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TECHNICAL MEMORANDUM

title: FIELD PLASTICS FABRICATION SYSTEM

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sponsor: CIVIL ENGINEERING LABORATORY
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program nos: NEW STARTS PROPOSAL

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 Encl. [1]

PROPOSED FIELD PLASTICS FABRICATION SYSTEM

Background: What is the program? The program proposes the development of a Field Plastics Fabrication System to provide the Navy Mobile Construction Battalions (NMCB) with a capability to fabricate construction materials from plastics for vertical and horizontal construction tasks (see exhibit 1 Proposed Operational Requirement - Field Plastics Fabrication). The system will be designed so that the skills and techniques required for fabrication of structural (vertical and horizontal) construction materials will be an integral part of the present NMCB Personnel Readiness Capability Program (PRCP).

Exhibit 2. "Analysis of Plastics Fabrication Process" was submitted to NAVFAC (Code 03) as a new start exploratory development program for FY-78 on 2 March 1976.

Why the program is needed. Lessons learned study from the construction of the U.S. Naval Communications Station, Diego Garcia Island indicates both the need and trend of the use of plastics in construction. The ROICC Thailand's study of "Lessons Learned" based on construction in Diego Garcia indicates areas in which plastics can be used.

Exhibit 3. Of the five permanent NMCBC deployment sites, Diego Garcia is an ideal location to develop the NMCBC's Field Plastics Fabrication System as a joint CESO and CEL program. The assumption is made that most MCBC personnel will deploy to Diego Garcia, and that from "Lessons Learned Study" plastics can replace many line items used in the assemblies for facilities at Diego Garcia.

Exhibit 4. Feasibility of Fabricating Plastics Construction Materials in the Theater of Operations by Navy Mobile Construction Battalion (NMCB). This brief study proposed the evaluation of NMCB's present capabilities, directives and plastics fabrication processes.

Accomplishments. A literature search of five DOD studies provided examples of possible cost savings attributed to use of plastics materials.

Exhibit 5. "The Evaluation Matrix - Table I". The Matrix provides a table of materials based on initial cost per sq. foot. The relative scores show that steel (10) is the most inexpensive material initially, while the elaborate sandwich construction (1.0) costs are highest. The other attributes listed on this table and many more factors are required to establish cost-effectiveness. Therefore, the fabrication of plastics construction materials in the field are cost-effective when factors of cost of transportation, storage, fabrication and installation or assembly of material line items and Matrix attributes are considerations.

Exhibit 6. Comparison of Plastics vs. Metal Articles. Metal structures are expensive to fabricate, and usually require machining operations and welding or other assembly methods. The corrosion of metal parts is a

constant problem in field use, particularly in a salt spray environment. Fiber reinforced plastics line items can be fabricated econimically by the compression molding process, using a platen press and heated mold dies. Design details such as holes, losses, lugs, etc., can be molded in, thus eliminating the need for separate fabrication and assembly. Inserts can be incorporated in the molded parts to provide threaded holes, studs, latches, or other fittings.

Exhibit 7. Table 11, Comparative Prices of FRP pipe and a Steel Pipe System. This table also shows the initial material costs of steel vs. plastics pipe.

Exhibit 8. Table 16, Pipe Cost Comparison. This a comparison of piping for cold water distribution in sizes up to four inches which can be designed and installed meeting standards established by national standard setting groups and trade organizations.

Exhibit 9. Table 4. Comparison of Weights, Material Costs, and Man-Hours. The production of plastics pipe and fittings in the theater of operations through the use of a portable pipe manufacturing plant is feasible using presently available commercial and military components. This was the conclusion of an Army study. Also, the skills required to install and operate a portable pipe plant and install plastics piping systems are within the skills of present available MOS categories. The proposed plant would be composed of four standard military trailer vans, each 40 feet long, plus two trailer-mounted 25 ton military heating and air conditioning units and a standard military 400 KW generator set, parked in a rectangle with an elevated work platform between trailers. Pipe and fittings would be fabricated using the an extruder. The required volume of plastics resin will be about one-half that of steel pipe with a required weight of plastics resin being one-sixth that of steel pipe. These savings in logistic requirements are significant.

DISCUSSION:

This discussion is based on knowledge gleened from a visit to plastics fabrication companies. The plastics processing techniques observed were injection molding of end items, extrusion of pipe and bags, blow molding of liquid containers, compression molding of roof shingles, plastics machining and stamping of parts for space system components, structural foam molding of cabinet and panels, molding of polyester resins, mineral fibers fiberglass reinforcement, catalysts and pigments into sheet form plastics compound. The machine process observed was set-up for continuous production runs, some on a three-shift basis. The machines and stamping and the hand fabrication of fume exhaust and duct-work systems could be easily done "now" with present NMCB capabilities.

Exhibit 10. ABFC System Number 45419, Duct, Fiberglass Construction Details F/HUAC. NOTE: Only the straight duct is fiberglass. All transitions, connectors, extracters, diffusers, turning valves, hangers and bracing

are fabricated in the field from galvanized steel metal. These two materials require different skills, tools and equipment. This complicates not only the fabricators and the installers jobs and in addition to the supply and training requirements, these assemblies and other assemblies listed in Exhibit 3 could be fabricated from plastics in the field at considerable savings in materials, manpower and logistics support.

Exhibit 11. What about Material Cost? The rule-of-thumb checklist presents the type of material properties for thermoplastic and thermosetting plastics materials. There are numerous companies supplying plastics materials, some under trade-names, others designed to properties derived, and yet very few are universally accepted.

Exhibit 12. Plastics concepts. Plastics materials are a way of life in Aerospace Industry. The construction industry has been lagging but commercial technology transfer of plastics materials developed for military weapon systems has been impacting most commercial products even construction hardware and module type facilities. Plastec Report R5D, Directory in Plastics, Plastic Technical Evaluation Center, Picatinny Arsenal, Dover, New Jersey, February 1975. The index lists over 500 items representing the engagements of 93 Government activities in various areas of plastics development, manufacture and use. These activities are a good source for CEL, CESO and NMCB for properties of plastics materials suitable for vertical and horizontal construction components. The Army CERL Study, Exhibit 9, concluded that the feasibility of fabricating plastics pipe and fitting for pressure and non-pressure pipe in the field are excellent. For mobility all infield equipment can be trailerized or containerized. Plastics processing machines ideal for either R&D work or small scale production are available commercially. The fast changing of end item molds and dies are also available commercially.

Exhibit 13. The application of urethane or isocyanurate foam to vertical facility construction would be a material first step or is within the present capability of NMCBs. Urethane foams have many desireable material properties:

- Low Thermal Conductivity
- Low Moisture Vapor Permeability
- High Strength-to-Weight Ratio
- Dimensional Stability
- Easy Installation
- Economy
- Durability
- Impervious to most fungi and mildew
- Little or no odor

Urethane foam plastics can be purchased as rigid, preformed materials, or a systems comprised of two or more liquids that, when mixed, can form a rigid mass up to 30 times their original volumes. NOTE: Urethanes and isocyanurates are organic materials which will burn in presence of sufficient heat and oxygen. Industry is working on this problem so that these materials will be fire-resistant and possibly fireproof.

CONCLUSIONS:

The critical question is whether the introduction of plastics material for vertical and horizontal construction is timely? This question should be given careful consideration to avoid training NMCB for systems which are becoming obsolete due to the rapid use of plastics by construction industries. As usual, weapons systems produced for DOD operational activities are leading in replacing natural materials with plastics. The benefits gained by changing to plastics materials are the result of the value analysis. A cost guideline, reference Exhibit 5., Evaluation Matrix-Table 1, can not be related to one factor. Therefore, value analysis is required. In developing the value analysis, all aspects of the NMCB operation must be properly weighed and interrelation of all elements such as initial equipment cost, installation, maintenance and repair cost, operating expense, training expenses, and all other costs related to Logistic Support must be determined. If this is accomplished then technical alternatives can be correlated against possible cost benefits.

Exhibit 14. Modern Plastics Encyclopedia, Volume 52, Index, October 1975, provides a guide to subjects. The encyclopedia contains information on materials and processes and design and specification data materials and equipment. The plastics industry is large; there are over 6000 companies producing plastics materials and products.

RECOMMENDATION:

It is recommended that the New Start Proposal, reference Exhibit 2., be funded. In addition, the ROICC Thailand's Study of "Lessons Learned" based on construction in Diego Garcia be used to determine the plastics processes, materials and capability NMCB's need to meet peace and wartime contingencies.

ACTION:

Exhibit 15. Advance System Concept (ASC), Plastics in Construction. This document was submitted to NAVFAC Code 03 for the FY-78 program caption candidate. This ASC was not included for the FY-78 NAVFAC submission.

April 1976
L03B/JRP/mh

OPERATIONAL REQUIREMENT
Field Plastics Fabrication System

I. Operational Need

a. Threat. Failure to recognize the material change of plastics being used in place of common construction materials will critically affect the Navy Mobile Construction Battalions' (NMCB) ability to perform its peacetime and wartime assigned mission. The NMCB Group 8 rating must be expanded to use the new materials and equipment produced by this technology change.

b. Operational Problem. The rapid development and wide use of plastics materials by the construction industry and application of plastics and composite materials to construction of utilities, shelters, and facilities for operational employment generates a requirement for plastics fabrication capability. The NMCB capability must be expanded to repair, maintain, modify and construct disposable structures using plastics composite materials. Fiberglass Reinforced Plastics (FRP), a composite material which is used with plywood for FRP/plywood and FRP/other materials has wide usage. FRP shall be used to construct personnel operational structures. These composite materials are being used in containers, Navy Tactical Container Shelter System which is a system of relocatable structures. The Pallet Container (PALCON) system, a plastic pallet which replaced the standard wood pallet, is very durable. This pallet is made from LEXAN^{R} polycarbonate foam. Thermosetting and thermoplastic pipes are also being used by Armed Services for utilities and POL transfer of liquids. The Navy/Marine Expeditionary Hangar for P-3 and other aircraft of this size and smaller is being constructed with LEXAN for wall-to-roof panels and using FRP for structural beams and arches.

II. Operational Concept

The Field Plastics Fabrication System will provide the capability to fabricate plastics and composite materials from bulk materials. Items fabricated from plastics composite materials are to be used to replace wood, metals, cement and other standard construction materials wherever adaptable based on use, life and other comparable cost factors. The materials will be fabricated either at the field on site or at the forward base. The capability would be an extension of present capability which supports the joint services retrievable and relocatable pre-engineered facilities and advanced base components system. This extension of capability would develop skills and special tools required for field support of these facilities and systems, and for new facilities in present and future research and development programs which are constructed with plastics and composite materials.

Exhibit 1

III. Capability Required

a. Performance Goals

(1) OR System Parameter/Criteria. Plastics are being used widely in commercial construction. The resins and molding compounds contain 181 different compounds for 42 major groups of materials. Ninety-three (93) Governmental agencies are engaged in plastic R&D which covers 670 specialized persons covering 500 items listed in the DOD Directory in Plastics. This directory is published by the Plastic Technical Evaluation Center, Picatinny Arsenal, Dover, New Jersey. Most of DOD efforts to date has been in plastics for major weapon systems.

The system will be made of a combination of modules used to fabricate the construction components and structures. For example, rigid urethane foam can be sprayed to insulate walls and ceilings.* It can be hand mixed and pured for floor insulation or pre-casting sandwich panels. Special equipment and an extra blowing agent for an application called frothing which dispenses urethane like an aerosol cream is used for other applications. The thermosetting pipe and thermoplastic pipe can be easily installed.

All of the modules required to fabricate the plastics shall be transportable by truck, no module being larger than a container 8'X8'X20', using present inventoried electrical and power equipment as required. The capabilities required are: thermoplastics and thermosetting pipe repair and installation, patching and molding fiberglass reinforced plastics, spraying foams to form structural panels, beams, arches and disposable shelters. This capability will require skill in processing bulk materials under general classification of resin and molding components, films, foams and laminates, adhesives for pipes and material to form molds. Special tools and techniques will be developed for each of the field plastics fabrication systems modules.

(2) Target Parameter Criteria. Not applicable.

(3) Operational Employment. The system shall be modular so it can be deployed by sea, air, or land. Special consideration will be given so that modules can operate in climate zones of temperate, tropical and desert. Arctic operations of systems are desired but not mandatory. The system should be deployed and operated, if required, to Roda, Guam, Puerto Rico, Diego Garcia or Okinawa NMCB peacetime deployment sites. The system will be designed so that the skills and techniques required for fabrication of structural plastics materials will be an integral part of the present NMCB Personnel Readiness Capability Program (PRCP).

*Must be covered with fire-resistant wallboard.

b. Quantities and Cost Objectives.

(1) System Required: (Total 10)

a. 5 systems for present THEATER OF OPERATIONS
b. 2 systems for training schools
c. 3 systems for war reserve stock

(2) System Cost:

Item (Modules)	FY 77 (x1000)			FY 78 (x1000)			FY 79 (x1000)			FY 80 (x1000)	
	6.2	6.3	other	6.2	6.3	other	6.2	6.3	other	6.3	other
Feasibility Study	50		30			10					
Foam				90			90				250
Pipe				30			15				100
Molding							60			60	100
Pre-Casting							60			60	200
TOTAL	50	0	30	120		10	225		0	120	650 (1)

(1) 10 systems or system special modules for 5 forward sites, 2 NMCB schools, and 3 for inventory.

IV. Initial Operational Capability (IOC)

Desired mission support introduction date is beginning FY 81.

V. On-Going Related Efforts (as of January 1976)

1. Navy -

(a) Tactical Container Shelter System, YF53.536.006.01.014
(b) Pallet Container, YF53.536.10M.01.014
(c) Expeditionary Hanger, YF53.536.006.01.019
(d) Fiberglass Reinforced Plastic Pipe for Naval Aviation Distribution, YF54,543.008.01
(3) Pipe and Pipe Fittings, Reinforced Plastic for Condensate Return Lines - MIL-P-28584 (YD), 15 Apr 1975

2. Army -

(a) Military Van - Specification - MIL-C-52661A(ME) - Container, Cargo, 25 June 1974

(b) Plastic Laminates, Fibious Glass Reinforce, MIL-P-17549

(c) Foam Material Applications for Theater of Operations Construction - Project No. 4A66719AT41

(d) Multi-Purpose Structural Components - Project No. 4A763734DT34

(e) Improve Portable CP Bunker (Air Mobile) Project No. 4A763734DT34-01/002

(f) Structures Evaluation in DICE THROW Event - Project No. 4A76374DT34-01/003

3. Air Force

(a) "Navy LOCARCH" Aircraft Shelter, Project No. 00DE2007

VI. Principle Warfare Area - Amphibious Warfare

Related Warfare Area - Personnel and Medical

February 1976

CEL/L03B/SRP/mh

NEW START PROPOSAL

ANALYSIS OF PLASTICS FABRICATION PROCESSES

A. DEFINITION OF LONG-TERM PROBLEM. The rapid development and wide use of plastics composite materials and new plastics fabrication methods in the construction industries shall have a significant impact on the capability of the Navy Mobile Construction Battalion (NMBC's) to accomplish their field mission. Plastics composite materials are rapidly relacing wood, steel, and cement in construction. Mobile on-site fabrication of plastics building materials and components is forecasted for 1980 - 2000 period. Fiberglass reinforced plastics (FRP) and other composite plastics materials are gaining wide usage in DOP for shelters, hangers, floors, walls, and containers.

B. NEW CAPABILITY. The analysis of plastics fabrication processes will provide the selection of methods and plastics processes to fabricate composite plastics materials from bulk materials on-site in the operational theater. Items to be fabricated from plastics composite materials to replace standard construction materials would be based on use, life cycle and other comparable cost factors. This analysis of plastics fabrcation processes would recommend the skills and special tools required for field construction support as plastics materials are introduced into the theater of operation during the 1980 to 2000 period.

C. THE APPROACH. Plastics are being used widely in commercial construction. The principal areas of plastics - resins, foams, films, sheeting and laminates; chemicals, additives, fillers and reinforcement; primary processing machinery; and fabricating, finishing and auxiliary equipment would be studied. The study would provide a cost-analyses for the selection of plastics composite materials and fabricating processes to be adaptable to field use by the NMCB. Capabilities are required in thermoplastic and thermosetting pipe, repair and installation, patching and molding fiberglass reinforced plastics, spraying foams to form structural panels, beams, arches and disposable shelters. Special tools, machines, and techniques will be recommended as required for each of the field plastics fabricating processes. Special consideration will be given to fabricating in climate zones of temperature, tropical and desert. Note: The field fabrication of plastics composite materials will be an integral part of the NMCB Personnel Readiness Capability Program (PRCP).

D. COSTS, MILESTONES and CONTRACTING (In Thousands of Dollars)

	FY-78	FY-79	FY-80
Funding	$180K	$200K	$230K
Contract	100	120	150
Manyears	1.2	1.2	1.2

Exhibit 2

Milestones

1.	Complete analysis of principal areas of plastics	9/79
2.	Complete selection of plastics fabrication processes.	4/80

PLASTICS

ROICC Thailand's study of "Lessons Learned" based on construction in Diego Garcia points up numerous areas in which plastics can be used.

Some of the more obvious are:

Pg. 3 1.1.6 Condensation: Water pipes, air conditioning ducts and many other metal surfaces incur accelerated corrosion....whenever possible, materials not subject to corrosion, such as stainless steel or plastics should be used.

Pg. 4 1.1.10 Thermal Insulation: Insulation which is exposed to outside conditions should be covered with a non-metallic encasement.

Pg. 5 1.2.3. Exterior Wood Doors: A nearly perfect moisture seal is required to prevent swelling....and deterioration. Either pre-finished/pre-hung wood doors and frames....or pre-hung aluminum doors and frames with special anodized treatment and alloy should be used.

Pg. 16 2.1.7 Shipment and Installation Damage: Selection of materials should take into consideration susceptability to damage.... selection of cement asbestos piping for water lines resulted in this type of problem. Use of materials of higher initial cost....should be specified when dictated by these considerations.

Pg. 22 3.1.3 Pre-Assembled Modules: Consideration should be given to modular and pre-assembled head and shower units, and to use of wall treatments more easily constructed and maintained.

Pg. 41 Form Work: Waterproof plywood or double tempered hard board are satisfactory for structural forming if kept well oiled. Steel pavement forms are satisfactory but require continuous maintenance both in and out of use.

Pg. 43 Adhesives: Structural bonding of metal, wood, glass, and synthetic resins to each other or in combination can be accomplished utilizing epoxy resin adhesives. Assembly, gluing, and bonding of rigid or non-flexible materials can be accomplished with phenol, resorcinol and melamine base adhesives. For repair of concrete, adhesive epoxy binders may be used.

Pg. 44 Galvanized Sheet Metal: This material have proven suitable when treated during fabrication with an appropriate protective coating system and handled with reasonable care in shipment, onsite storage and erection.

Pg. 44 Aluminum Sheet Metal: Sheet aluminum observed in construction is not performing to an acceptable level and is not recommended for future use due to corrosive action of airborn salts.

Exhibit 3

Pg. 45 Windows, Doors and Louvers: Difficulty in operating window units was experienced, primarily due to the use of aluminum materials in moving parts. When left stationary for a short time, they freeze. Some pitting of extruded sections was noted....these conditions will persist and grow worse....all moving items such as windows, doors, etc., must receive frequent maintenance.... otherwise in areas like Diego Garcia they become inoperative in as little as three months after construction.

Pg. 46 Louvers: Anodized aluminum Louver sections used in the power plant, transmitter sites and for buildings of similar classification have been observed to be pitting and corroding.... light gauge louver units for door louver installations are showing deterioration from corrosion and salts.

Pg. 47 Doors: Aluminum doors, frames and overhead power door panels have shown signs of beginning corrosion and pitting, even though procurement documents indicate that proper specification requirements have been followed.

Pg. 50 Interior Conduit and Conduit Fittings: Conduit and fittings embedded in concrete in walls and slabs of buildings should be rigid poly (vinyl chloride).

Pg. 51 Exterior Conduit and Fitting: Non-metallic conduit with concrete encasement is recommended for underground duct runs.

Pg. 51 General Comments: Steel enclosures for exterior installed devices exposed to the elements are corroding at a rapid rate.

Pg. 52 Air Conditioning: Piping. Chilled water piping is black iron pipe with screwed fittings. There are many areas where condensation on the steel pipe could be observed. If this is not remedied, the piping will fail prematurely from outside surface corrosion.

Pg. 53 Air Conditioning: Ductwork. Ductwork for air conditioning systems is galvanized sheet metal. As long as it is properly protected, it will be adequate. The difficulty with ductwork is that it is subject to corrosion from the inside as well as outside.... presently known duct materials are no more resistant to corrosion than galvanized, except stainless steel or plastics.

Pg. 53 Air Conditioning: Fans and Blowers. Fans and blowers are presently standard steel or aluminum construction. There are indications of corrosion in these units which have been in operation for less than one year. In all cases, possible FRP fans should be used.

Pg. 53 Air Conditioning: Refrigeration Equipment. Refrigeration equipment used is either air cooled water chillers or condensing units which are necessary to locate outside. These have resulted in many maintenance problems. The unit casing, particularly in the area of the air inlet, is corroding very rapidly.

Pg. 54 Plumbing: For ease of installation and corrosion resistance, consideration should be given to the use of plastics pipe.

December 1975
CEL/L03B/JPP

FEASIBILITY OF FABRICATING PLASTICS CONSTRUCTION MATERIALS IN THE THEATER OF OPERATIONS BY NAVY MOBILE CONSTRUCTION BATTALION (NMCB)

INTRODUCTION:

The rapid development and wide use of plastics materials by the construction and the manufacturing industries requires new capability for the NMCBs to accomplish their tasks. Plastics materials are fast replacing wood, steel, rubber and cement on a cost-effective basis and common use. Therefore, the questions must be answered:

1. When should the NMCBs shift over to the use and fabrication of plastics replacing wood, steel, rubber and cement for construction tasks?
2. Can inventories be simplified by field fabrication of plastics materials and components?
3. What multiple function compounds can replace or combine with wood, steel, rubber and cement materials?
4. How many items of supplies can be reduced by use of a field plastics fabrication plant? (Standard and non-standard items).

The overall objective of the program would be to evaluate the possible advantages and the versatility and reduced costs of fabricating plastics composites construction materials in the Theater of Operations. The prime factors being the reduction in shipping cube, other costs vs. the manufacture of same items by suppliers and costs of storing items in CONUS and the theater of operations.

Areas to investigate are:

The use of plastics materials in present vertical construction areas of:

1. Electrical
2. Plumbing
3. Metals
4. Fabric
5. Glass
6. Wood
7. Cement
8. Synthetic materials

The use of plastics materials for horizontal construction:

1. Roads and surfaces
2. Buildings
3. Bridges
4. Pipes and Culverts

Exhibit 4

5. Fences
6. Protective construction
7. Utility systems
8. Small parts
9. Thermal and moisture protection
10. Bridge abutments
11. Free standing piers
12. Earth fill containers
13. Earth Revetments
14. Dust control
15. FRP Erosion control
16. Pol and sewage pipe
17. Culverts
18. Sewage lagoons

The present NMCBs capabilities would be used as a guide:

1. Sheet metal fabrication
2. Concrete block manufacture
3. Batch plant operations
4. Asphalt plant
5. Soil cementing
6. Liberty bridge construction
7. Rigging for airlifts
8. Quarry operations
9. Generator systems
10. Utility poles
11. Power distributing systems
12. Refrigeration equipment
13. Well drilling
14. Advanced base construction
15. Remote area construction
16. DESAL plant
17. Precaste yards
18. Sewage and Water distribution systems

Guides for NMCBs construction functions:

1. OPNAV P41 (P-3) Table of Advanced Functional Base Components
2. NAVFAC P-437 - Facilities Guide Vol I and II
3. NAVFAC P-315 Naval Construction Force Manual

The primary processes to be investigated for field fabrication are:

1. Blow molding
    a. Extrusion
    b. Injection
    c. Vinyl

2. Calendering

3. Casting of thermoplastics

    a. Acrylic
    b. Nylon
    c. PVC

4. Casting of thermosets

    a. Epoxy
    b. Phenolic
    c. Polyester
    d. Polyurethane elastomers

5. Centrifugal molding of RP

6. Coating

    a. Extrusion
    b. Power
    c. Spray and roller
    d. Transfer

7. Compression molding

8. Extrusion

9. Foam processing

    a. Expandable PS
    b. Extruded PS
    c. Melt injection
    d. Urethane molding

10. Forging and stamping

11. Injection molding

12. Radiation processing

13. Rotational molding

14. RP molding

    a. Filament winding
    b. High pressure
    c. Low pressure
    d. Pultrusion

15. Thermoforming

16. Transfer molding

17. Web impregnation

APPROACH:

Portable plastics fabrication plants could be established for contingencies and peace-time maintenance and new construction requirements which the NMCBs conduct at Roda, Guam, Puerto Rico, Diego Garcia and Okinawa. Plastic Report R 50, Directory in Plastics - Knowledgeable Government Personnel, identifies and lists personnel within DOD who are knowledgeable in areas of plastics development, manufacture and uses. The subject listing indexes over 500 items covering contributions from 670 persons for 93 Government activities. Therefore, the evaluation can use this source as a base for possible materials and processes to be used for fabrication of plastics in the theater of operations by NMCBs. The major objective of a study program will be to establish the following: (Conventional Construction Methods vs. Plastics Construction).

Cost	Acquisition Standard Replacement Repair Maintenance
Productibility	Method Specification Limitations Quality Control Standards Costs
Applicability	Purpose Design Criteria Composite Materials Development Programs Manpower Training Logistic Support

PLANNING:

Schedule	FY 77
Manpower	1.2 Man Years
Costs	90K

REPORTS FOR LITERATURE SEARCH

Technical Report TR-830,	"Fiberglass Reinforced Plastic Pipes for Aviation Fuel Systems", December 1975 (CEL)
Technical Note TN-1399,	"Structural Tests of a Fiberglass Reinforced Polyester Housing System and its Components", July 1975 (CEL)
Letter Report,	"Plastic Pipe for Naval Construction", August 1970
Technical Report TR-491,	"Reinforced Plastics as Structural Materials", November 1966 (CEL)
Technical Report TR-E-16,	"Theater of Operation Water Supply - Feasibility of Manufacturing and Using Plastic Pipes in the Theater of Operations", October 1973 (CERL)
Technical Report TR-E-14	"Plastic Pipe for Interior and Exterior Cold Water Distribution Systems", May 1973 (CERL)
Technical Brief	"Molded Composite Bridge Beams", March 1974 (Lockheed, Georgia)
ORA Research Project No. 05215	"The Potential use of Foam Plastics for Housing in Under-Developed Areas", Feb 1963 (Architectural Research Laboratory).
Technical Forecast, (page 11)	John Motsko - "Ceramics Section. Fire Proof Foams, Energy Absorption, Insulation and Buoyancy Systems"- a Low Density Foam Wt. 202 - 409 Gram/C.C. March 1975 (Sandia Laboratory, Albuquerque, New Mexico

SOURCE: AMERDC Report 2055
"The Container Material Study" Page 37,
U.S. Army Equipment Research and Development
Center, Fort Belvoir, Va.

Table I. The Evaluation Matrix

ATTRIBUTES (weighting factor) / MATERIALS	Corrugated Steel .047 inches	Corrugated Steel .062 inches	Corten Steel	Mulller Steel	Martinsite Steel	Stainless Steel	Corrugated Aluminum .047 inches	Corrugated Aluminum .062 inches	Corrugated Aluminum .100 inches	Corrugated Aluminum .152 inches	Aluminum Sheet .1875 inches
Preventive Maintenance	4	4	8	10	2	6	6	6	8	8	8
Repairability	6	6	6	6	4	4	6	6	6	6	8
Corrosion Resistance	4	4	6	8	4	10	8	8	8	8	8
Weight	6.7	5.7	6.7	6.7	6.7	6.7	4.9	5.9	9.5	6.9	6.8
Flexibility	2.3	1.9	2.3	2.3	2.3	10	4.5	4	2.9	2.2	10
Safety Factor Based On Ultimate Strength	4.4	4.9	4.5	5	10	9.8	1.0	3.2	5.9	7.3	7.1
Impact Resistance	1.1	2.4	2.1	1.0	5	7.4	1.0	4	7.8	7.8	[illegible]
Safety Factor Based On Yield Strength	4.5	4.6	4.6	1.0	8.7	8.4	2.7	4.6	6.8	8.0	7.7
Insulation Properties	1.1	1.1	1.1	1.1	1.1	1.2	1	1	1.0	1.1	1.1
Modulus of Elasticity	1	1	1	1	1	1	3.3	3.2	3.3	3.3	3.3
Deflection	2.3	1.9	2.3	2.3	2.3	10	4.5	4	2.9	2.2	10
Workability	10	8	10	10	6	6	8	8	6	8	6
Flame Resistance	10	10	10	10	10	10	8	8	8	8	8
Joining	10	10	8	8	8	6	8	8	8	10	8
Percent Elongation	10	10	9.5	9	6.7	5	1.5	1.5	1.5	1.5	1.5
Usable Cube	5.6	5.6	5.6	5.6	5.6	10	5.6	5.6	5.6	5.6	9.3
Initial Cost	10	9.3	8.8	4.4	6.8	2.7	6.3	5.6	4.0	2.9	3.5
Modulus of Rigidity	10	10	9	9	10	10	3.8	3.3	3.8	3.8	3.8

ATTRIBUTES (weighting factor) / MATERIALS	Aluminum Sheet and Post	24 ounce FRP/Plywood 1/2 inch	18 ounce FRP/Plywood 1/2 inch	.5 inch Plywood Sandwich .040 Aluminum Facing	.5 inch Plywood Sandwich .040 Steel Facings	24 ounce FRP/Plywood 5/8 inch	18 ounce FRP/Plywood 5/8 inch	.625 inch Plywood Sandwich .040 Aluminum Facings	.625 inch Plywood Sandwich .040 Steel Facing	24 ounce FRP/Plywood 3/4 inch	18 ounce FRP/Plywood 3/4 inch
Preventive Maintenance	4	10	10	6	6	10	10	6	6	10	10
Repairability	4	10	10	4	2	10	10	4	2	10	10
Corrosion Resistance	6	10	10	8	6	10	10	8	6	10	10
Weight	8	7.3	8.0	7.0	3.8	6.3	6.7	6.0	3.5	5.5	5.8
Flexibility	2.4	9.1	10	5.6	2.5	6.6	7.2	3.6	2.2	5.1	5.5
Safety Factor Based On Ultimate Strength	3.2	6.8	6.3	5.3	7.0	7.7	7.3	6.3	7.5	8.3	8.1
Impact Resistance	[illegible]	[illegible]	[illegible]	[illegible]	3.1	3.6	5.6	3.9	7.1	5.6	5.6
Safety Factor Based On Yield Strength	4.5	7.7	7.5	6	7.1	8.5	8.2	6.9	7.6	9	8.7
Insulation Properties	1	4.1	4	2.1	2.1	5	4.9	2.2	2.2	6.5	6.7
Modulus of Elasticity	3.3	10	10	3.3	1	10	10	3.3	1	10	10
Deflection	2.4	9.1	10	5.8	2.5	6.6	7.2	3.6	2.2	5.1	5.5
Workability	6	10	10	8	6	10	10	6	6	10	10
Flame Resistance	8	6	6	8	10	6	6	8	10	6	6
Joining	6	10	10	8	6	8	8	8	6	8	8
Percent Elongation	1.5	1.8	1.8	5	9.5	1.8	1.8	5	9.5	1.8	1.8
Usable Cube	2.4	8.4	8.6	8.6	8.6	7.9	7.9	8.0	8.0	7.2	7.3
Initial Cost	5.4	4.4	4.6	1.7	1.5	4.7	4.5	1.7	1.5	4.3	4.4
Modulus of Rigidity	3.8	1	1	3.8	9	1	1	3.8	9	1	1

ATTRIBUTES (weighting factor) / MATERIALS	.75 inch Plywood Sandwich .040 Aluminum Facing	.75 inch Plywood Sandwich .040 Steel Facing	.75 inch Plywood Sandwich .040 Aluminum Face and .040 Steel Face	2 inch Foam Sandwich 2 pound Density .040 Aluminum Facings	2 inch Foam Sandwich 2 pound Density 24 ounce FRP Facings	2 inch Foam Sandwich 4 pound Density, .040 Aluminum Facings	2 inch Foam Sandwich 4 pound Density, 24 ounce FRP Facings	1 inch Foam Sandwich 2 pound Density, .040 inch Aluminum Facings	1 inch Foam Sandwich 2 pound Density, 24 ounce FRP Facing	1 inch Foam Sandwich 4 pound Density, .040 Inch Aluminum Facings	1 inch Foam Sandwich 4 pound Density, 24 ounce FRP Facing
Preventive Maintenance	6	6	6	4	6	4	6	4	6	4	6
Repairability	4	2	2	2	4	2	4	2	4	2	4
Corrosion Resistance	8	6	8	8	10	8	10	8	10	8	10
Weight	5.3	3.2	4	8.2	7.6	9.9	9.5	7.2	6.6	8.2	7.6
Flexibility	2.8	1.3	2.1	1.0	2.4	1.0	2.4	2.9	5.6	2.9	5.6
Safety Factor Based On Ultimate Strength	7.1	8.0	8.0	8.1	8.7	8.1	8.7	7.0	6.1	5.9	7.2
Impact Resistance	3.9	2.4	[illegible]	1.1	8.1	1.1	5.0	3.4	5.6	3.4	5.6
Safety Factor Based On Yield Strength	7.6	8.1	8.1	8.4	9.3	8.4	9.3	7.6	7.3	6.5	8.2
Insulation Properties	2.3	2.3	2.3	10	10	10	10	9.6	9.6	9.6	9.6
Modulus of Elasticity	3.3	1	1.5	3.3	10	3.3	10	3.3	10	3.3	10
Deflection	2.8	1.3	2.1	1.0	2.4	1.0	2.4	2.9	5.6	2.9	5.6
Workability	6	6	4	4	4	4	4	4	4	4	4
Flame Resistance	8	10	10	4	6	4	6	4	6	4	6
Joining	8	6	6	4	6	4	6	2	4	2	4
Percent Elongation	5	9.5	9.5	5.0	1.8	5.0	1.8	5.0	1.8	5.0	1.8
Usable Cube	7.4	7.4	7.4	1.1	1.0	1.0	1.0	6.1	5.9	6.1	5.9
Initial Cost	1.6	1.5	1.6	1.6	1.4	1.3	1.1	1.9	1.7	1.5	1.4
Modulus of Rigidity	3.8	9	9	3.8	1	3.8	1	3.8	1	3.8	1

ATTRIBUTES (weighting factor) / MATERIALS	2 inch Honeycomb Sandwich 2 pound Density, 24 ounce FRP Facings	2 inch Honeycomb Sandwich 2 pound Density, .040 Aluminum Facings	2 inch Paper Honeycomb Sandwich 4 pound Density, 24 ounce FRP Facings	2 inch Paper Honeycomb Sandwich 4 pound Density, .040 Aluminum Facings	1 inch Paper Honeycomb Sandwich 2 pound Density, 24 ounce FRP Facing	1 inch Paper Honeycomb Sandwich 2 pound Density, .040 inch Aluminum Facings	Titanium .062	Expanded Metal Steel and Plastic	Expanded Metal Aluminum and Plastic	Punched Plate Steel and Plastic	Punched Plate Aluminum and Plastic
Preventive Maintenance	5	4	4	4	5	4	6	10	10	10	10
Repairability	2	2	4	2	2	2	1	4	4	4	4
Corrosion Resistance	10	8	10	8	10	8	10	10	10	10	10
Weight	7.6	8.2	9.5	9.9	6.6	7.2	10	6.8	9.4	4.2	8
Flexibility	2.4	1.0	2.4	1	5.6	2.9	2.5	2.5	5.2	4	7.6
Safety Factor Based On Ultimate Strength	8.7	8.1	8.7	8.0	7.2	7.0	5.9	9.2	8.9	8.2	7.5
Impact Resistance	8.1	1.1	5.3	3.8	5.6	3.4	5.1	8.4	7.9	10	8.2
Safety Factor Based On Yield Strength	9.3	8.4	9.2	8.5	8.2	7.6	10	9.2	9.1	8.0	8.0
Insulation Properties	10	10	9.8	9.8	9.1	9.1	1.5	1.6	1.6	1.6	1.6
Modulus of Elasticity	10	3.3	10	3.3	10	3.3	2	1	3.3	1	3.3
Deflection	2.4	1.0	2.4	1	5.6	2.9	2.5	2.5	5.2	4	7.6
Workability	2	2	2	2	2	2	2	2	2	2	2
Flame Resistance	4	4	4	4	4	4	10	2	2	2	2
Joining	4	2	6	4	4	2	2	8	6	10	8
Percent Elongation	1.8	5.0	1.8	5	1.8	5	5.0	10	5	10	5
Usable Cube	1.0	1.0	1.0	1.0	5.9	6.1	5.6	9.0	9.0	9.0	9.0
Initial Cost	1.1	1.3	1.0	1.2	1.4	1.7	1.0	1.6	1.4	1.6	1.4
Modulus of Rigidity	1	3.8	1	3.8	1	3.8	5.9	10	3.8	10	3.8

Comparison Of Plastics Versus Metal Articles

The properties of the new materials were used in a feasibility study of a plastic arch beam for the LocArch relocatable shelters. The beams, designed in aluminum as well as plastic, were to be suitable for a building which would have a span of 140'. The comparative results are shown below:

	WEIGHT	COST
Aluminum Beam 6061 T-6	100	100
Plastic Beam 33% Glass-Polyester	93	100
Plastic Beam 65% Glass-Polyester	65	66

The use of the newer plastics with 65% chopped glass offers a potential of 35% weight reduction over aluminum and a similar reduction in cost.

SOURCE: Technical Brief -
"Fiber Reinforced Plastic Parts for
Structural Application"
Lockheed - Georgia Co.
Marietta Georgia, 15 Jan 76

Exhibit 6

PROBABLE PROBLEM DETAILS THAT WILL REQUIRE SPECIAL STUDY

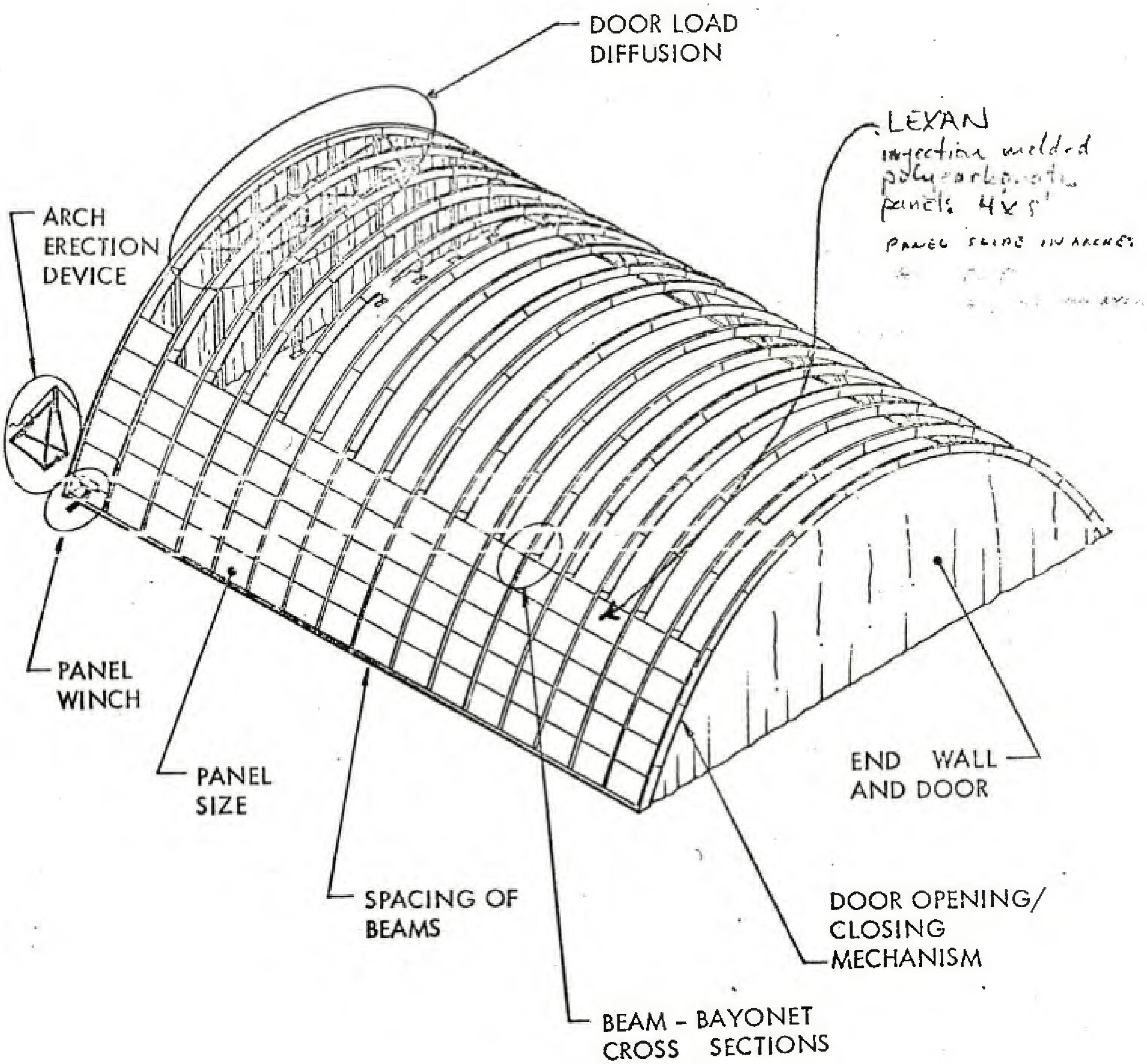


Table 11. Comparative Prices for FRP Plastic Pipe and a Steel Pipe System[a]

(All pipe materials are 6 inches in diameter.)

Item	Amount	Red Thread	Blue Streak	Bondstrand	Steel (Schedule 40)	
					Threaded	Welded
Pipe	100 ft	$418.00	$405.00	$ 950.00	$ 642.00	$642.00
90-degree elbow	1 ea	55.00	94.50	78.45	50.66	34.58
45-degree elbow	1 ea	45.00	94.50	73.85	63.95	25.56
Tee connection	1 ea	72.00	102.00	83.15	72.63	71.89
Coupling	1 ea	17.00	15.00	13.85	20.20	NA
Bell flange	2 ea	50.50	49.50[b]	75.50	82.00	79.40
Blind flange	2 ea	54.00	60.00	76.90	72.60	72.60
Adhesive kits	3 ea	18.00	13.00	11.40	NA	NA
Heat packs	10 ea	13.50	14.50	NA[c]		NA
Total		$743.00	$848.00	$1,363.00	$1,004.04	$926.03

[a] Prices as of August 1975.

[b] No longer filament wound.

[c] Electric heat blanket also available at $87.50 each.

SOURCE: TR 830
"Fiber Reinforced Plastic Pipe for Naval Aviation Fuel Distribution Systems"
CEL, December 1975

✓Cost is, of course, always a major consideration in any fuel distribution system. The costs for 100 feet of the three plastic pipes with fittings are compared to the costs for a similar schedule 40 steel pipe system in Table 11. This table shows that, from the standpoint of material costs, the Red Thread is about 26% less and the Blue Streak system is about 15% less than the steel pipe system. The Bondstrand material cost, however, is about 35% higher than the steel pipe system. However, the cost of fabricating steel pipe joints in the field is from two to four times the fabrication cost of FRP joints. This makes the comparative costs of a distribution system using Bondstrand more competitive with one fabricated from steel. Because of these factors, an economic analysis of each planned distribution system should be conducted to determine whether it is most economical to use plastic or steel pipe. Such an analysis should include estimated service life for each system being considered.

Exhibit 7

construction engineering research laboratory

TECHNICAL REPORT E-14
May 1973

PLASTIC CONSTRUCTION MATERIALS

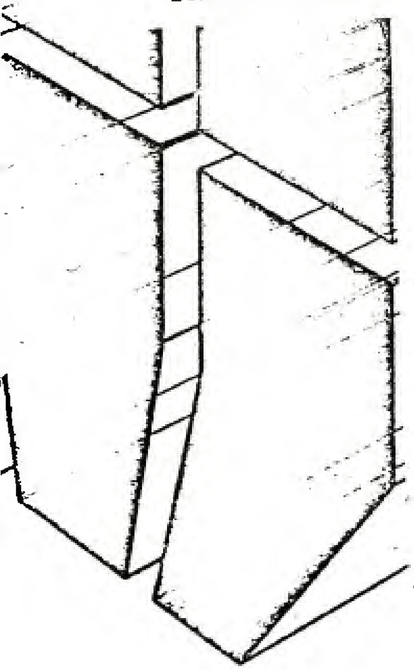
PLASTIC PIPE FOR INTERIOR AND EXTERIOR COLD WATER DISTRIBUTION SYSTEMS

by
Walter J. Mikucki

Table 16
Pipe Cost Comparison[18]

Pipe Size (in.)	Cost per Type of Pipe*			
	Steel	Galvanized	Copper	Plastic (PVC or ABS)
1"	$0.40	$0.50	$1.20	$0.30
2"	0.85	1.00	3.15	0.50
4"	2.65	3.15	9.70	1.45
6"	5.35	6.50	19.85	2.95

* Cost per linear foot of pipe for material only—does not include handling and installation.
[18] Godfrey, R.S. Editor-in-Chief, *Building Construction Cost Data 1972*, Vol 30 (R.S. Means Co. Inc., 1972), p 238.



Piping System Costs. The economics offered by plastic pipe and fittings are evident in every phase of application, from original purchase to installed service. On an initial cost basis, the price of plastic pipe and fittings is less than that of other materials used for the same purpose. Table 16 illustrates the cost per type and size of material commonly used for water service.

While no definitive cost studies comparing plastic and metal pipe which included installation and maintenance costs were identified during this study, contact with users indicates savings can amount to approximately 30% with the use of plastic pipe in lieu of other materials. Construction cost estimating manuals indicate that material and installation costs for plastic pipe are significantly lower than for cast iron, copper, or steel pipes used in similar installation.

Exhibit 8

Table 13
Summary of Characteristics of Plastic Piping Materials

Material	Properties	Applications	Maximum Operating Temperature	Joining Methods	Standards
PE Polyethylene Low, Medium and High Density	Good chemical and crush resistance Excellent impact strength and flexibility High level elongation at freezing Good low temperature performance Non-toxic NSF approved for potable water	Low pressure water systems distribution Irrigation and golf course sprinkler system Corrosive liquids & gasses Underground conduits and gas liners Industrial and chemical laboratory drainage systems Natural gas Water service Distilled and demineralized water	120°F 200°F	Insert fittings Butt welding Heat fusion External compression fittings Transition fittings	PE PS 10-69 PS 11-69 PS 12-69 ASTM D 2104, ASTM D 2239, ASTM D 2447, ASTM D 2513, F-S 00545, MIL-P26692, MIL-P22634.
ABS Acrylonitrile-Butadiene-Styrene	Good chemical resistance to household chemicals Good crush resistance Non-toxic NSF approved for potable water and DWV Rigidity at higher temperatures Excellent impact strength especially at low temperature Fast-setting joints	DWV piping systems—mobile and residential Pressure piping and drainage systems Water service Irrigation, industrial and municipal Gas service Underground electrical conduit	180°F	Solvent welding Transition fittings	ABS PS 18-69, PS 19-69, ASTM D 1527, ASTM D 2282, ASTM D 2465, ASTM D 2468, ASTM D 2469, ASTM D 2513, F-S 322, FHA-MPS Rev. No. 31, IAPMO TSC 6-61, TSC 3-62, IAPMO PS 17-65, IS 5-65.
PVC Polyvinyl Chloride	Excellent chemical resistance Good crush and impact strength Fire-resistant (self/extinguishing) High tensile strength Non-toxic NSF approved for potable water and DWV	DWV piping systems Pressure piping and drainage systems Water and gas distribution Irrigation and golf course sprinkler systems Sewage treatment Above and underground conduit Industrial chemical piping Corrosive fume ducting Crude oil flow lines Water well casing	150°F 180°F	Solvent welding Threaded Flanged Compression fittings O-rings Transition fittings Bell-ring Rubber gasket	PVC PS 21-70, ASTM D 1785, ASTM D 2241, ASTM D 2464, ASTM D 2466, ASTM D 2467, ASTM D 2513, F-S 320, F-S 540, MIL-P 22011, FHA-MPS Rev. No. 31, FHA UM 41.

SOURCE: Technical Report E-16

"Feasibility of Manufacturing and using Plastic Pipe in Theater of Operation," Army/CERL, October 1973

Table 4

Comparison of Weights, Material Costs, and Man-Hours

	Weight – Short Tons			Material Costs*			Installation Man-Hours			Manu-facturing Man-Hours
	Water	Drain	Total	Water	Drain	Total	Water	Drain	Total	
1500 TROOP CAMP										
Present Steel and Bituminous Fiber Pipe	8.92	5.90	14.82	3457	1583	5040	1087	1129	2216	
Purchased Bell-end Plastic Pipe										
CPVC Pipe	1.05	3.20	4.25	4796	12549	17345	648	1016	1664	
PVC Pipe	1.05	3.20	4.25	1202	3624	4826	648	1016	1664	
**ABS Pipe	0.85	2.60	3.45	1210	3408	4618	648	1016	1664	
Troop Camp Made Bell-end Plastic Pipe and Fabricated Fittings										
CPVC Pipe	1.05	3.20	4.25	1092	3328	4420	648	1016	1664	340
PVC Pipe	1.05	3.20	4.25	483	1472	1955	648	1016	1664	340
ABS Pipe	0.85	2.60	3.45	425	1300	1725	648	1016	1664	325
3000 TROOP CAMP										
Present Steel and Bituminous Fiber Pipe	30.20	15.84	46.04	13201	4316	17517	2738	2919	5657	
Purchased Bell-end Plastic Pipe										
CPVC Pipe	4.04	8.60	12.64	17250	33718	50968	1614	2627	4241	
PVC Pipe	4.04	8.60	12.64	4707	9820	14527	1614	2627	4241	
**ABS Pipe	3.58	6.99	10.57	4356	9930	14286	1614	2627	4241	
Troop Camp Made Bell-end Plastic Pipe and Fabricated Fittings										
CPVC Pipe	4.04	8.60	12.64	4202	8944	13146	1614	2627	4241	540
PVC Pipe	4.04	8.60	12.64	1859	3956	5815	1614	2627	4241	540
ABS Pipe	3.58	6.99	10.57	1790	3495	5285	1614	2627	4241	490

* Material costs do not include freight. Troop Camp made pipe material usages do not include material losses at the Troop Camp.

** ABS Pipe is available in bell-end only in DWV pipe.

Exhibit 9

Exhibit 9

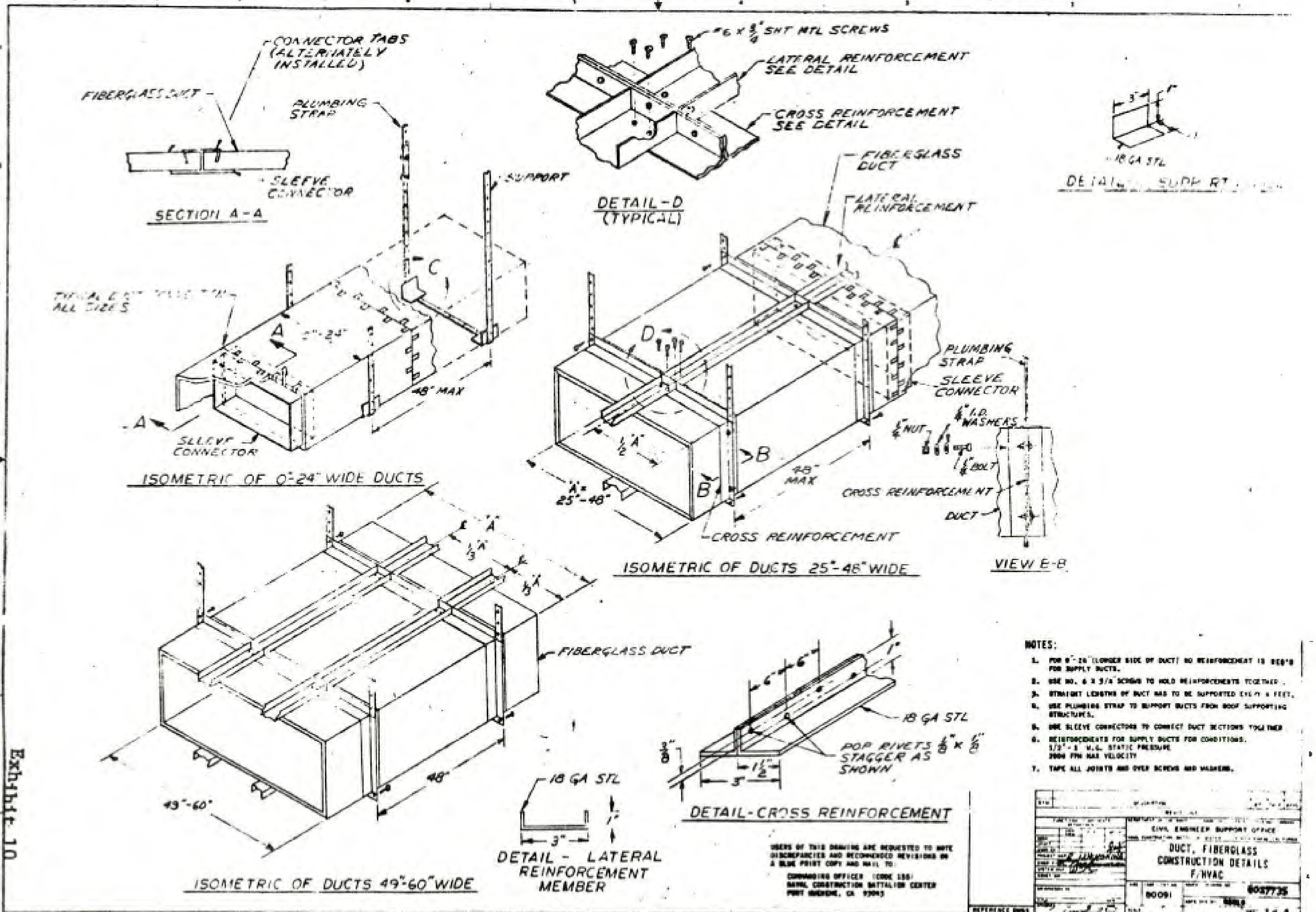
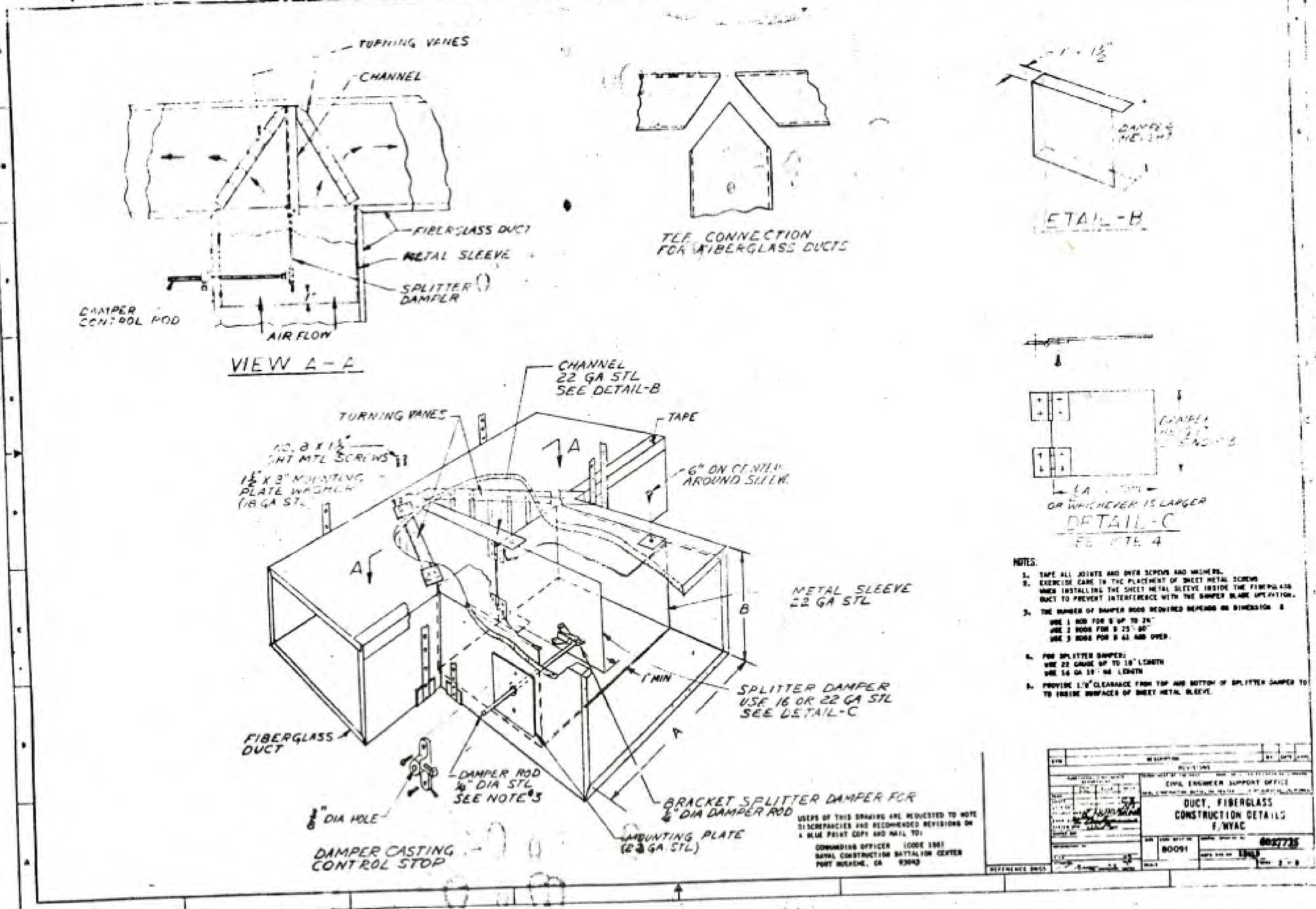


Exhibit 10.

Exhibit 10


TURNING VANES
CHANNEL
FIBERGLASS DUCT
METAL SLEEVE
SPLITTER DAMPER
DAMPER CONTROL ROD
AIR FLOW
VIEW A-A
TEE CONNECTION FOR FIBERGLASS DUCTS
DETAIL-B
OR WHICHEVER IS LARGER
DETAIL-C
CHANNEL 22 GA STL SEE DETAIL-B
TURNING VANES
TAPE
NO. 8 X 1½" SHT MTL SCREWS
1½" X 3" MOUNTING PLATE WASHER (18 GA STL)
6" ON CENTER AROUND SLEEVE
A
A
METAL SLEEVE 22 GA STL
B
1" MIN
SPLITTER DAMPER USE 16 OR 22 GA STL SEE DETAIL-C
A
FIBERGLASS DUCT
DAMPER ROD ¼" DIA STL SEE NOTE 3
⅜" DIA HOLE
BRACKET SPLITTER DAMPER FOR ¼" DIA DAMPER ROD
MOUNTING PLATE (22 GA STL)
DAMPER CASTING CONTROL STOP
NOTES:
1. TAPE ALL JOINTS AND OVER SCREWS AND WASHERS.
2. EXERCISE CARE IN THE PLACEMENT OF SHEET METAL SCREWS WHEN INSTALLING THE SHEET METAL SLEEVE INSIDE THE FIBERGLASS DUCT TO PREVENT INTERFERENCE WITH THE DAMPER BLADE OPERATION.
3. THE NUMBER OF DAMPER RODS REQUIRED DEPENDS ON DIMENSION B
USE 1 ROD FOR B UP TO 24"
USE 2 RODS FOR B 25"-40"
USE 3 RODS FOR B 41 AND OVER.
4. FOR SPLITTER DAMPERS:
USE 22 GAUGE UP TO 18" LENGTH
USE 16 GA 19"-48 LENGTH
5. PROVIDE 1/8" CLEARANCE FROM TOP AND BOTTOM OF SPLITTER DAMPER TO TO INSIDE SURFACES OF SHEET METAL SLEEVE.
USERS OF THIS DRAWING ARE REQUESTED TO NOTE DISCREPANCIES AND RECOMMENDED REVISIONS ON A BLUE PRINT COPY AND MAIL TO:
COMMANDING OFFICER (CODE 15E)
NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CA 93043
REFERENCE DWGS
REVISIONS
CIVIL ENGINEER SUPPORT OFFICE
DUCT, FIBERGLASS
CONSTRUCTION DETAILS
F/WVAC
80091

What about Material Cost?

Some high-priced materials mold at very high speeds, and are thus less expensive to mold than they appear to be at first glance. Other materials will run automatically, or will adapt easily to fully automatic production systems, and this will often justify a premium-priced material.

Furthermore, careful design calculations that minimize wall thicknesses, while using the higher-priced engineering materials, may result in lower costs than the combination of heavier wall sections and lower-priced commodity materials.

The product engineer must evaluate the essential properties demanded by the application, and come up with a design and a material that will deliver these properties at minimum cost. Material selection, a process of elimination, is most often a compromise based on the most favorable balance of advantages and disadvantages.

In every case, however, the wrong material is by far the most costly, and the price-per-pound tells only a small part of the story.

Rule-of-Thumb Checklist

Property	Thermoplastics	Thermosets
Low temperature	TFE	DAP
Low cost	PP, PE, PVC, PS	phenolic
Low gravity	polypropylene methylpentene	phenolic/nylon
Thermal expansion	phenoxy glass	epoxy glass
Volume resistivity	TFE	DAP
Dielectric strength	PVC	DAP
Elasticity	EVA, PVC, TPR	silicone
Moisture absorption	chlorotrifluoroethylene	alkyd-glass
Steam resistance	polysulfone	DAP
Flame resistance	TFE, PI	melamine
Water immersion	chlorinated polyether	DAP
Stress craze resistance	polypropylene	all
High temperature	TFE, PPS, PI, PAS	silicones
Gasoline resistance	acetal	phenolic
Impact	UHMW PE	epoxy-glass
Cold flow	polysulfone	melamine-glass
Chemical resistance	TFE, FEP, PE, PP	epoxy
Scratch resistance	acrylic	allyl diglycol carbonate
Abrasive wear	polyurethane	phenolic-canvas
Colors	acetate, PS	urea, melamine

11.

Exhibit 11

FRP lightning mast perched 80 feet above launch gantry

One of the many variables that can cause nervous smiles at NASA's launch site at Cape Canaveral is lightning. It is, of course, an unpredictable phenomenon of potentially catastrophic destructive force. Direct strikes on a launch pad can easily scrub a mission and mean a loss of millions of dollars and many man-hours.

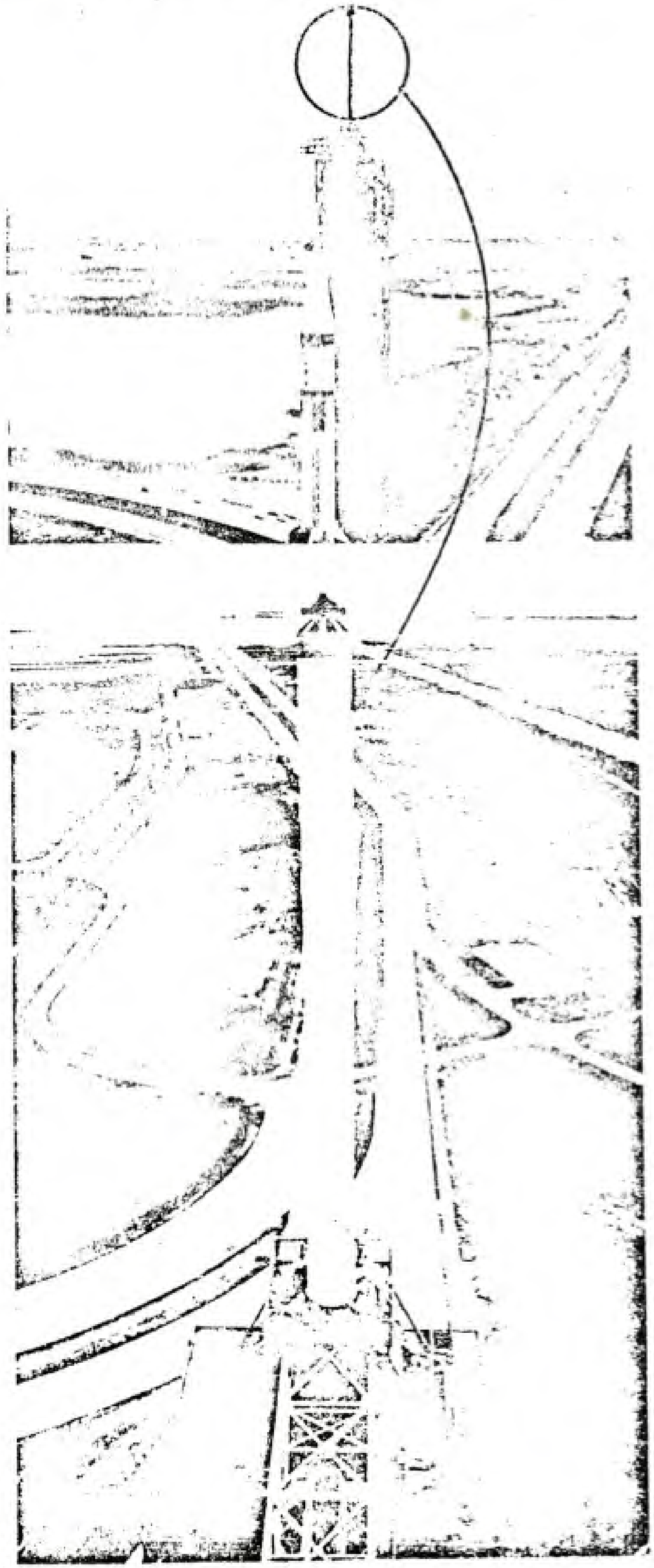
To minimize the threat, NASA decided on a lightning mast and awarded a contract to Jones & Hunt, Inc., of Orwigsburg, Pa., for its design and fabrication. The result is the installation atop the launch gantry of an 80-foot mast with a 1/2-inch-diameter cable that passes over it to ground points located 1000 feet on either side of the pad.

Some form of plastic had to be a natural to meet rigid NASA standards, but which? Namely one with exceptional dielectric properties; lightness of weight; proven corrosion resistance to salt and to potentially intense degradation resulting from sunlight and high humidity; resistance to repeated cycles of condensation and evaporation; resistance to extremely high heats during liftoff, resistance to surface erosion due to wind, sand, and salt; and resistance to high wind forces. Jones & Hunt chose glass-reinforced polyester, employing over 7000 pounds of Atlac 382, a product of ICI United States Inc., Wilmington, Del.

The mast, now installed, will withstand a wind force of 135 mph or roughly 472 pounds per lineal foot and a deflection of 7 inches at the top. The key to the design is a 0-90 winding pattern, a new and proprietary technique used by Jones & Hunt for making pressure vessels, stacks, and piping. The 0-90 wind puts down glass fibers circumferentially and axially along a structure that yields greater hoop strengths than is to be found in a typical wound structure and axial strengths on a 1-to-1 basis with the hoop strengths. Prior to delivery, the mast was successfully tested at General Electric Company's high-voltage laboratory.

The unusually high hurricane wind force loading was demonstrated by Jones & Hunt in their plant by filling the mast with water to equal the forces that might be encountered in service. Internal diaphragms hold the mast round under such loads, and create more uniform distribution of the water throughout the structure. The specifications called for a total deflection in the center of the mast of 5-1/2 inches, but maximum actual deflection turned out to be less than 2 inches. A molded-in, spirally wound air spoiler was also added to reduce turbulence as air moves up the mast. This aerodynamic "fence" was made entirely of Atlac from top to bottom.

The mast was designed to take up to five direct lightning strikes per day; several hits registering up to 20,000 amperes have been recorded. The mast is expected to become an integral part of the launch of the space shuttle program, which is due to start in the early 1980s.



Plastics continue to play a vital role in America's space program, on the ground as well as in the space vehicles themselves. Top photo locates 80-foot-tall glass-reinforced polyester lightning mast jutting up from a missile launch gantry at Cape Canaveral. Bottom photo is a closeup of the mast—using 7000 pounds of Atlac polyester, supplied by ICI United States, Inc. The structure will withstand a wind force of 135 mph.

Rigid Boardstock

Rigid urethane or isocyanurate foam, in the form of boardstock, is manufactured in precured bun form and further processed by a network of fabricators throughout the U.S. for specific end uses. From non-critical through cryogenic applications, CPR's rigid boardstock offers a complete range of products to meet customer requirements, whether for roofing, perimeters or cavity walls. Service temperatures of boardstock range from −423°F to +300°F. Ease of fabrication, plus low k-factor and high strength-to-weight ratio, make rigid boardstock a prime consideration for most insulation requirements.

Applications:

- **Roof Insulation***
- **Building Perimeters**
- **Cavity Wall Insulation***
- **Floor Slab Isolator, Cold Storage Room***
- **Plaster and Dry Wall Base***

Spray Foam Systems

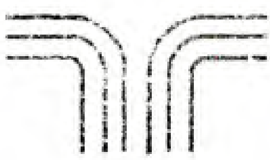
CPR rigid urethane or isocyanurate foam can be sprayed right on the job by competent, trained applicators using equipment that mixes and atomizes the foam as it is being applied. Inaccessible areas become easy to insulate regardless of their configuration.

The use of sprayed foam in interior applications presents a major fire hazard, however, unless the foam is protected with an approved fire barrier which has a heat endurance equivalent to that of one-half inch of cementitious coating, gypsum plaster, or gypsum board. To meet this need, Upjohn has developed FoamKoat™ a sprayable gypsum-based coating that is a proven thermal barrier.

Sprayed urethane foam used in exterior applications as tank and vessel insulation should be coated for protection from the elements and to lower the fire risk hazard. Consultation with building code officials and insurance agency personnel before application is recommended.

Applications:

- **Floor Insulation, Wall Insulation***
- **Building Interiors***
- **Tanks and Vessels***
- **Large Pipes***
- **Roof Insulation***
- **Plaster and Dry Wall Base***

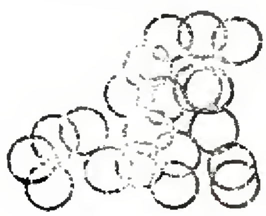


Pour Foam Systems

CPR rigid urethane or isocyanurate foam can be poured-in-place, right on the job. It can be hand mixed or processed through automatic equipment. In minutes the mixture poured into the form foams up to 30 times its volume and sets to a strong, cross-linked, closed-cell plastic that bonds securely to most materials. Foaming and fabrication thus become simultaneous. Its adhesion and strength may allow thinner gauge skin materials with little or no loss in structural strength or insulation efficiency. This on-location production can mean savings in fabrication, installation, shipping, inventory, and labor costs.

Applications:

- **Floor Insulation, Curtain Walls***
- **Stressed Skin Walls***
- **Sandwich Panels***
- **Flotation, Cavity Wall Insulation***
- **Refrigeration Cabinets***
- **Insulated Transportation Vehicles***



Froth Foam Systems

In frothing (a modification of pour-in-place) the mixture is dispensed partially pre-expanded similar to aerosol cream. Frothing requires special equipment and an extra blowing agent for immediate pre-expansion; final expansion then occurs as the chemical reaction goes to completion. Since frothing exerts less pressure, fewer forms or jigs may be needed. Frothing is ideal for curtain walls, and stressed-skin sandwich panels of high strength/weight ratio. It can be brought to the job in concentrated liquid form, shipped in tank cars or drums.

Applications:

- **Floor Insulation, Cavity Wall Insulation***
- **Curtain Walls***
- **Stressed Skin Panels***
- **Sandwich Panels***
- **Flotation, Refrigeration Cabinets***
- **Insulated Transportation Vehicles***

*CAUTION: Polyurethanes or polyisocyanurates produced from these products may present a fire hazard in certain applications if exposed to fire and/or excessive heat, e.g. welding and cutting torches, in the presence of oxygen or air.

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Flammability data and numerical flame spread ratings presented in the Encyclopedia are not intended to reflect hazards presented by the materials under actual fire conditions.

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Exhibit 14

Modern Plastics

Exhibit 14

1975-1976 Modern Plastics Encyclopedia

PLASTICS IN CONSTRUCTION

OPERATIONAL SYSTEM CATEGORY - Mission Support/Personnel

1. Problem. Plastics materials are being introduced to the Navy Mobile Construction Batallion, NMCB.

2. Deficiencies. The NMCB's knowledge and training to handle these new materials is meager. The job sheets completed to provide procedures to perform tasks using plastics materials are very incomplete for assuring safe trouble-free operations. The step-by-step procedures are derived from another era from another set of materials. The similarity is not there, especially in testing. A new series of tests must be developed based upon the characteristics of plastics, not common or old standard for construction materials. The Civil Engineering Laboratory should lead in this effort and support the NAVFAC FACILITIES DIVISIONS who provide the design for facilities to be constructed by the NMCBs. It is paramount that the introduction of new "Plastic" materials for components are able to perform a function as well as conventional materials and in addition, and it is most important, that NMCBs can and have "precise" construction procedures and methods to cover installation, test, repair and maintenance. This documentation or instruction must clearly obviate the situation where a material or component can be accepted for use in one facility and be rejected for an identical purpose in another. Therefore, methods of evaluating, or the rejection of old methods, must be based on tests and correct comparison with the old and new materials. The plastic materials are available, being introduced at a rapid rate; the properties of these materials must be evaluated for suitability, utility and economy.

3. New Technology. It is necessary for engineers to experiment with new plastics materials with their knowledge of field requirements, thereby helping to concentrate research along the right line. This is being done on a limited scale.

a. Completed Projects:

(1) Navy:

(a) Structural Tests of a Fiberglass Reinforced Polyester Housing System and its components. (1975)

(b) Plastic Pipe for Naval Construction (1970)

(c) Reinforced Plastics as Structural Materials (1966)

(2) Army:

(a) Feasibility of Manufacturing and Bring Plastic Pipes in the Theater of Operations (1973)

(b) Plastic Pipe for Interior and Exterior Cold Water Distribution Systems (1973)

(3) Other:

(a) Fire Proof Foams, Energy Absorption, Insulation and Buoyancy Systems (1975)

(b) Molded Composite Bridge Beams (1974)

(c) The Potential Use of Foam Plastics for Housing in Under-developed Areas (1963)

b. <u>On-Going Related Efforts (as of April 1976)</u>

(1) Navy:

(a) Tactical Container Shelter System, YF53.536.006.01.014
(b) Pallet Container, YF53.536.10M.01.014
(c) Expeditionary Hangar, YF53.536.006.01.019
(d) Fiberglass Reinforced Plastic Pipe for Naval Aviation Distribution, YF54.543.008.01
(e) Pipe and Pipe Fittings, Reinforced Plastic for Condensate Return Lines - MIL-P-28584 (YD), 15 Apr 1975

(2) Army:

(a) Military Van - Specification - MIL-C-52261A(ME)-Container, Cargo, 25 June 1974
(b) Plastic Laminates, Fibious Glass Reinforce, MIL-P-17549
(c) Foam Material Applications for Theater of Operations Construction - Project No. 4A66719AT41
(d) Multi-Purpose Structural Components - Project No. 4A763734DT34
(e) Improve Portable CP Bunker (Air Mobile) Project No. 4A763734DT34-01/002
(f) Structures Evaluation in DICE THROW Event - Project No. 4A76374DT34-01/003

(3) Air Force:

(a) "Navy LOCARCH" Aircraft Shelter, Project No. OODE2007

DOD has spent very little on plastics research for military construction. The Directory in Plastic - Knowledgeable Government Personnel, Plastic Technical Evaluation Center, Picatinny Arsenal, Dover, New Jersey, February 1975 indicates most of the plastics research efforts are for major weapon systems and not for structural or components used in horizontal and vertical construction. Technology transfer is possible, using plastics materials developed for structures and moving parts of weapon systems.

The NMCB will be assigned the task of assembling the expeditionary hangar. This LOCARCH relocatable structure with a 140' span, and 45 feet high will be used as expeditionary hangar for the P-3 and other Marine-Navy smaller aircraft. The beams and arches are FRP structural foam and the wall and roof panels are LEXAN [R], an injection molded polycarbonate panel 4' X 8' which slide into the arches. This is the way NMCBs are being introduced to plastics construction. Presently the NMCBs are using plastics pipe for dreinage/water systems. The Naval Construction Training Center conducts only one course for plastics, "Cutting and Joining Plastic (PVC) Pipe". The PVC pipe is used for hot and cold water systems. The NMCBs are installing ABS pipe for drainage systems. Therefore, the NMCBs are being introduced to plastics in construction, slowly. Although, daily the proliferation of new plastics products, plastics materials, and plastics systems are being used by the construction industry.

TECHNICAL APPROACH.

The broad basic technical objective is to compile, synthetize, and evaluate currently known performance characteristics, testing procedures, standards, materials, processes and systems developed for using plastics in construction. The program phases are:

PHASE	TITLE
I	Broad look at plastics in construction
II	Application of plastic to Advanced Base Functional Components System (ABFC)
III	Evaluate potential materials and fabrication for use by NMCBs
IV	Introduction of plastic into ABFCS and training under NMCB Personnel Readiness Capability Program (PRCP)

These titles of phases to be covered are self-explanatory. The program must provide scientifically reliable and coordinated design data obtained from tests, on, but not limited to,

Design strengths
Thermal properties, expansion, conductivity
Acoustics, sound attenuation
Fume ability and toxic fumes
Optical properties
Weather and life cycle
Joining and jointing

The major areas of plastics - resins, foams, film, sheeting and laminates, chemicals, additives, filler and reinforcement; primary processing machinery; and fabricating, finishing and auxiliary equipment would be studied.

The objective being to select plastics composite materials and fabricating process for field use by NMCBs. This would include special tools, machines and techniques or capabilities required for tasks like installation and maintenance of thermosetting and thermoplastic pipe, fabrication, repair and installation, patching and molding fiberglass reinforced plastics; spraying foam to form structural panels, beams, arches and disposable shelters. Special consideration will be given to fabricating and installation and repair of plastics components in climate zones of temperate, tropical, desert and arctic.

c. Operational Effectiveness

Plastics building materials are justified over traditional building materials. They have the following desireable characteristics: light, ease of erection, corrosion resistance, minimum maintenance. In addition, they offer cost savings in shipping, fabrication on-site, storage, installation, repairability and workability. These attributes are needed to increase the effectivity of the Advanced Base Functional Components (ABFC). The "Lesson Learned Study, Diego Garcia Island", published by Officer in Charge of Construction, Thailand, pointed out obvious areas, twenty or more, where plastics should have been used versus traditional construction materials. The attributes being protection from corrosion, moisture and ease of installation and fabrication of end items on site which were made from galvanized sheet metal and aluminum sheet metal.

The selection of materials for NMCBs Tactical Container Shelter Systems (TACOSS) Units XI and XII used the Army Mobility Equipment Research and Development Center Material Evaluation Matrix; both benefits of cost and utility analysis confirm the preference for panels with sandwiched plywood and surface of Fiberglass Reinforced Plastics over aluminum or steel surfaces. The attributes used were preventative maintenance, repairability, corrosion resistance, weight, flexibility, safety factor based on alternate strength, impact resistance, safety factor based on yield strength, insulation properties, modulus of electricity, deflection, workability, flame resistance, joining, percent of elongation, and modulus of rigidity. Examples of cost savings are shown in Exhibit 1.

d. Critical Technology

The program will use existing technology developed by DOD Weapons System Programs and the construction industry. Quality control of materials for end item fabrication in the field or on site will be an area which will receive special attention. Therefore, special machines, equipment and tools will be developed for NMCB use on site or at overseas staging areas, like Guam, Rota, etc.

e. Project Costs

Plan, schedule and cost for plastics in construction:

PHASES	FY78	FY79	FY80	FY81	FY82
I. Plastic in Construction	180K				
II Application of Plastics to ABFC		200K			
III Potential Plastic Materials & Fabrication			250K		
IV Plastic Capability for PRCP				300K	500K
COST	180K	200K	250K	300K	500K

f. References:

Proposal - Feasibility of Fabricating Plastic Construction Materials in the Theater of Operations, by Navy Mobile Construction Battalion (NMCB), CEL, L03B, December 1975.

New Start Proposal, Analysis of Plastic Fabrication Processes, CEL, L03B, February 1976

Draft- Operational Requirements, Field Plastic Fabrication System, CEL, L03B, April 1976.

Technical Memorandum - Field Plastic Fabrication System, CEL L03B, April 1976.

g. Associated R&D Activities

Contribution - Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

Coordination - Naval Facilities Engineering Command, Plans and Program Division, Alexandria, VA 22332

Originator - Civil Engineering Laboratory, Plans and Analysis Office, Naval Construction Battalion Center, Port Hueneme, CA 93043.

h. Time ready for Advanced Development is FY-78.

EXHIBIT 1

Table 11. Comparative Prices for FRP Plastic Pipe and a Steel Pipe System[a] 1.

(All pipe materials are 6 inches in diameter.)

Item	Amount	Red Thread	Blue Streak	Bondstrand	Steel (Schedule 40)	
					Threaded	Welded
Pipe	100 ft	$418.00	$405.00	$ 950.00	$ 642.00	$642.00
90-degree elbow	1 ea	55.00	94.50	78.45	50.66	34.58
45-degree elbow	1 ea	45.00	94.50	73.85	63.95	25.56
Tee connection	1 ea	72.00	102.00	83.15	72.63	71.89
Coupling	1 ea	17.00	15.00	13.85	20.20	NA
Bell flange	2 ea	50.50	49.50[b]	75.50	82.00	79.40
Blind flange	2 ea	54.00	60.00	76.90	72.60	72.60
Adhesive kits	3 ea	18.00	13.00	11.40	NA	NA
Heat packs	10 ea	13.50	14.50	NA[c]		NA
Total		$743.00	$848.00	$1,363.00	$1,004.04	$926.03

✓Cost is, of course, always a major consideration in any fuel distribution system. The costs for 100 feet of the three plastic pipes with fittings are compared to the costs for a similar schedule 40 steel pipe system in Table 11. This table shows that, from the standpoint of material costs, the Red Thread is about 26% less and the Blue Streak system is about 15% less than the steel pipe system. The Bondstrand material cost, however, is about 35% higher than the steel pipe system. However, the cost of fabricating steel pipe joints in the field is from two to four times the fabrication cost of FRP joints. This makes the comparative costs of a distribution system using Bondstrand more competitive with one fabricated from steel. Because of these factors, an economic analysis of each planned distribution system should be conducted to determine whether it is most economical to use plastic or steel pipe. Such an analysis should include estimated service life for each system being considered.

Table 16 2.

Pipe Cost Comparison[18]

Pipe Size (in.)	Cost per Type of Pipe*			
	Steel	Galvanized	Copper	Plastic (PVC or ABS)
1"	$0.40	$0.50	$1.20	$0.30
2"	0.85	1.00	3.15	0.50
4"	2.65	3.15	9.70	1.45
6"	5.35	6.50	19.85	2.95

* Cost per linear foot of pipe for material only—does not include handling and installation.

[18] Godfrey, R.S. Editor-in-Chief, *Building Construction Cost Data 1972*, Vol 30 (R.S. Means Co. Inc., 1972), p 235.

✓Piping System Costs. The economics offered by plastic pipe and fittings are evident in every phase of application, from original purchase to installed service. On an initial cost basis, the price of plastic pipe and fittings is less than that of other materials used for the same purpose. Table 16 illustrates the cost per type and size of material commonly used for water service.

While no definitive cost studies comparing plastic and metal pipe which included installation and maintenance costs were identified during this study, contact with users indicates savings can amount to approximately 30% with the use of plastic pipe in lieu of other materials. Construction cost estimating manuals indicate that material and installation costs for plastic pipe are significantly lower than for cast iron, copper, or steel pipes used in similar installation.

Sources:

1. TR 830 "Fiber Reinforced Plastic Pipe for Naval Aviation Fuel Distribution Systems"CEL-75
2. TR E-14 "Plastic Pipe for Interior & Exterior Cold Water Distribution Systems" Army/CREL-73