THE DESIGN OF BUILDING DETAIL AND THE CONSTRUCTION PROCESS: AN ANALYSIS OF COMPONENT INTERFACE AND POSITIONAL DEPENDENCY

by

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Submitted in partial fulfillment
of the requirements for the degrees of
Master of Science in Civil Engineering

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ABSTRACT

The rationalization of building construction is dependent upon an understanding of the relationships between the interfaces of components and the assembly process. This thesis is an attempt to identify the effects of the design of assemblies in residential building finishes upon the process of construction. The examples analyzed include kitchen cabinet and bathtub installations in the United States and Israel, representing two different methods of construction and levels of industrialization. The respective assemblies are similar in form and function, and require the participation of several trades in each case.

Two graphic methods of portrayal of the sequences of installation and placement of components have been designed in order to identify the physical and procedural interrelationships between the elements of the assemblies. Interface networks depict the physical joints between the elements, and identify the critical components and degree of interrelationship of the assemblies. Analyses of the details of the interfaces identify the types of joints and tolerances affecting the placement and position of the components. The patterns of positional dependencies which have been depicted in another network diagram represent the sequential nature of the assembly process, and the interaction and returns of the trades involved.

The interface and positional dependency networks have provided a means of analysis of the complex interrelationships between components and the respective trades, yielding several recommendations which have been shown to facilitate the construction of the Israeli assemblies without abandoning the traditional materials.

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CHAPTER I

INTRODUCTION

Every attempt to increase the efficiency of the construction process, by rationalization, industrialization, or systems design has encountered dependence upon the interfaces of components. The methods of accomplishing those interfaces determine the sequence of construction operations, acceptance of tolerance, degree of difficulty in assembly, capacity for change, and overall quality and integrity in the performance of the structure itself.

The construction process can be described as the fabrication of components and the joinery of those components into a completed structure. It is remarkable that so little research has been done on the design of component interfaces, a subject so pervasive and consequential to the totality of design and construction.

The goal of this thesis is to determine the differences that exist in the relationship of detail and process in the finish construction of multi-unit housing in the United States and Israel. It is hoped that this study will provide a basis of information on the nature of the interface of components such that new construction systems may be designed for a more rationalized process of construction.

Rationalization and modular concepts aimed at industrializing construction have identified and isolated the problem to some degree, yet efforts toward a subsequent rationalization of the process of interfacing components have admittedly been somewhat neglected.

The logic of arranging repetitive units to form larger dimensions, as typified by brick and mortar courses, has been the basis of the modular coordination concept. The application of bricks as increments to the module does not create any particular problem with joints, yet it can contribute very little to the solution of any joint problem involving the interface of different types of components.

"The point being made is elementary but it is well worth emphasizing since an enthusiasm for modular construction in particular and standardization of components in general may make one forget the importance of joints." (Hutcheon and Kent, Toward Industrialized Building). It has been noted that the mortar joint in brick masonry accommodates the functional as well as the dimensional requirements, which exist for any type of joint. The extent to which the requirements of joints can be met, rather than the properties of the components being joined will often be the limiting factor in the final performance of the combination. (Hutcheon and Kent)

Research concerning the industrialization of building finish detail has been largely ignored in favor of studies of more comprehensive building systems. However, the materials of construction in the U.S., particularly those of finish detail, are designed and produced by a wide range of manufacturers and most building systems are aggregations of elements from these various sources.

Harvey R. Geiger, addressing the current status (up to 1969) of dimensional precoordination in the United States, described the supply complex of the construction industry as a modified open system, with each building component related by standards of tradition into functional groupings. Within these functional groupings, manufacturers, trade associations and governmental agencies have assured the coordination of dimensional standards and performance criteria specific to the function group. However, most products are designed to be used in a custom building market, requiring field adaptation. This cutting and fitting was estimated in 1969 by Architectural & Engineering News to take from 5 to 45 percent of construction time.

Geiger concluded that: "Many products are not universally used or exchanged from one project to another due to lack of coordination in joint design and/or standardized dimensions." (Geiger, Precoordination Basis for Industrialized Building). He attributed this closed-system aspect to the proprietary nature of the building industry and its supply complex.

The logistical and administrative difficulties in establishing joinery conventions have placed the performance of this role in governmental agencies and large-scale research projects. Building materials organizations in fields where interface with a separately produced component is inherent to the product have historically borne the budren of research and development of connections, but this information is specific to those particular interfaces. Projects in systems design have discovered that the largest part of planning is in the coordination of different proprietary systems. Ezra Ehrenkrantz described it simply by: "...one man's system is another man's component." (Interview) In the Southern California School District project, great overall savings were found through the specifically expensive production of a special structural connector, especially designed for the project. (Ehrenkrantz interview).

Coordinating functions have been extensively large government projects, as in the General Services Administrations efforts for federal office building systems, and programs such as Operation Breakthrough. In these instances, the programs required concerted efforts on the part of each facet of the industry to produce either a completely satisfactory proprietary closed system, or a synergetic attempt to offer specific components that were conducive to a synergetic open system.

The need for the establishment of conventions with regard to the connections of industrialized components in modular coordination is self evident, yet very little progress has been made. G. Blachere, Director of the Centre Scientifique et Technique du Batiment in Paris, addressed the problem of tolerances and joinery conventions coincident with the particular tolerances to be bridged. "There exists a convention whereby a component must stand within its modular space. Actually, it is merely a specialized form of a general convention on jointing, though it is commonly regarded as a major principle of coordination. It is a simple and effective convention, but an extremely limiting one from the technical point of view. In practice most prefabricated elements do not conform to this rule. There is, consequently, a need for a true general convention which will take into account actual jointing technology." (Blachere, Account of the Principles of Modular Coordination: Industrialization in Building)

It should be noted that studies of the building process have not approached the subject of rationalization from a standpoint of "general conventions" deriving from actual jointing technologies. Therefore, this thesis proposes to analyze the interrelationships of joints and processes as they exist in different construction systems.

The objective of this thesis is to analyze the interfaces between components in assemblies in order to identify the interrelationship of details and the processes of construction. Similar assemblies in two very different finish construction systems in multi-unit housing provide excellent examples for such an investigation, since variables related to the form and functions of the assemblies would be common to both, and thus the differences may be isolated to be the result of detail and process in each case.

A comparison of building detail in finish construction must consider the elements and components which make up the parts of the system, the processes involved in the sequence of assembly of those parts, and the details of the junctures between the parts, or the respective component interfaces. In order to establish patterns and concepts which are present within a given system, an appropriate example in each system should be comparable in form and function, such that the materials and processes of construction within each example may be isolated. Likewise, the examples should be of sufficient complexity, including a number of different materials and trades, such that the interrelationships that exist between these factors may be identified. The construction of kitchen cabinets and bathtubs provide such examples.

The two systems which are to be compared are the conventional methods of construction in the United States, and those in Israel. The information concerning building practices in Israel has been made available through a research project which has as its goal the reduction in costs and time, and increase in productivity of housing construction in that country: "Improvement and Innovation in Housing in Israel."

Observations and analyses of the Israeli construction systems have determined that certain aspects of the building practice are more time consuming and expensive than the counterpart aspects in the United States. Specifically, it has been found that trades return many times during the process of construction of finish elements. These returns of trades to complete an assembly have been linked to details of the design of the building finish elements, though the relationship between the details and the process as a whole have not been examined.

A comparison of the Israeli building schedule and costs with multi-unit housing finish construction in the United States has shown that there are fewer returns of trades, and lower costs in the U.S.

The concepts of building are very different between the two countries, relating to materials and methods. In general, the U.S. practice is one of assembling pre-fabricated components and materials within interior partitions of metal stud framing, which have been accurately laid out to the plan, and upon which the remainder of elements are dependent. The Israeli convention is different in principle, with masonry partitions and structural floors roughly constructed, to be finished by skilled workmen on site with thick plaster coatings and floor tiles on sand beds.

Servicing strategies between the two systems are likewise different, with the electrical and plumbing lines run within the wall framing in the U.S., while the services in Israel are run in the sand bed under the floor tiles, and in grooves cut in the block wall, covered with plaster.

The detail assemblies, such as cabinets, are prefabricated and affixed to the partitions in the U.S., whereas those in Israel are built-in, and assembled on site with many elements.

A more extensive study may compare the relative merits of various building materials, and servicing systems, with regard to the industrialization of building as a whole. But a more elementary rationalization of building practices first requires a thorough understanding of the relationships between components and processes of construction, at the detail level.

The examples of building detail which shall be examined in this thesis are kitchen cabinets and bathtubs built in the United States and Israel. This investigation will be divided into four case examples; Chapter III will examine the kitchen cabinets built in the United States, and then those constructed in Israel. Chapter IV will compare the two bathtub examples. Each case example will be comprised of seven sections. The first three sections will describe the parts and method of assembly: Form, Elements, and Process. The remaining four sections comprise an analysis, first of the joints between parts that are made on site, in sections Interface Network and Detail, and finally an analysis of the positional dependencies of the components: Placement/Position and Control Planes.

A preliminary comparison of the two examples of each assembly will be found in the introduction to each chapter. The functions and user requirements of the assembly will be briefly described, and each assembly will be illustrated with isometric drawings and a series of drawings comparing the stages of assembly of each example. The next chapter will describe in detail the methodology used in the analysis of each case example.

CHAPTER II

METHODOLOGY

The seven sections within each case example provide a means of defining the relationships between components in the assembly. The causes and effects of the placement of each component must be identified in order to examine the relative significance of the component to the assembly process.

The first three sections comprise of descriptions of the assembly and the process by which it is built. The form of the completed assembly will be described accompanied by an isometric drawing of the assembly. The elements illustrated on a sectional drawing of the assembly will be listed in a table, including their dimensions, material, method of fixation, and finish. Specific parts of the section will be identified as details which include the junctures between the elements listed. The process of assembly will be established by the identification of the elements as components which are installed by a given trade. The junctures between elements may then be identified as interfaces of components. The sequence with which those components are installed will be listed in a table, including a description of the activities necessary to bring about the interface of each component to those which precede it.

The analysis of each assembly is based upon the interface network, a diagramatic representation of the interfaces between components. The U.S. kitchen cabinet assembly will serve as an example as to how this network is constructed and will contain definitions pertinent to the following analyses. However, some of the concepts which will be seen to be relevant in the analysis are listed below.

In general, the manner of construction of the assembly will be graphically evident in the pattern of interfaces. Whether or not the assembly is primarily sequential may be seen by the number of interfaces between successive components. The degree of interrelationship of the assembly and whether it is built-in to the structure or attached will be determined by the number of interfaces which will be seen to exist in the network. The number of components which are brought to interface with those components which represent the structure is an indicator of the degree to which the assembly is built-in. Whether the structural or other components are found to be controlling will be determined by the number of subsequently placed components which are brought to interface with a given component. The degree of interrelationship of the assembly, as well as the critical elements in the assembly will be identified by counting the number of interfaces which a given component has to those which precede it. Each example will contain a table of those components which are brought to interface with more than one precedent.

The interfaces of critical and controlling elements will be examined in an analysis of detail. A distinction will have been made on the interface network between normal interfaces, which are direct and positive junctures between two elements, and lower degree interfaces, which are junctures within which a considerable tolerance exists. The configuration of the component interfaces will be shown to be of significance.

Such configurations as slip planes and overlapping butt joints will be defined and their relationship to the tolerances of specific interfaces identified.

Having identified the component interfaces and the detail of those interfaces, the process by which the position of each component is determined will be discussed. A table of positional dependencies will identify the determinant interfaces and measurements which need to be performed with the placement of each component. A positional dependency network will graphically portray these factors in a similar manner to the interface network. Some of the most important patterns of interdependencies that will be observed in the network are whether the dependencies are sequential, whether controlling components are seen to determine positions of a number of subsequent components, and whether the positional dependencies to a component are accumulated from several precedents. With the positional dependencies listed, a reference to the details and section of the assembly will identify the location and number of control planes which affect the placement of components in the assembly. From these analyses, groups of positional dependencies will be established and shown on the positional dependency network. These groupings will provide an indication of the general patterns of interdependencies that exist between components and the amount of coordination which will be needed between the trades which are involved with the placement of those components.

The case examples will be analyzed in the following chapters in accordance with the above format and as stated before, the U.S. kitchen cabinet example will explain the construction of interface and positional dependency networks.

CHAPTER III

KITCHEN CABINET ASSEMBLIES

INTRODUCTION

The first case examples in this analysis are kitchen cabinets constructed in the United States and Israel. The two examples are similar in form and user requirements, yet it will be demonstrated that kitchen cabinets in the two countries represent two very different approaches to the construction and installation of finish building detail.

The prefabricated cabinets and countertops in the U.S. are sequentially assembled and affixed to the essentially finished wall. A certain type of joint interface, called a slip plane, will be seen to facilitate the placement of components in the assembly. In contrast, the Israeli kitchen cabinet is built in to the structure using many interrelated components. Special attention must be given to attain the proper fit of each component.

The common functions of kitchen cabinets will be discussed after a graphic presentation of the two examples of cabinets, Figures 3.1 and 3.2. A comparative illustration of the stages of construction of the two cabinets is shown in Figures 3.3.1 through 3.3.6. The letters identifying the components installed at each stage correspond to the system of identification of components in the analyses to follow. The U.S. cabinets will then be discussed in the format described in the introductory chapter, followed by a discussion of the Israeli assembly.

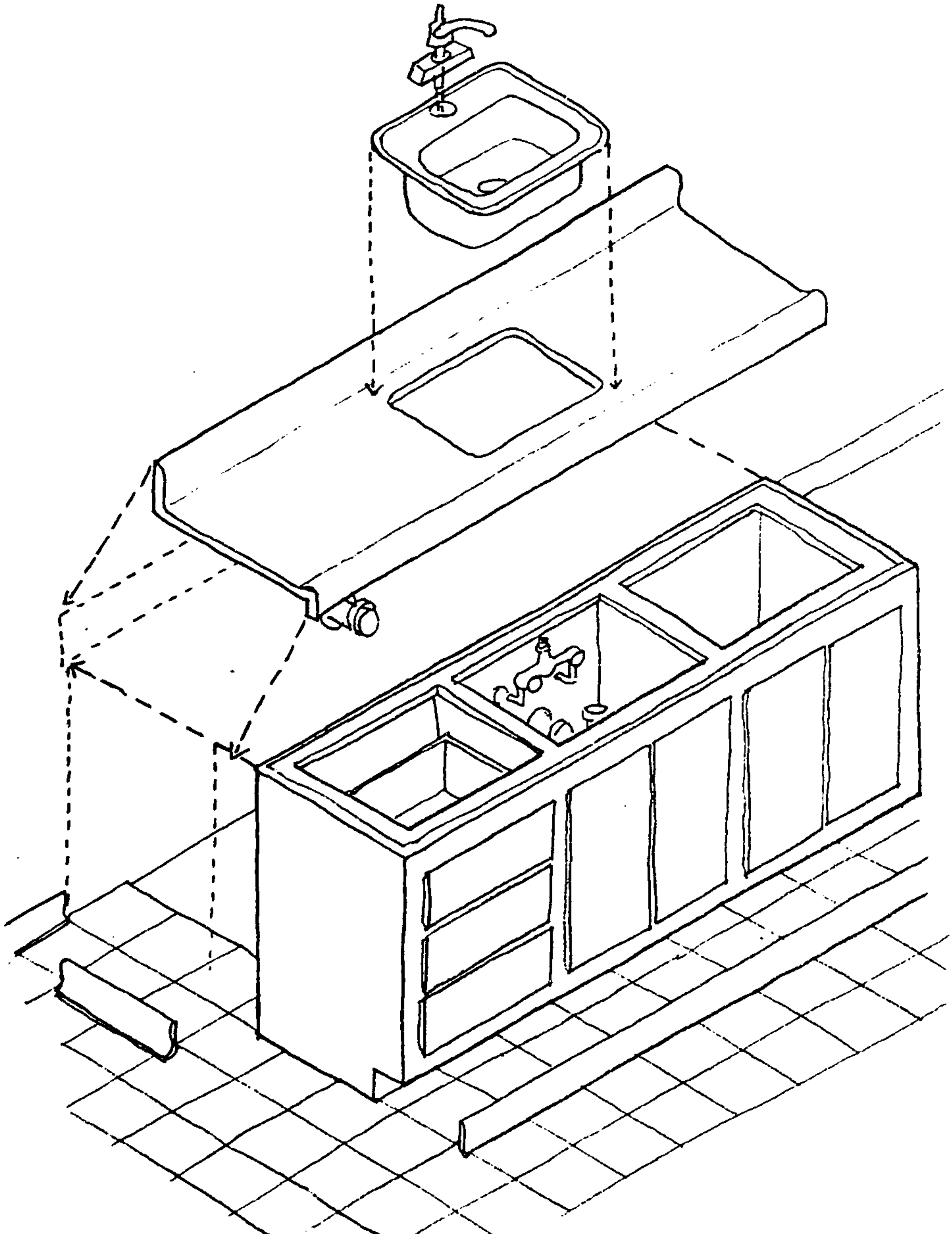


FIG. 3.1
U.S. KITCHEN CABINET : EXPLODED ISOMETRIC

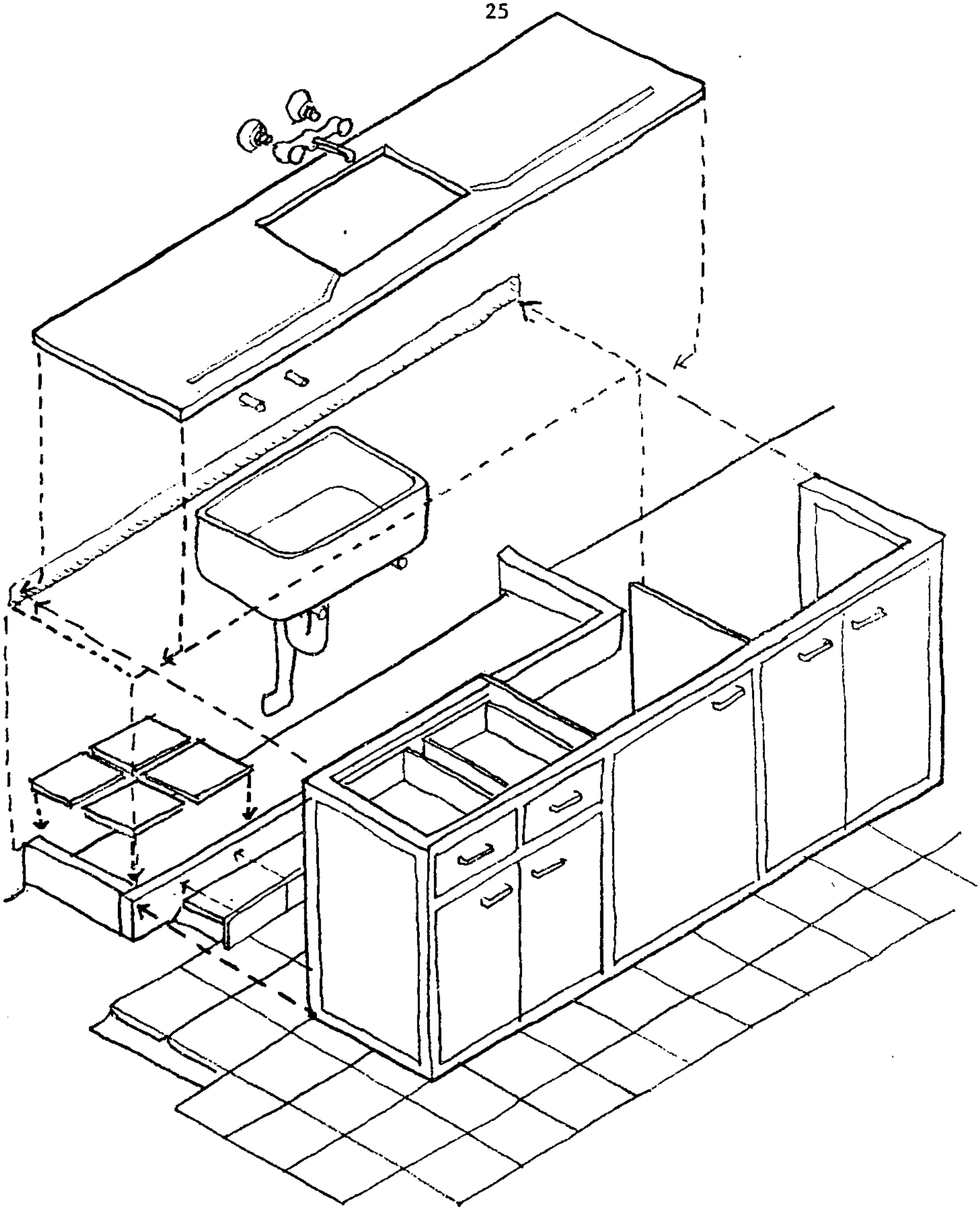


FIG. 3.2
ISRAELI KITCHEN CABINET : EXPLODED ISOMETRIC

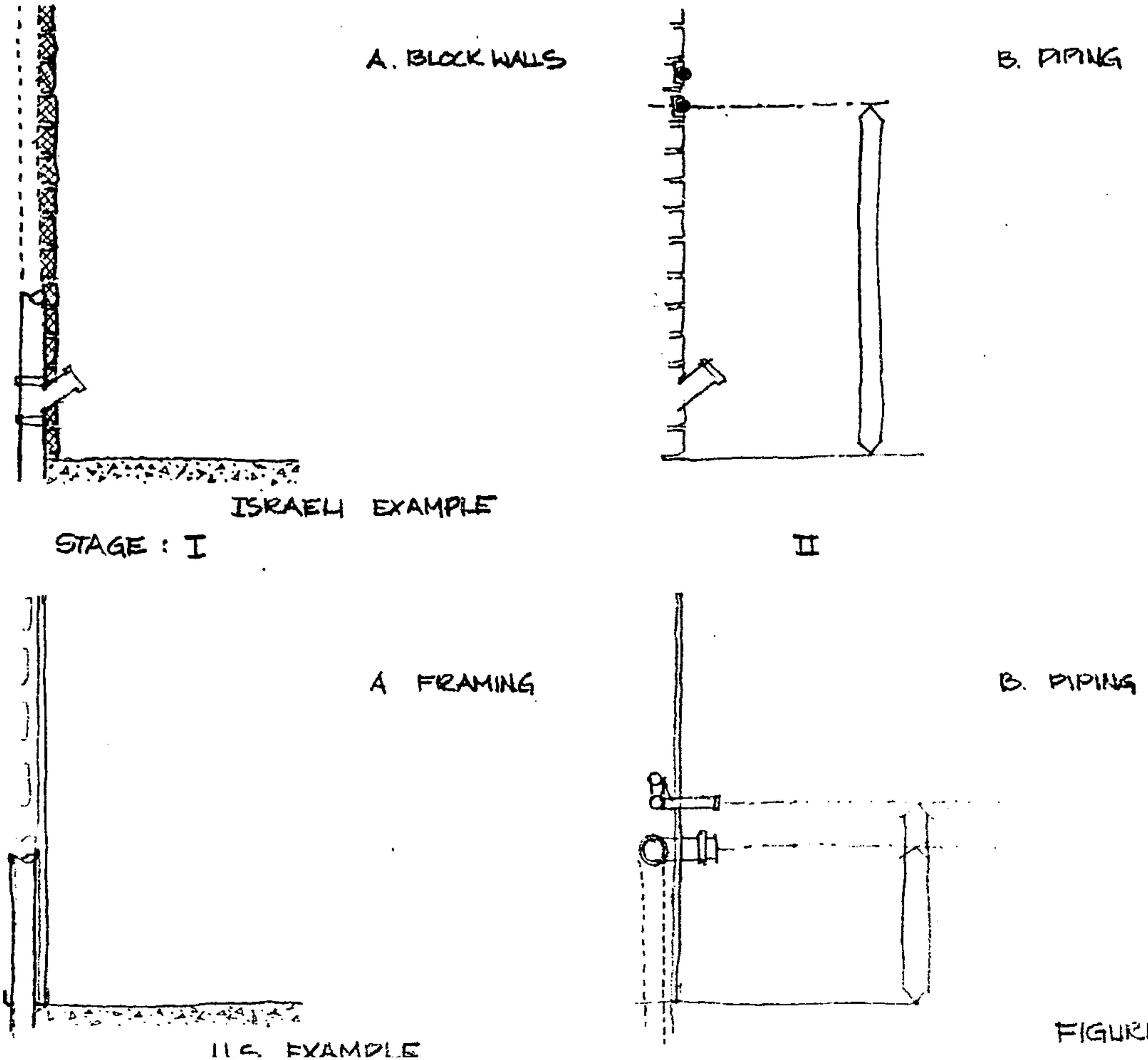

A. BLOCK WALLS
B. PIPING
ISRAELI EXAMPLE
STAGE : I
II
A FRAMING
B. PIPING
U.S. EXAMPLE

FIGURE 3.3.1

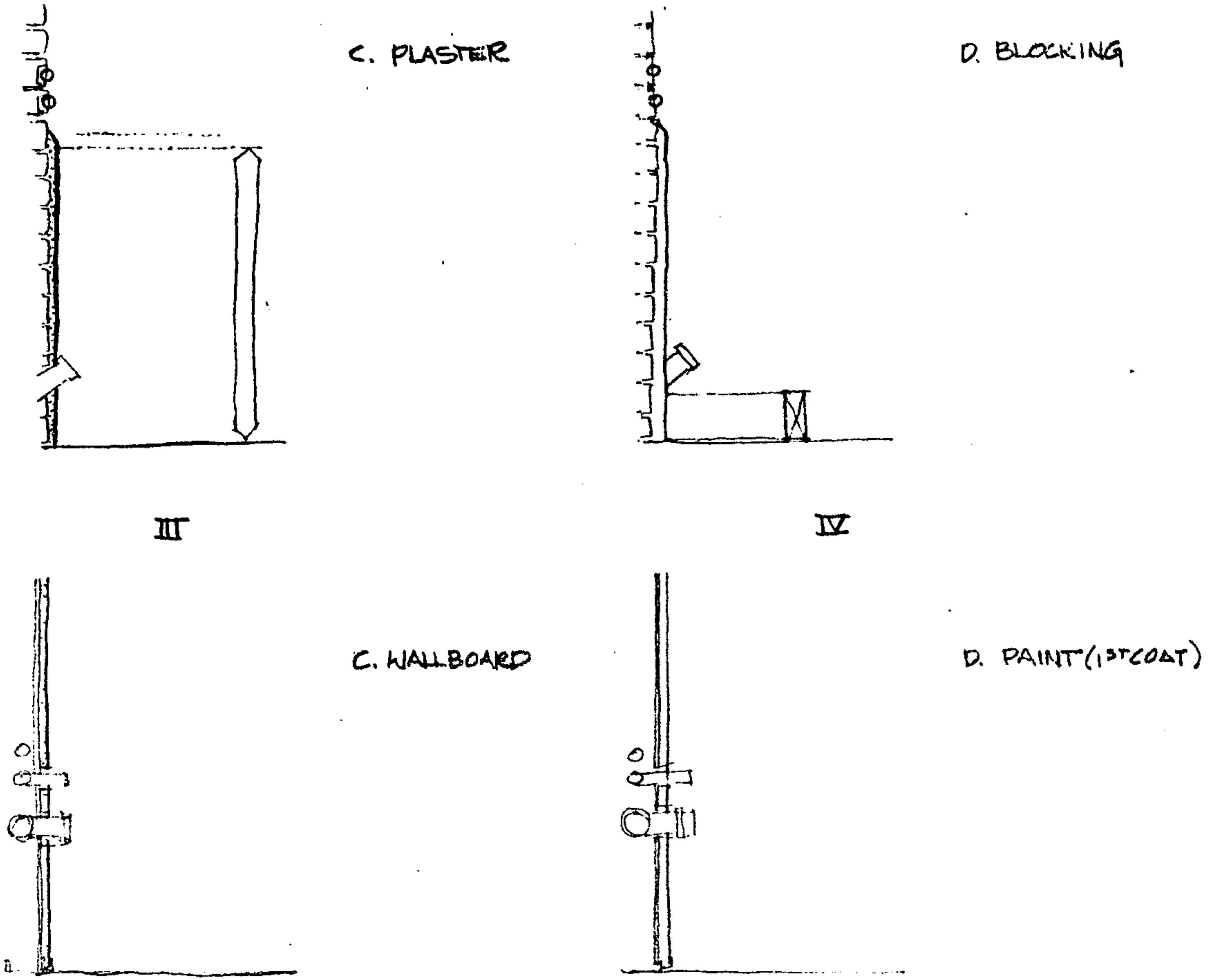
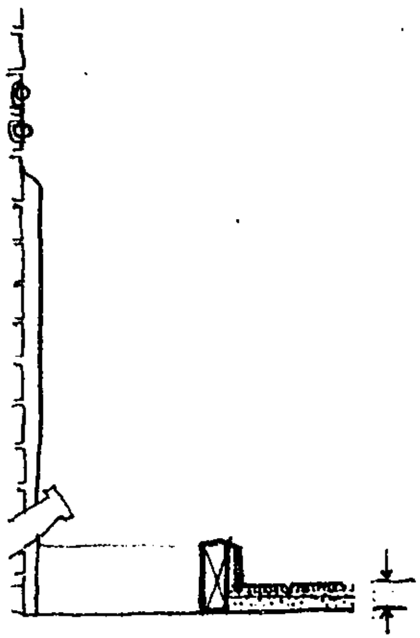
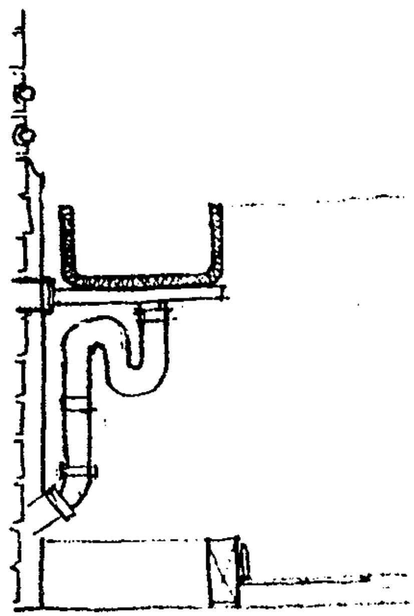


FIG 3.3.2



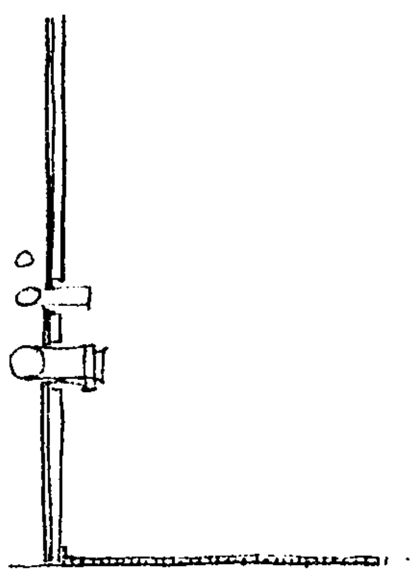
E. FLOOR TILE

F. BASEBOARD

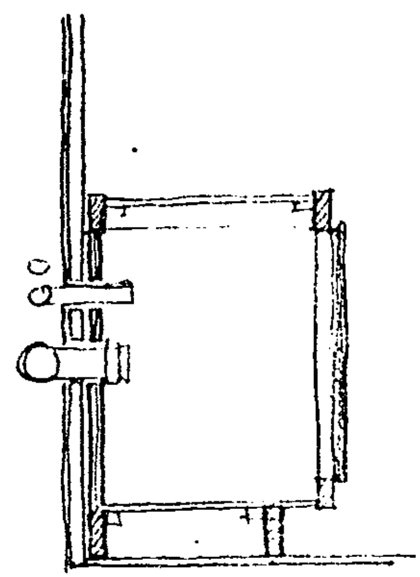


G SINK (PIPE SUPPORTS & HOOK-UP)

V

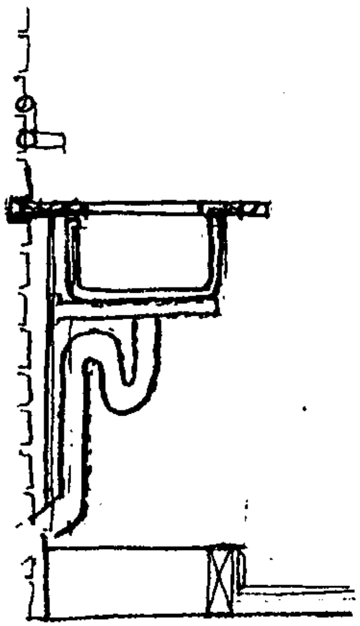


E FLOORING

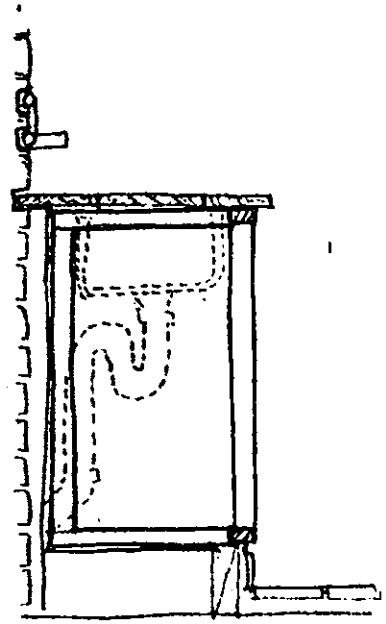


F CABINET

FIG. 3.3.3



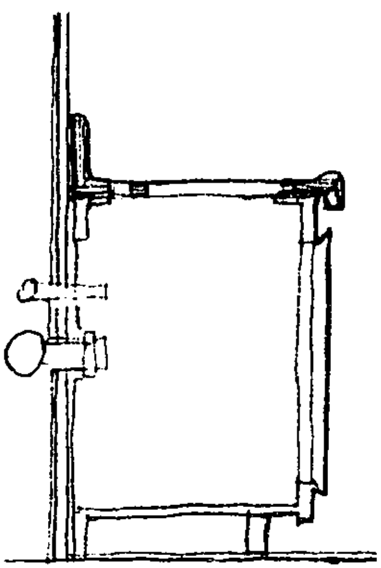
H COUNTERTOP



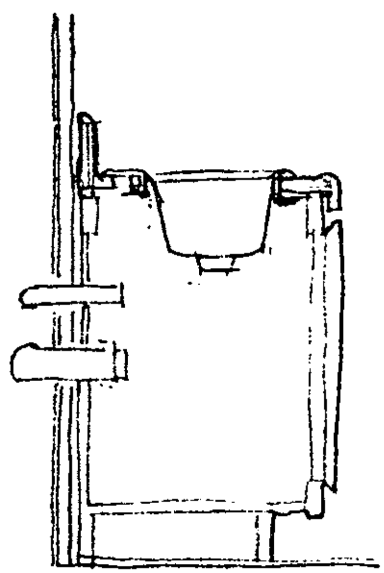
I CABINET

VII

VIII

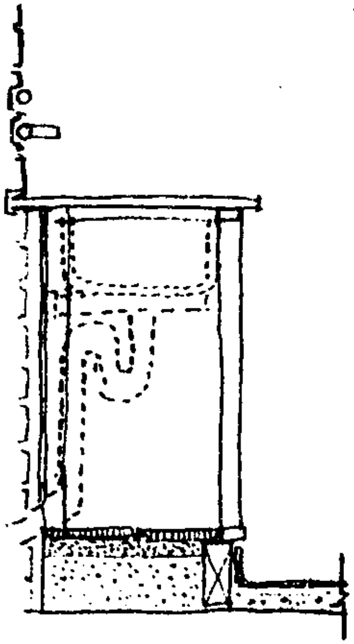


G COUNTERTOP

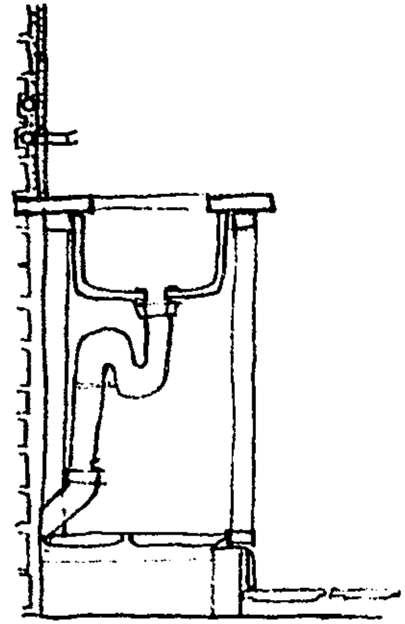


H SINK

FIG. 3.B.4



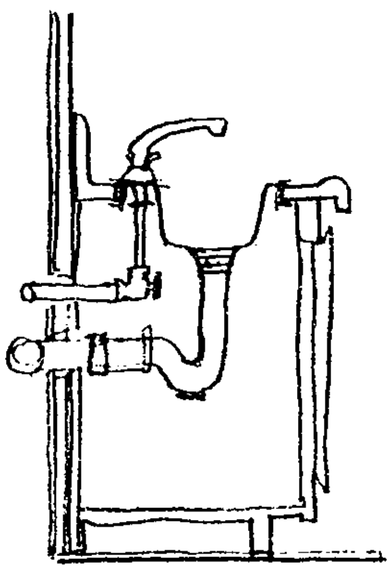
J CABINET FLOOR TILE



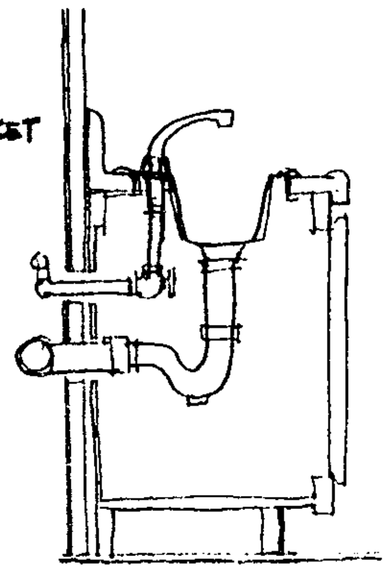
K CERAMIC WALL TILE

IX

X

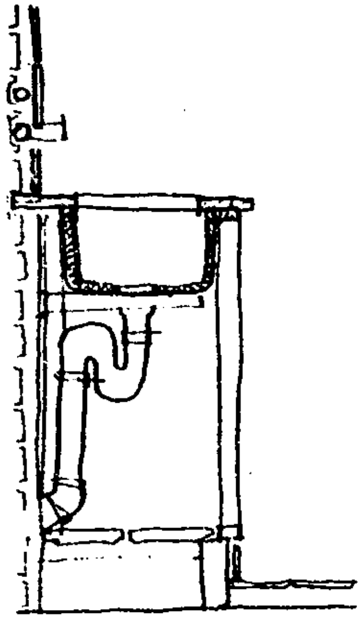


I HOOK-UP SINK & FAUCET



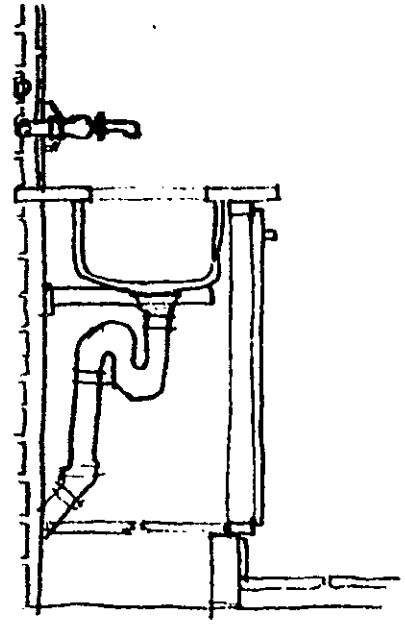
J PAINT (2ND COAT

FIG. 3.3.5



L PLASTER TOUCH-UP

XI



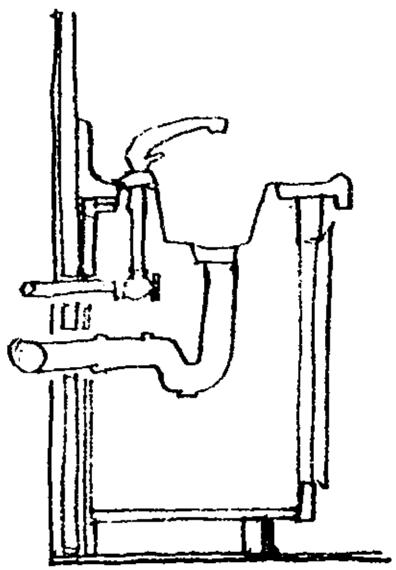
M. WHITEWASH

N. LACQUER

O. FAUCET

P. CABINET DOORS (RE-FIX)

XII



K BASEBOARD

FIG 3.3.6

FUNCTIONS

Finish construction materials and methods may bring housing structures to a point at which the dwelling is ready for occupancy. A range of facilities are commonly provided to satisfy user requirements such as storage, work surfaces and sanitary fixtures, aside from the basic shelter needs of protection, privacy, security and environmental comforts. Kitchen cabinets are an example of a type of building fixture which provides several functions such as storage, many of which are also provided by furnishings, but which is permanently installed in the building.

The primary functions of kitchen cabinets are to support and house kitchen lavatories, to conceal their drain pipes (and supply pipes in the U.S.), to provide a cleanable water draining work surface, and to provide storage facilities in the form of cabinets and drawers. Kitchen cabinets in the U.S. also are used to house cooking stoves, ranges, and other appliances, and are standardized for this purpose.

Much of the demands imposed upon the materials are based upon protection from water. Countertops are required to be drainboards, and as such the back wall must be protected from water penetration at the connection to the countertop. Likewise, the cabinet base must be protected from water when the kitchen floors are mopped. Methods of washing down the floors are different, with the Israeli tile floor subjected to more standing water since they are actually washed down, whereas most U.S. kitchen floors are sponge-mopped.

The two examples of cabinet construction are in appearance quite similar and frequently U.S. cabinets are found in the same configuration as the Israeli: two cabinet bays on each side of a central wash basin with a continuous countertop bridging the three segments. However, while this unit is the only cabinetry commonly found in the Israeli kitchens, other wall cabinets and range and oven cabinets of the same materials would also be found in the U.S. example.

The greatest departure between the two systems is due to the industrialized pre-fabrication of standard systems to receive any type of kitchen appliances which are likewise designed to be incorporated in the cabinetry. This systemic concern is responsible for the dimensional and material standardization of cabinetry in the U.S. rather than solely as a means of housing washbasins, although this was the original concern.

At one time, and in a few instances still, kitchen cabinetry in this country was custom built on site, more comparable to the on-site fabrication of cabinets in Israel. But the overwhelming prevalence of pre-fabricated stock cabinets and the usage of the same materials for custom cabinets are the reason that this comparison should consider the stock pre-fabricated cabinets as the U.S. example.

KITCHEN CABINET - UNITED STATE EXAMPLE

In the United States, the term "kitchen cabinets" refers to a system of prefabricated cabinet and countertop assemblies within which are housed all fixed appliances, services and storage units found in the kitchen. There are two basic types of cabinets manufactured for installation on site: wall cabinets and base cabinets. Wall cabinets are primarily storage units, which may also be designed to house range hoods with exhaust fans. Base cabinets are floor units which support countertops and are specifically designed as sections for storage, to house sinks, ranges, ovens, dishwashers, or garbage compactors. Special corner sections and end units enable combinations of base cabinets to be assembled to any configuration with a single section of countertop set atop each line of cabinet base units.

The type of cabinet chosen for this analysis, the kitchen sink base cabinet, is the most common of all cabinet base units in U.S. kitchens. For purposes of comparison, we shall assume the cabinet to be isolated, not connected to other-function cabinets, such as corner-units or range-units. Although such combinations are very common, the process of constructing combined installations is not significantly different from the installation of a single unit. Thus, this particular example is representative of cabinet installations in general.

The sink base cabinet is directly comparable in form to the Israeli cabinet example, and for these reasons may be considered a suitable example for comparison in this isolated configuration.

The cabinet is assumed to be placed within a building with interior partitions, constructed of metal stud framing, sheathed with gypsum wall board. Plumbing supply and waste lines are run within the wall cavity to the designated location of the sink. The floor system is assumed to be concrete with vinyl tile finish flooring. These materials are typical of most multi-dwelling buildings presently constructed in the U.S.

FORM

The finished form of a kitchen cabinet composed of a sink base cabinet unit is essentially no different from other types of base units, since dimensions are standardized. The sink itself is installed with a continuous countertop, and this is the only evidence of difference between this and other types of cabinet base units.

Standard prefabricated cabinet bases form a box of standardized dimensions: 34 1/2" (876 mm) in height, 24" (610 mm) in depth, and of widths ranging from 54" to 84" (1,372 mm to 2,134 mm), in increments of 6" (152 mm).* Each cabinet unit has a 4" (102 mm) toe-space recessed 3" (76 mm) from the cabinet face.

A 3/4" (19 mm) thick countertop with an integral 4" (102 mm) backsplash rests on the cabinet, shimmed to a finish height of 36" (914 mm). The

---

*Sink and range base cabinets are of the same dimensions, other base cabinets have the same height and depth (34 1/2" (876 mm) x 24" (610 mm) and range in length in increments of 3" (76 mm) from 24" to 48" (610 mm to 1,219 mm), single door and drawer units from 12" to 24" (305 mm to 610 mm). (Ching, p. 9.20) sink itself is fitted into a hole cut in the countertop, with a flange on all sides concealing the hole and supporting the sink. The faucet is affixed to a back flange of the sink. Countertops are rounded in profile, with curved edges at the front, over the top of the backsplash and at the inside juncture of backsplash and drainboard surface. A square profile is also available, with square edge strips over blocking at the front, and square backsplash edges. In this instance a small (roughly 1/4" (6 mm) metal cove trim is placed at the inside edge of the backsplash.

Most often the floor and wall by the cabinet are undifferentiated from other areas in the room. The floor is commonly vinyl asbestos tile, and the wall is painted gypsum wallboard, though vinyl wallcovering may be substituted for paint or plastic laminate or ceramic tile with organic adhesive may be placed on the wall behind the countertop.

ELEMENTS

In order to examine the effect of joint details on the process of construction of the kitchen cabinet assembly, the elements which are necessary to complete the assembly must be identified. The section which shall be examined may be imagined to be taken through the wall and floor structures just including the face of the metal studs and the concrete floor surfaces, and from a point above the backsplash to a point on the floor beyond the face of the cabinet, as shown in Figure 3.4.

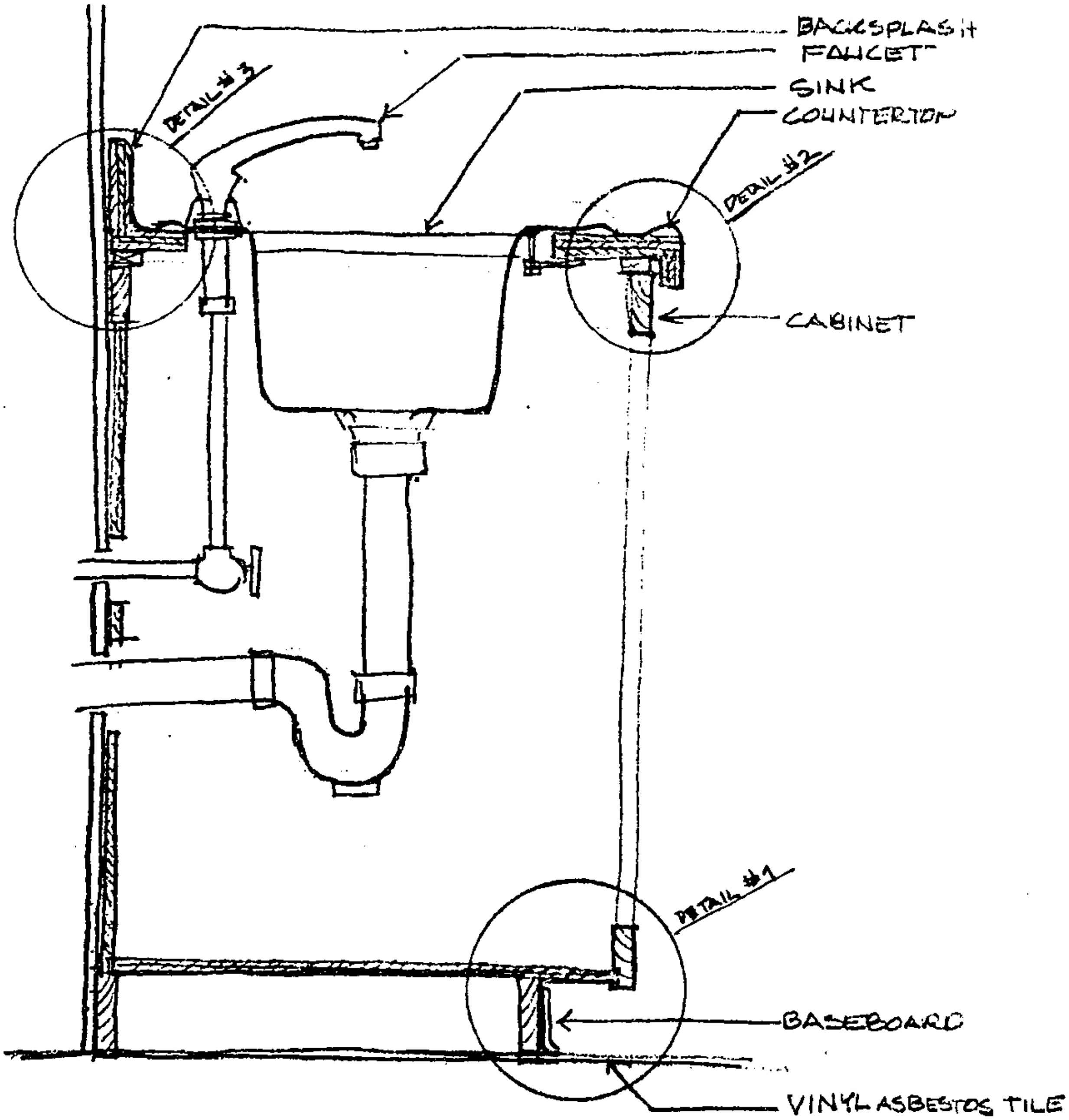


FIG 3.4
U.S. KITCHEN CABINET : SECTION

The elements pertaining to the kitchen cabinet assembly are listed in Table 3.1.

The manner in which these elements are brought together is shown by the details, located on the section in Figure 3.4. Detail #1 shows the front edge of the cabinet, at the toestrip. Three elements are represented in this detail:

1. Vinyl asbestos floor tile, set on the concrete floor.
2. The cabinet base, with the toe strip bearing upon the tile while the front frame position, in respect to the toe-strip, creates a reveal, shadowing the edge at the tile.
3. The resilient base, which covers the edge between the toestrip and the tile and protects the toestrip.

Detail # 2 is taken at the front edge of the countertop, and shows the interface between it and the cabinet. This juncture may be shimmed up to 3/4" (76 mm) to achieve a flush fit between this section of countertop and other sections, which would commonly be the case, as when cabinets are installed against two walls. The juncture is shown to be hidden from view by the overhanging edge strip.

Detail #3 includes the interfaces of the cabinet back and countertop backsplash to the wall board, as well as the interface between the

TABLE 3.1

ELEMENTS OF THE U.S. KITCHEN CABINET ASSEMBLY

Concrete floor - Cast in place or pre-cast hollow core plank patched and smoothed, if necessary.

Face of wall framing - Metal studs, top and bottom plates. Steel or aluminum "C" or channel shapes, commonly 1 5/8" (41 mm) x 3 5/8" (92 mm), of 18 gauge thickness, spaced 16" (406 mm) or 24" (610 mm) on center. Fixed with self-threading sheet metal screws. The section shall include the face of the 1 5/8" (41 mm) part of the studs.

Plumbing services - Hot and cold supply lines (usually copper), drain lines (cast iron or p.v.c.). Included in the section are fixture run-outs, which emerge from fixture branches or stacks within the cabinets of the stud wall.

Wallboard - Gypsum dry wall sheathing, commonly 1/2" (13 mm) thick, in 4' x 8' sheets (1,219 mm x 2,483 mm), affixed to metal studs with self-tapping sheet metal screws, finished by taping and floating at joints, screw heads "spackled" by smoothing with compound.

Vinyl asbestos tile flooring - Commonly in 9" x 9" (229 mm x 229 mm) tiles, 1/8" (3 mm) thick, applied directly to concrete floor with adhesive.

Cabinet - Prefabricated of hardwood and plywood, 34 1/2" (876 mm) x 24" (610 mm), 72" (1,829 mm) in length, resting on flooring, screwed through wallboard to studs, all exposed surfaces are pre-finished, and hardware is either affixed at delivery or enclosed, with holes drilled to receive it.

Countertop - Prefabricated, of 3/4" (19 mm) plywood for drainboard and backsplash, rounded wood forms and blocking at edges, with entire top surface covered by 1/16" (2 mm) plastic laminate, post formed and thermosetted to countertop at the factory; precut to desired length, and ends covered with laminate. Sink holes may be precut as well, but for this example we assume that it is cut on site. Shimmed and fixed to cabinet with screws, pre-finished.

Kitchen sink - Stainless steel, 2'8" x 1'8" (813 mm x 508 mm) with flange on four sides at top, wider flange at back with holes prepunched for faucet. Fixed to cabinet with clamps from underneath.

TABLE 3.1 (continued)

Service hook-ups - Copper drain trap, electric waste-disposal unit affixed to sink and drain line, copper supply lines and fixture shut off valves installed under sink, faucet and escutcheon affixed to sink flange.

Paint - 2 coats on floated and spackled wall board.

Baseboard - Vinyl resilient base, with rounded cove-bottom edge, fixed to cabinet toestrip with adhesive.

countertop and the cabinet, corresponding to that in Detail #2.

The fixation of the sink to the countertop is shown in Detail #4. A flange extends on four sides of the sink, and covers the countertop by about 2" (51 mm) around the hole, which has been cut on site. A bead of sealant or gasket is placed under a ridge in the flange at the outer edge, and when the sink is clamped to the countertop from below, a waterproof juncture is created.*

Since the services are supplied from below the sink, the cabinet serves as a box, hiding the connections for plumbing supply and drain lines. These lines emerge from the wall cavity, through holes roughly cut in the wallboard. Likewise, the back of the cabinet is cut out where the pipes are to be passed through, and since all is to be hidden, little concern is needed for pipe positioning or high quality finishing at the wallboard and cabinet back.

The faucet installation is shown in Figure 3.5. Holes are precut in the sink flange, and an escutcheon is clamped over a waterproof gasket, covering the nuts on the top, so no special care is needed to obtain proper fit or closure.

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*An alternative method of fixing sinks to countertops is used with porcelain enameled, cast iron sinks, mounted to countertops, as with bathroom washbasins in vanity cabinets.

A special trim piece clamps the sink to the countertop, and the juncture is concealed by a double flange on the clamp itself. This device secures and supports the sink and provides a waterproof seal at the edge. This part has a relatively low tolerance, in that the hole which has been cut in the countertop must be within about 1/4" (6 mm) of the design dimension at each edge (overall 1/2" (13 mm) across the width of the opening). However, in most instances where this type of fastening is used, the hole has been pre-cut at the factory to an accurate dimension.

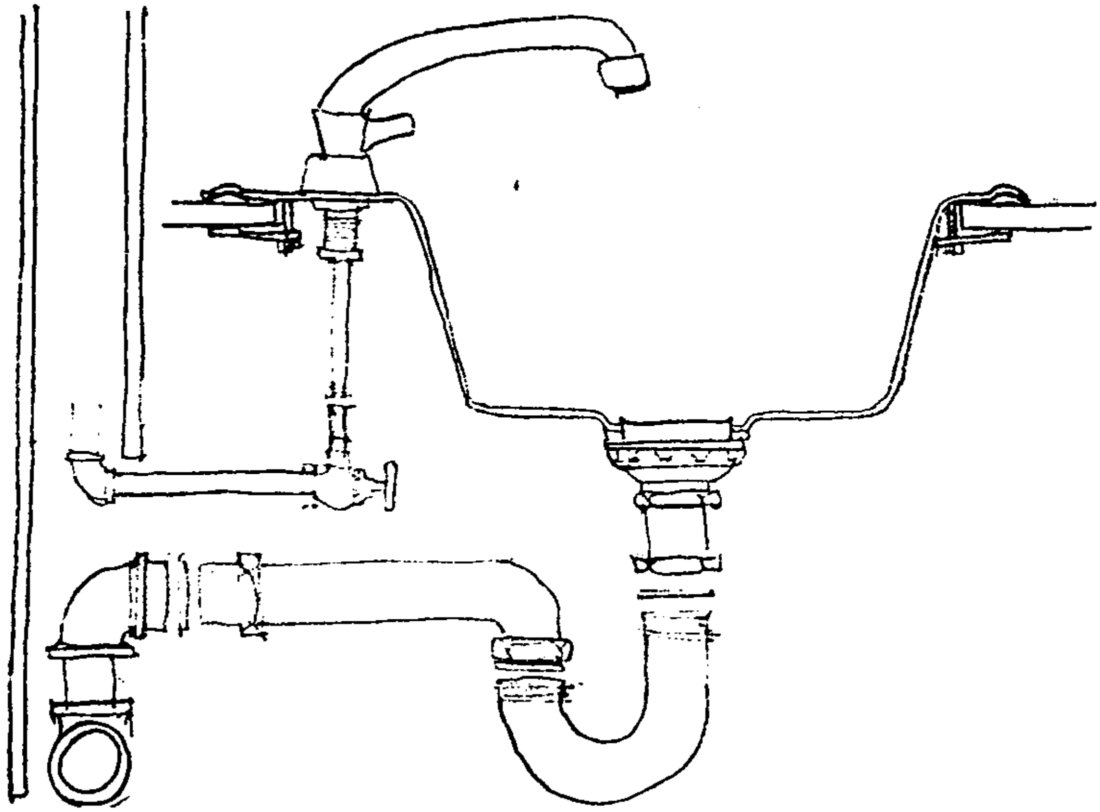


FIG. 3.5
U.S. KITCHEN CABINET : SERVICES

PROCESS

The process of installation of U.S. kitchen cabinets is straightforward, with little special attention needed on site for placement of components. Certainly this is due in great part to the fact that the cabinet and countertop are pre-fabricated and pre-finished, such that these two elements are almost complete upon delivery, and in this respect bear more a resemblance to furnishings than to the building fabric itself. The only alterations of material dimension (either by build up or substitution) are to be found in cutting the countertop for the sink, and shimming the countertop to fit where it joins another section.

The countertop hole is easily determined, simply by centering and placing the sink upside down on the countertop and scribing its outline, to be cut with a power jigsaw. The other adjustment, that of shimming the countertop up from the cabinet, serves to correct any irregularities in the floor surface that might cause two or more base cabinets to rest unevenly. The juncture to be shimmed will be hidden beneath the countertop, behind its edge strip. Irregular alignment of cabinet units will cause little visibly apparent discrepancies in terms of lines or edges out of parallel, for the overhanging edge of the cabinet acts as a reveal, removing this line from direct visual association from others. However, these alignments of cabinet units are accommodated by shims under the bottom members (the edges being hidden by the resilient base).

All matters of positioning are self evident, in that components are placed on or adjacent to previously placed components. The cabinet is set on the floor, against the wall. Its position is not rigidly defined since the position of the plumbing lines, with respect to the cabinet back, is not a matter of concern. No difficulties will arise so long as they are within about ± 1' (300 mm) of either side of the center line of the sink. There is nothing on the wall or floor planes that affects the position of the cabinet, and its placement is thus determined by the room plan.

The sequence of activities leading to the completion of the kitchen cabinet installation is described in the following summary, Table 3.2. Each activity is associated with the installation of a component, such that the influence of each component upon the process of installing another may be examined.

In Table 3.2, the components and the trades involved (in parenthesis) are listed on the left, and the corresponding activities associated with interfaces to preceeding components are shown on the right.

In order to effectively illustrate the interdependence of components, a direct sequence of activities has been chosen, as described in Table 3.2. This sequence of activities is also shown in Figure 3.6 as a diagonal line of boxes. Each activity is associated with a component, such that the component (G), Countertop, includes the activities of measuring and cutting the hole for the sink, aligning the countertop to the desired height, and fixing it with screws to the cabinet.

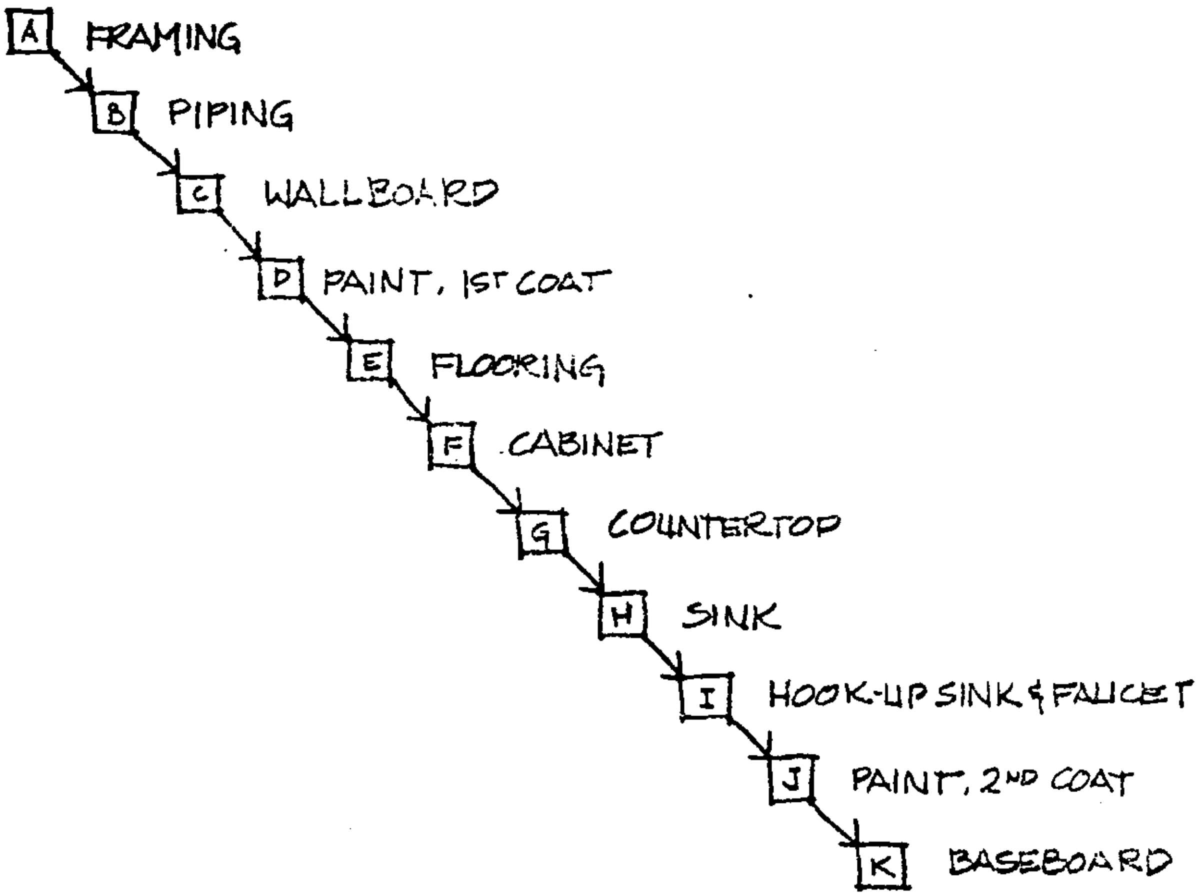


FIG. 3.6
U.S. KITCHEN CABINET : SEQUENCE OF COMPONENTS

TABLE 3.2

U.S. KITCHEN CABINET: SEQUENCE OF ASSEMBLY

Component	Activity Description
A. Framing (carpenter)	Located by measuring and laying out from plan, accurately placed, all other measurements from plan depend upon wall placement.
B. Piping in wall (plumber)	Interface: framing Hot and cold water pipes, drain pipe are run within space between studs of framing, and through holes punched in metal studs. Location of outlets, points where pipes are brought forward to fixture locations are measured from plan.
C. Wallboard (drywaller)	Interface: framing Gypsum wallboard sheets fastened to face of studs with self-tapping metal screws, position is evident. Tape and float with joint compound closes junctures, screwhead are spackled.
	Interface, piping Wallboard is cut out around pipes at points where they emerge from plane of stud face, measured and marked from their actual position.
D. Paint, 1st coat (painter)	Interface: wallboard (nominal) Painted overall with alkyd latex.
E. Flooring (floorer)	Interface: wallboard Resilient, vinyl asbestos tiles laid over floor to beyond cabinet position.
F. Cabinet (carpenter)	Interface: wallboard Location measured from plan, placed flush and fixed to wallboard and studs with screws.
	Interface: flooring Rests on flooring, may be shimmed if necessary.
	Interface: piping Holes cut in back of cabinet at location of pipes.

G. Countertop (carpenter)	Interface: wallboard Countertop backsplash set flush with wall. Interface: cabinet Shimmed to achieve height, fixed to cabinet top after wall fit verified. Subsequent interface: sink Countertop is cut out to receive sink prior to installation. Position measured to center line, hole is scribed from template or sink itself.
H. Sink (plumber)	Interface: countertop (with trim) Trim/clamp covers top edges of each, is tightened from below to clamp in place.
I. Hook-up sink and faucet (plumber)	Interface: sink Faucet is affixed through hole pre-cut in sink flange, covered by escutcheon. Interface: piping (nominal by connection) Within cabinet, faucet lines and valves connected, drain lines connected to trap.
J. Paint, 2nd coat (painter)	Interface: 1st coat of paint (nominal) Applied up to edge of backsplash.
K. Baseboard (floorer)	Interface: cabinet Applied to toe-strip of cabinet, at sides and to wallboard elsewhere, position is evident. Interface: flooring Cove base, resiliency seals edge between cabinet and flooring, creates waterproof joint.

There are several opportunities for alternative sequences of operations in the process of constructing kitchen cabinets. The first such opportunity has already been mentioned: when a hole in the countertop may be cut for the sink. There are three choices regarding the time when this may be done.

The first choice is to have the hole cut at the factory. Besides reducing the number of on site operations, the risk of cutting the hole in the wrong place or of cutting too large a hole is placed upon the material supplier, rather than on the installer. Naturally, if the hole is to be pre-cut, the counter itself is assumed to be pre-cut to length. There exists the possibility of on site cutting of countertops to lengths needed, which might be desirable if many different cabinet lengths and configurations are to be found within a project.

The second and third alternatives exist when the holes are to be cut in the countertop on the site, either before or after the countertop is installed. This may be of advantage not only when the countertops themselves are to be cut to length, but if some counters are to have different types of sinks, or some not at all. Leaving the countertop uncut also avoids having to make an early commitment as to type of sink, size, or style, whether the sinks are to be affixed with edge strips or by their flanges.

Another opportunity for choice in the assembly sequence is whether to install the sink in the countertop after the installation of the countertop on the cabinet, or to affix it before. This choice is more a question of convenience and storage than any other factor. If sinks were to be installed into several countertops at a time, in one location, then to be carried to various kitchens, the storage and handling of such assemblies might create more problems than group production would solve. This opportunity for choice serves primarily to illustrate the lack of any dependencies other than between the two elements themselves. The faucet may be installed and trap, drain and supply lines may be connected at any time after the sink is installed.

There are alternative positions in sequence for painting as well. Factors to be considered include: ease of work, affected by the number of obstacles, in this case, the cabinets; the need to protect and clean up surfaces afterward; a risk of damaging a previously completed operation, such as the first coat of paint, in subsequent operations.

Painting may proceed as soon as the wallboard is taped and floated and nail heads spackled. Only the installation of baseboards may be considered to be contingent upon the completion of painting, but even this is not a stringent requirement, since it would save only the operation of cleaning the baseboard.

The simplest, most direct choice would be to paint both coats immediately after the wallboard is finished, before flooring is placed. No clean up would then be necessary, but it is almost certain that some scratches and marks would be incurred while moving the cabinets and countertops into position, as well as smudges and dirt which would be expected with the number of trades to follow. Since painters would have to return for touch-up, the second coat may as well be delayed until after most of the other operations have been finished.

ANALYSIS

INTERFACE NETWORK

The process by which the components outlined in Table 3.2 are assembled and brought to interface is illustrated in Figure 3.7. At this level of detail, the operations to be performed are shown to be in direct sequence, reflecting the actual situation in which one trade at a time is able to work on the cabinet assembly.

Each component is placed with one or more relationships to preceeding components that are manifested by a physical interface between the two, determined from an examination of the detail. These interfaces are shown by the lines between components on the chart. Dotted lines denote an interface of a lower degree, which is not a fixed juncture, e.g. wallboard to piping. In this case the actual interface is through holes cut in the wallboard.

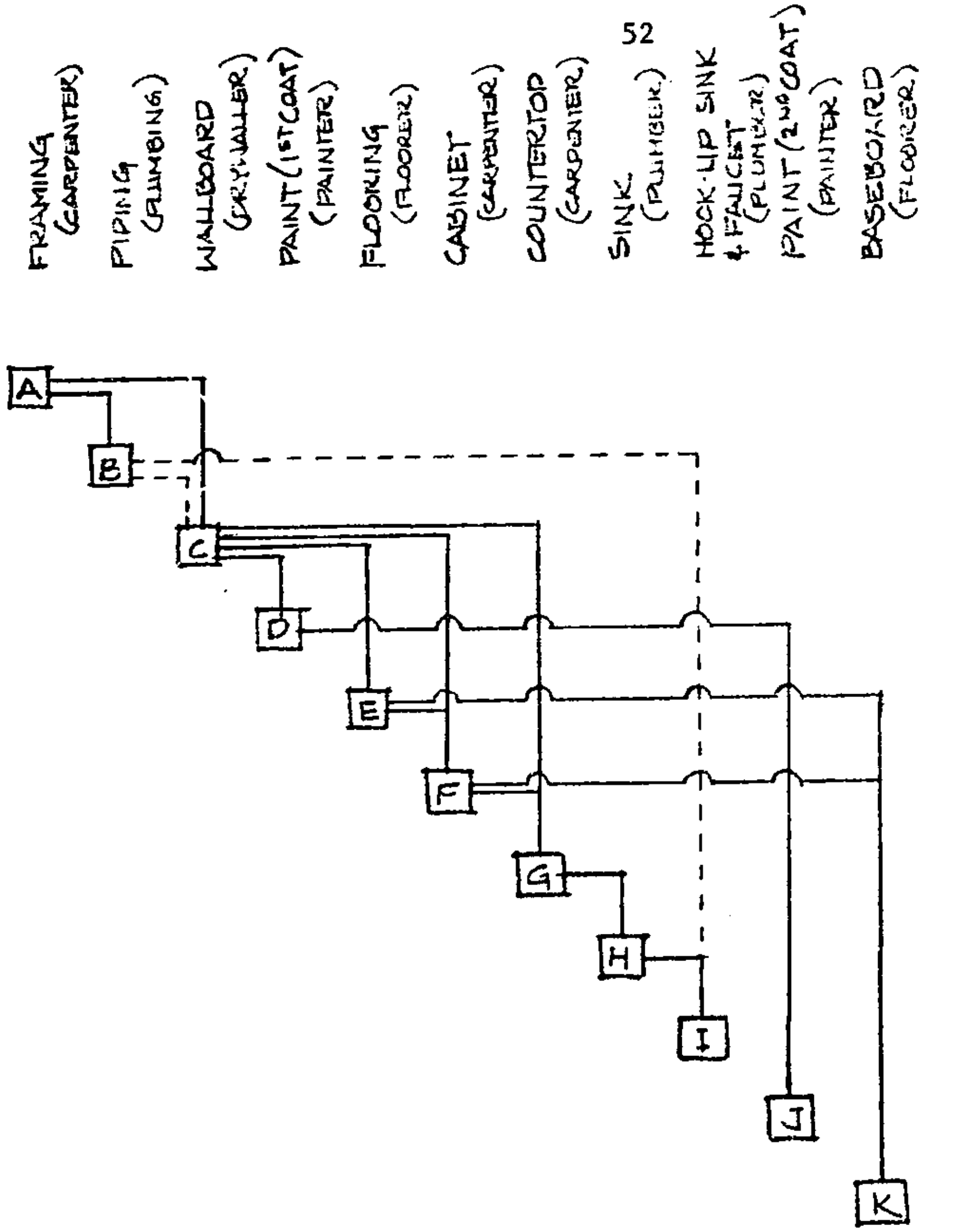


FIG. 3.7
U.S. KITCHEN CABINET : INTERFACE DIAGRAM

Eight of the eleven components illustrated have an interface with the immediately preceeding component. This is an indication of direct sequential placement of components, in which one element becomes the base for the next, which in turn receives another, and so on.

The three components which do not interface with directly preceeding components are: E flooring; J 2nd coat of paint; and K baseboard. Each of these elements has been shown to have a number of alternatives in terms of position in sequence, and only the baseboard is interdependent with another component, the cabinet, for its position, and this dependency is not critical because the position is evident, and there is ample room for placement.

The number of previously installed components to which a component must interface is an indicator of the degree of interrelationship that the element has to the assembly as a whole. If an element is brought to interface with a number of other elements, the possibilities for an improper fit are increased with the number of interfaces. The type of interface certainly affects the ability of a component to fit properly, and will be shown to also affect the number of interfaces necessary.

In the U.S. cabinet, no component is brought to interface with more than two preceeding components. Five components in the assembly interface with two precedent components, listed in Table 3.3. The two paint components, D and J are excluded from this interface analysis since their interfaces are nominal, having no material dimension.

TABLE 3.3

U.S. KITCHEN CABINET COMPONENTS

WHICH INTERFACE WITH MORE THAN ONE PRECEDENT

Component	Precedent
C. Wallboard	A. Framing B. Piping (low degree interface)
F. Cabinet	C. Wallboard E. Flooring
G. Countertop	C. Wallboard F. Cabinet
I. Hook-up sink and faucet	B. Piping (low degree interface) H. Sink
K. Baseboard	E. Flooring F. Cabinet

Two of these five components with more than one interface, wallboard, (C) and hook-up sink and faucet, (I), may be considered to be less important than the other three components. This is because in each case, one of the two precedent interfaces is of a lower degree, shown as a dotted line on the interface diagram, Figure 3.7.

The wallboard and piping interface, C/B, is of a lesser degree due to the manner in which the holes are cut, since they are concealed. Interface I/B, between hook-up sink and faucet and piping is also a lesser degree interface, also because the connections are adjustable, and concealed by the cabinet.

A possible difficulty arises when a component of stringent positioning dependencies, (either because of low tolerance, or a subsequently dependent component) must interface with a component that has been placed several stages earlier in the sequence. When a component has been improperly placed such that subsequent component placements are affected, the mistake may be found at the next succeeding component that interfaces with it. If several stages have been installed the possibility to correct such an error has been diminished, and the consequences of such a correction are greater than if other elements are not involved, such as with successive component interfaces.

Of the five components which interface with more than one precedent, three are significant since the other two have a lower degree interface with one of their precedents. The three component's interface conditions which are therefore representative of the highest degree of interrelationship in the cabinet assembly are:

1. Cabinet (F) interfaces: wall (C) and floor (E)
2. Countertop (G) interfaces: cabinet (F) and wall (C)
3. Baseboard (K) interfaces: cabinet (F) and floor (E)

Certainly the type of interface, and the positional dependencies associated with these interfaces greatly affect the nature of the component sequence and placements; these questions shall be examined in the following section.

ANALYSIS OF DETAIL

Three details, shown in Figures 3.8, 3.9 and 3.10 are significant in terms of having an affect upon the process of assembly of the cabinet:

1. Cabinet base at toe-strip
2. Front edge of countertop at cabinet
3. Cabinet and countertop at wall

The details will be examined in terms of the interfaces of the components represented, illustrated in Figure 3.7. The interfaces will be referenced by this format:

letter of component/letter of precedent.

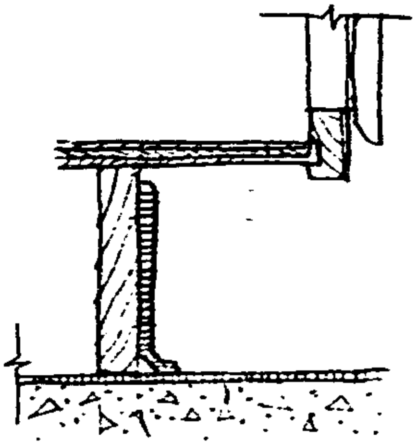
DETAIL #1

CABINET BASE AT TOE-STRIP

This detail shows the interfaces between components (F) cabinet; (E) flooring; and (K) baseboard. Interface E/F is the point upon which the cabinet bears upon the floor tile and the position of this juncture is determined elsewhere (by the interface of the cabinet and wall interface F/C). Since the cabinet may fall on any point on the plane of the floor tile, it may be said to be able to slip with respect to that plane. This type of joint interface will be referred to as a "slip plane," which may be defined as the juncture between two planes in which the interface is not constrained by the juncture itself. (This slip plane configuration would not exist if, for example, there were a notch or dado in the floor into which the cabinet were inserted.)

The baseboard component, (K) is affixed with adhesive to the cabinet toe-strip at interface K/F. Interface K/E is the point where the covered base of the resilient baseboard rests on the floor tile. A snug juncture at K/E is insured by the resiliency of the baseboard. This configuration is akin to a trim piece of moulding which is fitted into a corner. As in this case, the two faces of the baseboard are simultaneously placed against the two perpendicular planes of the corner. This may be called a "corner fit." In addition, a vertical slip plane exists at K/F, between the baseboard and cabinet toe-strip, which enables the "corner fit" to occur, with a tolerance of ± 1" (25 mm), though this tolerance would be needed only to allow shims to be placed under the cabinet, with the caseboard concealing the edge.

It should be noted in the interface network, Figure 3., that the (K) baseboard component is four components removed in sequence from the cabinet to which it is dependent for position. However, it may be seen from the detail that no other elements are dependent upon the baseboard, no measurements need be taken, and the fit is not constrained. If the flooring were to be placed after the cabinet, an alternative to the sequence here illustrated, the baseboard would be called upon to serve another function at this detail. If this were the case, the resilient tile would be placed up to the edge of the cabinet in the same manner it is placed up to the wallboard. As long as the edges were within 1/4" (6 mm), the cove case of the baseboard would conceal that juncture, as well as the edge of the base of the cabinet (E/F).



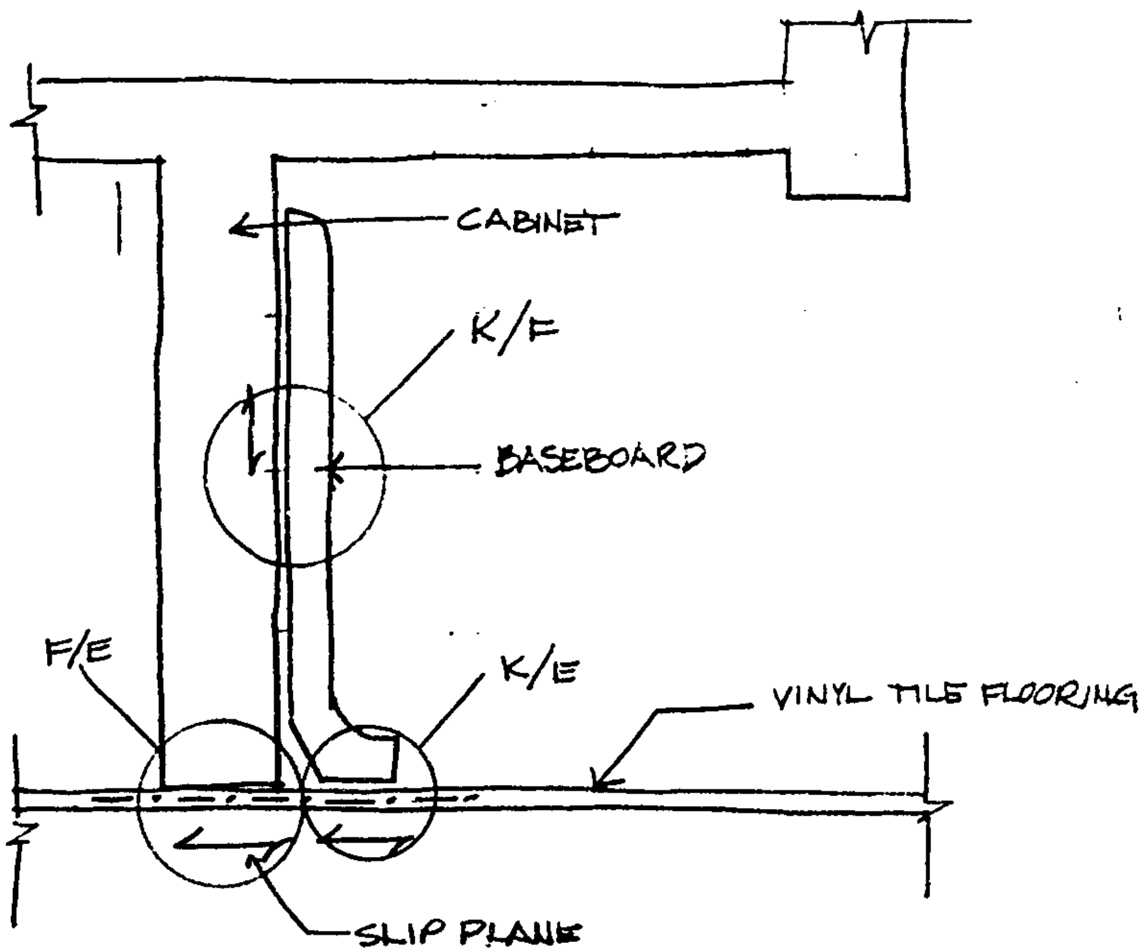


FIG. 3.8
DETAIL # 1
CABINET BASE @ TOE STRIP

DETAIL #2

FRONT EDGE OF COUNTERTOP

This detail shows the interface between countertop (G), and cabinet (F), see Figure 3.9. There is a direct sequence of placement of the countertop which is set directly after the cabinet is installed, as seen in the interface diagram, Figure 3.7. Both elements are pre-fabricated and the dimensions are thus coordinated to allow sufficient clearance. The interface F/G may be shimmed up to 3/4" (19 mm) to attain a finish countertop height of 36" (914 mm). The interface itself constitutes a limited slip plane in the horizontal plane of the bottom of the countertop.

Both cabinet (F), and countertop (G), are to be placed flush with the wall (C), as will be shown in Figure 3.10. The overhanging front edge strip of the countertop conceals the interface. The bottom edge of the countertop is brought forward from the cabinet and thus any differential position of the countertop with the cabinet is not visible. Since the countertop may in fact be positioned at any point with respect to the cabinet until the back of the edge blocking comes into contact with the top of the face of the cabinet, a tolerance of ± 1/2" (13 mm), the horizontal slip plane between the countertop and cabinet is "limited."

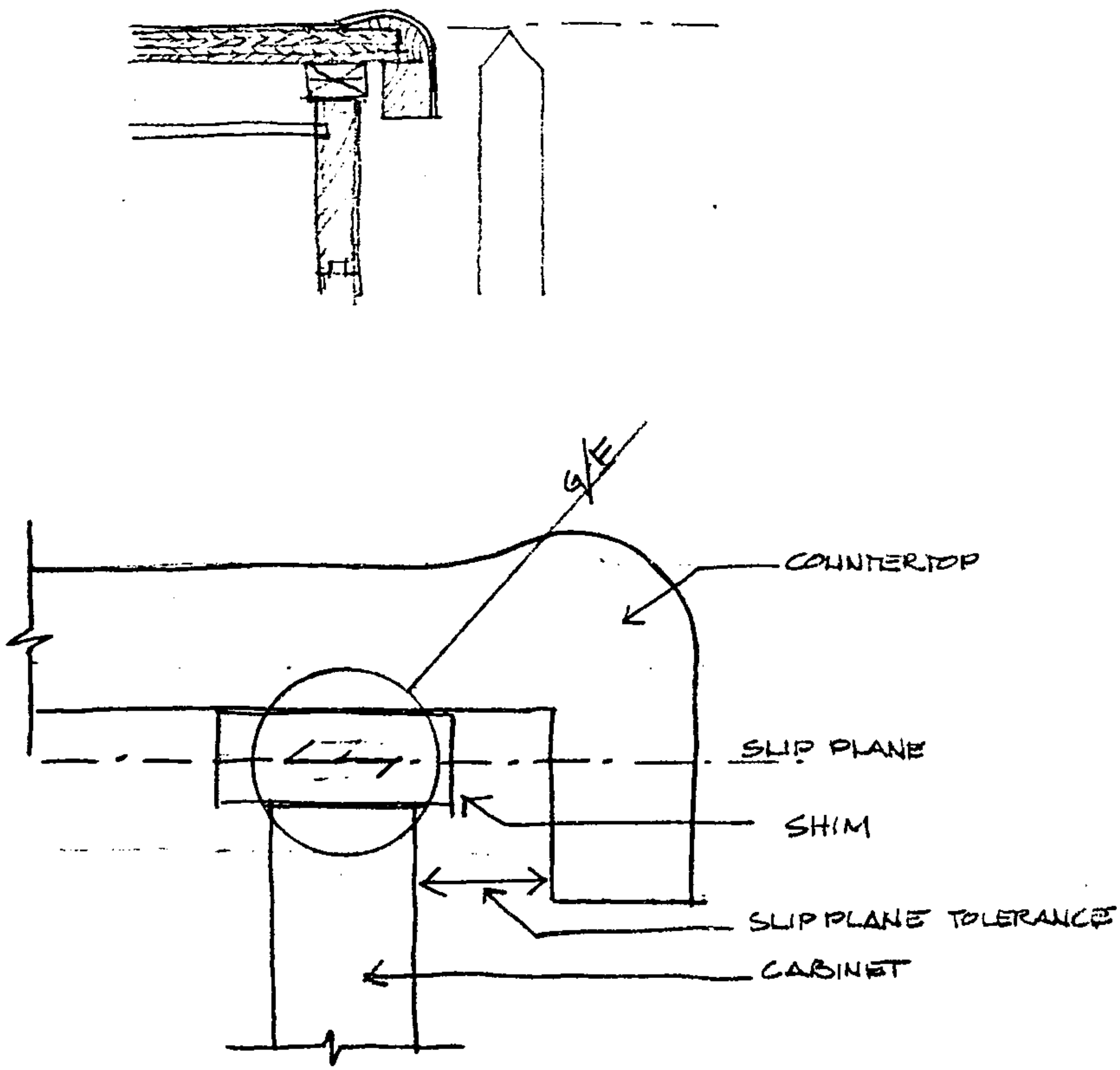


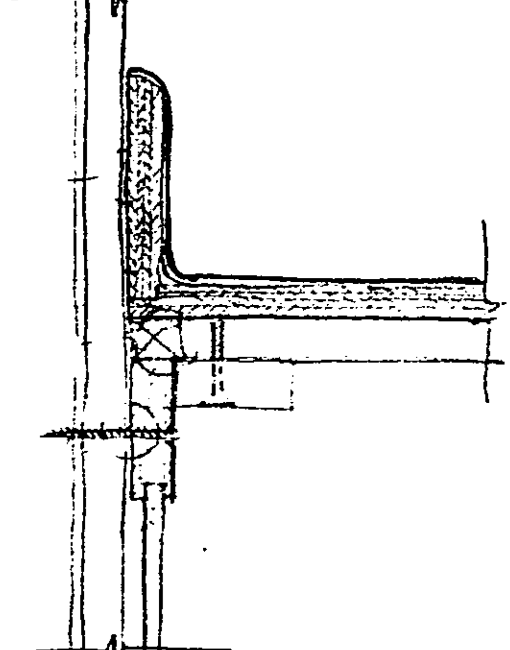
FIG. 3.9
DETAIL #2
FRONT EDGE OF COUNTERTOP

DETAIL #3

CABINET AND COUNTERTOP AT WALL

Detail #3, Figure 3.10, represents the interfaces between the wallboard (C), cabinet (F), and countertop (G). The positions for the cabinet and the countertop, and thus for the positions of the interfaces shown in Details #1 and #2, are determined by the junctures with the wall. The first interface to be performed is F/C. The cabinet is placed flush against the drywall and is screwed to the studs behind. The countertop is shimmed at G/F which corresponds to the same configuration in Detail #2. Interface G/C is a slip plane allowing for shim at G/F. After the back of the backsplash is placed flush against the drywall at G/C, as with the cabinet at F/C, the countertop is secured to the cabinet with screws from below.

As its name implies the backsplash acts as an upturned section of the countertop protecting the wall from water. The only visible edge between the kitchen cabinet assembly and the wall structure occurs at the top of the backsplash. Assuming that the wall is straight and since the straightness of the backsplash is assured by pre-fabrication, there is no difficulty in achieving a flush fit. The horizontal slip plane capacity ($\pm$ 1/2" (13 mm)) of the shims at G/F isolate interface G/C from the cabinet for the purpose of bringing the backsplash flush against the wall, and the vertical slip plane between the backsplash and wall, likewise, does not restrict the capacity of the countertop to be shimmed.



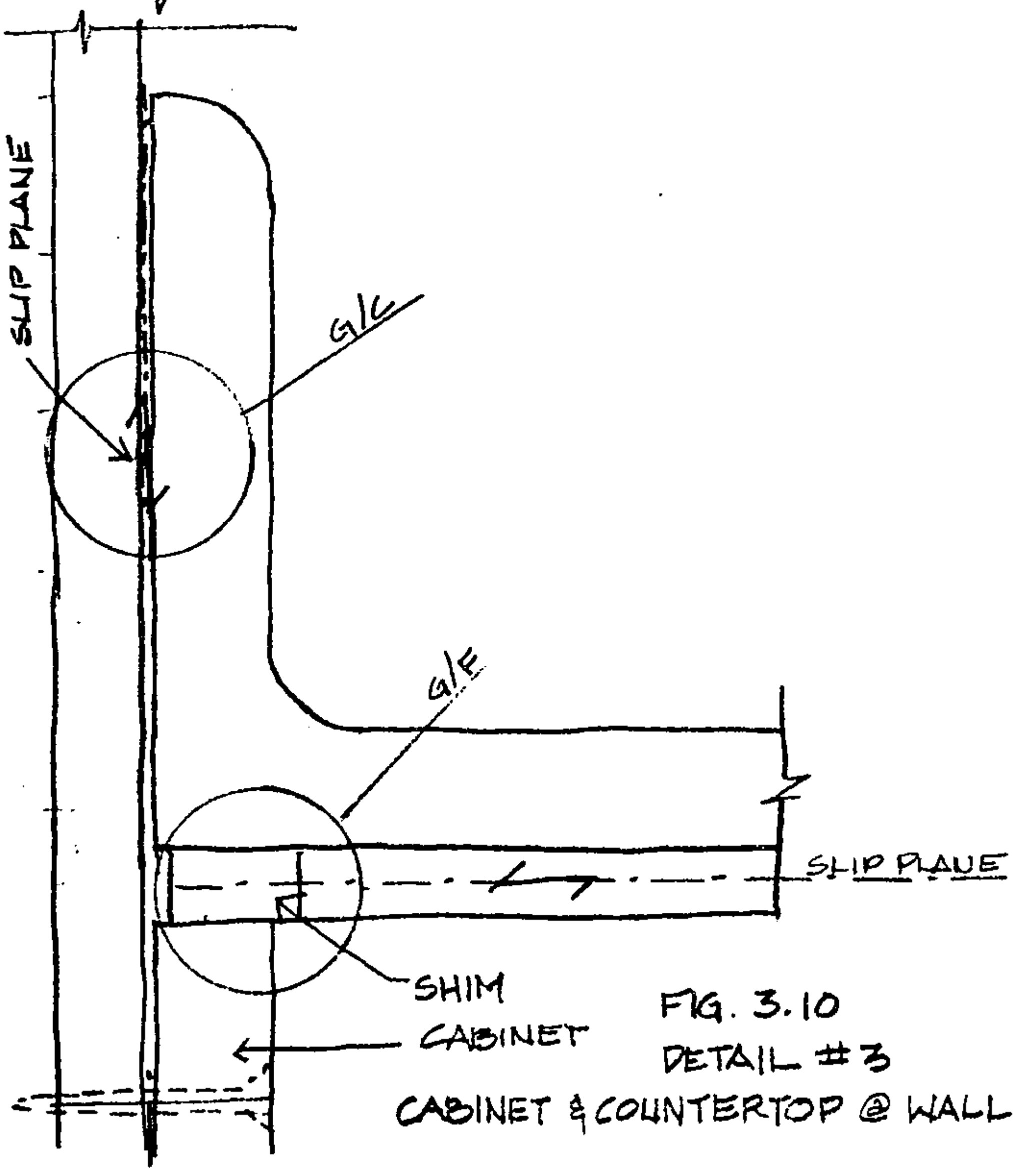


FIG. 3.10
DETAIL #3
CABINET & COUNTERTOP @ WALL

PLACEMENT/POSITION

It has been shown that in the U.S. the positions of components are dependent upon the position of those elements to which they are affixed, and that some details call for measurement from control lines in order to coordinate the placement of elements in the assembly.

Where components are sequentially placed, the position of each being dependent only on the previously placed component, positions are determined by the joint itself. This is generally the case in the American cabinet in which the only measurements take place to determine where the piping should emerge; and to verify the horizontal position of the cabinet along the wall - rough measurements in both cases. All other positions are determined by the components which have been placed on others of dependable position, due to the nature of the component or joint. For example, the wallboard, being pre-fabricated to constant thickness, serves as a vertical control plane and subsequently placed elements fixed to it depend upon its accuracy.

The positional dependencies and horizontal and vertical measurements are depicted in Figure 3.11. The lines below the diagonal sequence of activities represent the components on which each component is dependent for position. Each line also exists as an interface on the interface diagram, Figure 3.7, since the position is determined by the physical interface with a precedent component.

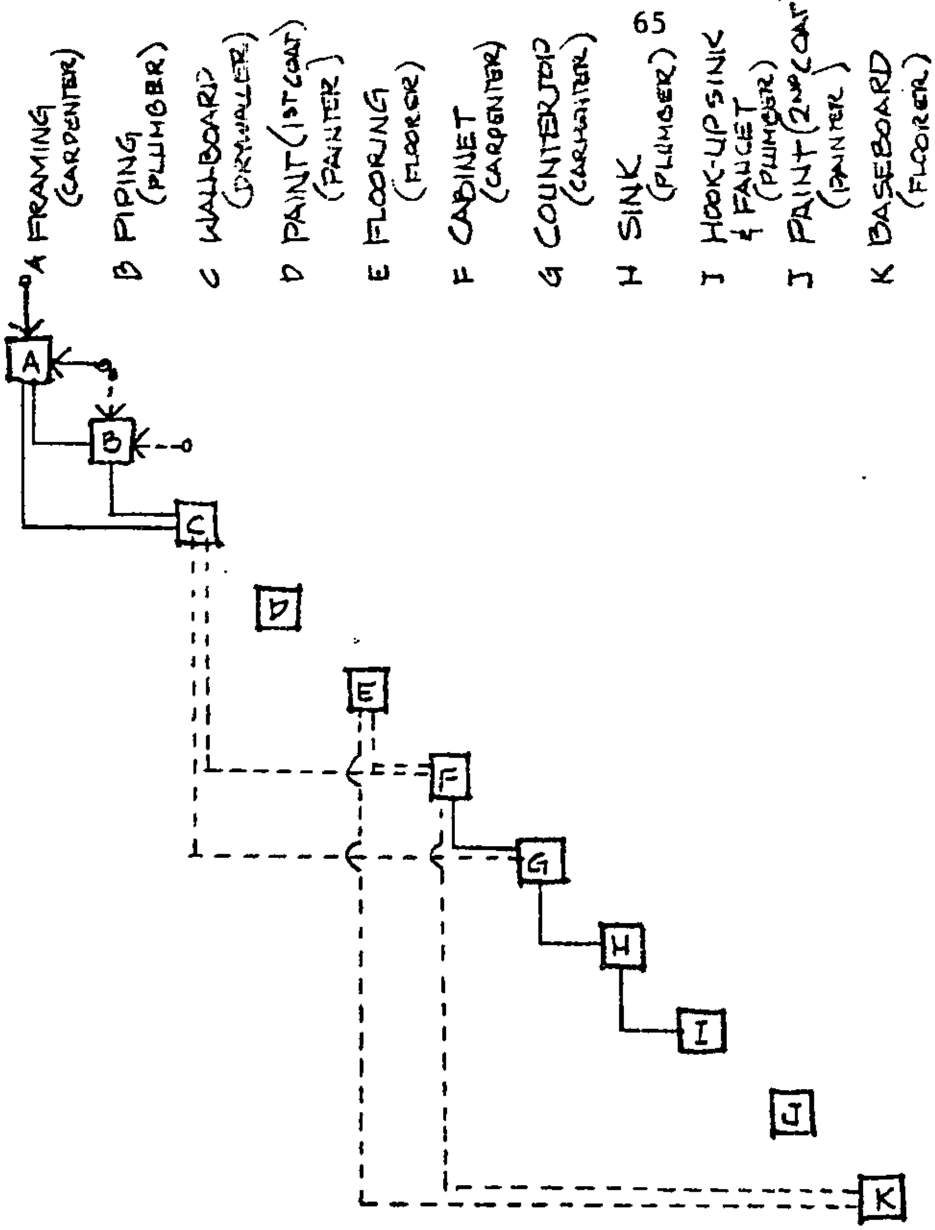


FIG 3.11

U.S. KITCHEN CABINET: POSITIONAL DEPENDENCY NETWORK

Positional dependencies are identified by the format:

precedent component - subsequent component

and may be a solid line, indicating a high degree of positional dependency, i.e., a constrained fit, with low tolerance; or a dotted line for a lower degree of positional dependency, i.e., with considerable tolerance. For example, F-G indicates the positional constraints that the countertop has upon the sink, indicated by a solid line. However, the fit of the cabinet against the wall is not constrained, since slip planes exist on the floor and wall, and C-F and E-F are indicated as dotted lines.

The horizontal and vertical arrows above the diagonal sequence of components correspond to measurements taken in those directions, with dotted arrows representing measurements taken with less dependency, for verification or alignment.

CONTROL PLANES

Control planes are vertical or horizontal planes in space (represented by lines in section) to which components are placed and from which positions are measured. Control planes may act as a datum line for coordination of position, or may be coincident with the edge, or surface plane of a component where the control of position is exerted by the physical interfaces with that plane.

In the U.S. cabinet assembly, two control planes exist, a vertical plane, coincident with the surface of the wallboard, and a horizontal plane, represented by the flooring.* Both of these planes are determined and manifested by actual construction before any of the components of the cabinet assembly are installed. The concrete floor is expected to be a level plane for all finish components, and is built to be such, by smoothing and patching if the concrete surface is not adequately flat and smooth. Likewise, wall framing members are installed to accurate positions with respect to the plan. All subsequently placed components are dependent in some way upon the position and orthagonal planarity of the wall studs which set the vertical control plane of the wallboard. The wallboard elements are manufactured to constant thickness, and special efforts are made to maintain planarity, such as double railing to assure that no warping exists and taping and floating to ensure flush smooth joints.

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*When more than one countertop is placed adjacent to another, a control plane 36" (914 mm) from the floor is represented by the top surface of the drainboards. The 3/4" 910 mm) shim space under the countertops allow adjustment to meet this plane.

No other control planes are necessary in the cabinet assembly for a dependence of component position. The cabinet itself is manufactured in jigs to make certain that it is built absolutely square, and corner blocks are installed in order that no racking occurs during shipment or installation.

The cabinet transfers the square position of both horizontal and vertical control planes to the countertop and baseboard, by virtue of its inherent orthagonality: the countertop is placed on the cabinet, which transfers the level floor plane to the top edges of the frame. The interfaces at those points (G/F, Figures 3.9 and 3.10 are slip planes, in the horizontal. This configuration now corresponds to the manner in which the cabinet is itself fitted to the wall, with the cabinet transferring the floor plane. The countertop is thus permitted to slip on the cabinet and be set flush to the wall. The baseboard configuration is a similar one, except the slip plane exists on the vertical interface K/F, Figure 3.8.

The positional dependencies indicated in Figure 3.11 and those dependencies which involve control planes are summarized in Table 3.4. The significant points with regard to the relationship of elements to control planes in the U.S. cabinets are:

1. Control planes are established with the structure.
2. Interfaces with the control planes are flush, slip planes.
3. Components transfer positions from the control plane by the fact that the components are inherently square.

TABLE 3.4

U.S. KITCHEN CABINET POSITIONAL DEPENDENCY

SUMMARY

Component	Positional Dependencies
A. Framing (carpenter)	Measured from plan, face of studs in an ubroken plane, which is to be the vertical control plane for the assembly, manifested by the sheathing.
B. Piping (plumber)	Position within wall determined by studs, emergence for outlets measured from plan, with tolerance due to cabinet-back cut out procedure.
C. Wallboard (drywaller)	Position evident to stud face; wallboard becomes vertical control plane for assembly. Piping holes are cut from position of pipes shown.
D. Paint, 1st coat (painter)	No positional dependencies.
E. Flooring (tile layer)	Position evident on concrete floor. Transfers the horizontal control plane for cabinet (E-F) and baseboard (E-K).
F. Cabinet (carpenter)	Measured from plan to determine position along wall, placed flush with wallboard and flooring in a "corner fit" condition; C-F, E-F both junctures are slip planes at interfaces F/E and F/C, see Figures 3.8 and 3.10
G. Countertop (carpenter)	Position determined by cabinet F-G, slip plane at interfaces G/F, Figures 3.9 and 3.10, allows position to wallboard C-G to be without critical dependency. Measured to level from floor.
H. Sink (plumber)	Position determined by hole in countertop (F-G).
I. Hook-up sink and faucet (plumber)	Position of faucet determined by pre-cut holes in sink flange (G-H); piping is concealed within cabinet, no positional dependencies.

TABLE 3.4 (continued)

Component	Positional Dependencies
J. 2nd coat paint (painter)	No positional dependencies.
K. Baseboard (tile layer)	Position determined by cabinet, but "corner fit" and condition of interface (K/F) and K/E) (see Figure 3.3), causes dependencies E-K and F-K to be slight.

The diagram of Component Placement Groups, Figure 3.12, may be seen as groups of strong positional dependencies between sequences of components, with lower degree relationships between the groupings. The components included within the two groups show that these patterns may be associated with identifiable assemblies of physical components, shown with their respective trades:

Wall group:	A. Framing (carpenter)
	B. Piping (plumber)
	C. Wallboard (drywaller)
Cabinet group:	F. Cabinet (carpenter)
	G. Countertop (carpenter)
	H. Sink (plumber)
	I. Hook-up sink and faucet (plumber)

No strong positional dependencies exist between components of the two groups as the interfaces of (C) wallboard and (E) flooring with (F) cabinet and (G) countertop have been shown to be slip planes, as are the interfaces of (K) baseboard.

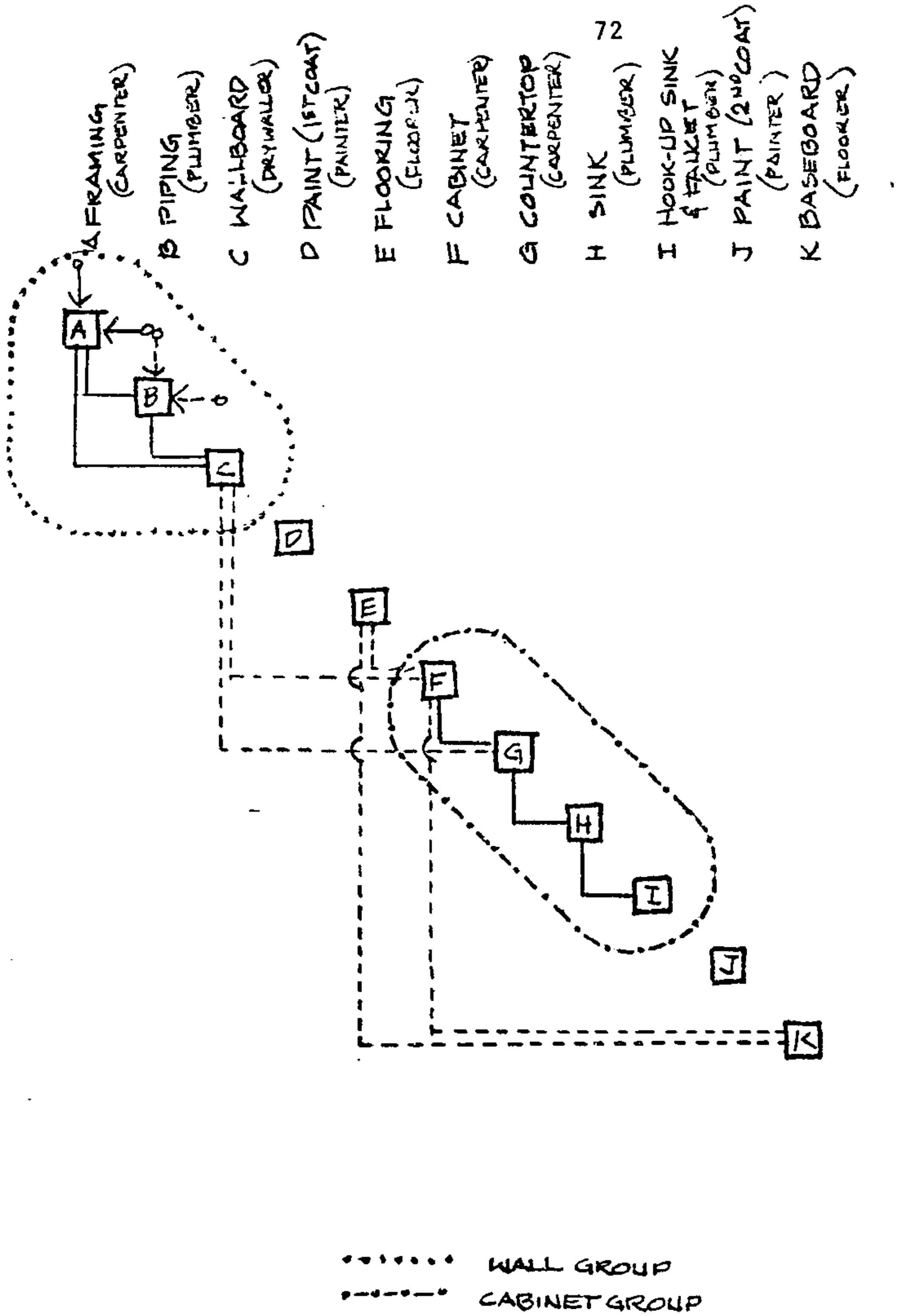


FIG 3.12
U.S. KITCHEN CABINET: COMPONENT PLACEMENT GROUPS

SUMMARY - U.S. KITCHEN CABINET ASSEMBLY

It was shown that five components in the U.S. assembly had more than one precedent interface; and that of those five, two components had one interface each that could be termed of lesser degree. It may therefore be concluded that these three components, and their interfaces represent the highest degrees of interrelationship among components in the U.S. cabinet assembly:

1. Cabinet (F) interfacing wall (C) and floor (E).
2. Countertop (G) interfacing cabinet (F) and wall (C).
3. Baseboard (K) interfacing cabinet (F) and floor (E).

An analysis of the detail of interfaces of these components showed that these three elements have a common joint configuration in their interfaces with the two precedent components: each component's primary interface is a slip plane, which then allows the component to be brought flush to the second interface. In the cabinet, the floor allows the cabinet to slip to be set flush with the wall. The countertop is shimmed at its interface with the cabinet, and slips along that plane of interface such that the backsplash may be brought flush with the wall. And the baseboard may slip on its interface with the cabinet to rest against the floor. Those elements to which the cabinet, countertop and baseboard are brought flush against: wall, wall and floor, respectively, place no restrictions on the location of the interface, and in that sense are also slip planes. These second slip planes are concomitant and perpendicular to the primary planes.

In each of these cases, the components are brought to a slip-plane interface with either the horizontal or vertical control planes. These control planes are manifested by the structure of the floor and wall, at the first stage of construction. Positional dependencies to the control planes are made by transference through components which are inherently square.

The direct sequence of component installation in the U.S. example is therefore evident in the interface and placement networks, and is made possible by:

1. Control planes established with the structure.
2. Components interface with one or at most two precedent components.
3. Interfaces that are critical for position are slip planes.
4. Components that are dependably orthagonal are used to transfer positions from control planes.
5. Pre-fabrication reduces the number of components to be assembled on site.
6. No finishing is necessary for components that are specific to the kitchen cabinet assembly.

KITCHEN CABINET - ISRAELI EXAMPLE

While kitchen cabinetry in the United States is a system of pre-fabricated units which are standardized and pre-finished to be assembled on site, there is one cabinet built in Israeli kitches specifically for the sink. Though of a standard design, the cabinet is built in to the structure using many separate elements.

It will be shown that the Israeli cabinet assembly, though not different in appearance from the American version, is constructed in a very different manner. There are many more elements involved, and this certainly affects the complexity of the assembly process. But the detail of the interfaces between components will be shown to reflect a much different concept than those of the U.S. assembly. The different detail concepts, which are reflected in the manner in which component positions are determined, will be shown to create a highly interrelated process of assembly.

FORM

The Israeli kitchen cabinet resembles a long rectangular box, a framed unit with doors and drawers, topped by a flat marble countertop. The cabinet box appears to have three bays, the center bay for the sink, and two side bays for drawers and shelves. Doors are hung from vertical stiles which define the bays and are part of the box frame.

The cabinet is built up on site of wooden railes and stiles, each 45 x 35 mm, with wooden side panels, panel bay divisions, drawer supports and doors affixed to the 45 x 35 mm frame members, see Figure 3.2. The assembled cabinet measures 2,070 by 500 mm which allows for a slight projection of the countertop beyond the cabinet face.

The countertop, set 900 mm from the finish floor, measures 2,130 mm in length, 560 mm deep and is 20 mm thick. It is a flat slab of marble or cast stone, and is an uninterrupted plane except for a 540 x 340 hole in the center for the sink, and two gooves routed in the top at the front, which drain into the sink hole.

The floor and back wall are tiled and the faucet is on the back wall, one tile course (150 mm) up from the countertop. The cabinet is set up on a pedestal which is finished with floor tiles laid within the cabinet.

ELEMENTS

The elements that are necessary to complete the Israeli kitchen cabinet include all components depicted within a section through the wall and floor at the cabinet, as shown in Figure 3.13. It will be shown that the faucet supply lines and tile placements are of importance to an understanding of the dimensions and positions involved in constructing the cabinet assembly.

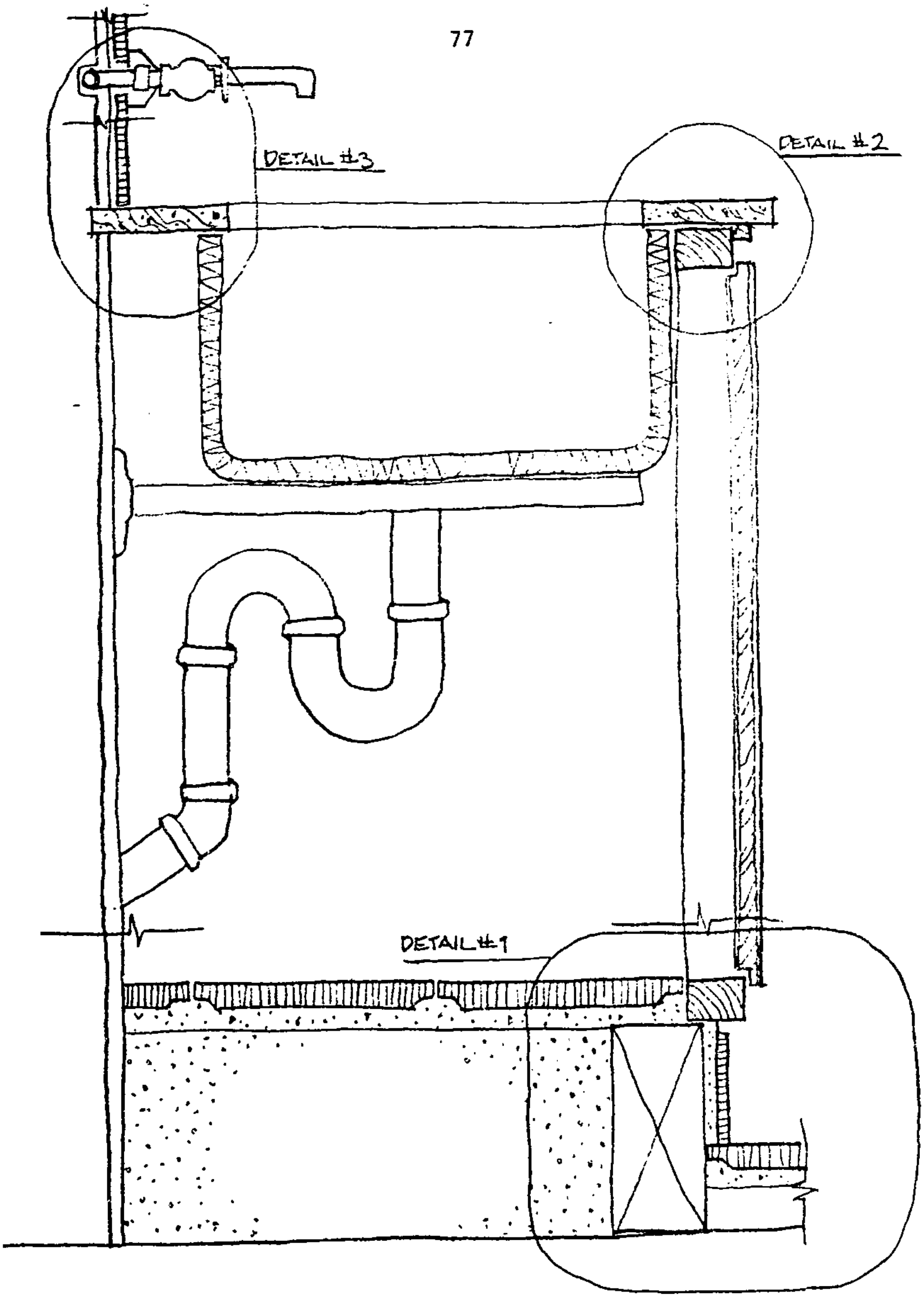


FIG 3.13
ISRAELI KITCHEN CABINET : SECTION

For this reason the section which shall be examined includes the tile wall to just above the faucet, and extends to a point on the floor in front of the blocking and baseboard. The face of the concrete floor surface is included, as it is important in attaining a level assembly and flush fit of parts. The face of the concrete block is also important to the assembly, in that as it is an irregular plane, special efforts are necessary to bring about a proper fit of components. In fact, the wall itself must be altered by chiselling out grooves in order to fit the countertop and accommodate the supply pipes.

The elements used to construct the cabinet assembly are shown in Table 3.5.

The detail interfaces which shall be examined are shown in Figure 3.13. Detail #1 includes the front edge of the cabinet frame, represented by the bottom rail; the blocking, which defines the pedestal on which the frame rests; the sand fill, mortar beds and floor tiles for the kitchen floor and inside the cabinet; and the tile baseboard, set against the blocking. The bottom rail overhangs the baseboard slightly, creating a small toe-space, at the base of the cabinet.

Detail #2 illustrates the interfaces between the cabinet frame and countertop, and between the sink and countertop. A small ($\pm$ 3 mm) shim space is provided under the countertop, and is hidden behind the square moulding trim piece. The sink is shown, supporting the countertop, with sealant applied at the joint. The proximity of the sink to the cabinet should be noted, and will be shown to be of importance in the assembly

TABLE 3.5

ELEMENTS OF THE ISRAELI KITCHEN CABINET ASSEMBLY

Concrete floor - Cast in place, rough surface finished by covering with sand fill and floor tiles.

Block walls - 200 mm, hollow core, rough surface houses drain stack from sink, face chiseled out for grooves for supply pipes, finished by plastering and tiling.

Plaster - ± 15 mm thick, spread over block behind cabinet, to be touched up, smoothed and whitewashed.

Wood blocking - 170 mm x 70 mm rough wood members, pedestal for cabinet frame.

Cabinet frame - Not a complete box, front and side panel frames built of 45 mm x 35 mm stiles and rails. Wood panels, doors, shelves, drawers and bay divisions affixed to frame. Frame is screwed to back wall.

Wood trim - 10 mm x 12 mm wood moulding, affixed to frame at edge with countertop lacquered.

Countertop - 2,130 mm x 560 mm x 20 mm pre-cut marble slab, fixed into groove cut in wall.

Sink - Cast iron, enameled, bowl shape with straight edges at top. Supported on pipes fixed to wall.

Drain lines - 50 mm p.v.c. with trap connected to sink and drain stack in block wall.

Supply lines - Galvanized iron, hot and cold water supply, run in grooves cut in block wall, threaded connections.

Faucet - Fixed to threaded ends of hot and cold supply lines emerging from wall, with escutcheon to cover holes cut in tiles around pipes.

Floor tiles - 20 mm x 200 mm x 200 mm, terrazo, on sand bed to attain ± 70 mm finished floor elevation above concrete floor, also placed on thicker sand bed within blocking under cabinet.

TABLE 3.5 (continued)

Baseboard - 10 mm x 150 mm x 100 mm, tile placed with edge on top of floor tile against blocking and wall.

Ceramic wall tiles - 10 mm x 150 mm x 150 mm, placed on mortar bed on back walls and with edge on countertop, cut around faucet supply lines.

Whitewash - On plaster, two coats.

Lacquer - On wood frame, two coats.

process.

Detail #3 illustrates the connection of the countertop into a groove cut in the wall, which is referred to as a kerf. The tile is shown to be placed flush against the top plane of the countertop on a mortar bed on the block wall. The supply pipes for the faucet are shown to pass through holes cut in the tiles on the line of the top of the first tile course. An escutcheon covers the cut tile edges. The kitchen sink and countertop interface in the detail is identical to that in section #2.

The drain pipe and trap are shown in Figure 3.13 to be enclosed by the cabinet. The drain pipe is brought out from the block wall from a stack enclosed within the cores of the block wall.

PROCESS

The process of assembly of the components that make up the kitchen cabinet is such that the positions of many individual parts are important to the proper fit of the whole. Components must often interface simultaneously with several preceeding components.

The process may be generally described as an installation of separate elements which must be measured and positioned carefully, and which must fit together in a highly interrelated fashion to arrive at a finished assembly.

The components of the Israeli assembly are listed in Table 3.6, accompanied by the activities necessary to bring about the installation of those components in interfaces with others in the assembly.

The process of installation of kitchen cabinets in Israel involves many activities and interrelationships. There are many distinct components, and each must interface with a number of other elements, sometimes to those which have just been installed, and often to elements that have been affixed at an earlier stage. The position and function of some elements are not immediately manifested. There are instances in which certain elements (e.g., the faucet supply lines) must be placed to accuracies that are required for the proper fit of other elements which are not to be affixed until a much later stage (e.g. the ceramic wall tile).

The positional requirements during the installation are often such that if there is an error not only is the succeeding component disturbed, but many other components at various stages are also affected. For example, the pipe supports, secured to the wall, support the sink. The top edge of the sink must be level, since the countertop is set on this edge (and recessed into a groove into the wall). The countertop must be level in order that the wall tile may be set on level courses, starting with the first course which rests directly on the countertop. The height of the countertop must be correct so that the supply pipes fall at the top edge of that first course, where the tile may be cut to accommodate the pipes, since cut-outs in the tile must be from the

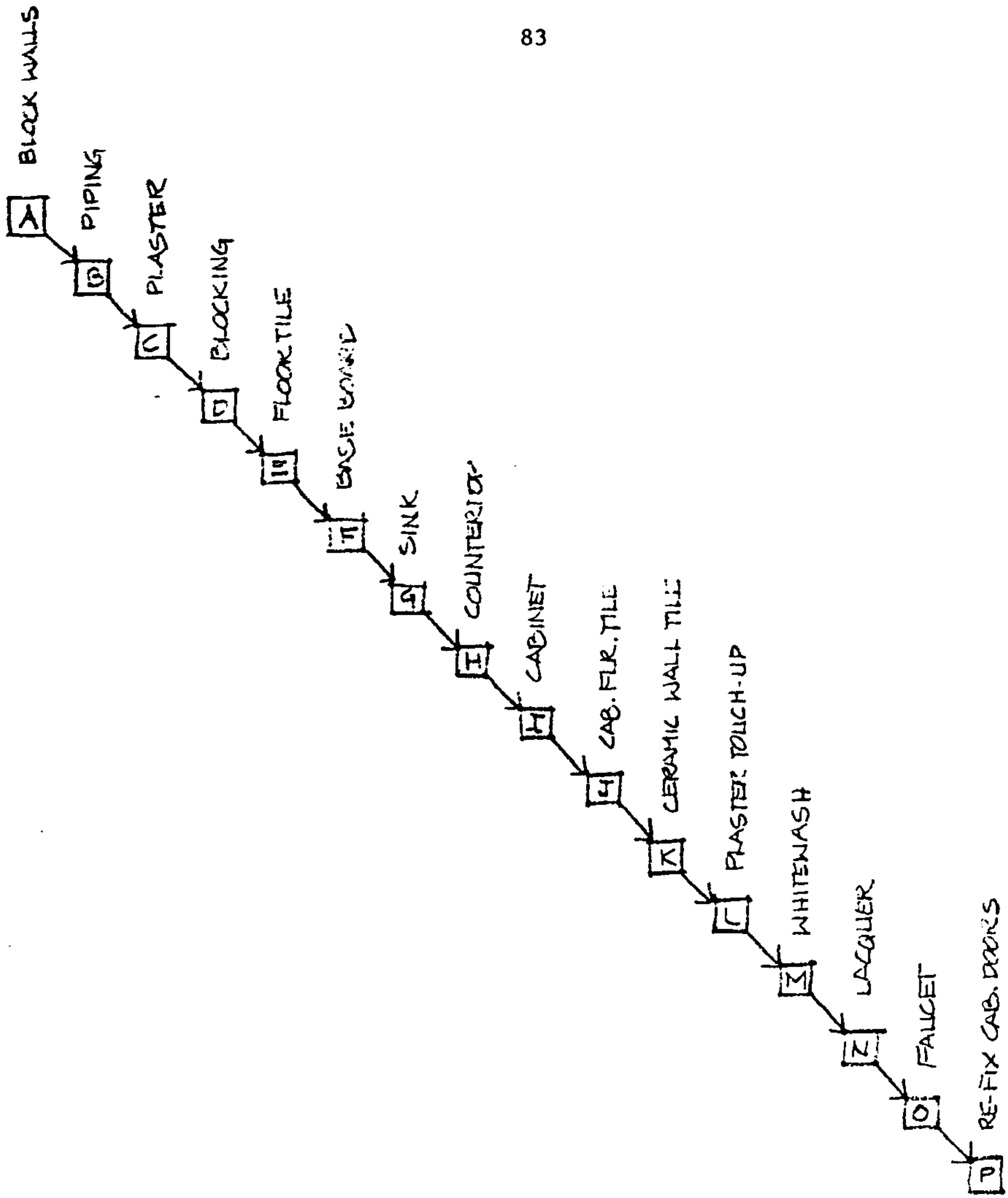


FIG. 3.14
ISRAELI KITCHEN CABINET : SEQUENCE OF COMPONENTS

TABLE 3.6

ISRAELI KITCHEN CABINET - SEQUENCE OF ASSEMBLY

Component	Activity Description
A. Block walls (mason)	Roughly placed. Hollow core houses 2" drain pipe, irregularity in the wall plane is to be rectified by plaster.
B. Piping in wall (plumber)	Interface: block wall Grooves cut into block to allow pipes to be recessed. Pipes run above countertop to location determined by measurement from floor and brought forward to faucet.
C. Plaster (plasterer)	Interface: block wall Smooths out irregularities in wall. Applied throughout except where wall tiles are to be placed. Interface: piping Covers parts of pipes not fully recessed into grooves.
D. Blocking (carpenter)	Interface: plaster Blocking placed on floor as pedestal for frame. Measurements determined from plan. Side pieces placed flush against wall.
E. Sand Fill and Floor tile (floorer)	Interface: blocking Interface: plaster Elsewhere horizontal runs of pipe are placed in sand fill. Sand is spread to bring floor tiles up to a finish elevation of 70 mm from concrete floor. Sand, mortar bed, and floor tiles are brought flush against blocking and plaster on wall.
F. Base board (floorer)	Interface: sand fill Interface: blocking Interface: plaster Tile baseboard placed on mortar bed on blocking with edge resting atop floor tile. Is brought to plaster at sides. The top edge of the baseboard may rise no higher than the blocking.

TABLE 3.6 (continued)

Component	Activity Description
G. Pipe Supports & sink hook-up (plumber)	Interface: plaster Interface: block wall Pipe supports are affixed to the wall. Position determined by measurement from floor. Must be accurate. Sink is placed on the pipes. Drain lines and trap are installed.
H. Countertop (plumber)	Interface: pipe supports and sink Countertop is set on sink with a bead of sealant. Must be to a finished height of 900 mm from tile floor.
I. Cabinet (carpenter)	Interface: countertop Interface: blocking Cabinet is assembled and is inserted under the countertop to rest on the blocking. Any gaps that exist between the countertop and cabinet are shimmed. Interface: plaster The stiles of the frame at the back are fixed to the wall. Moulding is affixed to the edge of the frame at the countertop and the intersections with the countertop and plaster. Interface: baseboard Interface: sink There must be enough clearance at the top of the baseboard so that the bottom rail may fit on the blocking, likewise the front edge of the sink must have been positioned correctly for the top rail to be in position.
J. Kitchen Cabinet Fill & Floor Tiles (floorer)	Interface: cabinet Interface: blocking Interface: plaster The space within the blocking is filled with sand and tiles are placed on the sand and over the blocking to the flush with the top of the bottom rail of the cabinet and against the plaster on the back wall.

TABLE 3.6 (continued)

Component	Activity Description
K. Ceramic Wall Tile (wall tiler)	Interface: countertop Interface: piping Interface: block wall Modular courses of ceramic tiles are placed flush to the countertop and cut out around the pipes. Centered on position of faucet.
L. Plaster touch up (Plasterer)	Interface: ceramic wall tile Interface: plaster The edge between the ceramic tile and the plaster is smoothed.
M. Whitewash (painter)	Whitewash applied to plaster.
N. Lacquer (painter)	Lacquer is applied to cabinet.
O. Faucet (plumbing)	Interface: ceramic wall tile Interface: piping Faucet is affixed to piping and an escutcheon covers the holes in the tiles.
P. Cabinet doors refix (carpenter)	Cabinet doors are affixed to cabinet after being lacquered.

edges of the tiles such that they may be within the area concealed by escutcheons of the faucet. In addition, the bottom edge of the countertop must be level and to the correct height so that the cabinet may be inserted in the space between the countertop and the blocking.

ANALYSIS

INTERFACE NETWORK

The sequence of activities described in Table 3.6 is illustrated with each component interface in Figure 3.15. The analysis of the number of component, block walls (A), and the painting components, whitewash (M) and lacquer (N), which have no dimensional characteristics, reducing the total to 13. The most significant pattern that emerges in the diagram is that 9 of the 13 components are required to interface with more than one precedent. These components, listed in Table 3.7, indicate the degree to which the individual elements of the assembly are interrelated, to be seen graphically in the interface network.

Four components do not interface with components placed immediately beforehand: (G) pipe supports, sink; (K) ceramic wall tile; (O) faucet; and (P) cabinet doors. In the case of the sink and the tile, these components represent significant positional dependencies, which may be critical to the successful completion of the cabinet.

It is important to note the concentration of interfaces, and subsequently the number of dependencies, that are placed upon the components: (A) block walls, which has five component dependencies;

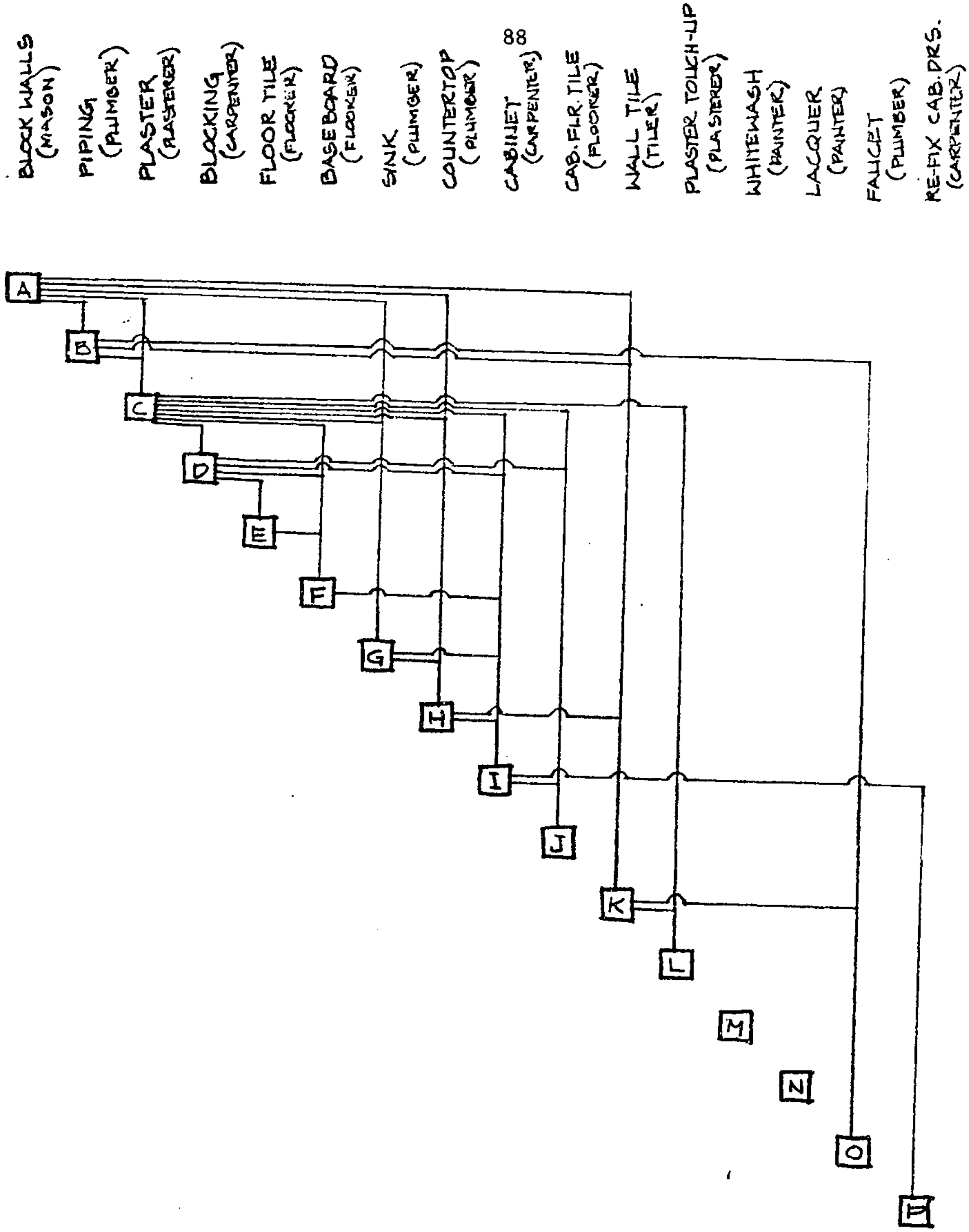


FIG. 3.15
ISRAELI KITCHEN CABINET : INTERFACE NETWORK

TABLE 3.7

ISRAELI KITCHEN CABINET COMPONENTS

WHICH INTERFACE WITH MORE THAN ONE PRECEDENT

Component	Precedent
C. Plaster	A. Block walls B. Piping
F. Baseboard	C. Plaster D. Blocking E. Floor tile
G. Pipe supports, sink	A. Block walls C. Plaster
H. Countertop	A. Block walls C. Plaster G. Pipe supports, sink
I. Cabinet	C. Plaster D. Blocking F. Baseboard G. Pipe supports, sink H. Countertop
J. Kitchen cabinet floor tiles	C. Plaster D. Blocking I. Cabinet
K. Ceramic wall tile	A. Block walls B. Piping H. Countertop
L. Plaster touch up	C. Plaster K. Ceramic wall tile
O. Faucet	B. Piping K. Ceramic wall tile

(C), plaster, with seven; and (D), blocking, with four. Excluding components (M) and (N), every component except (P), cabinet doors must interface with at least one of these three elements.

Since these components represent wall and floor elements, this constitutes a measure of the degree to which the assembly is "built-in" to the structure. It can therefore be concluded that the Israeli kitchen cabinet assembly possess the following characteristics:

1. The assembly is made up of many elements and is "built-in" to the structure (see Figure 3.15).
2. The elements of the assembly are highly interrelated.

ANALYSIS OF DETAIL

It was shown in the U.S. cabinet analysis that the details at the bottom, front and back of the cabinet and countertop assembly include the critical interfaces. This is also the case in the Israeli assembly.

This may be inferred from the number of elements listed in Table 3.7 which are brought to interface with precedent components at the following details, located in Figure 3.13:

Detail #1	D. Blocking
	E. Floor tile
	F. Baseboard
	I. Cabinet
	J. Cabinet floor tile

Detail #2	G.	Sink
	H.	Countertop
	I.	Cabinet
Detail #3	A.	Block walls
	B.	Piping
	C.	Plaster
	G.	Sink
	H.	Countertop
	I.	Cabinet
	K.	Ceramic wall tile
	O.	Faucet

DETAIL #1

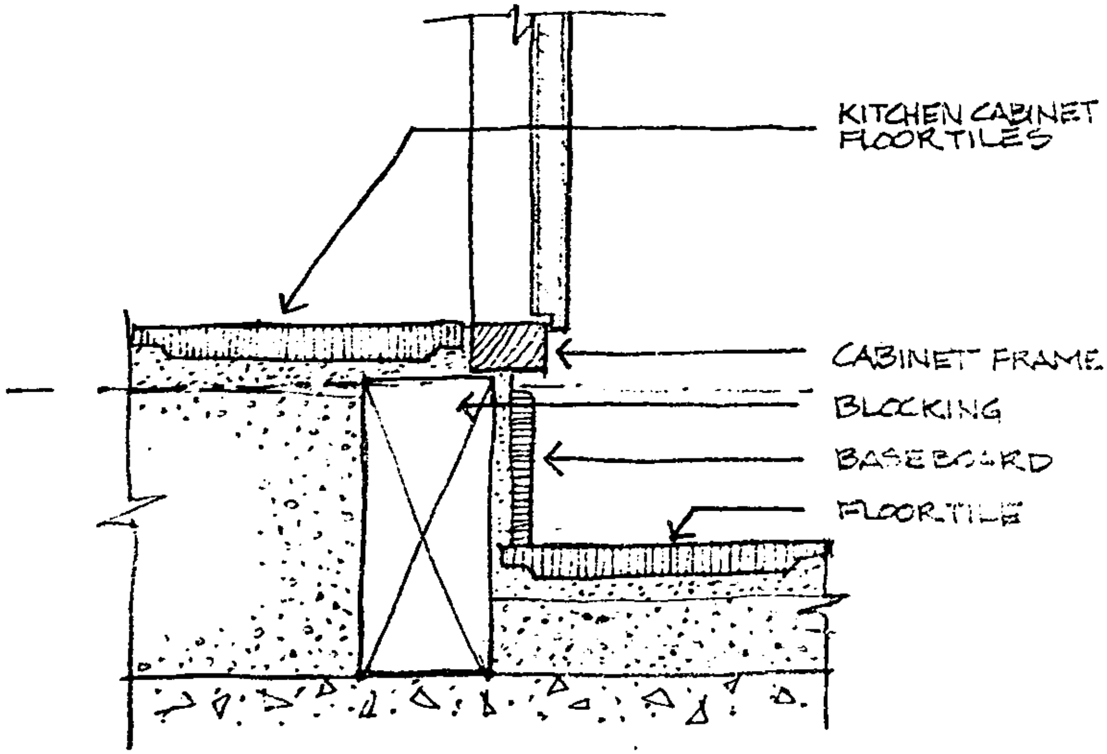
BLOCKING, FLOORING AT CABINET BASE

The first element to be placed in this detail is the blocking, and all other elements are affixed to it in some manner. The top of component D, blocking, forms the first control plane for the assembly. The blocking must be at least 170 mm in height to allow sufficient clearance for the bottom rail of the cabinet frame (component I). The center line of the cabinet has been established during installation of (B), piping in walls. Blocking, set to this center line must be positioned to within 10 mm of proper location out from the wall. Any irregularities in the concrete floor must be shimmed in order that the top face may be on a level plane.

The second component to be installed is (E), sand fill and floor tile, which is placed flush against the edge of the blocking 100 mm down from the line of the control plane. This enables the finished floor level to be roughly 70 mm above the concrete floor. The sand fill beneath the tile is used as a service zone for horizontal runs of piping elsewhere in the building. The tile baseboard is placed against the blocking on a mortar bed. The edge of the baseboard and mortar backing must rest flush with the floor tile to provide a watertight seam.

Interface E/D is a butt joint, the edge of which is concealed and made waterproof by interface F/E. These two perpendicular elements form a configuration which may be called overlapping butt joints.

After the sink and countertop are installed, the cabinet frame is inserted to rest on the blocking at interface I/D which is a slip plane and allows for this to occur. Interface I/F is actually a 9 mm gap which must be maintained for the cabinet to rest on the countertop. The kitchen cabinet sand fill and floor tiles, component J, are placed within the blocking such that the top of the floor tile rests flush with the top of the bottom rail of the cabinet.



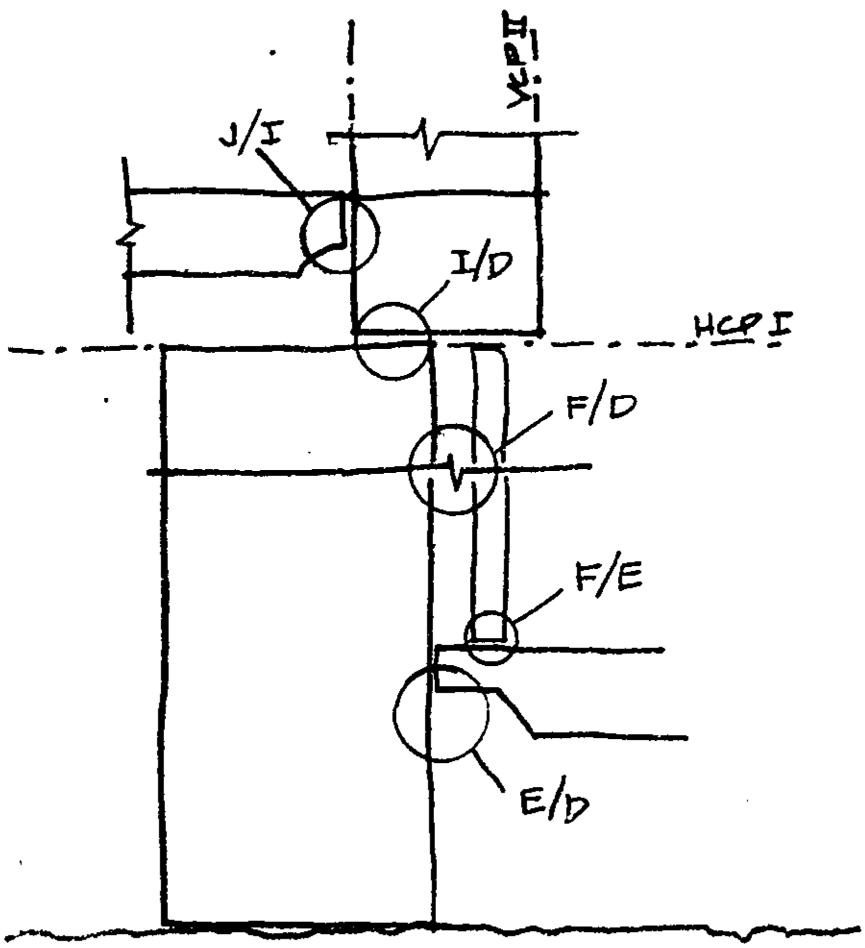


FIG. 3.16
ISRAELI KITCHEN CABINET : DETAIL #1

DETAIL #2

FRONT EDGE, SINK, COUNTERTOP AND CABINET

This detail shows the second control plane which is manifested by the countertop itself. This plane is established by the installation of component G, pipe supports, sink. At the time of installation, the top edge of the sink falls on an imaginary plane which has been measured to location for the pipe supports to be mounted in the correct position. The countertop is then placed to rest on a bead of sealant on the sink shown in this detail at interface H/G. Both elements must be positioned such that the opening in the countertop should overhang the sink edge on all sides of the sink and such that the sink does not interfere with the installation of the cabinet, shown by the gap at interface I/G. The cabinet I is inserted under the countertop and shimmed to fit at the interface I/H with the trim "corner fit" to conceal the juncture. The two control planes must be parallel and level to within the capacity at I/H.

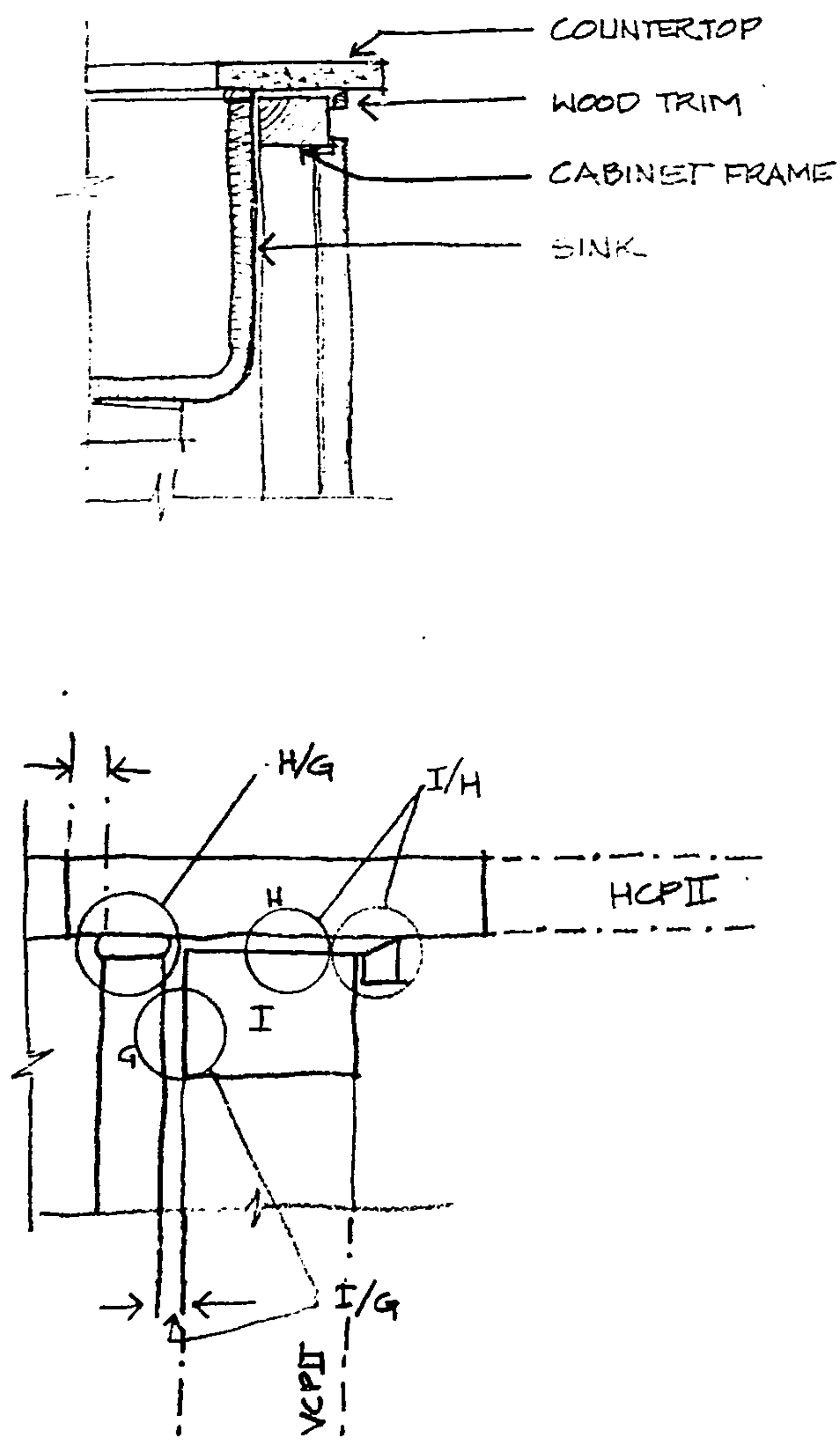


FIG. 3.17
ISRAELI KITCHEN CABINET : DETAIL # 2

DETAIL #3

COUNTERTOP AND KERF, FAUCET SUPPLY LINE

This detail illustrates the manner in which the countertop and hot and cold water pipes are recessed into grooves cut into the wall. The first component to be installed is the piping (B), which must be set into grooves in the wall to allow it to be covered by the plaster, interfaces B/A and C/B. The piping must be positioned to the center line if the cabinet, which is yet to be installed and to fall on a line of 150 mm from the top of the countertop. Five component activities later, the sink is installed to the second control plane, as described in detail #2. On that plane a groove is cut through the plaster into the block wall at interface H/C and H/A to allow the countertop to be set flush with the wall structure. The groove removes the irregularity of the block wall plane from this interface. The faucet escutcheon, component O, conceals the cut edges of the ceramic tile at interface K/B by overlapping at interface O/K.

The details of joint interface in the Israeli cabinet possess the following characteristics:

- Several components are brought to interface in each detail.
- The interface configurations are butt-joints.
- Components abutt the sides of components which abutt others, etc., creating "overlapping" butt-joints.

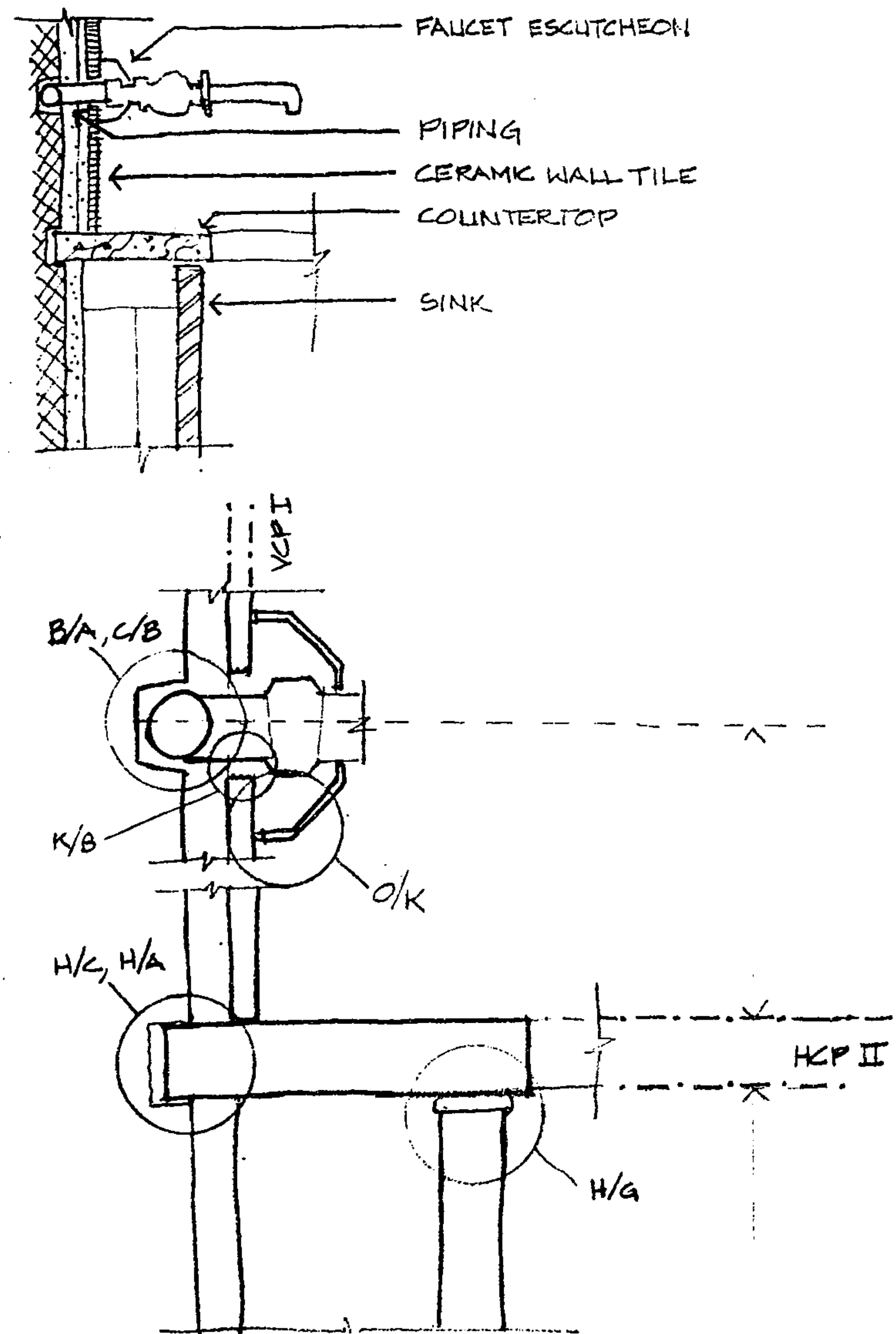


FIG. 3.18

ISRAELI KITCHEN CABINET: DETAIL #3

- Components must fit within a sepace defined on each side by previously placed components.
- Components have interfaces on several sides, with other components which in turn interface with others on several sides, e.g., the cabinet.

The consequence of these interface characteristics in respect to the sequence of assembly are that each component possesses several positional dependencies. The patterns of these dependencies will be explored in the next section.

PLACEMENT/POSITION, CONTROL PLANES

The interrelationships involved in the placement of components, shown in Figure 3.19 (positional dependency network) are outlined in Table 3.8 As the detail analysis suggests, there are many positional dependencies for several of the components. Also of significance is the manner in which the dependencies extend forward and backward across several stages in the process, not a sequential pattern of dependency from one to the next.

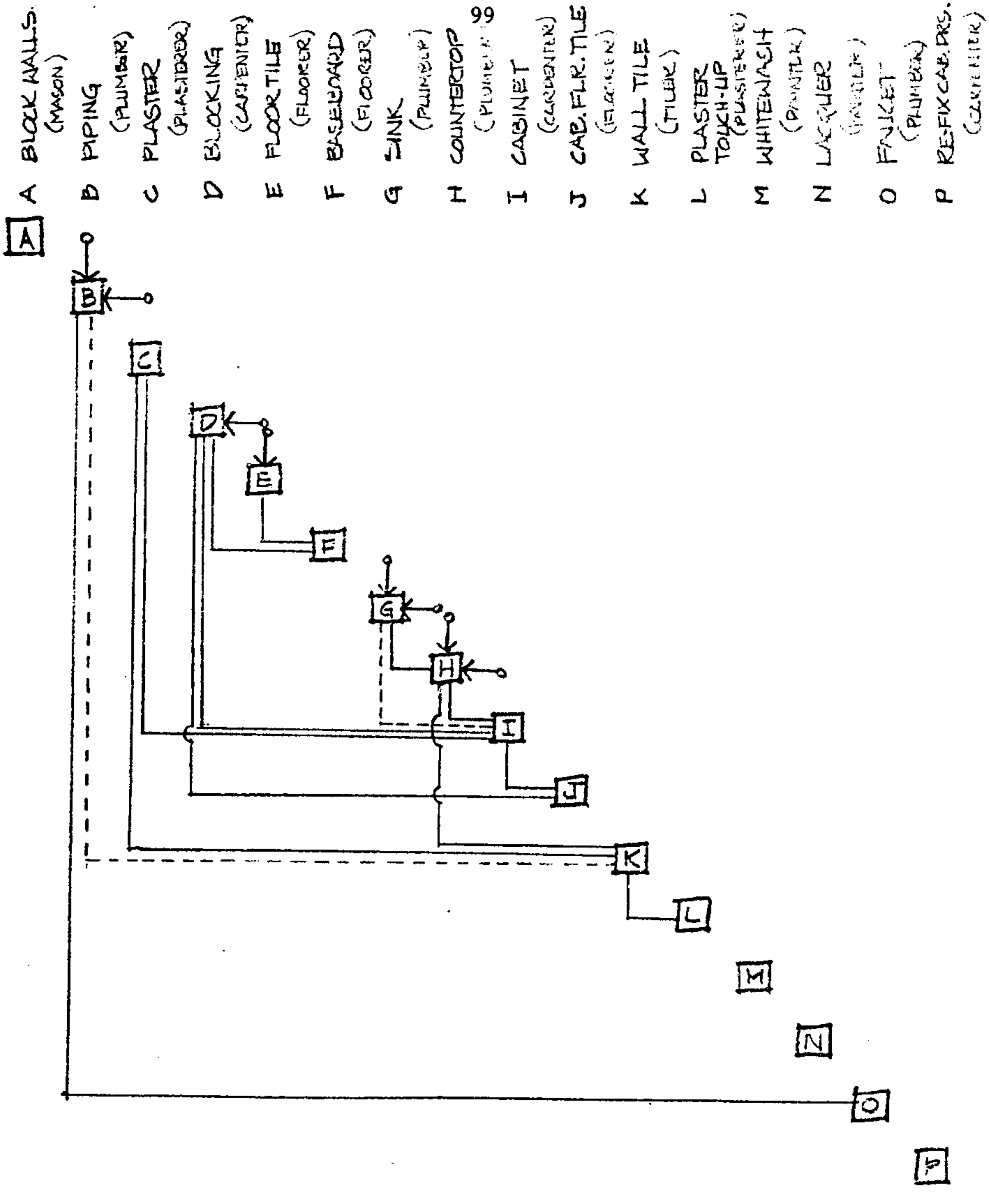


FIG 3.19
ISRAELI KITCHEN CABINET : POSITIONAL DEPENDENCY NETWORK

TABLE 3.8

POSITIONAL DEPENDENCIES: ISRAELI CABINET

Component	Positional Dependencies
A. Block Walls (mason)	Measured from a plan, rough surface not a dependable control plane.
B. Piping in Walls (plumber)	Recessed by convention into block position of pipes for faucets on cabinet center line, and to height by measurement from floor to lines not yet manifested by components.
C. Plaster (plasterer)	Establishes VCP I for cabinet frame (C-I) and wall tile (C-K).
D. Blocking (carpenter)	Establishes HCP I at top of members, for cabinet frame (D-I) and for top edge of baseboard (D-F). Position measured to location of second VCP, at front cabinet frame, for limited slip plane at (I/D) (detail #1).
E. Sand Fill and Floor Tile (floor tile layer)	Measured from floor, measurement confirmed to be 100 mm, down from HCP I for base-board fit.
F. Baseboard (floor tile layer)	Dependent upon blocking (D-F) and floor tile (E-F)
G. Pipe Supports, Sink Hook-up (plumber)	Measured to center line of cabinet on faucet pipe line. Vertical position measured for top of sink and countertop interface (H/G) to determine position of HCP II, to be established with countertop (H). Front position of sink must clear VCP II to be established with cabinet.
H. Countertop (plumber)	Establishes HCP II, dependent upon position of sink (G-H).
I. Cabinet (carpenter)	Become VCP II at front frame, set between both horizontal planes, dependent upon blocking and countertop (D-I (H-I), dependent upon plaster (C-I) and sink (G-I) for correct position of VCP.

TABLE 3.8 (continued)

Component	Positional Dependencies
J. Cabinet Fill & Floor Tile (floor tile layer)	Dependent upon cabinet frame (I-J) for level of floor tile, dependent upon blocking (D-L) to contain sand fill.
K. Ceramic Wall Tile (wall tile layer)	Interfaces with VCP I, HCP II simultaneously (H/K), (H/A) (detail #3) dependent upon countertop (H-K) for level line for 1st course, upon plaster (C-K) for position out from wall, and dependent upon piping (B-K) for cuts from tile edges around pipes. Measured for vertical lines to be centered on countertop and faucet.
L. Plaster Touch Up (plasterer)	Smooths edge at tile (K-L).
M. Whitewash (painters)	No positional dependencies.
N. Lacquer (painters)	No positional dependencies.
O. Faucet (plumber)	Fixed to piping, both hot and cold lines must be level, and centered on cabinet (B-O).
P. Cabinet Doors (carpenter)	Having been removed from cabinet for lacquer, no positional dependencies.

The plaster (C), blocking (D), countertop (H), cabinet (I), and wall tile (K) are significant centers of dependency in the network. The plaster is significant because of the dependencies that are not manifested until five subsequent elements have been installed. The other components, D, H, I, and K have at least three position relationships each.

These elements in fact are associated with four control planes in the assembly, listed in order of placement:

> Vertical control plane I (VCP I), which must be established by skilled workmen on site, formed by plaster applied to the rough block walls.
>
> Horizontal control plane II (HCP I), represented by the top of the blocking (acting as a surrogate floor surface).
>
> Horizontal control plane II (HCP II), created by the countertop.
>
> Vertical control plane II (VCP II), in the form of the front frame of the cabinet.

The most important pattern that emerges concerning the sequence and placement of components with respect to the position of the control planes is that there are several components which have a critical relationship to the control planes which are actually installed prior to the components which make up those planes. The most obvious example is found in the piping which must be placed within the thickness of the plaster which makes up VCP I and to a position relative to HCP II, the countertop, which is not to be installed till much later. The location of the pipe supports and sink are the most critical in the assembly since the sink supports the countertop itself, and must be measured to an imaginary line. In addition, the front edge of the sink must clear the cabinet forming HCP II, also, yet to be installed. The positional dependency network has been shown to illustrate the higher degree of interrelationships that exist between components and the control planes.

Six components must be measured to determine their position. These measurements, indicated by the arrows in Figure 3.19, during the process occur to establish and confirm the second horizontal and vertical control planes, and the positional dependencies are not sequential. Since components have so many interfaces and bear relationships directly and indirectly to all of the planes, the sequence of positional dependencies is frequently interrupted.

Three groupings may be seen in the positional dependency network. The first grouping (wall group) is centered around VCP I and is comprised of activities (B) piping, (C) plaster, (K) ceramic wall tile, (L) plaster touch up, and (O) faucet. The second grouping (pedestal group) includes components (D) blocking, (E) sand fill and floor tile, (F) baseboard, and (J) kitchen cabinet fill and floor tile, and is associated with HCP I serving as a floor plane for the assembly. Both HCP II and VCP II are created by the third group (cabinet and countertop, and (I) cabinet. Component (J) cabinet fill and floor tile, must be installed after this group because of its interface with the bottom cabinet member. These groupings are seen to be interdependent primarily through the placement dependencies of (I) cabinet, and (K) ceramic wall tile. It may also be seen that these two elements are simultaneously dependent upon several control planes. This is shown on the placement network by the dependencies that these components have with the components that form the control planes, see Figure 3.20.

SUMMARY

ISRAELI KITCHEN CABINET ASSEMBLY

Kitchen cabinet construction in Israel was shown to be a complex, on-site assembly of many interrelated components, built in to the structure.

All but one component was shown to interface with one or more of the three controlling components, and nine components had more than one precedent interface.

The analysis of the details of interfaces in the assembly indicated that the predominant configuration was of overlapping butt joints, with junctures of several elements in each detail. Components were shown to have interfaces on several sides, with several instances of low tolerance constrained fit conditions.

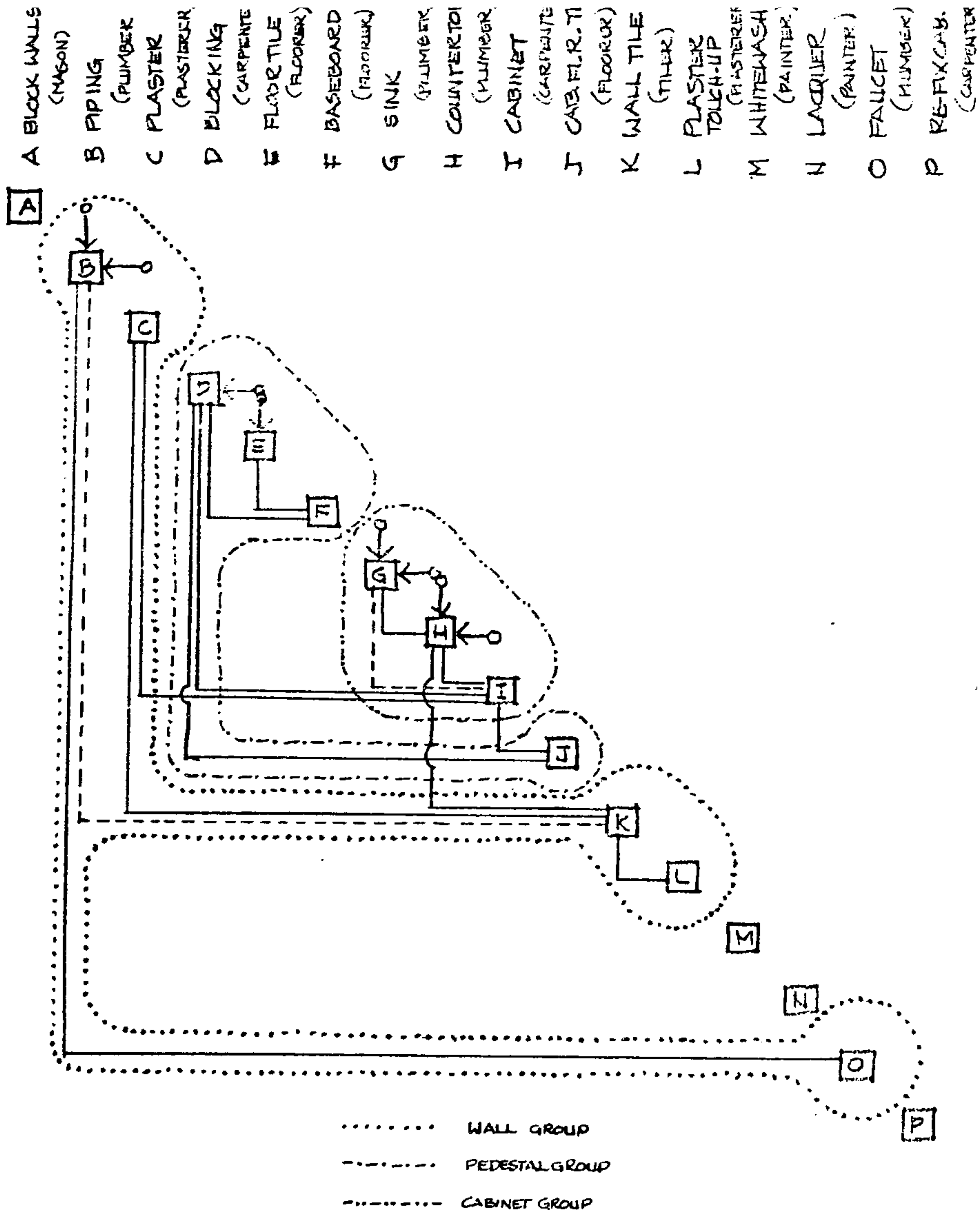


FIG 3.20

ISRAELI KITCHEN CABINET : COMPONENT PLACEMENT GROUPS

Four control planes were shown to be the result of a high degree of interrelationship of positional dependencies. The patterns of the positional dependency network illustrated a multiple, interrupted grouping of component placement, requiring six trades to return to complete the assembly.

CHAPTER IV

BATHTUB ASSEMBLIES

INTRODUCTION

Bathtub installation in the United States and Israel have been chosen as the second case examples in this analysis. Several trades are necessary to complete bathtub assemblies, which interface with components in a different manner than kitchen cabinets.

Bathtubs occupy a unique position in residential building systems because they are large, pre-fabricated components, with special structural, service, and performance requirements imposed on their joints with the surrounding components. Often they are the first components installed with finish surfaces, yet bathtubs are directly affixed to the interior structure; and are in a sense a specialized extension of wall and floor elements, differing in this respect from other plumbing fixtures.

A brief preliminary comparison of the two examples may be found in the isometric drawings, Figures 4.1 and 4.2. The comparative stages of construction of the two assemblies is illustrated in Figures 4.3.1 through 4.3.4. The interface details and positional dependencies of bathtub assemblies in the United States and Israel will be examined in the same manner as the kitchen cabinet examples.

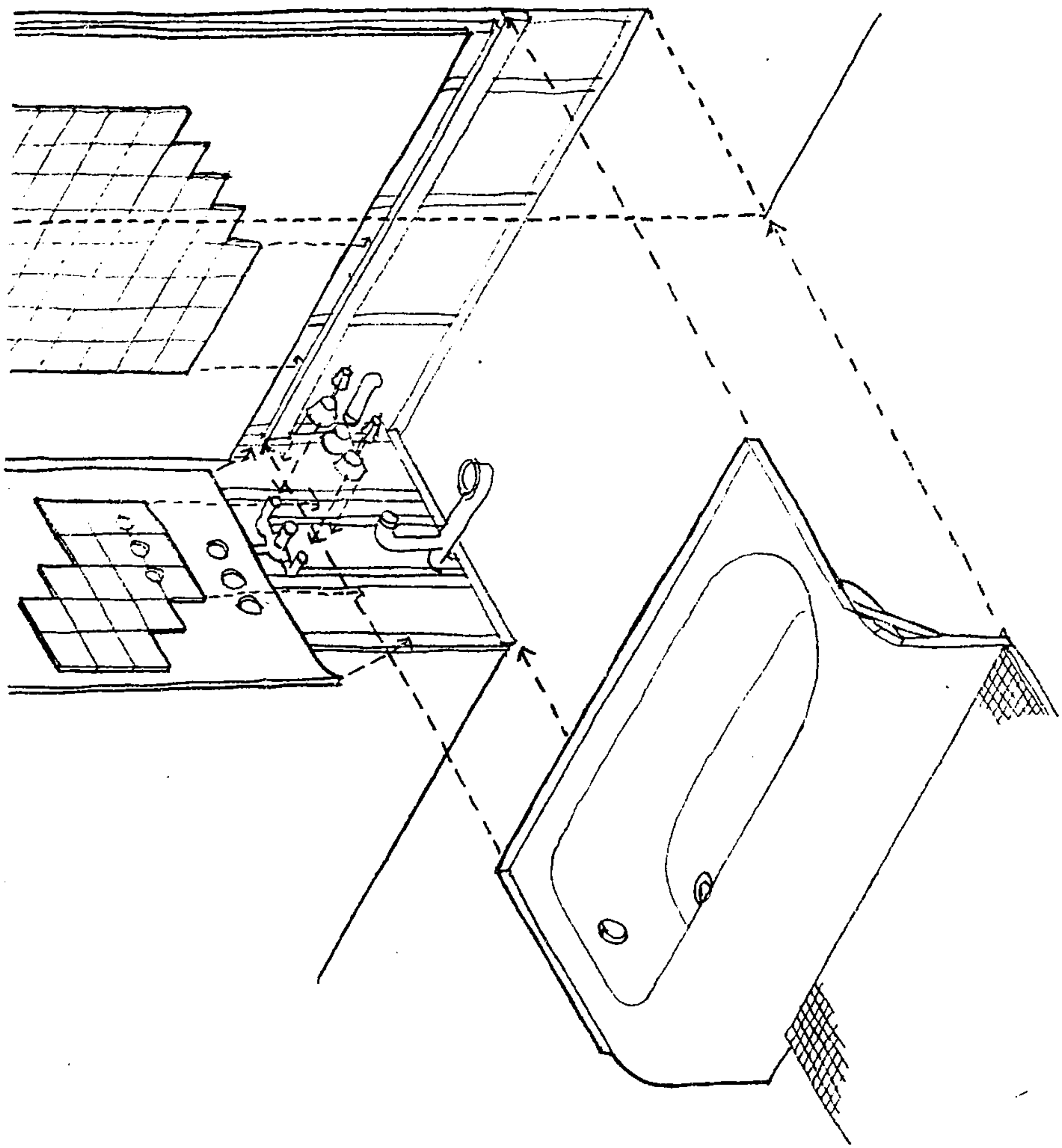


FIG. 4.1
U.S. BATHTUB : EXPLODED ISOMETRIC

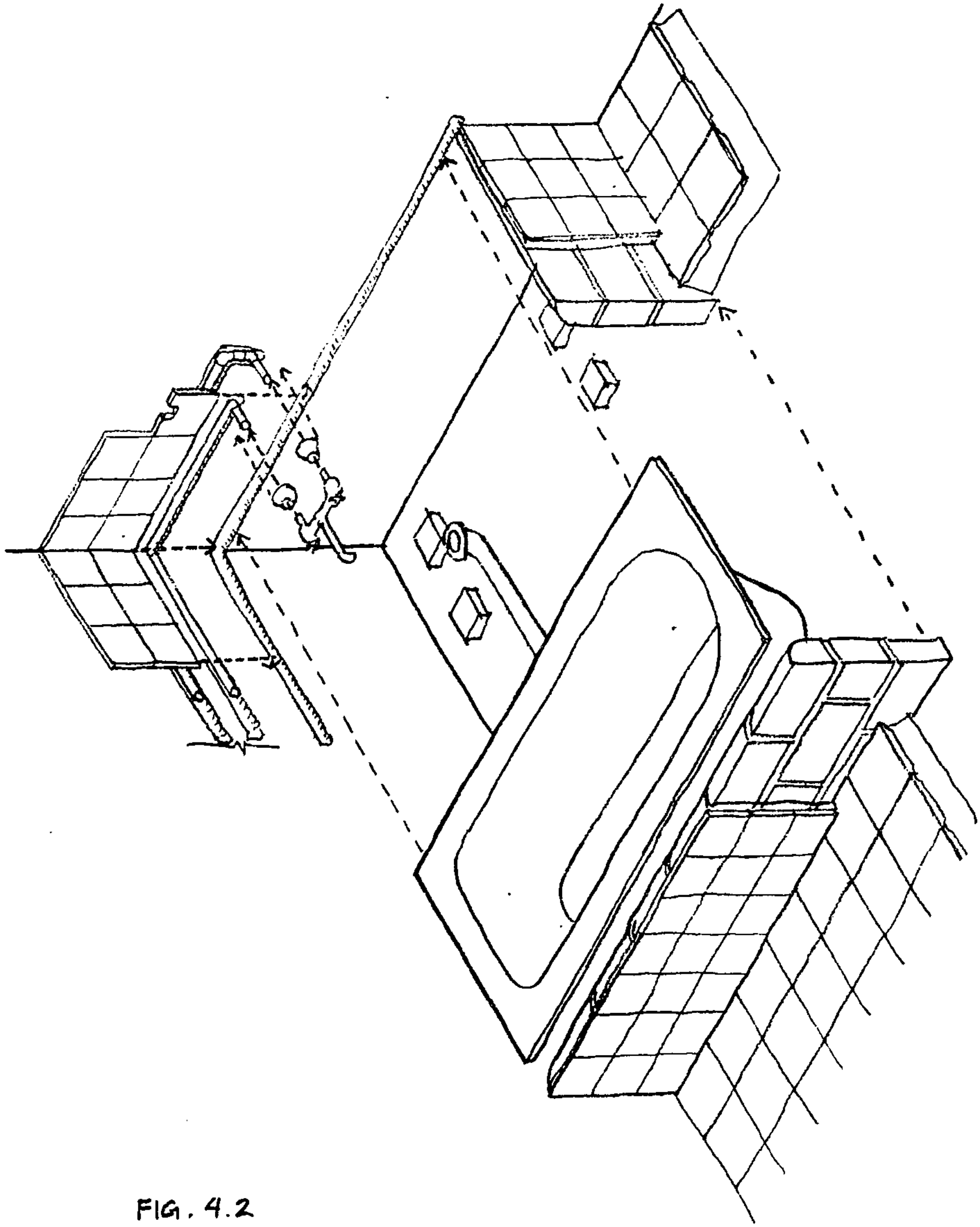


FIG. 4.2
ISRAELI BATHTUB : EXPLODED ISOMETRIC

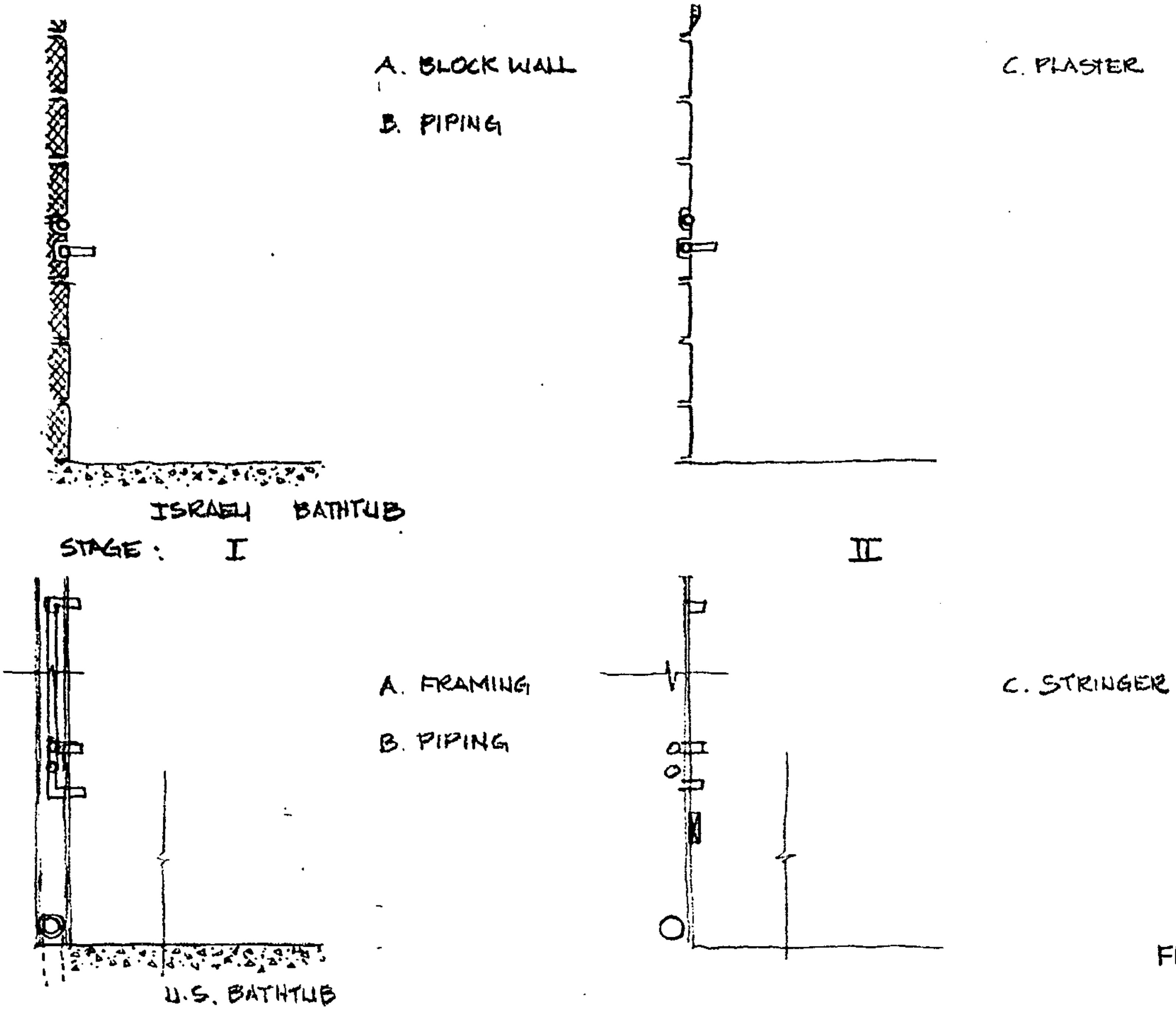

A. BLOCK WALL
B. PIPING
C. PLASTER
ISRAELI BATHTUB
STAGE: I
II
A. FRAMING
B. PIPING
C. STRINGER
U.S. BATHTUB

FIG 4.3.1

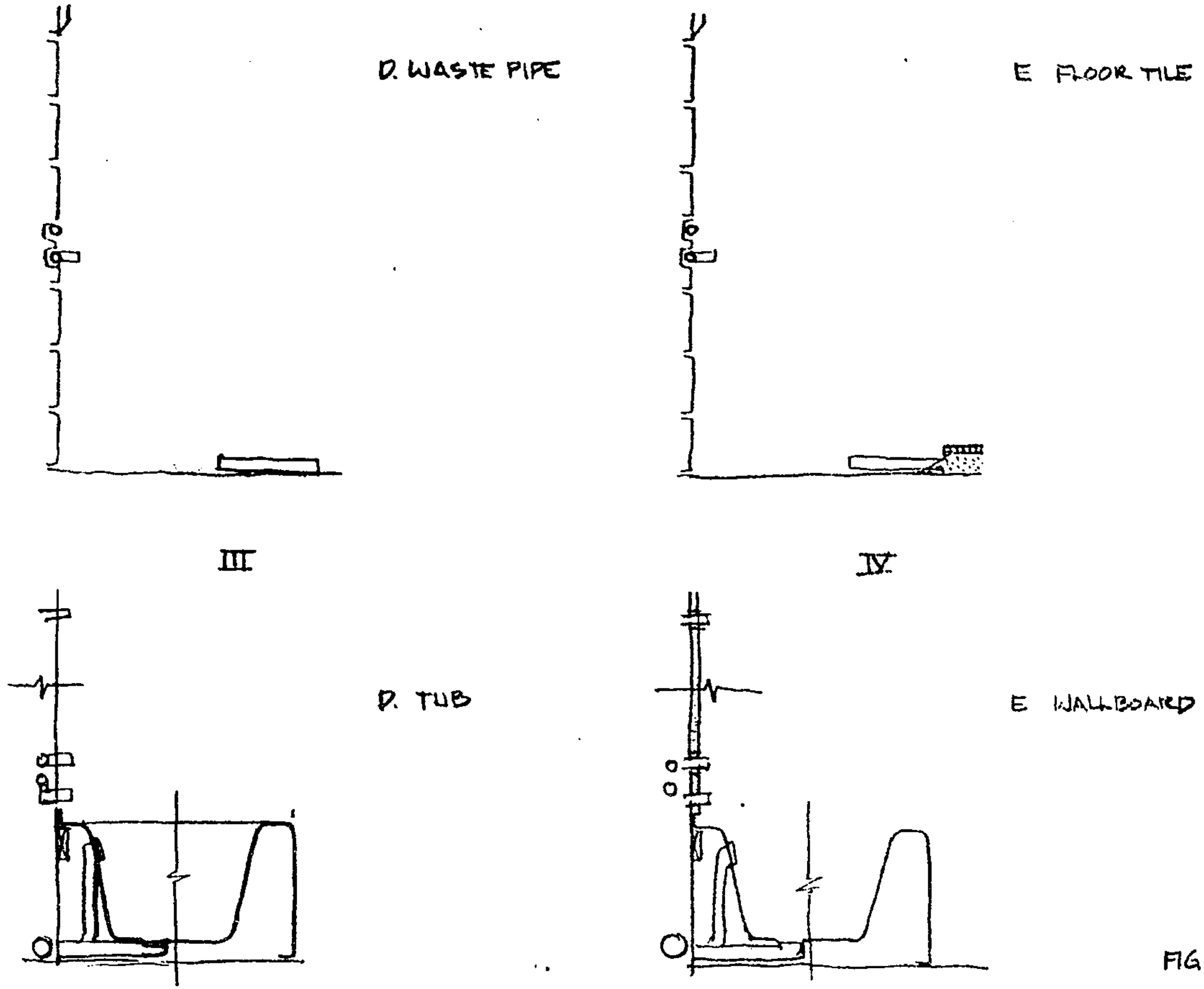


FIG 4.3.2

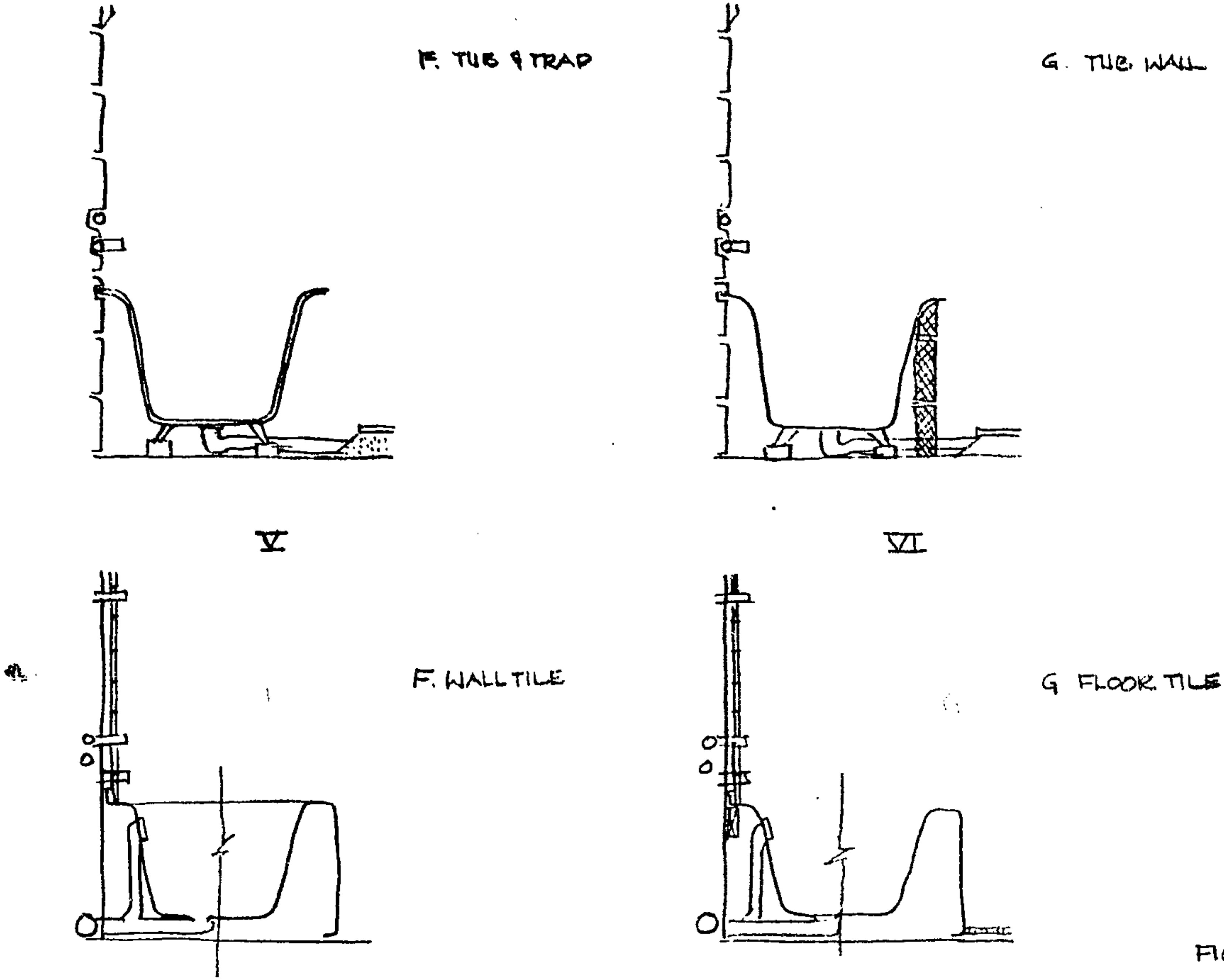
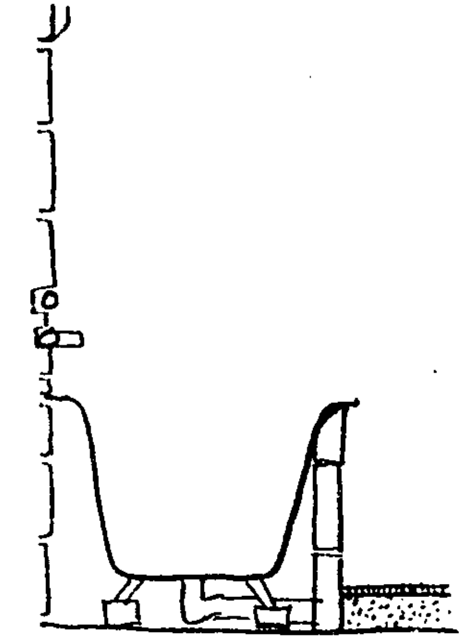
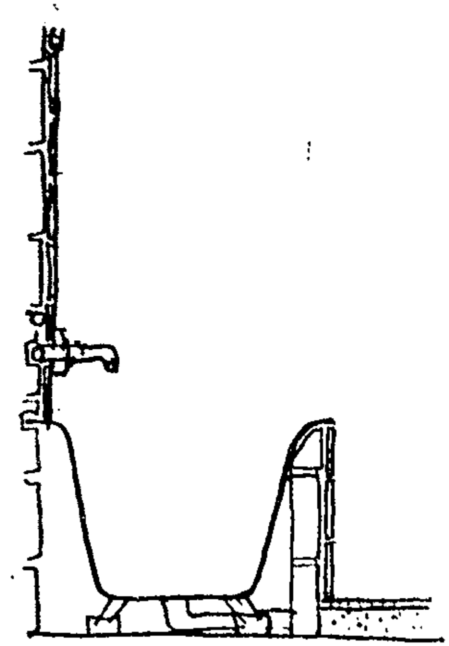


FIG 4.3.4



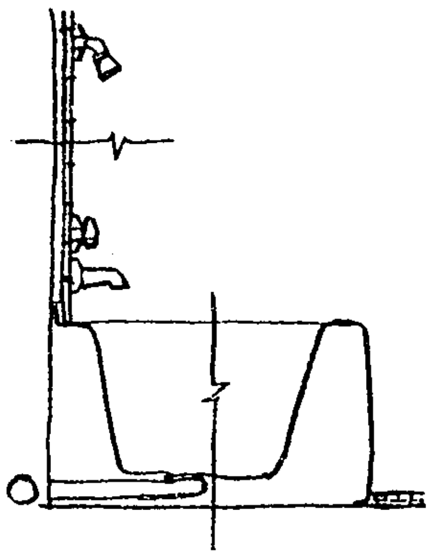
H. REPAIR FLOOR TILE

VII



I CERAMIC WALL TILE
J PLASTER TOUCH-UP
K WHITEWASH
L FAUCET

VIII - X



H. FAUCET

FIG 4.3.5

FUNCTIONS

The primary functions of bathtubs are, of course, related to their uses as receptacles for bathing. The supports and joints of bathtubs must be able to withstand the varying live loads to which they are subjected. The junctures and finish materials of the surrounding walls, as well as the tub, must be cleanable and resistant to water and mildew. The flooring and its joints must also satisfy these requirements.

Bathtubs in the U.S. serve an additional function, as shower receptacles, and therefore the wall surfaces and joints with the tub must be able to turn back direct spray, to drain into the tub.

Hot and cold water services are to be supplied at the walls in each example, and the wall surfaces must accommodate the faucets and valves. A space beneath the tub is required for the connection of traps and drainlines.

BATHTUB - U.S. EXAMPLE

FORM

Bathtubs in the United States are constructed to standardized sizes of enameled cast iron or enameled press steel (see Figure 2.1). Although a range of sizes and shapes are offered by different manufacturers, the most common tubs are 5'0" (1,524 mm) in length, 2'6" (762 mm) wide, and 1'4" (406 mm) high. These tubs all have an integral front panel, which is turned down from a flange extending around the rim of the tub. Tubs are manufactured to be right-hand or left-hand, dependent upon the location of the drain. Most tubs are designed to be installed within an alcove of the bathroom wall, in which they also serve as a shower receptor. However, tubs may be constructed with a flange on the end opposite the drain, to be installed against one corner of the room.

Both cast iron and pressed steel tubs incorporate a raised lip at the back edges of the flange to divert water. In cast iron tubs, this lip is a ridge at the rim, while steel tubs employ a 1" (25 mm) lip, actually an upturned section of the flange itself for this purpose.

Bathtub and wall surfaces are also constructed of one-piece fiberglass units, which provide complete shower enclosures, but these units are not as frequently used as the conventional tub shapes.

Wall surfaces are commonly covered with ceramic tile on moisture resistant gypsum board, but laminated panels and other materials may also be used.

ELEMENTS

The elements of the U.S. bathtub assembly are listed in Table 4.1. Figure 4.4 is a section taken through the width of the tub, from the back wall including the front tub panel. The faucets and shower heads are not shown in this section, as they are located at the end of the tub. (The section in the stages of construction drawings, Figure 4.3 represents a composite longitudinal and lateral section, to include the

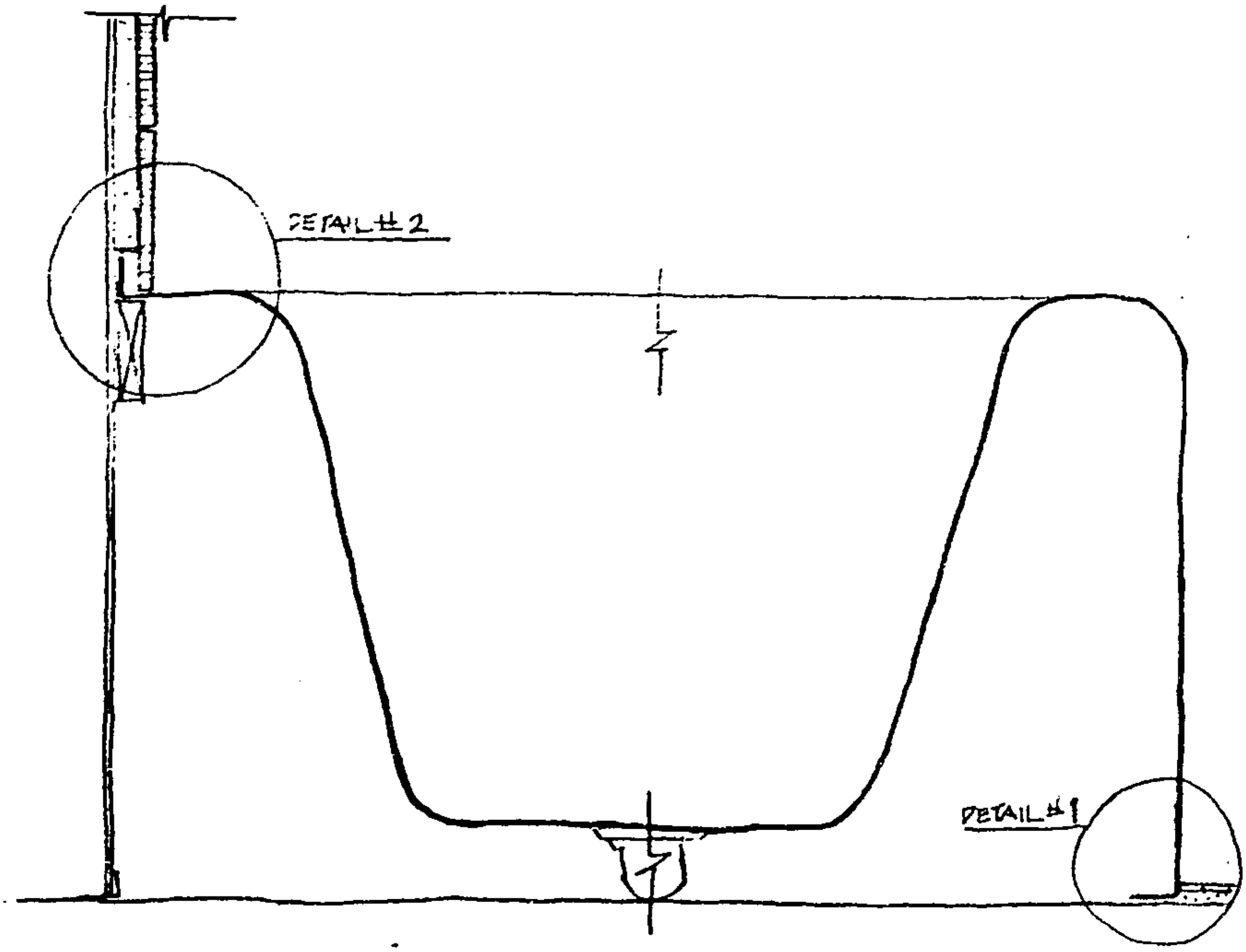


FIG 4.4
U.S. BATHTUB : SECTION

TABLE 4.1

ELEMENTS OF THE U.S. BATHTUB ASSEMBLY

Concrete floor - Pre-cast or cast in place, with smooth flat surface.

Framing - Metal stud framing, spaced 16" (406 mm) or 24" (610 mm) on center, fixed with self-threading screws.

Piping - Copper (3/4" (19 mm)) hot and cold supply lines, cast iron 2" drain lines run in wall cavity. Mixer connection with valves and shower pipe sweat-jointed to pipes in wall, with faucet spout run-outs and valve extensions and shower head extension extending beyond face of studs.

Stringer - 1 x 4 (25 mm x 107 mm) (nominal) wood framing or metal channel, fixed to back wall studes to support back flange of tub.

Tub - Porcelain enameled steel, pressed to shape, with 1" (25 mm) upturned lip on flanges at sides and back, with integral front panel turned down from front flange, and 1" (25 mm) under at bottom. Strip braces at inside corners maintain rigidity. Fixed to studs at back with screws through holes in back lip or with metal clamps. Copper closet-bend trap and over flow drain connected to drain line in wall.

Wallboard - Gypsum drywall, in 4' x 8' (1,219 mm x 2,438 mm) sheets cut to fit on wall, with 1" (25 mm) $\pm$ 1/4" (6 mm) clearance from tub flange, fixed with self-threading sheet metal screws to metal studs. Finished by taping, floating and spackling nail heads.

Wall tile - Ceramic, 5/16" x 4 1/4" x 4 1/4" (8 mm x 108 mm x 108 mm) with organic adhesive, in 16 tile sheets, fixed to wall-board, tiles at edges cut to fit if necessary to attain a level course, cut around faucet run-outs where needed, finished by grouting seams, caulking joints by tub with sealant.

Floor tile - 1" square (25 mm), 1/4" (6 mm) thick mosaic tile in sheets laid on 3/4" (19 mm) mortar bed, edges cut to fit, finished by grouting, caulking at joint with tub.

Faucet - Faucet knobs, spout and shower head threaded to valves and fixture run-outs in wall, escutcheons placed to cover holes cut in tiles.

piping).

It can be seen in the section that there are only two areas of junctures between the elements. Detail #1 illustrates the bottom edge of the tub's front panel, which rests directly on the concrete floor. The floor tiles and mortar bed abutt the panel face. Detail #2 includes the upturned lip on the back flange of the tub.* The tub lip is flush with the back wall framing, and the flange is a seat for the tile, placed on the wallboard. A silicone caulking compound provides waterproofing at the edge of the tile.

PROCESS

The process of installing bathtubs, shown in Figure 4.5, is different from kitchen cabinets in that the tub is built into the structure, which will be shown by the interface network analysis. Bathtubs are affixed to the framing early in the assembly, and in a sense, perform as part of the overall wall and floor structure; both in response to loading and in the nature of the interfaces made to the tub itself.

The installation of the tub itself resembles that of the structure, in this case the wall framing in that its position is carefully measured and determined, to prevent the need of measuring and placing subsequent elements to correct irregularities. Indeed, the tub is aligned with a stringer, a length of framing material.

*This detail is typical for the back and ends of the tub, although the flange lip is not necessarily brought absolutely flush with the wall framing at the ends of the tub, as is shown to be the case with the back wall framing. This tolerance will be explained in the detail analysis.

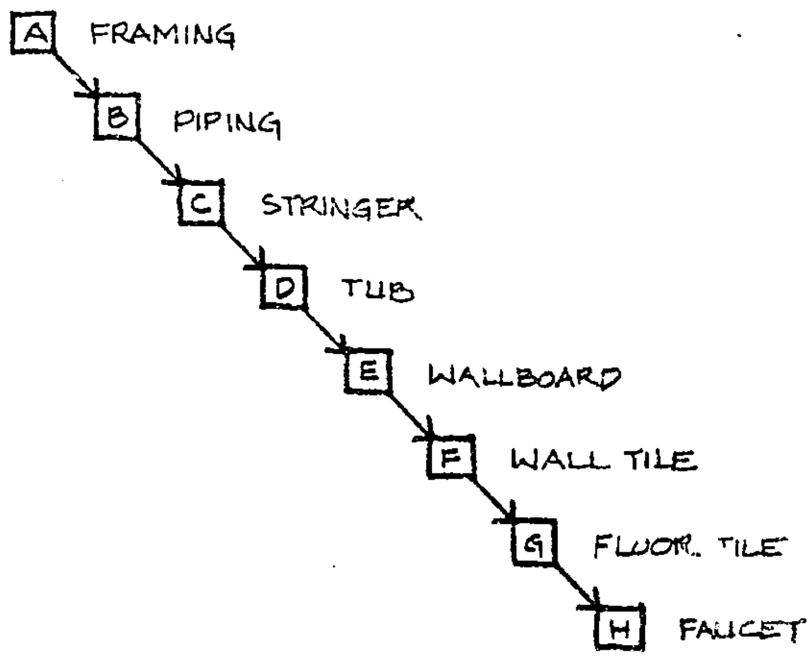


FIG. 4.5
U.S. BATHTUB : SEQUENCE OF COMPONENTS

The stringer supports the back flange of the tub, and its installation ensures that the top of the tub will be placed level, for the ceramic wall tiles to fit properly.

Plumbing lines and valves are positioned and installed in the wall frame, and with the positioning of the stringer, constitute the only measurements that need to be taken during the process, aside from measurements to lay out and level the ceramic wall tile.

Table 4.2 summarizes the activities involved in the bathtub assembly.

ANALYSIS

INTERFACE NETWORK

The interface between components in the bathtub assembly are illustrated in Figure 4.6. Of the eight components in the assembly, the three elements to which most of the components are brought to interface are:

A. Framing, with 4 subsequent component interfaces

B. Piping, with 4 subsequent component interfaces

D. Tub, with 3 subsequent component interfaces

Of the other components, (C) stringer, (E) wallboard and (F) wall tile, each have only one subsequent component interface. Every component is brought into direct interface with one or more of the three components, (A), (B), and (D). The tub may therefore be considered part of the structure, with regard to the interface pattern. This being established,

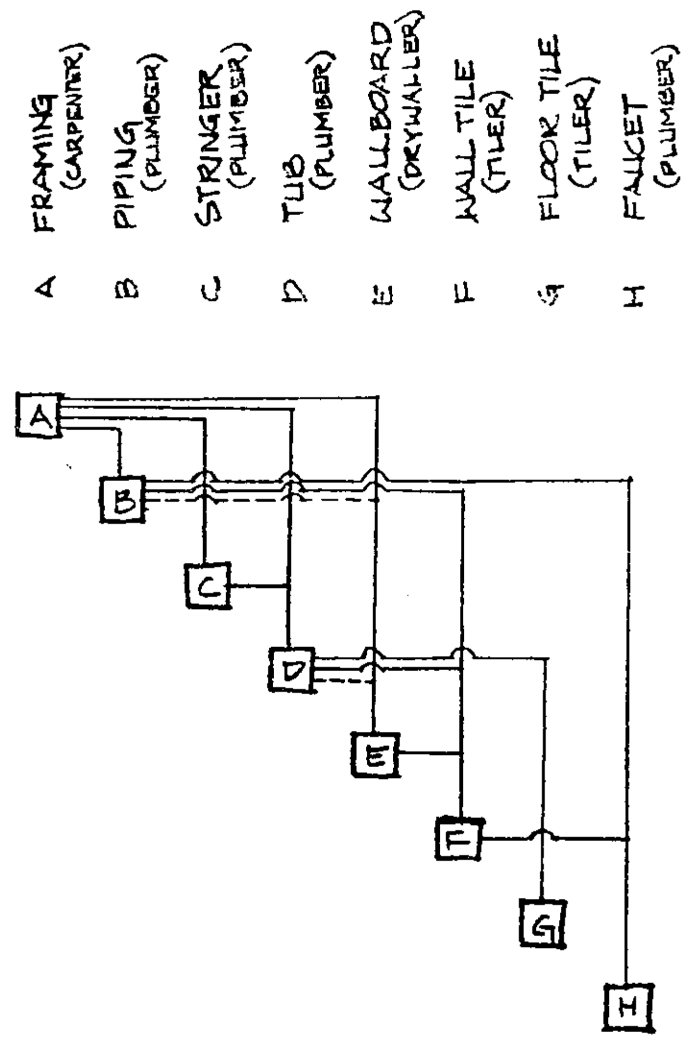


FIG. 4.6
U.S. BATHTUB : INTERFACE NETWORK

TABLE 4.2

U.S. BATHTUB: SEQUENCE OF ASSEMBLY

Component	Activity Description
A. Framing (carpenter)	Set out from plane, sole and top plates anchored to floor and ceiling, studs affixed with self-threading screws.
B. Piping (plumber)	Interface: framing Piping run within wall cavity and through holes punched in metal studs, fixture valves and connections sweat jointed.
C. Stringer (plumber or carpenter)	Interface: framing Position measured from floor, set level and screwed to studs.
D. Tub (plumber)	Interface: stringer Interface: framing Tub flange set on stringer, lip brought flush with studs and screwed in place; traps and drain connected.
E. Wallboard (drywaller)	Interface: framing Interface: piping Interface: tub Cut to fit, fastened to wall with screws, joints taped and floated, screw-heads spackled.
F. Wall tile (tiler)	Interface: piping Interface: tub Interface: wallboard Cut to fit where necessary, applied to wallboard, with edges against tub flange
G. Floor tile (tiler)	Interface: tub Cut to fit where necessary, laid on mortar bed, up to edge of tub front panel.
H. Faucet (plumber)	Interface: piping Interface: wall tile Faucet spout, knobs and shower heads, with escutcheons threaded or screwed to fixture run-outs.

the fact that all components interface with these three confirms that the assembly is "built-in."

Four components are brought to interface with the immediately preceeding component, leaving three components which do not, excluding the initial component. As an indication of successive placement, the sequence: D/C (tub to stringer), E/D (wall board to tub), and F/E (wall tile to wallboard) is a direct chain of installation of the four most important elements in terms of position. The significance of these components will be shown in the detail and positional dependency analyses.

The number of precedent components in assembly to which components are brought to interface is an indicator of the degree to which the assembly as a whole is interrelated. Of the seven components in the bathtub assembly which have precedents, four components interface with more than one precedent, listed in Table 4.3. The components which have three interfaces (D) tub, (E) wallboard, and (F) wall tile, include low degree interfaces, which have considerable tolerance in the juncture, as will be indicated in the detail analysis. Discounting the low degree interfaces, three components are brought to direct interface with only two precedent components: (D) tub, (F) wall tile, and (H) faucet.

TABLE 4.3

U.S. BATHTUB COMPONENTS

WHICH INTERFACE WITH MORE THAN ONE PRECEDENT

Component	Precedent
D. Tub	A. Framing B. Piping (low degree interface) C. Stringer
E. Wallboard	A. Framing B. Piping (low degree interface) D. Tub (low degree interface)
F. Wall tile	B. Piping (low degree interface) D. Tub E. Wallboard
H. Faucet	B. Piping F. Wall tile

The bathtub assembly is thus shown to be interrelated, with each of three components interfacing three precedents. But the degree to which the assembly is interrelated is mitigated by the types of interfaces between components. The joint interfaces which constitute lower degree interfaces and their relationship to direct interfaces in the assembly will be examined in the following section.

The types of joint interfaces that affect the placement of the components in the assembly will be examined in the analysis of detail.

ANALYSIS OF DETAIL

Two details located in Figure 4.4 will be analyzed for the purpose of understanding the relationships of the type of joint interface with the sequence of assembly of the U.S. bathtub example. These details, #1, bottom edge of tub face, and #2, back edge of tub flange, represent the primary interfaces in the alignment, support and fixation of the bathtub and finish materials.

It was noted in the discussion of the interface network that the lower degree interfaces are of significance in understanding the interrelationships of the assembly. Those interfaces which are shown to be of lesser degree in Figure 4.6 involve gaps or tolerances between components. Such a gap will be illustrated in detail #2, between the wallboard and the flange of the tub, (D/E). Interface E/D is listed in Table 4.3 along with three other lower degree interfaces: D/B (tub/piping), E/B (wallboard/piping), and F/B (wall tile/piping).

The other three lower degree interfaces are not shown in the details, but deserve some discussion, since they contribute to reducing the interdependency of the components. These three interfaces are all brought to the elements included in the component, piping (B).

The first interface is between the tub and drain pipe, D/B. In this case the junctures are hidden beneath the tub, and a closet-bend trap is adjusted with a length of pipe to bring about the connection to the drain stack within the wall cavity. The adjustability of the connections causes this interface to be of lesser degree.

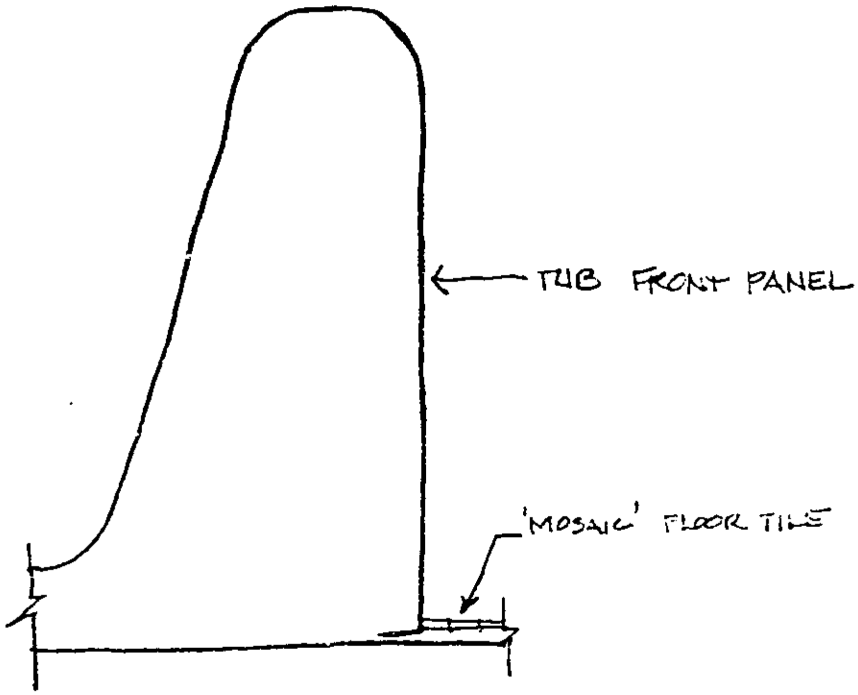
The two remaining lower degree interfaces are: E/B and F/B, are of the wallboard (E), and wall tile (F), with elements included in piping (B): run-outs for the faucet spout, knobs, and shower head. These interfaces are so classified because a gap or hole exists at the juncture and there is no need of a positive, direct joint between the components, albeit each hole must be within the limits of the capacity of the next component's concealment: the wall tile over the wallboard hole and the faucet escutcheon over the wall tile hole.

Since the actual valves and connections are within the wall cavity, only the faucet spout, knobs and shower head run-outs need to pass through holes cut wherever they fall on the wallboard and tile, to be concealed by escutcheons in component H, faucet. The positions of these knobs and spout with respect to each other and to the wall tile courses are thus not of concern during the installation of these components.

DETAIL #1

BOTTOM EDGE OF THE TUB FACE

This detail represents the bottom edge of the tub face, which is turned under to rest on the floor supporting the tub. The position of the front tub edge is determined by the interface of the tub lip and framing, D/A, shown in detail #2. The pre-fabricated tub is braced such that the edges remain square and parallel. This determination of position is not constrained by the slip plane between the tub edge and floor. If the tub is set properly against the framing, the orthagonality of the tub transfers the alignment with the wall to the tub face as well. The interface between the floor tile and tub face (G/D) is therefore square with the other walls of the room and the line of tiles may be brought evenly to the tub. The thickness of the mortar bed conceals the edge between tub and floor, at interface D/G. A slip plane of sorts may be identified at this interface, since nothing on the tub affects the thickness of the tile.



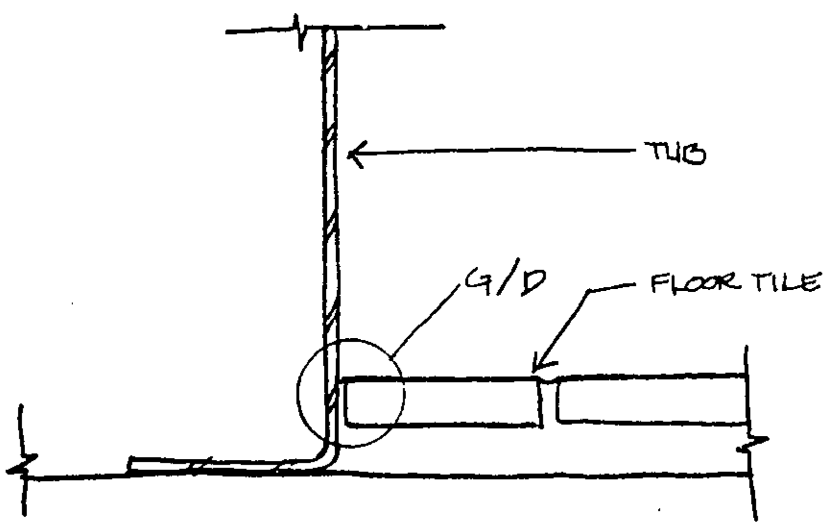


FIG 4.7
U.S. BATHTUB : DETAIL #1

DETAIL #2

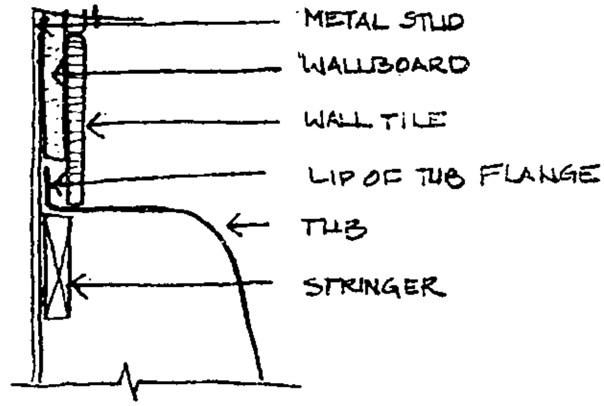
BACK EDGE OF TUB FLANGE

This detail represents the most critical interfaces of the U.S. tub assembly, between the framing (A), stringer (C), tub (D), wallboard (E), and wall tile (F). The face of the framing studs represents the primary vertical control plane of the assembly, and is the first component to be installed. The stringer is affixed to the framing at interface C/A, which constitutes a vertical slip plane coinciding with the vertical control plane. The top edge of the stringer is measured to be set at the correct height and leveled prior to fixation. The bottom edge of the tub rests on the top face of the stringer at interface D/C. This interface is also a slip plane by which the tub lip may be brought flush against the face of the studs to be centered between the two end walls. The interface of the tub lip and framing, D/A, also constitutes a slip plane, constrianing neither the leveling of the tub by the placement of the stringer, nor in centering the tub between the end wall framing which must be within 1/2" (13 mm) of the tub lip at each end.

The tub lip must be brought flush against the framing so that it may be square with the walls of the room and therefore the floor tiles, as explained in the discussion of detail #1. Also, the tub must be square with the end walls of the alcove, such that the lip does not interface with the placement of the wall tiles.

The wallboard is brought to interface with the framing at E/A, and is shown to be cut to clear the tub flange by up to 1 1/2" (38 mm) at interface E/D. The thickness of the wallboard brings the front face, the plane of interface with the wall tile (F/E) forward, clearing the tub lip by 1/2" (13 mm) at the back edge. This configuration also establishes the 1/2" (13 mm) tolerance for the interface of the tub lip with the framing of the end walls of the alcove.

With a clearance with the tub lip thus assured, the tiles are brought to rest on the top of the tub flange at interface D/F. The height and level of the stringer determines the level plane of the tub flange, such that the tiles may be set in a level course and flush with the tub. Interface D/F is sealed with a silicone compound.



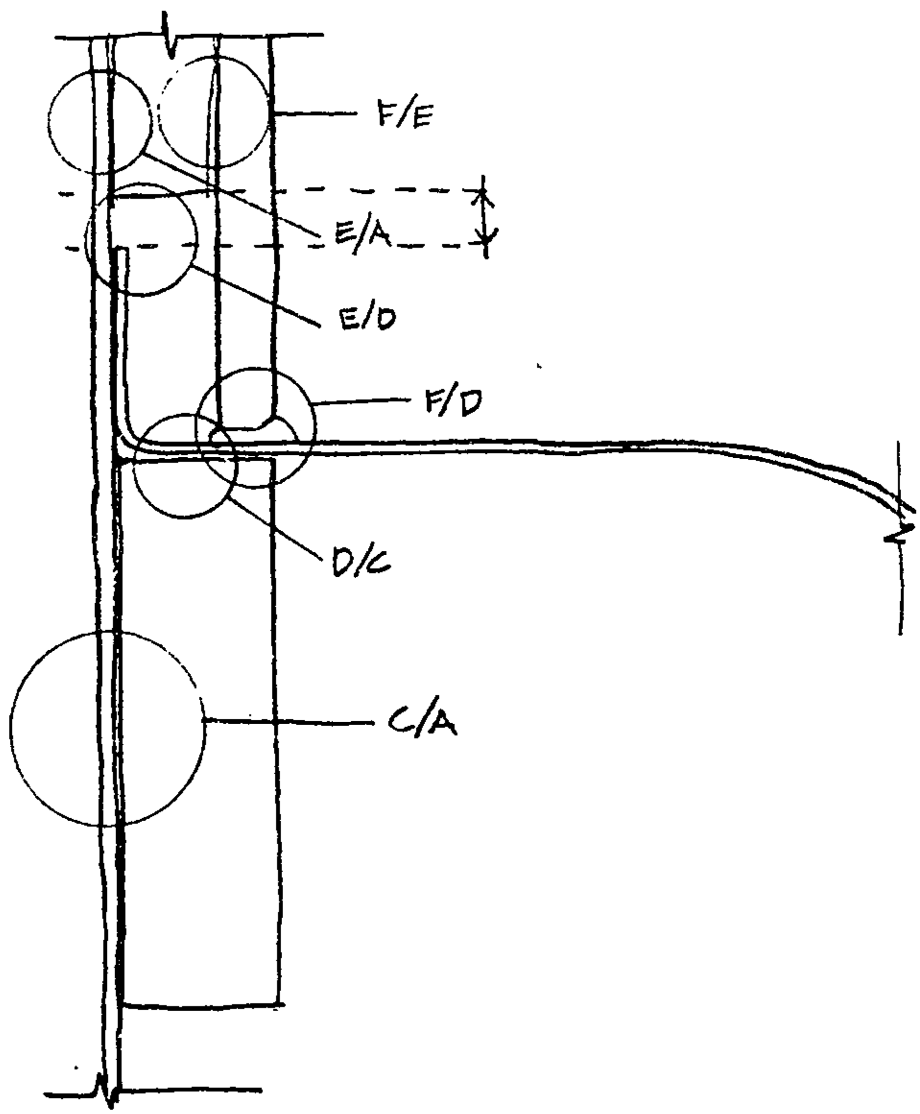


FIG 4.8
U.S. BATHTUB : DETAIL #2

PLACEMENT/POSITION AND CONTROL PLANES

The dependency of finish construction in the U.S. upon the accurate position, planarity and orthagonality of the wall framing is exemplified by the bathtub assembly.

As in the kitchen cabinet assembly, two control planes are manifested by the structure of wall and floor in the bathtub assembly, HCP I and VCP I. A second horizontal control plane, HCP II, is yet to be established, but only one measurement is necessary to align and level this plane, which is manifested by the flange around the tub. It will be shown that the tub and control plane it represents as an ortagonal, pre-fabricated component, is linked to the structure for determination of positions of components in the assembly. These positional dependencies are summarized in Table 4.4.

Two components, (A) framing, and (D) bathtub, are depended upon for the positions of the other components in the assembly. This is readily observable in the positional dependency network, Figure 4.9. The bathtub is dependent upon the back wall framing for its position in plan, and upon the accurate placement (to within 1/2" (13 mm)) of the end

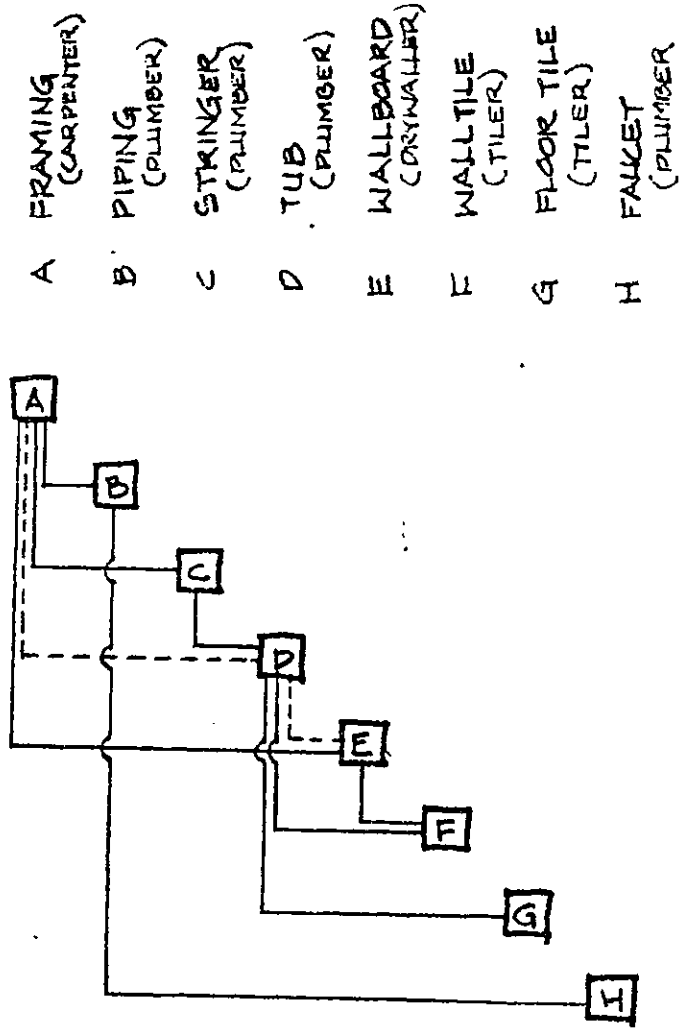


FIG. 4.9

U.S. BATHTUB : POSITIONAL DEPENDENCY NETWORK

TABLE 4.4

U.S. BATHTUB: POSITIONAL DEPENDENCY SUMMARY

Component	Positional Dependencies
A. Framing (carpenter)	Establishes vertical control plane at face of studs, position determined from plan. Distance between end walls for tub is measured carefully.
B. Piping (plumber)	Fixture run-outs measured for position, run within wall framing cavities (A-B)
C. Stringer (plumber or carpenter)	Critical element in tub placement, top edge represents HCP II, measured to determine height from floor and leveled. Affixed to studs along slip plane at C/A, (A-C).
D. Tub (plumber)	Dependent upon framing end walls and back walls to be square and to proper dimensions (within ± 1/4" (6 mm) (A-D), and dependent upon stringer (C-D) to be level and correct height, transfers vertical control plane to front panel for floor tile.
E. Wallboard (drywaller)	Dependent upon framing (A-E) for position, cut to clear top flange (D-E) interface E/D in detail #3, transfers vertical control plane for wall tile.
F. Wall tile (tiler)	Dependent upon wallboard (D-F) and tub (E-F) to be square and level, tile represents finish of vertical control plane and intersection with HCP II at tub flange, interface (F/D), to within a tolerance of 1/8" (3 mm).
G. Floor tile (tiler)	Relies upon transference of VCP from back wall to front panel of tub, (D-G), for square fit with other walls in room, to within 1/4" (6 mm).
H. Faucet (plumber)	Positions determined by faucet run-outs, but since connections and valves are within walls, positional dependency is not critical, only hook-up of knobs, spout, and shower head.

walls for a successful fit, A-D. The back wall establishes the vertical control plane for the assembly, and the bathtub transfers alignment to this plane at the parallel line at the base of the face panel of the tub, to which the floor tiles are placed.

The other component to which the bathtub is positionally dependent is the stringer, C-D, whose placement is the most critical in the assembly. The stringer established the height and level of the second horizontal control plane, manifested by the top flange of the tub; and by transference, the vertical position of the tub's front panel.

Two groups of positional dependencies are associated with the two components (A) framing and (D) tub, which have been shown to dominate the positional dependency network. The components which are dependent upon (A) framing constitute the structure group, and include: (B) piping, (C) stringer, (D) tub, and (E) wallboard. Those which are dependent upon the tub make up the finish group: (E) wallboard, (F) wall tile, and (G) floor tile. The inclusion of (D) tub and (E) wallboard in both groups is shown in Figure 2.11. This overlapping condition is justifiable in the light of the dual nature of the two elements in performing both structural and finish functions. The ability of these elements to be included in each group is attributable to the qualities of each having dependable dimensions: the orthagonality of the tub and the planarity and constant thickness of the wallboard. The positional dependencies of these two elements are concentrated at particular interfaces, with their other interfaces being

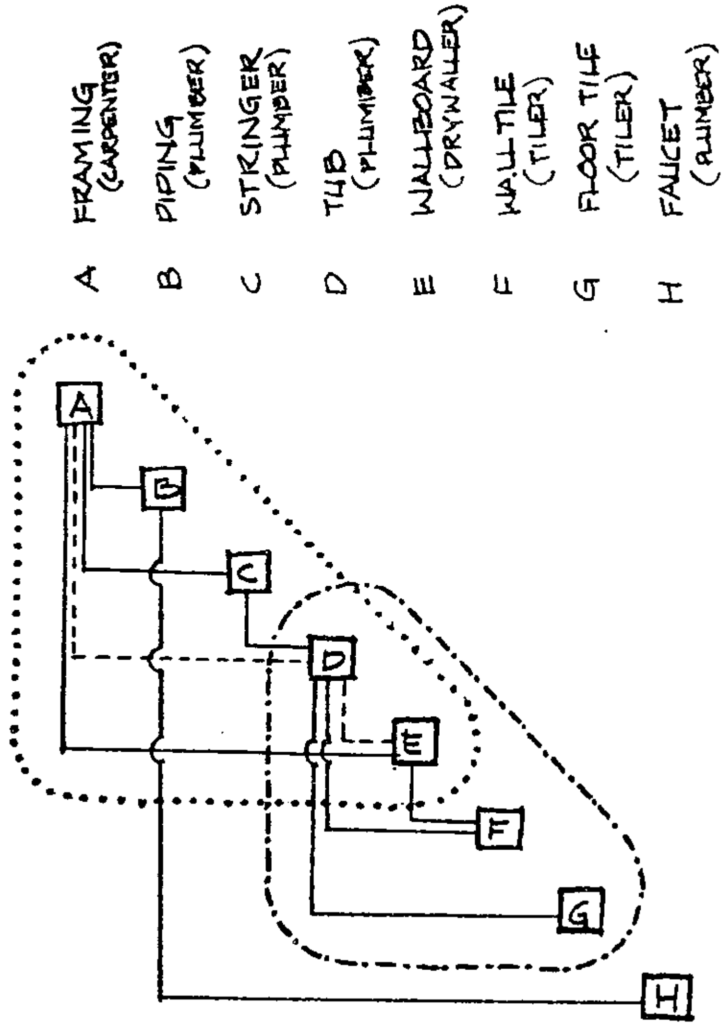


FIG. 4.10
U.S. BATHTUB: COMPONENT PLACEMENT GROUPS

made of lesser concern, by tolerance or slip plane.

To illustrate further, the interfaces of the tub and floor, shown in detail #1, are not constrained with regard to position due to the slip plane that exists at that juncture. A tolerance of 1/2" (13 mm) between the lip and side wall framing relieves constraint at the tub ends, therefore all placement concerns are centered on the back lip interface with framing and the stringer. Likewise, the gap between the tub and wallboard eliminates concern about placement and fit between those two components.

Three trades are involved in each group, with carpenters, plumbers, and drywallers in the structure group; and plumbers, drywallers and tilers in the finish group. The critical positional dependency between the stringer and tub is accomplished within the same trade, and other dependencies that require coordination are immediate and in direct sequence. The single return of trade in the assembly is for the plumber to install the faucets to which there are no constraints that might be induced by preceding components or trades.

BATHTUB - ISRAELI EXAMPLE

Bathtubs in Israel are installed in a quite different manner than those in the United States. This is attributable to a different configuration of the tub itself, its manner of support, and the details of interface with the finish materials. The installation process has been shown in Figure 4.3 to include more stages of assembly that the U.S. counterpart, and this is partly due to a greater number of components in the Israeli. But the effect of supporting methods, serving strategies, and alignment procedures and finish details upon the process will be shown to be more significant than the number of components involved.

Israeli bathrooms include a bathtub and a laundry hamper cabinet, similar in construction to the kitchen cabinet. The cabinet is often built next to the bathtub in an alcove, or on one wall of the room which is built to receive both units. These two units are interrelated in dimension and placement, as the side panel of the cabinet is placed flush against the end of the tub. The components of the two units are installed in an interdependent, parallel process, and alignments between the components are critical.

A comparison between the U.S. bathtub and the Israeli bathtub and cabinet assembly would be inappropriate since the additional interfaces and positional dependencies imposed by the cabinet are overwhelming, and from a unit which has no direct counterpart in the U.S. bathtub assembly. For this reason the type of bathtub installation chosen for this analysis is one in which the bathtub is installed against a corner formed by two walls in the bathroom, without the cabinet. The interface and positional dependency networks of the bathtub and cabinet assembly are included for comparison in Appendix A.

FORM

The Israeli bathtub installation resembles a tiled box, set against a corner, with a bowl depression in the enameled top rectangle of the box. The shape of the cast iron tub is indeed rectangular, formed by the flat horizontal flange on all sides of the rounded bowl (see Figure 4.2).

The 1,610 mm x 720 mm tub flange is surrounded by 450 mm high tile walls on the front and end, and the back walls are tiled to match. A mixing faucet on the long back wall joins the hot and cold water supply pipes which are centered on horizontal tile seams, with the spout on center with a vertical tile seam. The wall tiles rest flush on the tub flanges; and on line and flush with the edges at the front and end tub flanges, resting on floor tiles at the base of the respective tub walls.

ELEMENTS

The elements of the Israeli bathtub assembly, listed in Table 4.5, are depicted in Figure 4.11. This section includes the face of the concrete floor and block wall, from a point on the floor beyond the front of the tub wall to a point above the wall tile on the plastered wall.

The tub rests upon four integral feet, which are shimmed upon blocks from the concrete floor. The block walls under the tub flange also rest upon the concrete floor, while the tiles on that wall rest upon the floor tiles, and are in three complete courses to meet the edge of the tub flange. The interface of the tub wall, floor tile, and ceramic wall tile is illustrated in detail #1, Figure 4.11.

The front tub flange will be shown to be of importance in setting the position of the tub wall, which is built to fit under the flange, to support the tub. Tiles set on a mortar bed on the tub wall are brought flush to the edge of the tub flange. These interfaces are depicted in detail #2.

The tub flanges at the back and end are recessed into kerfs cut into the block walls. Detail #3 represents this interface, as well as the interface of wall tiles upon the top of the flange.

Also shown in the section are the different means of bringing the water services to the tub, and the drainage from it. The hot and cold supply pipes are run in grooves cut in the wall above the tub, while the drain

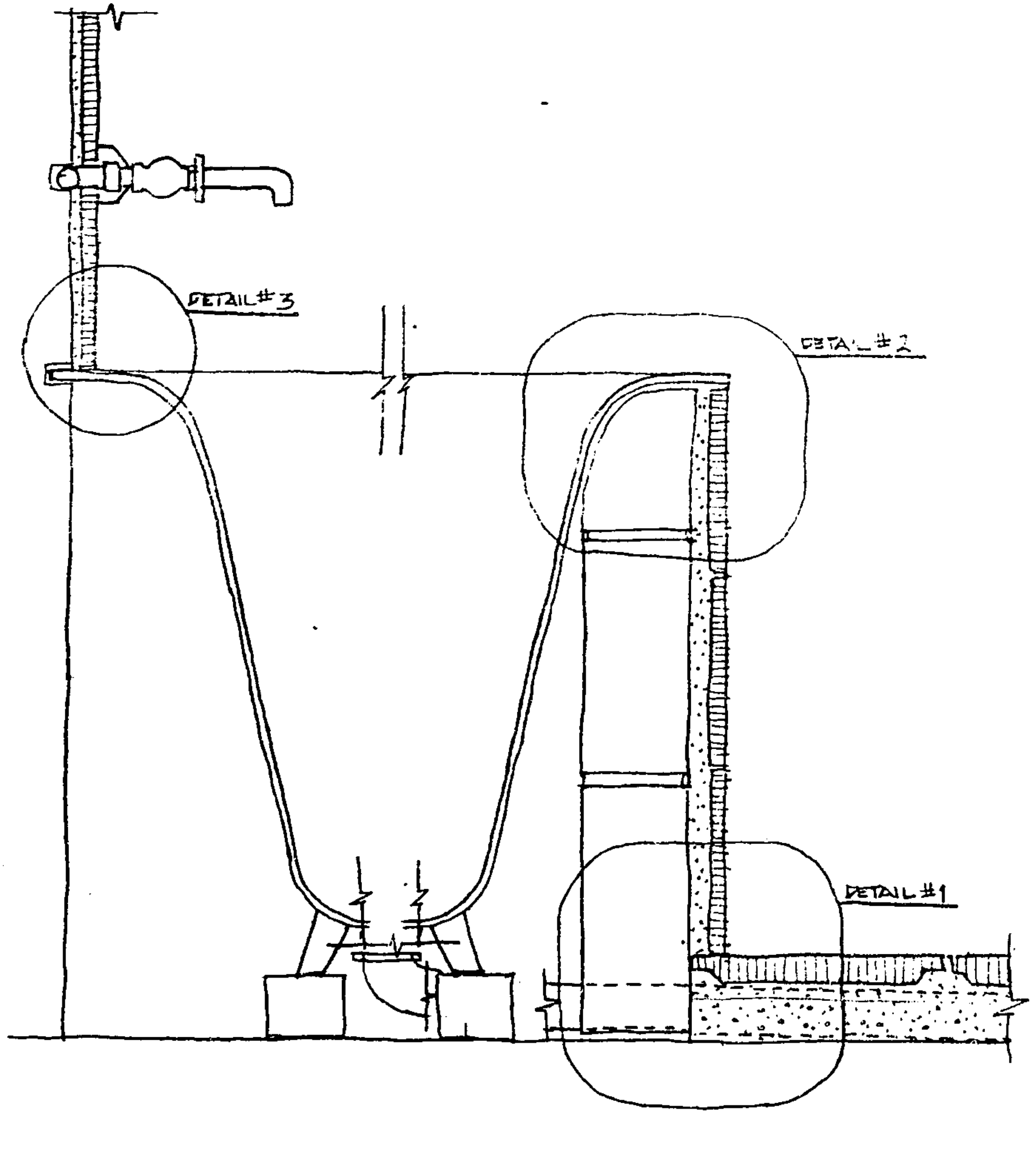


FIG 4.11
ISRAELI BATHTUB: SECTION

TABLE 4.5

ELEMENTS OF THE ISRAELI BATHTUB ASSEMBLY

Concrete floor - Cast in place, rough surface finished by covering with sand fill and floor tile.

Block wall - Concrete block partition 100 mm or 200 mm block, no drain stacks run within cores. Finished by plaster and ceramic tile.

Piping - Galvanized, threaded end, hot and cold water supply lines run in grooves chiseled into block face.

Plaster - ± 15 mm thick plaster, finishes block wall, concealing piping.

Waste pipe - 50 mm p.v.c., run on concrete floor.

Floor tile - 10 mm x 200 mm x 200 mm terrazzo tiles on sand bed fill, covering waste pipe, ± 70 mm finished floor surface above concrete.

Tub and traps - 1,610 mm x 720 mm x 52) mm enameled cast iron, square, straight edge, (symmetrical edge configuration), supported by integral feet on blocks.

Tub wall - 100 mm thick blocks set under tub edge finished in ceramic tile.

Ceramic wall tile - 150 mm x 150 mm x 10 mm tiles, set on mortar bed on block walls behind and under tub.

Whitewash - On plaster, 2 coats.

Faucet - With escutcheon to cover tile holes, fixed to threaded ends of supply pipes.

is run unde~ the tub wall and under the floor tiles.

PROCESS

The elements of the Israeli bathtub assembly may be readily identified as components with corresponding trades and activities in order to identify the process of assembly. These components and activity descriptions associated with interfaces to components previously placed are listed in Table 4.6.

The sequence of components illustrated in Figure 4.12 indicates returns of trade for (G) tub wall, (H) repair floor tile and (J) plaster touch up. These occurrences are indicative of a concept of assembly of the bathtub: the details of interface and component placement are such that components are installed in a sequence that is determined by more than one preceding component. The interfaces that are involved in the assembly will be examined in the following section.

The process of assembly of the bathtub will be shown to be a sequence of built-in components that are interdependent upon one another, by interface and in determination of position. The positions of each element are significant, not to be confirmed until the installation of the wall tile.

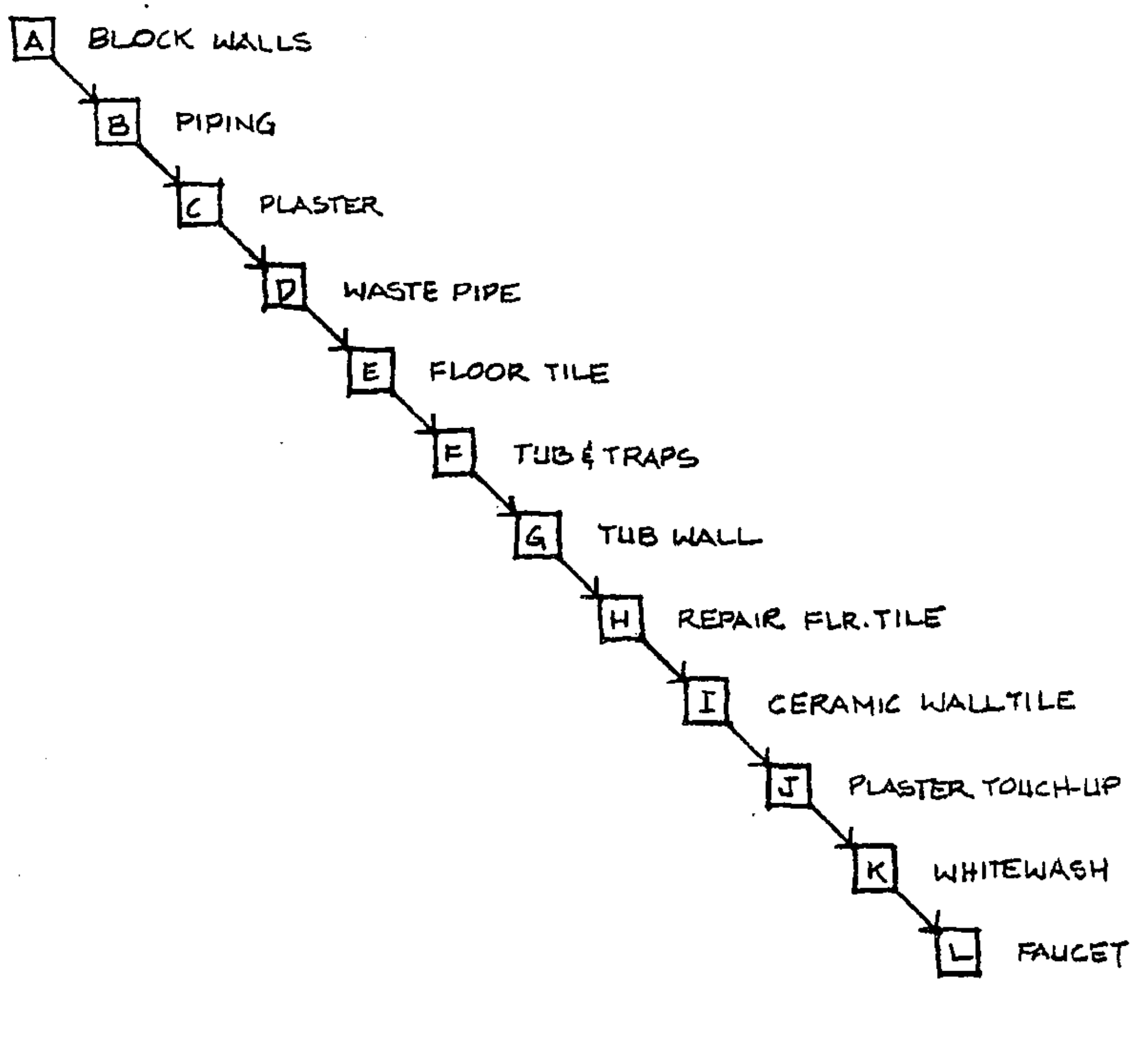


FIG. 4.12
ISRAELI BATHTUB : SEQUENCE OF COMPONENTS

TABLE 4.6

ISRAELI BATHTUB: SEQUENCE OF ASSEMBLY

Component	Activity Description
A. Block walls (mason)	Roughly placed block partiitions, irregularities to be rectified by chiseling at interfaces and plaster.
B. Piping (plumber)	Interface: block wall Grooves chiseled to receive pipes which are run above line of tub around walls to faucet location, to be measured from floor.
C. Plaster (plasterer)	Interface: block wall Interface: piping Spread over block wall and piping to create a plane surface except where wall tile is to be placed.
D. Waste pipe (plumber)	Laid on floor to location of traps, to be covered by sand fill and floor tile.
E. Floor tile (floorer)	Interface: waste pipe Laid on sand bed spread over concrete floor and pipes, close to location of tub to be finished after tub wall is placed.
F. Tub and trap (plumber)	Interface: block wall Kerfs in block wall for edges of tub are measured level from floor and chiseled. Tub feet are set on blocks, tub is slipped into place with edges in kerfs and shimmed to level under feet. Interface: waste pipe Drain trap is connected to drain lines on floor
G. Tub wall (mason)	Interface: tub Interface: block wall Block wall built at side and end of tub, under and up to meet the flanges. Interface: waste pipe Built over waste pipe, with hole to allow passage.

TABLE 4.6 (continued)

Component	Activity Description
H. Repair floor tile (floorer)	Interface: floor tile Interface: tub wall Tile floor finished to sides of tub wall.
I. Ceramic wall tile (wall tiler)	Interface: block wall Interface: tub Wall tiles placed flush on flanges of the tub against block wall on both sides (tub must be set level and to correct height). Interface: piping Tile course lines centered on faucet run-outs of piping, tiles cut to fit around pipes. Interface: tub wall Interface: repair floor tile 3 tile courses set on block wall to edge of tub and top of floor tile, on plane with edge of tub.
J. Plaster touch up (plasterer)	Interface: plaster Interface: ceramic wall tile Smooth edge of plaster and tile.
K. Whitewash (painter)	Interface: plaster (nominal) Two coats painted over plaster.
L. Faucet (plumber)	Interface: piping Interface: ceramic wall tile Affixed to threaded ends of pipe run-outs, escutcheon covers holes cut in tile.

ANALYSIS

INTERFACE NETWORKS

The component sequence and interfaces noted in Table 4.6 are illustrated in Figure 4.13.

The first observation that may be made regarding the interface network is that the assembly is built in to the structure, noting the five components that are brought to interface with the block wall, from various stages in the sequence.

There appears to be a direct sequence of assembly (components interfacing their immediate precedent) from component (F) tub and trap, through (J) plaster touch up. It should be noted, however, that three of the components in this sequence are those cited as a return of trade in the previous section: (G) tub wall, (H) repair floor tile, and (J) plaster touch up. In addition, (I) ceramic wall tile is brought to interface with all three components preceeding it in the sequence.

Seven of the ten components having precedents* in the assembly are brought to interface with more than one precedent, and are listed in Table 4.7. The bathtub assembly is highly interrelated, particularly in regard to the ceramic wall tile, which is critical since it is placed in modular courses, and not cut to fit at the edges.

*(A) block wall (the initial component) and (K) whitewash (not a dimensional component) discounted.

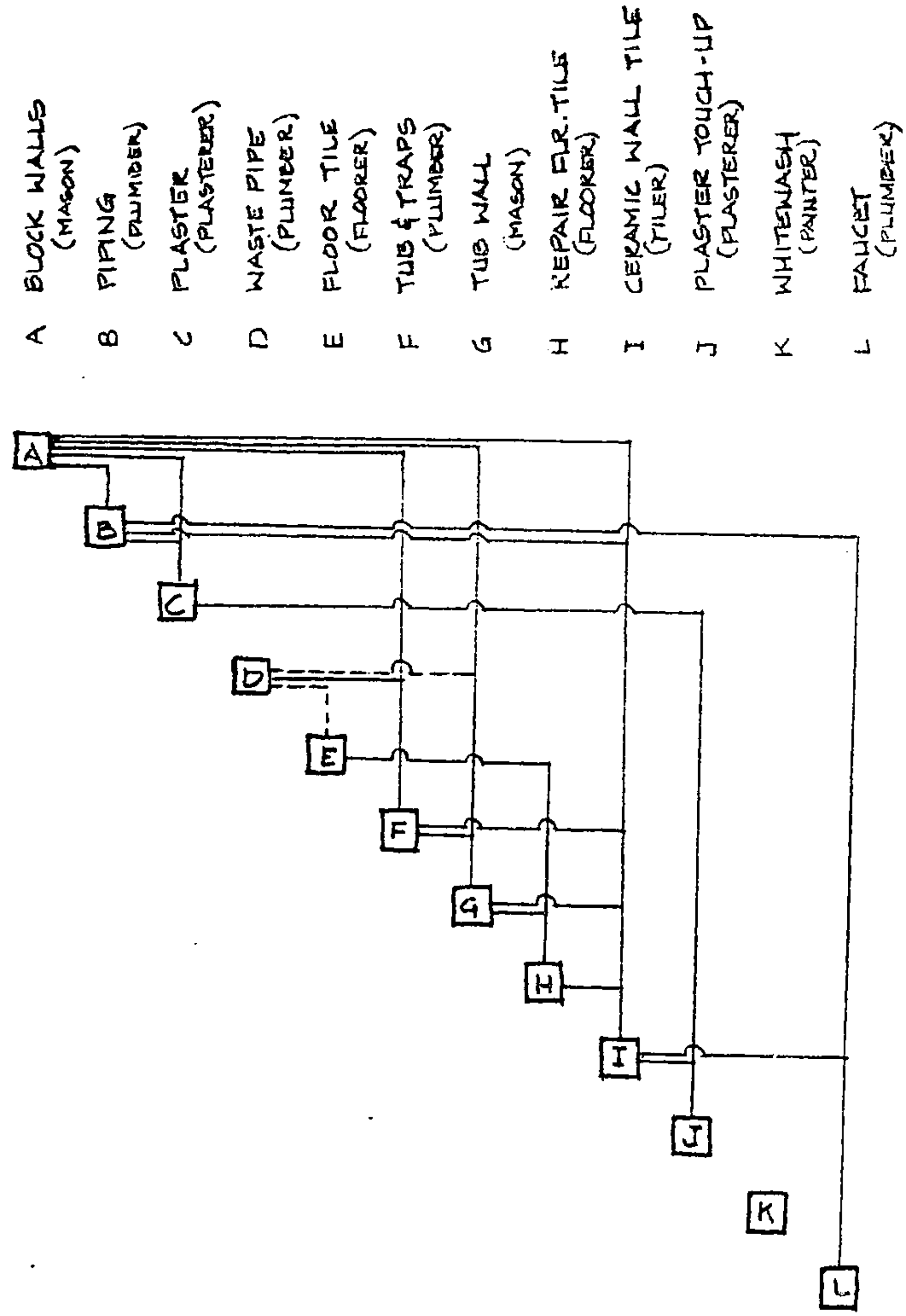


FIG. 4.13
ISRAELI BATHTUB: INTERFACE NETWORK

TABLE 4.7

ISRAELI BATHTUB COMPONENTS

WHICH INTERFACE WITH MORE THAN ONE PRECEDENT

Component	Precedent
C. Plaster	A. Block wall B. Piping
F. Tub and Trap.	A. Block wall D. Waste pipe
G. Tub wall	A. Block Wall D. Waste pipe (low degree interface) F. Tub and trap
H. Repair floor tile	E. Floor tile G. Tub wall
I. Ceramic wall tile	A. Block wall B. Piping C. Plaster F. Tub and trap G. Tub wall H. Repair floor tile
J. Plaster touch up	C. Plaster I. Ceramic wall tile
L. Faucet	B. Piping I. Ceramic wall tile

ANALYSIS OF DETAIL

DETAIL #1

BOTTOM OF TUB WALL AT FLOOR TILE

Detail #1 includes the interfaces of components: (E) floor tile, (G) tub wall, (H) repair floor tile, and (I) ceramic wall tile. The waste pipe (D) is indicated by a dotted line passing through a hole in the tub wall and under the floor tile. The first component installed in this detail is the waste pipe, which is laid on the floor and covered by the sand fill and floor tile (E) whose finish floor height of 70 mm is just sufficient to clear the 50 mm drain pipe, considering a 20 mm thickness of the tiles themselves.

The block tub wall, whose position is determined by its interface with the tub flange in detail #2, is cut out to clear the drain pipe, and establishes a surface to which the floor tiles may be finished, at interface H/G. There is a ± 10 mm tolerance at this edge, since the thickness of the ceramic tile and mortar bed will cover the edge in an overlapping butt joint.

The ceramic tile may be brought forward by 15 to 30 mm from the block wall, at interface I/G, to suit the alignments imposed by the tub edge in detail #2.

However, since three modular tile courses are placed on the tub wall, there is little tolerance to achieve a flush fit at I/H, and the floor tile (H) must have been correctly placed.

The overlapping butt joint of this detail, with variable thickness of materials, (represented by the sand bed and mortar bed), offers the possibility of slip plane adjustments, and tolerance in interfaces since the edges are concealed. However, the very tolerances afforded by the configuration became uncertainties when the fit of the final component is constrained in length, as is the ceramic wall tile in this case.

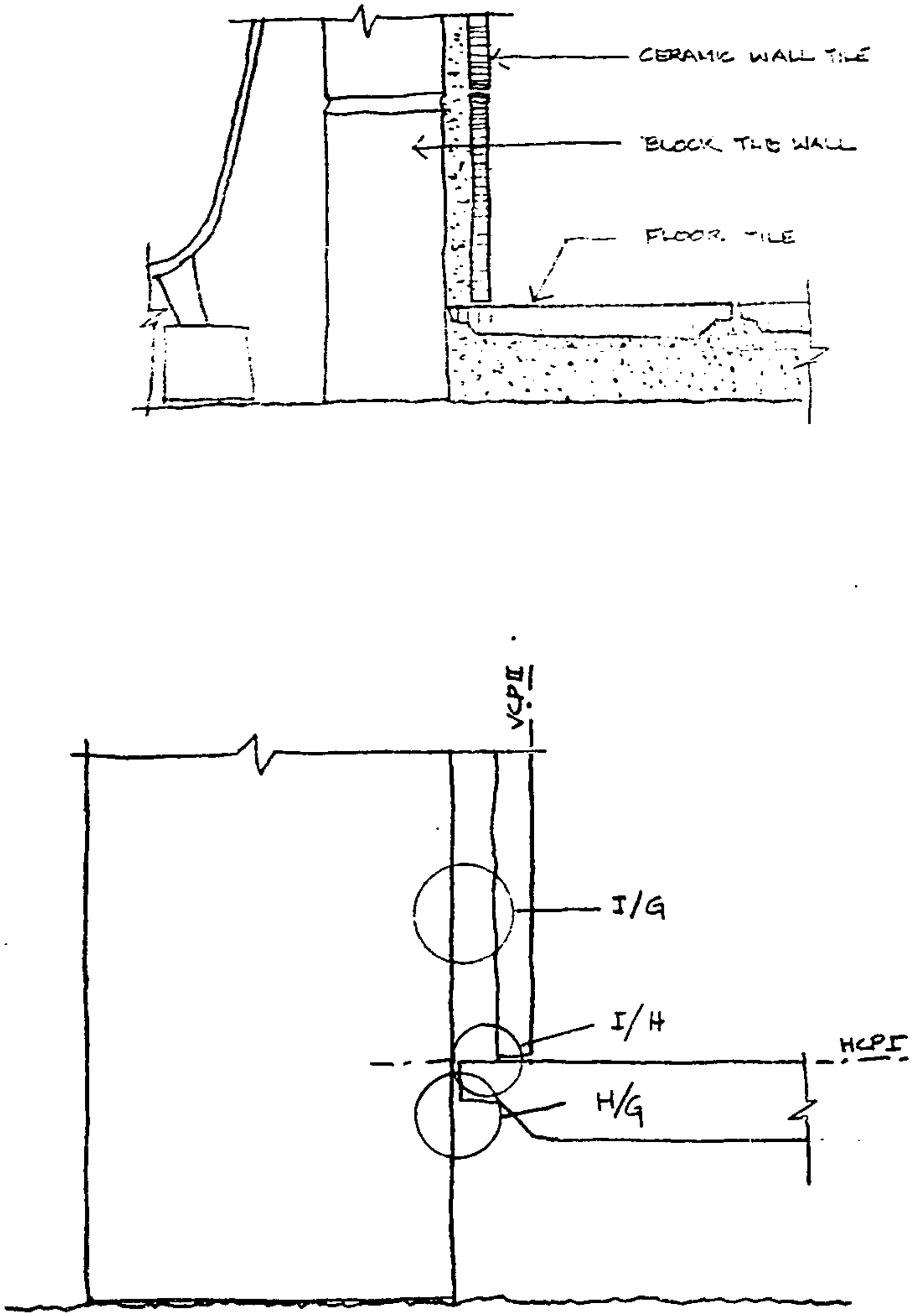


FIG. 4.14
ISRAELI BATHTUB : DETAIL #1

DETAIL #2

TOP OF TUB WALL AT TUB FLANGE

The tub (F), tub wall (G) and ceramic wall tile (I), are represented in this detail. The position of the tub flange, the first component to be installed determines the position of the other two components at this point and in detail #1.

The tub flange is supported by the tub wall at interface G/F, but its position is set by shims under the feet and by the kerf cut in the wall (shown in detail #3). The tub wall is built up to meet the underside of the tub, with the blocks cut and mortar at the juncture providing a secure supporting bed for the tub. The front edge of the tub wall must be placed sufficiently behind the front edge of the tub (± 15 to 30 mm) to allow the wall tile to be placed correctly.

Interface I/G corresponds to the same labeled interface in detail #1, and the thickness of the mortar bed provides the tolerance for the placement of the tub wall, smooths out irregularities, and brings the tile forward to be set in a vertical plane even with the edge of the tub flange and flush with the underside (I/F). The tolerance of this juncture, (± 2 mm), is the least of any in the assembly.

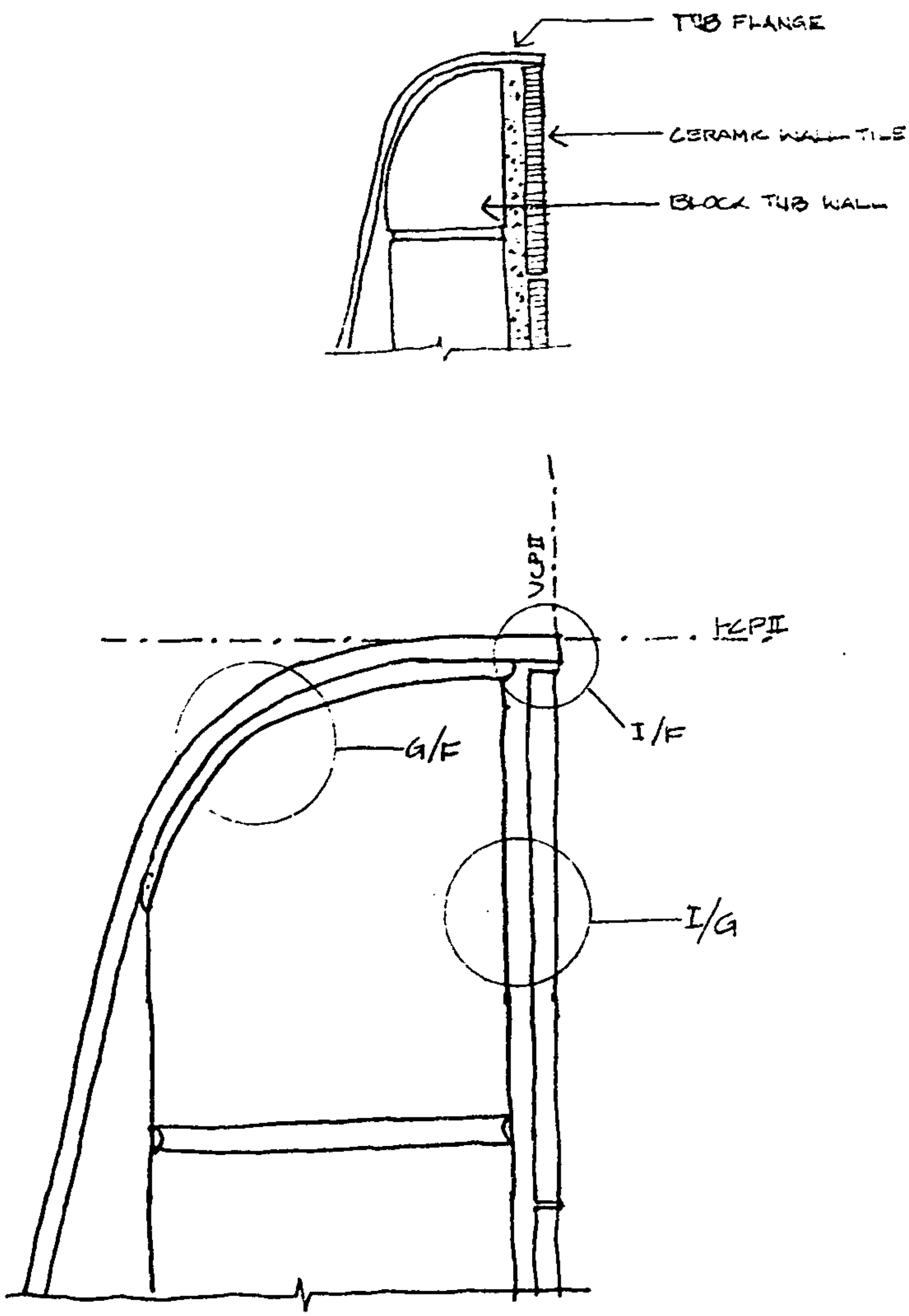


FIG 4.15
ISRAELI BATHTUB: DETAIL #2

DETAIL #3

BACK OF TUB FLANGE AT BLOCK WALL

This detail shows the interfaces of the block wall (A), piping (B), tub (F), and faucet (L).

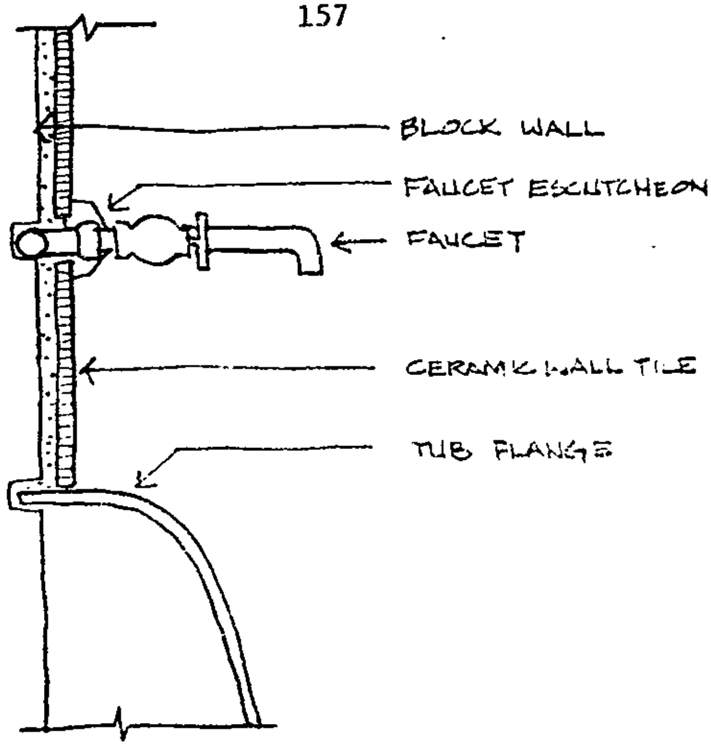
The piping is the first component to be installed in this detail and must be placed to a tolerance of ± 3 mm from its designed location. The other components which interface with the piping, the ceramic wall tile (I), and faucet (L), require such a highly accurate placement, yet are not installed until much later in the process.

The second component installed is the tub (F). The kerf in the wall is cut to a level, measured height, and the edge of the flange is inserted in the kerf (F/A) and leveled by the shim blocks placed under the feet.

The kerf provides a continuous, closed juncture between the tub edge and the irregular block wall surface. Also, the tub may be adjusted horizontally within the kerf by ± 10 cm to be set square with the back and side walls.

The interfaces of the ceramic tile with the wall (I/A), the tub flange (I/F), and piping (I/B), constitutes a constrained fit. The first tile course is set directly upon the tub flange (I/F) and the thickness of the tile and mortar bed brings the tile forward, concealing interface F/A, the tub edge in the kerf. The fixture run outs, centered on the seam at the top of the first tile course, pass through holes cut from the edges of the tile, (I/B).

The faucet is threaded on to the hot and cold faucet run out pipes, requiring that they be positioned accurately in respect to each other. Escutcheons conceal the holes cut in the tile (L/I).



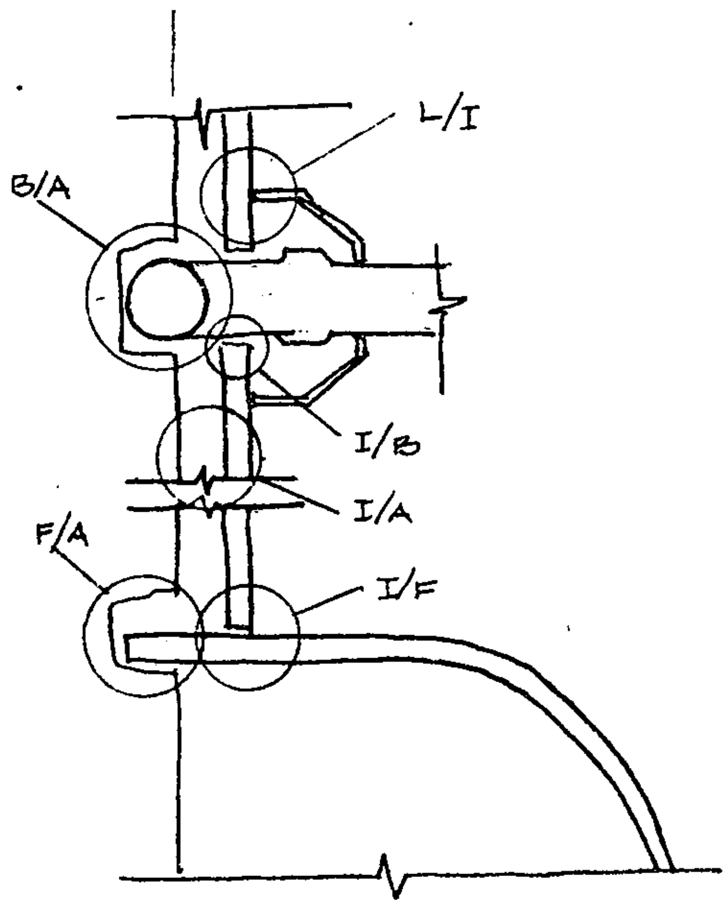


FIG 4.16
ISRAELI BATHTUB : DETAIL # 3

PLACEMENT/POSITION, CONTROL PLANES

The positional dependency network, Figure 4.17 and the list of dependencies in Table 4.8, illustrate the accumulative nature of the placement of components in the Israeli bathtub. The network reflects the positions and tolerances indicated in the detail analysis with regard to the positional dependencies of the ceramic wall tile, which is dependent upon the positions of five precedent components.

The most significant patterns to be observed in the diagram are that the ceramic wall tile (I), should depend on so many precedent components; and that the positional dependencies brought to the block walls (A), and piping (B) are from components installed much later in the process.

The number of positional relationships (to precedent and subsequent components), of a component also indicates the relative significance of that component to the placement of the assembly. The components with the most relationships are as follows:

A. Block walls - 4 (2 lower degree)

F. Tub and trap - 3

G. Tub wall - 4 (1 lower degree)

H. Repair floor tile - 3

I. Ceramic wall tile - 7

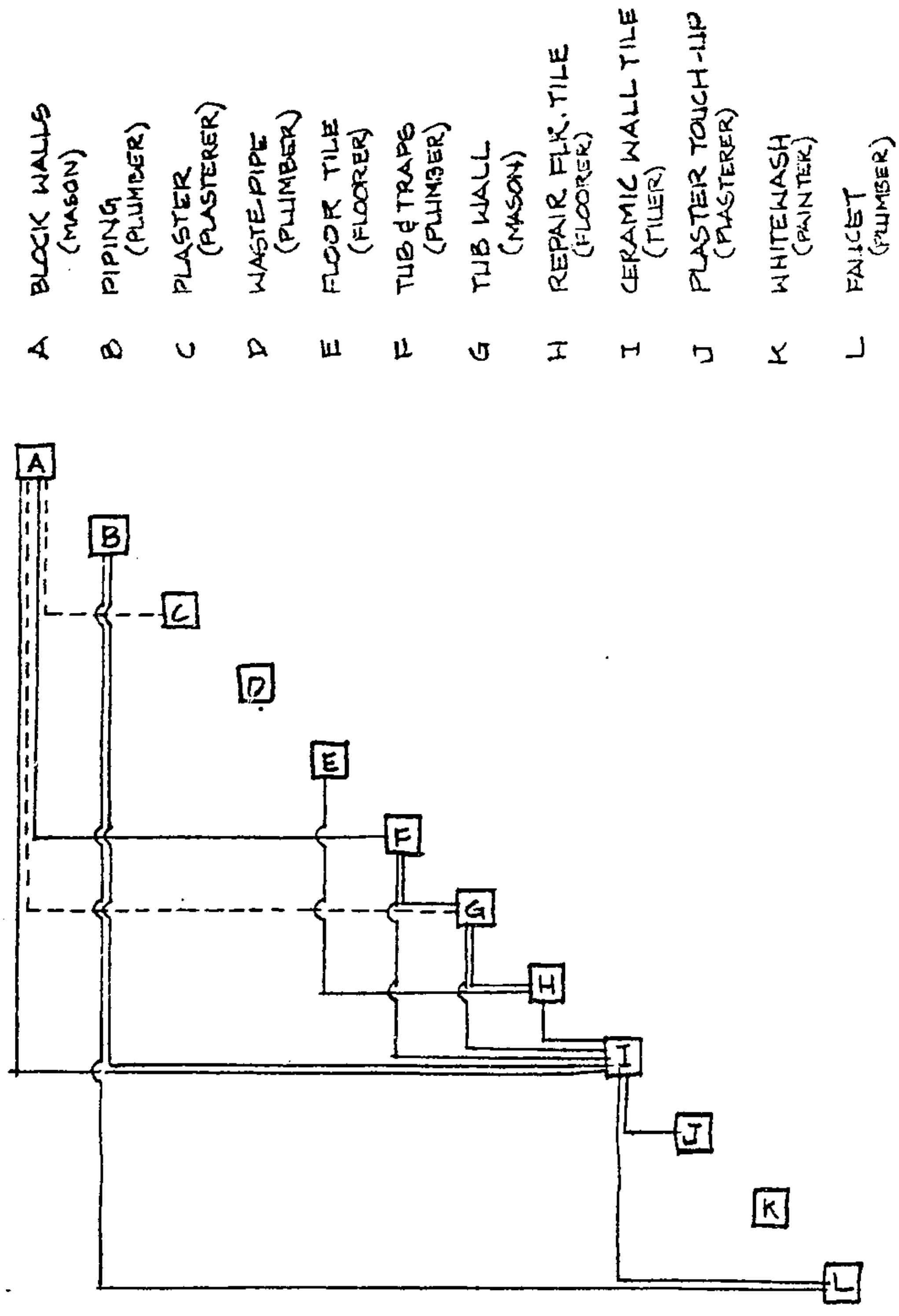


FIG. 4.17
ISRAELI BATHTUB: POSITIONAL DEPENDENCY NETWORK

TABLE 4.8

ISRAELI BATHTUB - POSITIONAL DEPENDENCY SUMMARY

Component	Positional Dependencies
A. Block walls (mason)	Measured from plan, not a dependable control plane.
B. Piping (plumber)	Location of faucet run out critical to tile, measured up from floor, hot and cold faucet run outs are to be centered on vertical and horizontal tile course seams.
C. Plaster (plasterer)	Thickness of ± 15 mm rectifies block wall irregularity, (A-C), future position of tile on walls determined in order that plaster may be excluded, edges with plaster and tile to be patched.
D. Waste pipe (plumber)	No precedent positional dependencies, laid to future position of tub, determined from plan.
E. Floor tile (floorer)	Sand bed must cover waste pipe, D-E, tiles brought to finished floor level of 70 mm from concrete floor, laid to within 1 or 2 tiles of future position of tub, determined from plan.
F. Tub and trap (plumber)	Establishes two control planes: HCP II, formed by top of tub flange, and VCP II, tangential to front edge. Position and level of tub edge kerf lines are critical, measured from floor, tub is shimmed to rest in kerf cuts and for top flange (HCP II) to be made level. Front line of edge of flange (VCP II) is set square and parallel with wall planes by alignment of tub, within depth of kerf cut (± 5 mm maximum), A-F.
G. Tub wall (mason)	Position determined by tub flange, F-G, built to fit under side of flange at front and side of tub, 25 mm ± 3 mm from front edge (VCP II) to allow tiles to be set in plane on block wall.

TABLE 4.8 (continued)

Component	Positional Dependencies
H. Repair floor tile (floorer)	Positioned by being brought flush with tub wall, G-H, completing floor tile to match height of floor tiles already in place (E-H).
I. Ceramic wall tile (wall tiler)	Brought to meet HCP I, VCP II, and HCP II. Tile on back and end wall dependent upon level tub flange for HCP II, with 1st course resting on both flanges at both walls, A-I, F-I, dependent upon piping faucet run outs to fall on center line of top edge of 1st course, such that tiles may be cut around pipes, B-J. Tiles on front tub wall dependent upon top edge and floor tile to be three course (450 mm) apart, and upon tub wall to be behind line of front edge of tub (VCP II) for tile to be placed on front and side walls of tub, F-I, G-I, H-I.
J. Plaster touch up (plasterer)	Smooths edge at tile I-J.
K. Whitewash (painter)	No positional dependencies.
L. Faucet (plumber)	Absolutely dependent upon piping faucet run outs for position, B-L, and upon tiles for holes to be cut within coverage of escutcheon, (I-L).

Each of these components are associated with a control plane in the assembly:

> Vertical control plane I (CVP I), located by the rough block wall (A) manifested by the ceramic wall tile (I) and plaster (C) and (J).
>
> Horizontal control plane I (HCP I), the finished floor level, defined by floor tile (E) and completed by repair floor tile (H).
>
> Horizontal control plane II (HCP II), manifested by the top flange of the tub (F).
>
> Vertical control plane II (VCP II), defined by the front edge of the tub flange (F), backed by the tub wall (G), and manifested by the ceramic wall tile (I), on the tub wall.

The placements of components which determine the positions of the control planes are not confirmed until the installation of the ceramic wall tile. This pattern was observed in the positional dependency network, and the detail analysis showed the tolerances of interfaces with the ceramic wall tile to be $\pm$ 2 to 3 mm, the smallest in the assembly. Constrained fit conditions were shown to exist at the wall tile placed on the back tub flange and piping, and again between the front tub flange and floor tile, against the tub wall. These constrained fit conditions exist at the intersections of the finish elements of each of the control planes.

It is difficult to define any patterns or groupings by component function in the Israeli bathtub positional dependency network. For example, a wall group would include:

A. Block wall

B. Piping

C. Plaster

I. Ceramic wall tile

J. Plaster touch up

K. Whitewash

L. Faucet

The floor group would include (E) floor tile, and (H) repair floor tile, and is interrupted by (F) tub and trap and (G) tub wall, which constitute the tub group.

However, the number of interdependencies between such a grouping pattern would make it not a realistic representation of the assembly. Likewise, a grouping by structure and finish components would not reflect the patterns of interdependencies.

One possible arrangement that seems to be the result of the actual positional dependencies in the sequence is shown in Figure 4.18. This grouping method includes ceramic wall tile (I), in both the floor group, as defined before, and in a composite floor and tub finish group, including components:

E. Floor tile

F. Tub and trap

G. Tub wall

H. Repair floor tile

I. Ceramic wall tile

This grouping reflects the interdependencies of components isolated in the analysis of the interface network, detail analysis, and positional dependency network.

The wall group includes components installed by five trades: masons, plumbers, plasterers, tilers, and painters, involving a return of plasteres for (J) plaster touch up and (L) faucet. There are four trades in the floor, tub, and tub finish group: floor tilers, plumbers, mascns, and wall tilers. Including a return of floorers within the group for component (H) repair floor tile.

The interdependencies may be seen to require the coordination of many trades, and the return of several, as noted in the section discussing the interface network: (G) tub wall, masons; (H) repair floor tile, tiler; and (J) plaster touch up, plasterer; as well as a return of

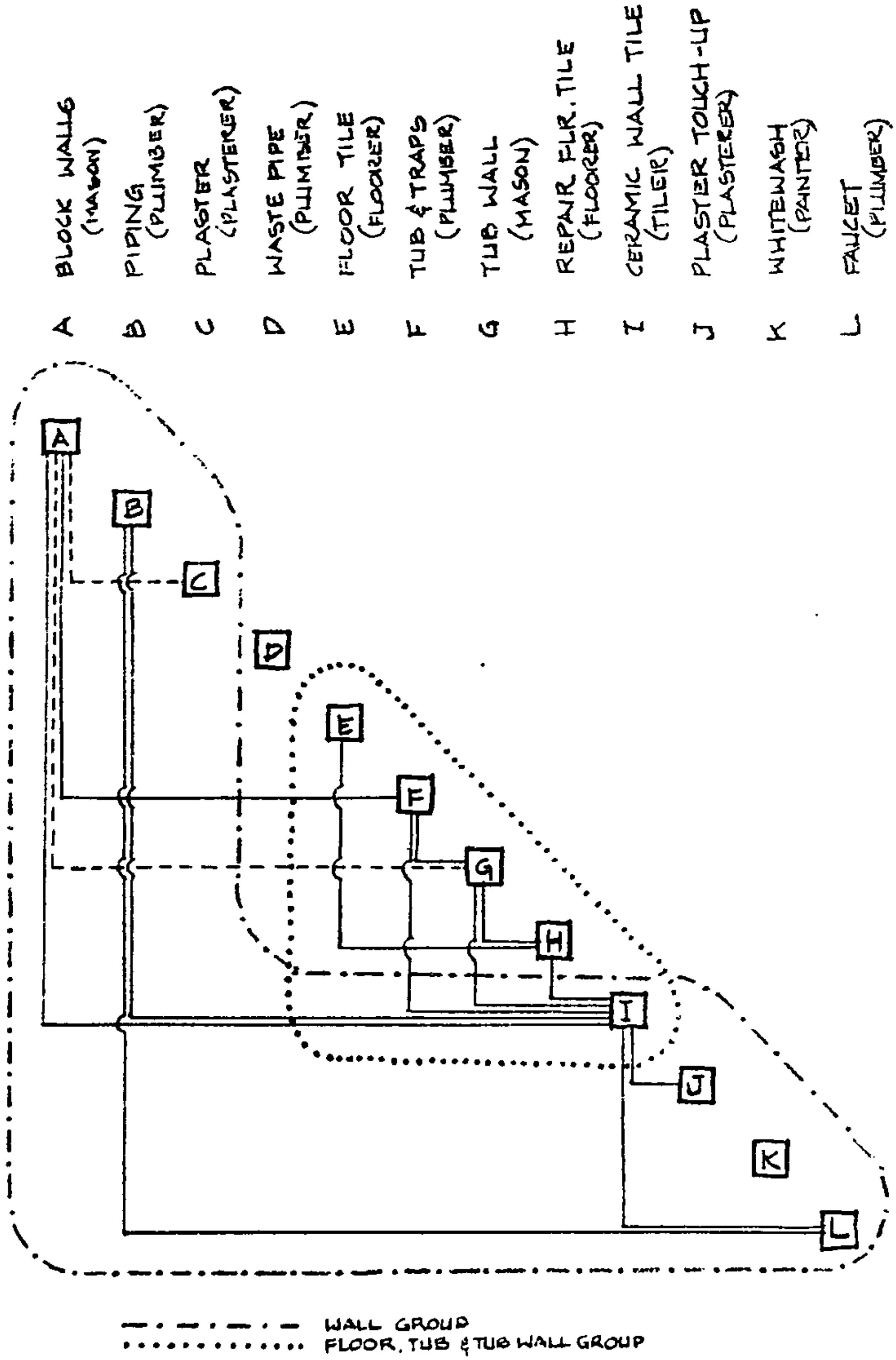


FIG 4.18
ISRAELI BATHTUB: COMPONENT PLACEMENT GROUPS

plumbers for (F) tub and trap, and (L) faucet.

SUMMARY

ISRAELI BATHTUB

The Israeli bathtub assembly is shown in the interface network to be built in to the structure, and highly interrelated. The most significant aspect of the assembly is that another structure and finish sequence of components, with corresponding returns of trades, must occur with the construction of a front tub wall, after the tub itself has been placed. The ceramic wall tile must interface with six preceding components, and is the most critical component in the assembly.

The positional dependency network confirms the influence of the returning sequence for the front tub wall, with dependencies culminating in the ceramic wall tile. The component placement groups are not clearly defined, due to the interrelationships of positional dependencies, and therefore must be classified as a composite group, with floor, tub, and tub finish elements included. In effect, the returns of trades for the tub walls comprise another complete assembly, with control planes defined by the tub.

CHAPTER V

CONCLUSIONS

There are a great many factors to be considered in a comparative analysis of building systems in different nations. This thesis has sought to examine the relationship between details and the process of assembly of the elements that make up those details, through an analysis of the interface of components. The examples chosen are sufficiently similar in form and in the requirements imposed upon them that such an analysis of assembly may be comparable. The other factors affecting the industrialization of building may be related to these findings, in order to achieve a balance of efficiency and economy at each level in the building industry.

KITCHEN CABINETS

It has been shown that while the kitchen cabinets built in the U.S. and Israel are similar in form, there are many differences in details and the processes by which they are assembled.

The most significant difference in both detail and process stems from the factory-built "box" construction of the U.S. cabinet. The Israeli assembly, though a "box" in form, is assembled by a complex interrelationship of individual parts, and the "box" itself or frame, is not a determinant of the form, but rather results from filling in between the blocking and countertop.

The components of the U.S. assembly are called upon to interface with primarily those components which immediately precede them, while those of the Israeli assembly must interface with components that are placed several stages before in the sequence. The number of interfaces with preceding components which each element is found to possess has been shown to be an indication of the degree of interrelationship of the assembly in general. In the American assembly, no component is brought to interface with more than two preceding elements. The Israeli components, however, must interface with several others - in the case of the cabinet, with as many as five.

The detail studies illustrate the relationship of component interfaces to control planes critical to the positioning of these interfaces. In the U.S. cabinet, two control planes at the structure establish dominant determinants to component positions throughout the sequence of assembly. This is accomplished by the cabinet's "box" configuration and dependable orthagonality, which transfers a flush alignment with the control plane to the subsequently placed elements. The pattern of slip-planes enables components to interface with two other elements, while having primary positional dependencies focused on only one of those elements.

In the Israeli assembly, nearly every interface carries with it a dependence upon the position of all preceding elements. There are several components which must be measured to determine their correct placements, for reasons of an interface with other subsequent elements, which are not immediately affixed. In the American assembly few measurements need to be taken during the process.

The different nature of methods of achieving correct positions and alignments may be best illustrated by the fact that the Israeli assembly not only must establish its two primary control planes, but two other control planes must be built during the process by the component interfaces themselves. Patterns of positional dependencies, and the sequence of installing components to complete the assembly are an indicator of the amount of coordination needed on site during the process.

The groupings shown on the position dependency diagram, Figures 3.11 and 3.19 (U.S. and Israeli network) indicated concentrations of dependencies and interfaces necessary during the process of assembly. The pattern of dependencies in the U.S. process shows that two groups exist: the wall group, with three trades involved, and the cabinet group with two trades. That these two groupings comprise few trades is significant in that coordination difficulties are minimized at these concentrations of interdependency of components. In the Israeli assembly, there are three such groups, with the first two, wall and pedestal, being divided, requiring return of three trades after the installation of the elements in the cabinet group. The wall group includes three trades; the pedestal group two, and the cabinet group, two.

The differences between the processes of assembly of the two examples are most readily seen by the different patterns of groupings shown in the positional dependency.

The additional pedestal group in the Israeli assembly is due to the materials used for the cabinet floor, which is part of the cabinet upon delivery. But the fact that the wall group must be completed in three stages, and the number of critical positional dependencies between different groups and between different trades within groups are due to a general concept of joint interface in the Israeli cabinet: components must interface with many precedent components. A direct sequence of assembly may therefore be achieved in the Israeli cabinet only by changing the concept of assembly of the cabinet as a whole.

BATHTUBS

The bathtub analyses are less comparable in terms of interfaces than the kitchen cabinets, since the process differences are attributable to different configurations of the tubs.

The basic concept of the U.S. bathtub assembly is that the tub performs as a structural unit, supported partly by its integral front panel and partly though connection to the dimensionally precoordinated framing. The concept of the Israeli assembly requires that the support of the tub be from multiple connections, including the construction of an additional wall and finish assembly, built to fit the tub.

Both the U.S. and Israeli bathtub assemblies require that special attention be given to alignment, position and support conditions. These requirements are satisfied by the upturned flange and integral front panel configuration of the U.S. bathtub. And the only additional structural element, the stringer, simultaneously establishes the control plane alignment and structural support of the tub assembly. The three dimensional orthagonality of the tub itself therefore facilitates straightforward interfaces and positional dependencies with the finish components.

The interface networks and detail analyses of the examples indicated that although both assemblies are built-in, the U.S. example achieves this by dimensional precoordination and tub configuration, while the Israeli counterpart is built-in by the placement of additional structural elements.

The degree of interrelationship of each assembly is indicated by the number of components which have more than one precedent interface. The four components of the U.S. assembly have been shown to be mitigated by lower degree interfaces, due to joint configurations. There are seven such components in the Israeli counterpart; the critical element in the Israeli assembly, ceramic wall tile, having interfaces with six precedent components.

The control planes of the U.S. bathtub are established with the structure, and the tub is integrated in this respect. But the four control planes in the Israeli assembly must be established during the process, two of which are manifested by the wall tile.

The component placement groups of the two bathtubs are a valid reflection of the differences in concept of the assembly. The tub itself is central to the U.S. structure and finish groupings, while the Israeli assembly requires the interruption of a composite structure and finish group before the completion of the accumulatively dependent wall group. Therefore the concept of the support conditions of the Israeli bathtub assembly must be changed in order to eliminate the redundancy and returns of trades in the process.

RECOMMENDATIONS

Based upon the findings of interface and positional dependency analyses, it is apparent that the highly interrelated nature of the Israeli assemblies precludes any effective rationalization of the process other than through a change in the overall concept of the assembly. Such a concept should include the following systemic principles:

- A low number of interfaces, through consolidation of elements.
- Isolated components, using continuous connections such as slip planes.
- Straightforward and not redundant methods of support,

fixation and closure.

- Establishment of accurate control planes with the structure, early in the process.
- Transferral of alignments through pre-fabricated orthagonal components.
- Single and sequential, rather than multiple and accumulative positional dependencies.

These principles should be implemented through a thorough reevaluation of the design of the Israeli components by studying their performance in the finish building system as a whole, together with the impacts on the building process. A symptomatic change of individual details, however, would not be effective because of the complex precedural aspects of the assembly, as evidenced by the numerous interrelationships of interfaces and positional dependencies.

KITCHEN CABINET RECOMMENDATIONS

A change in the concept of assembly of the kitchen cabinet, while using the same materials, would offer substantial benefits to the process by implementing the principles as follows:

<u>Consolidation of elements</u> - To achieve the goal of a reduction in the number of interfaces, the elements may be grouped into sub-assemblies which may be centered on the cabinet frame and countertop. The frame is capable of assuming a greater role in the assembly as a complete, orthagonal element. A base, toe strip, and back frame could be

constructed of similar materials as those used in the present frame, incorporating an integral floor and back in a cabinet "box."

The countertop sub-assembly should include the sink and faucet. Ideally, the sink should be affixed directly to the countertop, either from above, with a flange, or by mounting from below. If material changes in the sink and countertop to provide this method of fixation prove to be unfeasible, the sink may be supported by cross members in the cabinet frame. Junctures with the countertop similar to the present configuration could be achieved by shims under the sink supports. One aspect of the consolidation of a countertop sub-assembly that would greatly relieve critical tolerances and dependencies would be the inclusion of the faucet. The faucet should be affixed to holes in the countertop, with the supply line run-outs and flexible connections hidden within the cabinet.

Isolation of components - Continuous, slip plane interfaces may be established if the components are grouped into sub-assemblies and if the wall and floor elements are built as uninterrupted planes. The flooring should be placed as a continuous control plane, abutting the vertical control plane established by plastering the entire wall surface. The expense of the materials to be covered by the cabinet and wall tiles is offset by the systemic advantages of slip-plane interfaces and the corresponding reductions of measurements, site-specific operations and returns of trades. The ceramic wall tile itself may be isolated from the plaster coat by placing the tile after the finish plaster to the surface, using "bullnose" edge trim tiles at the perimeter.

Straightforward support, fixation and closure - Concurrent with a consolidation and isolation of components is the need for direct interfaces and support conditions. The cabinet box should rest on shims on the finish flooring, with the edge concealed by the baseboard. The cabinet back frame should then be affixed to the wall. The countertop should be shimmed and affixed to the cabinet, and set flush with the plaster wall, not into a kerf. The sink should be shimmed to fit the countertop, and faucets connected from below.

Control planes, transfer of alignment and sequential dependencies - The interface and positional dependency networks, Figures 5.1 and 5.2, which would result from the changes noted above, illustrate the benefits derived by the implementation of these principles. The control planes established by the wall and floor elements are dependent upon through slip planes for the position of the cabinet frame. The frame then transfers the position of the horizontal plane to the countertop, to within the tolerance of shims. The ceramic wall tile remains as the only multiple, delayed dependency, but this must be expected with this material, and the criticality of its position is much alleviated by the relocation of faucets and method of achieving the placement of the countertop.

Several components and corresponding trade returns and activities by a reorganization of the cabinet. The original activities which would no longer be necessary include:

D. Blocking (carpenter) - an isolated entry activity, in which this trade measures and places a horizontal control plane, not to return until five components later in the process. Since the blocking function is incorporated in the cabinet base in the suggested assembly, it eliminates a return of trade.

I. Cabinet floor tile (floorer) - as with the blocking, this return of trade is not necessary since the cabinet floor would be integral. This reduction would reduce the entry of floorers to one component, from the two, six components removed between entry and return in the original.

L. Plaster touch-up (plasterer) - in the original, this constitutes a return after six intermediate components. The revised assembly eliminates the need for this return by the application of a continuous plaster layer and the use of bullnose trim ceramic wall tile.

N. Lacquer (painter) - painters apply whitewash (M) to the plaster, and lacquer (N) to the cabinet frame and removed doors consecutively in the original assembly. Because of the complete box construction of the cabinet frame in the suggested assembly, the need to carefully lacquer the cabinet on-site and in place is avoided.

The cabinets may be prefinished, where assembly-line techniques may facilitate their production.

P. Re-fix cabinet doors (carpenter) - the cabinet doors are lacquered separately from the frame in the original system and delays due to drying time for the lacquer require this return of trade. If the cabinet frame and doors are pre-finished elsewhere, not only are the difficulties and delays associated with lacquer removed from the site, but the need for this return of trade is eliminated.*

The revised cabinet assembly therefore reduces the number of components by five, and eliminates the need for four returns of trades, and the time consumed by several on-site sequences of activities. These reductions alone would warrant such a reorganization, but additional advantages to the process are obtained through a reduction in control planes from four to two, and through a corresponding reduction in interfaces positional dependencies and on-site measurements.

The procedural advantages of the reorganized kitchen cabinet assembly are best illustrated by an analysis of the interface and positional dependency network. Table 5.1 demonstrates a reduction in the number of components required to interface with precedent components from the nine listed in Table 3.7, to five. It is important to note that of the

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*Original components are identified as shown in Figures 3.15, 3.19 and 3.20.

two with the greatest number of precedent interfaces, (G), countertop and (H) faucet and drain, each have three precedent interfaces. This number of interfaces is further mitigated by the fact that the interfaces with (B) piping and (F) sink are lower degree interfaces, due to the adjustability of the interfaces with those components. With lower degree interfaces excluded, no component in the revised assembly is brought to interface directly with more than two precedent components. The cabinet now is required to interface only with (C) plaster and (D) floor tile, compared to the six precedent interfaces in the original assembly.

Perhaps most significant of all, the interface network and component placement group diagrams, Figures 5.1 and 5.2 illustrate a direct sequential placement of the six most important elements from (C) plaster to (H) faucet and drain, comprising the wall, floor cabinet and countertop components.

Therefore a reorganization and redesign of the kitchen cabinet assembly through implementation of the principles derived from a comparative analysis of the U.S. and Israeli kitchen cabinets may yield a more efficient, sequential assembly process, allowing greater tolerances, only one returning trade, and an on-site sequence of activities less likely to be interrupted.

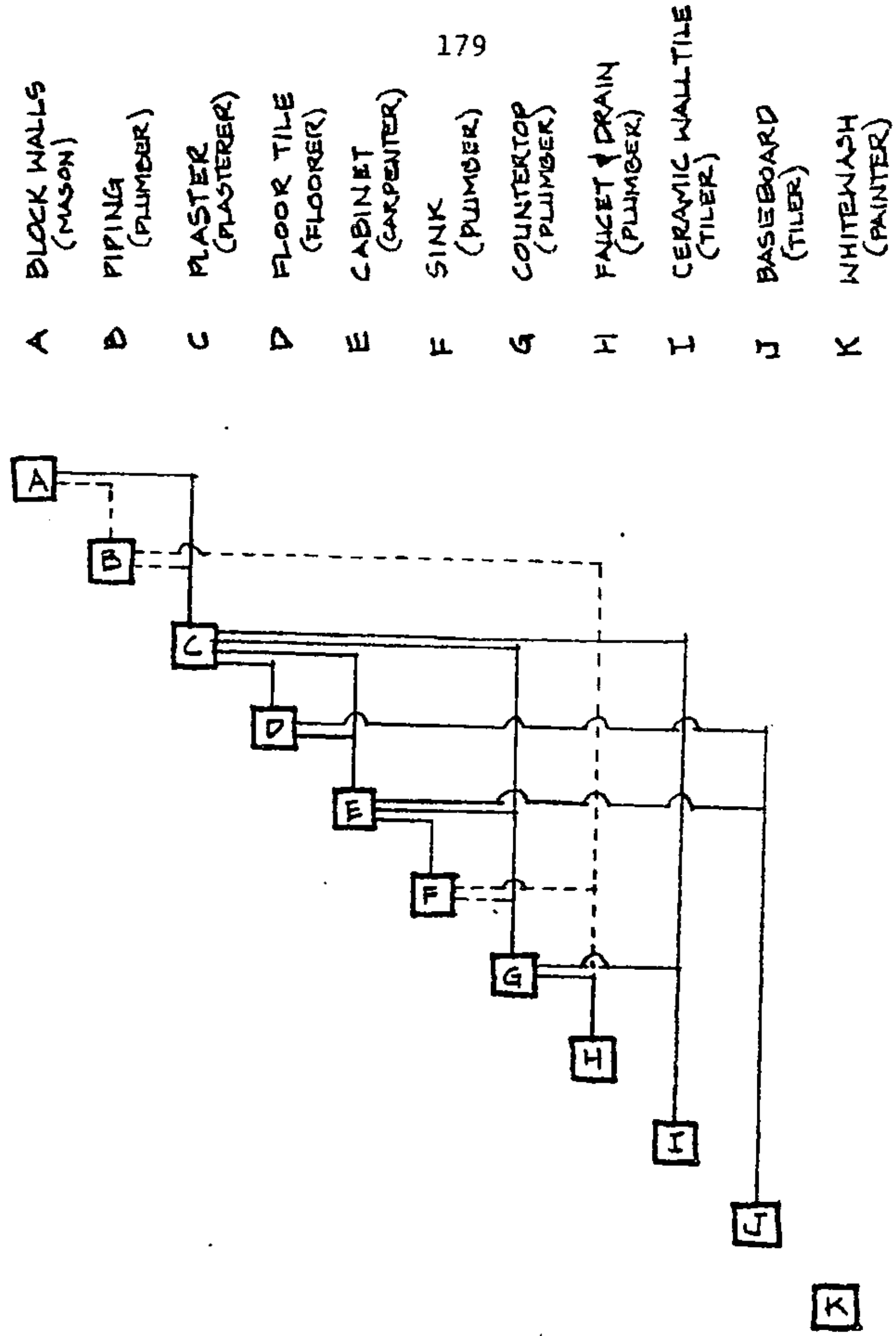

FIG 5.1
RECOMMENDED ISRAELI KITCHEN CABINET : INTERFACE NETWORK

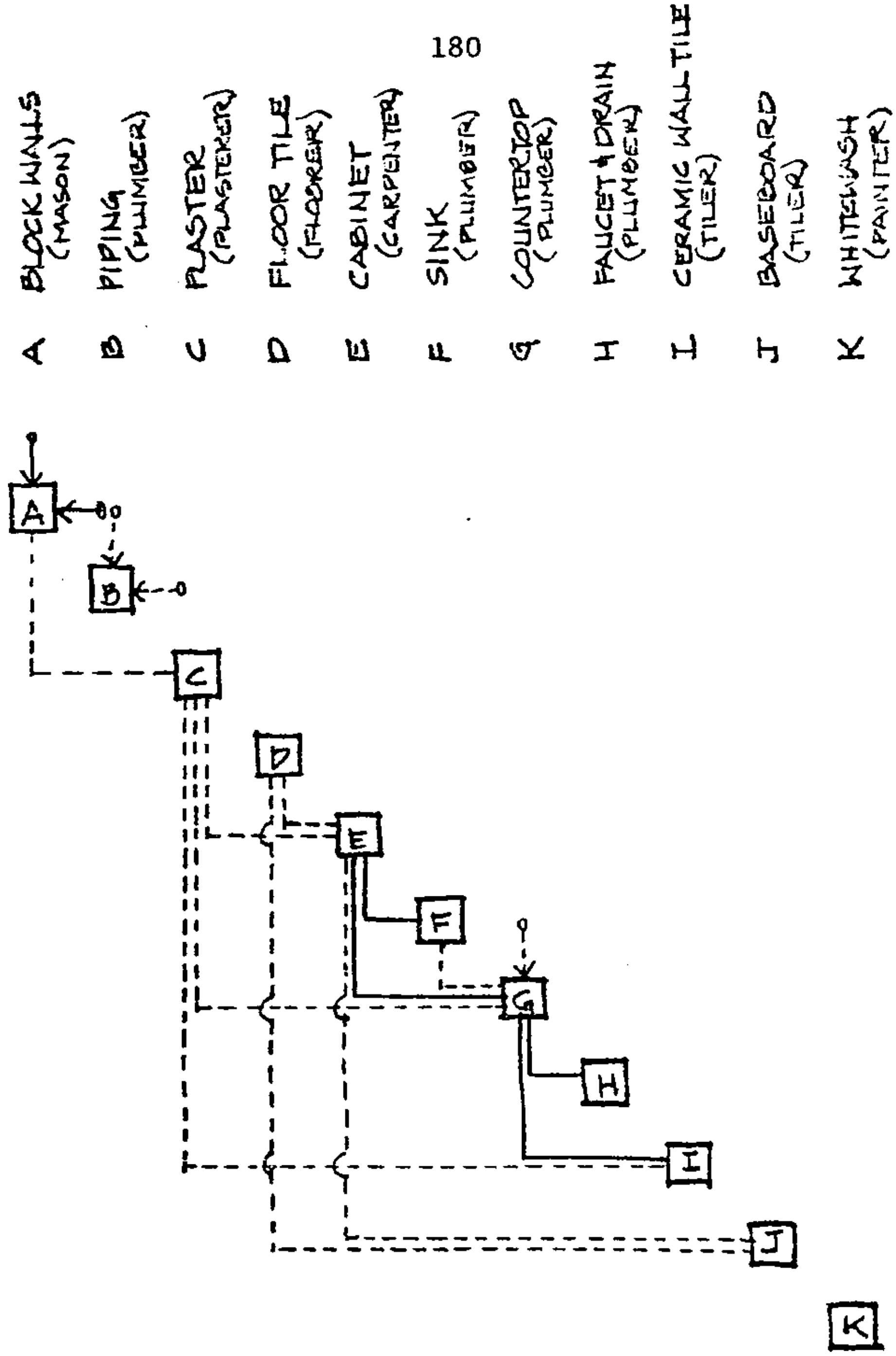

FIG 5.2
RECOMMENDED ISRAELI KITCHEN CABINET:
POSITIONAL DEPENDENCY NETWORK

TABLE 5.1

RECOMMENDED ISRAELI KITCHEN CABINET

COMPONENTS WHICH INTERFACE WITH MORE THAN ONE PRECEDENT

Components	Precedent Interfaces
C. Plaster	A. Block walls B. Piping (lower degree interface)
E. Cabinet	C. Plaster D. Floor tile
G. Countertop	C. Plaster E. Cabinet F. Sink (lower degree interface)
H, Faucet and drain	B. Piping (lower degree interface) F. Sink (Lower degree interface) G. Countertop
I. Ceramic wall tile	C. Plaster G. Countertop
J. Baseboard	D. Floor tile E. Cabinet

BATHTUB RECOMMENDATIONS

The Israeli bathtub assembly is characterized by a return of trades constituting an additional assembly of the block wall at the front of the tub. The support and fixation of the bathtub is also redundant, since it is shimmed up on blocks, set inter kerfs and blocked-in. These procedures have come about as the result of a bathroom installation abutting the tub and a laundry hamper cabinet within a single alcove. The consequences of such an installation are evidenced by the interface and positional dependency networks of the combined tub and cabinet in the assembly. While the separation of these elements would greatly reduce the interdependencies, it would also isolate the components for further improvement. The cabinet assembly is virtually identical to the kitchen cabinet construction, and the kitchen recommendations for improvement are applicable in this case as well. The bathtub's method of support is no longer necessary, but is an inherent result of the design of the tub itself.

The recommendations for improvement of the kitchen cabinet assembly are made possible by changing the concept of assembly of the existing type of construction materials. However, the bathtub assembly is determined by component configuration, not by the sequence of interfaces, as in the cabinet. As such, specific procedural improvements such as those suggested for the cabinet are not applicable.

The major differences between the Israeli and U.S. tub assemblies are attributable to the methods of support, particularly as the result of an integral front panel. The structural aspects of the interface of the U.S. tub's back flange, framing, and drywall are not comparable to the Israeli block and plaster construction.

Therefore, recommendations for improvement of the Israeli tub assembly are simple in concept, but with great implications: to redesign the tub itself, eliminating the need for the block wall and ceramic tile front panel. It the tubs were to be manufactured with an integral front panel, the process of assembly would be simplified as follows:

- Floor tile installation would be made continuous, not requiring a return of trade for completion.
- There would be no need for a return of masons to the site to build the tub wall.
- The additional, low tolerance vertical control plane necessary for ceramic wall tile on the tub face would be eliminated.

The principles of isolated components, with continuous applications, should be implemented including such improvements as the use of bullnose trim ceramic wall tile, eliminating the need for a return of plasterers.

However, the principles of straightforward support, fixation and closure, and a sequential network of positional dependencies may be achieved only through a redesign of the manufactured tub. The implications of such a material change are significant, primarily through the elimination of the interruptions in the schedule caused by the return of masons to build the tub wall and the return of floorers to complete the floor tile.

The costs and benefits of a material change in the design of the tub are beyond the scope of this analysis, but it has been shown that the process of assembly and sequence of activities would be greatly improved.

Diagramatic methods of analysis, such as the interface and positional dependency networks, can never be comprehensive models of the process which they depict but can be objective representation of conditions which are known to exist. General concepts such as the interrelationship and significance of components in an assembly have been discussed from two viewpoints; one physical, with respect to the properties and behavior of the elements, and the other procedural, examining the activities involved in the process. An understanding of the relationship between these two aspects is crucial to the rationalization of building, which must therefore be the design of both form and process. It is hoped that this elementary attempt to examine the relationships between components and process by means of interface and positional dependency networks will lead to better methods of attaining greater efficiency in building.

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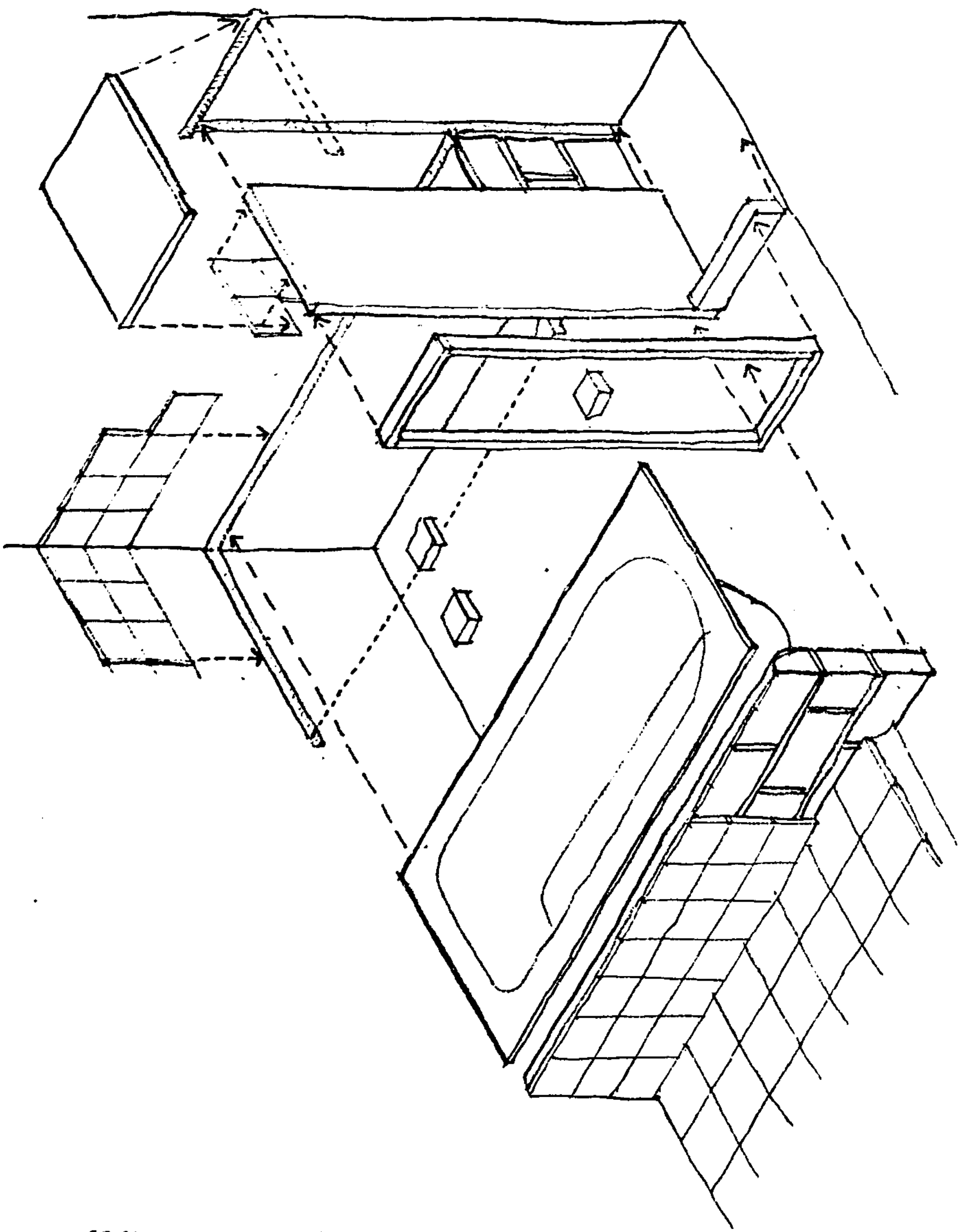
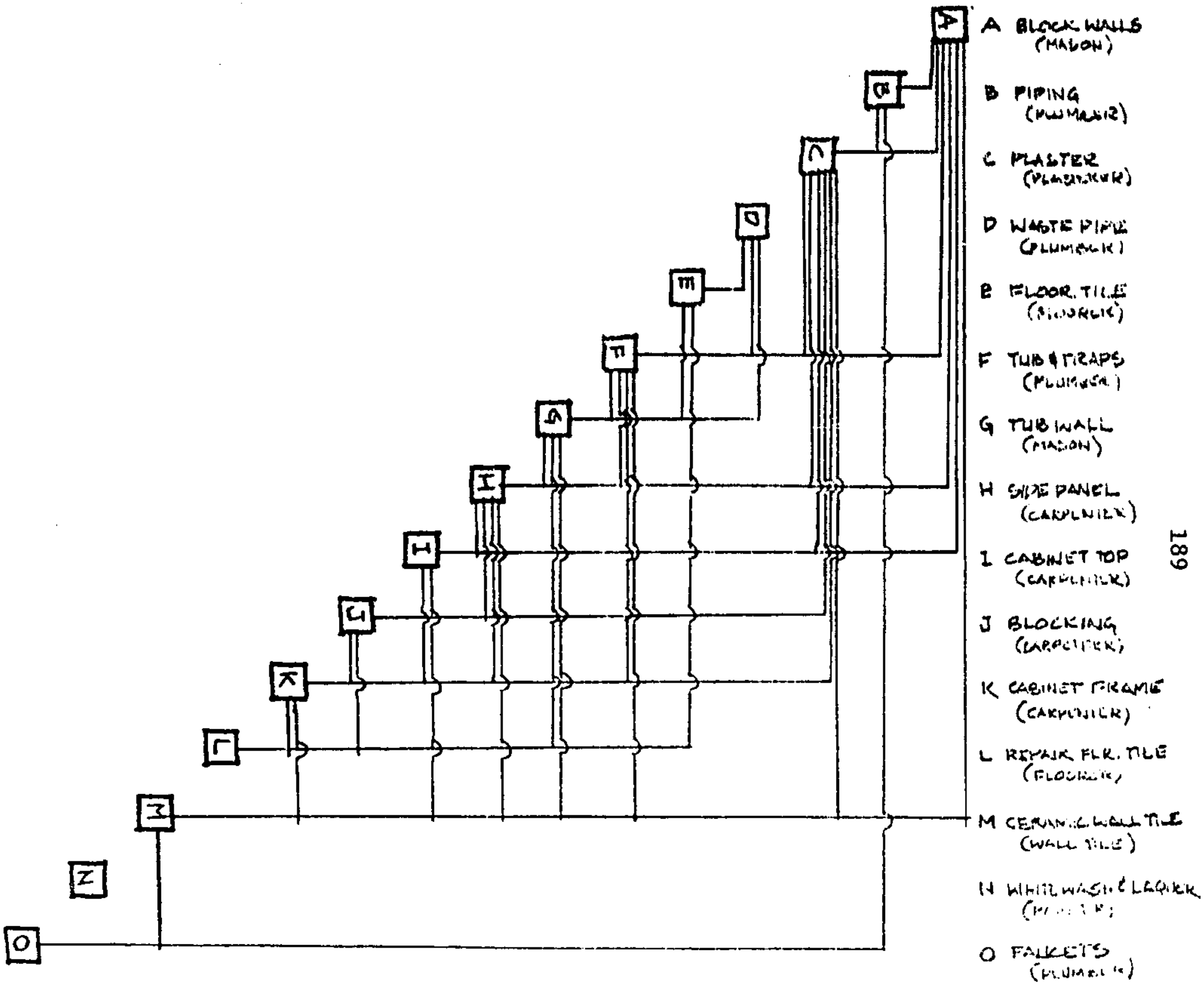
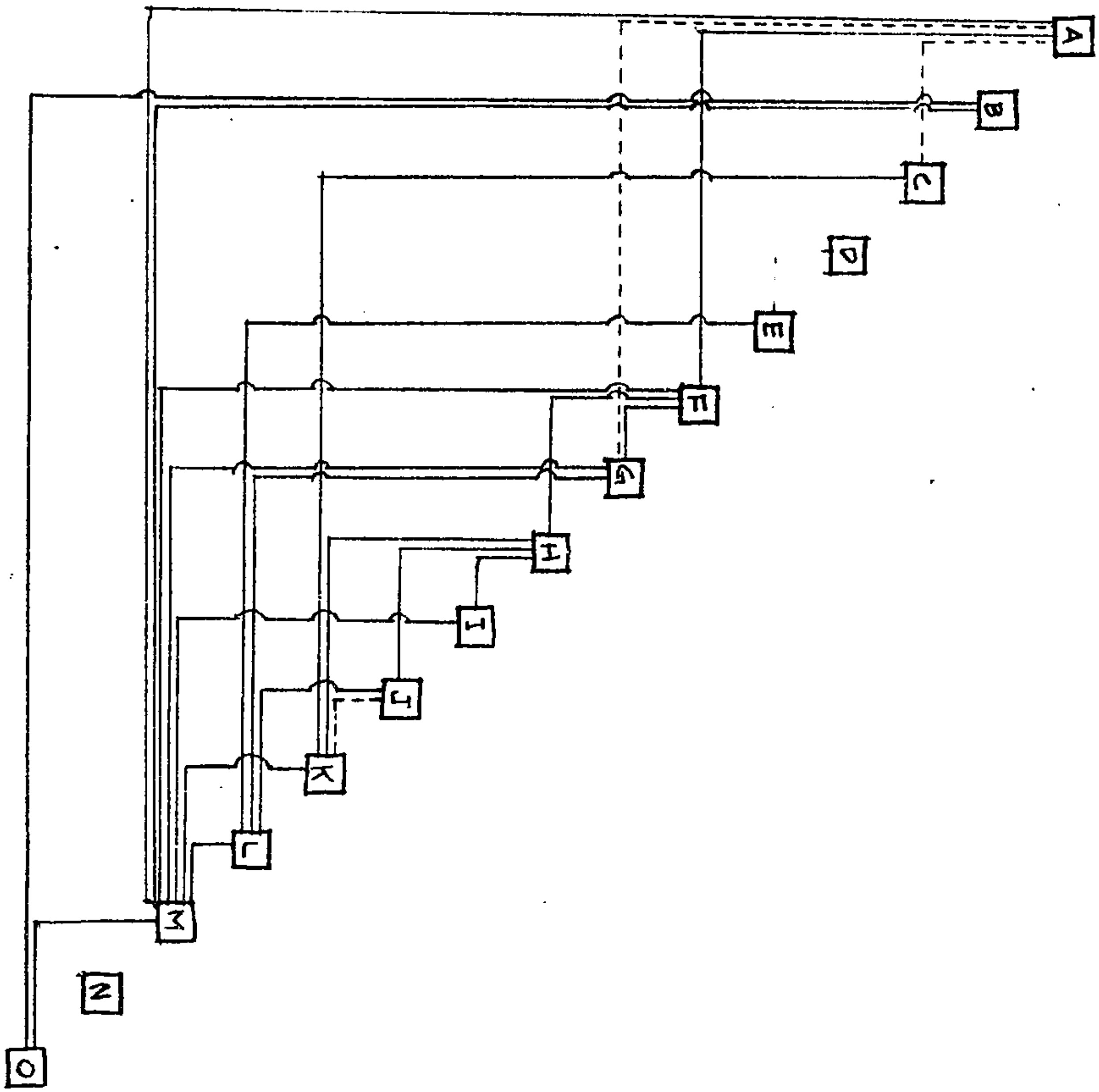
APPENDIX



ISRAELI BATHTUB & CABINET : EXPLODED ISOMETRIC


A BLOCK WALLS
(MASON)
B PIPING
(PLUMBER)
C PLASTER
(PLASTERER)
D WASTE PIPE
(PLUMBER)
E FLOOR TILE
(FLOORER)
F TUB & TRAPS
(PLUMBER)
G TUB WALL
(MASON)
H SIDE PANEL
(CARPENTER)
I CABINET TOP
(CARPENTER)
J BLOCKING
(CARPENTER)
K CABINET FRAME
(CARPENTER)
L REPAIR FLR. TILE
(FLOORER)
M CERAMIC WALL TILE
(WALL TILE)
N WHITEWASH & LACQUER
O FAUCETS
(PLUMBER)



A BLOCK WALLS (MASON)

B PIPING (PLUMBER)

C PLASTER (PLASTERER)

D WASTE PIPE (PLUMBER)

E FLOOR TILE (FLOORER)

F TUB & TRAPS (PLUMBER)

G TUB WALL (MASON)

H SIDE PANEL (CARPENTER)

I CABINET TOP (CARPENTER

J BLOCKING (CARPENTER

K CABINET FRAME (CARPENTER)

L REPAIR FLR TILE (FLOORER)

M CERAMIC WALL TILE (TILER)

N WHITEWASH & LACQUER (PAINTER)

O FAUCET (PLUMBER)