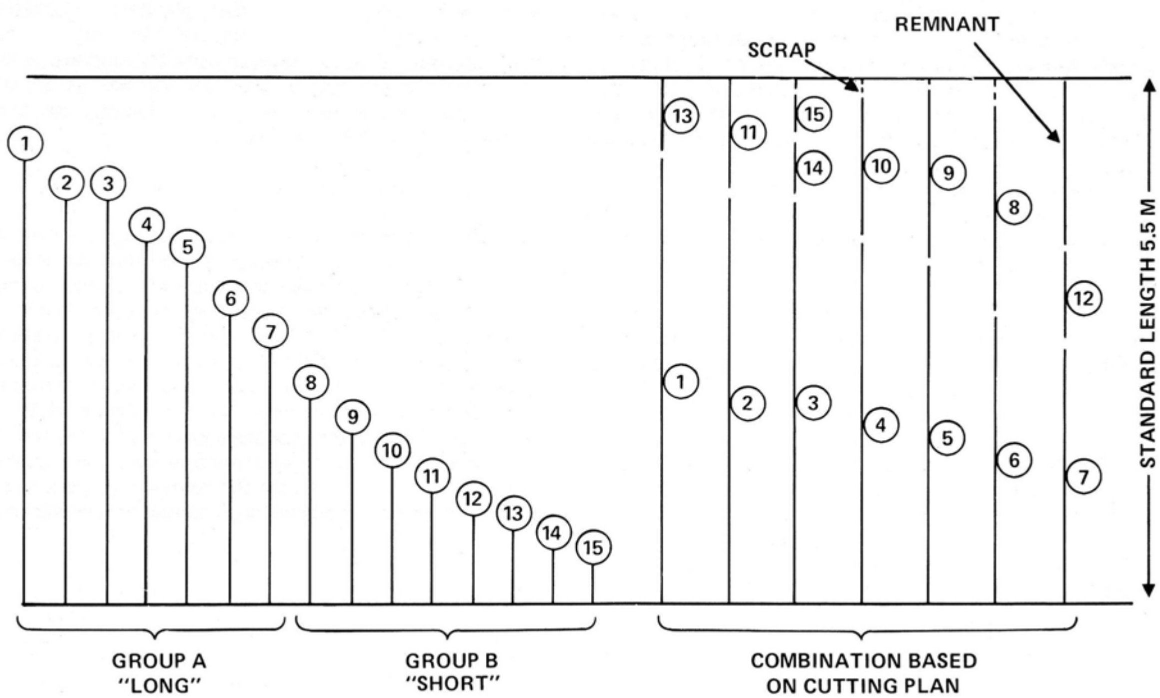


Figure 2-10: A cutting plan facilitates scrap reduction and simultaneously provides a sequence for issue of materials. Purchasing pipe material in standard lengths facilitates control.

2.4.1 Cutting Plan

One of the printouts, a cutting plan, serves to obtain maximum utilization of pipe material; see Figure 2-10. Simultaneously, it is used to sequence work, required materials and work instructions. Sequencing pipe pieces to be cut, defines the order that flanges and other fittings, such as tees and reducers, are required. Thus, cutting plans control all work through control of material.

Cutting plan preparations address actual cut-lengths of pipe within a lot organized by nominal diameter, wall thickness and material type. These are subclassified as "long" and "short". Long and short requirements are matched in order to utilize as much as possible of standard length pipe material. As a rule of thumb, pipe pieces for the same ship are grouped together.

Standard limits for scrap are related to pipe diameters and to standard minimum branch lengths, e.g.:

- 300 mm diameter and larger - lengths less than 1,000 mm
- 250 mm diameter and smaller - lengths less than 400 mm

Lengths which exceed such limits and are unallocated, are remnants. If a separate cutting facility is employed for fabricating branches, remnant pipe is allocated by a separate cutting plan.

Information on a cutting plan includes:

- cut length and position,
- indication of scrap or remnant,
- identification numbers (Ship, MLF, MLP, Lot, Serial),
- pipe diameter and specification,
- schedule cut date,
- end preparation required,
- bending machine grasping position, and
- subsequent operation (flow lane).

2.4.2 Subcontracting Expense Calculation

During the weekly meeting, if it is decided to utilize outside firms, designation of a subcontractor and the pertinent work amount yields a printout of relevant expenses. These are based on files of normal work, unit prices, transportation costs, etc. A format for subcontracting expense calculations is shown in Appendix D.

2.4.3 *Operations Control Lists*

Additional printouts useful for operations control are:
- *Branch-pipe List* which groups branch-pipe pieces to be fabricated in order to facilitate scheduling of pertinent work stations.
- *Pallet-composition List* which is MLF data arranged more conveniently for palletizing finished pipe pieces. Features are incorporated to facilitate checks of fabrication-work progress.
- *Group I Pipe-piece List* which identifies pipe-pieces of a special nature which require tests that are to be witnessed by owner and/or classification society representatives.

Examples of operation control lists including those for surface treatment and coating schemes are in Appendix D.

2.4.4 *Material-issue Confirmation*

Typically, after operations control lists are prepared, pertinent data is transferred to the material control system. In response to a pipe-shop material-issue order, printouts list material sorted by specified issue dates and destinations. An example is included in Appendix D. Materials which are not in-stock are identified on a separate "shortage list".

2.4.5 *In-process Identification*

The numbers which appear on a cutting plan for each pipe piece to be fabricated identify ship, MLF, MLP, lot and serial. Once a lot is established for a particular week, by definition, all pipe pieces manufactured during that week will not jeopardize their respective pallet issue dates.

Internal pipe-shop operations, except for palletizing, are concerned only with problem area and stage classifications. Until palletizing, there is no need to maintain identities by ship, MLF and MLP. Thus, the cutting list also serves as a matrix for transforming these relatively complex identifications into simple lot and serial numbers; see Figure 2-11.

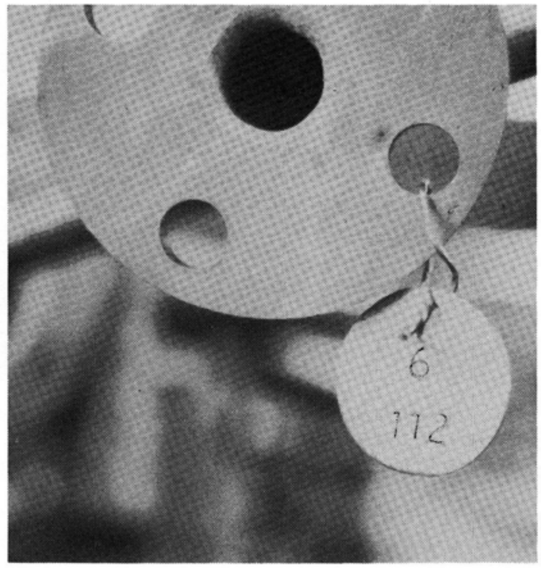


Figure 2-11: As shown, a single digit identifies a specific lot. The serial number peculiar to one pipe piece appears below. In some pipe shops a color code is used to identify pipe pieces in a specific lot (dab of paint or a colored tag on each pipe piece). A large calendar is color coded accordingly so that even a casual visitor can observe whether the work in process is on schedule.

During palletizing, the final work process, pallet composition lists are employed to substitute specific ship, MLF and MLP identifiers for lot and serial identifications which are no longer needed, see Figure 2-12.

2.5 *Material Flow*

2.5.1 *Input*

Successful PPFM is logical classification and control of material. A warehouse organization dedicated to pipe shop methods is mandatory.

Where PPFM is effectively applied by a shop planned for 450 tons per month nominal capacity, the dedicated organization consists of one supervisor and three warehousemen. Of the latter, one has responsibilities for pipe, another is concerned with flanges and the third has cognizance of pipe fittings such as ells, tees and reducers. As each warehouseman is responsible for both receivals and issues, together they have handled over 900 tons per month.

Every Wednesday morning each warehouseman receives an appropriate printout which is a "picking" list for pipe, flanges or pipe fittings based on:
- final definition of the coming week's work at the shop manager's meeting the day before, and
- cutting plans which sequence work for specific work flows, e.g., for large, medium and small diameter and other flows and for subcontractors, see Figure 2-13.

2.5.2 *Output*

In order to fully exploit the principles of Group Technology (GT) for an entire shipbuilding process, pipe pieces are not regarded as complete until they have been painted and palletized. Coating and palletizing, as shown in Figure 1-1, are manufacturing stages just as much as welding and bending.

Figure 2-12: A single lot usually contains pipe pieces for different pallets needed for more than one ship. Also, because of different standard lead times some pipe pieces for a single pallet are produced in different lots. *Left:* Numerous printouts are needed to convert in-process identifications to ship, pallet and piece numbers as needed for palletizing. These same printouts served for checkoff purposes. *Right:* Identification numbers needed for palletizing are applied after coating each pipe piece.

The paint system applied to each pipe piece is consistent with that of its surroundings during outfitting on-unit, on-block and on-board. For example, when outfit assembly, clean-up, and touch-up work are completed, no pipe piece requires "catch-up" painting before finish undercoat is applied to the entire assembly.

Palletizing is simply collecting together pipe pieces needed for specific assembly work packages. The matrix used to shift from identification needed during fabrication to a specific assembly work package is described in Part 2.4.5.

The shop area and numbers of containers allocated for palletizing should anticipate that pipe pieces required for a particular pallet will sometimes be fabricated in different weeks preceding the pallet issue date. The number of weeks is dependent on the normal lead times established for pipe-piece families as described in Part 1.3.1. Thus, the collection of pipe pieces for a particular pallet could start two or three weeks before the last required pipe piece is produced.

In the interest of overall shipbuilding productivity, pipe-shop output is groups of coated pipe pieces, regardless of size and systems, which are required to support outfit assembly work packages organized by zone/problem area/stage.

2.6 Productivity Indices

A basic objective of PPFM is to collect costs by pipe-piece families. As shown in Figure 1-2, PPFM is based primarily on problem area and stage classifications. Thus, the only practical methods for collecting man power costs are by problem area, stage or a combination of both.

In the few cases where a production line is dedicated to one pipe piece family, collecting man power costs by family is sufficient. Man power assigned and total weight and number of pipe pieces produced per unit time, yield averages for:

- man-hours/manufactured weight/family, and
- man-hours/manufactured piece/family.

However, production lines are intentionally merged for most PPFM in order to:

- avoid redundant facilities, and
- treat pipe pieces for some families as straight pipe early in their fabrication cycles.

Merged work flows impose a slight complication which requires collection of man power costs by work station (stage). Man power assigned, number of pipe pieces and weight per unit time yield:

- man-hours/manufactured weight/stage, and
- man-hours/manufactured piece/stage.

These two productivity indices are averages for an identical work process applied to a mix of pipe-piece families.

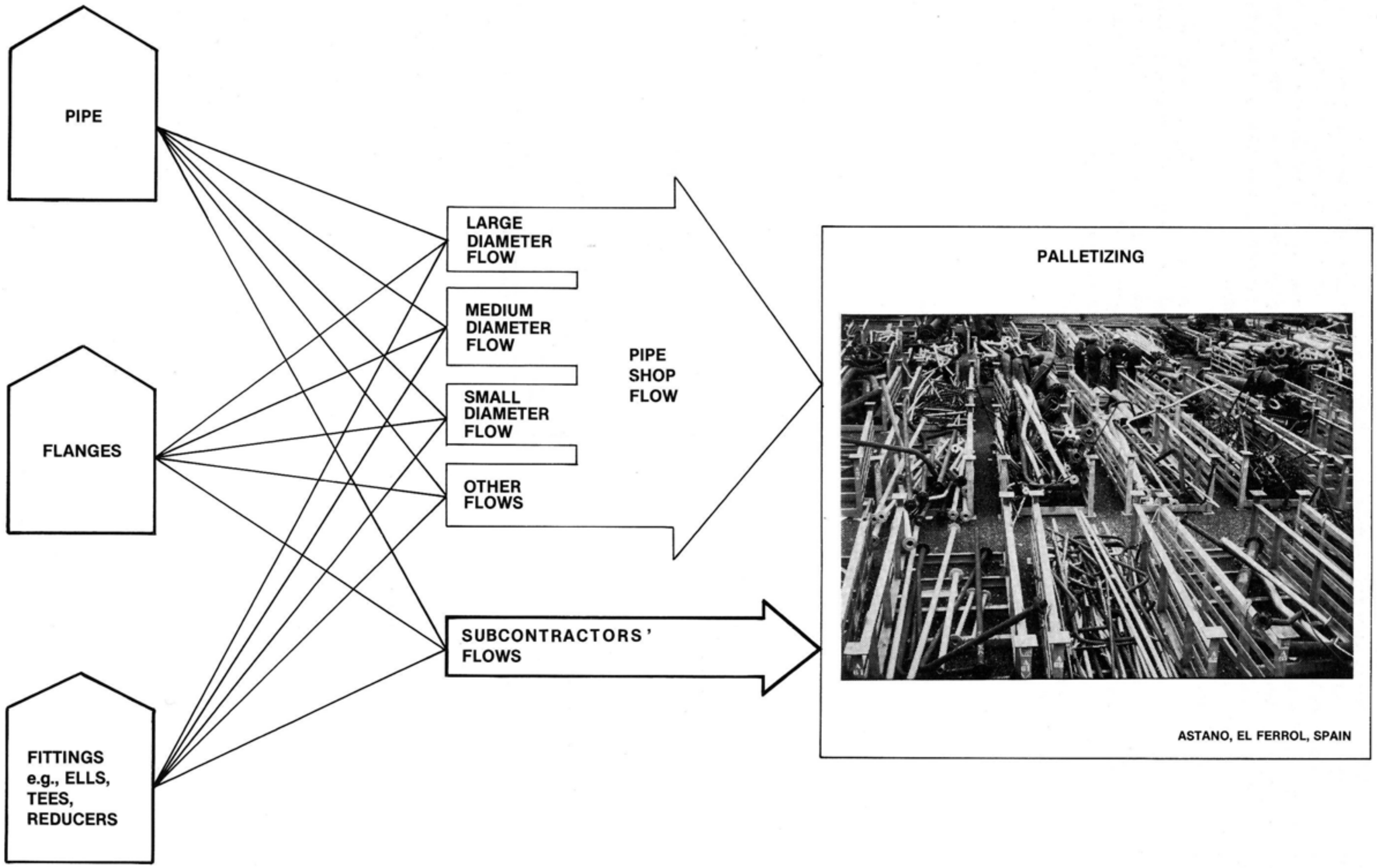


Figure 2-13: PPFM productivity is very dependent on accurate inventory records and timely deliveries of defined materials to specified addresses in specified sequences. Work flows for large, medium and small diameters and other flows are interdependent as shown in Appendix B.

Because varieties and quantities of pipe pieces in lots differ from week to week, work flows change from week to week. A shop manager's most effective reaction is to transfer workers between flow lanes and adjust their numbers on work stations using man-hours/manufactured weight/stage and man-hours/manufactured piece/stage as guidance. These productivity indices are posted at each work station; see Figure 2-14. They convey to workers just assigned to a work station the history of *normal* efficiency at the station.

As pipe-piece families usually share common work stations, costs per pipe family are achieved indirectly. As shown in Figure 2-15, productivity indicators for only pertinent stages are summed. The summations are:

- man-hours/manufactured weight/family, and
- man-hours/manufactured piece/family.

The foregoing describes the feedback needed for both work load forecasting and for monitoring productivity, i.e., matters of shop operations. However, man-hours/manufactured weight/family, which is an average, times the weight of each pipe piece of that family yields an estimate of man-hours/pipe piece. The summation of all such estimates by system is an estimate of fabrication man-hours/system which is feedback for estimators.

Obviously, because of the large number of pipe pieces usually involved, derivations and applications of productivity indicators require computer-processing capabilities. This is another example of why competitive shipbuilders regard computer-aided material definition as their most important computer application.

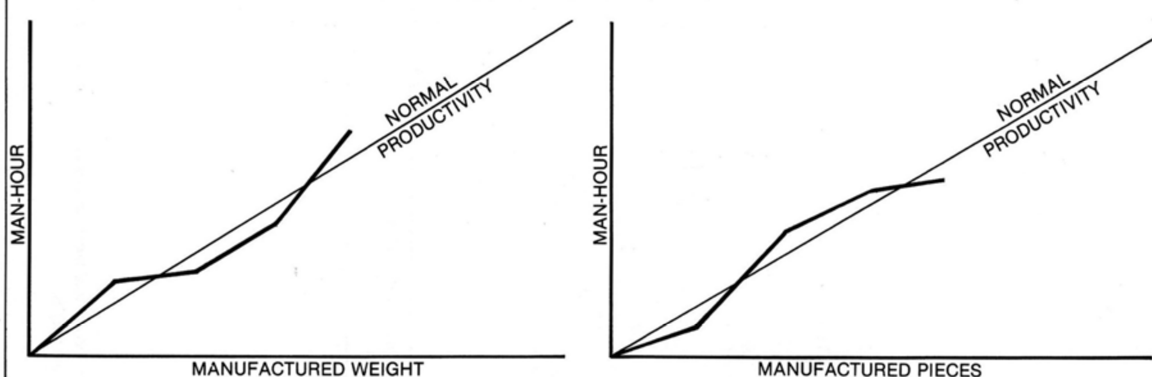
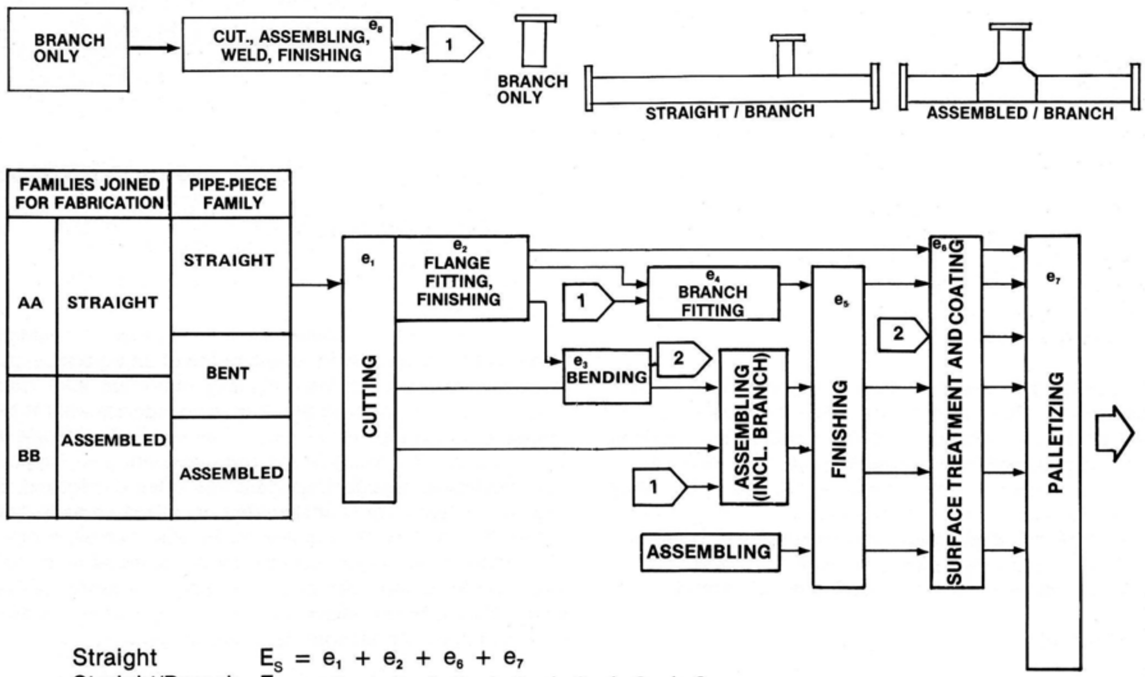


Figure 2-14: Because required pipe-piece weights and quantities fluctuate weekly, particularly for building ships of different sizes and types, two productivity indices are employed and are posted at each work station. As workers are necessarily reassigned to compensate for changing work flows, they need to know what is normal efficiency at each work station.



Straight $E_S = e_1 + e_2 + e_6 + e_7$

Straight/Branch $E_{SB} = e_1 + e_2 + e_4 + e_5 + e_6 + e_7 + e_8$

Bent After Fab. $E_{BAF} = e_1 + e_2 + e_3 + e_5 + e_6 + e_7$

Bent Before Fab. $E_{BBF} = e_1 + e_3 + e_4 + e_5 + e_6 + e_7$

Assembled $E_A = e_1 + e_4 + e_5 + e_6 + e_7 + e_8{}^*$

when E = productivity index/family

e = productivity index/work station

* if branch is included

Figure 2-15: Man-hours/manufactured weight/family is obtained by summing the pertinent productivity indices for each work station (stage) as shown. Man-hours/manufactured piece/family is obtained the same way.