A Paper for Presentation to

The Royal Institution of Naval Architects
Australian Division

PRODUCT WORK BREAKDOWN: THE CHALLENGE TO PRODUCTION AND DESIGN ENGINEERS

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29 April 1988 - Melbourne
4 May 1988 - Sydney

The following, quoted from a recent paper, succinctly describes the transformation that is gradually taking place in management of North American and United Kingdom shipyards:

"Information that had been grouped only by system, e.g., as on a system arrangement and detail drawing, is now grouped to exactly anticipate the parts, subassemblies, and assemblies, i.e., the interim products, required to build ships. In each case, the build strategy which guides designers in so grouping information, is imposed before contract design starts!

"When interim products are grouped by the problems inherent in their manufacture, even for different ships being built simultaneously, production lines can be organized which are just as effective as counterparts in the automobile manufacturing industry. This approach which examines required interim products with different eyes so to speak, looks for manufacturing commonalities and ignores differences in design details. The organization of alike work in this manner is called Group Technology (GT). GT is the most ideal way to process interim products of different designs in varying quantities as required for ships and for many end products other than ships.

"For certain interim products, production lines sometimes constitute real work flows wherein materials are conveyed from work station to work station. In contrast, when a team of workers is moved from site to site and the work category at each site remains the same, the effort is regarded as virtual work flow. The impact on people is the same as if they were at fixed work stations and a conveyer was transporting the materials being worked. The objective of work flows, both real and virtual, is to avoid the greatest single loss in any industrial endeavor, i.e., people waiting for work." [1]

Traditional naval architects who participate in basic and subsequent design phases will wonder, "What has that got to do with us?" The answer is, "Very much, indeed!" If the productivity level achieved by the world's most effective shipbuilder is used as a yardstick, traditional designers have been grouping information the wrong way for at least the last twenty years!

Some private-shipyard managers in North America and the United Kingdom accepted the challenge and organized information differently for new designs or invested in changing the way information was grouped for existing designs. The latter involved changes in locations of hull butts and seams and rearrangement of fittings. So far, the different and far more productive approach has been applied by them for construction of merchant ships, naval auxiliaries, and naval landing ship docks (LSD).

U.S. naval shipyards (dockyards) have taken the lead in applying the more productive approach for alterations equivalent in nature to construction work, e.g., installation of a close-in weapons system in the aircraft carrier RANGER, installation of a significant part of a Tomahawk missile system in the cruiser TEXAS, extensive changes in the electronic suits of 637-class submarines, and, currently, extensive modernization and overhaul work in the aircraft carrier KITTY HAWK.

The different way of grouping information to facilitate the building effort does not detract from a ship's performance characteristics. In fact, the opposite is true. Some characteristics are significantly enhanced. For example, accuracy is emphasized as necessary means to maintain coordination of the various interim-product work flows. So while productivity improves, end products, e.g., 3,400 displacement-ton destroyers produced by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan, are within 10-millimeters of principal design dimensions. Benchmarks needed for aligning weapon and navigation components relative to each other, are positioned well within tolerances specified.

The linkage of accuracy and productivity routinely yields curved plates that idealize seawater flows such as around sonars. Also the linkage yields better aligned strength members so as to contribute to protection from high-impact shock. In the case of submarine hulls, the higher order of accuracy pursued to enhanced productivity, increases allowed submergence depth.

Regarding outfitting, some machinery foundations, even for different systems, are combined. Pipe runs are organized in parallel and pipe for different systems often share common hangers or are attached to walkway supports. A greater percentage of straight pipe pieces are featured. Pipe bends are mostly limited to 90 and 45 degrees. Average pipe length is increased. While such features obviously improve productivity, they often result in less volume occupied and less weight. Regarding high-pressure piping as in submarine systems, the increased order of accuracy associated with improving pipe-piece fabrication, minimizes the need for high-capacity chain falls to force pipe joints into place. Eliminating such practices minimizes locked-in stresses so as to enhance high-impact shock protection and prevents dangerous spring back when pipe joints are disassembled.

Also, grouping information to match specific interim products is the basis for production control through control of material. The validity of man-hour budgets and schedules are absolutely linked to how well and how early basic, functional, and detail designers define and refine material requirements. One consequence of this extraordinary attention to material is very accurate ship-configuration records that are prerequisite for providing the right technical manuals, test equipments, and spare parts in the quantities needed to sustain operations. For naval ships, correct such provisioning is a military requirement.

Thus, in addition to lowering costs, product-oriented methods inherently improve quality so as to be attractive to ship operators, particularly operators of warships.

The unprecedented vitality demanded of designers in a product-oriented operation pertains to the increased interaction of design engineering with production engineering. Starting with the beginning of the contract design phase, the design process literally becomes an aspect of planning. Managers must anticipate that design man-hours will increase. In addition, managers in North America who have successfully achieved the transformation, invested in IHI consultants to guide their design organizations in product-oriented grouping of information. In other words, managers must increase design budgets commensurate with the challenges being imposed by the logic revolution, i.e., the shift from system to product (zone) orientation.

Managers should also be aware that the logic revolution could be imposed when computer-aided-design (CAD) is not fully developed. In such instances, designers should be given added consideration because two profound revolutions would be underway simultaneously. Those who would hestitate should realize that CAD without the logic revolution would only achieve many archaic notions more quickly and more accurately. Without the shift to product orientation, the full capabilities of CAD cannot be exploited.

For example, product-oriented designers produce diagrammatics that are slightly more sophisticated than in the past as they are quasi arranged. Further, they show separations which reflect the build strategy and establish the first refinement of material requirements. Information is thus grouped in an intermediate-frame sense. Then, specialist designers, say for a machinery space, superimpose the diagrammatics on a machinery arrangement which was conceived in the context of the same build strategy. These are very experienced people who know where key valves should be with respect to machinery and gauges, who know which systems require more frequent repair work so they may be located outboard in a pipe bank, who know where space reservations must be imposed such as for inspection access and for disassembly of machinery, etc. Their output, sometimes called a "transition" or "right-of-way drawing" is a road map which detail designers assigned to the various zones must follow.

Each detail designer transforms an assigned zone of the transition drawing into a composite detail and arrangement drawing. Where CAD is employed, after a group of such composities are completed, say for the lower engine room, each system is separately displayed as an isometric. Modifications are evaluated to maximize the use of straight pipe pieces, to minimize the locations of bends near flanges so that such pipes may be bent after flanges are fitted, to minimize the need for odd-angle bends, etc. A reexamination is conducted after a shift back to the composite format. Sometimes, the consideration of one proposed adjustment to improve productivity may require more than one isometric/composite iteration. Also, pipe pieces are coded by problem category so that managers may evaluate designers by the percentages of pipe pieces in the lowest-cost categories. The CAD "layering" capability is employed to separate by type of work, e.g., welding all supports in a zone during one stage without regard for different systems represented. As shown in these examples, the efficiencies of fabrication and assembly workers are largely determined by designers' appreciation of production costs and by how well they exploit CAD capabilities.

Expertise commensurate with the foregoing is only achievable through specialization along product lines as shown in Figure 1 for outfitting activities. The organization shown reflects a basic separation by problem categories per GT logic. For example, problems inherent in outfitting machinery spaces are inherently different from those for accomodation spaces. Thus, the mix of disciplines necessary for a machinery space work together under a common supervisor. As also shown in Figure 1, there are counterpart organizations in production which replace traditional shops.

The purpose of such organizations is to focus each design speciality and its counterpart in production on costs per parts, subassemblies and assemblies within a region that requires unique expertise. Thus for hull construction the analogous organizational divisions, except for erection work, are unique for flat-panel blocks, curved-panel blocks, and superstructure blocks with all further subdivided in both design and production by parts fabrication, sub-block assembly and block assembly. The interim products assigned to each group are clearly identifiable. Such products enhance design/production communications because they constitute common objectives. They serve as focal points for organizing all resources necessary for their just-in-time production on organized work flows.

Following the same logic for part of the Ship Life Extention Program (SLEP) overhaul of the aircraft carrier KITTY HAWK, the Philadelphia Naval Shipyard organized unique specialities in both design and production as illustrated in Figure 2.

If designers think that they can stay in their traditional roles as functional specialists and effectively group information to support work flows for a modern shipbuilding operation, all that can be said to them is, "Pleasant dreams!" If they are educated in what product orientation is and how their responsibilities would become more generalized so as to make design a more dynamic part of the shipbuilding process, their new roles will be a tremendous source of job satisfaction. But, if they remain dyed-in-the-wool traditionalists, their's will be the most traumatic experience in a shipyard destined for modernization. As such disbelievers or curators of ivory towers are a grave threat to the development of modern product-oriented methods, determined management will have to deal with them accordingly.

Designers who accept the challenge of change in the basic logic they employ, cannot operate in a vacuum. Even before contract design starts they require a production-engineered build strategy to guide their grouping of information. Thereafter for each design phase, as shown in Figure 3, when more information is available as a consequence of design development, they have need for a refined build strategy. In other words, during each phase an entire ship is addressed, at first in a large-frame sense, then in an intermediate-frame sense, and finally in a small-frame sense corresponding to work packages. Production engineering commensurate with this need does not exist in traditional functionally organized production departments regardless of the experiences and skills of shop managers.

Traditional production organizations feature centralized planning that cannot possibly cope with the amount of information involved in guiding complete design efforts. For the most part, traditional grouping of information ends with system arrangement and detail drawings or portions of them corresponding to relatively large geographical divisions of a ship. The conventional drawings used to preoutfit a transverse section of a frigate hull are typical examples. Information is not grouped zone/stage by type of work as needed to support work flows in a product-oriented shipyard. When such system-by-system drawings are referenced in work orders to various production supervisors they are, in a defacto sense, accompanied by the management cop-out, "Somehow coordinate among yourselves."

Also, for piping systems less than 2-inches in diameter, traditional grouping of information ends with diagrammatics. It is left to shop personnel to field run such pipe systems wherever they can be fitted. This practice accounts for small pipes that run across the tops of strainers and across machinery inspection covers. Rework is prevalent. Accurate cost collection is elusive. Corporate data is not precise enough for effectively estimating future costs.

A dictionary definition of production control is "systematic planning, coordinating, and directing of all manufacturing activities and influences to insure having goods made on time, of adequate quality, and at reasonable cost." In this context, specialization by product and decentralization of production control, not just planning, is essential for ideal production engineering/design interaction. In IHI yards, design and production people are organized along product lines and production control is decentralized. Nothing is field run. Even tubing is controlled. Planning is before the fact, i.e., before design.

What is necessary is college-educated people, or people having equivalent ability to think analytically, assigned as production engineers in a production control department that reports directly to the yard's general manager. They are concerned with the initial build strategy, i.e., information grouped in a large-frame sense as needed for master planning and scheduling and for the purpose of guiding the contract-design effort. They have to be supplemented with people having similar capabilities who are assigned to the production department and to the various shops and assembly organizations. The latter are concerned with information in an intermediate-frame sense as needed to sufficiently refine the build strategy before the functional and transition design efforts, and to establish intermediate, perhaps monthly, schedules for shops and assembly sections.

Finally, qualified foremen and assistant foremen are needed to perform the same production engineering functions with information grouped in the smallest-frame sense as needed to guide detail designers and to produce biweekly and weekly schedules. As experience is gained, assistant foremen guide designers in reducing the size of work packages to as small as 40 man-hours, as in IHI, by making divisions on material lists. Thus, at all subordinate levels of the decentalized hierarchy, goals are refined in terms of zone/problem area/stage for marshaling work instructions, materials, and manpower as needed to support organized work flows for integrated hull construction, outfitting and painting.

People with only traditional experience who are drawn upon to participate in production engineering compatible with product-oriented shipbuilding, will have to accept some very important concepts. As shown in Figure 2, one of the specialities organized for the SLEP overhaul of KITTY HAWK pertains to a group of miscellaneous spaces, i.e., pump rooms, air-conditioning machinery rooms, etc. The logic employed is explained in the following:

"Product orientation is often called zone orientation and perhaps for this reason traditionalists immediately envision major divisions of a complete ship that usually coincide with compartments. Per GT logic, separations are different because they are by problem category. It doesn't matter where in a ship work of the same problem category is located for organizing virtual work flows. Thus, as shown in Figure 2, the spaces that are assigned to each speciality do not comprise neat geographical divisions of the ship. In fact, the spaces for the miscellaneous speciality are not even contiguous with each other. Geographical boundaries, grouping of classes of problems and needed horizontal communications were all factors in developing the specialities for KITTY HAWK in addition to applying a basic GT principle, i.e., matching classes of problems to sets of solutions.

"An additional concept that is hard for the uninitiated to understand is the nature of zone/stage. It is possible to control by divisions in geography, i.e, by zones. It is also possible to control by divisions in time, i.e., by stages. But, the most effective and flexible way to control large industrial endeavors is by combinations of both. If a particular zone scheme is optimum at one point in time, as soon as time changes it can be abandoned for a different zone scheme that is more opportune. Thus, for example, planners are entirely free to organize an on-board zone/stage work package that straddles a bulkhead during hot work on the bulkhead, knowing full well that later in time, zones that coincide with the compartments on both sides of the bulkhead make more sense for painting. Zone/stage designations are synonymous with opportunities." [1]

A decade before the logic revolution discussed herein started in North American and United Kingdom shipyards, it was put into practice in Whyalla, South Australia in response to a technical cooperation agreement between Broken Hill Proprietary Limited (BHP) and IHI. At that time, some BHP managers, engineers, and draftsmen visited Japan to acquire firsthand knowledge of IHI's production engineering, design, and production methods. Despite an impressive degree of implementation, product-oriented shipbuilding appears to have vanished from Australia with the closing of BHP's Whyalla Shipbuilding and Engineering Works.

Since the BHP/IHI venture, IHI's manufacturing system has reached another recognizable level of technology development, i.e., the fifth or top level shown in Figure 4. But, the basic logic which some Australians once exploited, remains unchanged. Prerequisite understanding exists as manifested by an excellent paper in this Institution's literature. If encouraged and provided with resources, the people who understand can reestablish product orientation in the Australian shipbuilding industry. [2]

The logic and principles that IHI exploits are now described in English and associated with disciplines that are taught in universities, e.g., product organization, GT, and statistical control. As a consequence, product-oriented methods are now routine in some North American and United Kingdom shipyards. Employees are manifestly working smarter not harder even for building end products other than ships. Also, some labor leaders now appreciate the need for a more efficient way to organize work. Thus, the opportunity to effect a tranformation has never been better. And, because of current economic conditions that have adverse impact on shipbuilders and their customers everywhere, undertaking the challenge to adopt product orientation has never been more imperative. [3] [4]

"The innovator has for enemies all those who have done well under the old conditions."

MACHIAVELLI

[1] Chirillo, L.D., "A Product Work Breakdown Approach for Ship Overhauls", Pacific Northwest Section, The Society of Naval Architects and Marine Engineers, 12 March 1988.

[2] Lord, J.M., "A Review of Developments in Shipbuilding Technology and the Potential for Application to Naval Shipbuilding in Australia", The Royal Institution of Naval Architects, Australian Division, October 1984.

[3] Responding to a shipyard manager's statement that labor imposed trade separations impeded productivity advances, Paul J. Burnsky, President of the AFL/CIO Metal Trades Department said in effect, "Labor is not your problem. If you do not like the way we are organized, change the way you organize work. If you do, you will cause problems for people like me, but we will get to where you want to go. It won't be as fast as you want, but we will get there. Management infers leadership so act like leaders, take the first step."

[4] The logic and principles of what is described herein reflect the very effective management system employed by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan as published by L.D. Chirillo Associates, P.O. Box 953, Bellevue, Washington 98009, U.S.A., in a series of booklets for the National Shipbuilding Research Program (NSRP). Some of the material so published is incorporated in "Ship Production" by Storch, Hammon, and Bunch, Cornell Maritime Press, P.O. Box 456, Centreville, Maryland 21617, U.S.A. (ISBN 0-87033-357-7), Chapters III, IV, VI, VII, and VIII. Additional pertinent booklets based on IHI methods and published for the NSRP by L.D. Chirillo Associates are: Precontract Negotiation of Technical Matters - December 1984, Product Oriented Material Management - June 1985, Shipyard Organization and Management Development - October 1985 (Reprinted in the May 1986 issue of The Society of Naval Architects and Marine Engineers' Journal of Ship Production, pp. 74-79.), Flexible Production Scheduling System - April 1986, Product Oriented Safety and Health Management - May 1986, Analytical Quality Circles - September 1986, and Flexible Production Indices - April 1987. Copies of the latter publications are available from the University of Michigan, NSRP Microfiche Library, 2901 Baxter Road, Ann Arbor, Michigan 48109, U.S.A.

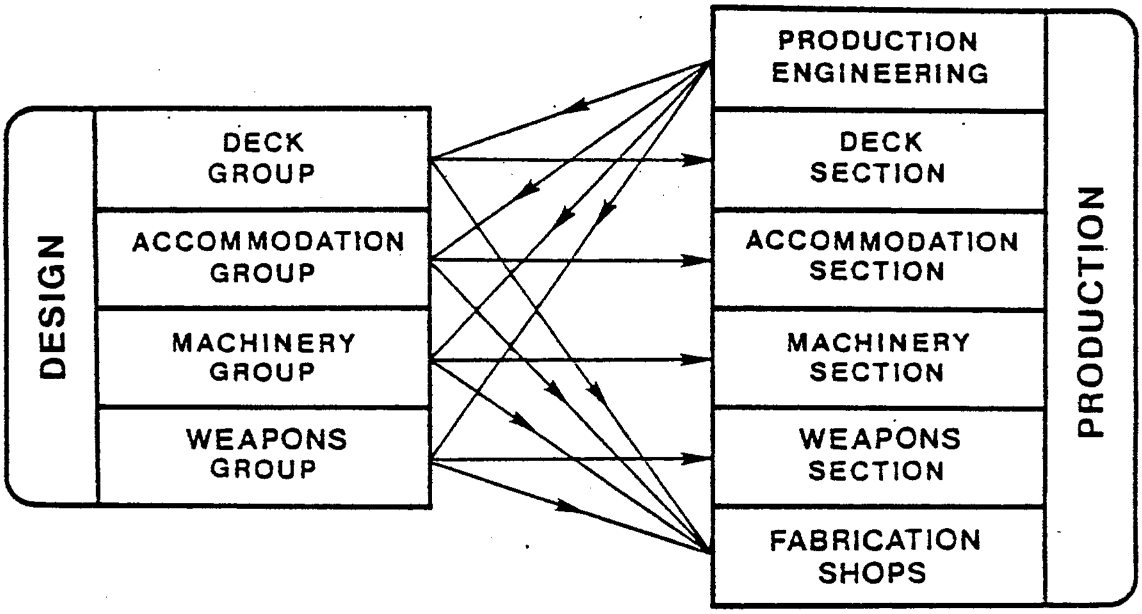

FIGURE 1: Basic Product-Oriented Organization for Outfitting Warships. "Deck" refers to all spaces that are not accomodation, machinery, or weapons spaces. The word "section" implies an assembly organization that moves to wherever outfitting on-unit (no structure), on-block, or on-board is to take place. "Shop" has the connotation of a fixed work place dedicated to fabricating parts. As shown by the information flows, production-engineer specialists advise designers how to group information as needed for ideal work flows in fabrication shops and assembly sections.

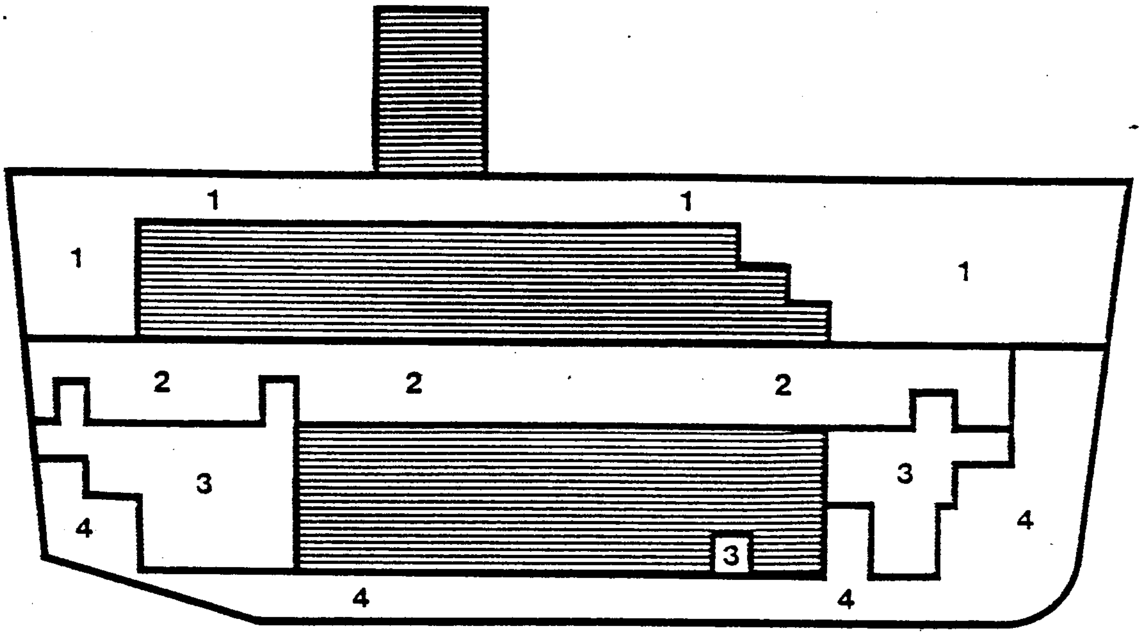

FIGURE 2: Product Organization Applied by Philadelphia Naval Shipyard for Modernization of KITTY HAWK. The specialists in design with counterpart specialists in production are for: (1) electronic and accomodation spaces between the flight deck and the hangar deck, (2) accomodation spaces below the hangar deck, (3) miscellaneous spaces, such as, pump rooms, air-conditioning machinery rooms, and storerooms, and (4) tanks and voids. Two specialities involve accomodation spaces because work in those between the flight deck and the hangar deck has to be carefully coordinated with work in various electronic spaces, including the combat information center, which are located in the same region. The same problem does not exist below the hangar deck.

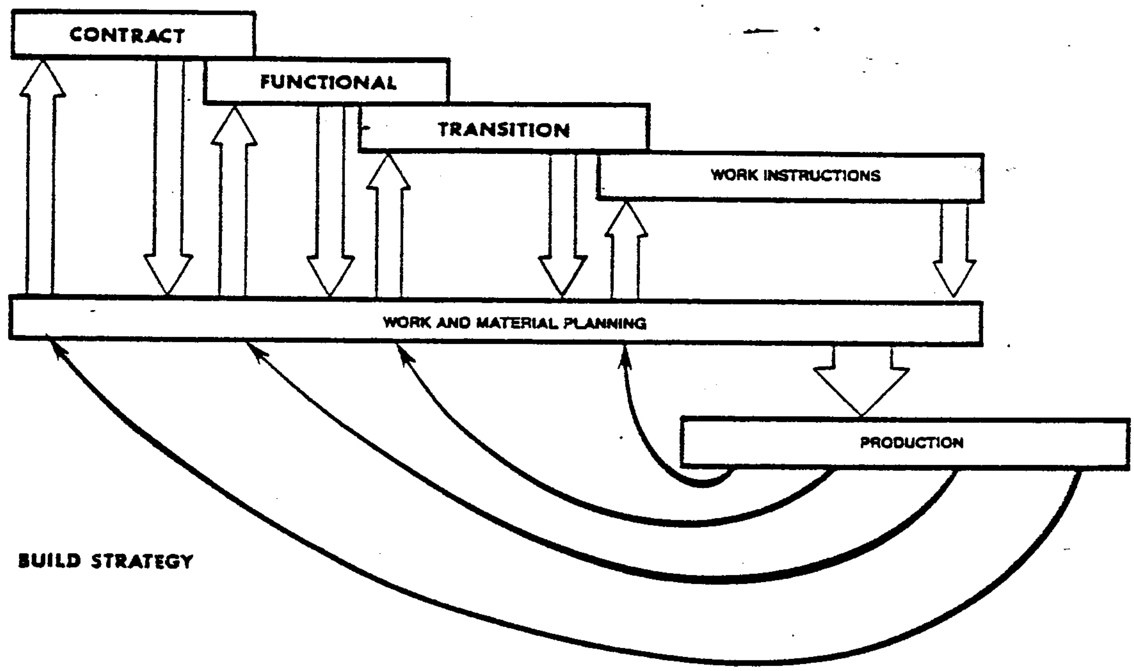

FIGURE 3: Production Guides How Information is Grouped in Each Design Phase. With just preliminary design input, production engineers document a build strategy which is included in the contract design being negotiated with the customer. As the various design phases make more information available, production engineers constantly refine the strategy until it becomes tactical in nature. Before the last design phase, production engineers provide specific work methods, requirements for reference marks, precautions, etc., that are to accompany sketches and material lists in work instructions.

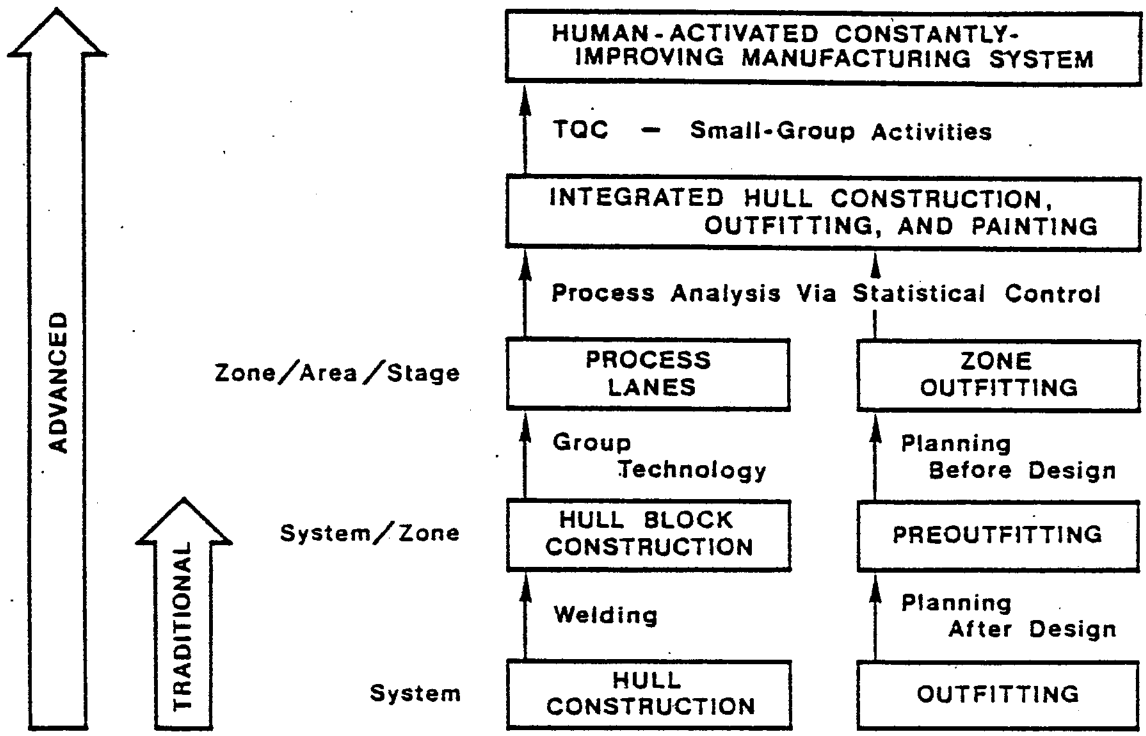

FIGURE 4: Identifiable Levels of Shipbuilding Technology Development. "Zone/area/stage" are product aspects. "Area" (problem area) designates the problems inherent in manufacture. Statistical control techniques provide the "barometers" which indicate how work processes are performing as needed for integrating inherently different kinds of work and as needed to identify problems. When such conditions exist, the worker groups that match the organization of work flows are likely to respond with suggestions for bit-by-bit improvements as a routine matter. This is the character of a constantly self-improving manufacturing system needed to achieve the fifth level of technology development.

Hampton Roads Section
The Society of Naval Architects and Engineers (SNAME)
21 April 1988

Paper: SEAWOLF Producibility by LCDR B.R. Brucker, U.S. Navy

Discusser: L. D. Chirillo, Bellevue, Washington

The author's paper is commendable because it acknowledges that technology is more than hardware and it recognizes manufacturing as a system. It, along with relatively recent efforts by other mid-career naval officers and some civilians employed by the Navy, are countering the long valid opinion that military contributions to the development of manufacturing tend "...towards ignoring the systemic nature of manufacturing." [1]

Pertinent research to fill the gap was recommended by Panel SP-2 of the SNAME Ship Production Committee. The late Robert E. Thomas, a key participant at that time, was the first to advocate, "outfitting is not a successor function." Bob's insight was gained as a member of a Newport News Shipbuilding (NNS) team which had spent more than a month in the mid 1970s observing methods in the Kure shipyard operated by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan. Probably, because the NNS team members were so functionally oriented at that time, there was little focus on the nature of the entire manufacturing system. Bob Thomas was one of the very few, if not the only one, to suspect a difference in basic logic that was accounting for the extraordinary effectiveness of IHI's approach to heavy construction.

Research by the Maritime Administration/industry National Shipbuilding Research Program (NSRP) was directly aimed at the logic and principles of IHI's approach and was assigned to IHI for implementation. LCDR Brucker seems to have benefited from those of the research end products which are reprinted in the textbook referenced in his paper.

The research disclosed that IHI's shipyard organizations were product (interim product) oriented in the early 1960s. It also disclosed that people in all levels of the management hierarchy were being developed as generalists, i.e., as experts knowledgeable of the entire management system. This specifically included shop managers who as production engineers and assistant shop managers were job rotated approximately every two years in order to give them real responsibilities in hull construction, outfitting and painting shops. The latter were product oriented, e.g., specialized for just machinery spaces to address parts, sub-assemblies, assemblies, and on-board work classified by inherent manufacturing problems per Group Technology logic.

Thus, IHI management development is similar to the way the Navy forms officer careers in order to qualify generalists to be Chief of Naval Operations (CNO). And, just as the Navy retires each CNO after a reasonable incumbancy, IHI shipyard general managers move on after four or five years in order to ensure a viable management hierarchy. The practice is essential for a modern, product-oriented, decentralized, constantly self-developing manufacturing system which sharply focuses on cost per interim product.

Training in modern product organizations specifically addressing technical and managerial issues was recommended by the National Research Council. The recommendation was one of a number in response to a Navy request to identify promising technology developments that have the potential to improve productivity. Only two North American shipbuilding firms, both Canadian, are known to have fully responded to the council's identification of such training needs for senior managers, middle managers, and first-line supervision. [2]

While disclosing methods, IHI identified five levels of technology development as shown in Figure 9 (provided with this discussion). The figure is useful for assessing the level of technology which the author's paper suggests will be achieved by the unique combination of submarine builders and the Naval Sea Systems Command regarding SEAWOLF.

As shown in the figure, the third level is achieved when planning precedes design. Figure 10 (also provided with this discussion), shows a build strategy imposed before the initial design phase which is constantly refined thereafter as designers make more information available. Design, literally, is an aspect of planning.

In yards that have achieved the third level, such predefinition and constant refinement is a production engineering function performed in the context of a product work breakdown structure. Thus, starting with the initial design phase, interim products are envisioned classified by zone/problem area/stage as required to organize production lines, i.e., both real and virtual work flows. So guided, the design process basically groups information at first by system with indication of zone divisions in a large-frame sense, next by system diagrammatics with further division by zones in an intermediate frame sense, and finally information grouped by zone in the smallest frame sense, e.g., composite arrangements and details accompanied by material lists, specific work instructions, precautions, etc., as required to produce interim products.

Designs produced in accordance with the third level feature such benefits as a greater percentage of straight pipe pieces and pipe runs in parallel sharing common or walkway supports that facilitate shop assembly and painting. Such designs also feature increased average pipe-piece length and bends limited to 90° and 45° in order to facilitate statistical process analysis for pipe-piece manufacture. Statistical process control also enhances accuracy so as to greatly reduce the practice of forcing the fit of high-pressure pipe pieces.

In addition, designs produced in accordance with the third level feature "layering" by types of work so that no two worker groups are unintentionally scheduled to be in the same on-board zone at the same time. Hot work within an on-board zone, for example, is scheduled for accomplishment in one or two stages regardless of the systems represented. In contrast, the author's statement, "...product-oriented people are being brought into the mock-up to review the design from the standpoint of the ease of construction" infers planning after the fact. This suggests only the second level of technology development for at least the work associated with the mock-up.

In order to achieve the forth level, statistical control techniques have to be applied to all fabrication and assembly work flows in order to achieve their integration. This is the heart of a pull system in which requirements for materials in-process and work areas are reduced, i.e., just-in-time procurement of components and manufacture of parts and assemblies. Man-hour requirements for such work flows are related to physical characteristics of materials defined, e.g., man-hours/welding length and man-hours/length of electric-cable pulled. Work in control in a statistical sense, identifies such productivity indicators in terms of mean values and standard deviations. As statistics is the branch of mathematics that deals with variation, budgeting man-hours and scheduling in IHI shipyards is based on certainty, not a super work ethic peculiar to the Japanese people.

Thus, statistical methods are essential for high productivity. They in effect permit man-hour budgets and schedules to function as music scores. Without the latter, the principal operating manager, department managers, shop managers, foremen, and assistant foremen could not monitor and constantly make adjustments for the purpose of maintaining effective integration of hull construction, outfitting, and painting activities. One work flow pulling ahead or slipping behind would disrupt harmony just as a single musician being out of phase with other musicians when their conductor is trying to realize a composition.

LCDR Brucker's statement, "Fundamentally, zone-oriented construction consists of building the largest possible piece of the ship in a shop and then loading it into a slice of the ship (depicted in Figure 2)...." is not exactly consistent with the foregoing emphasis on integrated work flows. Fundamentally, the objective is to achieve the same goal with very efficiently operating, just-in-time, integrated work flows. This goal may require smaller hull units, even smaller than existing capacities in shipyards. Otherwise, some outfitting and painting work in the interior of a large hull unit could degenerate to the old-time system-by-system approach.

Idealization of integrated work flows is facilitated by many relatively small hull units. After maximum productivity is extracted from the idealized work flows, the units could be joined together to create grand units commensurate with heavy lift and/or transfer capacity just before the erection process. Between grand-unit joining and erection, a stage dedicated to additional outfitting and painting is often effective.

Once work flows are in control, statistical methods make available charts that describe how work processes are performing. In other words, the charts serve as barometers which accurately show the effects of various causes. The charts also distinguish between problems that are a consequence of management's manufacturing system and those which are caused by workers.

Per Dr. W. Edwards Deming, usually the system accounts for about 85% of the problems encountered. "When management reacts accordingly and workers find that they are not being blamed for things they can do nothing about, they are more apt to make suggestions. These, are spontaneous quality circles." In such environments, people grouped to match how work is organized, perform as defacto quality circles. When supplemented with worker training in simple problem-analysis techniques and constantly challenged with targets for small improvements, as in IHI shipyards, the fifth technology level is achievable.

Finally, the idea of competitive submarine builders sharing in the development of a build strategy is a paradox. A build strategy is a singular element of competition.

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[1] "Manufacturing Technologies in the 1980's: A Survey of Federal Programs & Practices", W.A. Hetzner, L.G. Tornatsky, National Science Foundation; and K.J. Klein, University of Texas; 3 September 1981.

[2] "Toward More Productive Naval Shipbuilding", Marine Board, National Research Council, National Academy Press, 1984.

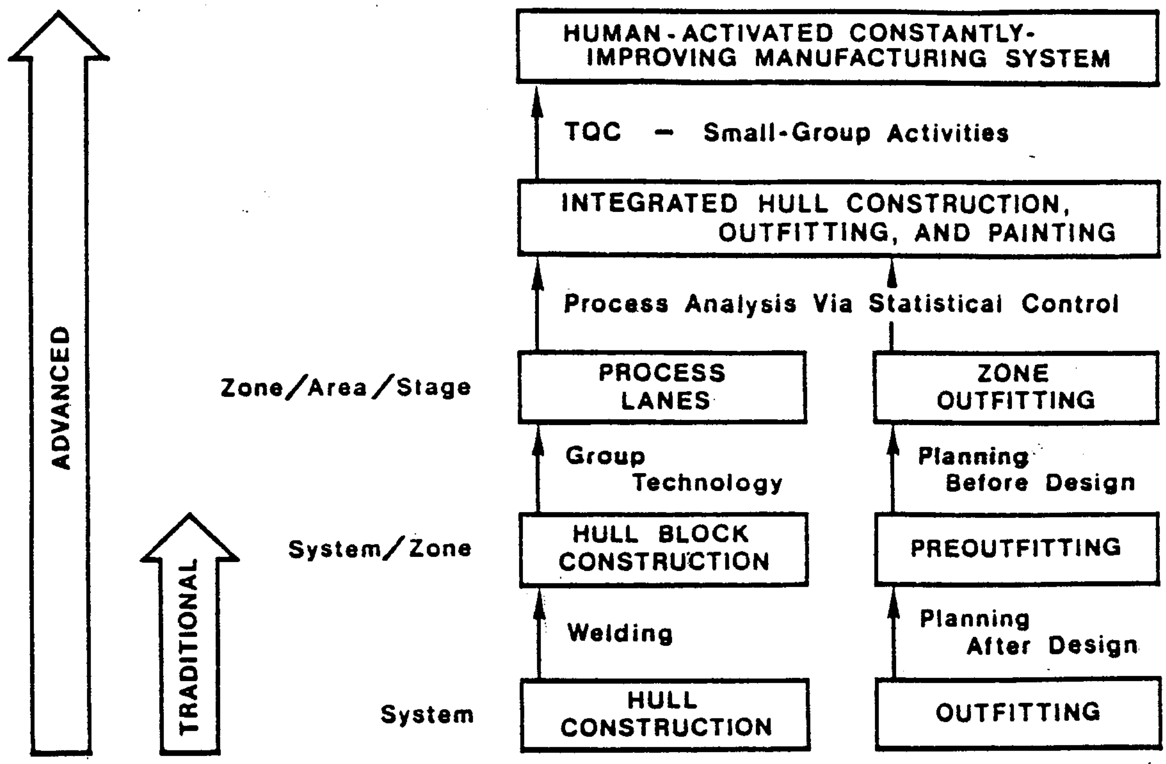


FIGURE 9: Identifiable Levels of Shipbuilding Technology Development. "Zone/area/stage" are product aspects. "Area" (problem area) designates the problems inherent in manufacture. Statistical control techniques provide the "barometers" which indicate how work processes are performing as needed for integrating inherently different kinds of work and as needed to identify problems. When such conditions exist, the worker groups that match the organization of work flows are likely to respond with suggestions for bit-by-bit improvements as a routine matter. This is the character of a constantly self-improving manufacturing system needed to achieve the fifth level of technology development.

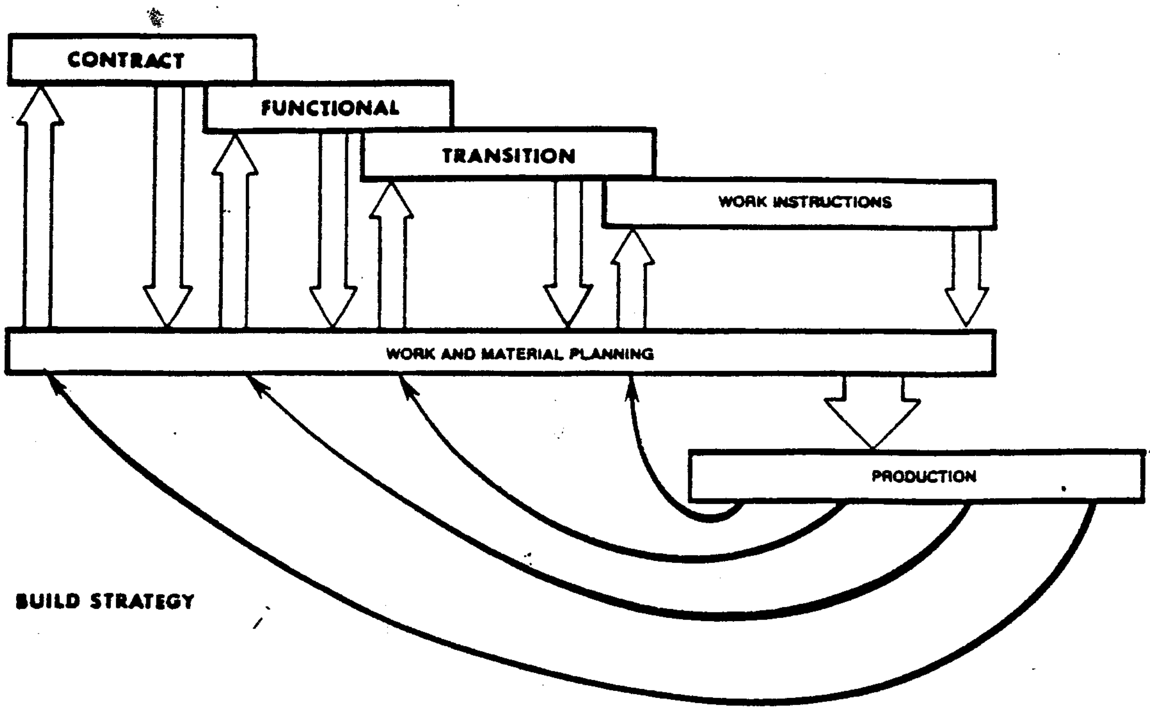
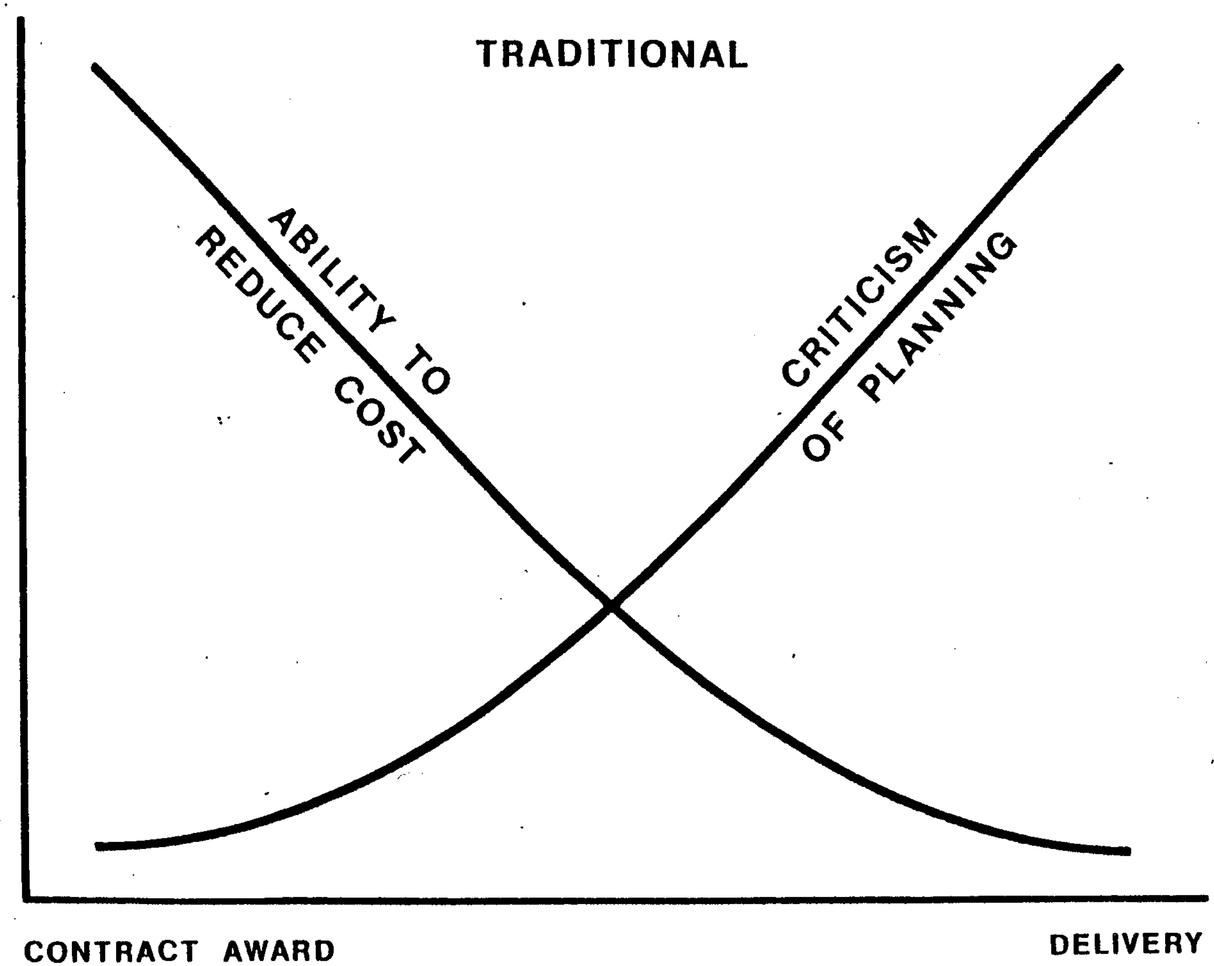
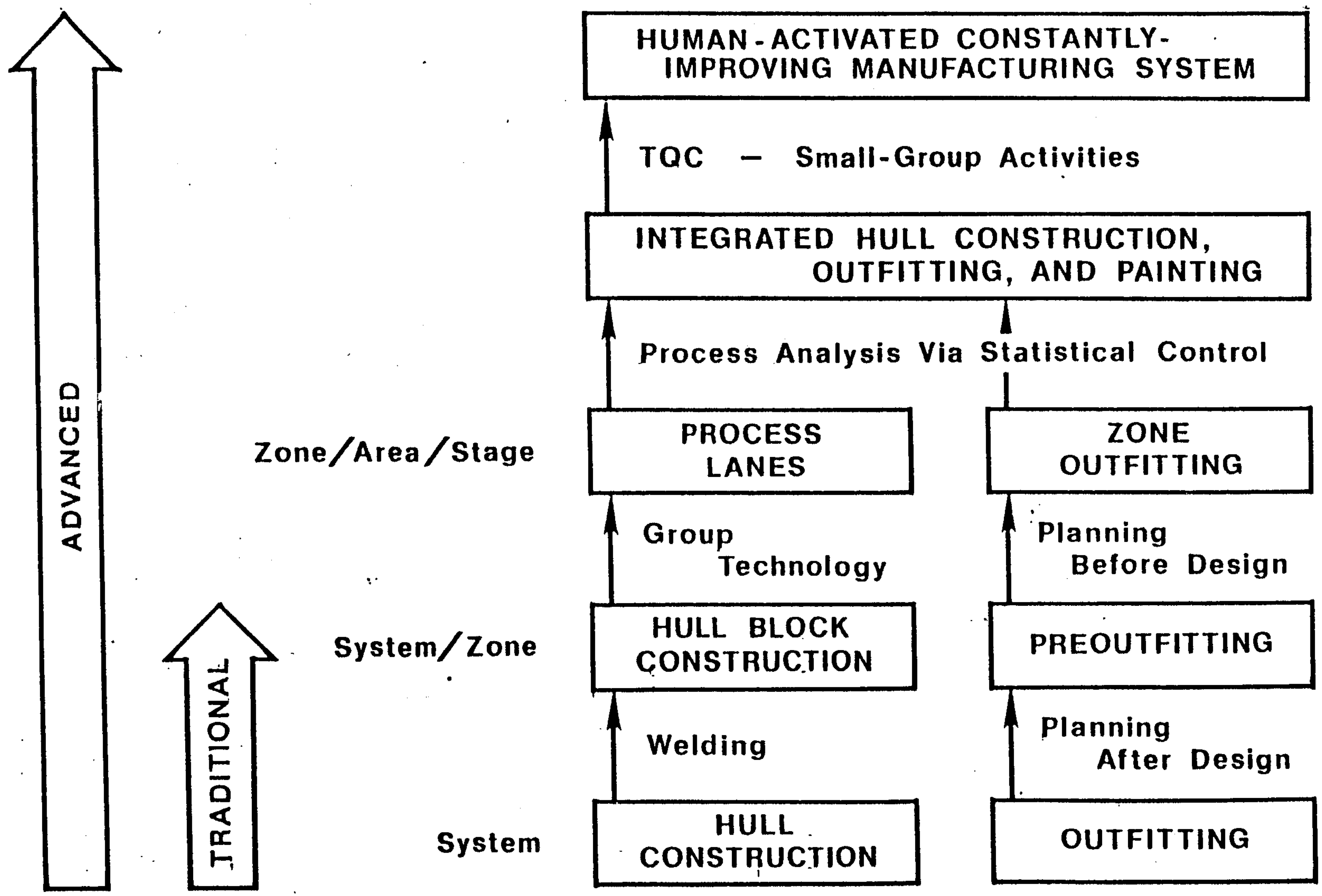
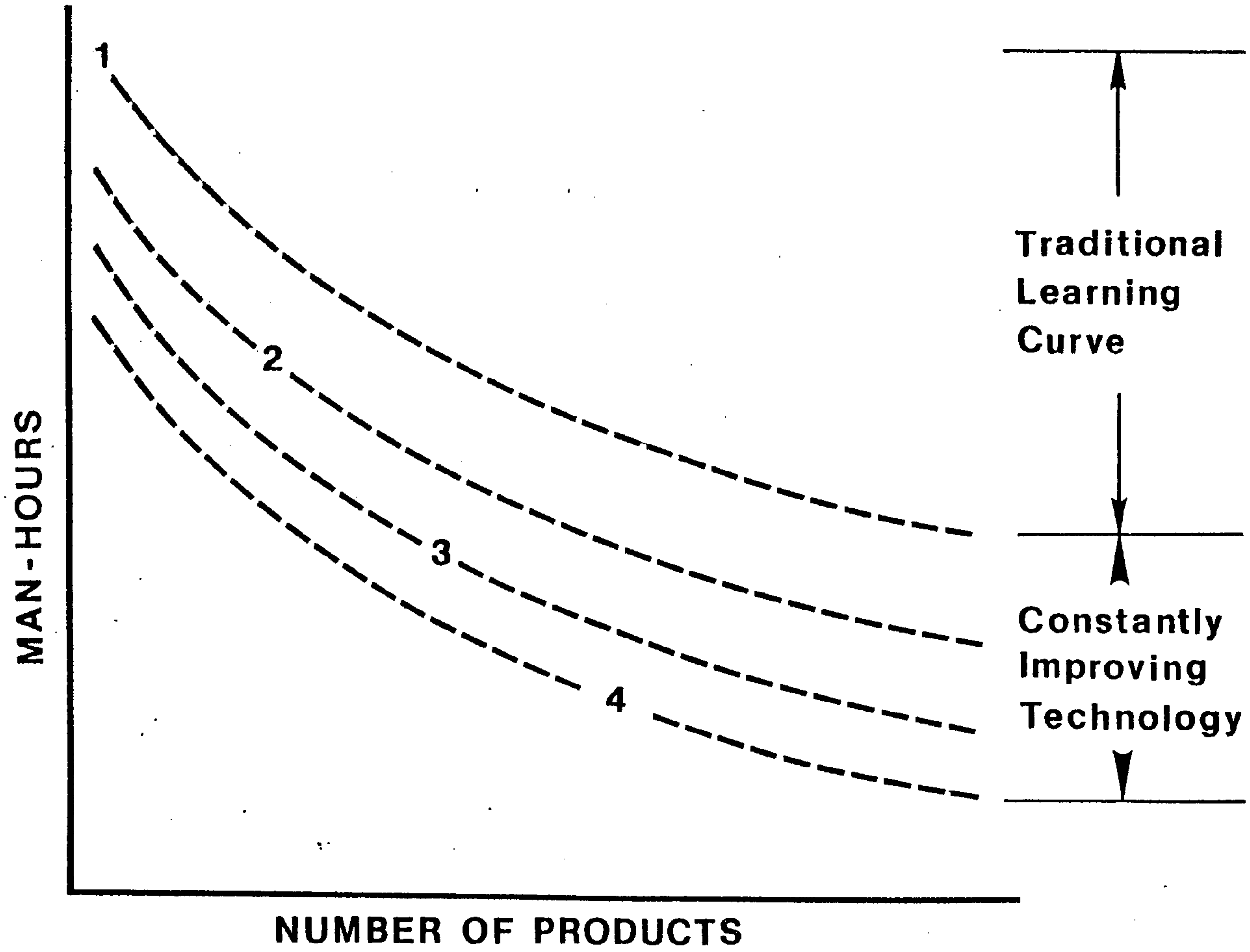
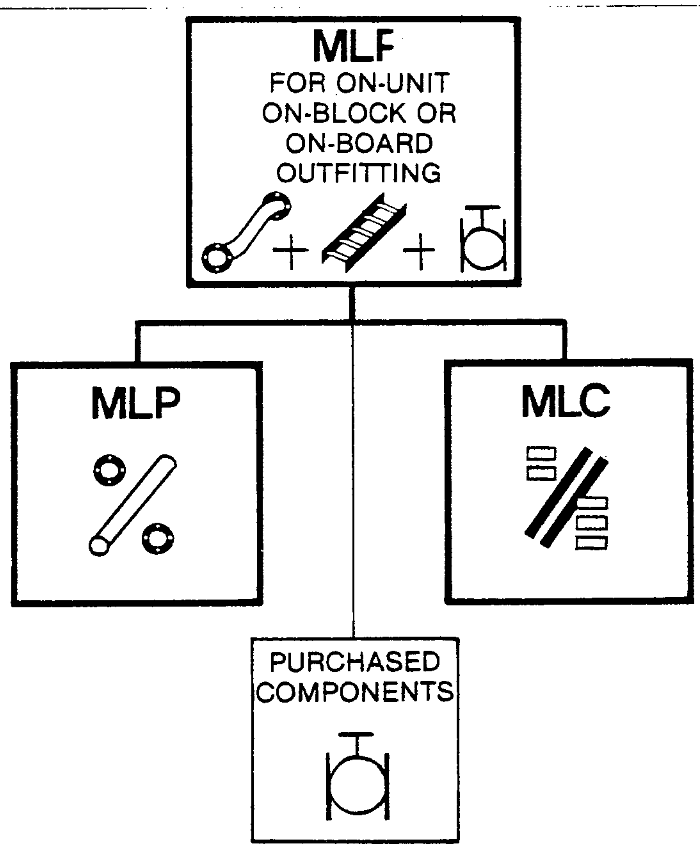


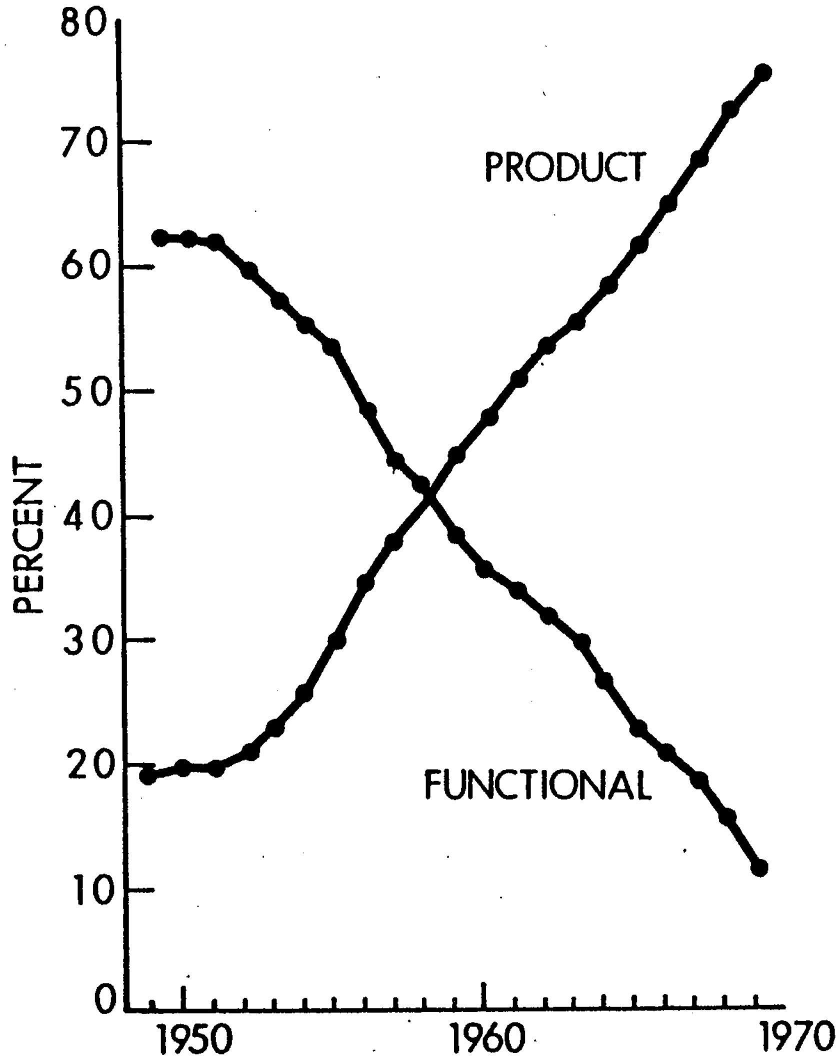
FIGURE 10: Production Guides How Information is Grouped in Each Design Phase. With just preliminary design input, production engineers document a build strategy which is included in the contract design being negotiated with the customer. As the various design phases make more information available, production engineers constantly refine the strategy until it becomes tactical in nature. Before the last design phase, production engineers provide specific work methods, requirements for reference marks, precautions, etc., that are to accompany sketches and material lists in work instructions.

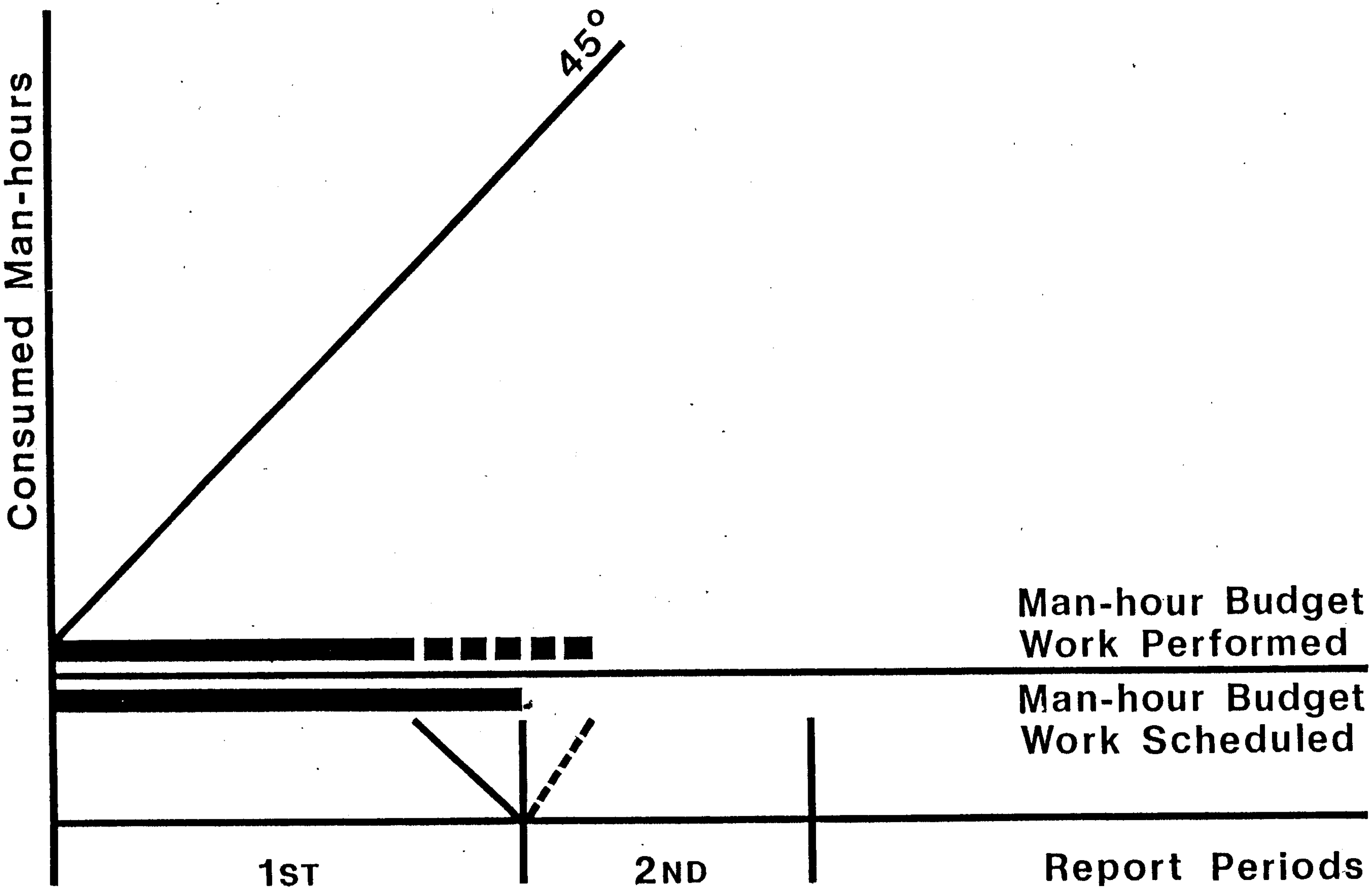

TRADITIONAL
ABILITY TO
REDUCE COST
CRITICISM
OF PLANNING
CONTRACT AWARD
DELIVERY


HUMAN-ACTIVATED CONSTANTLY-IMPROVING MANUFACTURING SYSTEM
TQC — Small-Group Activities
INTEGRATED HULL CONSTRUCTION, OUTFITTING, AND PAINTING
Process Analysis Via Statistical Control
Zone/Area/Stage
PROCESS LANES
ZONE OUTFITTING
Group Technology
Planning Before Design
System/Zone
HULL BLOCK CONSTRUCTION
PREOUTFITTING
Welding
Planning After Design
System
HULL CONSTRUCTION
OUTFITTING
ADVANCED
TRADITIONAL


MAN-HOURS
NUMBER OF PRODUCTS
1
2
3
4
Traditional Learning Curve
Constantly Improving Technology


MLF
FOR ON-UNIT
ON-BLOCK OR
ON-BOARD
OUTFITTING
MLP
MLC
PURCHASED
COMPONENTS


PERCENT
80
70
60
50
40
30
20
10
0
1950
1960
1970
PRODUCT
FUNCTIONAL


Consumed Man-hours
45°
Man-hour Budget
Work Performed
Man-hour Budget
Work Scheduled
1ST
2ND
Report Periods

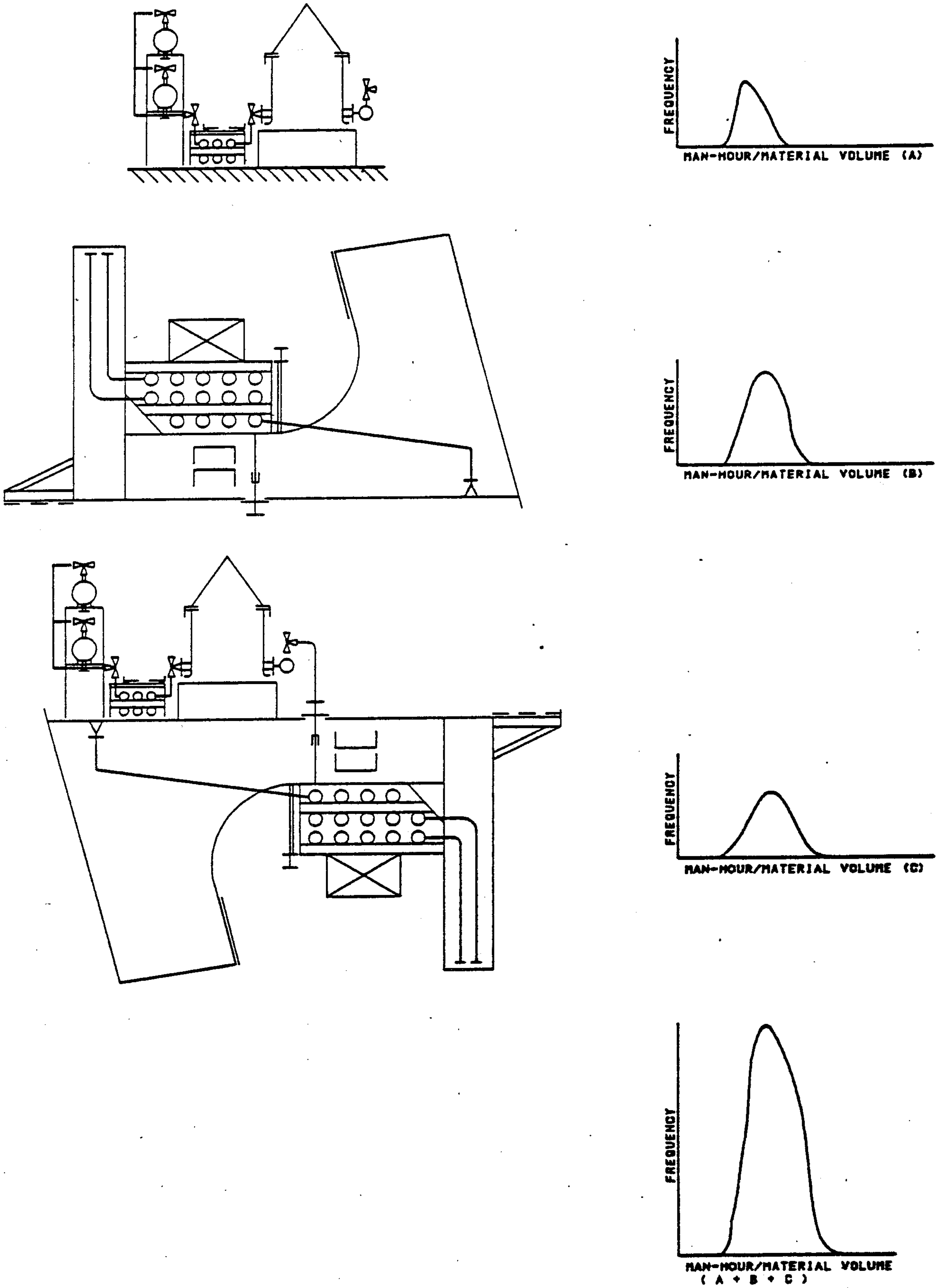
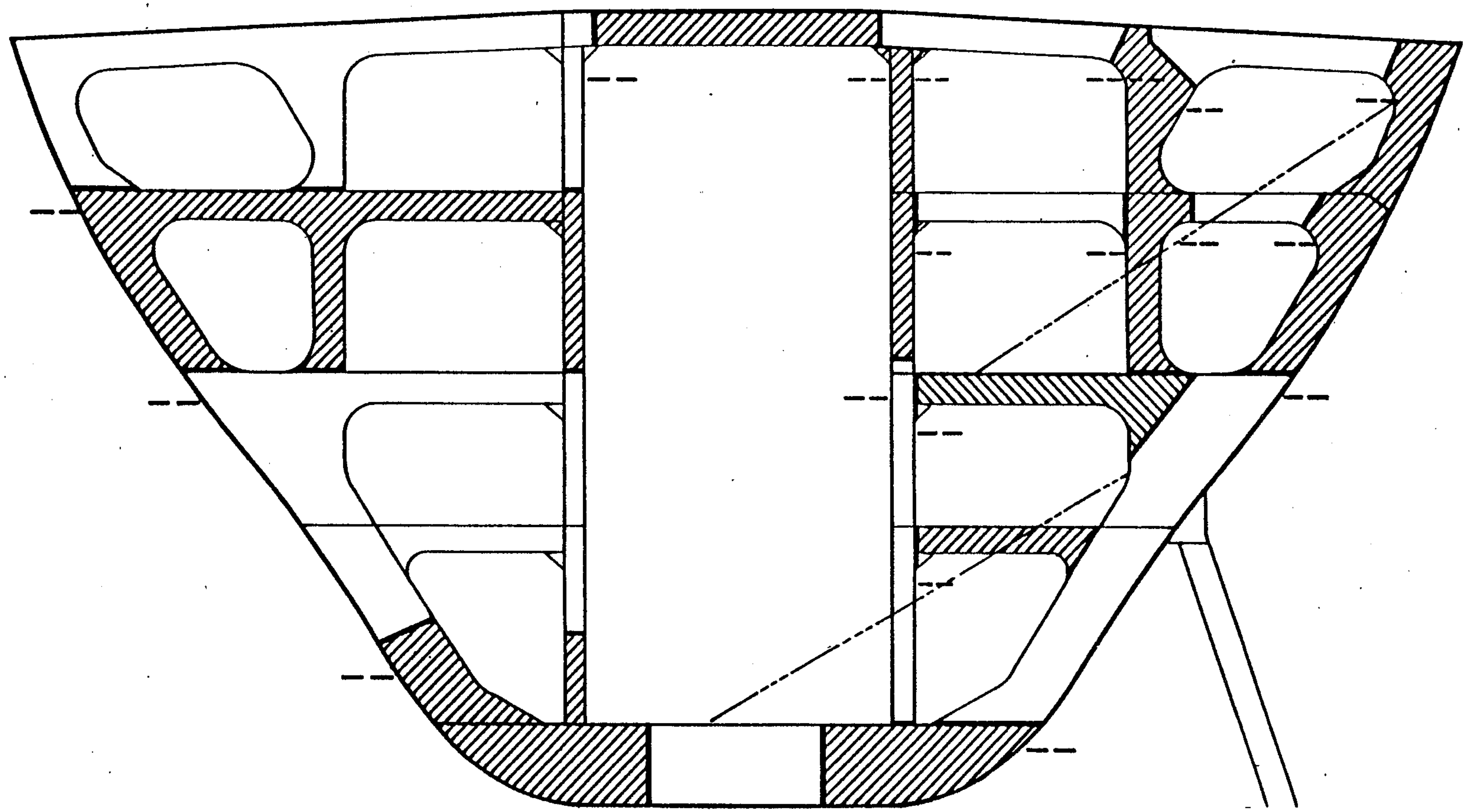
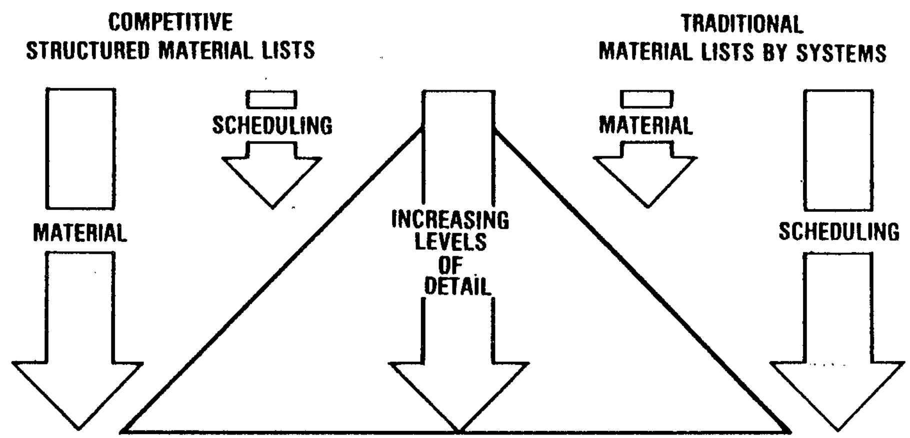


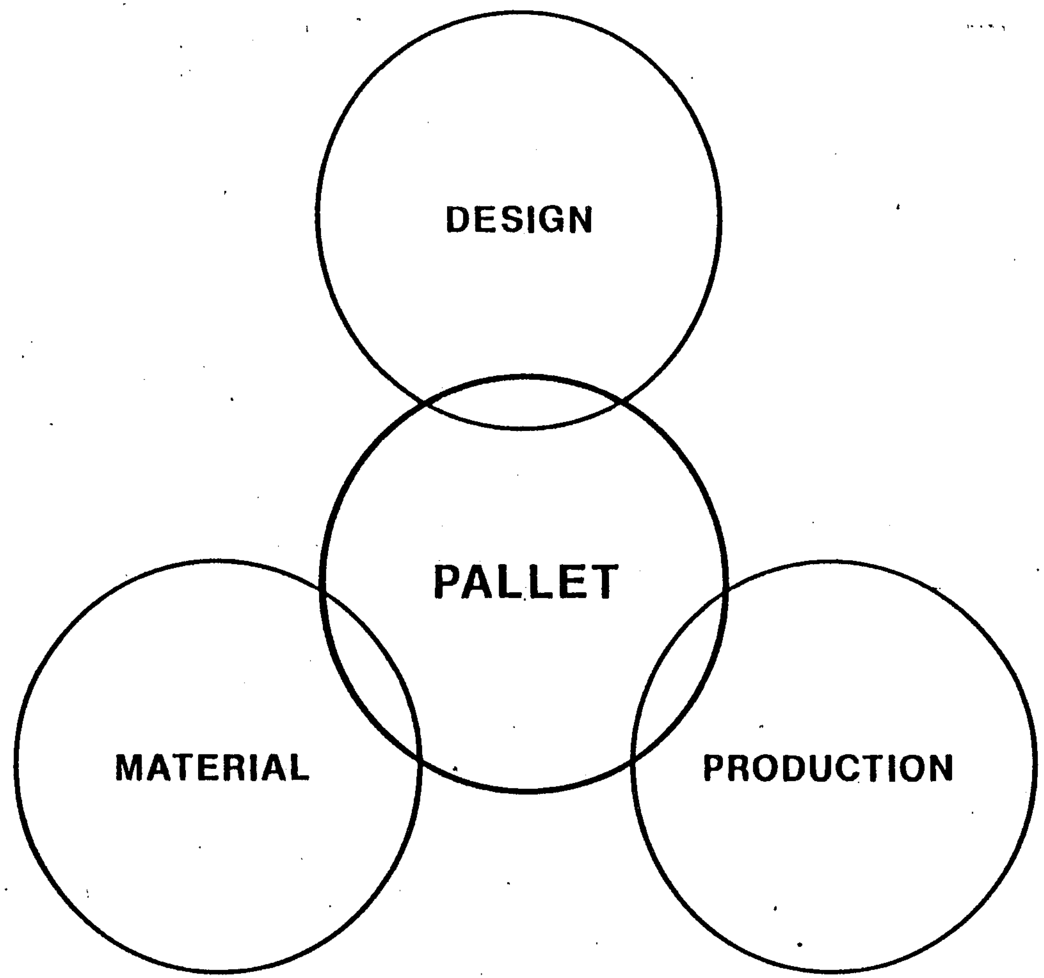
Figure Deferences of Outfitting Productivity Indices by Group Technology

Graphs show distribution of man-hour/material volume which indicate only defrence between conventional and advenced ways.

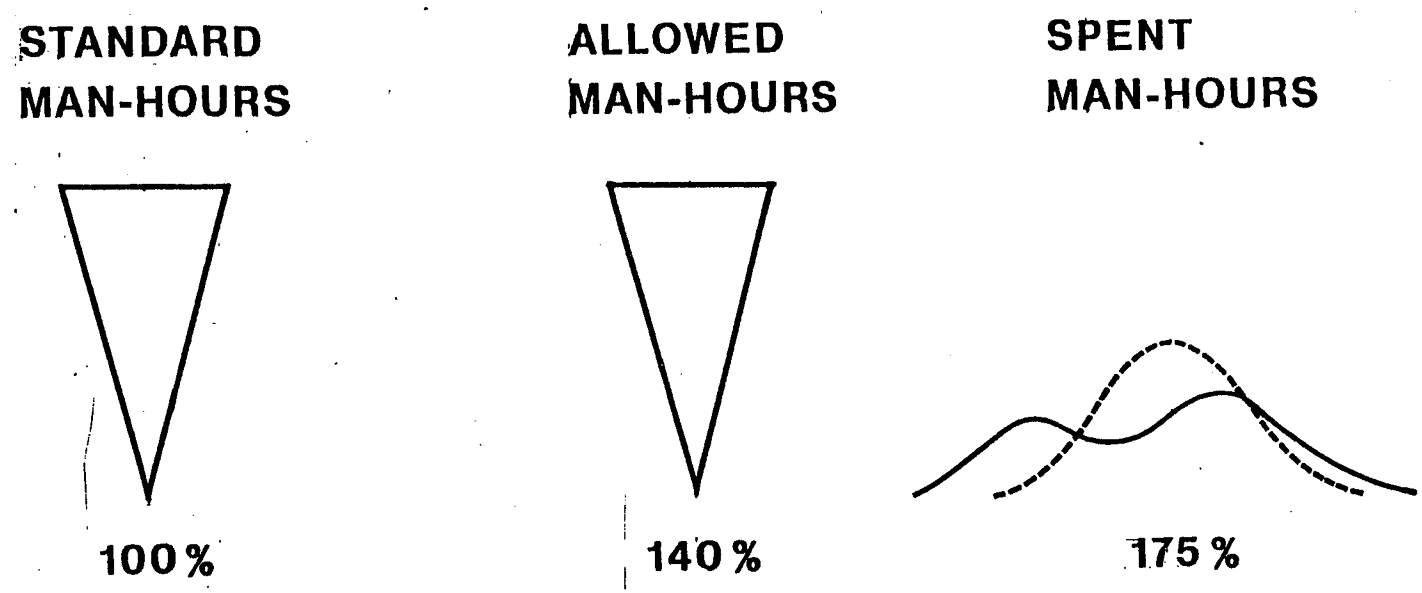




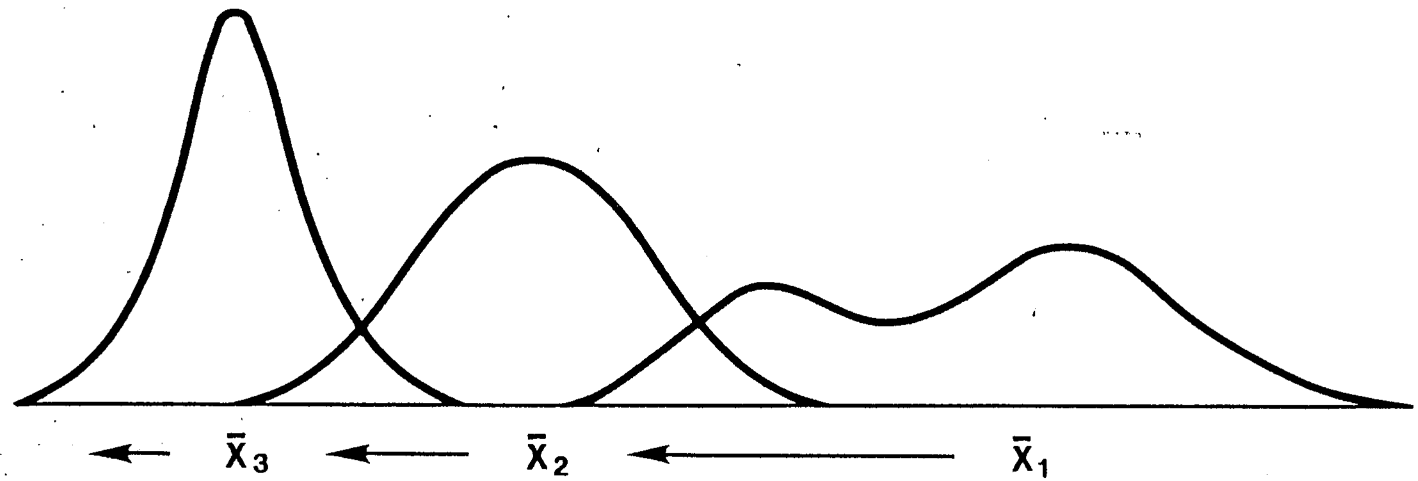
COMPETITIVE
STRUCTURED MATERIAL LISTS
TRADITIONAL
MATERIAL LISTS BY SYSTEMS
SCHEDULING
MATERIAL
INCREASING LEVELS OF DETAIL
MATERIAL
SCHEDULING



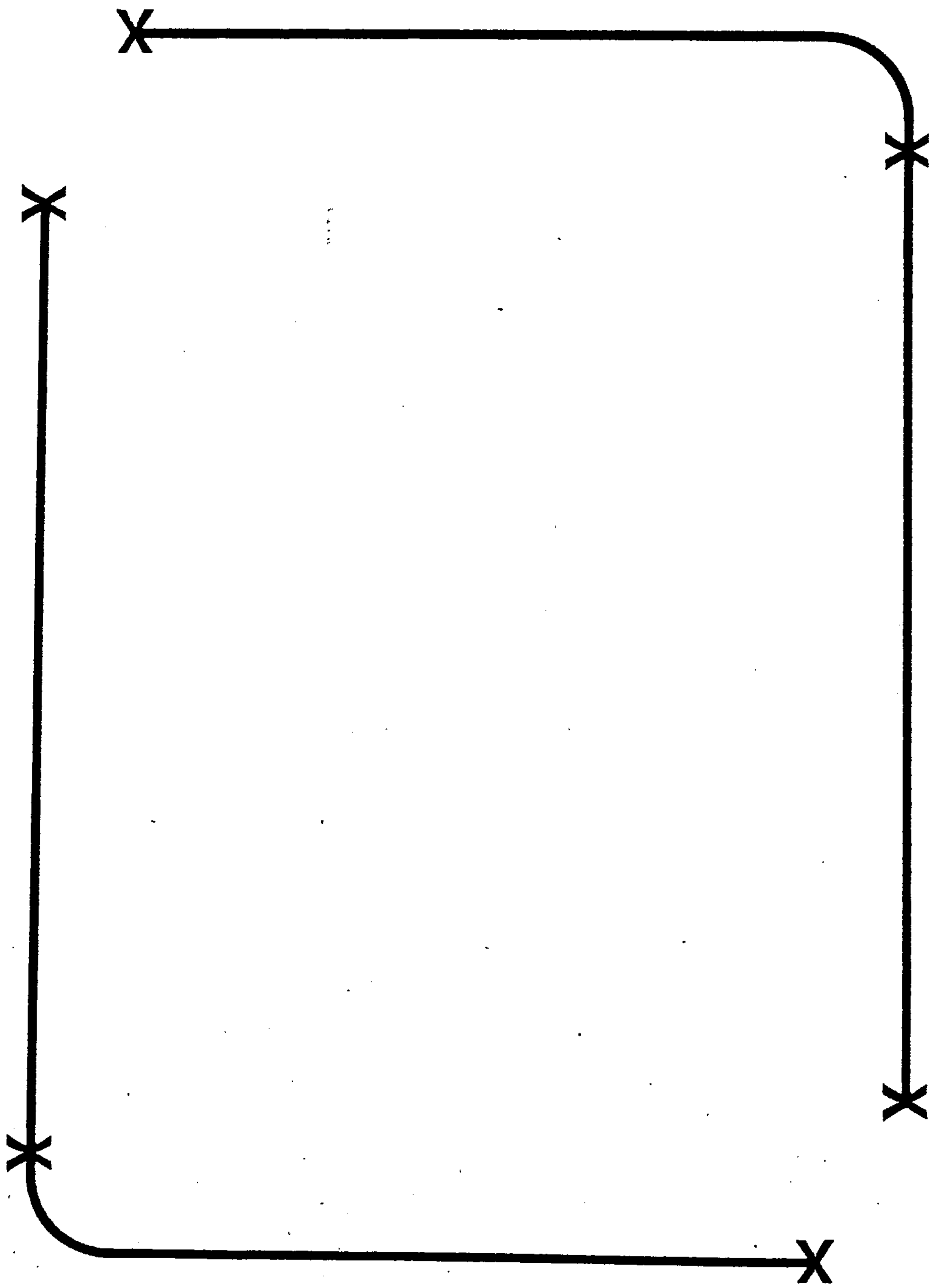
PALLET = ZONE/STAGE = MLF = WORK PACKAGE

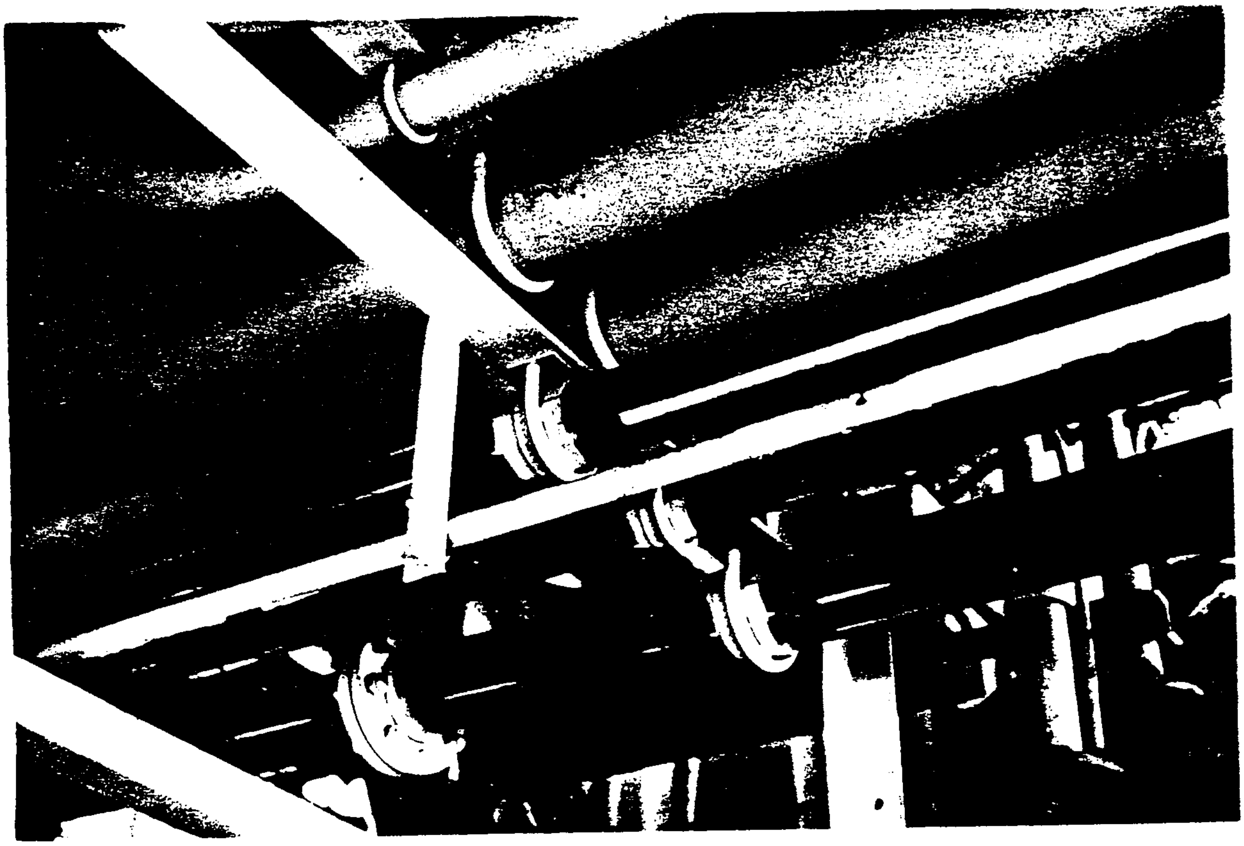


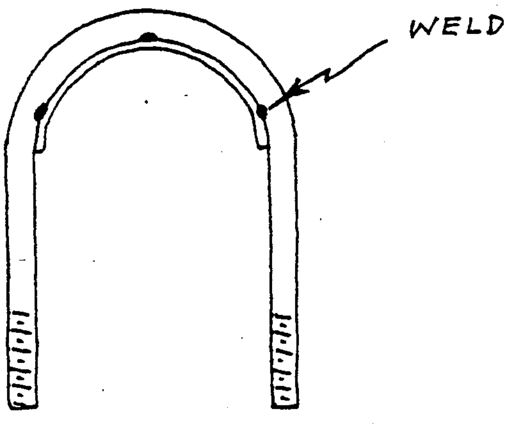
STANDARD
MAN-HOURS
100 %
ALLOWED
MAN-HOURS
140 %
SPENT
MAN-HOURS
175 %

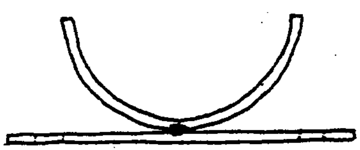


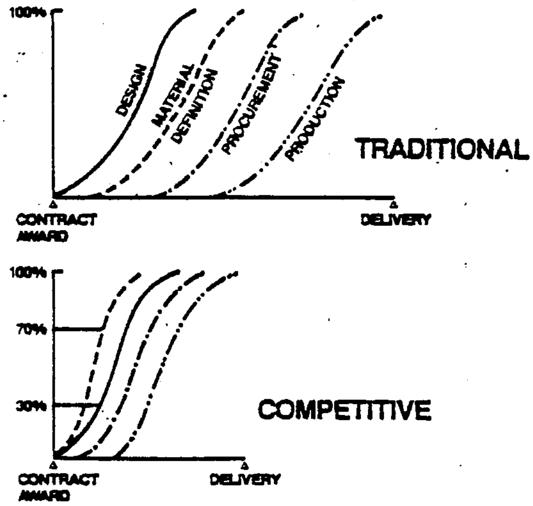
Work in accordance with a product work breakdown structure is susceptible to control by "... eliminating special causes one by one on statistical signal leaving only the random variation of a stable process."






WELD





A Presentation to the
IREAPS* Technical Symposium
15 September 1981
Baltimore, Maryland

by

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National Shipbuilding Research Program
and
Chairman, SNAME** Panel SP-2

*Institute for Research and Engineering for Automation and Productivity in Shipbuilding

**The Society of Naval Architects and Marine Engineers

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
One World Trade Center, Suite 1369, New York, N.Y. 10048
Paper presented at International Maritime Innovation Symposium, Waldorf Astoria Hotel, New York, September 27-28, 1984

Interim Products - An Essential Innovation In Shipyards

No. 25

Louis D. Chirillo, Member, L.D. Chirillo Associates, Bellevue, Wash.

ABSTRACT

Ships of the same kind built in series are not a panacea for lagging productivity. The solution is more fundamental and imaginative. The solution involves a rethink of an entire shipbuilding system. The world's most productive shipbuilders employ "standard" series interim products made possible by a production system that classifies parts, subassemblies and assemblies by the problems inherent in their manufacture. The result is highly rationalized design modules and highly organized work. Such interim products are flexible enough to be parts of many sizes and types of ships. Runs of such interim products, not ships is the key!

Research managed and cost shared by the Los Angeles Division of Todd Pacific Shipyards Corporation for the Maritime Administration created National Shipbuilding Research Program has motivated the current revolution in U.S. shipbuilding methods even for building warships. Guidance was provided by Panel SP-2 of the Ship Production Committee of the Society of Naval Architects and Marine Engineers.

INTRODUCTION

During 1983, the U.S. shipbuilding industry entered the most peculiar era of its entire history. Numerous orders for American-flag ships were issued; all were placed overseas. But for the construction and conversion of ships for the Reagan administration's naval expansion, the industry would be virtually extinct. Yet, at the same time U.S. shipbuilders demonstrated increasing command of the world's most effective shipbuilding methods and provided implementation experience which encouraged their adoption in the United Kingdom and Canada.

The revolution in shipbuilding methods has come to the attention of Congress while, paradoxically, some reputable people of the industry express beliefs that do not acknowledge the impact of the beneficial changes that are well and irreversibly underway. Quotations of some such beliefs are noted and evidence of their untimeliness, disclosed by end products of the National Shipbuilding Research Program, are presented.

"There are appreciable differences between U.S. and foreign ships....U.S. ship designs call for more material and more intricate work ---- partly because of domestic regulatory requirements and partly because of U.S. preferences and practices." [1]

Abandonment of their domestic shipbuilding industry by U.S. owners in 1983, because of temporary build-abroad authority without forfeiture of operating subsidies, and ready acceptance of such orders by the Japanese and Koreans, ought to finally dispel the notion that U.S. regulatory requirements and traditional preferences are a significant deterrent to any shipbuilder. The files of the American Bureau of Shipping (ABS) confirm that U.S. regulatory requirements have been imposed in the Far East long before such construction and have caused no particular problems.

In Japan special concern for U.S. Coast Guard requirements, now mostly administered by ABS, is limited mainly to life-saving and electrical systems. At most they would account for a cost increase of $1-to $1½-million for a typical merchant ship. Delivery of two American-flag 45,000-dwt bulk-carriers by a Japanese shipyard late in 1983 for about $30 million per ship addresses the substantially greater differential that attracted the owner, Ogden Marine. The same ships, if built in a traditional U.S. shipyard would have cost about $70 million each and would have required nearly twice the time between contract award and delivery. Many now concede that a large part of the $40 million difference and elapsed-time saved are due to scientific management methods which also reduced the man-hours required by the Japanese shipbuilder to one-third of those needed by traditionalists.

STATISTICAL CONTROL

Among the methods, statistical control of manufacturing provides a unique advantage which U.S. shipbuilders do not now possess but are beginning to understand. When statistical evidence of quality exists, as in some shipyards in Japan, regulators have justification to, and usually do, perform less inspection. [2]

Statistical control is most effective in shipbuilding when applied to regulate accuracy during hull construction. The work processes mostly employed, gas cutting, welding and distortion removal, cause steel shrinkages due to the application of heat. Therefore, no matter how precise people try to be during a specific work process, variations from specified dimensions are always measurable and normal. For shipbuilders, accuracy exists only in terms of normally achieved ranges.

If the distribution of such variations for a specific work process is Gaussian, i.e., normal per a bell-shaped curve, the process is said to be under control. The work is being repeated in the same way. No machine or worker is behaving erratically. When work is so controlled, and verified daily by nominal random sampling, the normal distribution of a work stage can, in accordance with the Theorem of Variance, be added to that for a second work stage in order to predict the distribution for a third work stage.

As applied by Ishikawajima-Harima Heavy Industries, Co., Ltd. (IHI) of Japan, all work stages preceding hull erection are addressed in rather complex variation-merging equations which are based on ship-design details and planned work sequences. Thus, with statistical evidence of how work stages normally perform, production engineers routinely predict the percentage of erection butts and seams that will be ideal for welding as well as the percentages that will require rework by gas cutting and by backstrip welding.

If, for a ship not built before, at least 70% satisfactory butts and seams are not predicted, design details will be modified, work sequences will be changed and, if necessary, improved work processes will be devised before fabrication work starts. In contrast, traditional shipbuilders employ margins, i.e., an extra amount of material nearly everywhere. Margins are commitments to rework.

The disciplines for producing statistical evidence are particularly credited by Japanese shipbuilders for tremendous improvements in productivity. Seventeen years ago they reported in English that statistical control of manufacturing "epoch makingly" improved the quality of hull construction, laid the foundation of modern ship-construction methods and made it possible to extensively develop automated and specialized welding. [3] Regrettably, U.S. shipbuilders and academia did not catch on then but are now making up for lost time. Statistical control for shipbuilding and related disciplines are now part of regular courses at the Universities of Michigan and Washington. The technique has recently started in a few U.S. shipyards even for the construction of submarines and aircraft carriers.

"Some U.S. labor, social, safety and ecological statutes, requirements and standards have adverse effects on production and work efficiency...." [1]

Much of labor, social, safety, and ecological demands are a reflection of how work is traditionally organized. Also, they depend on the extent of available knowledge about how work processes are performing. Surely, both are managerial responsibilities.

Labor has to adjust to changing technology. The rates at which such adjustments occur depend on many factors. But, the change processes will not start unless there are management initiatives to significantly improve their manufacturing systems. In shipbuilding, and elsewhere, adjustments in trade cognizances are not apt to become routine until managers create manufacturing systems with built-in methods for constant self-improvement. Such methods, American in origin and routinely applied by shipbuilders in Japan, require employment of a product work breakdown structure to facilitate statistical control of manufacturing operations. [4]

With such techniques, long advocated by American statisticians, detailed knowledge of how work processes perform is made available to everyone concerned. Workers, just as much as they have been trained to mark, cut, fit or weld, are trained to read statistical charts. Such charts clearly separate problems caused by management's manufacturing system from those for which there are probably findable causes of a different nature, e.g., an erratic performing machine or worker. [5]

REAL QUALITY CIRCLES

When managers respond accordingly and workers find that they are not being blamed for problems they can do nothing about, human nature, not a cultural characteristic, causes a positive response. Thus in Japan, where very effective shipbuilding systems exist, where labor is supposed to have a work ethic that would justify envy by traditional managers, the fundamental element is, instead, the knowledge produced by statistical analyses. That knowledge, far greater than that employed by shipbuilding traditionalists, is a tremendous competitive edge.

In Japan, statistically derived knowledge caused a natural evolution of real quality circles, i.e., those having an analytical basis. However, to fully exploit everyone's wish to work smarter not harder, Japanese managers took the next logical step. They trained workers in analysis techniques such as the use of Pareto and Ishikawa (cause and effect) diagrams. Thus, there is routine exploitation of workers' mental capacities for constantly improving work processes.

Managers in Japan worked hard to create this juggernaut of scientifically derived constant self-improvement. They are frustrated when managers who cannot match their low man-hour expenditures for equivalent work, refer to the mythical certain something of Japanese society which produces better workers. One industrialist so frustrated noted that traditional managers in the West believe that, "If Russian military might and Japanese industrial might did not exist, the world would be paradise." [6]

Ecological and safety impositions are not sufficient to justify the wide disparity between shipbuilding man-hours required in the U.S. relative to those required in certain Japanese shipyards for the same work accomplished. One observer reporting on the plight of U.S. industry in general noted, "Safety regulations also add some costs to operations but the reduction in accidents has meant savings in time and expense that go far to offset these extra costs. Overall capital expenditures on pollution control and safety combined have never exceeded 6 percent of industrial investment, and can be blamed for at most a tenth of the slowdown in productivity." [7]

Knowledgeable people are well aware that in the most effective Japanese shipyards, workers and supervisors are trained to routinely implement safety and health measures just as they are trained for work. There is less dependence on staffs which are removed from immediate production responsibilities.

Such observers are also aware of the greater safety investments made by Japanese shipbuilding firms. The most manifest were investments in unique work units which, at first glance, are like Roman siege machines. They were conceived because managers observed that when erecting very-large crude-carriers (VLCC), many workers "were using one hand for themselves" and when erecting ultra-large-crude carriers (ULCC), "both hands for themselves." Work units featuring built-in walkways and substantial handrails were a means of overcoming natural fear of high places.

But the most important contribution to both safety and ecology in Japanese shipbuilding is perfection of integrated hull construction, outfitting and painting. Much work is performed indoors on idealized process lanes where effects on safety and environment are better controlled. Outfit units for machinery spaces are assembled complete with walkways and handrails so that no scaffolding planks are required when the units are landed on hull blocks or on board. Fitting and painting on ceilings are always performed when blocks are upside down so that people work downhand and to eliminate staging requirements as much as possible. Work packages for on-block and on-board outfitting are scheduled, i.e., controlled, zone by stage so that no two work teams are competing for access to work in the same place at the same time. As a consequence, productivity is significantly enhanced along with safety and ecology. [8] However, there is another misconception that is far more harmful to shipbuilding technology development in the U.S.

<u>"Japanese shipbuilders, who have long dominated the world market...have been able to decrease costs and increase productivity considerably through series construction on 'runs of ships' of identical or near identical design."</u> [1]

The author of this quotation advocates such production runs as a panacea for the U.S. shipbuilding industry. Learning curves reflecting lower costs are manifest. What is not stated is that the curves are also manifest to shipbuilders abroad. For example, a Freedom class ship is produced in Japan with about one half of the man-hours required for a comparable SD-14 built in the U.K. Thus, even with a standard ship the British are not competitive in the world market and traditional U.S. shipbuilders would be even less competitive. However, the specter of China, already with enough modern facilities and already delivering acceptable ships to European

SHIPS DELIVERED BY ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD. IN 1982

(ZOSEN, Tokyo News Service, Ltd., April 1983)

	Ship Type	DWT	Engine Type	HP
Tokyo Shipyard				
Poros Shipping Co. (Greece)	O-BC	23,071	IHI Pielstick	7,800
Blue Venus Co. S.A. (Panama)	C	21,821	"	8,000
Aioi Shipyard				
Iino Kaiun K.K. (Japan)	BC	64,471	IHI Sulzer	14,000
Trophy Company (Panama)	"	67,485	"	13,680
Termar Navigation Co. (Liberia)	"	36,800	"	12,000
South African Marine Corp. (South Africa)	Cont.	34,098	"	21,600
Way Yuen Shipping Inc. (Panama)	C	37,840	"	11,100
Neptune Epsilon Lines Pte. Ltd. (Singapore)	BC	37,659	IHI Pielstick	7,800
Ratnakar Shipping Co. (India)	T	60,725	IHI Sulzer	14,700
Kure Shipyard				
A.P. Moeller (Denmark)	PC	47,803	IHI Sulzer	14,400
Industrial Freighters Corp. (Panama)	BC	63,886	"	14,400
Japan Line, Nisshin Kisen, Hiroumi Kisen (Japan)	"	85,352	IHI Pielstick	12,000
Mobile Tankers Ltd. (Australia)	T	149,235	IHI Sulzer	23,800
A.P. Moeller (Denmark)	PC	39,336	Mitsui B&W	13,100
Ras. Van Ommeren (France)	"	29,900	IHI Sulzer	11,100
Kuwait Oil Tanker Co., S.A.K. (Kuwait)	T	294,739	"	34,000

Legend:

O-BC	Ore and Bulk Carrier	Cont.	Containership
C	Cargoship	T	Tanker
BC	Bulk Carrrier	PC	Product Carrier

FIGURE I: One firm in one year delivered 16 ships, no two identical, to 15 owners in 11 countries. The ships feature 3 types of main-propulsion diesels in various sizes. Even the two product carriers (PC) delivered to the same owner, A.P. Moeller, are of different sizes and have different main engines. Such response to whatever the market demands is evidence of sophisticated flexible-system production.

owners, means that no other nation's shipbuilding industry, including Japan's, can afford to link its security to high-volume standardized production. The need to shift to flexible-system production is imperative for U.S. shipbuilding as it is for many other U.S. industries. [7]

FLEXIBLE MANUFACTURING

Evidence that Japanese shipbuilders employ fairly sophisticated flexible-system production is contained in Figure I which shows that in 1982 one firm, Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI), delivered 16 ships, no two identical, to 15 owners in 11 countries. Moreover, the ships feature 3 types of main-propulsion diesels in various sizes. Simultaneously, the same manufacturing system was producing a polyethylene plant for installation in South America and complex warships.

The essence of such flexible-system production is not computerization nor is it robotics. Instead, it is an organized work force skilled in problem solving as well as in industrial processes as needed to produce whatever the world market requires. Unlike the where-with-all for high-volume standardized production, a work force qualified in flexible system production cannot be bought by a Third World country. Thus, the U.S. shipbuilding industry's survival is dependent upon tapping large numbers of educated people and organizing them for flexible-system production. While the literacy rate in Japan is higher, the U.S. has more educated people available due to greater population. Their abilities to understand a product work breakdown structure, statistical control of manufacturing and related disciplines are essential. [9]

"This approach (runs of ships of identical or near identical design) allows the shipyard to fit design details to its specialized capabilities and to control design, industrial engineering, and material procurement in a manner that will contribute to more efficient construction." [1]

U.S. shipbuilders surrendered effective control of design when they acquiesced to owner practice to engage independent design firms for contract design. [10] As practiced in Japan, contract design is part of the shipbuilding process. It depends on a building strategy prepared and documented by educated production engineers for any type ship to be built in any quantities especially including one ship of a kind.

Anticipating a particular shipbuilding opportunity, production engineers are able to devise and describe, on documents just as formal as those produced by designers, a building strategy in time for it to be incorporated in contract drawings. The subsequent design and production engineering efforts are implemented in coordinated phases so as the design develops, greater details of the building strategy are documented for the benefit of designers before they start each phase.

ZONE-ORIENTED DESIGN

Further, the process includes a transition phase wherein design information is regrouped so as to be organized by zones. The end products are zone-oriented work instructions, each with its own material list, for needed interim products, i.e., parts, subassemblies and assemblies. What is especially remarkable is that the work instructions are produced and material is defined in the same sequence that they are required for material marshalling and production. Also, there are no time consuming and expensive system-arrangement drawings. [11]

All prerequisites are fullfilled for zone outfitting which is in itself required for integrated hull construction, outfitting and painting. There is no need for a separate planning effort after detail design, characterized by planners obtaining bits of information from various system drawings in order to devise work packages for archaic preoutfitting.

The interim products, both for hull construction and outfitting, are carefully contrived through production engineering/design interaction so that the manufacture of most can be classified as problems for which solutions already exist, e.g., work stages organized into work-flow lanes having sufficient worker skills and facilities. Regardless of differences in the designs of interim products, if the problem category remains unchanged and the work required for each is about the same, all conditions exist for production-line manufacture just as Lee Iacocca assembles automobiles. Yet, there are no specialized facilities dedicated to design details.

CONCLUSION

Such process flows are already operating in, or being planned for, U.S. and U.K. shipyards in direct response to NSRP disclosures. [12][13] The flows are controlled and coordinated by schedules so that with nominal buffer capacities, subordinate flows for parts and subassembles support a major flow such as organized for assembling blocks of a particular problem category, e.g., separately for flat blocks, curved blocks, superstructure blocks, etc. Thus, without yielding design flexibility, IHI shipbuilders are able to produce different ships in varying quantities, including one of a kind, and at the same time, they produce learning curves normally associated only with "runs of identical or near identical ships." Their curves, however, are in far greater detail because they exist as sets of productivity curves for each flow lane.

U.S. shipbuilders can no longer dwell on excuses such as those quoted. There are no alternatives. They have to address some difficult problems in order to manage transitions. In short, information, people and work have to be organized differently. [10] "Flexible-system production is rooted in discovering and solving new problems; high volume, standardized production basically involves routinizing the solutions to old problems. Flexible-system production requires an organization designed for change and adaptability; high volume, standardized production requires an organization geared to stability." [7]

"Runs of ships of identical or near identical design" do not do enough for developing shipbuilding technology. Runs of interim products, not ships, is the key! The world's most productive shipbuilders are experts in contriving and manufacturing interim-products regardless of what they are building, ships of any type and size, chemical plants, offshore platforms, or whatever. [14]

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3. "Technical Progress in Shipbuilding and Marine Engineering," The Japanese Society of Naval Architecture, 1967.

4. "Product Work Breakdown Structure," NSRP, Revised December 1982.

5. The American statisticians most credited are W. Edwards Deming and J.M. Juran. According to the experiences of both in many industries, about 85% of the problems identified are due to systems controlled by management. Also, see: W. Edwards Deming, Quality, Productivity, and Competitive Position, M.I.T.Center for Advanced Engineering Study, Cambridge, MA, 1982.

6. Etsuro Tani, "Quality Through Knowledge and Effort," Quality Control for the Foreman (FQC), Japan Union of Scientists and Engineers, Tokyo, January 1983 (Japanese language).

7. Robert B. Reich, "The Next American Frontier," The Atlantic Monthly, March 1983.

8. In 1980 there were only 649 lost-time accidents in Japan's shipbuilding industry consisting of 130,000 people working about 278-million hours. Zosen, March 1981.

9. "Line Heating," NSRP, November 1982 and "Pipe Piece Family Manufacturing," NSRP, March 1982.

10. Louis D. Chirillo, "Scientific Shipbuilding - The Challenge," STAR Symposium Proceedings, SNAME, 1984.

11. "Integrated Hull Construction, Outfitting and Painting," NSRP, May 1983 and "Design for Zone Outfitting," NSRP, September 1983.

12. As of January 1984, consultants provided by IHI Marine Technology, Inc. were active in five U.S. shipyards. In October 1983 Avondale Shipyards, Inc., delivered Exxon Charleston, a 42,000-dwt complex products carrier, which is the first ship built in North America in accordance with flexible-manufacturing methods adapted from the IHI shipbuilding system. Although actual production man-hours are confidential, their reduction compared to discarded traditional methods must be at least 30%.

13. Roger Vaughan, "Productivity in Shipbuilding," North-East Coast Institution of Engineers and Shipbuilders, U.K., 12 December 1983.

14. In January 1984, Avondale Shipyards, Inc. was planning to apply the techniques used for integrated hull construction, outfitting and painting of Exxon Charleston (Footnote 12) for manufacture of a hydroelectric plant and an energy-generating waste-treatment plant.

Quality

Deming's Way

The Japanese revere the man who taught them that higher quality means lower cost. But in his own country, W. Edwards Deming has found few who will listen.

MYRON TRIBUS
DIRECTOR
AKT SYSTEMS AND ENERGY COMPANY
FOUNDER AND DIRECTOR
AMERICAN QUALITY AND PRODUCTIVITY INSTITUTE
HAYWARD, CALIFORNIA

The ultimate curse is to be a passenger on a large ship, to know that the ship is going to sink, to know precisely what to do to prevent it. And to realize that no one will listen! This is the curse that for a quarter of a century has been visited on W. Edwards Deming, the man revered in Japan as the father of quality control, who taught the Japanese how to produce goods of high quality at low cost.

Deming has known for at least twenty-five years that as the Japanese developed their skill in manufacturing, no American producer using conventional American approaches would be able to survive the competition. He knew that no amount of American cleverness in innovation could make up for the Japanese ability to make goods of superior quality for less money. Deming had taught the Japanese that higher quality *meant* lower cost, an idea foreign to most American managers. He foresaw what would happen. Japanese entrepreneurs, observing such successful American industries as textiles, steel, automobiles, and consumer electronics, would study the products, reverse the process of their engineering, and produce higher-quality versions at lower cost. If one nation has access to another's technologies and is better at the art and science of mass production, that nation will invade the other's markets. It is just a matter of time. Thus it is that one by one, elements of our economy have suffered. Deming has known for a quarter century that unless Americans changed their approach to quality and productivity, the economy would be destroyed. And he has had to endure the ultimate curse: no one has listened.

Americans do not appreciate the reverence with which Deming is regarded by the Japanese. The annual Deming Prize is the most coveted industrial award in Japan. Its presentation is a national event, reported on national television, with parades and ceremonies at which children present flowers to Deming and monuments are erected in his honor. The Deming medal, with his profile on it, is displayed prominently and proudly.

Japanese industrialists telephone Deming regularly at his home in Washington, D.C. They invite him to Japan as often as he can come. They listen. They apply his methods. And they succeed, as the world knows all too well. But in the United States, if managers have heard of him at all (and most have not), they are likely to say, "Oh yes, the quality control expert." Very few Americans understand what Deming's way is all about. The president of the United States appoints a blue-ribbon panel to advise on problems of productivity, and Deming's name is not even mentioned.

Too many people believe that Deming merely teaches simple statistical quality control. They miss the point. American managers travel to Japan, marvel at the behavior of factory workers, and conclude that it is something inherent in Japanese culture. They come home convinced that productivity problems in this country are not their fault. They put the blame on the American worker, on taxes, on government regulation, on the decay of society, on everything except their own managerial philosophy.

They do not realize that Deming has developed an entirely new concept of how systems of machines and people ought to be managed. It is a revolutionary idea, and it works. Deming's way is not taught in any school of management in America. Indeed, many things taught to managers in our schools and seminars about how to manage enterprises are actually *contrary* to Deming's way.

Deming's way has an interesting history. During World War II, the statisticians of America, under the leadership of such men as Deming, Joseph Juran, and Walter Shewhart, pioneered new methods of control in wartime industry. America's ability to produce large quantities of high-quality armaments using an unskilled labor force was the miracle that won the war, a miracle due in no small measure to the methods introduced by these men. These were not just methods of statistical analysis, but the beginnings of an entirely new way of looking at the operation of a factory. But when the war ended, the mass markets of America were waiting to be filled and skillful production management was no longer required. By 1950, many of the lessons of the war had been discarded. The new managers who came to run the new factories believed they had little need for methods that would increase quality and productivity. They did not study them and business schools did not teach them.

The American market was a powerful deterrent to anyone who wanted to concentrate on high quality. Apparently insatiable markets swallowed up goods of inferior quality. Americans accepted appliances that performed inadequately as though they were the best that could possibly be made. Until Deming showed that it was false. Americans firmly believed in the myth that an increase in the reliability of their appliances would mean an increase in cost. And by and large they still do.

The years 1941 to 1945 had taught Deming a profound lesson. He realized the possibility of a whole new philosophy of management based on his experiences. And he saw that the basic idea could be put to work in *any* industry, even in the service industries, and in ways not thought of during World War II. In retrospect we can understand why Americans would not listen. While the rest of the world was in disarray, America was exploding hydrogen bombs, providing help abroad through relief programs and the Marshall Plan, winning Nobel Prizes, and greatly expanding its economy. Americans believed that they faced a limitless frontier of opportunity, not that they needed advice on how to produce quality goods and increase productivity. After all, weren't we Number One? We had no problem with productivity and innovation. We had no competition. If anything, our problem was going to be filling up our leisure time.

The Japanese had a different story. Theirs was a conquered country, its economy in ruins. Gone was the dream of a "Greater East Asia Co-prosperity Sphere," based on Japanese military conquest. The country, smaller than California but with a population almost half that of the United States and very few natural resources, faced a momentous challenge. In 1950, with the aid of the MacArthur government, the Japanese Union of Science and Engineering invited Deming to come and tell them about quality con-

Deming's 14 Points

1. Create consistency and continuity of purpose.
2. Refuse to allow commonly accepted levels of delay for mistakes, defective material, defective workmanship.
3. Eliminate the need for and dependence upon mass inspection.
4. Reduce the number of suppliers. Buy on statistical evidence, not price.
5. Search continually for problems in the system and seek ways to improve it.
6. Institute modern methods of training, using statistics.
7. Focus supervision on helping people to do a better job. Provide the tools and techniques for people to have pride of workmanship.
8. Eliminate fear. Encourage two-way communication.
9. Break down barriers between departments. Encourage problem solving through teamwork.
10. Eliminate the use of numerical goals, slogans, posters for the workforce.
11. Use statistical methods for continuing improvement of quality and productivity and eliminate all standards prescribing numerical quotas.
12. Remove barriers to pride of workmanship.
13. Institute a vigorous program of education and training to keep people abreast of new developments in materials, methods, and technologies.
14. Clearly define management's permanent commitment to quality and productivity.

trol. This turned out to be a monumental piece of good luck for the Japanese.

During his first visits, Deming examined what the Japanese were doing, their work force and its habits, and became convinced that his methods could be applied there. With his characteristic audacity, he issued an invitation to the top 45 industrialists in Japan to come to a meeting the next Tuesday; all 45 attended. At the meeting he told them about his methods and promised that if they applied them, within five years Japan would be an important factor in international trade.

To discuss systems that are inherently random, workers and managers need a common language: statistics.

In later years some of the attendees would write about that meeting, admitting that they and their associates did not believe this strange American who was proposing an impossible scheme. The Japanese industrialists had a much more limited objective. They just wanted to bring Japan back to the level it had attained prior to World War II. They did not believe Deming, but having attended the meeting they felt they would lose face if they did not at least give his idea a try.

Within six weeks, some of the industrialists were reporting productivity gains of as much as 30 percent *without purchasing any new equipment.* When they compared notes, they realized that Deming's way really worked. The industrialists then devoted their time and energy to implementing it. The Japanese Union of Science and Engineering set up study teams. Deming suddenly found himself with a development laboratory and 90 million subjects. The whole of Japan's industry became his proving ground. Today, Deming has had over 30 years' experience with this laboratory. He has had a chance to test his ideas, and when he says he knows what to do to increase quality and cut costs at the same time, he does.

WHAT IS DEMING'S WAY?

Consider a trucking firm managed by a man educated according to the management methods currently taught in our schools of business management. He will consider that his job is to run the company as profitably as he can and to expand its business. To do this he may call on the best consultants he can get to help him design the best possible system. He may set up work standards for the drivers and institute computer-based procedures to keep track of the performance of drivers, trucks, and dispatchers. He will study his markets and their opportunities. And he will keep extensive records of income and expenses, ever on the alert for opportunities to make a profit.

Of course, he will not be able to do these things alone, and as his organization grows, he will institute methods for achieving the efficiency and performance he desires. Perhaps he will adopt the practice of management by objectives and teach it to his subordinates. He may assign as much as five percent of his work force to data gathering and performance monitoring.

In short, his idea of a good manager is one who sets up a system, directs the work through subordinates, and sets a standard of performance for his employees by making crisp and unambiguous assignments. He sets goals and production targets for his people. He rates the employees as objectively as he can, sometimes even calling on consultants to help him do so. He identifies poor performers and either educates them further to meet the work standards or replaces them. He hopes thereby to create the most efficient system possible.

Contrast this with the behavior of a manager who follows Deming's way. As this manager sees it, his job requires him to provide consistency and continuity of purpose for his organization and to seek ever-more efficient ways of achieving that purpose. For him, making a profit is necessary for survival but it is by no means the main purpose of his organization. His view of the purpose of his organization is to provide the best and cheapest transportation system for his customers and continuing employment for his workers. He does not view "best" and "cheapest" as contradictory goals.

He will consider that he and his workers have a natural division of labor. They are responsible for doing the work within the system, and he is responsible for improving the system. However, he realizes that the potential for improving the system is never-ending, so he does not call on consultants to teach him to design the "best" system, which he knows does not exist. Any system can be continuously improved.

He knows that the only people who really know where the potential for improvement lies are the workers themselves. He knows that the system is subject to great variability. Traffic conditions change, trucks break down, shipping docks are not always ready to discharge or receive goods, mistakes are made in routing or addressing. There are countless ways for the system to go wrong and out of control, decreasing quality and increasing cost. He knows that these events occur randomly.

For him and his employees to work together, he knows that all must regard the system in the same way and speak a common language. Therefore he learns elementary statistics and teaches it to the workers, if necessary engaging an expert consultant in statistics to help when he and the workers encounter a problem that goes beyond elementary statistics.

All employees learn to keep their own statistics. Truck drivers keep track of how long they have to wait at docks and the circumstances of each event. They develop their own control charts and look for trends and correlations with other events, usually events beyond their control. The drivers meet with each other, and sometimes with the dispatcher, to compare notes. They keep data on the performance of their trucks and discuss their statistical charts with the purchasing agent and with each other. The manager makes changes in the system based on these data, and the workers use their statistical information to help him learn how effective the changes have been. When the manager instructs the purchasing agent to buy on "quality," not just on first cost, the purchasing agent uses the information from the drivers to do just that, and to demonstrate that he has done so.

"I lit a number of fires. Some of them are continuing to burn."

Everyone in the system is involved in studying it and suggesting ways to improve it. *Everyone* spends about five percent of his time on this, but only the company statisticians spend 100 percent of their time on it. The employees will see the practice of setting work standards as a dumb idea, since it inhibits their ability to improve the system. They will not need to manage by objective, because they will be engaged in continually refining their own objectives and recording the performance of the system.

The workers and the management will be aware that the results are the same as those reported by Juran: in most systems, 80 to 85 percent of the problems are with the system, and only 15 to 20 percent are with the workers. This is important to understand, for it gives workers the freedom to speak out without fear, a freedom which the manager will assiduously cultivate.

In Deming's way, the manager understands that he needs workers not only to do the work, but also to help him improve the system. Thus, he will regard them not simply as robots made of flesh and bone, but as thinking, creative human beings. No one will have to teach him to be nice to people. He will not try to motivate the workers with empty slogans like "Zero Defects." There will be no need for slogans, because the workers themselves will be counting the defects and helping to remove them. Nor will the manager have to select a "Polite Trucker of the Week" or ask his workers to sign pledges to be polite to customers. Instead, they will all be studying the records of repeat orders and asking what they can do to improve the statistics.

From time to time the manager will ask for volunteers from the work force to take time out to interview customers and vendors in order to understand what they need or can supply to provide better service. These volunteers will analyze the statistics and report back to the manager and the rest of the work force on the results.

In short, the Deming-trained manager will have a natural basis for building a team and will not have introduced adversarial relations.

The management methods taught today assume that the relation between boss and worker is inherently adversarial. The result is that bosses who want to fit the conventional image avoid developing too intimate a relationship with the worker, lest they lose their objectivity in judging and rewarding performance. (Recall the restrictions on officers in the military against mixing socially with the enlisted men. This is probably a good idea in a system in which no one is supposed to propose improvements!) In Deming's way, the boss and the workers work together naturally and can even afford to like each other!

Deming's way is therefore more than just attention to quality control. It is a managerial philosophy for achieving lower costs and higher quality. And it works not only in the factory, but also in hospitals, in the service industries, and even in the office. It was in recognizing how a different managerial self-image could lead to phenomenal successes that Deming had one of those brilliant flashes of insight that few of us are privileged to have. Like Newton with the apple, Einstein with relativity, and Freud with the subconscious, so Deming saw a new way for management.

Deming's basic idea was this: if management is to be responsible for improving something as complicated as a modern assembly of machines and people (whether in a factory, a hospital, an office, or anywhere else), managers must have a way of learning which problems are caused by the workers and which are caused by the

The Dark Side of Taylorism

Today's press is filled with complaints about how American managers do their job. What managers choose to do and the abilities they choose to develop depend to a large degree on their self-image. They have an idea of what it means to be a manager and they act accordingly. One of the most powerful influences on American managers' idea of themselves was exerted by Frederick Winslow Taylor, the father of *scientific management*.

Taylor is probably best known for the work he did at Bethlehem Steel, where he studied how workers loaded iron castings onto freight cars. By analyzing how they lifted, how they organized themselves, and how often they rested he was able to teach them to double their output without increasing their fatigue. His methods of increasing the productivity of workers formed the basis for scientific management and introduced the era of the efficiency expert.

When Taylor formulated his methods in the late 1800s, the factory floor was a chaotic place by today's standards. Once the engineer had completed his drawings, a master mechanic took over and decided how to make the part. The master mechanic ordered the materials, told his apprentices what to do, and eventually the part was made. There was no inventory control, no scheduling of activities. Everything depended on the skill of the master mechanic. What Taylor and his associates did was to transfer the authority of the master mechanic to the manufacturing engineer. The result was a dramatic increase in productivity. As America's standard of living soared, its workers came to receive the highest wages in the world.

But Taylor's approach also had a darker side. For the workers, its implied message was, "Park your brains at the door." It created antagonism between workers and managers because it confirmed the managers' idea that while they supplied the brains, the workers could supply only the brawn. Nevertheless, the workers appreciated their wages and found it convenient to accept the situation. Ultimately they came to accept its underlying assumptions as well, equating lack of education with lack of intelligence. But at the same time they resented their status.

Taylor's ideas led to tremendous gains, but they also defined the image of both manager and worker for a long time to come. Of course, his views were those of his day. A worker's duty to his employer was considered the highest duty of all, greater than his duty to the public and to himself. But the manager considered his own first duty to be to serve the shareholders. Workers were considered expendable, no different from machines in their replaceability. Thus, managers demanded an allegiance that they did not reciprocate, and their employees eventually responded by giving allegiance to their unions.

system. He understood that learning this depends on workers and management speaking the same language, and on management's using the workers as instruments to understand what happens at the place where the work gets done.

Given the complexity of modern systems, there is no way managers can begin to understand what is happening without the full cooperation of the workers. And even given a cooperative spirit, there is no way all can work together if they do not have a language suited to discussing the inherent randomness of such systems.

And what is that language? It is the language of statistics. An established and esteemed statistician, Deming understood this immediately. We all use statistics every day. It dominates sports reports. We gamble; we handicap the horses; we listen to Jimmy the Greek. But for some reason or other, there is a tendency among "educated" people to shun statistics—even the simplest calculations of averages, expected variations, or of what constitutes an unusual event. As soon as something in elementary mathematics is introduced, one hears "educated" people (for example, hosts of TV talk shows) say, "Oh, I was never very good with numbers," as though this were a badge of honor and mathematical ability the mark of a drudge. Among the "common folk" there may be mathephobia, but no one is proud of it!

Uncontrolled variations in a factory or other workplace lead to low productivity, poor quality, and an increased need for capital equipment to obtain higher rates of production. If management is to control variation, it cannot escape learning how to use statistics. Furthermore, if the cooperation of the workers is to be obtained, they too must learn the language of statistics.

Most American managers today tend to take the system as a given, and they try to get the most out of it as it is. Thus, they believe that the solution to the problems of the factory is to be found in morale, the work ethic, work standards, job definitions, communication, slogans, exhortations, personnel, record keeping, better bargaining with unions, and so on. They equate increased productivity with increased capital spending (on automation, for example) and they avoid responsibility by blaming tax laws, interest rates, and labor rates. It never occurs to them that people do not have to work harder, just more intelligently. And they do not comprehend that *they* must provide the leadership in working intelligently.

Of course, better communication, better equipment, and better understanding of each job can contribute to efficiency. But these need to be seen as part of an overall managerial framework, not as isolated elements. When seen as part of an attempt to *improve* the system, not just to get more out of it as it already is, they take on a much different meaning.

In the conventional corporate environment, the system often works in a self-defeating way. How often is someone promoted because he or she knows how to get things done "in spite of the system?" And how often is someone passed over because he or she spends too much time developing corporate relations in a setting where departmental in-fighting is the order of the day? How many managers make exorbitant demands on their workers as a way of "keeping them on their toes," instead of taking the time to discuss with them how to change the system so they can do their jobs better?

The manager needs workers not only to do the work, but also to help him improve the system.

If workers and bosses both speak the language of statistics, they will have something to discuss at their quality circle meetings. If they don't, quality circles will be an invitation to controversy and misunderstanding. If managers adopt Deming's way, they will understand that they *need* the workers, not just as arms and legs to do what they are bid, but as intelligent human beings who can provide insights into how output and efficiency can be improved. And we know that an improvement in management-labor relations can come from such an attitude, if it is honestly felt and experienced.

What is happening to Deming's way in America today? Deming has undertaken to teach Americans because he senses that now they are ready to listen to him. Despite his age (he is in his 80s), he undertook 18 four-day seminars in 1982, plus many days of individual consultations. In 1984 alone he spoke to more than 2500 executives. Of that experience he said, "I lit a number of fires. Some of them are continuing to burn."

One of the fires that has burned more brightly is in Nashua, New Hampshire, where William Conway, president of the Nashua Corporation, has been implementing Deming's methods. He credits Deming with the turnaround in his company's fortunes.

Probably the biggest success of all is at the Ford Motor Company, whose president declared that the company "is committed to the adoption of the methods of W. Edwards Deming." A videotape prepared for Ford's employees, especially its middle management, provides examples of the success of Deming's methods. Similar pronouncements have been made by representatives of the Pontiac Division of General Motors.

From the experiences at Ford, Nashua, and several Japanese-managed companies in the United States, we now have substantial evidence that Deming's methods work wherever they are seriously tried. We can say with confidence that the poor showing of American industry in competition with Japan is due *entirely* to management. The attitude of the government also plays a role, of course, but in many cases it too is the result of previous managerial approaches. It is the culture of the managers that must change, and quickly.

There are some who say that eventually Deming will be recognized as the father of the second Industrial Revolution. Be that as it may, he has this to say about future competition: "There will be no room for managers who do not know how to work with their people to produce high-quality goods at low cost. High reliability cannot be secured without worker cooperation. Complex systems cannot be understood without statistics. In the competitive world of the future, companies which have not mastered these ideas will simply disappear. There will be no excuses." ■

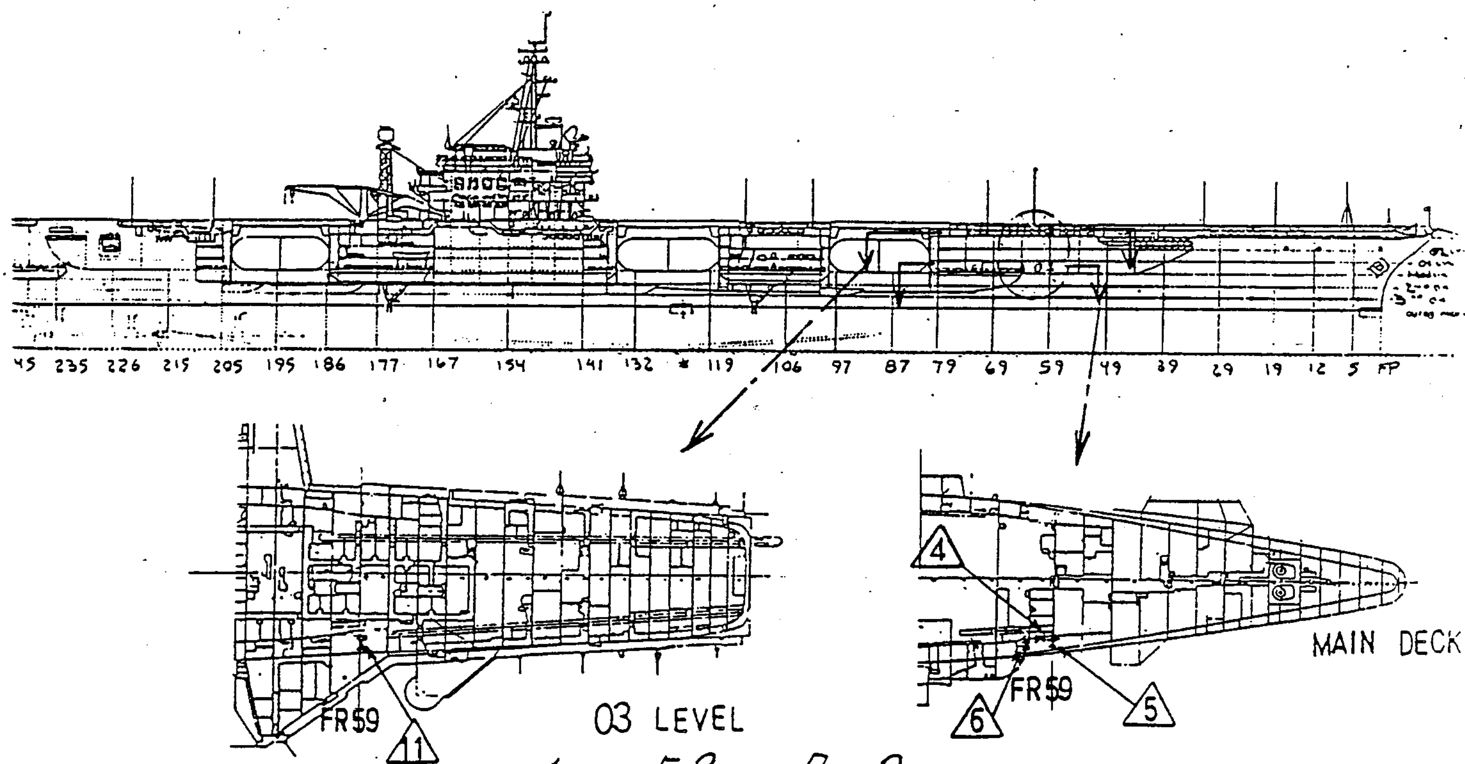
This article is adapted from the author's Selected Papers on Quality and Productivity Improvement, *which is available for $10 from the National Society of Professional Engineers, P.O. Box 96163, Washington, D.C. 20090-6163.*

1/7

PHILADELPHIA NAVAL SHIPYARD
UNIT WORK INSTRUCTION

USS KITTY HAWK (CV-63)

ZONE 8 UNIT WORK NUMBER 39-009-85101-02-0



COMPARTMENT NO.'S OR LOCATION (__DK__FR__P/S/CL)

1 - 59 - 7 - Q

NUMBER OF FIREWATCHES/SHIFT: 2 (MIN)

PRODUCT TRADE: PRE-OVERHAUL TEAM PHASE: PROVIDE ACCESS (FOR ACC. #4,5,6 & 11)

Hours Budgeted: 216 M/H Actual: ________

Start Date Sched (mdy): ___-___-___ Actual: ___-___-___

Completion Date Sched: ___-___-___ Actual: ___-___-___

PREPARED BY [signature], K. Murata & C. Smalley EXTENSION 2268 CODE 940

[initials]

(2/7)

UNIT WORK INSTRUCTION

USS KITTY HAWK (CV-63)

UNIT WORK NUMBER 39-009-85101-02-0

UNCTIONAL WORK GROUPS

HIFTS	FIRST	SECOND	THIRD
GEN FOREMAN			
FOREMAN			
LEAD MECH			
MECHANICS			

(NOTE: PRINT ALL NAMES)

ORK COMPLETE
FOREMAN SIGNATURE_______________________________DATE____________________

ERAL NOTES & INFORMATION:

1. Notify P&E of any missing or damaged items.

2. Authorization req'd from Ship Superintendent before removal of any accesses.

3. All work to be accomplished by employees with the knowledge of Tech. Directives:
   (a) #0111-370 (Access Openings)
   (b) #0152-390 (Struct. Joints; Gen Welding req.)
   (c) #0077-375 (Lead Paint)

4. Refer to interference list provided by layout team UWI #39-009-85101-01-0. List includes items to be removed and shipping tickets #'s.

5. Lifting pads/water-way bars provided by 11 Shop on U.W.I.#39-009-62401 - 03 - 0.

6. Steelworkers to initiate, complete and maintain file of QA forms to identify N.D.T. req'd when cutting access. Fwd copy to Code 135 for control purposes.

SAFETY INSTRUCTION:

1. Assure space to be worked is tagged "Safe for Hot Work or Human Entry".
2. Use safe work practices when Sanding, Grinding, Needle gunning, Cutting, Burning or Welding on painted surfaces.
3. WARNING: Prior to the start of any Hot Work, Product Trades must use safe work practices by Inspecting and taking necessary precautions to protect all Cable/Equipment.
4. SAFETY PRECAUTION: Prior to removing any access patches, lift clear of opening on deck and hold for ten minutes. Inspect pads for any deformation or evidence of failure before proceeding.
5. Stagging is a high risk operation, follow all applicable shipyard safty precausions.
6. Use safty precautions when handling asbestos.

SOURCE INFORMATION:

1. DDI S523-0168 (Access)
2. DDI S523-0174 (N.D.T.)
3. JOPC 12009 58793 Supp.008 (Provide Access)

JOB DESCRIPTION

PRE-OVERHAUL

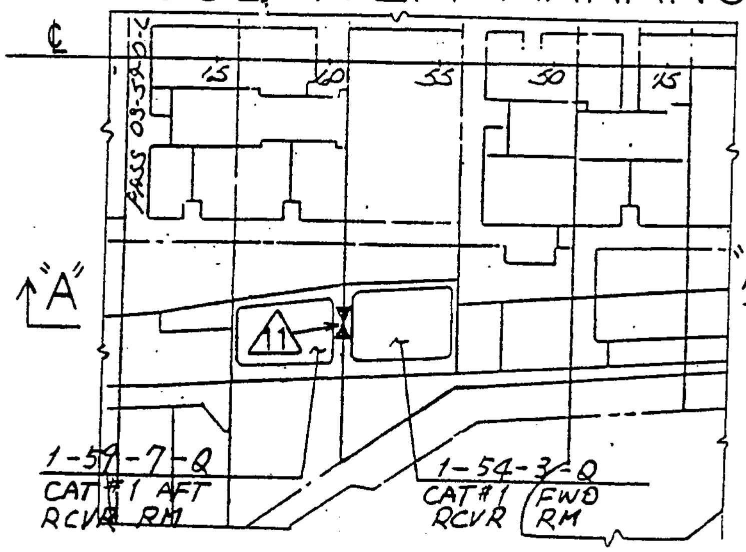
Provide Access (See attached graphics for locations)

1. For Access #4,5,6 & 11

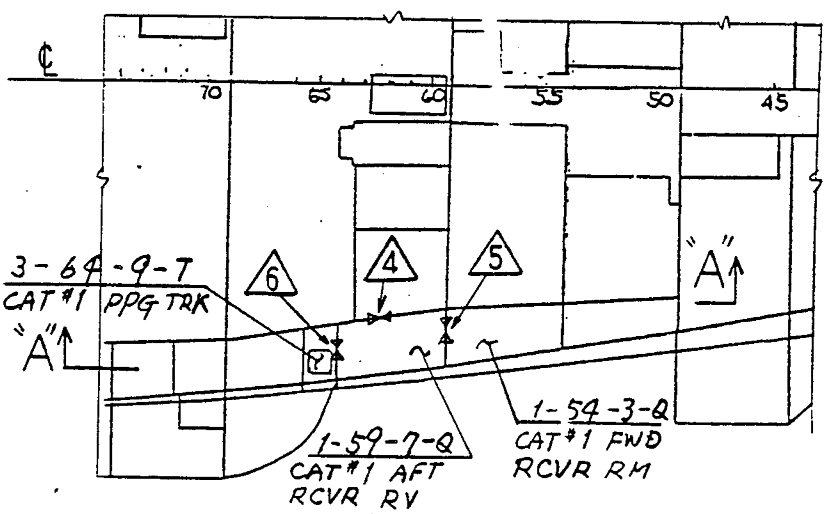
   a. Install 5,000# padeyes as shown.

   b. Cut patches, remove and FWD to 71A, assure that shipping tickets are attached to all items removed.

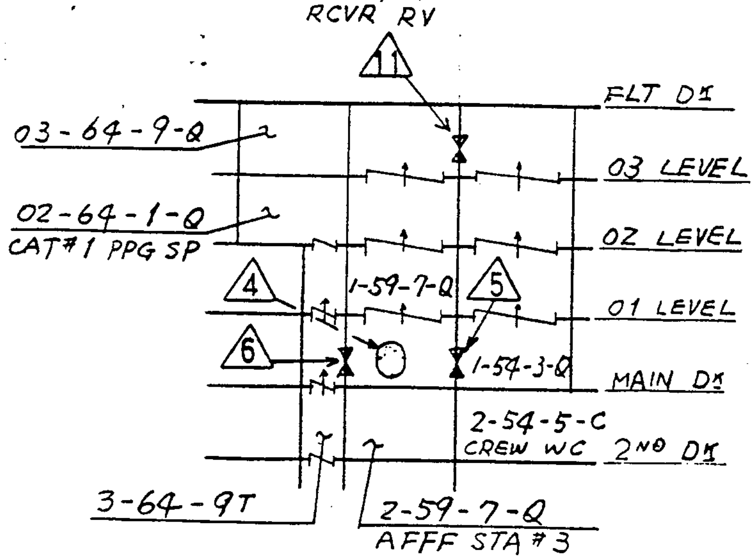
JOB ITEM ARRANGEMENT



03 LEVEL
ZONE NO 8-51-01



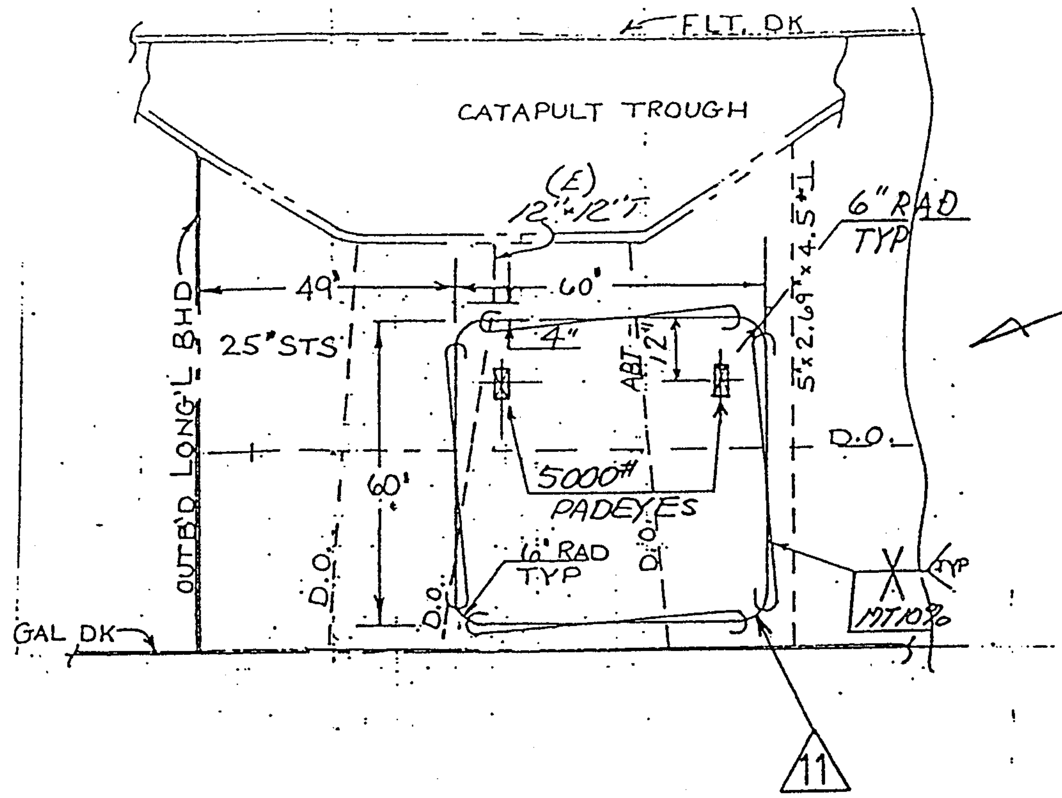
MAIN DECK
ZONE NO 8-51-01



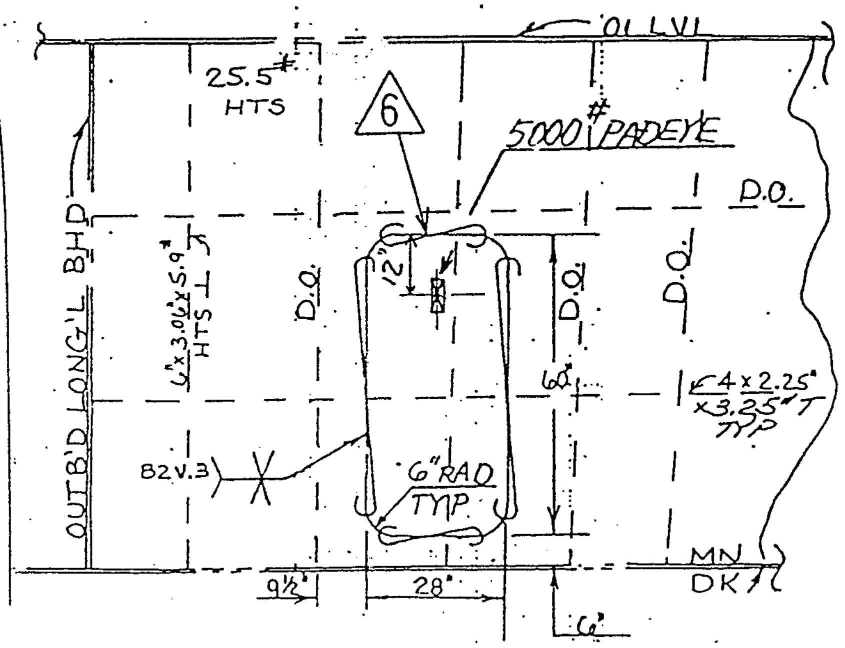
ELEV. "A-A"
LKG INB'D

NON SCALE

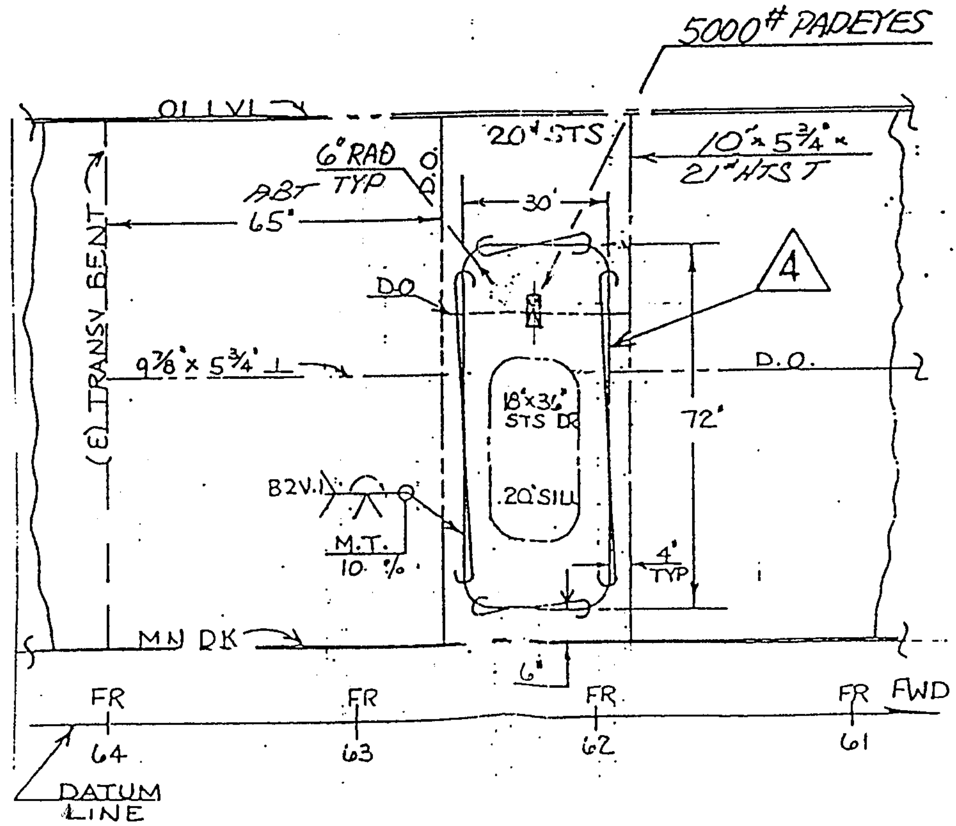
NOTES:



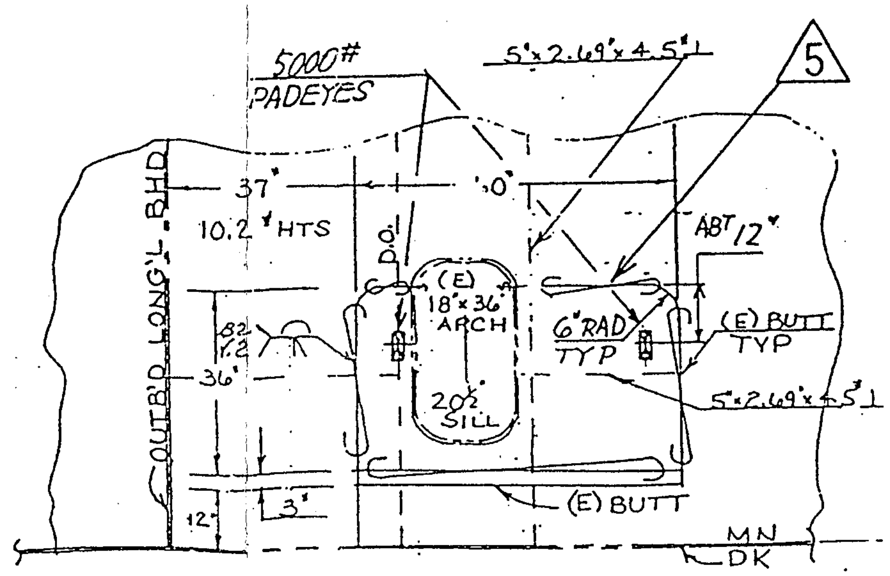
TRANSV. BHD FR59
LKG FWD (STB'D)



TRANSV. BHD FR64
LKG FWD (STB'D)



OUTB'D LONG'L BHD
LKG INB'D (STB'D)



TRANSV. BHD FR59
LKG FWD (STB'D)

UNIT WORK INSTRUCTION
USS KITTY HAWK (CV-63)
UNIT WORK NUMBER 39-009- 85101 - 02 - 0 (7/7)

FEED BACK SHEET

		Yes	No
1.	Was information provided detailed enough to accomplish work.	☐	☐
2.	Were Graphics detailed suffic·ently. Would composite isometric be necessary/helpful?	☐	☐
3.	Was instruction logically organized; proper sequence of steps; additional steps?	☐	☐
4.	Were Trade and Safety instructions clear and sufficient?	☐	☐
.	Was Material available and on-hand to support work?	☐	☐
6.	Was Material ordered/provided, correct? Fab defects.	☐	☐
7.	Was man-hour allowance sufficient? If not explain. How much?	☐	☐
8.	Was schedule time sufficient? If not explain. How much?	☐	☐

9. List additional information required to accomplish work.

10. List additional material not provided that was required.

ITIONAL COMMENTS; RECOMMENDATIONS CAN BE WRITTEN ON BACK

UNIT WORK PROCEDURE

SHIP/PROJECT SSN675 (BLUEFISH)	WORK LOCATION (ZONE) TORPEDO ROOM (304)	UWP NO. 92-304-D10-050	REV
[illegible] 955 359271 / SHOP W.C. 1102	SHOP AREA BOAT INSTALLATION	ZONE MANAGER W. F. QUINTELLA	
TITLE INSTALLATION MISCELLANEOUS FOUNDATIONS, TORPEDO ROOM		EVENT	
PREPARED BY R. DANIS	APPROVED BY SHOP: [signature] DESIGN: [signature] 2502	SPECIAL CONTROLS	

1. THIS UWP IS ISSUED FOR THE INSTALLATION OF FOUNDATIONS #3 & #5 OF DRAWING 113-5789605-J AND FOUNDATIN #2 OF DRAWING 113-5359551-L, IN THE TORPEDO ROOM.
2. THE KEY ISOMETRIC, SHEET 3, SHOWS THE AREAS TO BE WORKED.
3. SKETCH "A" SHEET 4, DETAILS THE INSTALLATION OF FOUNDATION #2 OF DWG. 113-5359551-L.
4. SKETCHES "B","C" &"D", SHEETS 5,6,& 7 INSTALL FOUNDATION #3 OF DWG. 113-5789605-J.
5. SKETCH "E" SHEET 8, INSTALLS FOUNDATION #5 OF DWG. 113-5789605-J.
6. SHEETS 9&10 ARE LIST OF MATERIALS AND ASSEMBLIES REQUIRED FOR THE INSTALLATION OF FOUNDATION #2 OF DWG. 113-5359551-L, AND FOUNDATIONS #3 & #5 OF DWG. 113-5789605-J.

NOTES:

I. REVIEW ALL SKETCHES PRIOR TO COMMENCING WORK.
II. PROTECT ALL PIPING, WIREWAYS, EQUIPMENT, ETC. FROM POSSIBLE DAMAGE.
III. UNLESS OTHERWISE NOTED ALL DIMENSIONS ARE TO BE IN INCHES.
IV. UNLESS OTHERWISE SPECIFIED ALL TOLERANCES ARE +/- 1/8 INCH WITH THE EXCEPTION OF DRILLED HOLES.
V. HOLES FOR HOLD-DOWN BOLTS TO BE TEMPLATED FROM EQUIPMENT OR MOCK-UP.
VI. ALL WELDING TO BE DONE IN ACCORDANCE WITH PROCESS INSTRUCTION 0152-913-317.
VII. INSTALLATION SHALL BE ACCOMPLISHED IN ACCORDANCE WITH PROCESS INSTRUCTION 0152-909-167.
VIII. MT REQUIRED ON THIS UWP ( ) YES (X) NO. IF REQUIRED AN MT DESIGNATOR WILL APPEAR IN THE APPROPRIATE WELD SYMBOL. ALL WELDING AND INSPECTION OF HY-80 MATERIAL SHALL BE IN ACCORDANCE MIL-STD-1688. NDT INSPECTION OF HY-80 SHALL BE DONE IN ACCORDANCE WITH PROCESS INSTRUCTIONS 7610-942-692 AND 9500-929-130.

DRAWINGS UTILIZED	JOB ORDERS TO BE CHARGED
113-5789605-J 113-5359551-L	39-675-11325 K/O 621

WORK COMPLETION CERTIFICATION: DATE:

COPIES	1					3	1	1	1	1			2		1						
ROUTING	MOLD LOFT	LAY OUT	MACH	FL CUT	ASSY	INST	DESIGN	P&E	377	190	330	31	92	93	95	96	97				TOT ISS

92 92 250 231

IMAGE 1

SHEET 1

UNIT WORK PROCEDURE (CONTINUATION SHEET)

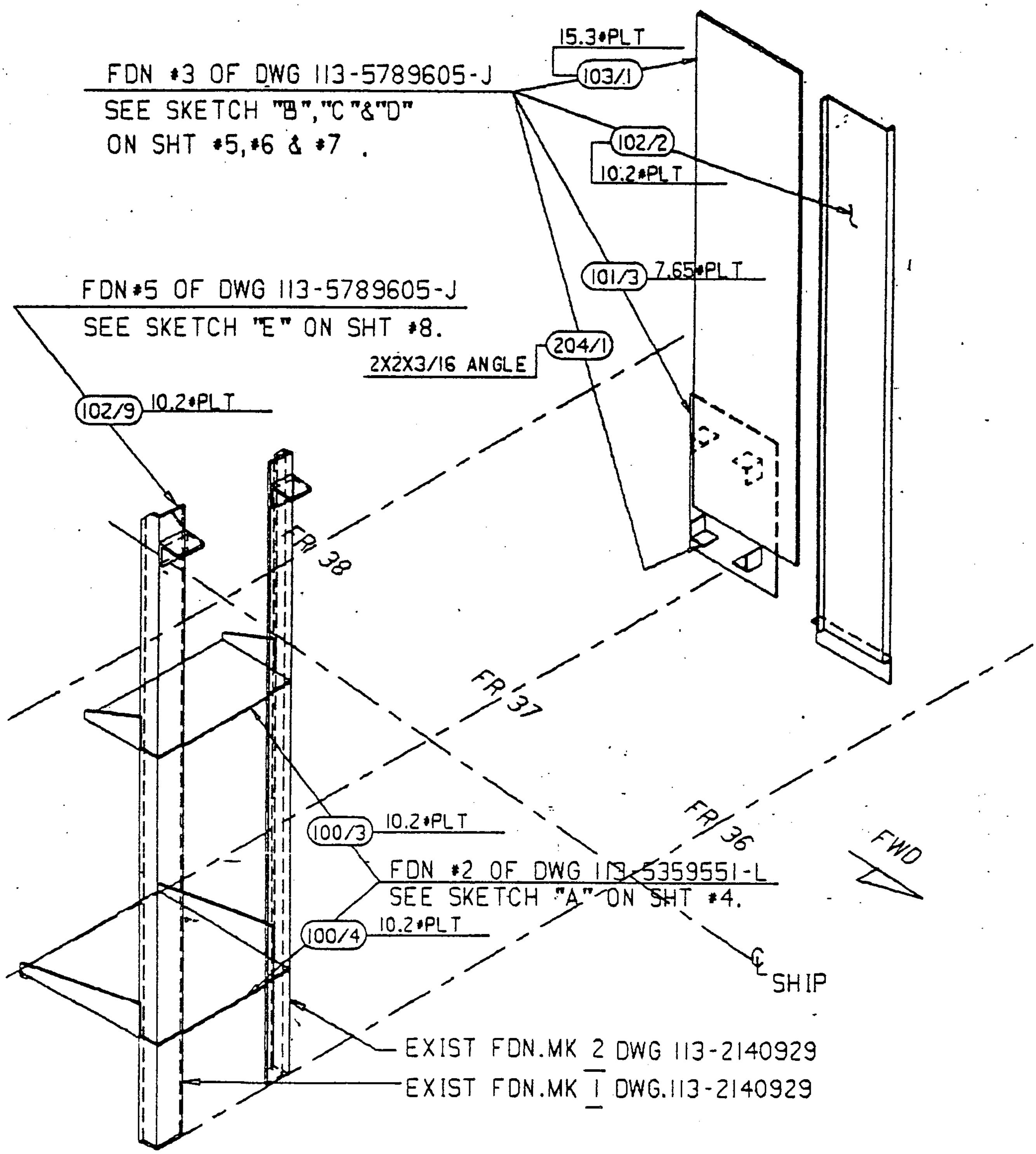
SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO (304)	92-304-D10-050	

REVISIONS

REV.	DESCRIPTION	DATE

UNIT WORK PROCEDURE (CONTINUATION SHEET)

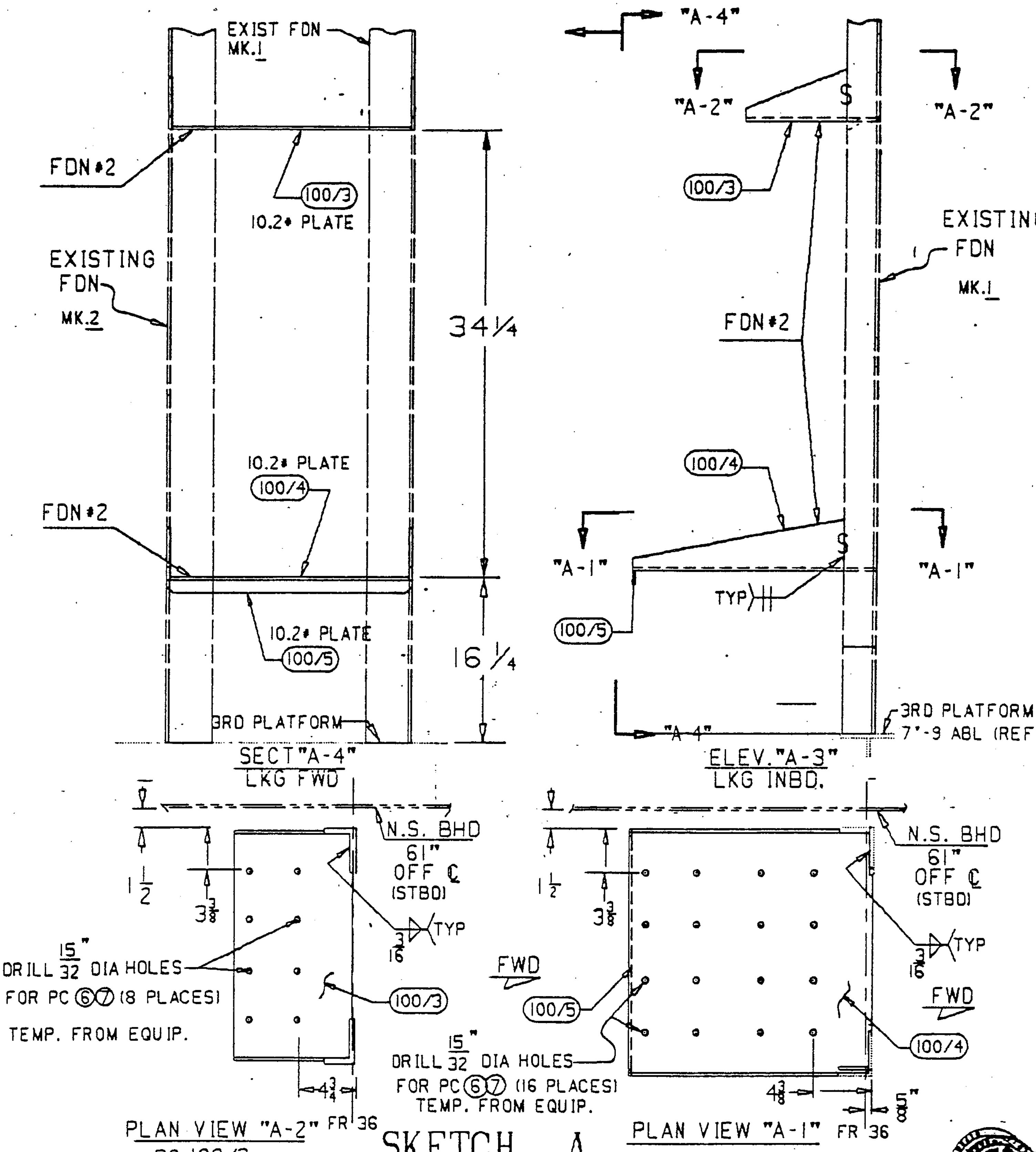
SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO (304)	92-304-D10-050	



KEY ISOMETRIC VIEW

UNIT WORK PROCEDURE (CONTINUATION SHEET)

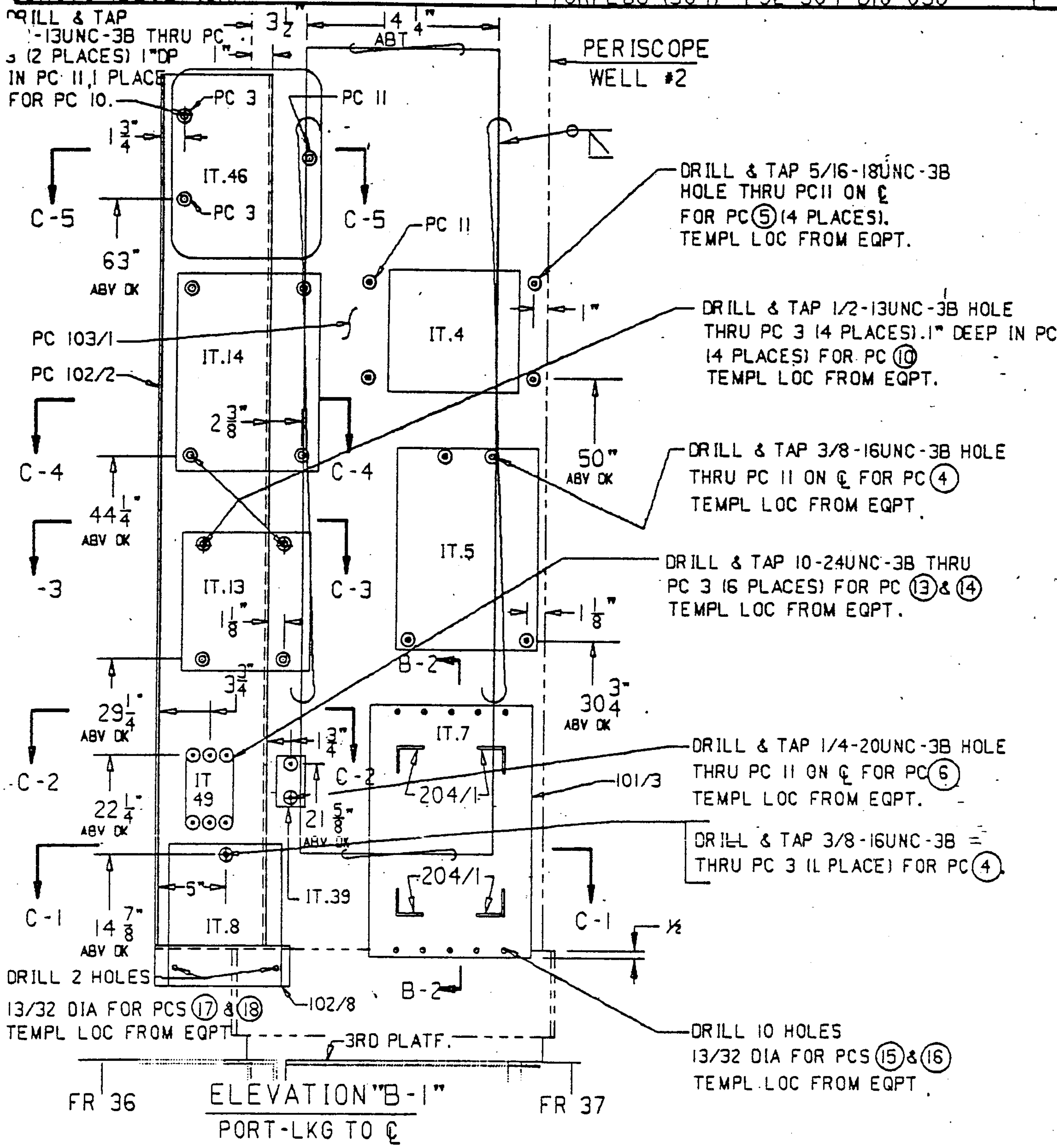
SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO (304)	92-304-D10-050	



SKETCH A

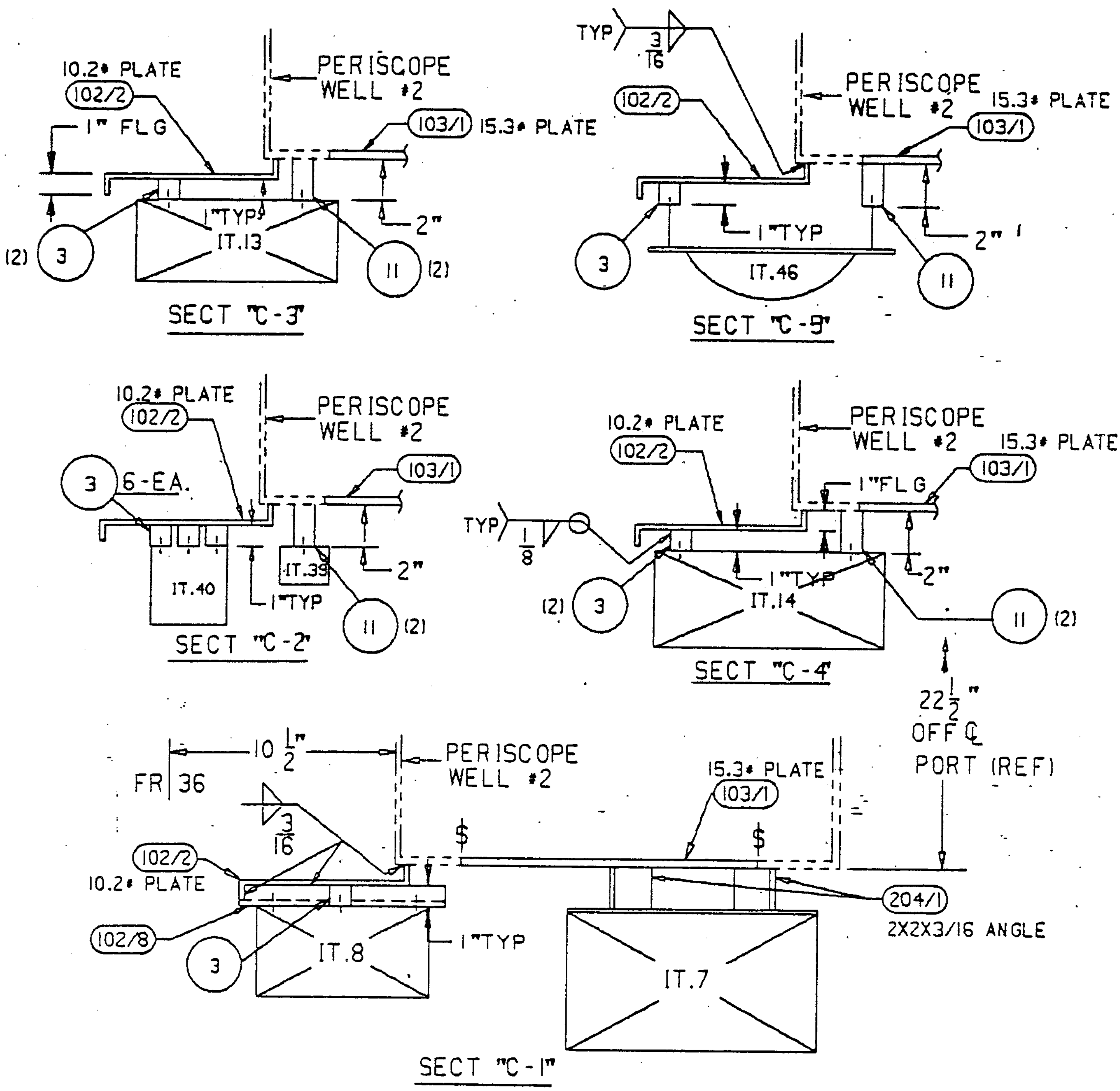
UNIT WORK PROCEDURE (CONTINUATION SHEET)

SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO (304)	92-304-D10-050	



SKETCH B

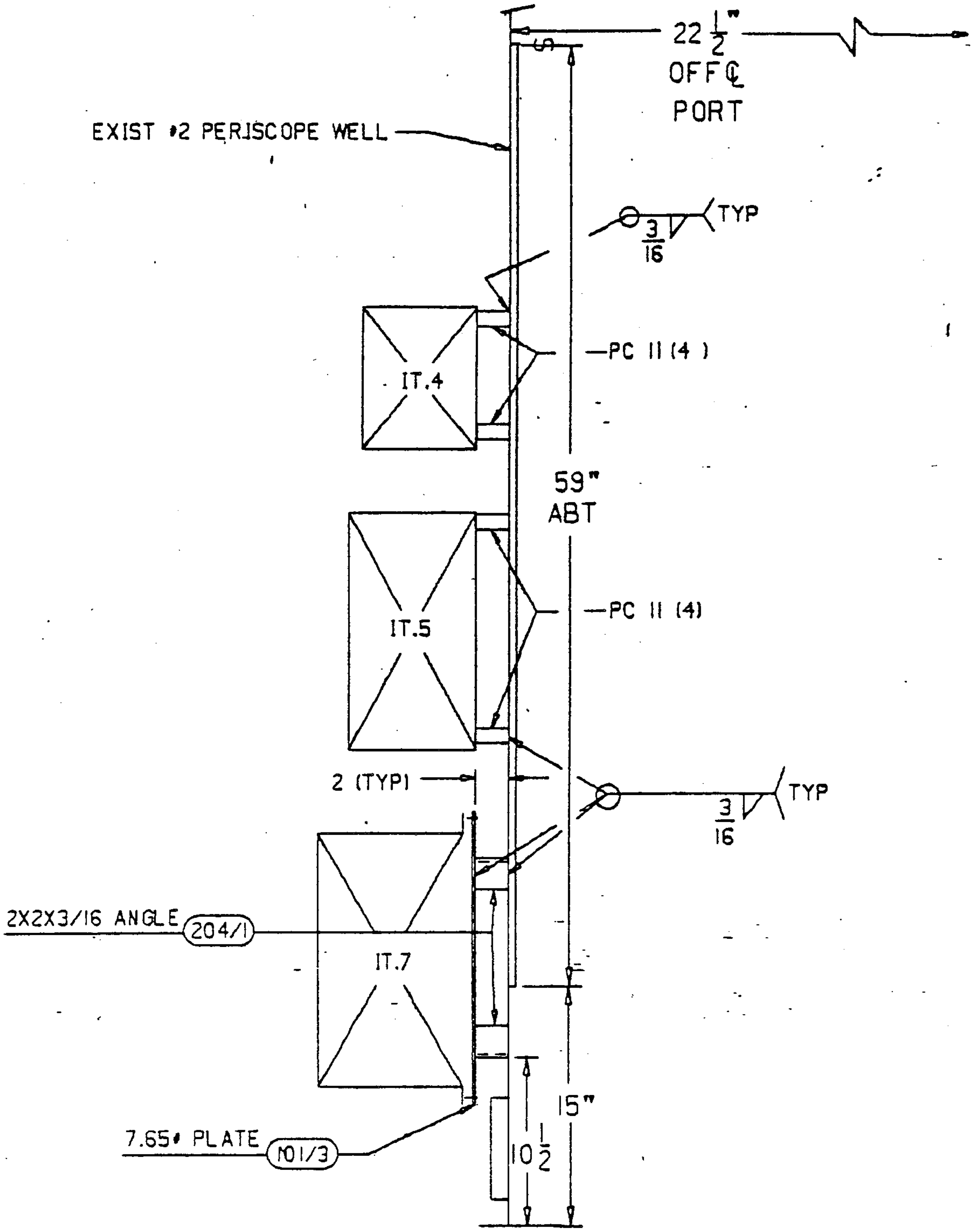
FDN #3 DWG 113-5789605-J



SKETCH C

FDN#3 DWG 116-5789605-J

FROM SKETCH "B" SHT 5

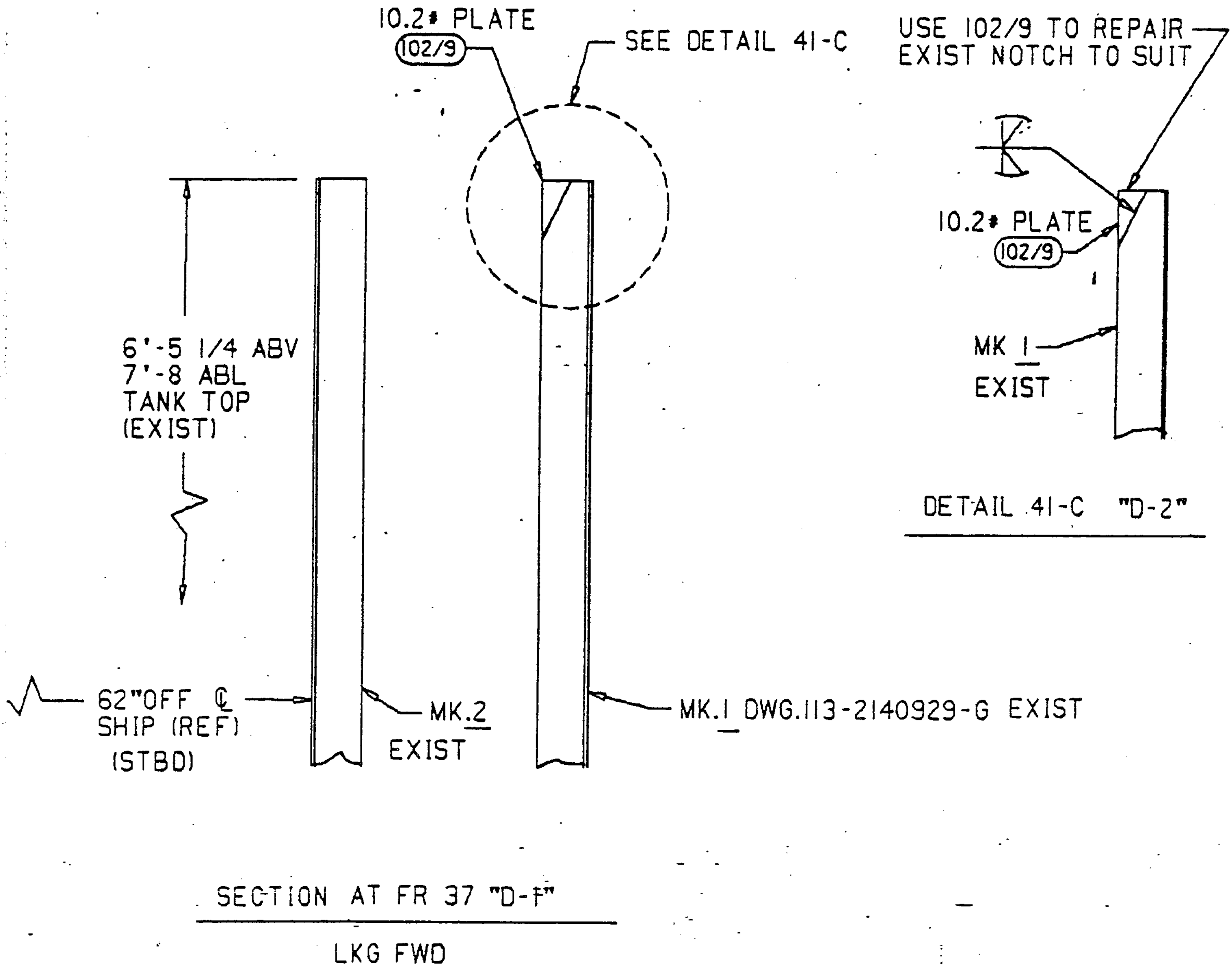


SKETCH D

FDN #3
DWG 113-5789605-J

UNIT WORK PROCEDURE (CONTINUATION SHEET)

SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO (304)	92-304-D10-050	



SKETCH E

FDN #5

DWG 113-5789605-J

UNIT WORK PROCEDURE (CONTINUATION SHEET)

SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO ROOM (304)	92-304-D10-050	

DWG PCNO OR DWG. FDN. NO.		QTY.	DESCRIPTION		MAT'L	MATERIAL SOURCE	REMARKS
	FDN 2		DWG 113-5359551-L				
PC. 6	↓	24	BOLT,HEX HD	7/16-14 UNC-2A X 2"LG	STL		
PC.7	↓	24	NUT,HEX SELF-LKG	7/16-14 UNC-3B	STL		
100/3	↓	1	10.2# PLATE	FLANGED	MS		
100/4	↓	1	10.2# PLATE	FLANGED	MS		
100/5	↓	1	10.2# PLATE	1" X 19"	MS		
	FDN 3		DWG 113-5789605-J				
PC. 3	↓	13	BAR,ROUND	1"DIA X 1"LG	STL		
PC. 4	↓	5	SCREW,CAP,HEX HD	3/8-16 UNC-2A X 1"LG	STL		
PC. 5	↓	4	SCREW,CAP,HEX HD	5/16-18 UNC-2A X 1"LG	STL		
PC. 6	↓	2	SCREW,CAP,HEX HD	1/4-20 UNC-2A X 1"LG	STL		
PC.10	↓	7	SCREW,CAP,HEX HD	1/2-13 UNC-2A X 1"LG	STL		
PC.11	↓	15	BAR,ROUND	1"DIA X 2"LG	STL		
PC.13	↓	6	SCREW,MACH,HEX HD	#10-24-3/4 LG	STL		
PC.14	↓	6	WASHER,LOCK	#10	STL		
PC.15	↓	10	BOLT,HEX HD	5/16-18 UNC-2A X 7/8 LG	STL		
PC.16	↓	10	NUT HEX,SLF-LKG	5/16-18 UNC-3B	STL		
PC.17	↓	2	BOLT,HEX HD	3/8-16 UNC-2A X 7/8 LG	STL		
PC.18	↓	2	NUT,HEX SLF-LKG	3/8-16 UNC-3B	STL		

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UNIT WORK PROCEDURE (CONTINUATION SHEET)

SHIP	ZONE	UWP SEQ. NO.	REV
SSN675 (BLUEFISH)	TORPEDO ROOM (304)	92-304-D10-050	

DWG PCNO	OR DWG. FDN. NO.	QTY.	DESCRIPTION	MAT'L	MATERIAL SOURCE	REMARKS
	FDN 3		DWG 113-5789605-J (CONTINUED)			
ASSY	1	1	INCLUDES THE FOLLOWING PC'S			
101/3		1	7.65# PLATE 12" X 18 1/2"	MS		
204/1		4	2" X 2" X 3/16" ANGLE BAR 2" LONG	MS		
ASSY	2	1	INCLUDES THE FOLLOWING PC'S			
102/2		1	10.2# PLATE FLANGED	MS		
102/8		1	10.2# PLATE 3" X 10"	MS		
ASSY	3	1	INCLUDES THE FOLLOWING PC			
103/1		1	15.3#PLATE 15"X 60"	MS		
	FDN 5		DWG 113-5789605-J			
102/9		1	10.2#PLATE	MS		

UNIT WORK PROCEDURE (CONTINUATION SHEET)

SHIP/PROJECT	UWP ZONE	UWP NO.	REV
SSN675 (BLUEFISH)	TORPEDO ROOM (304)	92-304-DIO-050	

INSTALLER'S COMMENTS

WERE GRAPHICS AND INFORMATION OF THIS UWP DETAILED ENOUGH TO ACCOMPLISH THE REQUIRED WORK? YES ☐ NO ☐

COMMENT?

WAS SEQUENCING OF WORK SUFFICIENT TO ACCOMPLISH WORK WITHOUT DELAY? YES ☐ NO ☐

COMMENT?

WAS MATERIAL READILY AVAILABLE TO EXPIDITE INSTALLATION? YES ☐ NO ☐

COMMENT?

LIST ADDITIONAL COMMENTS AND RECOMMENDATIONS BELOW.