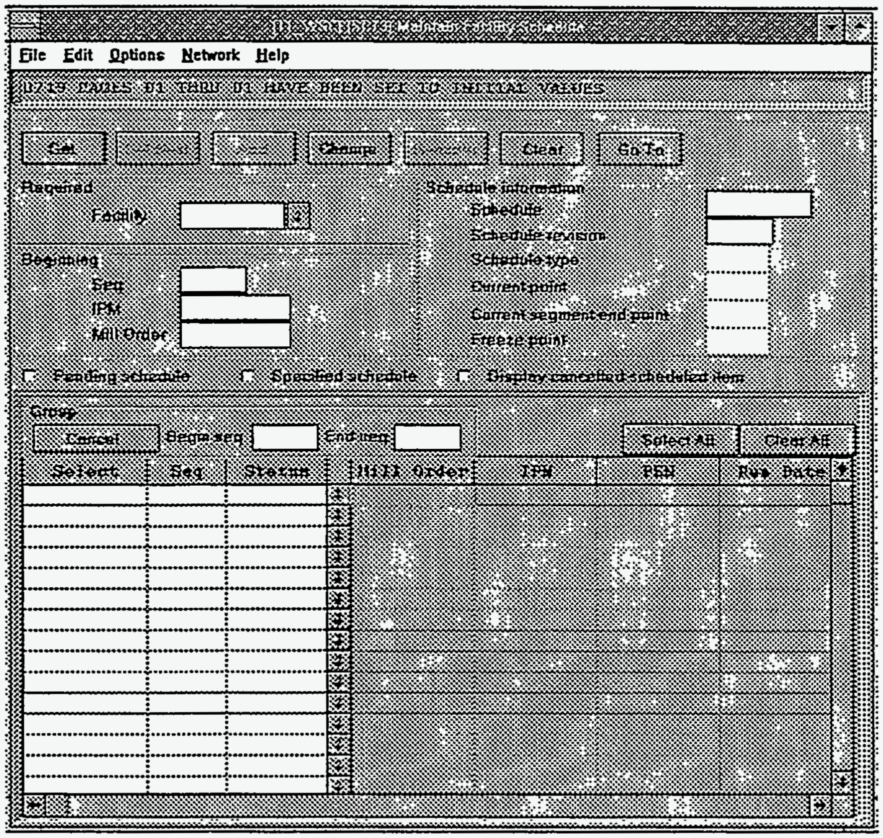
You can now activate the pending schedule set by pressing the Start Activation button.

3. Activate a pending schedule and monitor its activation status

You can use this screen to approve the pending set of facility schedules for release to the plant floor.

The system activates a pending schedule by appending it to the current freeze point of the active schedule. The pending schedule for each facility in the schedule set instance is made active in this way unless you have chosen to bypass activation for a particular facility on (SC63) Compose Facility Schedule set.

(SC73) Maintain Facility Schedule

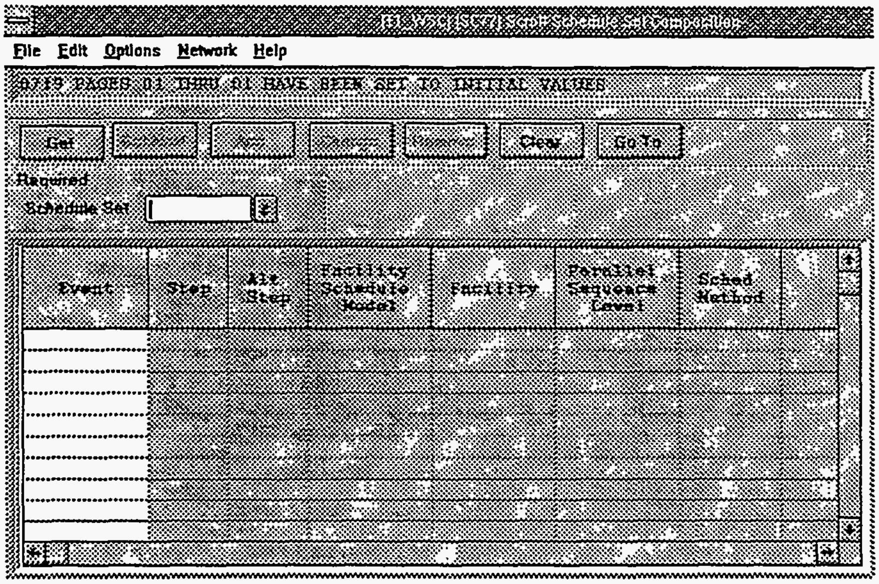


The Maintain Facility Schedule screen is used to review and modify facility schedules.

The SC73 screen enables you to:

- View active and pending schedules (and subsets of the schedules as well).
- Re-sequence and add schedule lines in an active schedule.
- Change the status of a schedule item.

(SC77) Scroll Schedule Set Composition



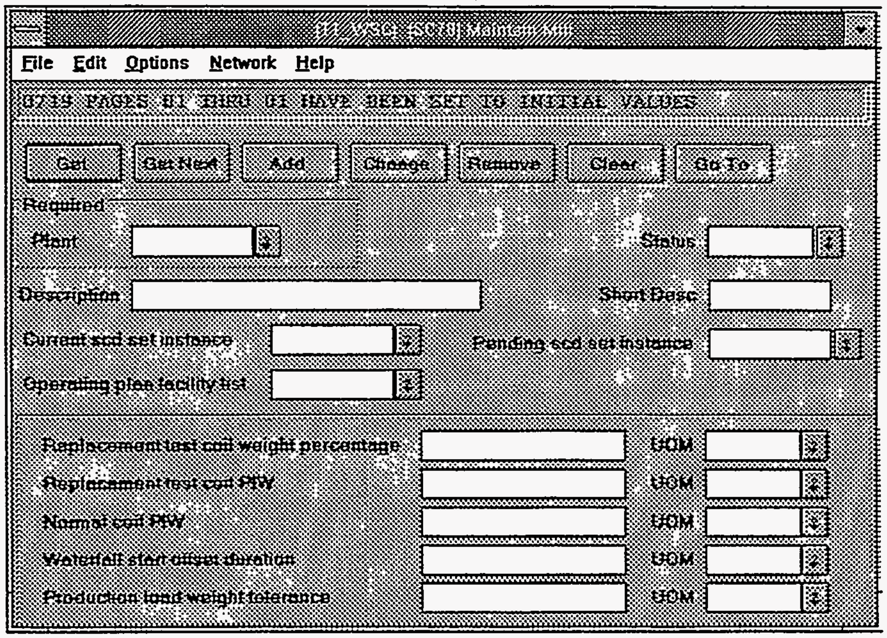
The Scroll Schedule Set Composition screen is used along with the (SC63) Compose Facility Schedule Model Set screen to create and maintain a schedule set model.

The SC77 screen enables you to scroll through the sequenced list of facilities that comprise a schedule set model.

The SC63 screen enables you to see scheduling information for one facility in the schedule set at a time. It provides details such as the facility model used, the scheduling method used, and other various scheduling parameters.

Toggling between the two screens gives you a detailed view of each individual facility schedule configuration as well as an overview picture of the sequenced schedule set.

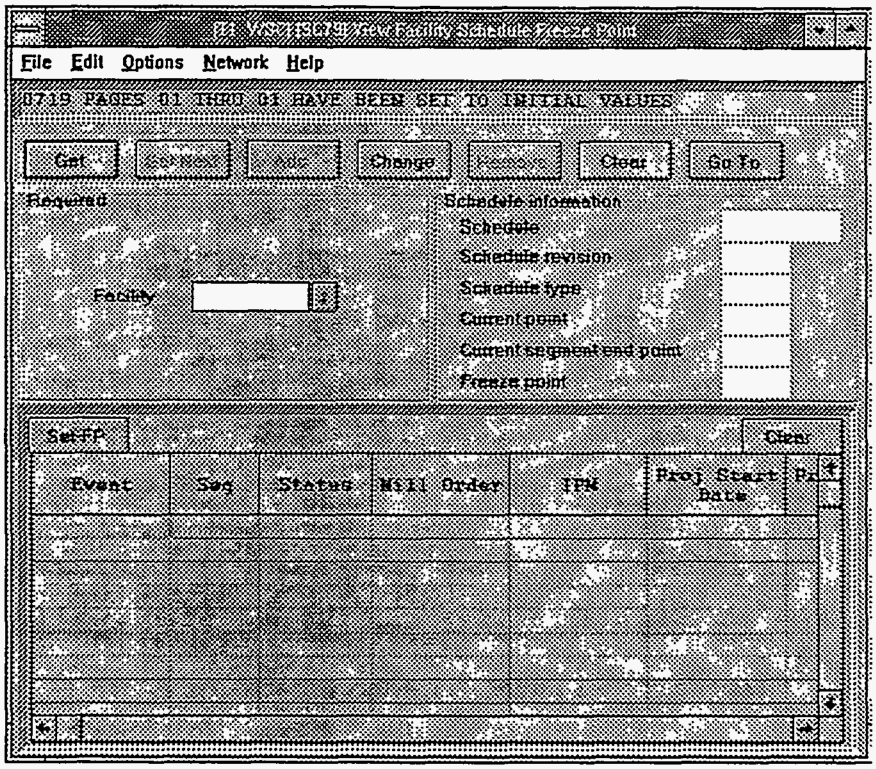
(SC78) Maintain Mill



The Maintain Mill screen is used to:

- Find out which schedules are current and which are pending
- Set rules for the scheduling system at the plant level

(SC79) View Facility Schedule Freeze Point



The View Facility Schedule Freeze Point screen is used to manually set or reset a freeze point and/or to scroll through the list of order items in a schedule.

If you choose not to set a freeze point on this screen, the system will set one automatically by using the default established in the Default Freeze Point Duration field on the (SC56) Maintain Facility screen.

How a default freeze point is set

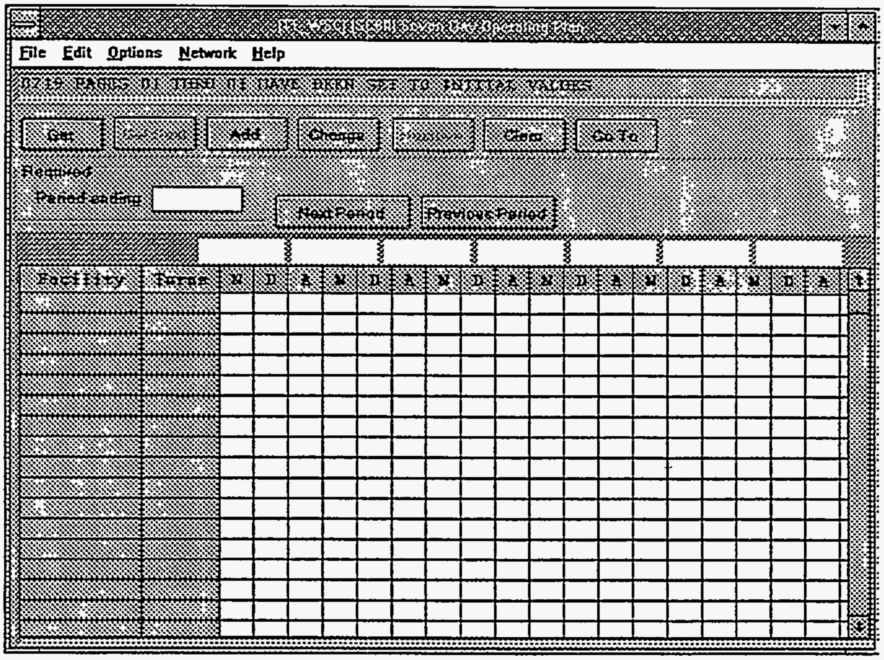
A facility's freeze point is usually set by a production planner through the SC79 or SC76 screen. However, if no freeze point is set, the scheduling system will use the Default Freeze Point field on the (SC56) Maintain Facility screen to set one automatically.

When the scheduling system is ready to build a new schedule, it finds the active schedule's current pointer. The system then adds together the projected production duration (PPD) of each item that follows the current pointer, stopping when the total exceeds the value entered in the Default Freeze Point Duration field.

When the addition stops, the system sets the freeze point after the last item that did not cause the freeze point duration to be exceeded. There are two exceptions to this method of freeze point placement:

1) If the last item not to exceed the freeze point duration falls inside an order item, the freeze point will be set at the end of the order.
2) If the last item not to exceed the freeze point duration falls inside a segment, the freeze point will be set at the end of the segment.

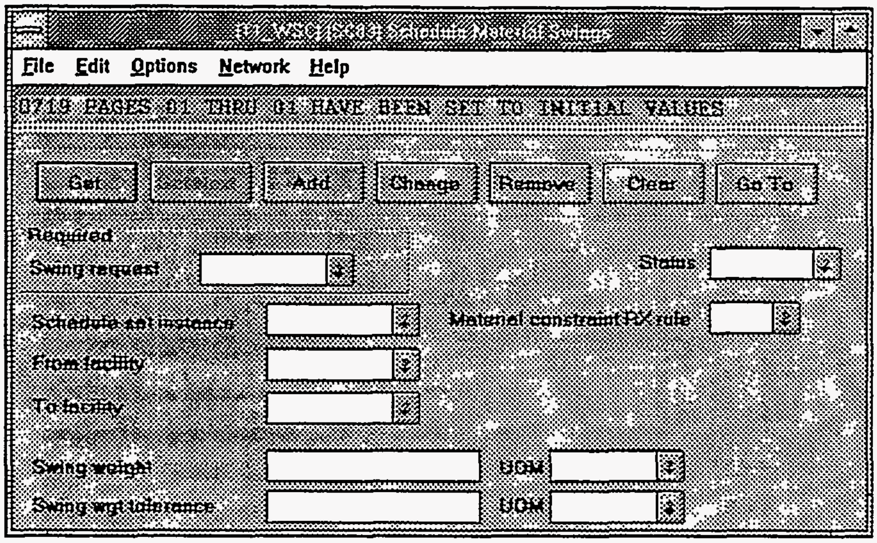
(SC80) Seven Day Operating Plan



The Seven Day Operating Plan screen is used to set a facility's weekly:

- Downturns
- Partial downturns
- Maintenance downturns

(SC83) Schedule Material Swings

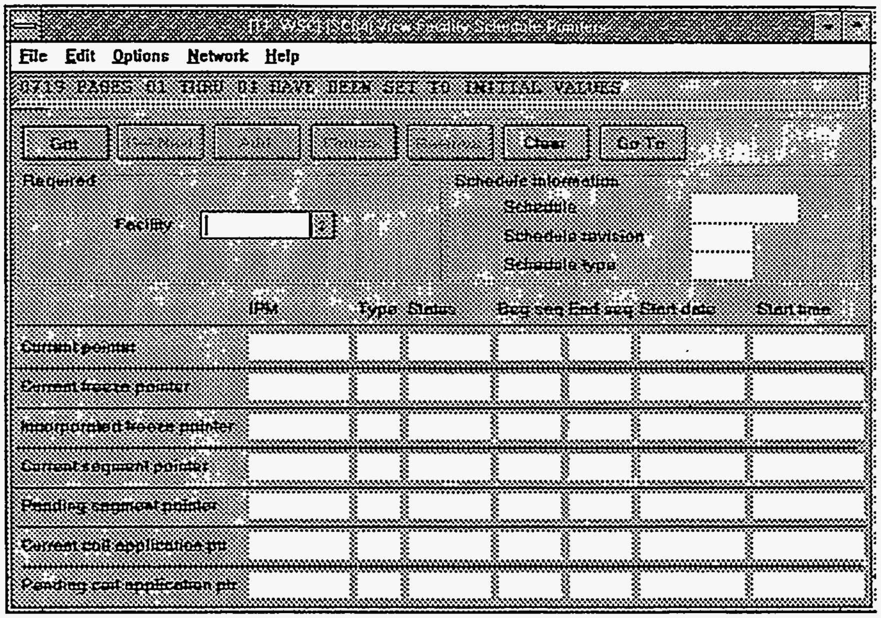


The Schedule Material Swings screen is used to submit a swing request in the next run of the scheduling program.

Before the system builds a set of schedules for the active schedule set instance, it will attempt to satisfy a swing request if one has been submitted through this screen.

A swing request tells the system that a quantity of material with particular characteristics should be swung from the currently scheduled next-facility/next-operation to an alternate next-facility/next-operation.

(SC84) View Facility Schedule Pointers



The View Facility Schedule Pointers screen is used to view information about a facility's schedule pointers.

The system will display the current status of the following pointers:

- <u>Current Pointer</u>

  A pointer in a facility's current schedule that identifies the last item to come off of the production line.

- <u>Current and Pending Segment Pointers</u>

  A pair of system pointers that identify a range of sequenced schedule lines that have been grouped into a segment and sent to the plant floor.

  The Segment Begin Pointer identifies the first schedule line in the range and the Segment End Pointer identifies the last schedule line in the range.

  Each schedule can have more than one segment, and the segments can be either active (currently on the plant floor) or pending (waiting to be sent to the plant floor).

- <u>Current and Incorporated Freeze Pointer</u>

  A set point in a facility's schedule that protects the schedule lines preceding it from being rescheduled.

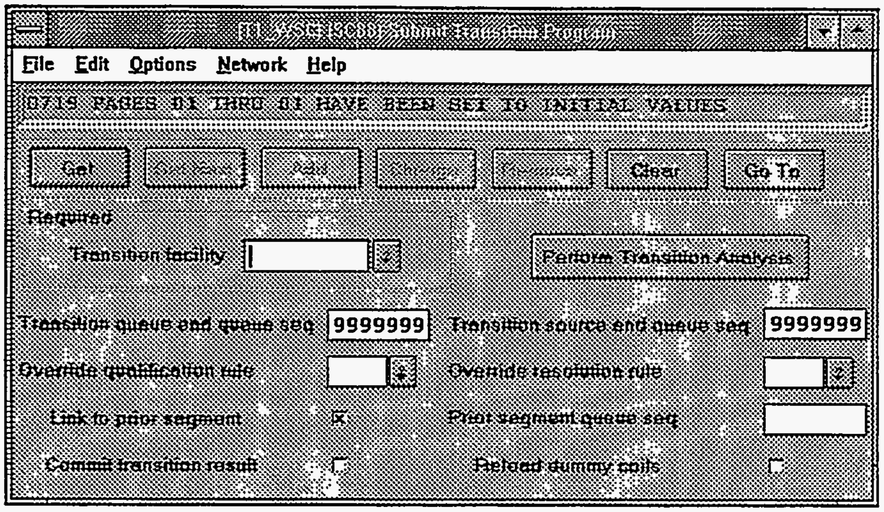
  All order items scheduled after the freeze point are considered available for rescheduling when a new schedule is built.

  After the new schedule has been built and appended to the current schedule, the freeze point is stored for reference and its status is changed from "ACTIVE" to "CLOSED." At that point, it becomes the "previous" freeze point and the next freeze point to be set becomes the "current" pointer.

  If the freeze point was set by the production planner through the SC79 screen, the system will display it in the Current Freeze Point Job field.

Otherwise, the system will use the default freeze point duration specified on the SC56 screen to calculate the current freeze point for this run of scheduling program. The system will display this freeze point in the Incorporated Freeze Pointer Job field.

(SC88) Submit Transition Program



The Submit Transition Program screen is used to execute transition analysis for a schedule segment.

Prior to submitting the program for execution, you can:

- Override the default Transition Qualification and Resolution Rules
- Link the resulting present segment with the prior segment

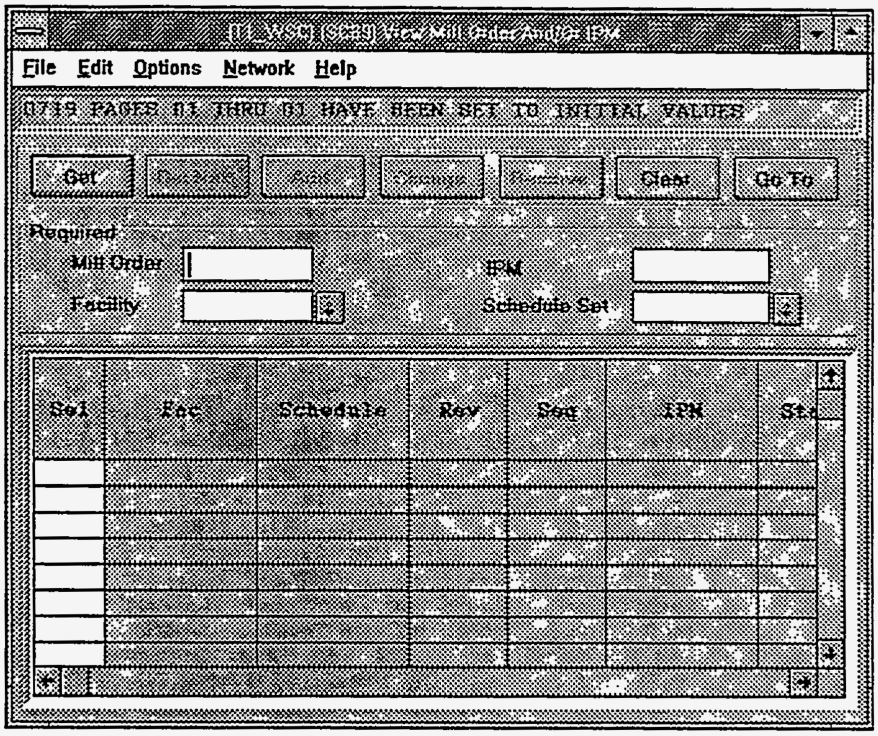
When to execute transition analysis for a schedule segment

Ordinarily, the entire schedule undergoes transition analysis when it is created. However, there may be times when a schedule consists heavily of placeholders rather than actual material.

This lack of actual material would severely limit the ability of the Transition Resolution Source Rule to provide material that could be used to solve detected transition violations, thus rendering transition analysis fairly ineffective.

In such cases, you may want to wait until the placeholders have been replaced by actual material before executing transition analysis. You can do that through this screen by telling the system to wait until a particular segment is about to be released to the floor before checking it for transition violations.

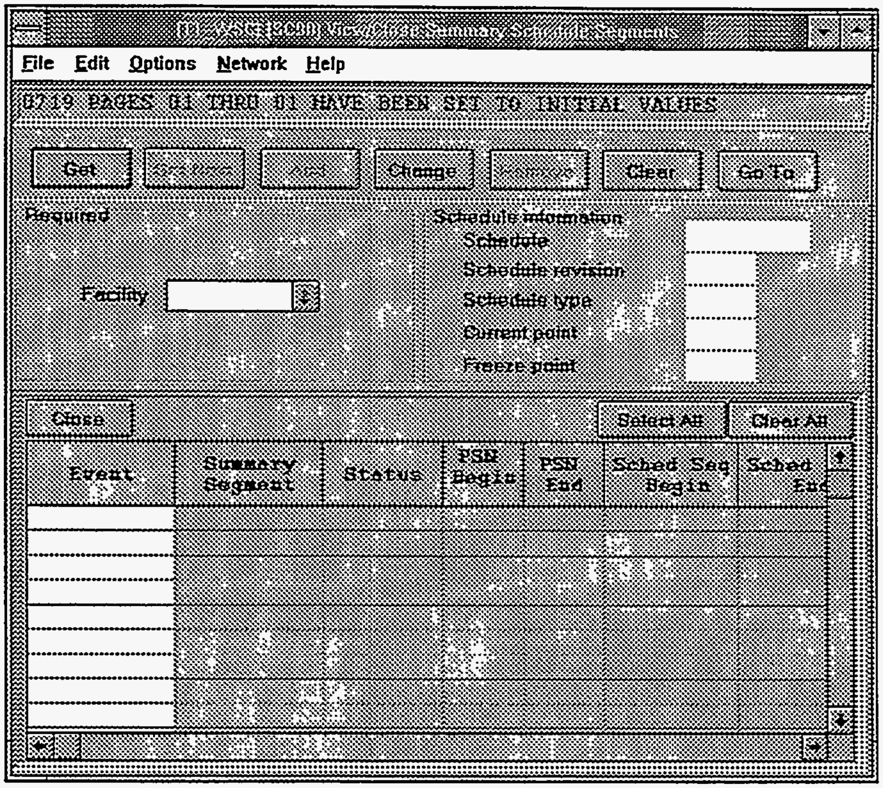
(SC89) View Mill Order And/Or IPM



The View Mill Order And/Or IPM screen is used to find and display all schedule occurrences of a particular millorder and/or IPM.

You can choose to see where the millorder/IPM is scheduled at a particular facility, or you can choose to see where it is scheduled at each facility in a particular schedule set.

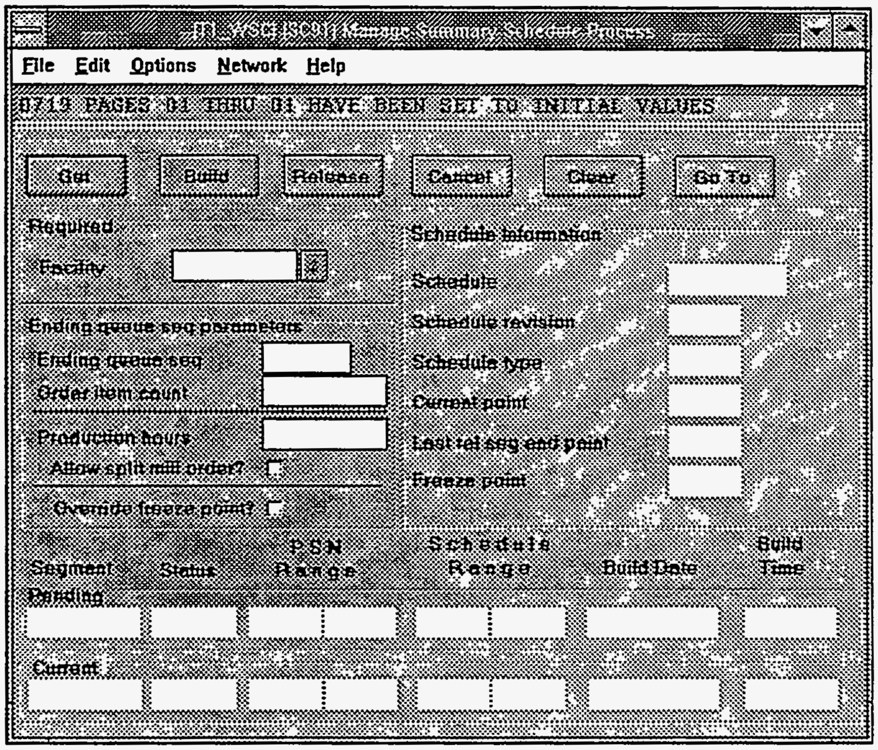
(SC90) View/Close Summary Schedule Segments



Use the View/Close Summary Schedule Segments screen to do one of the following:

- **View** (*Get*) summary schedule information for a facility
- **Close** a *completed* schedule segment
- **Close** *all* displayed schedule segments

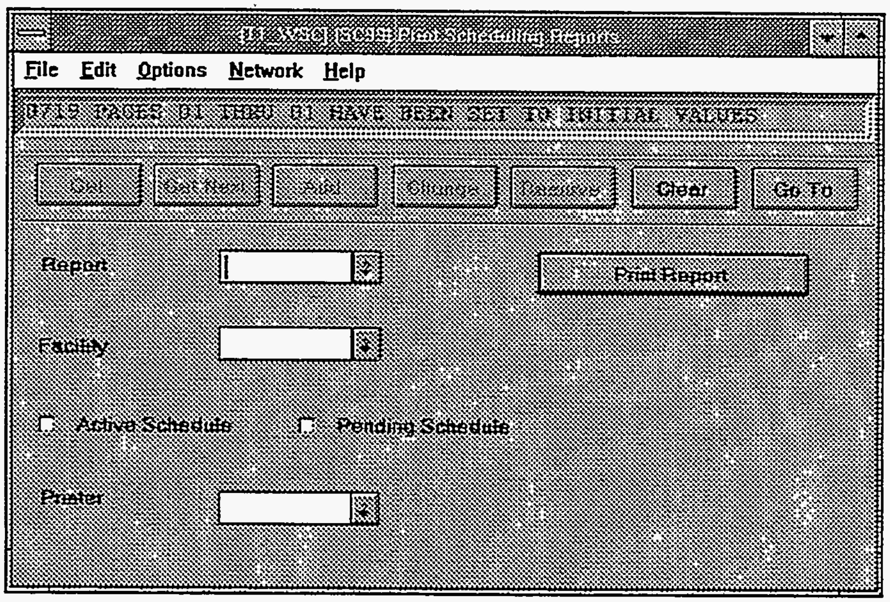
(SC91) Manage Summary Schedule Process



The Manage Summary Schedule Process screen is used to do any of the following:

- **View** (Get) the last released schedule segment and the currently pending schedule segment (if one exists).
- **Build** and/or **release** a new schedule segment.
- **Cancel** the pending schedule segment or the last released schedule segment.

(SC99) Print Reports



The Print Reports screen is used to print the following reports:

- Segment Report
- Schedule Report

Appendix G

Plant Floor Interface and Conformance Screens

TABLE OF CONTENTS

Page

Plant Floor Interface Screens

Conformance Screens

PLANT FLOOR SCREENS

Initial Material ID Screen

```
UNIT: H1  TURN:                 MATERIAL ID              08-24-94  04:16 PM
+---------------------------------------------------------------------------+
|Action:                                                                    |
|D-Display All Coils  S-Search for Coils  A-Add a Coil  R-Run Number  L-Lineup |
+---------------------------------------------------------------------------+
| IPM #   Mill Order Index  Heat  Sched Width    Gauge  Weight   Bwt  Grade  |
|                -                                                          |
|                              Ordered:                                    |
| Sold To:                                    Finish   Coating              |
| Ship To:                                                                  |
+---------------------------------------------------------------------------+
```

The operator can view the various schedules for his/her unit by using an existing IMIS DEC terminal. The operator will select the Material ID function key (F9), which will display a list of actions from which to choose.

Run Number Action

```
UNIT: H1  TURN:                MATERIAL ID                08-25-94  02:23 PM
+--------------------------------------------------------------------------------+
|Action: Run Number                                                              |
|D-Display All Coils  S-Search for Coils  A-Add a Coil  R-Run Number  L-Lineup |
+--------------------------------------------------------------------------------+
|   Run        Mill       Prod. Seq.  # of  Est #  Act #   Run     Run           |
|  Number      Order       Number     MO's  IPM's  IPM's   Date    Time  Duration|
+--------------------------------------------------------------------------------+
| H1030609  466139-002    00042        1     0      3  00-00-00     :     00000 |
| H1030609  515529-054    00043        1     0      5  00-00-00     :     00000 |
| H1030610  400304-062    00044        1     0     15  00-00-00     :     00000 |
|                 -                                       -  -      :            |
|                 -                                       -  -      :            |
+--------------------------------------------------------------------------------+
```

The operator will select the Run Number action to display all schedules that are pertinent to his/her operating unit. He/She will then be able to move the cursor up and down between the different run numbers. Note that there can be multiple Mill Orders for a single PSN (# of MO's greater than 1). In this instance, only the first Mill Order is displayed on the screen to the operator.

Selecting IPM's for a Run Number

```
UNIT: H1  TURN:               MATERIAL ID             08-25-94  02:26 PM
+-----------------------------------------------------------------------------+
|Action: Run Number                                                           |
|D-Display All Coils  S-Search for Coils  A-Add a Coil  R-Run Number  L-Lineup |
+-----------------------------------------------------------------------------+
| IPM #    Mill Order Index  Heat  Sched Width    Gauge  Weight   Bwt  Grade   |
|               -                                                             |
|                               Ordered:                                      |
| Sold To:                                        Finish   Coating           |
| Ship To:                                                                    |
+-----------------------------------------------------------------------------+
|      IPM #   Mill Order  Index   Heat  Sched   Width   Gauge  Weight        |
+-----------------------------------------------------------------------------+
|                                                                             |
|                                                                             |
| >   F224553  400304-062  400304  44654  9381   33.2500  0088  31240         |
|     F224554  400304-062  400304  44652  9381   33.2500  0088  31380         |
|     F224555  400304-062  400304  44655  9381   33.2500  0088  31070         |
|     F224556  400304-062  400304  44650  9381   33.2500  0088  30200         |
| >   F224557  400304-062  400304  44651  9381   33.2500  0088  31060         |
|     F224558  400304-062  400304  44648  9381   33.2500  0088  30990         |
|     F224559  400304-062  400304  44655  9381   33.2500  0088  31230         |
+-----------------------------------------------------------------------------+
Press PREV or NEXT for more coils, SELECT to add to lineup -OR- CANCEL.
```

By pressing the SELECT key, the IPMs that are scheduled for that PSN and Run Number will be displayed on the bottom-half of the screen, in sequence number order. Note, that if the Actual Number of IPMs is zero for a Run Number, then the operator will not be able to select that Run Number. IPMs that are consumed will be displayed to the operator with a 'C'onsumed indicator. The operator will be able to scroll up/down to view all available IPMs that are associated with the selected PSN and Run Number.

Toggling to the Location Information Panel

```
   UNIT: H1  TURN:               MATERIAL ID            08-25-94  02:27 PM
+----------------------------------------------------------------------------+
|Action: Run Number                                                          |
|D-Display All Coils  S-Search for Coils  A-Add a Coil  R-Run Number  L-Lineup |
+----------------------------------------------------------------------------+
| IPM #    Mill Order Index  Heat  Sched Width    Gauge  Weight   Bwt  Grade   |
|                                                                            |
|                              Ordered:                                      |
| Sold To:                                       Finish   Coating              |
| Ship To:                                                                   |
+----------------------------------------------------------------------------+
|      IPM #   Mill Order  Index   Location   SubArea   Row  Column  Height    |
+----------------------------------------------------------------------------+
|                                                                            |
|                                                                            |
| >   F224553  400304-062  400304 TMWL        PHN       0014  0001           |
|     F224554  400304-062  400304 TMWL        PHN       0014  0002           |
|     F224555  400304-062  400304 TMWL        PHN       0014  0003           |
|     F224556  400304-062  400304 TMWL        PHN       0014  0004           |
| >   F224557  400304-062  400304 TMWL        CAB       0080  0001           |
|     F224558  400304-062  400304 TMWL        CAB       0080  0002           |
|     F224559  400304-062  400304 TMWL        CAB       0080  0003           |
+----------------------------------------------------------------------------+
Press PREV or NEXT for more coils, SELECT to add to lineup -OR- CANCEL.
```

The location can be displayed for each IPM by pressing the INSERT HERE key while viewing the IPMs. The location information is extracted from the INVTLOC table in the RDB database. The operator can toggle between the physical characteristics view and the location view by pressing the INSERT HERE key.

Selecting an IPM to Add to the Lineup

```
UNIT: H1  TURN:              MATERIAL ID             08-25-94  02:59 PM
+-------------------------------------------------+--------------------------+
|Action: Run Number                               |                          |
|D-Display All Coils  S-Search for Coils  A-Add a C|  Steel Drum (Y/N) ? Y    |
+-------------------------------------------------+--------------------------+
| IPM #   Mill Order Index  Heat  Sched Width    Gauge  Weight   Bwt  Grade   |
| F224554 400304-062 400304 44652  9381 33 1/4   0088   31380    60  5050     |
|                            Ordered: 32 5/16    0066                         |
| Sold To: HEINZ PET PRODUCTS                    Finish   Coating             |
| Ship To: WEIRTON WV  26062                     000        5MGS/S- FT        |
+----------------------------------------------------------------------------+
| Comment:         LOT 137  #0 RIDGES                                        |
+----------------------------------------------------------------------------+
|                                                                            |
|                                                                            |
| >   F224553  400304-062  400304 TMWL        PHN       0014  0001           |
|     F224554  400304-062  400304 TMWL        PHN       0014  0002           |
|     F224555  400304-062  400304 TMWL        PHN       0014  0003           |
|     F224556  400304-062  400304 TMWL        PHN       0014  0004           |
| >   F224557  400304-062  400304 TMWL        CAB       0080  0001           |
|     F224558  400304-062  400304 TMWL        CAB       0080  0002           |
|     F224559  400304-062  400304 TMWL        CAB       0080  0003           |
+----------------------------------------------------------------------------+
Enter Y(es) or N(o) for the coil's Steel Drum and press RETURN.
```

If the operator presses the SELECT key while viewing the IPMs, the selected IPM will be displayed, at which time the IPM may be added to that operating unit's lineup. All of the current IMIS DEC Entry End functions (Move, Delete, Backoff, etc...) will continue to be available to the operator for necessary maintenance of the unit's lineup.

Process Parameters Screen from IPM Panel

```
UNIT: H1  TURN:               MATERIAL ID              08-25-94  02:30 PM
+--------------------------------------------+--------------------------------+
|Action: Search                              |  View Ship/Sold data           |
|D-Display All Coils  S-Search for Coils  A-A|  -OR- CANCEL                   |
+------------------+-------------------------+--------------------------------+
| Order 374843-037 | Customer  ALPO PETFOODS    ALPO       | Lineup Coils     0 |
| Index     374843 |     Weight Gauge  Width    Ln Ft      |                    |
| Sched       9152 | Ord         0060  33 1/8              |                    |
| Grade            | Max 25000  0064  33 7/16   34769      | 61 OD 16 1/2 ID    |
| Process    00295 | Min 22000  0057  33 3/8    30597      | Lb/Lf      0.70465 |
+------------------+-----------------------------------------+--------------------+
| ELECTROLYTIC CHROMIUM COATED STEEL , WEIRCHROME (2CRECCS) DOUBLE REDUCED     |
| MR , DR9 CA ,  5MGS/S- FT , STD DR FINISH , BSO OIL , EYE VERTICAL , BWT= 55 |
| END USE=DRAW - REDRAW BODY 307 X 110.5 , GAUGE CODE=4 , RW MIN:57 MAX:59 30T |
|                                                                              |
|                                                                              |
|                                                                              |
+-----------------+------------------+-----------------+-------------------------+
| Pkl Slit Width |  # 9 Tandem  Mill | Dbl Reduc Mill | Rockwell                |
|  Aim 34 1/16   |   Gauge     0083  | Gauge     0062 |                         |
|  Max           |   Grit            |            000 | HD1                     |
|  Min           |   Width  34 1/16  | Pct Reduc 25   |                         |
+-----------------+------------------+-----------------+-------------------------+
Enter S (Ship/Sold) and press RETURN -OR- Press CANCEL.
```

If the operator presses the Process Parameters key (F14) while viewing the IPMs, the process parameters information for the Mill Order of the IPM will be displayed.

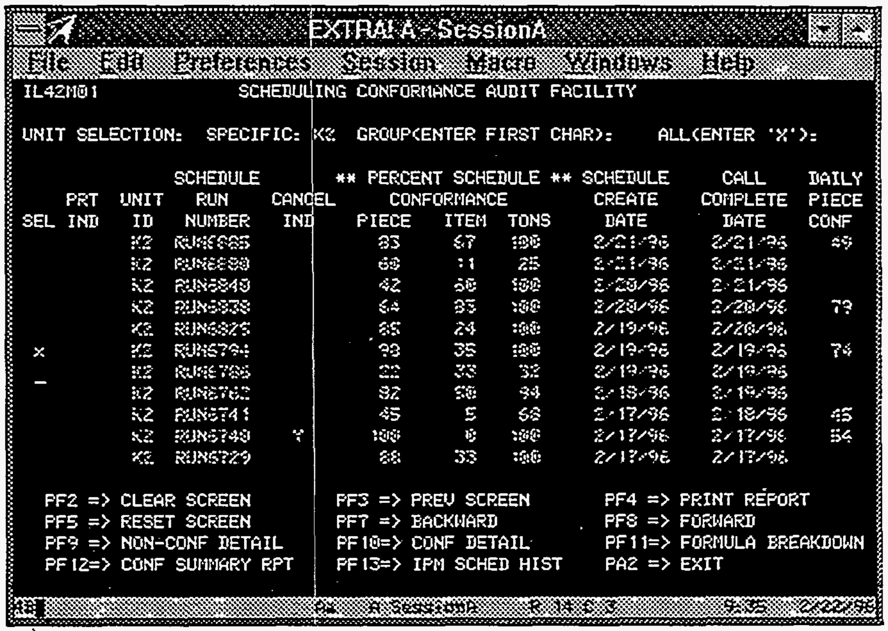
Process Parameters Screen from Run Number Action

```
UNIT: H1  TURN:                MATERIAL ID              08-25-94  02:24 PM
+-----------------------------------------+-------------------------------+
|Action: Run Number                       | View Ship/Sold data           |
|D-Display All Coils  S-Search for Coils A-A| -OR- CANCEL                 |
+-----------------+-----------------------+-------------------------------+
| Order 400304-062 | Customer  HEINZ PET PRODUCTS        | Lineup Coils     0 |
| Index     400304 |     Weight Gauge  Width     Ln Ft   |                    |
| Sched       9AG9 | Ord        0066  32 5/16            |                    |
| Grade            | Max 23900  0069  32 5/8     31526   | 60 OD 16 1/2 ID    |
| Process    00295 | Min 15696  0063  32 9/16    20704   | Lb/Lf      0.74294 |
+-----------------+-----------------------------------+--------------------+
| ELECTROLYTIC CHROMIUM COATED STEEL , WEIRCHROME (2CRECCS) DOUBLE REDUCED |
| MR , DR9 CA ,  5MGS/S- FT , STD DR FINISH , BSO OIL , EYE VERTICAL , BWT= 60 |
| END USE=DRAW - REDRAW BODY 307 X 111 , GAUGE CODE=4 , RW MIN:57 MAX:59 30T |
|                                                                          |
|                                                                          |
|                                                                          |
+----------------+------------------+----------------+----------------------+
| Pkl Slit Width | # 9 Tandem  Mill | Dbl Reduc Mill | Rockwell             |
|  Aim 33 1/4    |  Gauge     0088  | Gauge     0067 |                      |
|  Max           |  Grit            |            000 | HD1                  |
|  Min           |  Width   33 1/4  | Pct Reduc 25   |                      |
+----------------+------------------+----------------+----------------------+
Enter S (Ship/Sold) and press RETURN -OR- Press CANCEL.
```

This feature also works while displaying Run Numbers. The Mill Order of the Run Number that is highlighted will be used to display process parameters information.

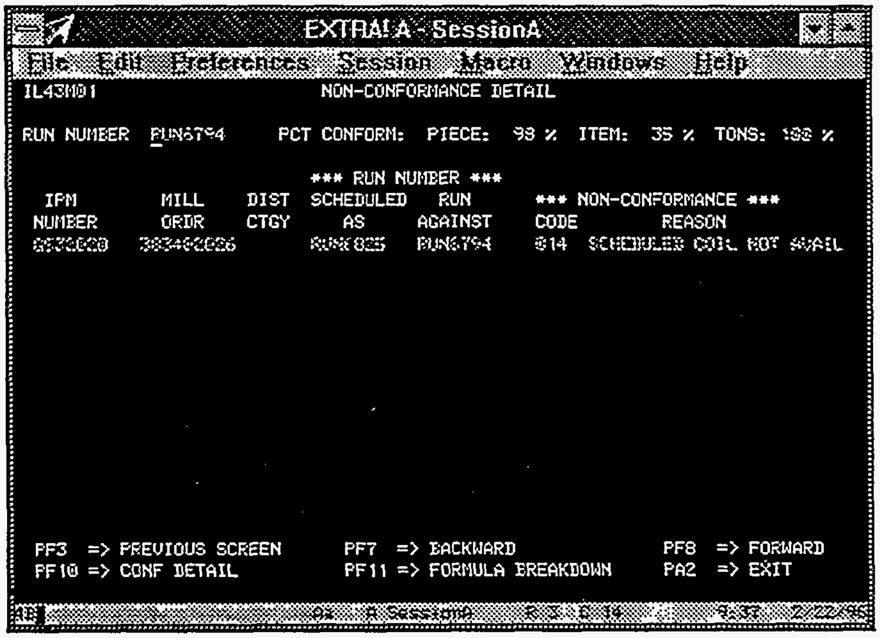
CONFORMANCE SCREENS

(IL42M00) Scheduling Conformance Audit Facility



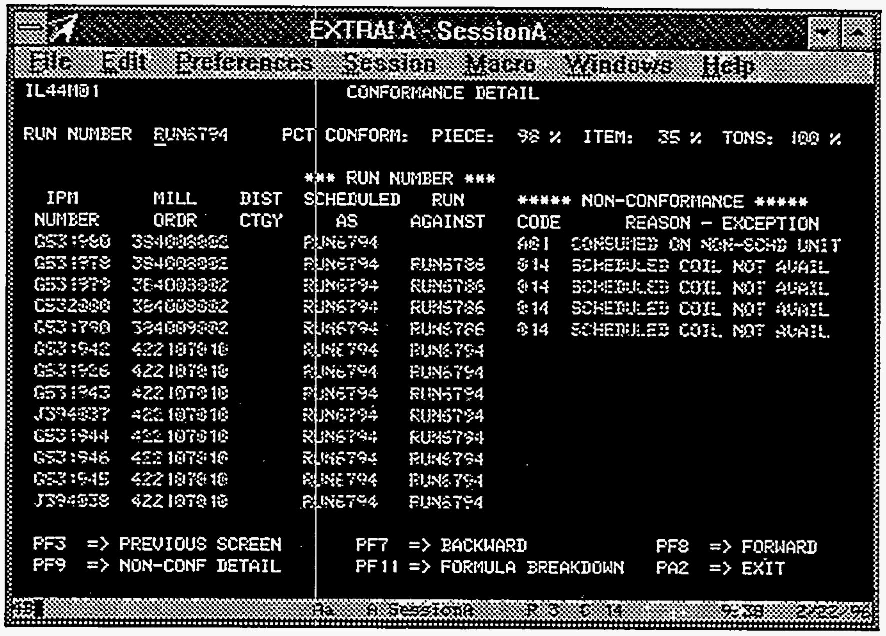
IL42M00 is the main screen. It displays all schedules on a given unit that have been called complete within the last thirty days. For each schedule, the piece, ton, and item percent conformances are displayed. From this screen, the user may select a schedule to prepare a hardcopy report or to transfer to one of the following screens.

(IL43M01) Non-Conformance Detail Screen



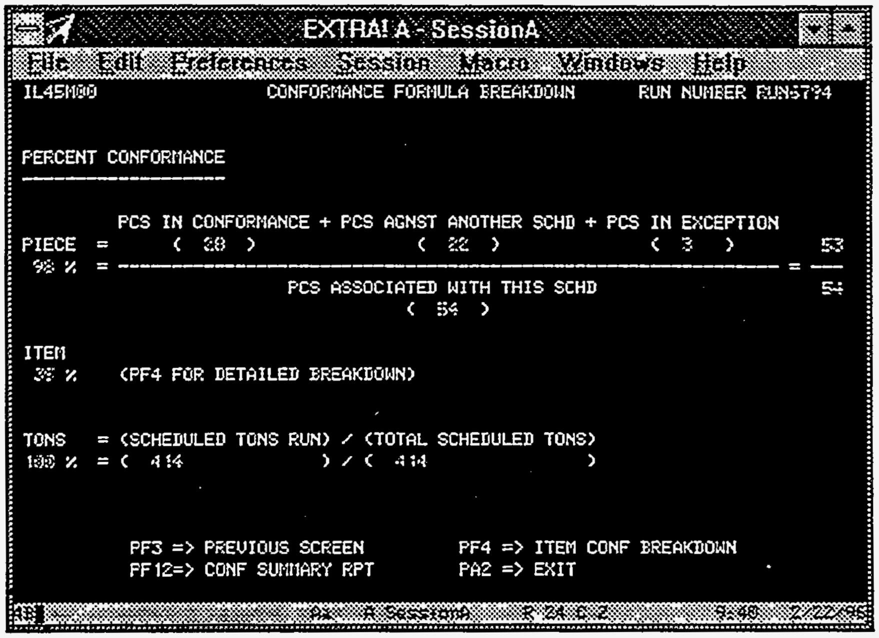
IL43M01 lists all IPMs that are not in conformance to the selected schedule.

(IL44M01) Conformance Detail Screen



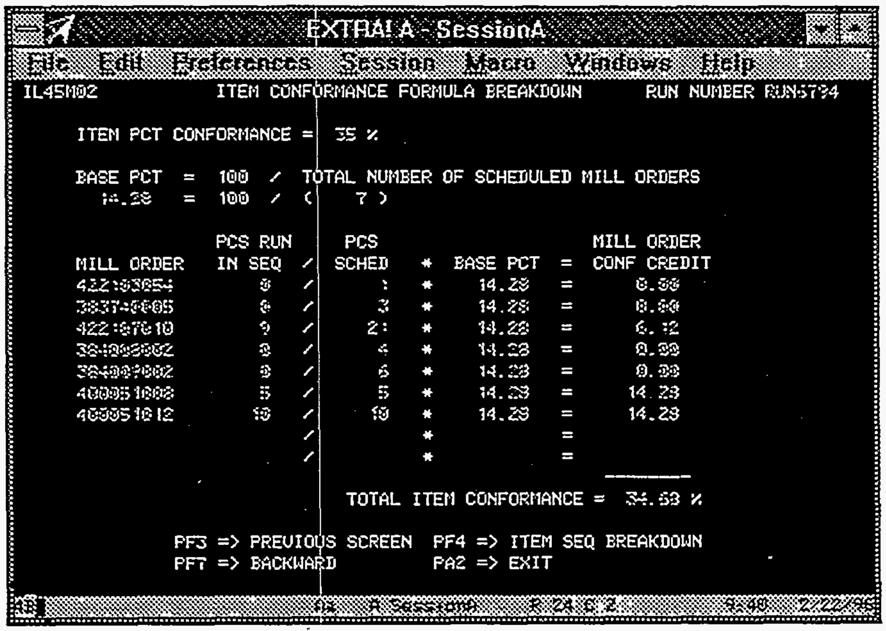
IL44M01 lists all IPMs, conforming and non-conforming, that are associated with the selected schedule.

(IL45M00) Conformance Formula Breakdown Screen



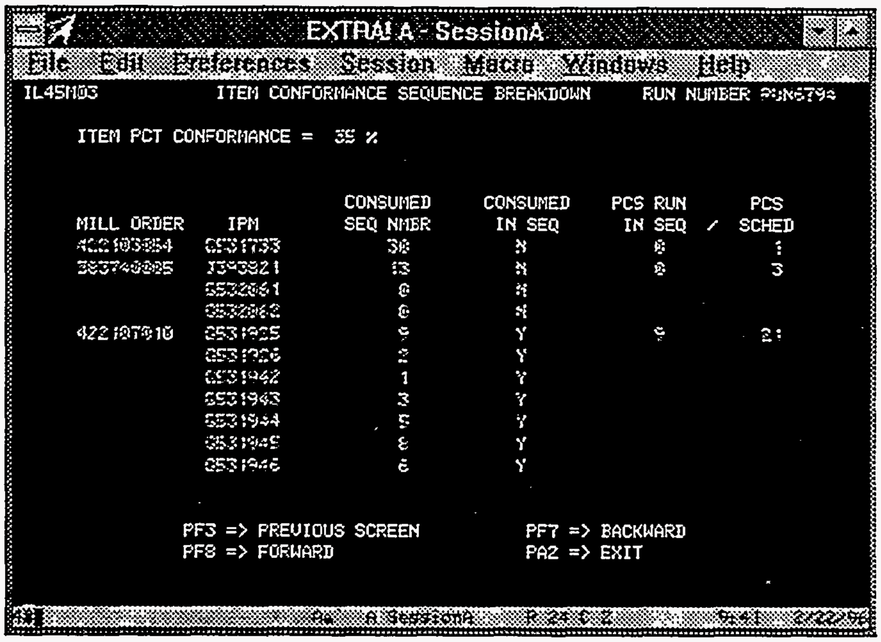
(IL45M00) provides a detailed breakdown of the conformance calculations.

(IL45M02) Item Conformance Formula Breakdown



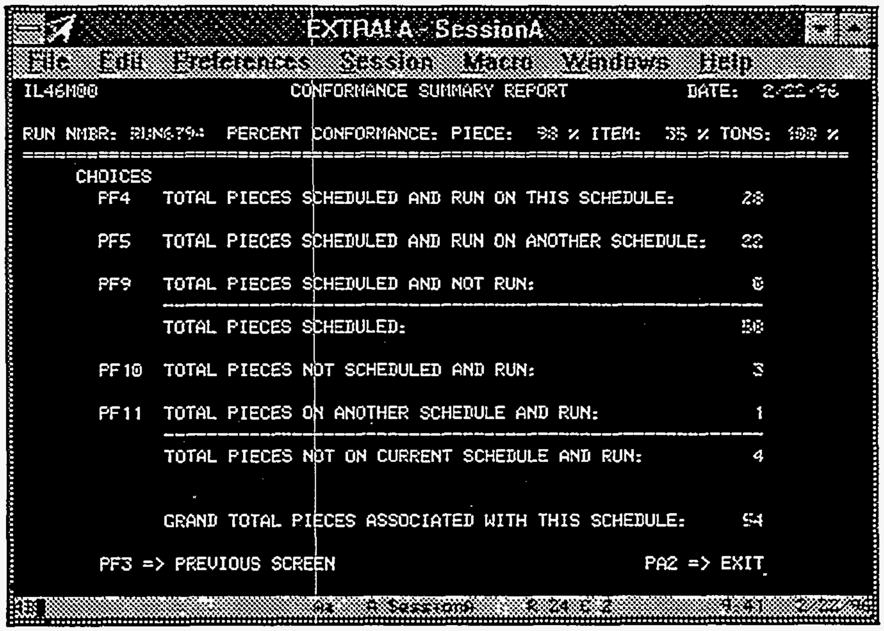
IL45M02 explains how the item percent conformance was calculated for the current schedule.

(IL45M03) Item Conformance Sequence Breakdown



IL45M03 indicates if the IPMs were consumed in the order in which they were scheduled.

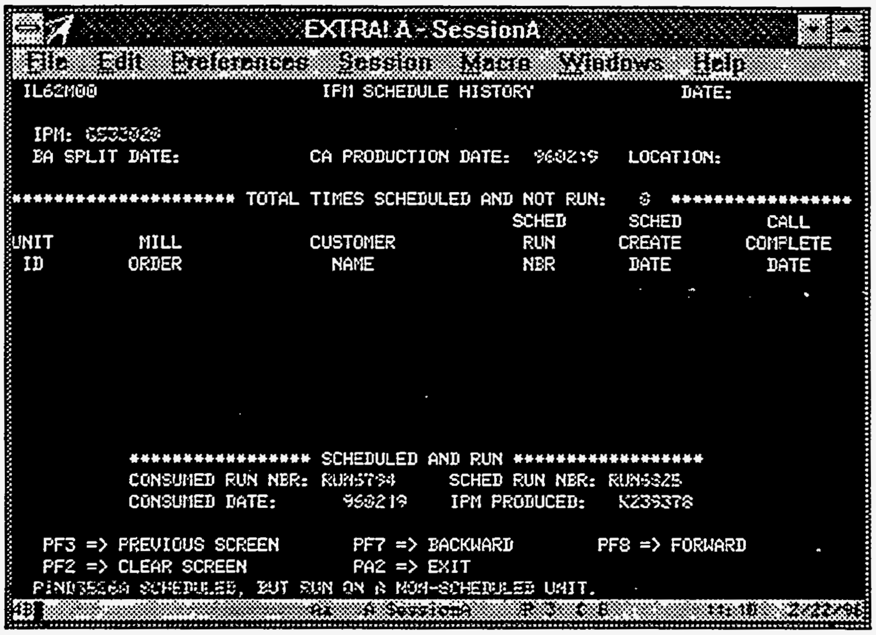
(IL46M00) Conformance Summary Report Screen



(IL46M00) provides summary information for the IPMs associated with the schedule.

- Pieces scheduled and run on current schedule
- Pieces scheduled on current schedule but run on another schedule
- Pieces scheduled on current schedule but not run
- Pieces not scheduled but run on current schedule
- Pieces scheduled on another schedule but run on current schedule

(IL62M00) IPM Schedule History



IL62M00 displays the dates on which an IPM has been scheduled but not run, and the date on which it was scheduled and then actually ran.

Appendix H

Glossary of Terms and Acronyms

Glossary of Terms and Acronyms

Active Schedule

A schedule that is currently released to production.

Active Schedule Current Pointer

A pointer in a facility's current schedule that identifies the last item to come off of the production line.

Active Schedule Freeze Pointer

A set point in a facility's current schedule that protects the order items preceding it from being rescheduled.

All order items scheduled after the freeze point are considered available for rescheduling when a new schedule is built.

Freezing a portion of the active schedule in this way gives the scheduler enough time to create, review, and release a new schedule while the facility's crew continues production of the current schedule.

The new schedule, when released, will be appended to the current schedule at the freeze point.

Block Cancellation Technique

If a component fails minimum run analysis, the system cancels the block and removes it and its items from the processing cycle. See also minimum run constraints.

Block Consideration Rule

A rule that lists facility schedule model components. Typically, it specifies schedule blocks that will be checked for minimum run analysis or used as sources for transition resolution.

CICS

Customer Information Control System.

CLD

Corporate Location Definition; a location code applied to steel as it moves through the mill.

Coating Weight Range Jump Rule

A rule that establishes coating weight jump limits for transitions that fall within specified coating weight ranges.

COBOL

A programming language.

CSP

Cross Systems Product; a software development tool.

Current Pointer

Indicates to the system the last item produced by the facility.

DB2

A database development tool.

DECmessageQ

A tool that allows messages to be passed across computer platforms.

Demand

A requirement for activity. For instance, a customer order is a demand. A facility's request for material for production of that customer order is a demand.

Distribute Facility Schedules

This is the fifth step in perpetual scheduling known as the segment build process. The production planner requests that a specified schedule segment be distributed to the facility crew. The segment build process prepares cutting instructions for the segment and sends it to its facility (either through on-line screens or through a process control download). The current pointer keeps the production planner aware of each facility's position so that he/she can decide when another scheduling run is necessary.

Entry Facility

The first facility in the steel production process.

The schedule for an entry facility consists of an ordered set of requests for material (either raw material, scrap material, or purchased steel).

Entry Facility Schedule

An ordered set of requests to start material. The sequence of events in each schedule is in compliance with the facility's requirements as defined by its facility schedule model.

Facility

A location where manufacturing operations occur. Each mill unit (caster, continuous annealing, plater) is defined as a **facility** to the scheduling program

Facility Schedule

Facility schedules are sequenced lists of order items and work-in process materials that are processed on a facility during a given time period.

Facility Schedule Model

A Facility Schedule Model describes to the system the operating characteristics and constraints of one facility. These are expressed as rules and descriptions, in the form of tables, defined to the system by production planning and operations personnel. They describe the material groups, preferred material sequence, minimum material group run times, transition rules, and many other operational requirements of each facility.

Facility Schedule Model Component

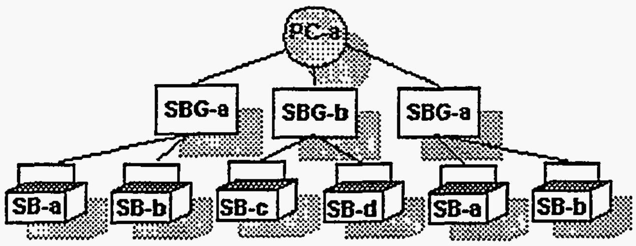
A node or component of the facility schedule model. A component can be a schedule block, a schedule block group or a processing cycle.

Facility Schedule Model Network

A hierarchical network of connected or "linked" blocks used to properly sequence model components during schedule generation.

At the lowest level of the hierarchy are schedule blocks (SB), followed (optionally) by schedule block groups (SBG). At the highest level of the hierarchy is a processing cycle (PC).

A typical facility schedule model hierarchy might look something like this (with the processing cycle block highlighted in yellow):



Each pair of linked blocks is referred to as a "parent-child" link, with the block in the higher level serving as the parent and the block in the lower level serving as the child. For example, schedule block group SBG-b serves as the parent block to schedule block SB-c and a child block to the processing cycle PC-a.

Final Schedule

A term used in the old WSC Tin Rolling Mill Scheduling System that designates that a schedule is ready for release to the plant floor.

Fixed Block Type

A fixed block is a schedule block that is fixed with respect to its position in the processing cycle. It is scheduled in the sequence specified in the processing cycle definition.

Fixed Schedule Block

See fixed block type.

Floating Block Type

A **floating block** can occur at any position in the processing cycle. The scheduling program assigns orders to the floating schedule block and inserts it into the processing cycle at the proper position.

Floating Downturn Block Type

A **floating downturn block** is used to hold a place in the operating plan for downturns.

Floating Schedule Blocks

See floating block type.

Force Fill Resolution Technique

When a component in a cycle fails minimum run tests, this technique attempts to bring the component's duration up to the violated minimum (physical or preferred). See also minimum run constraints.

FPW

Finished Product Warehouse.

FORTRAN

A programming language.

Freeze Active Schedule

The first step in perpetual scheduling. A schedule is considered frozen through the freeze point; its remainder is subject to rescheduling. The freeze point allows the facility crew to continue processing the active schedule during the preparation of a new schedule.

Freeze Point

The system marks this point in the schedule that must remain unchanged during the upcoming scheduling process. A schedule is considered frozen through the freeze point, its remainder is subject to rescheduling.

Gauge Range Jump Rule

A rule that establishes width and gauge jump limits for transitions that fall within specified gauge ranges.

Geotronics

A Manufacturer of the optical technology that is used for capturing the X and Y coordinates of the crane's position.

GPS

Global Positioning System; a device that tracks the position of an object in three dimensional space.

IBM 3090

The computer operating on the IBM platform.

ICB

Interface control block; a block of code that controls the passage of data through a computer interface.

IO

Input/Output; the means by which data is sent and received.

IMIS™

Integrated Manufacturing Information System. At WSC, this is the collection of business applications that gather, edit and manage inventory descriptions and locations. Included within the business application portfolio is function that manages inventory relative to its position in the order cycle--a real-time order status or debiting and crediting of order requirements and delivery expectation fulfillment. These applications include Inventory Capture, Distressed Material, Material Reapplication, Material Movement, Order Status, Inventory Tracking, etc.

IPM

In Process Material. The identifier for a slab or coil.

Index Number

A set range of numbers that is assigned to a customer that defines his or her order. All millorders for a customer will contain the same information if the index remains constant.

Jeopardy

An item's scheduled date/time minus its required date/time at a specific facility. A positive result means that the item will be delivered late. See also Jeopardy Qualification Process.

Jeopardy Qualification Process

This process compares the impact of pushing already scheduled items out, by the duration of the newly inserted item, to the impact of holding the item out for later scheduling. The lesser quantity prevails. This process is the point where downstream delivery dates and facility processing rules converge.

Load Horizon

The user-defined date and time beyond which the scheduling system will not look for order items to schedule.

The load horizon is normally set several weeks past the summary horizon. This time allowance gives the scheduling system enough material to create a qualified schedule.

LU6.2 SNA

IBM interface software used for interface between IBM and DEC machines.

Manufacturing Distribution Network Diagram

A diagram that shows the paths of product flow through the plant. The diagram should contain all locations that can be scheduled and should include main inventory points. It is used as a central reference diagram to plan and design scheduling strategies.

Material

A piece of steel with a unique identity. See material constraint.

Material Constraint

A material constraint is specified by a production planner. It stipulates that for a certain time period, material of a prescribed characteristic cannot be scheduled on the facility. See material.

Material Constraint Rule

The rule that prescribes the material characteristics that cannot be scheduled during a specified time period.

Material Marking Transition Rule

A rule that establishes jump limits for transitions between items with specified material markings.

Millorder

The number assigned to all orders assign to one index. The field is 9 bytes long, the first 6 bytes identifying the index number and the last three numbers identifying the sequence of the millorder within the index.

Minimum Run Analysis

Each component in a processing cycle can be assigned a physical and preferred minimum run duration. When a component fails either minimum run test (physical or preferred), the scheduling program refers to a resolution rule to resolve the problem(s).

Each rule is a series of resolution steps that the program executes one at a time until attaining success. The rule's step sequence is user defined.

Minimum Run Constraints

When a facility is behind schedule, the tendency is to build smaller cycles to keep downstream units running on constantly replenished supplies of inventory. The minimum run constraints are rules, contained within the facility schedule model, that prevent the system from building cycles that are too small to run.

Minimum Run Resolution Rule

A rule invoked when a facility schedule model component (usually a schedule block) does not meet the specified minimum run-time. The rule prescribes the actions the system must take to resolve the minimum run condition. See also minimum run analysis.

MMSS

Material Marking and Sensing System

MQ

A tool that allows messages to be passed across computer platforms.

MTS

Material Tracking System

MVS

Multiple Virtual Storage.

Occurrence

The same schedule block appearing more than once within one processing cycle.

Oiling Transition Rule

A rule that establishes jump limits for transitions between items of specified oiling types.

OO

Object Oriented.

Open New Mill Schedule

The second step in perpetual scheduling in which the production planner indicates that a new set of pending schedules is to be generated and requests submission of the scheduling program through an on-line screen.

Operating Plan

A plan for the entire plant that specifies the operating level (turn level) and downturns of each facility on a weekly basis. The **operating plan** can extend for many weeks. Its purpose is to specify the weekly capacity for a facility.

Operating Plan Facility List

The list of facilities presented in the operating plan.

Order

A demand for production.

OS2

IBM operating system for personal computers.

PAMS

A messaging service for communication between the plant floor and the database

Parallel Scheduling

An option that instructs the system to schedule up to five facilities at one time. Parallel schedule levels are assigned to each of the facilities. The system will then build the schedules in level sequence, scheduling all of the facilities of the same level together.

Pattern Identification Rule

A rule that specifies a pattern of facility schedule model components. This rule qualifies a schedule by ensuring the validity of the sequence of the components of the processing cycle.

Pattern Resolution Rule

A rule invoked as a result of pattern identification. The pattern resolution rule defines techniques for re sequencing the processing cycle when a block pattern violation is found.

Pending Schedule

A facility or plant schedule that was created by the scheduling system but not yet authorized for production.

Perpetual Scheduling

The five main steps (freeze active schedule, open new mill schedule, schedule the mill, release mill schedule, distribute facility schedules) in the operation of the production scheduling system that allow the production planner to build a new schedule for each facility and join it with the schedule being processed on the plant floor giving on-line access to a seamless continual schedule.

Placeholder

Placeholders specify the order of production, but do not identify the actual material. Placeholders have three purposes: To provide summary information for the material scheduled for the order; To specify planned production for the unit; To reserve a place in the schedule for material that is not yet available for the facility. When the material becomes available, it is inserted in the schedule following the placeholder.

Planned Downturn

A planned downturn specifies a time-period when a facility will not be operating. The production planner determines a planned downturn.

Plant

Represents the entire steel mill. The term plant refers to the collection of attributes that affect the entire operation of the mill and all its facilities.

Preferred Processing Cycles

Determined by processing rules for each facility that seek to maximize facility throughput and minimize the cost of running the facility while acknowledging physical restraints and/or business policies that govern the grouping and sequencing of material to be processed. See also Material Constraints.

Process Codes

See Routings

Processing cycle

The top of the facility schedule model hierarchy.

The processing cycle defines the sequence in which material is processed at a facility. A processing cycle may have characteristics that dictate rules for the collection of schedule blocks and schedule block groups that are below it in the hierarchy. For example, the processing cycle's duration, which is the sum of the durations of all components immediately below it in the hierarchy, can also be subject to a minimum run requirement.

Processing Instructions

Instructions that detail the production operation for a given item at a facility. Processing instructions usually are expressed in the form of parameters, and typically are specified at the product specification level. Note that an order can override processing instructions.

Production Loading

A process by which downstream facilities pull their needs from upstream facilities. The process is initiated when the customer order book places production requirements on finishing facilities (called pulling the order from the finishing facilities). The finishing facilities, in turn, place requirements on intermediate facilities through production loading. Through production loading, all orders eventually arrive at entry facilities. Also see Pull scheduling.

Production Sequence Material Line

Prescribes processing requirements for a single piece of material. Corresponds to a single schedule line.

Projected Production Duration

The projected amount of time it takes an order item to be processed by a facility.

PSS

Production Scheduling System

Pull Run

See Pull scheduling.

Pull Scheduling Method

Pull scheduling is used to schedule an entire plant when in-time delivery to downstream facilities and/or the customer is the primary goal of the plant. With pull scheduling, downstream facilities (which are scheduled first) pull their needs from upstream facilities.

The Pull Scheduling Method is used to drive production according to customer promise dates. Pull Scheduling is based on the manufacturing concept of independent work centers focusing on what to deliver, and when to deliver it, to the next work center. The last work center in the manufacturing process, because it delivers finished product to the customer by the promise date, dictates the delivery requirements of upstream work centers.

All requirements for upstream production (including that of entry facilities) come from downstream work centers, thus biasing production toward what is needed first. Traditional scheduling methods rely instead on each work center's operating peculiarities and a gross estimate of necessary start dates.

Push Scheduling Method

The basic Push Scheduling Method produces a schedule from all work-in-process material in front of a facility. Where possible, the system attempts to look in downstream facility schedules for timing requirements of material to be scheduled. This method is applicable only to downstream facilities and not to entry facilities, because it doesn't provide for new material starts. The method also cannot see upstream in anticipation of material already started but yet to arrive.

Push-on-the-Come Scheduling Method

A variation of the push scheduling method. Using the On-the-Come Push Scheduling Method, the Scheduling Program looks in upstream inventory locations for work-in-process material yet to arrive. The program allocates time in each facility's schedule for the upstream material.

Push-on-the-Come-Downstream-Disqual

A variation of the push-on-the-come scheduling method. When using push-on-the-come, the system disqualifies all material that is not projected to meet its downstream required date/time.

QMF

Query Management Facility; a tool for creating and managing queries to the database.

Queue

The sequenced list of order items scheduled for one facility. Another name for a schedule.

Queue Sequence Number

The number assigned to each order item in a facility's queue.

RDB

Relational database.

Release Mill Schedule

The fourth step in perpetual scheduling where, after on-line review, the production planner releases the pending schedule set. The release process appends each facility's pending schedule to its frozen schedule and changes its status to active. See also freeze active schedule.

RF

Radio frequency.

RISC/RS6000

The computer operating on the AIX (IBM's version of UNIX) platform.

Routings

Defines a sequence of production operations or processes through which steel must pass. (Also known as a process flow. At WSC, referred to as Process Codes.)

Schedule Block

Schedule blocks are the atomic (at the bottom of the hierarchy) components of a processing cycle, and are like "buckets" to which orders with like-characteristics are assigned during the batch scheduling process. Schedule blocks represent the basic material groups that the facility processes.

Schedule Block Assignment Rule

A rule used to assign an item to its unique material group within a facility.

Schedule Block Group

An intermediate level in the facility schedule model hierarchy. Schedule block groups are optional and are used for classifying schedule blocks. A schedule block group can have characteristics of its own that dictate processing rules for that group. For example, the operators of the cold mill may not want to run any sheet product unless its duration (which is a sum of the durations of all sheet schedule blocks) meets or exceeds a minimum duration. The minimum run requirement is, therefore, set at the sheet schedule block group level.

Schedule Block Pattern Analysis

A step in schedule qualification where the program analyzes the cycle, looking for an invalid schedule block pattern. When a pattern is invalid, the scheduling program will refer to a resolution rule for instructions on how to swap and/or combine the remaining blocks.

Schedule Block Sort Rule

A rule that lists a sequence of sort parameters used to sequence items assigned to the same schedule block .

Schedule Block Type

Defines types of schedule blocks. The two schedule block types are:

1. A fixed block is a schedule block with a fixed position in the processing cycle. It is scheduled in the sequence specified in the processing cycle definition.
2. A floating block can occur at any position in the processing cycle, and is normally used to hold material that must follow a scheduled downturn. The Scheduling Program assigns orders to the floating schedule block and inserts it into the processing cycle at the proper position.

Schedule Construction

The building of a schedule for a facility based on its processing requirements and downstream delivery dates, striving for a balance between the two.

Schedule Line (Schedule Item)

An item or record in a facility schedule. The two types of schedule lines are Material and placeholder.

A material schedule line identifies the specific piece of material scheduled for production.

A placeholder schedule line reserves time in the schedule for the production of material for an order. The placeholder makes it possible to slot the material into the schedule when the material becomes available for production.

Schedule Qualification

Analysis routines (minimum run, schedule block pattern and transition), the scheduling program performs after building each cycle in a facility's schedule. They are used to identify and fix violations.

Schedule Queue

A production unit schedule in the new system. It's a schedule which is viewed and maintained by a production planning scheduler.

Schedule Segment

A segment of an actual schedule (see Schedule queue) prepared for release to the production floor. (See facility schedule instance.)

Schedule Segment End Pointer

A system pointer that identifies the last order item in a range of sequenced schedule lines that have been grouped into a segment.

Schedule Set Instance

An occurrence of the schedule set model.

Each time the system builds a set of schedules, it does so by making a copy, or an ***instance***, of the original schedule set model. The schedule set instance is given a unique ID and is used to create one, and only one, set of schedules.

Schedule Set Model

A sequenced list of facilities for which the system will build schedules. Also included in the schedule set model is the facility schedule model that contains the instructions the system will follow when building the schedules.

The system creates a copy of the schedule set model each time schedules are to be created for the facilities in the schedule set. These copies are called schedule set instances.

Schedule the Mill

The third step in perpetual scheduling that produces a pending schedule for each facility identified in open new mill schedule.

Schedule Transition Analysis and Resolution

A Scheduling System process that validates schedules against a set of operator specified scheduling rules which check that the transitions from one item to another item in a schedule. If a transition violation occurs, the system has the ability to invoke methods of solving the problem. This is called Transition Resolution. Schedule Transition Analysis and Resolution is a Phase 2 deliverable.

Scheduled Material

Material scheduled to be used for production.

Scheduled Placeholder

Reserves time in the schedule for the production of material for an order. The placeholder makes it possible to slot the material into the schedule when the material becomes available for production.

Segment Build Process

This is the final step in preparing a schedule for facility execution. The production planner requests distribution of a specified schedule segment to the facility crew. The segment build process prepares cutting instructions for the segment and sends it to its facility.

Soft Block Cancellation Technique

If a component fails minimum run analysis, the system cancels the block and removes it from the processing cycle, but reserves its items for later combination with another block. See also minimum run constraints.

SOP

Standard operating procedures.

Source Consideration Work File

The file that contains the unscheduled items that the system will consider for schedule insertion. The system builds the work file prior to schedule construction. The work file includes:

- Order book
- Production loads from downstream facilities
- Work-in-process material

The system reads the source consideration work file in the required delivery date and time sequence.

Start Up Requirements

Specific types and amounts of materials that must be run at a facility each time production begins.

Steal Technique

If a component fails minimum run analysis, the system attempts to fill the current block with material from another block. See also minimum run constraints.

Steel Type Transition Rule

A rule that establishes jump limits for transitions between items of specified steel types.

Swap/Combine

A technique for resequencing facility schedule model components within a facility schedule model.

Summary Horizon

The user-defined end date and time of a scheduling period. The scheduling system attempts to produce a qualified schedule (a schedule that meets all scheduling rules) up to the summary horizon.

Swing Demand

A requirement stated to the system by the production planner. A **swing demand** tells the system to attempt to divert an amount of material from one unit to another.

Symbol

Manufacturer of the terminals used for voice activated data entry.

TCP/IP

The transport protocol used for exchanging messages between the VAX and the RS6000

Transition Analysis

A step in schedule qualification, performed after schedule block pattern analysis, in which the scheduling program tests for violations such as width and gauge. The program analyzes each transition and attempts to fix violations by inserting other material in the gap. See also material constraint.

Transition Qualification Rule

A rule that prescribes a list of techniques used to test violation conditions when transitioning from item to item in a schedule.

Transition Source Rule

A rule that prescribes and prioritizes a list of material classifications for the system to use to resolve transition violations in a schedule.

Transition Qualification Technique

A technique used to test for item to item violation in a schedule (for instance, the width jump technique).

Transition Resolution Rule

A rule that prescribes a list of techniques for the system to use to solve item-to-item violations in a schedule.

Transition Violation Rule

A rule set that defines a sequence of schedule line items and lists those to a schedule line item transition.

Use Distressed Material Technique

The system uses this technique during transition analysis to identify transition candidates from secondary, excess prime and dummy material. See also transition resolution rule.

Use Order Book Technique

The system uses this technique during transition analysis to identify transition candidates in the unscheduled order book. See also transition resolution rule.

Use Scheduled Item Technique

Using this technique, the system pulls a transition candidate from ahead or behind in the schedule. This is used during transition analysis. See also transition resolution rule.

Value Override Rule

A rule used in resequencing a processing cycle. This rule overrides run-time values in the facility schedule model.

VAX

The computer operating on the DEC platform.

Verbex

Manufacturer of the unit that processes voice commands during voice activated data entry.

Violation Type

A value used to distinguish different types of schedule violations (for instance, a transition violation).

Width Range Rule

A rule that establishes width and gauge jump limits for transitions that fall within specified width ranges.

WSC

Weirton Steel Corporation

WSTC

Westinghouse Science and Technology Center

WVU

West Virginia University

ZZ87

The main IO routine for handling all on-line and interface updates for logistics. It handles all updates to the logistics tables from the IMIS™ on -line software and from the Plant Floor Interface System routine. IT handles coil movements and updates to the movement tracking and history tables.