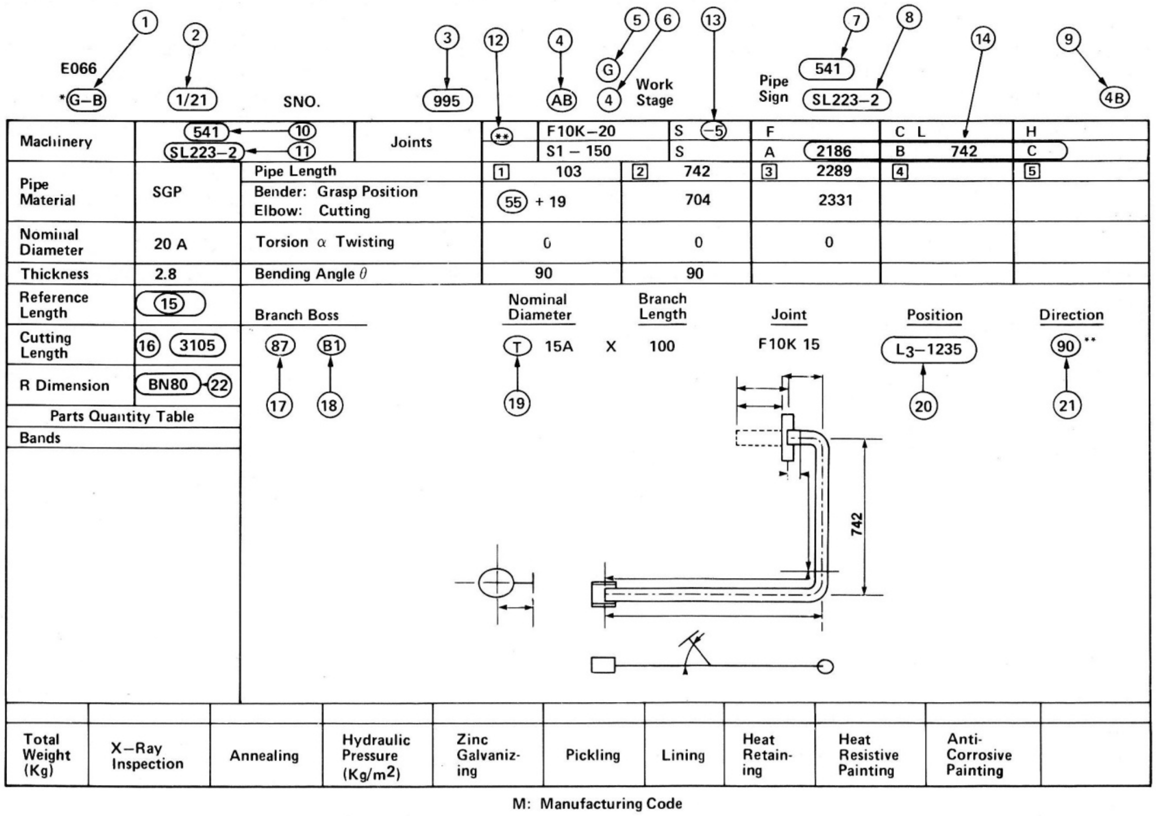


(1) Manufacturing Code
- * A-A: General pipes, straight pipes, elbows
- * G-A: Galvanized pipes, straight pipes, elbows
- * G-B: Galvanized pipes, pipes bent with bender
- * S-A: Pickling, straight pipes, elbows
- * S-B: Pickling, pipes bent with bender
- * H-P: Hydraulic pressure pipes
- * @@: Model pipes
- * YA: Pipes bent by heating

(2) Date
(3) Ship No.
(4) Ship Class
(5) Code for heat insulation
(6) Code for fitting stage or unit code
(10)(7) Zone code
(11)(8) Pipe code
(9) Pipe shape code
1: Straight
2: 1 bend
3: Zigzag bend
4: 2 bends
5: 2 bends (solid height)
6: 3 bends
7: 4 bends
B: With branch or boss

(12) Check marks for joints
@@: Model pipe
**: With 50-mm margin loose pipe
+: With 50-mm margin loose pipe (Galvanized after joining)
=: No-margin loose pipe
;: No-margin loose pipe (Galvanized after joining)
$: Check mark

(13) Flange thickness
(14) Distance between flange faces and/or solid height
(15) Indicator for reducer, elbow, model or loose pipes
(16) Margin for grip by bending machine and flange fitting
(17) Fitting angle between main and branch pipes
(18) Branch code
(19) Branch shape code
W: Boss
B: Special branch pipe
Y: Y-branch pipe
T: 90° T-branch pipe
(20) Branch pipe fitting position
L_3: Branch pipe fitted on 3rd leg
No.: Distance from pipe end to branch fitting position
(21) Mounting angle relative to around main pipe
(22) Bending dimensions
ST: Straight pipes
BN 80: Bending radius
SE 127: Elbow radius
YA: Pipes bent by heating

Figure 1-9: Coded data for fabrication of a pipe piece. This computer produced, relatively elaborate format would be more effective if it included pertinent production-control data, i.e., allocated man-hours, start fabrication and palletizing dates, etc.

How designers create and *classify* pipe-piece designs critically influences both fabrication and assembly processes. When pipe pieces have to be bent, bends should be specified which can be formed after fabrication, e.g., bending after flanges are attached. Such designs are beneficial because, as shown in Figure 1-10, they can be treated as straight pipe pieces for most of their fabrication cycle. An appropriate target for designers is to designate 40% of the total number of pipe pieces as straight pipe or pipe that is to be bent after fabrication.

Typical goals for people who perform work-instruction design are:

- 5.5 meter pipe-piece lengths for on-unit and on-block outfitting (access for cranes is always provided),
- not more than 3.0 meter pipe-piece lengths for on-board outfitting or otherwise limited by what an assembly worker can safely handle,
- common supports for parallel pipe-runs and walkways,
- ganged bulkhead and deck penetrations, and
- standard dimensions such as for bulkhead and deck penetrations, branch positions and lengths, etc.

1.2.4 Material Definition During Work-instruction Design

Planning functions performed by detail designers during their preparation of work instructions are crucial for effective PPFM. Such planning is the basis for all pipe-shop material and production controls. The planning essentials which detail designers provide are:

- designation of pallets, i.e., work packages for outfit assembly work organized by zone/problem area/stage, and
- classification of pipe pieces within each pallet, i.e., assigning each to a pipe-piece family, see Figure 1-11.

This matrix permits:

- detail design by zone,
- fabrication by pipe-piece family (problem area and stage), and
- grouping of pipe pieces from various families by zone for outfitting (palletizing), see Figure 1-12.

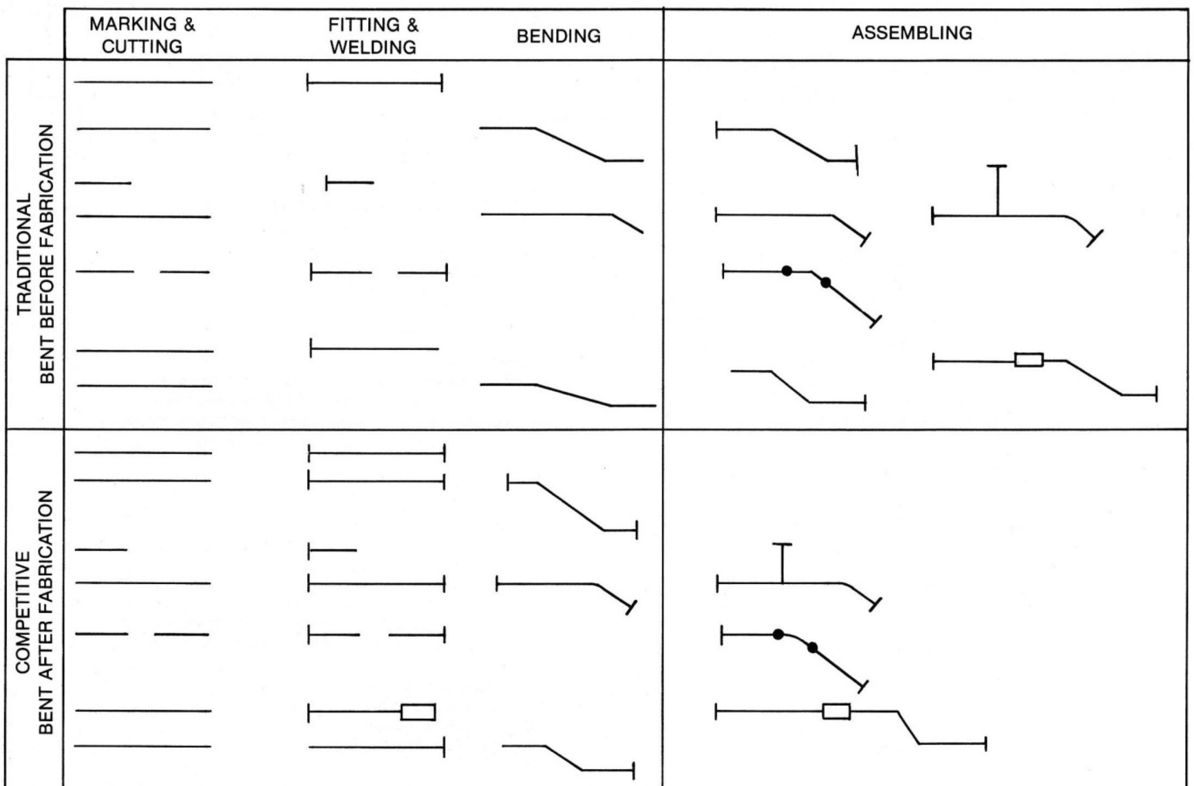


Figure 1-10: Regardless of whether manual or automated processes are used, pipe pieces which remain straight as long as possible, facilitate fabrication work and are easily rolled from one work station to the next.

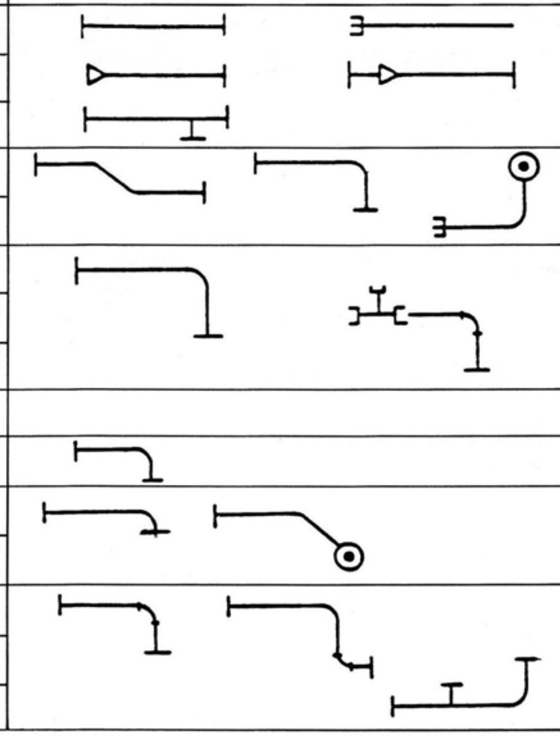
PPFM NO.	PIPE PIECE FAMILY		SKETCH
01	Straight	≦ 50mm	
04	Straight	65∼200mm	
07	Straight	≧ 250mm	
11	Bent After Fabrication	≦ 50mm	
14	Bent After Fabrication	65∼200mm	
21	Radiographic tested		
24	Hydrostatic tested	≧ 40 kg/cm^2	
27	Hydrostatic tested	< 40 kg/cm^2	
31	Plastic		
34	Bent by heating		
41	Bent Before Fabrication	≦ 50mm	
44	Bent Before Fabrication	65∼200mm	
51	Assembled	≦ 50mm	
54	Assembled	65∼200mm	
57	Assembled	≧ 250mm	

Figure 1-11: Typical Pipe Piece Families. Maximizing the relative number of straight pipe pieces ensures higher productivity. For necessary bends, the fitting man-hours for pipe pieces that are cold-bent after fabrication are one-third that required for pipe pieces with fitted ells. Pipe shop productivity depends on designers' knowledge of manufacturing methods and costs. More pipe-piece family classifications are included in Appendix A.

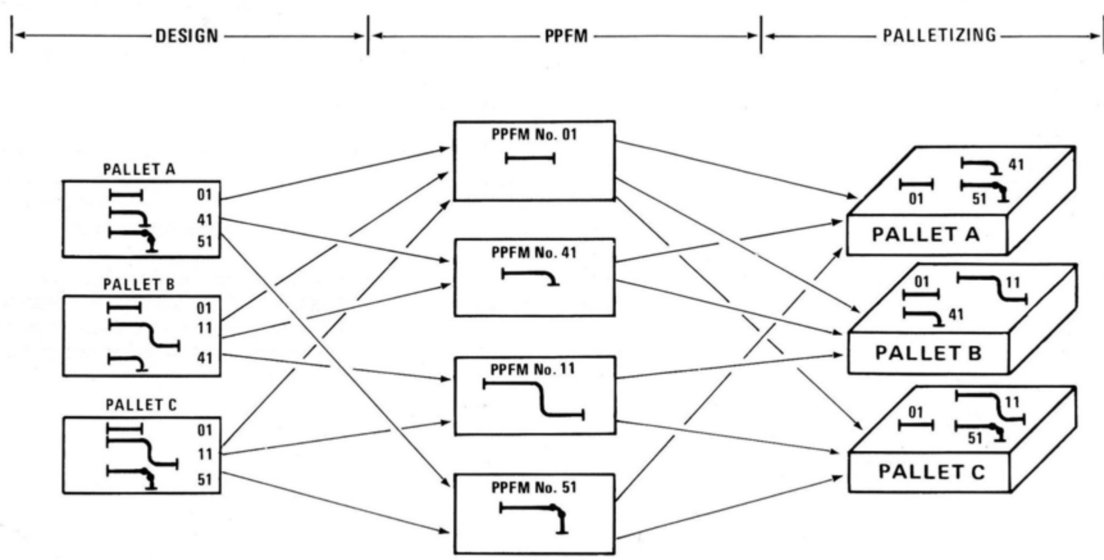


Figure 1-12: PPFM depends on control of material. Material control depends on material definition by designers. Early identification of required pipe pieces by family and pallet is essential for organizing fabrication and assembly work respectively.

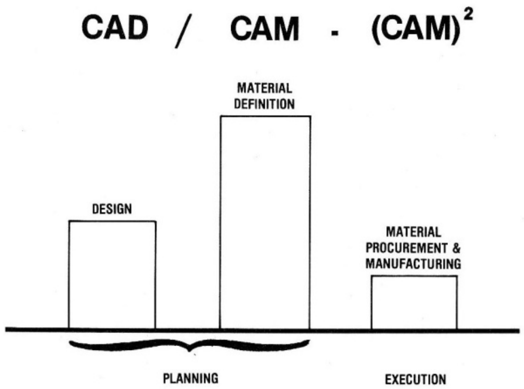


Figure 1-13: The acronym CAD/CAM as conventionally used does not identify the importance of material definition. CAD/CAM-(CAM)^2, as shown, illustrates that the need to apply a computer for defining and maintaining structured material lists is about twice as much as for design per se and four times that for material procurement and manufacturing combined. Competitive shipbuilders regard computer-aided material definition as their most important computer application.

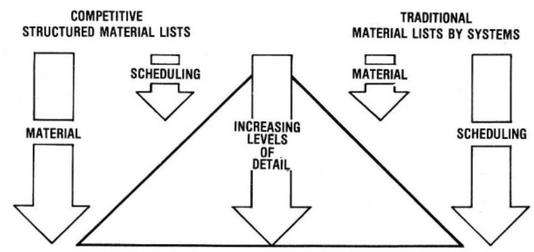


Figure 1-14: Competitive shipbuilders apply computer-aided material definition to quickly organize and maintain structured material lists. Scheduling is simplified because control is being applied to collections of material which represent work increments. Much responsibility and authority is delegated to people who make the day-to-day decisions which insure adherence to lower-tier schedules. Since control is simplified, competitive shipbuilders rely more on flexible, manual scheduling for conventional-ship construction projects.

Information developed by designers, having more than one character, allows rapid, detailed and accurate forecasts of the impact of outfit-assembly requirements on pipe-shop capacity. No less important, the same information is the basis for their preparation of structured bills of material. These link the various *material lists for pipe pieces* (MLP) for a specific outfit-assembly work package to the *material list of fittings* (MLF) needed to support the package. As GT necessarily features relatively small work packages in order to regulate work flows, as shown in Figures 1-13 and 1-14, production control through control of material is of utmost importance.[5]

Figure 1-15 illustrates the relationships between diagrammatics, composites, pipe-piece drawings and their respective material lists. Figure 1-16 depicts the data flow for a pipe-piece calculation program. This figure also shows how standards' files eliminate repetitive definition of material specifications and other such chores. Each need is defined once and placed in a standards' file by system.

Family identifiers also permit managers concerned with productivity to very exactly monitor a designer's contribution to pipe-shop productivity. Other indicators which are particularly useful for assessing designers' contributions to pipe-shop productivity are:

- number of pipe pieces that are to be custom manufactured from sketches or mock-ups made on board, and
- average length per piece.

For increased productivity, the former should be minimized and the latter should be maximized. Typically for approximately 3,500 engine-room pipe pieces in a 20,000 DWT ship, less than 11% and more than 1.85 meters respectively.

The numbers of pipe pieces per family, which have been designated for a 60,000 DWT tanker by a competitive shipyard, are tabulated in Appendix A. A decision logic table and formats for family coding used to guide designers, are also included in Appendix A.

[5] A senior manager in the world's foremost shipbuilding industry said: "In Japan we have to control material because we cannot control people." Y. Mikami to L.D. Chirillo, June 1980.

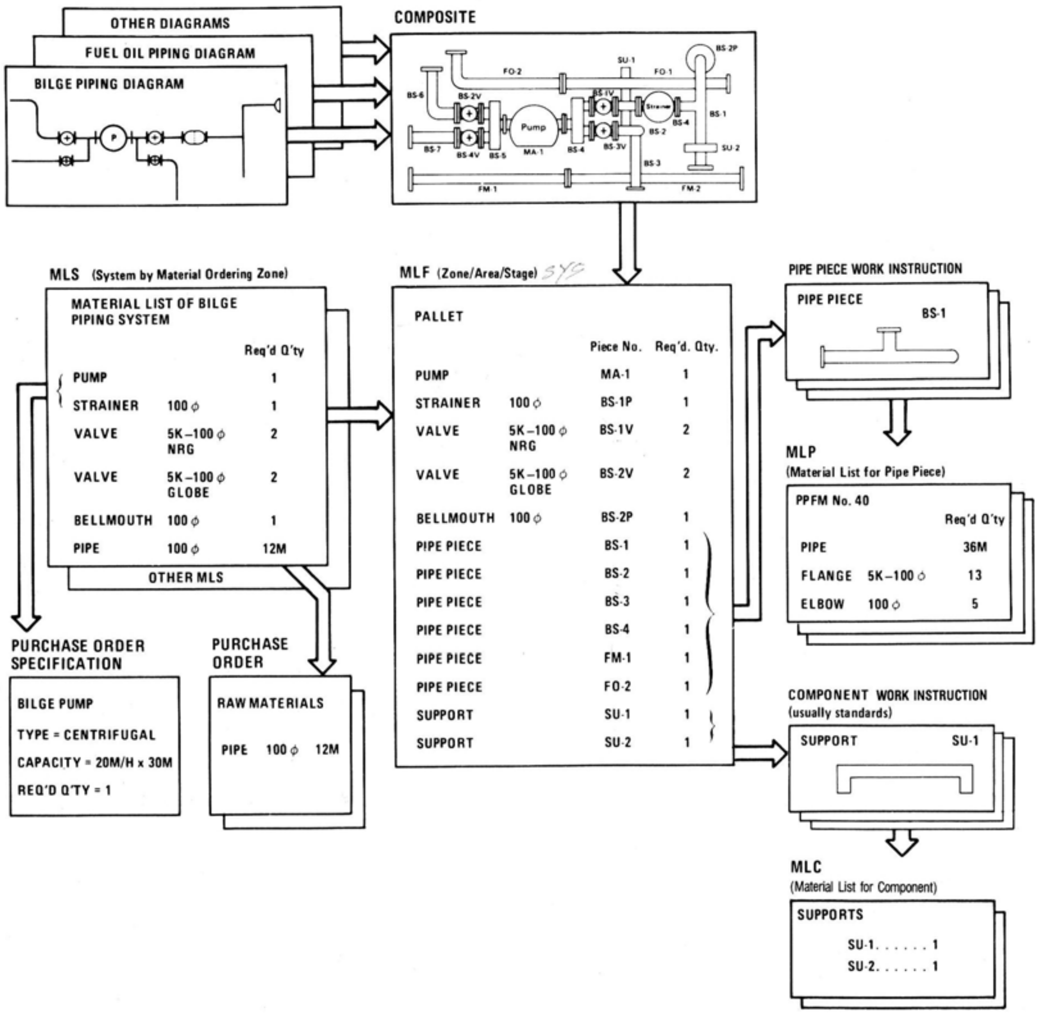


Figure 1-15: Relationships between diagrammatics, composites, fabrication-work instructions and their respective material lists.

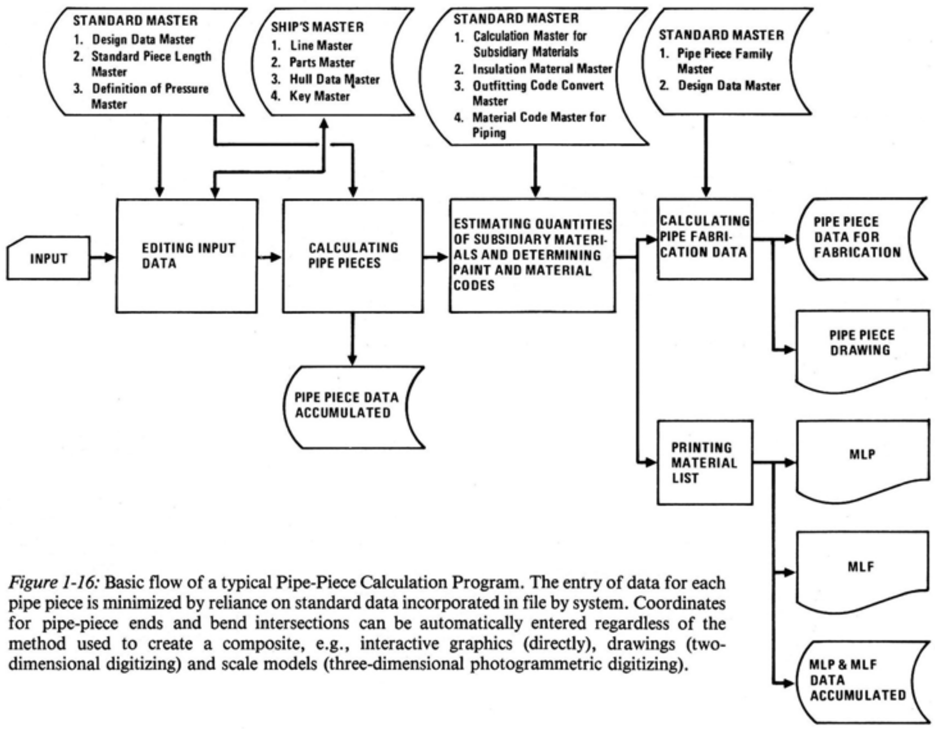


Figure 1-16: Basic flow of a typical Pipe-Piece Calculation Program. The entry of data for each pipe piece is minimized by reliance on standard data incorporated in file by system. Coordinates for pipe-piece ends and bend intersections can be automatically entered regardless of the method used to create a composite, e.g., interactive graphics (directly), drawings (two-dimensional digitizing) and scale models (three-dimensional photogrammetric digitizing).

1.2.5 Material Control

In order to simplify estimating, procurement and inventory, materials required for manufacturing pipe pieces are classified by unit price, frequency and quantity of use and certain other determinants. Consistent with integrated control of manpower budget, schedule and material, production control specialists devise material classifications and pertinent guidance for their use. Another planning function performed by detail designers is to assign the classifications accordingly. The materials for pipe pieces, just as the materials for other interim products, as shown in Figure 1-17, are classified as:

- Allocated (A)
- Stock (S), and
- Allocated Stock (AS).

A are of special nature, e.g., relatively expensive copper-alloy pipe needed in small quantities. Procurement is made for a particular ship, e.g., A materials are not stocked.

S are common to most ships, e.g., small, slip-on flanges and inexpensive welding rod. These materials are procured in economic batches at intervals determined by their rates of consumption (high-low inventory).

AS are any A or S materials which historically have caused problems that justify special controls.[6] The problems can be of any nature, but usually they relate to shortages and surpluses. AS materials vary for each shipyard. As an example, in certain shipyards they include steel pipe, preformed fittings (ells, tees, and reducers) and valve operators.

1.3 Capacity Planning and Scheduling

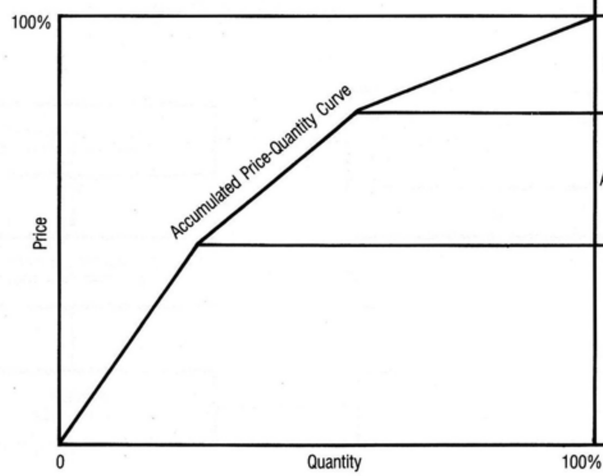
Figure 1-18 illustrates the hierarchical nature of schedules which address all fabrication and assembly work. As they integrate inherently different types of work, i.e., hull construction, outfitting and painting, the schedules necessarily are:

- control mechanisms which *command* work increments for fixed times, and are
- organized at each level to provide constraints for lower-level, more detailed schedules.

Emphatically, schedules are based upon:

- manpower expenditure, production progress and productivity indices that reflect *normal* shipyard performance, and
- *normally* available subcontractor resources.

[6] The controls are addressed in Chapter 4.0 of "Outfit Planning - November 1979" by C.S. Jonson and L.D. Chirillo for the National Shipbuilding Research Program.



Classification		Typical Material	Standardization
S	stock	welding rod	yes
AS	allocated stock	steel pipe	yes
A	allocated	copper-alloy pipe, cast-iron pipe	generally no

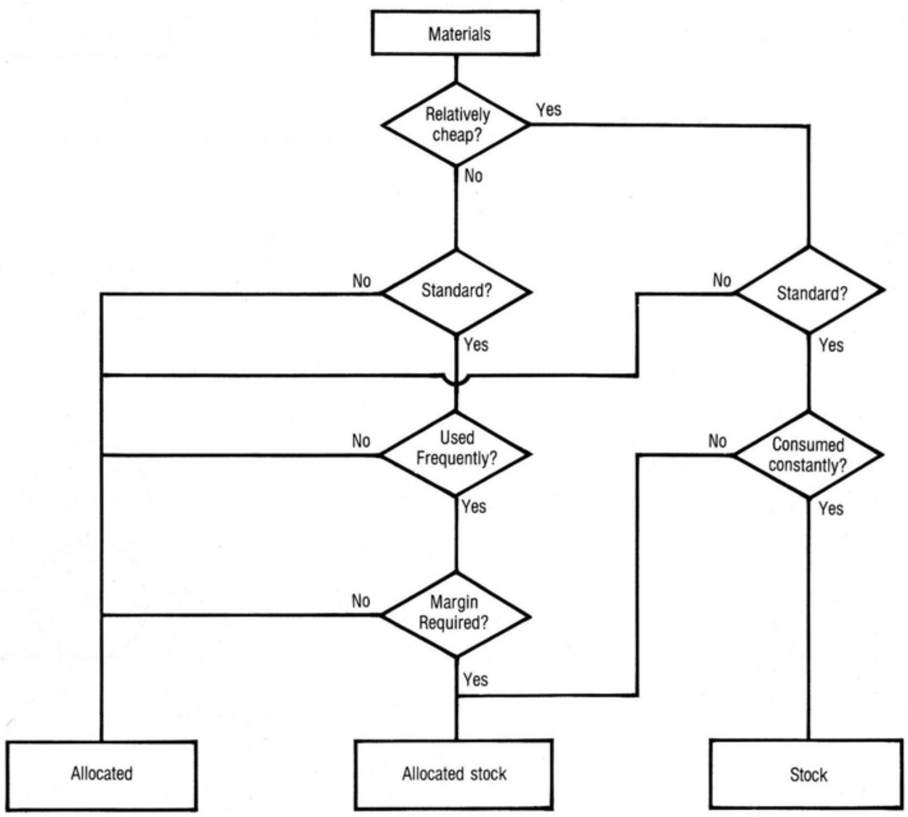


Figure 1-17: Material Control Classifications. A third classification, AS, in addition to the two traditionally employed, A and S, focuses on materials which historically cause problems of any nature.

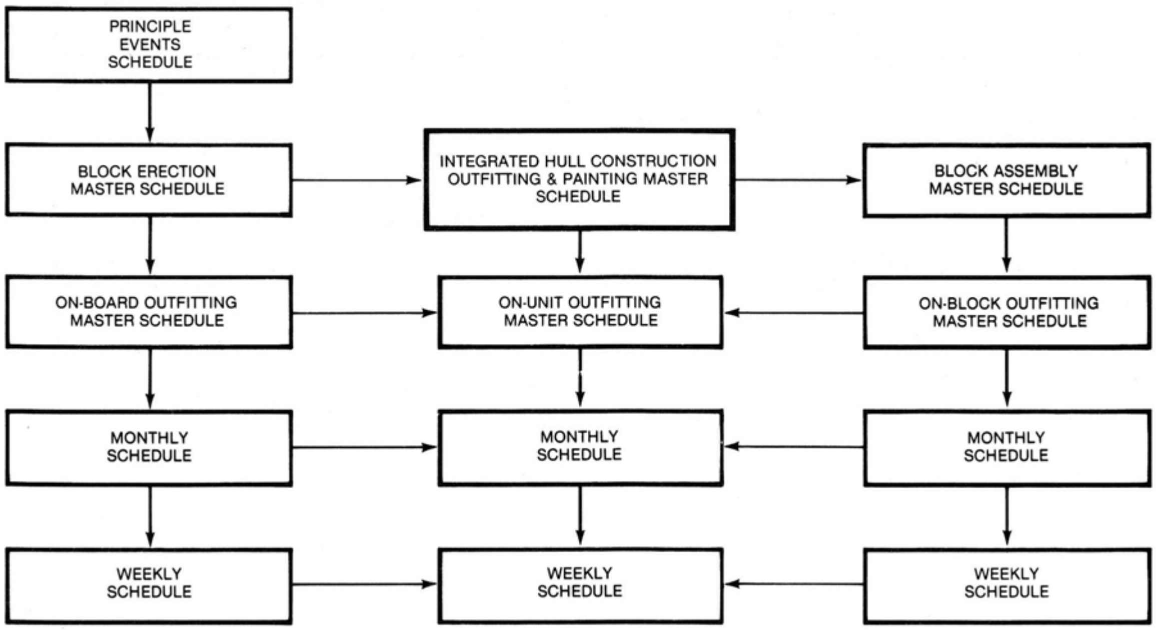


Figure 1-18: Organization of Integrated Hull Construction, Outfitting and Painting Schedules. A pipe-shop work load is fixed by the outfitting master schedules.

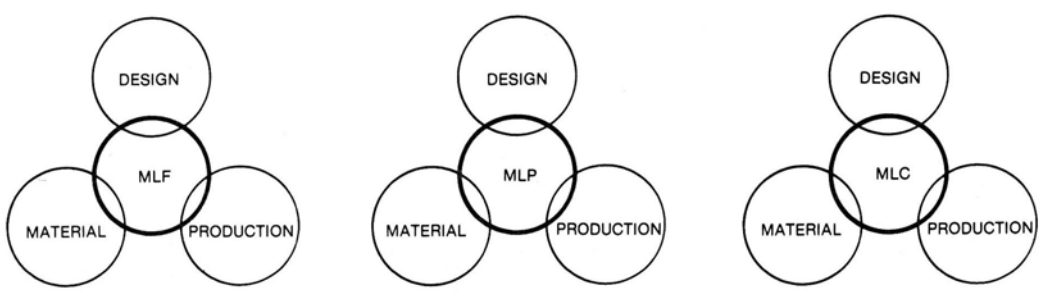


Figure 1-19: MLF, MLP and MLC are Information Links. They are collections of materials which represent work increments. They are widely used to follow-up on flows of drawings, material and work. They are also used to assess productivity.

1.3.1 In-house

For convenience, MLF, which designates the material list of fittings for an outfit work package, is also used to designate a specific part of an arrangement and the required outfit-assembly work; see Figure 1-19. Similarly, MLP, which means the material list for a pipe piece, is used to designate the required work instruction and the associated fabrication work. MLC, which applies to a component other than a pipe piece, is used the same way. Each MLF is supported by increments of work which must be performed earlier, i.e., MLP and MLC; Figure 1-20.

Further classification of MLP by pipe-piece family is essential for planning pipe-shop operations in accordance with Group Technology (GT). Grouping MLP in order to create work lots simplifies control.

Typically, a work lot is the volume of work for loading a shop during one workweek. An ideal lot contains a quantity and mix of pipe pieces which achieves uniform work flow for each operation and optimizes tool set-ups, e.g., pipe-bender die changes. A reasonable number of such changes is necessary because limiting a lot to just one pipe diameter, i.e., keying all work flow to bender operation, creates more in-process storage with correspondingly higher overall costs. Further, this requires design and material procurement efforts that are not sequenced to match optimized outfit-assembly requirements. If this overriding requirement is ignored, such as by a manager concerned only with pipe-shop operations, i.e., apparent performance, there is adverse impact on real performance which must consider productivity for the entire shipbuilding process.

Obviously, detail-design output must also include a description of each pipe piece including type, linear measurement of welds, paint system and surface area to be painted. Since the total number of pipe pieces that can be produced per week is also dependent on the complexity of pipe pieces, managers should also monitor man-hours per type and linear measure of weld, and, man-hours per coating and area measure of surface, etc.

Rescheduling work to optimize flow can be accomplished only within certain limits. The process produces schedules which are leveled and balanced so that weekly work volumes do not unnecessarily fluctuate or exceed shop capacity. The leveling and balancing process is possible because of standardization of lead times by production controllers and inclusion of family identifiers in fabrication-work instructions by detail designers. Generally, the numbers of pipe pieces that must be considered require computer processing.

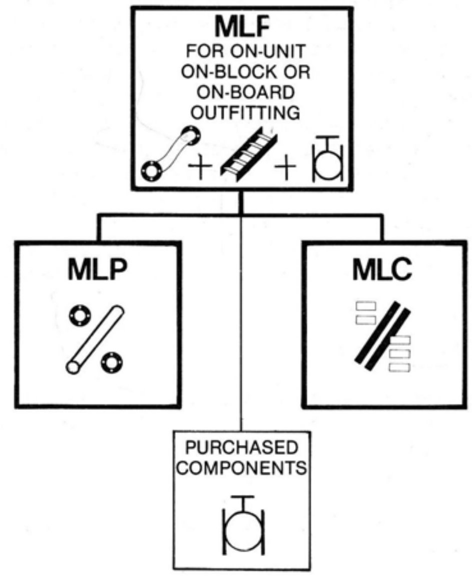


Figure 1-20: Each MLF is supported by increments of work, MLP and MLC, which must be performed earlier. MLF and supporting MLP and MLC are also called structured bills of material. Structuring material lists is crucial for effective coordination of design, material and production activities.

Pipe pieces for overhaul, conversion and other work should be included in leveling and balancing routines whenever their respective normal lead times can be accomodated.

When the word "pallet" is substituted for MLF, pallets are outfit work packages classified by zone, problem area and stage. Sequenced, they comprise a *pallet list* which is scheduled before work-instruction (detail) design commences. In other words, a pallet list serves as a game plan for executing outfit-assembly work.

Each pallet for on-unit, on-block or on-board outfitting, because it contains pipe pieces from various families, imposes a mix of fabrication work and contributes to total pipe-shop work. Because all pipe pieces have been categorized into families and each family has a normal lead time, a list of pipe pieces that should be fabricated in a given week can be readily determined. In other words, the completion date for fabrication-work instructions for a particular pipe piece is its pallet issue date minus the normal lead time for its family; see Figure 1-21.

This methodology permits early capacity planning. First, man-hours required for each operation for each family is computed weekly. This results in a total man-hour requirement by work station within each production line, e.g., cutting, bending, welding, assembling and coating. The work load is leveled and balanced for each line by examining the workload on a particular work station and scheduling earlier any work exceeding normal capacity. For example, if the work load on a welding station presents a bottleneck, some pipe pieces which require welding are scheduled for the previous week. The lead times shown in Figure 1-21 anticipate such rescheduling based on a particular shipyard's experience.

1.3.2 Subcontracting

A schedule for outfitting on unit, on block and on board exists in the form of a pallet list which sequences the development of composite drawings. Pipe-piece family identifiers are assigned by detail designers as they develop a composite for a particular pallet. Thus, critical planning is performed even before time is taken to prepare fabrication-work instructions. Just this association of numbers of pipe pieces per family with pallets, permits *quick* assessment of capacity requirements and determinations of how many pipe pieces, by family, must be assigned to subcontractors. Reasonable time is available to negotiate pertinent subcontract terms.

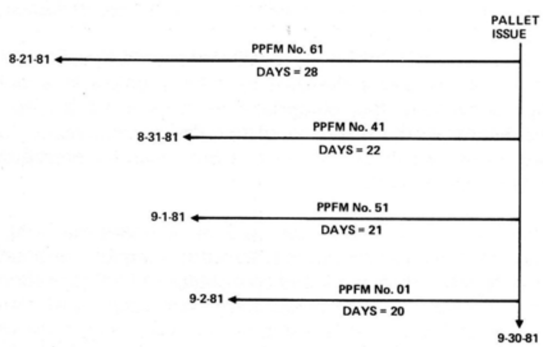


Figure 1-21: Normal lead times are usually different for each pipe-piece family. They are based on a particular shipyard's normal experience. Lead times consider the normally encountered need to schedule particular work earlier to avoid bottlenecks and to allow time for subcontractors to perform special tasks, e.g., bending by induction heating and plastic lining pipe pieces that are otherwise finished.

Because of scheduling restraints, leveling and balancing routines minimize but do not eliminate work load fluctuations. Generally, a shipyard's pipe-shop capacity should be less than even the normally encountered, minimal work load. This avoids:

- unused shipyard capacity during low work loads, and
- maintains a constant working relationship with several subcontractors who are relied upon to absorb work load peaks.

Large fluctuations in subcontracted work might jeopardize the stability of a few regularly used subcontractors in terms of work load and income. This problem is significantly reduced by distributing the work among more subcontractors so as to minimize the effect of large fluctuations on any one of them.

Ability to foresee pipe-piece fabrication work loads by families, permits a shipyard to reserve portions of subcontractors' capacities in the same manner that mill reservations are made for steel plate.

Preassigned purchase orders which are complete except for the designation of specific pipe pieces during specific periods, permit remaining make-or-buy decisions to be delegated to the pipe-shop manager. These decisions are made at a weekly meeting at least three workdays before the pertinent workweek. The three-day period is for delivering work instructions and necessary materials to the subcontractors. Furnishing the required materials provides a practical means for control of material quality, timeliness and costs. A shipyard's ability to purchase materials in larger quantities results in lower unit costs.

Subcontracting is especially productive when special facilities are required such as for plastic-lining steel pipe or high-frequency induction heating for small-radius bends in large diameter pipe.

In order to develop subcontractors who literally serve as an extension of a shipyard, special management attention is required. A small staff, representing both the pipe shop and the quality control section should be regularly assigned and charged exclusively with providing technical support to pipe-piece fabricators. The assistance should include instructions in the shipyard's information formats, terminology, methods etc. With such aid even the smallest of firms, having no design or material procurement departments, can provide significant pipe-piece fabrication services.